Montana Department of
ENVIRONMENTAL QUALITY

Final - Lower Beaverhead River and Upper Jefferson River Temperature TMDLs

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ACRONYM LIST

Acronym	Definition
ARM	Administrative Rules of Montana
BMP	Best Management Practices
BOR	Bureau of Reclamation
BRDM	Beaverhead River at Dillon, MT sampling site
BWC	Beaverhead Watershed Committee
CFR	Code of Federal Regulations
CWA	Clean Water Act
DEQ	Department of Environmental Quality (Montana)
DNRC	Department of Natural Resources & Conservation (Montana)
DOI	Department of the Interior (federal)
EBID	East Bench Irrigation District
EPA	Environmental Protection Agency (U.S.)
EQIP	Environmental Quality Incentives Program
FWP	Fish, Wildlife & Parks (Montana)
GIS	Geographic Information System
IR	Integrated Report
JRWC	Jefferson River Watershed Council
LA	Load Allocation
MCA	Montana Code Annotated
MFISH	Montana's Fisheries Information System
MOS	Margin of Safety
MPDES	Montana Pollutant Discharge Elimination System
MSU	Montana State University
NLCD	National Land Cover Dataset
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
RIT/RDG	Resource Indemnity Trust / Reclamation and Development Grants Program (RIT/RDG)
TMDL	Total Maximum Daily Load
TPA	TMDL Planning Area
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WLA	Wasteload Allocation
WRP	Watershed Restoration Plan
WWTF	Wastewater Treatment Facility
WWTP	Wastewater Treatment Plant

DOCUMENT SUMMARY

This document presents a total maximum daily load (TMDL) and framework water quality improvement plan for two temperature impaired waterbody segments, one on the Beaverhead River (lower) and one on the Jefferson River (upper) (see **Figure 2-1** found in **Section 2.1.1**).

The Montana Department of Environmental Quality (DEQ) develops TMDLs and submits them to the U.S. Environmental Protection Agency (EPA) for approval. The Montana Water Quality Act requires DEQ to develop TMDLs for streams and lakes that do not meet, or are not expected to meet, Montana water quality standards. A TMDL is the maximum amount of a pollutant a 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 state-designated beneficial uses.

This project area encompasses roughly 106 river miles in western Montana and includes portions of the Beaverhead TMDL Planning Area (TPA) and the Upper Jefferson River TPA.

The Beaverhead TPA is located in Beaverhead County, with a small portion in Madison County and includes the towns of Dillon and Twin Bridges **(Section 2.1.1, Figure 2-1)**. The Beaverhead TPA encompasses the Beaverhead River watershed (fourth-code hydrologic unit code 10020002), which begins at the outlet of the Clark Canyon Reservoir and flows northeast 79.5 miles before joining the Big Hole River to form the Jefferson River. The TPA is bounded by the Pioneer Mountains on the west, the Ruby Range to the east, and the Snowcrest Range and Blacktail Mountains to the south.

The Upper Jefferson River TPA is located in Madison, Silverbow, and Jefferson counties and includes the Jefferson River and its tributaries, from Twin Bridges to the Boulder River confluence near Whitehall. The tributaries originate in the Tobacco Root Mountains, located in the southern portion of the watershed, and the Highland Mountains to the north. The watershed drainage area encompasses about 469,994 acres, with federal, state, and private land ownership.

DEQ determined that the two waterbody segments, the lower Beaverhead River and the upper Jefferson River, do not meet the applicable water quality standards for temperature. The scope of the TMDLs in this document addresses problems only with temperature (see **Table DS-1**). Although DEQ recognizes that there are other pollutant listings for these two rivers, this document addresses only temperature and associated non-pollutant listings.

Temperature was identified as impairing aquatic life on the lower Beaverhead River and upper Jefferson River and a TMDL will be written for each. Historic removal of riparian vegetation, which is important for regulating stream temperature by providing shade, is the primary cause of impairment. Water quality restoration goals focus on improving riparian shade, however, maintaining stable stream channel morphology and in streamflow conditions during the hottest months of the summer are also important for meeting the TMDL. DEQ believes that once these water quality goals are met, all water uses currently affected by temperature will be restored given all reasonable land, soil, and water conservation practices.

The Beaverhead and Jefferson River temperature TMDLs indicate that reductions in maximum daily water temperatures ranging from no reduction to 7.9°F are necessary. General strategies for achieving the in-stream water temperature reduction goals are also presented in this plan and include best management practices (BMPs) for managing riparian areas. Sediment TMDLs were developed in 2012 for the 18 stream segments in the Beaverhead TMDL planning area (Montana Department of Environmental Quality, 2012a), including the lower segment of the Beaverhead River addressed in this document. Sediment TMDLs were also developed for four tributaries to the upper Jefferson River (Starr and Kron, 2009), but not the segment included in this document. However, the sediment load allocations and associated BMPs contained in those documents will also help address many of the causes of temperature impairment in the segments discussed here.

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

A flexible approach to most nonpoint source TMDL implementation activities may be necessary as more knowledge is gained through implementation and future monitoring. The plan includes a monitoring strategy designed to track progress in meeting TMDL objectives and goals and to help refine the plan during its implementation.

Although most water quality improvement measures are based on voluntary measures, federal law specifies permit requirements developed to protect narrative water quality criteria, a numeric water quality criterion, or both, to be consistent with the assumptions and requirements of wasteload allocations (WLAs) on streams where TMDLs have been developed and approved by EPA. There are 10 permitted point sources in the lower Beaverhead River and 1 in the upper Jefferson River (**Table 5-5**). The wastewater treatment facility in Dillon is the only permitted discharger with reasonable potential to contribute thermal pollution, therefore requiring the incorporation of a wasteload allocation on the lower Beaverhead River.

Table DS-1. List of Impaired Waterbodies and their Impaired Uses on the Lower Beaverhead and Upper Jefferson Rivers with Completed temperature TMDLs Contained in this Document

Waterbody & Location Description	TMDL Prepared	TMDL Pollutant Category	Impaired Use
Beaverhead River, Grasshopper Creek to mouth (Jefferson River)	Temperature	Temperature	Aquatic Life
Jefferson River, headwaters to confluence of Jefferson Slough	Temperature	Temperature	Aquatic Life

1.0 PROJECT OVERVIEW

This document presents an analysis of water quality information and establishes total maximum daily loads (TMDLs) for temperature problems in the lower Beaverhead and upper Jefferson Rivers. This document also presents a general framework for resolving these problems. **Figure 2-1**, found in **Section 2.1.1**, shows a map of the area including the lower Beaverhead and upper Jefferson Rivers.

1.1 WHY WE WRITE TMDLS

In 1972, the U.S. Congress passed the Water Pollution Control Act, more commonly known as the Clean Water Act (CWA). The CWA's goal is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." The CWA requires each state to designate uses of their waters and to develop water quality standards to protect those uses.

Montana's water quality designated use classification system includes the following:

- fish and aquatic life
- wildlife
- recreation
- agriculture
- industry
- drinking water

Each waterbody in Montana has a set of designated uses from the list above. Montana has established water quality standards to protect these uses, and a waterbody that does not meet one or more standards is called an impaired water. Each state must monitor their waters to track if they are supporting their designated uses, and every two years the Montana Department of Environmental Quality (DEQ) prepares a Water Quality Integrated Report (IR) that lists all impaired waterbodies and their identified impairment causes. Impairment causes fall within two main categories: pollutant and non-pollutant.

Montana's biennial IR identifies all the state's impaired waterbody segments. The 303(d) list portion of the IR includes all of those waterbody segments impaired by a pollutant, which require a TMDL, whereas TMDLs are not required for non-pollutant causes of impairments. **Table 1-1** in **Section 1.2** identifies all impaired waters for the lower Beaverhead and upper Jefferson Rivers from Montana's 2014 303(d) List, and includes non-pollutant impairment causes in Montana's "2014 Water Quality Integrated Report" (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2014). **Table 1-1** provides the current status of each impairment cause, identifying whether it has been addressed by TMDL development.

Both Montana state law (Section 75-5-701 of the Montana Water Quality Act) and section 303(d) of the federal CWA require the development of total maximum daily loads for all impaired waterbodies when water quality is impaired by a pollutant. A TMDL is the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards.

Developing TMDLs and water quality improvement strategies includes the following components, which are further defined in **Section 4.0**:

- Determining measurable target values to help evaluate the waterbody's condition in relation to the applicable water quality standards
- Quantifying the magnitude of pollutant contribution from their sources
- Determining the TMDL for each pollutant based on the allowable loading limits for each waterbody-pollutant combination
- Allocating the total allowable load (TMDL) into individual loads for each source

In Montana, restoration strategies and monitoring recommendations are also incorporated in TMDL documents to help facilitate TMDL implementation (see **Sections 7.0** and **8.0** of this document).

Basically, developing a TMDL for an impaired waterbody is a problem-solving exercise. The problem is excess pollutant loading that impairs a designated use. The solution is developed by identifying the total acceptable pollutant load (the TMDL), identifying all the significant pollutant-contributing sources, and identifying where pollutant loading reductions should be applied to achieve the acceptable load.

1.2 WATER QUALITY IMPAIRMENTS AND TMDLS ADDRESSED BY THIS DOCUMENT

Table 1-1 below lists all of the impairment causes from the "2014 Water Quality Integrated Report" (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2014) that are addressed in this document.

TMDLs are completed for each waterbody – pollutant combination, and this document contains two temperature TMDLs (**Table 1-1**). There are several non-pollutant types of impairment that are also addressed in this document. As noted above, TMDLs are not required for non-pollutants, although in many situations the solution to one or more pollutant problems will be consistent with, or equivalent to, the solution for one or more non-pollutant problems. The overlap between the pollutant TMDLs and non-pollutant impairment causes is discussed in **Section 6.0**. **Sections 6.0** and **7.0** provide some basic water quality solutions to address those non-pollutant causes not specifically addressed by TMDLs in this document.

DEQ recognizes that there are other pollutant listings for the upper Jefferson River segment without completed TMDLs (identified in **Table 1-1** below); however, this document only addresses the temperature impairments on the lower Beaverhead and upper Jefferson. This is because DEQ sometimes develops TMDLs in a watershed at varying phases, with a focus on one or a couple of specific pollutant types. Sediment TMDLs were previously completed for the Beaverhead TMDL Planning Area (TPA) in 2012 (Montana Department of Environmental Quality, 2012a) and the Upper Jefferson TPA in 2009 (Starr and Kron, 2009). **Table 1-1** includes impairment causes with completed TMDLs, as well as non-pollutant impairment causes that were addressed by those TMDLs.

Table 1-1. Water Quality Impairment Causes for the Lower Beaverhead and Upper Jefferson Rivers

Waterbody & Location Description [1]	Waterbody ID	Impairment Cause	Pollutant Category	Impairment Cause Status[2]
Beaverhead River, Grasshopper Creek to mouth (Jefferson River)	MT41B001_020	Alteration in streamside or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by a Sediment TMDL in a previous document (2012)
		Low flow alterations	Not Applicable; Non-Pollutant	Addressed by a Sediment TMDL in a previous document (2012)
		Physical substrate habitat alterations	Not Applicable; Non-Pollutant	Addressed by a Sediment TMDL in a previous document (2012)
		Sedimentation/ Siltation	Sediment	Sediment TMDL contained in a previous document
		Temperature	Temperature	Temperature TMDL contained in this document
Jefferson River, headwaters to confluence of Jefferson Slough	MT41G001_011	Low flow alterations	Not Applicable; Non-Pollutant	Addressed within this document (**Section 6.0**); not linked to a TMDL
		Temperature	Temperature	Temperature TMDL contained in this document
		Iron	Metals	Not yet addressed
		Lead	Metals	Not yet addressed
		Physical substrate habitat alterations	Not Applicable; Non-Pollutant	Not yet addressed
		Sedimentation/ Siltation	Sediment	Not yet addressed
		Solids (Suspended/ Bedload)	Sediment	Not yet addressed

[1] All waterbody segments within Montana's Water Quality Integrated Report are indexed to the National Hydrography Dataset

[2] Included in 2014 Integrated Report

1.3 WHAT THIS DOCUMENT CONTAINS

This document addresses all of the required components of a Total Maximum Daily Loads (TMDL) and includes an implementation and monitoring strategy. TMDL components are summarized within the main body of the document. Additional technical details are contained in the appendices. In addition to this introductory section, this document includes:

Section 2.0 Lower Beaverhead and Upper Jefferson Watershed Descriptions:
Describes the physical characteristics and social profile of the Beaverhead River and Jefferson River corridor.

Section 3.0 Montana Water Quality Standards
Discusses the water quality standards that apply to the lower Beaverhead and upper Jefferson Rivers.

Section 4.0 Defining TMDLs and Their Components
Defines the components of TMDLs and how each is developed.

Sections 5.0 Temperature TMDL Components:
This section includes (a) a discussion of the affected waterbodies and temperature's effect on designated beneficial uses, (b) the information sources and assessment methods used to evaluate stream health and pollutant source contributions, (c) water quality targets and existing water quality conditions, (d) the quantified pollutant loading from the identified sources, (e) the determined TMDL for each waterbody, (f) the allocations of the allowable pollutant load to the identified sources.

Section 6.0 Other Identified Issues or Concerns:
Describes other problems that could potentially be contributing to water quality impairment and how the TMDLs in the plan might address some of these concerns. This section also provides recommendations for combating these problems.

Section 7.0 Water Quality Improvement Plan:
Discusses water quality restoration objectives and a strategy to meet the identified objectives and TMDLs.

Section 8.0 Monitoring for Effectiveness:
Describes a basic water quality monitoring plan for evaluating the long-term effectiveness of the Lower Beaverhead River and Upper Jefferson River Temperature TMDLs.

Section 9.0 Public Participation & Public Comments:
Describes other agencies and stakeholder groups who were involved with the development of this plan and the public participation process used to review the draft document. Addresses comments received during the public review period.

2.0 WATERSHED DESCRIPTIONS

This watershed description provides a general overview of the physical and cultural characteristics of the Beaverhead River and Jefferson River corridor. Unless otherwise noted, geospatial data used for the figures and accompanying discussion is obtained from the Montana GIS Portal (http://gisportal.msl.mt.gov/geoportal/catalog/main/home.page).

2.1 PHYSICAL CHARACTERISTICS

The following information describes the physical characteristics of the Beaverhead River and Jefferson River corridor.

2.1.1 Location

The project area encompasses roughly 106 river miles in western Montana, extending from the mouth of Grasshopper Creek to the mouth of Jefferson Slough (**Figure 2-1**). This includes the lower 66 miles of the Beaverhead River and approximately 40 miles of the upper Jefferson River. The project is restricted to the mainstem river corridor, although it passes through two existing total maximum daily load (TMDL) planning areas: the Beaverhead and Upper Jefferson. The adjacent upland areas and tributary streams are addressed in separate TMDL projects. Elevation ranges from approximately 4,260 feet at the mouth of Jefferson Slough to approximately 5,300 feet at the mouth of Grasshopper Creek.

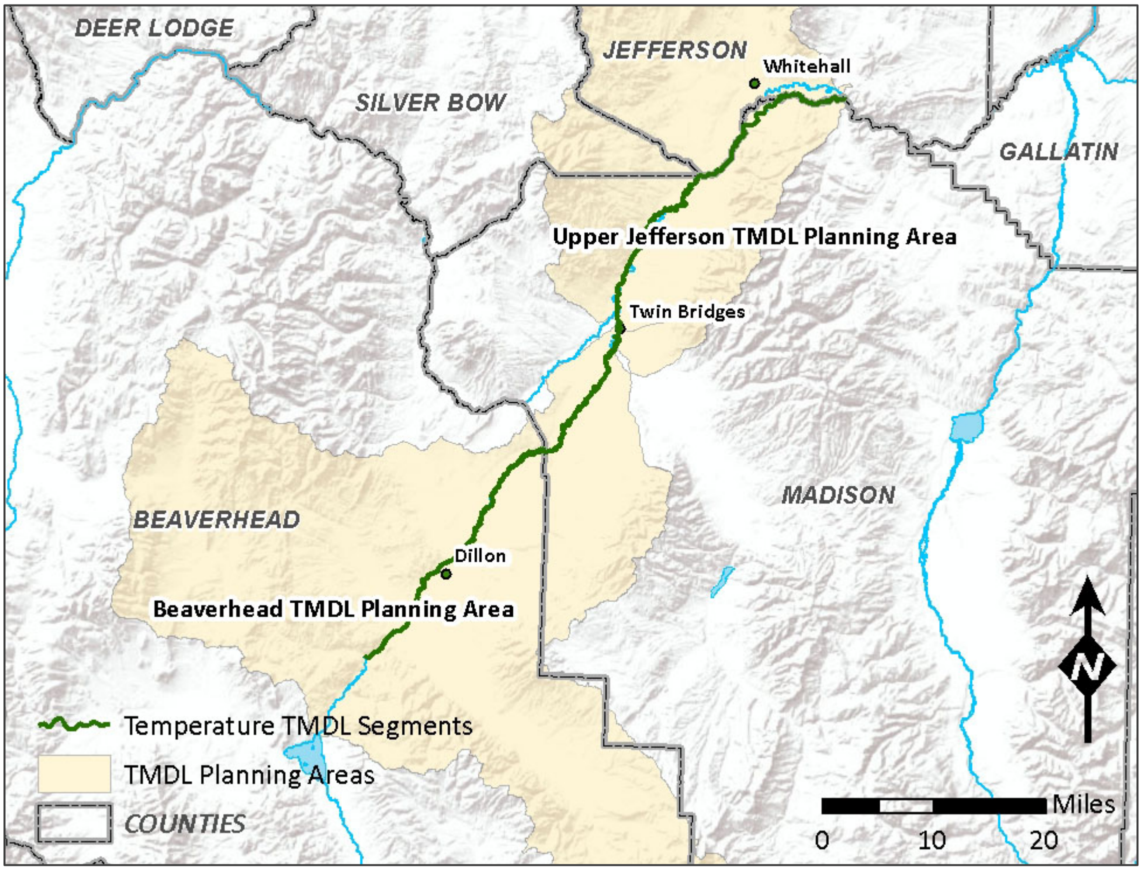


Figure 2-1. Location of temperature TMDL segments

2.1.2 Hydrology

The Beaverhead River is formed by the confluence of the Red Rock River and Horse Prairie Creek. Since the construction of the Clark Canyon Reservoir in 1964, the Beaverhead River begins at the outlet from the Clark Canyon Dam. The Bureau of Reclamation built the dam and associated irrigation infrastructure in order to irrigate the bench east of Dillon. Below the dam, the Beaverhead River flows about 15 miles through a canyon before entering the Beaverhead Valley near Barretts. Major tributary streams are Grasshopper Creek, Blacktail Deer Creek, Rattlesnake Creek, and the Ruby River. The Ruby River flows into the Beaverhead River slightly over a mile south of Twin Bridges. The Big Hole River meets the Beaverhead River just north Twin Bridges. The confluence of the Beaverhead and Big Hole Rivers marks the start of the Jefferson River. The Jefferson River flows north through the Jefferson Valley and turns eastward south of Whitehall and Cardwell. Tributary streams that flow into the Jefferson River are generally smaller than those flowing into the Beaverhead River. Prominent tributaries to the Jefferson River include Hells Canyon Creek, Beall Creek, Cherry Creek, and Fish Creek. The Beaverhead and Jefferson rivers have distinct mainstems, but there are many anastomosing channels that diverge and converge, the largest of which is Jefferson Slough. Jefferson Slough receives flow from the Boulder River and several smaller streams, and rejoins the Jefferson River at the point where the Jefferson River leaves the valley and enters the canyon. This point is the break between the upper and lower Jefferson River, and represents the downstream end of this project. United States Geological Survey (USGS) gages located in the project area are summarized below in **Table 2-1** and illustrated in **Figure 2-2**.

Table 2-1. USGS Gage Stations on the Beaverhead River and the Jefferson River

Station ID	Station Name	Active?	Area Drained (miles^2)
06015400	Beaverhead River near Grant	No	2,322
06016000	Beaverhead River at Barretts	Yes	2,737
06017000	Beaverhead River at Dillon	Yes	2,895
06018000	Beaverhead River near Dillon	No	3,484
06018500	Beaverhead River near Twin Bridges	Yes	3,619
06023100	Beaverhead River at Twin Bridges	Yes	4,779
06026500	Jefferson River near Twin Bridges	Yes	7,632
06027000	Jefferson River near Silver Star	No	7,683
06027200	Jefferson River at Silver Star	No	7,683

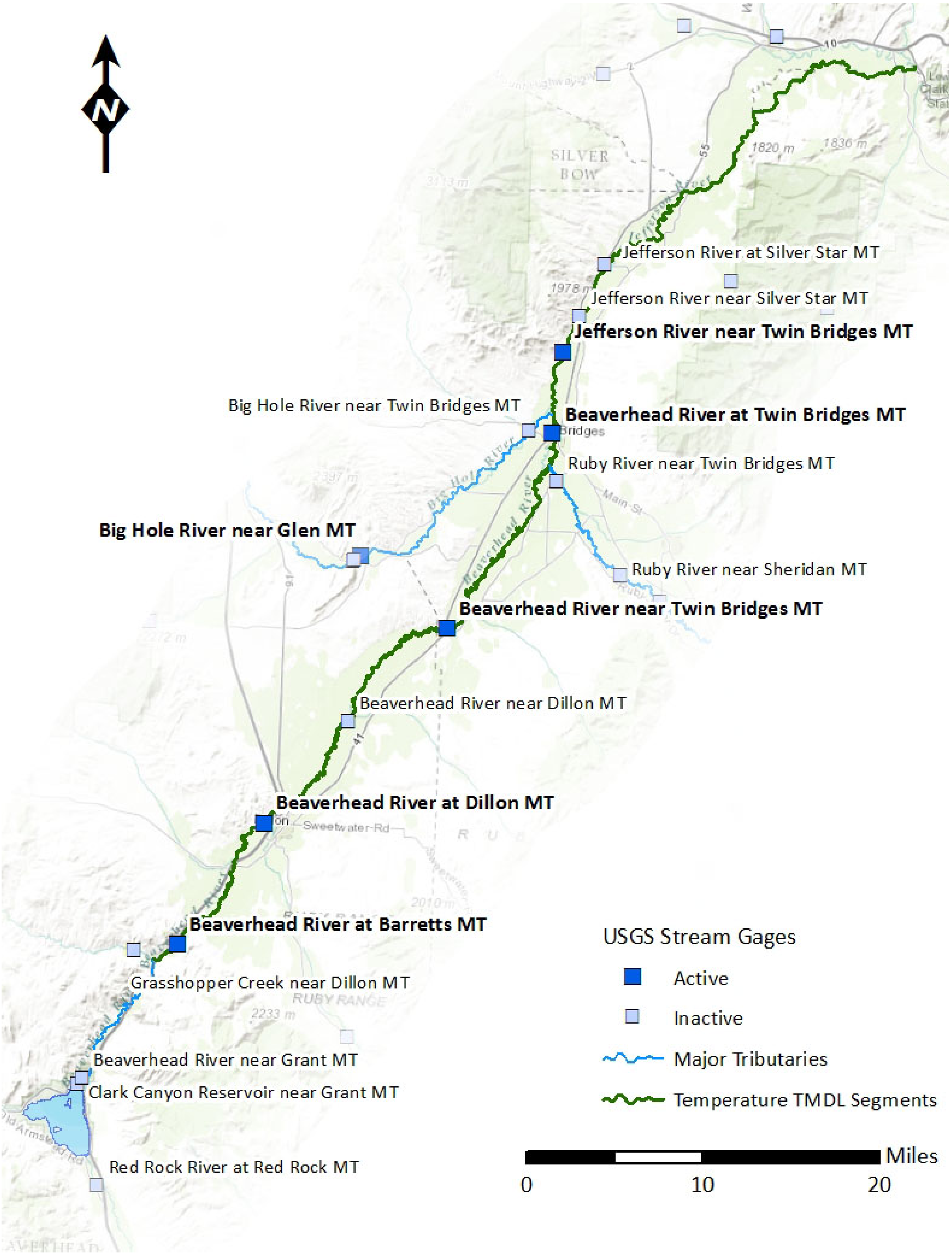


Figure 2-2. USGS Gages

Streamflow in the Beaverhead River is strongly influenced by operation of the Clark Canyon Reservoir. This is demonstrated graphically in a hydrograph of Beaverhead River discharge (**Figure 2-3**), measured at USGS gaging station 06016000 (Beaverhead River at Barretts). The peak of the hydrograph is shifted later in the year, reflecting controlled release of stored water that was captured during the spring runoff. The low flow regime is fairly stable, reflecting average low-flow discharge from the reservoir. Diversion of river water to the East Bench Unit irrigation system is reflected at gaging stations further downstream, such as 06017000 (Beaverhead River at Dillon). Reduced flows are distinct between April and November, resulting in an inverted hydrograph. Although the flow at Barretts starts to decrease in late August/September due to reduced irrigation demand, flows in the lower stretches of the Lower Beaverhead River increase as irrigation return flows contribute to flow recovery in the late summer/early fall.

Streamflow in the Jefferson River follows a hydrograph more typical for the region (**Figure 2-4**). This is due to the fact that there are no impoundments on the Big Hole River, and although there is an impoundment on the Ruby River (Ruby Reservoir), the flow in the Ruby River also generally follows a typical hydrograph. Flow in the Jefferson River is highest in June. May and June are the months with the greatest amount of precipitation and snowmelt runoff, but the higher elevations of the Big Hole River watershed melt off later. Streamflow begins to decline in July, reaching minimum flow levels in August and September when many tributary streams go dry. Streamflow generally begins to rebound in October and November when fall storms supplement the base-flow levels. Example hydrographs are provided below, based on the gages at Barretts and near Twin Bridges.

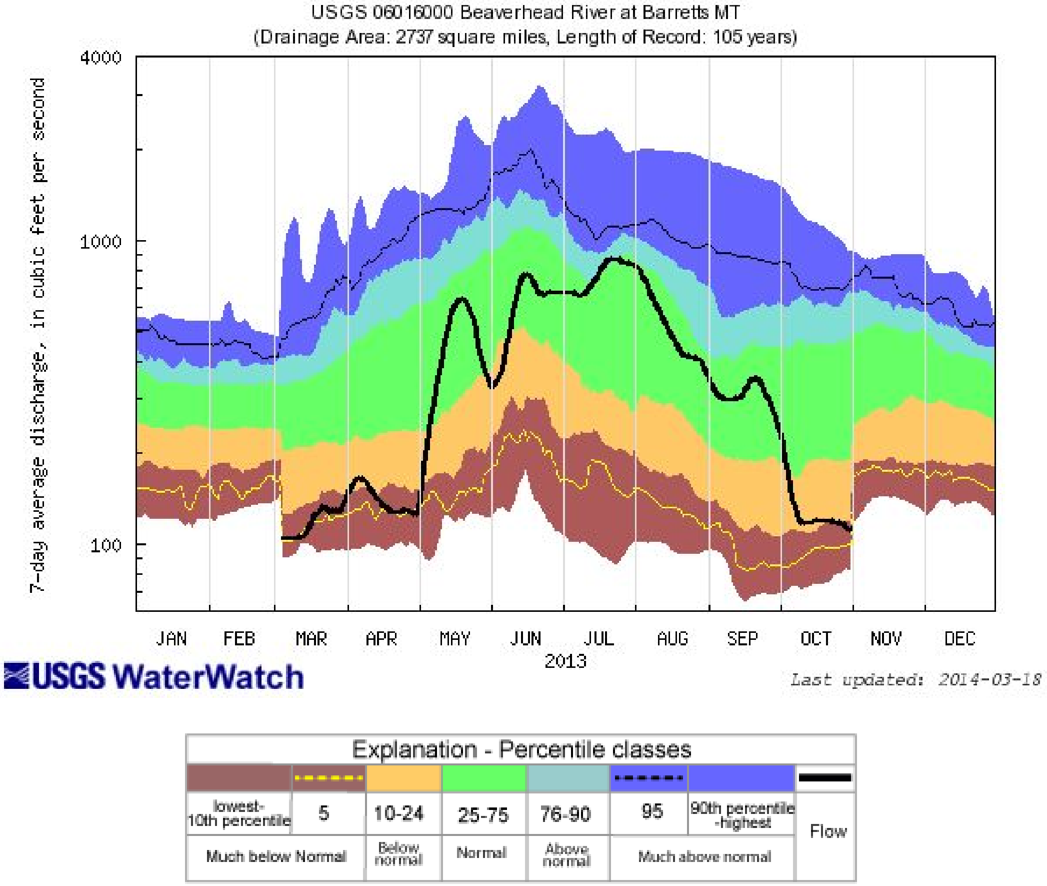


Figure 2-3. Hydrograph at Beaverhead River at Barretts

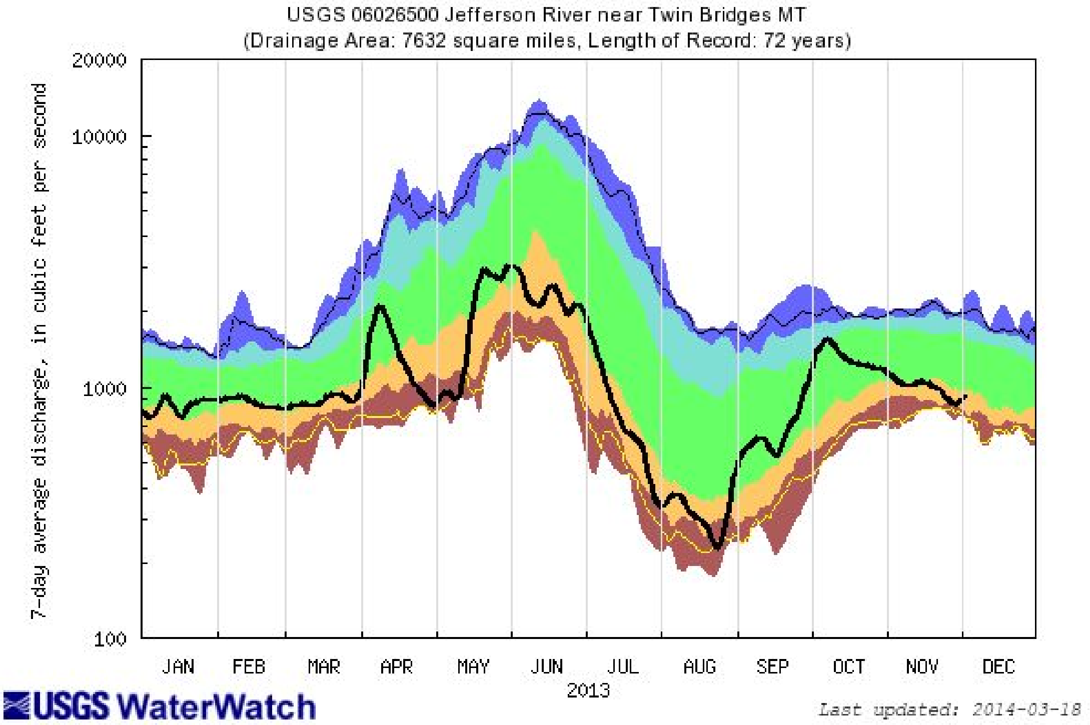


Figure 2-4. Hydrograph at Jefferson River near Twin Bridges.

2.1.2.2 Impoundments

Although there are no impoundments located on the temperature-impaired segments of the Beaverhead and Jefferson rivers, there are two reservoirs influencing these segments. One is located upstream on the Beaverhead River (Clark Canyon Reservoir). The other (Ruby Reservoir) is located on the Ruby River, a major tributary.

The Clark Canyon Reservoir was constructed in 1964 and stores roughly 75,000 acre-feet of water. The Bureau of Reclamation operates the Clark Canyon Reservoir for the purposes of irrigating the East Bench Unit south of Dillon. The East Bench Unit irrigates 49,800 acres via the diversion dam at Barretts (Rogers, 2008). Minimum discharges usually occur during late summer and often result in late-season shortages of irrigation water (Kendy and Tresch, 1996).

The Ruby Reservoir stores roughly 37,600 acre-feet of water for irrigation. The dam is owned by Montana Department of Natural Resources Conservation (DNRC). The dam was constructed in 1938, and is operated by the Ruby Water Users Association. Water is distributed via two canals: the West Bench and Vigilante canals.

2.1.2.3 Dewatering

The State of Montana Fish, Wildlife and Parks (MT FWP) maintains a list of Montana streams that support important fisheries or contribute to important fisheries (i.e. provide spawning and rearing habitats) that are significantly dewatered. Dewatering refers to a reduction in streamflow below the point where stream habitat is adequate for fish. The two categories of dewatering are “chronic” – streams where dewatering is a significant problem in virtually all years and “periodic” – streams where dewatering is a significant problem only in drought or water-short years. The list was initially prepared by MT FWP in 1991 and was revised in 1997, 2003, and most recently in December 2011 (Montana

Department of Fish, Wildlife and Parks, Fisheries Division, 2011). The revised list includes a total of 297 streams and 2,921 stream miles that are chronically dewatered and 108 streams and 1,562 stream miles that are periodically dewatered.

The Beaverhead River is classified as periodically dewatered from the Clark Canyon Dam to Rattlesnake Creek. It is classified as chronically dewatered from Blacktail Deer Creek to the mouth. The Statewide Fisheries Management Plan (Montana Fish, Wildlife and Parks, 2013b) states:

> “Clark Canyon Reservoir and irrigation diversions affect the flow pattern of the Beaverhead River. Prior to construction of the reservoir, much of the lower river was severely dewatered during the summer irrigation season. In general, reservoir management has resulted in higher flows in the lower river during the historically low flow months of May, July, August and September. However, much of the lower 64 miles still suffer from dewatering. In recent years, sections of the lower river have been totally dry. Massive withdrawals of irrigation water have virtually eliminated high water flows in the lower river. During periods of drought, the upper river is now severely affected by low flow releases during the non-irrigation season when water is being stored for the following year.” (page 215)

The Jefferson River is classified as chronically dewatered from its headwaters to mouth. According to the Statewide Fisheries Management Plan (Montana Fish, Wildlife and Parks, 2013b):

> “Water quality and quantity is severely impaired during drought years when water recedes from structural habitat along the shoreline, and water temperature approaches 80°F. Quality tributaries able to provide suitable trout spawning and rearing habitat are rare.
> Over the past 25 years, priority habitat enhancement efforts have focused on flow improvements during summer irrigation, tributary restoration projects to enhance spawning and rearing habitat, and encouraging sound floodplain function practices during permit review processes. Participation in the implementation of the Jefferson River Drought Plan with the Jefferson River Watershed Council and water users has been the primary tool for preventing acute dewatering of the river.” (page 233).

Among major tributaries, the Big Hole River is identified as chronically dewatered. The Ruby River is not included in the list of dewatered streams. However, the habitat narrative in the Statewide Fisheries Management Plan identifies dewatering of the Ruby River downstream of the Ruby Reservoir as a “serious habitat issue” (Montana Fish, Wildlife and Parks, 2013b). In addition to the river mainstems and the major tributaries, some smaller tributaries are identified as dewatered as well. These include Grasshopper Creek, Rattlesnake Creek, Blacktail Deer Creek, and Fish Creek. Dewatered streams are shown on **Figure 2-5**.

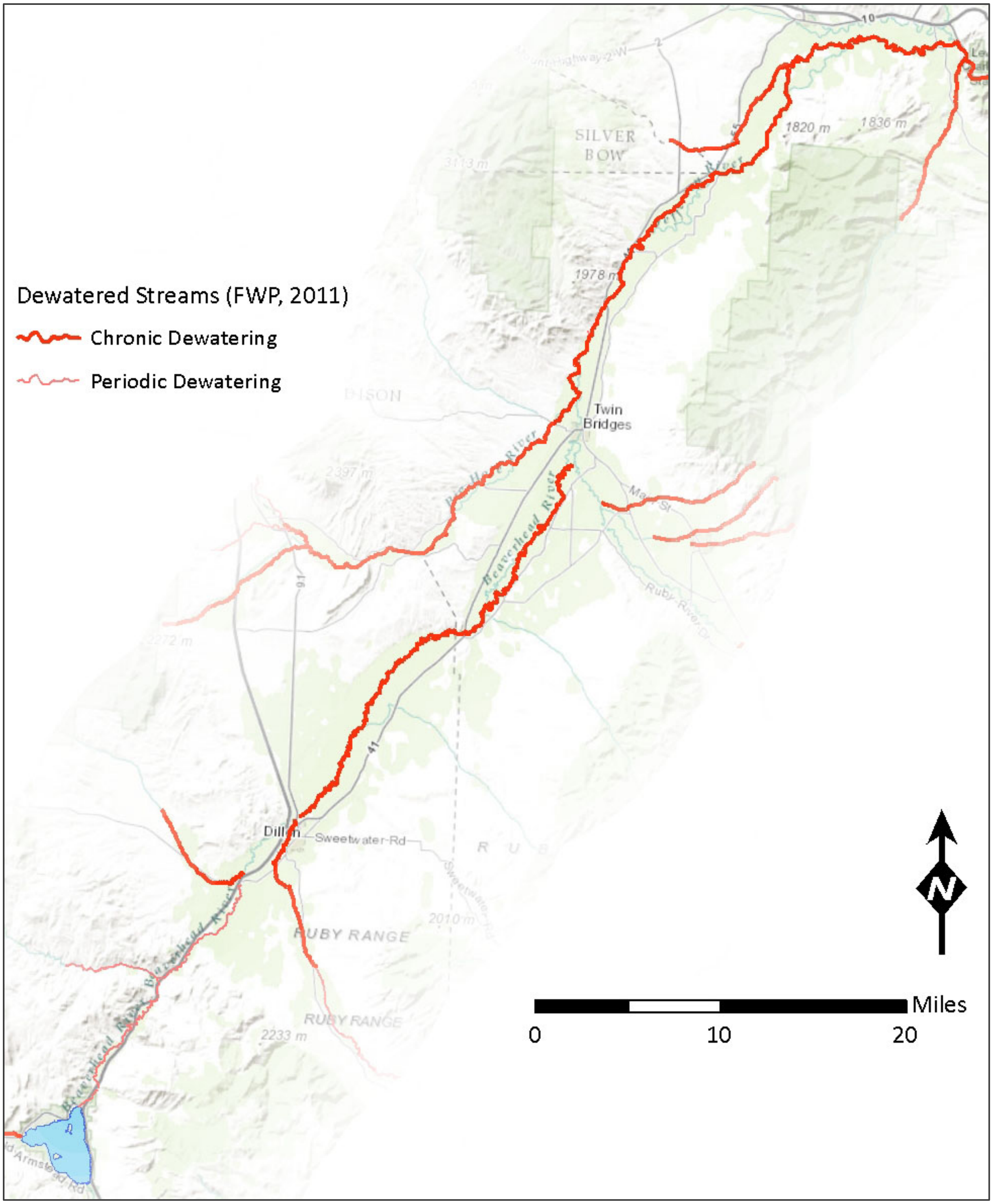


Figure 2-5. FWP dewatered streams inventory

2.1.3 Climate

The Beaverhead and Jefferson rivers run through contiguous intermontane basins. The climate is typical of higher-elevation intermontane basins east of the Continental Divide, with mild summers and cold winters (Kendy and Tresch, 1996). Average precipitation ranges from just under 10 inches per year at

Dillon to 13.5 inches per year at Cardwell. May and June are consistently the wettest months of the year and winter precipitation is dominated by snowfall. Climate summaries from Dillon, Twin Bridges and Cardwell are provided below in **Table 2-2**.

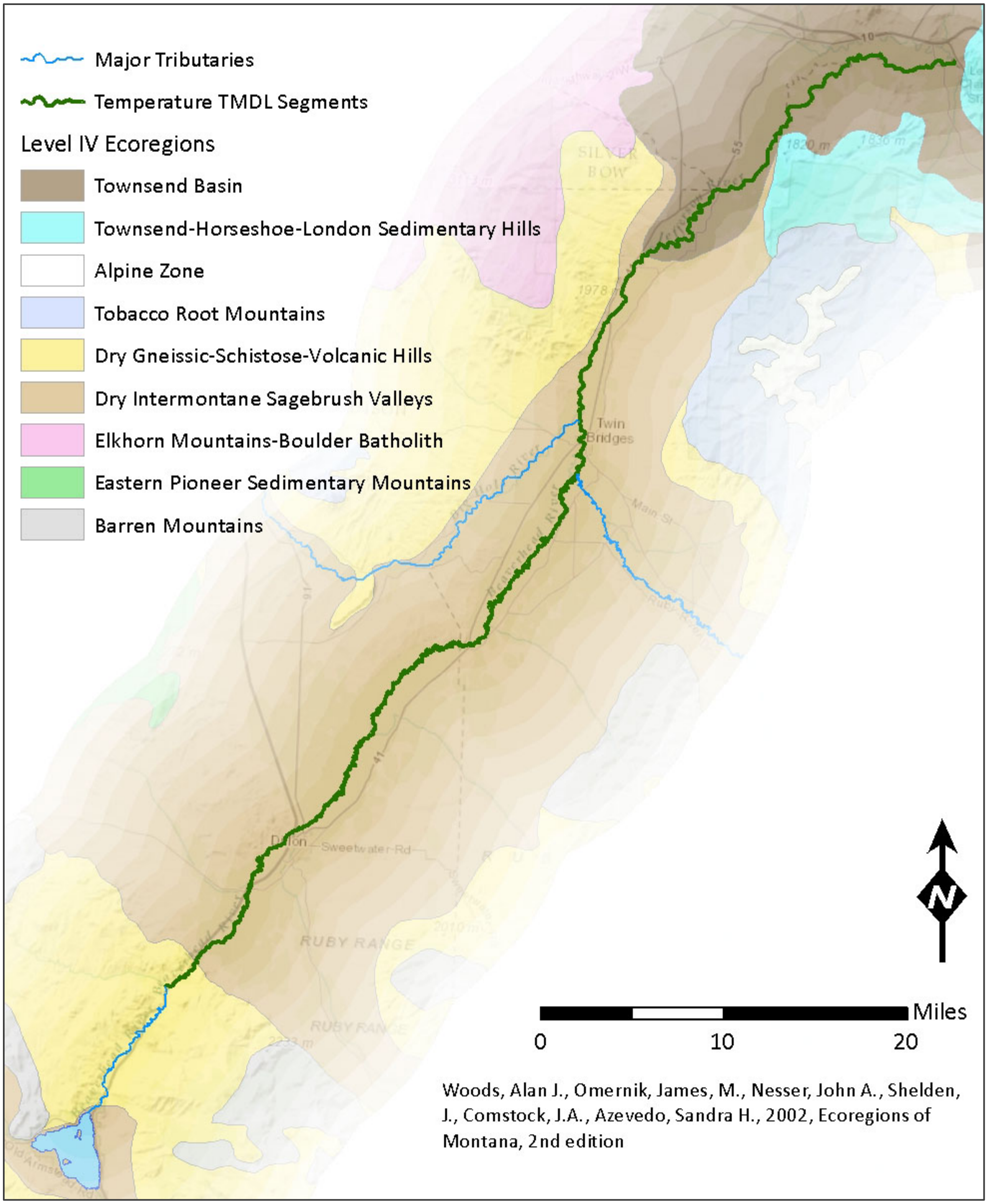
Table 2-2. Climate Summaries

Dillon Airport (242404)							Period of record: 1/1/1940 to 3/31/2013						
	Jan	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Annual**
Ave Max (°F)	32.2	37.5	44.3	54.5	63.8	72.2	83.2	81.4	70.5	58.3	42.4	33.3	56.1
Ave Min (°F)	11.1	14.9	20.3	28.4	36.4	43.4	49.1	47.4	39.4	30.9	20.2	12.7	29.5
Ave Total Precip (in.)	0.25	0.23	0.51	0.93	1.72	1.91	0.97	0.93	0.99	0.62	0.38	0.26	9.69
Ave Total Snow (in.)	4.9	3.8	7.1	6.2	2.3	0.1	0	0	1.3	2.5	4.1	4.1	36.4
Ave Snow Depth (in.)	1	1	1	0	0	0	0	0	0	0	1	1	0
Twin Bridges (248430)							Period of record: 6/1/1950 to 2/28/2013						
	Jan	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Annual**
Ave Max (°F)	34.6	40.2	47.8	57.1	66.8	75	84.3	82.3	72.5	60.4	44.3	35.1	58.4
Ave Min (°F)	11.4	14.9	20.8	27.6	35.4	42.3	45.7	43	35.4	27.5	19.2	12.2	28
Ave Total Precip (in.)	0.24	0.21	0.46	0.85	1.65	1.94	1.02	0.99	0.94	0.59	0.37	0.28	9.54
Ave Total Snow (in.)	1.5	1.9	1.8	0.9	0.1	0	0	0	0	0.3	1	0.8	8.3
Ave Snow Depth (in.)	0	0	0	0	0	0	0	0	0	0	0	0	0
Cardwell (241500)							Period of record: 5/1/1978 to 4/30/1991						
	Jan	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Annual**
Ave Max (°F)	37.4	43.1	50.7	60.9	68.3	78.7	86.2	84.6	73.5	63.2	45.4	36.3	60.7
Ave Min (°F)	12.5	15.7	23.3	29.3	37.3	43.9	48.3	45.6	37.1	28.7	20.4	11.8	29.5
Ave Total Precip (in.)	0.41	0.4	1.18	1.28	2.67	1.84	1.32	1.22	1.6	0.7	0.54	0.41	13.56
Ave Total Snow (in.)	3.2	2.5	7.9	1	0	0	0	0	0.5	0.8	4.2	4.1	24.2
Ave Snow Depth (in.)	0	0	0	0	0	0	0	0	0	0	0	0	0

Climate summaries are provided by the Western Regional Climate Center [http://www.wrcc.dri.edu/]

2.2 ECOLOGICAL PROFILE

These waterbodies flow through the Middle Rockies Level III ecoregion, and three Level IV ecoregions: dry gneissic-schistose-volcanic hills, dry intermontane sagebrush valleys, and the Townsend Basin. Ecoregions are mapped in **Figure 2-6**.



Woods, Alan J., Omernik, James, M., Nesser, John A., Shelden, J., Comstock, J.A., Azevedo, Sandra H., 2002, Ecoregions of Montana, 2nd edition

Figure 2-6. Level IV ecoregions

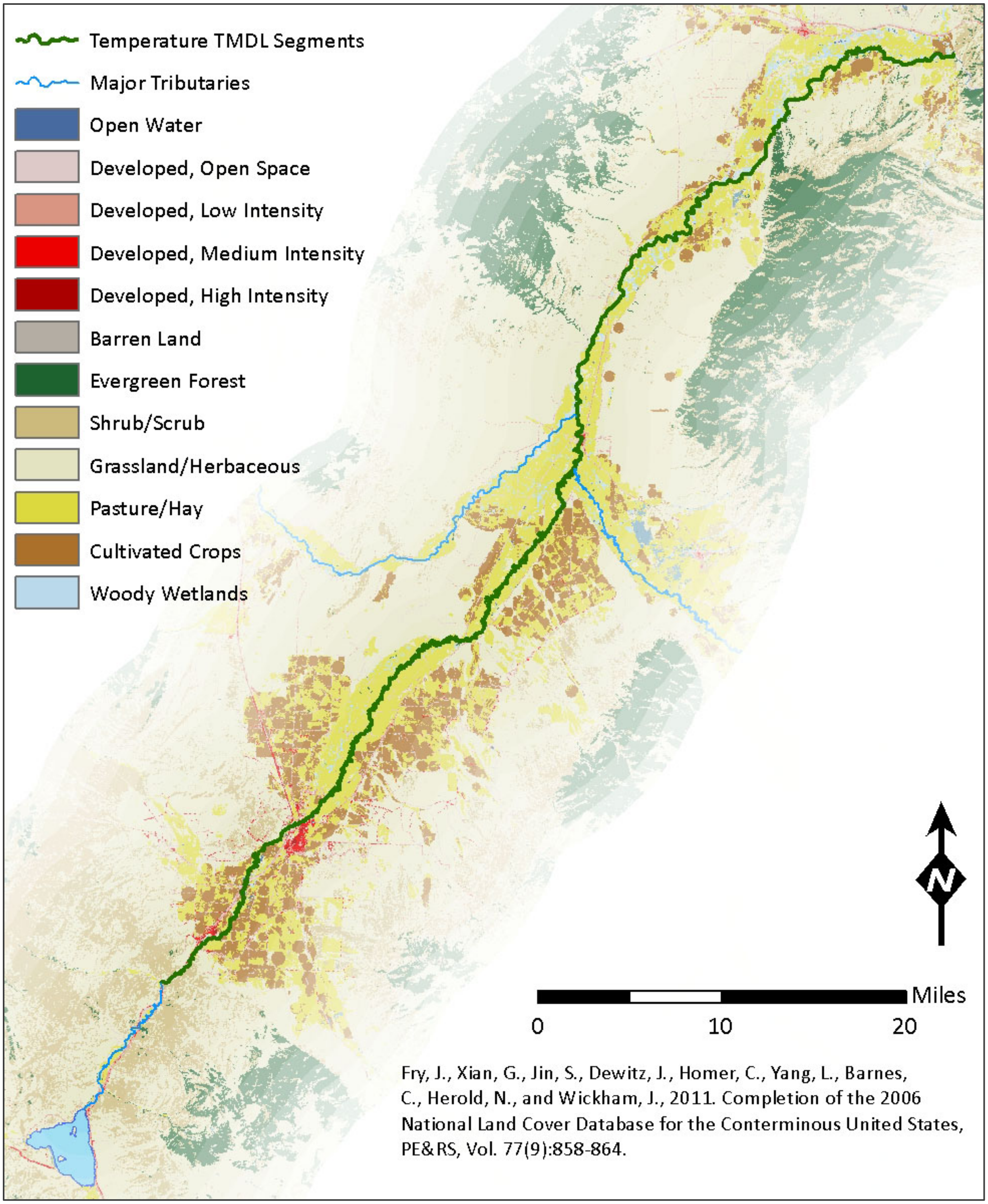
2.2.1 Land Cover and Land Use

The river corridor includes a wide range of land uses. Since this project addresses only the mainstem river corridor rather than upland areas or tributary watersheds, DEQ queried the 2006 National Land Cover Dataset (NLCD) (Fry et al., 2011) within a 100 meter buffer of the rivers' centerline. Land use and cover excluding the “Open Water” category is summarized below in **Table 2-3**. Pasture and riparian vegetation classes comprise the majority of the land use along the banks.

Table 2-3 Land Use and Land Cover along the Beaverhead River and the Jefferson River

NLCD Cover Type	Acres	Percent of Total
Pasture/Hay	3,315.89	42.5%
Woody Wetlands	2,285.54	29.3%
Grassland/Herbaceous	1,033.69	13.2%
Evergreen Forest	290.89	3.73%
Cultivated Crops	282.89	3.63%
Developed, Open Space	271.32	3.48%
Developed, Low Intensity	183.48	2.35%
Shrub/Scrub	79.84	1.02%
Developed, Medium Intensity	49.82	0.64%
Barren Land	5.34	0.07%
Developed, High Intensity	2.89	0.04%

The 2006 NLCD is mapped in **Figure 2-7**.



Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., and Wickham, J., 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, PE&RS, Vol. 77(9):858-864.

Figure 2-7. Land use and land cover from the 2006 NLCD

2.2.2 Aquatic Life

Fish distribution is mapped by Montana Fish Wildlife and Parks and reported on the Internet via the Montana's Fisheries Information System (MFISH) site (Montana Fish, Wildlife and Parks, 2013a).

The Beaverhead and Jefferson rivers host fish species common to this part of Montana, including: rainbow trout, brown trout, brook trout, mountain whitefish, burbot, carp, longnose dace, longnose sucker, Rocky Mountain sculpin, and white sucker. Westslope cutthroat trout are mapped in isolated tributaries. Westslope cutthroat trout and arctic grayling are Montana Species of Concern. Westslope cutthroat trout are mapped only in tributary streams, but arctic grayling are reported in the Beaverhead River (miles 11.25 to 26.57). Distribution of selected species is mapped in **Figure 2-8**. These species are selected based on sensitivity to temperature, discussed further in **Section 5.2.2**.

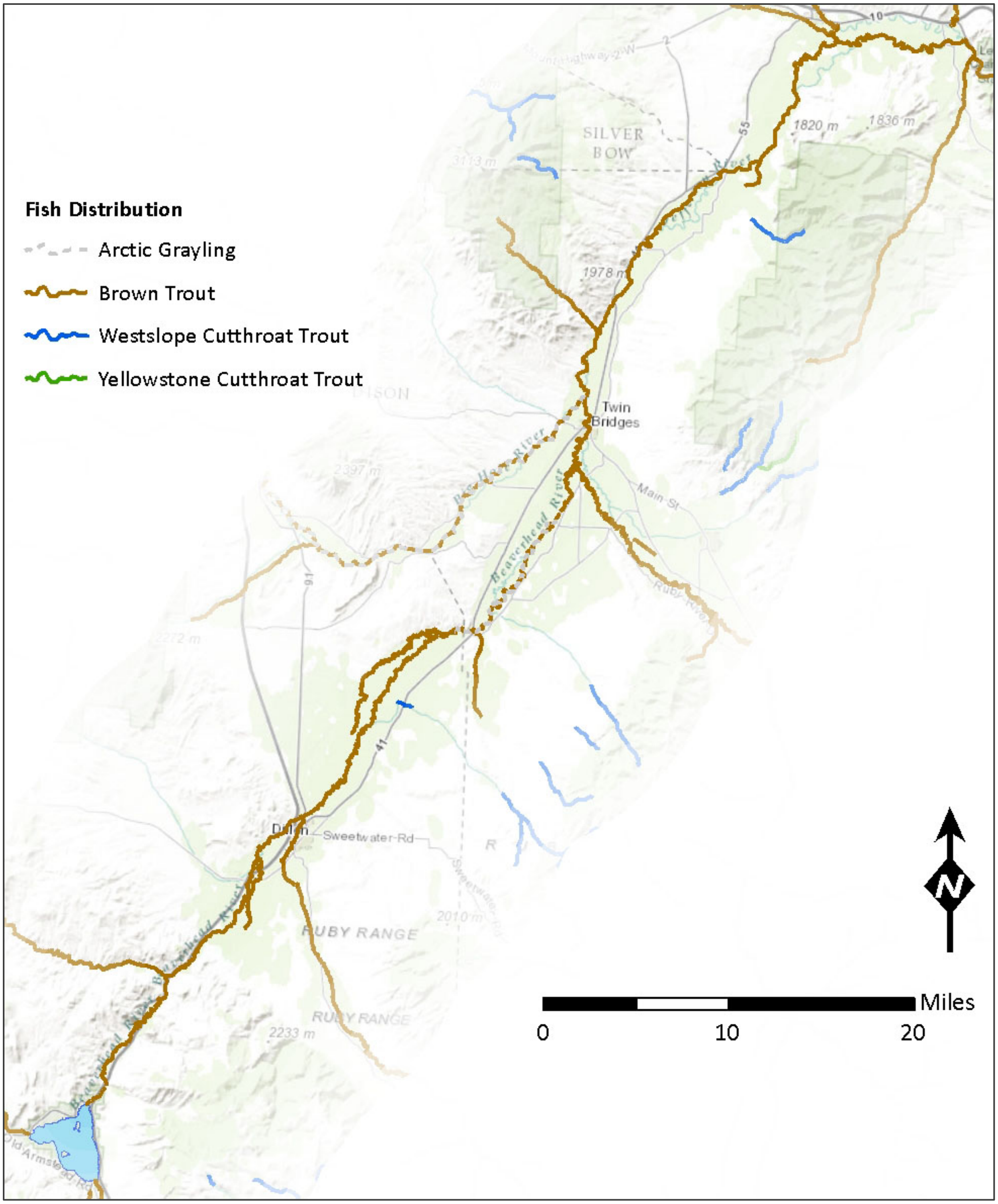


Figure 2-8. Distribution of selected fish species

2.3 CULTURAL PROFILE

The following information describes the social profile of the Beaverhead and Jefferson river corridors.

2.3.1 Population

As this project addresses only the mainstems of these rivers, population estimates are problematic. However, populations of communities located along these two valleys are reported in the 2010 Census as:

- Dillon: 4,134
- Twin Bridges: 375
- Silver Star: 141
- Whitehall: 1,038
- Cardwell: 50

2.3.2 Land Ownership

The majority of the land that these rivers flow through is privately owned. Exceptions to this include county and state rights-of-way for bridge crossings, Montana Fish, Wildlife and Parks fishing access sites, and isolated State Trust and US Bureau of Land Management lands. Public and ownership is illustrated on **Figure 2-9**.

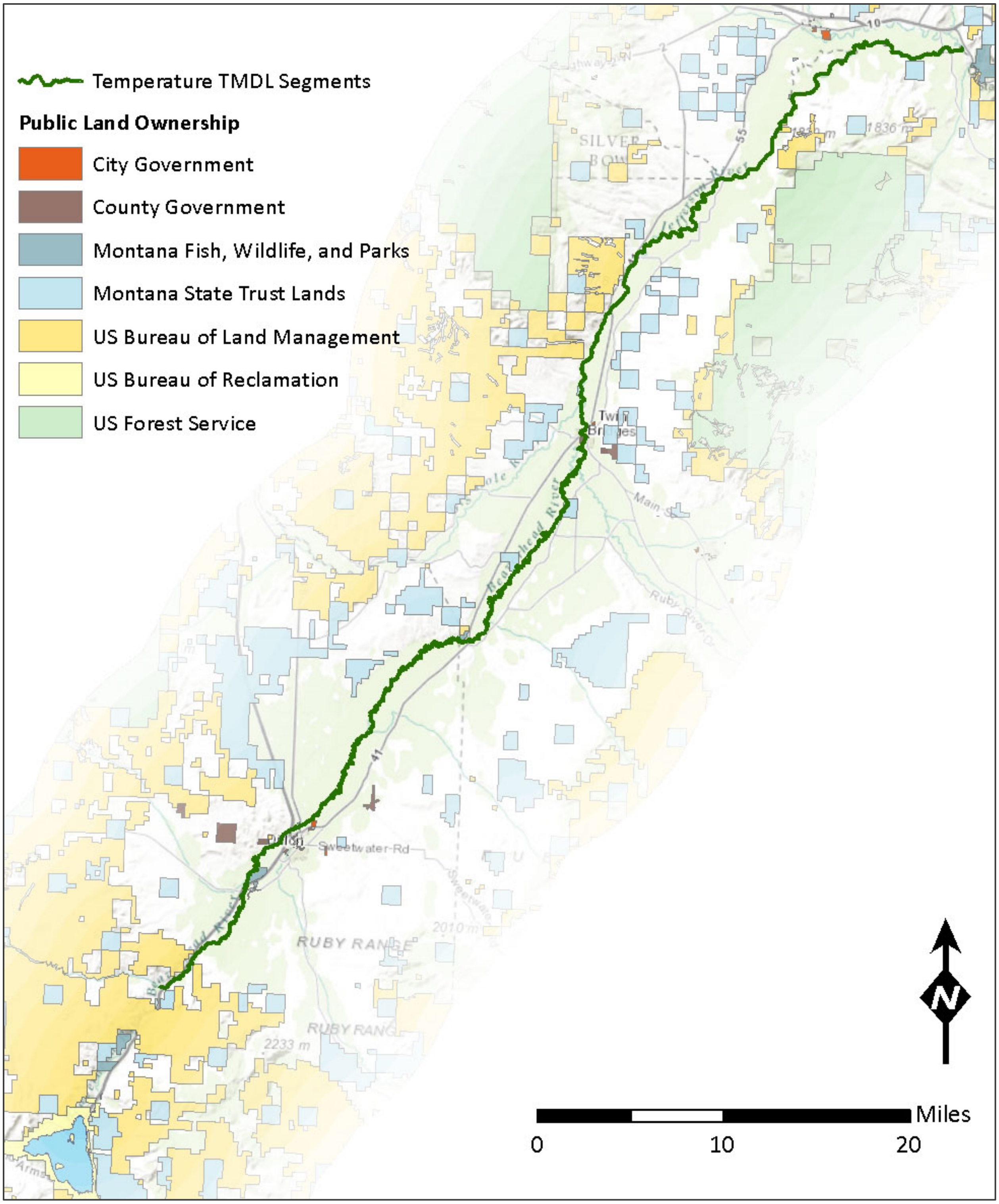


Figure 2-9. Public land ownership

2.3.3 Transportation Networks

The Beaverhead and Jefferson river corridors host a number of major transportation routes, including Interstate 15, State highways 51 and 44. A rail line is located parallel to the Beaverhead River from Dillon south. These routes parallel and cross the waterbodies in many locations. In some areas, the transportation networks restrict the stream channel. Conversely, there are also reaches along which roads and railroads are set back from the rivers.

2.3.4. Permitted Point Sources

Twelve permitted point sources are identified as discharging to the river segments included in this project. They are summarized below in **Table 2-4** and discussed in more detail in **Section 5.5.2**.

Table 2-4. Permitted Point Source in the lower Beaverhead and upper Jefferson Rivers

Facility Name	National Pollutant Discharge Elimination System (NPDES) ID	Permit Type	Waterbody Name
City of Dillon Wastewater Treatment Facility	MT0021458	Montana Pollutant Discharge Elimination System (MPDES) Individual Permit	Beaverhead River
Clark Canyon Hydro US Bureau of Reclamation Beaverhead River Dam Alteration	MTB001814	Turbidity Related to Construction (318)	Beaverhead River
Beaverhead Livestock Auction	MTG010176	Concentrated Animal Feeding Operation	Beaverhead River
City of Dillon - Wastewater Treatment Plant Dewatering	MTG070695	Construction Dewatering	Beaverhead River
Beaverhead County Weed Dist. Beaverhead River Corridor Pesticide	MTG870001	Pesticides	Beaverhead River
Barretts Minerals Incorporated	MTR000508	Storm Water - Industrial Activity	Beaverhead River
Clark Canyon Hydro - Clark Canyon Dam Hydroelectric Facility	MTR104018	Storm Water - Construction Activity	Beaverhead River
Dick Anderson - Dillon Wastewater Treatment Plant	MTR105067	Storm Water - Construction Activity	Beaverhead River
RE Miller and Sons - Montana Center for Horsemanship	MTR104116	Storm Water - Construction Activity	Beaverhead River and Blacktail Deer Creek
Tilstra Ranch	MTG010139	Concentrated Animal Feeding Operation	Irrigation ditch to Beaverhead River
Coronado Resources - Madison Project (SW Mining)	MTR000558	Storm Water - Industrial Activity	Tom Benton Gulch and Jefferson River
Twin Bridges Wastewater Treatment Facility	MT0028797	Montana Pollutant Discharge Elimination System (MPDES) Individual Permit	Bayers irrigation ditch

3.0 MONTANA WATER QUALITY STANDARDS

The federal Clean Water Act provides for the restoration and maintenance of the chemical, physical, and biological integrity of the nation's surface waters so that they support all designated uses. Water quality standards are used to determine impairment, establish water quality targets, and to formulate the total maximum daily loads (TMDLs) and allocations.

Montana’s water quality standards and water quality standards in general include three main parts:

1. Stream classifications and designated uses
2. Numeric and narrative water quality criteria designed to protect designated uses
3. Nondegradation provisions for existing high-quality waters

Montana’s water quality standards also incorporate prohibitions against water quality degradation as well as point source permitting and other water quality protection requirements.

Nondegradation provisions are not applicable to the TMDLs developed within this document because of the impaired nature of the streams addressed. Those water quality standards that apply to this document are reviewed briefly below. More detailed descriptions of Montana’s water quality standards may be found in the Montana Water Quality Act (75-5-301,302 Montana Code Annotated (MCA)), and Montana’s Surface Water Quality Standards and Procedures (Administrative Rules of Montana (ARM) 17.30.601-670) and Circular DEQ-7 (Montana Department of Environmental Quality, 2012b).

3.1 STREAM CLASSIFICATIONS AND DESIGNATED BENEFICIAL USES

Waterbodies are classified based on their designated uses. All Montana waters are classified for multiple uses. The lower Beaverhead and upper Jefferson Rivers are both classified as B-1.Waters classified as B-1 are to be maintained suitable for the following uses (Administrative Rules of Montana (ARM) (17.30.623(1)):

- 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
- Agricultural and industrial waters supply

While some of the waterbodies might not actually be used for a designated use (e.g., drinking water supply), their water quality still must be maintained suitable for that designated use. More detailed descriptions of Montana’s surface water classifications and designated uses are provided in **Appendix A**. Department of Environmental Quality’s (DEQ) water quality assessment methods are designed to evaluate the most sensitive uses for each pollutant group, thus ensuring protection of all designated uses (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2011). For streams in Western Montana, the most sensitive use assessed for temperature is aquatic life. DEQ determined that the lower Beaverhead and upper Jefferson Rivers do not meet the temperature water quality standards (**Table 3-1**).

Table 3-1. Impaired Designated Uses in the Lower Beaverhead River and Upper Jefferson River

Waterbody & Location Description	Waterbody ID	Impairment Cause *	Impaired Use(s)
Beaverhead River, Grasshopper Creek to mouth (Jefferson River)	MT41B001_020	Temperature	Aquatic Life
Jefferson River, headwaters to confluence of Jefferson Slough	MT41G001_011	Temperature	Aquatic Life

* Only includes those pollutant impairments addressed by TMDLs in this document

3.2 NUMERIC AND NARRATIVE WATER QUALITY STANDARDS

In addition to the use classifications described above, Montana's water quality standards include numeric and narrative criteria that protect the designated uses. Numeric criteria define the allowable concentrations, frequency, and duration of specific pollutants so as not to impair designated uses.

Numeric standards apply to pollutants that are known to have adverse effects on human health or aquatic life (e.g., metals, organic chemicals, and other toxic constituents).

Narrative standards are developed when there is insufficient information to develop numeric standards and/or the natural variability makes it impractical to develop numeric standards. Narrative standards describe the allowable or desired condition. This condition is often defined as an allowable increase above "naturally occurring." DEQ often uses the naturally occurring condition, called a "reference condition," to help determine whether or not narrative standards are being met (see **Appendix A**). For temperature TMDL development in the lower Beaverhead and upper Jefferson Rivers, only narrative standards are applicable; they are summarized in **Appendix A**.

4.0 DEFINING TMDLS AND THEIR COMPONENTS

A total maximum daily load (TMDL) is a tool for implementing water quality standards and is based on the relationship between pollutant sources and water quality conditions. More specifically, a TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive from all sources and still meet water quality standards.

Pollutant sources are generally defined as two categories: point sources and nonpoint sources. Point sources are discernible, confined and discrete conveyances, such as pipes, ditches, wells, containers, or concentrated animal feeding operations, from which pollutants are being, or may be, discharged. Some sources such as return flows from irrigated agriculture are not included in this definition. All other pollutant loading sources are considered nonpoint sources. Nonpoint sources are diffuse and are typically associated with runoff, streambank erosion, most agricultural activities, atmospheric deposition, and groundwater seepage. Natural background loading is a type of nonpoint source.

As part of TMDL development, the allowable load is divided among all significant contributing point and nonpoint sources. For point sources, the allocated loads are called “wasteload allocations” (WLAs). For nonpoint sources, the allocated loads are called “load allocations” (LAs).

A TMDL is expressed by the equation: TMDL = ΣWLA + ΣLA, where:

ΣWLA is the sum of the wasteload allocation(s) (point sources)
ΣLA is the sum of the load allocation(s) (nonpoint sources)

TMDL development must include a margin of safety (MOS), which can be explicitly incorporated into the above equation. Alternatively, the MOS can be implicit in the TMDL. A TMDL must also ensure that the waterbody will be able to meet and maintain water quality standards for all applicable seasonal variations (e.g., pollutant loading or use protection).

Development of each TMDL has four major components:

- Determining water quality targets
- Quantifying pollutant sources
- Establishing the total allowable pollutant load
- Allocating the total allowable pollutant load to their sources

Although the way a TMDL is expressed can vary by pollutant, these four components are common to all TMDLs, regardless of pollutant. Each component is described in further detail in the following subsections.

Figure 4-1 illustrates how numerous sources contribute to the existing load and how the TMDL is defined. The existing load can be compared to the allowable load to determine the amount of pollutant reduction needed.

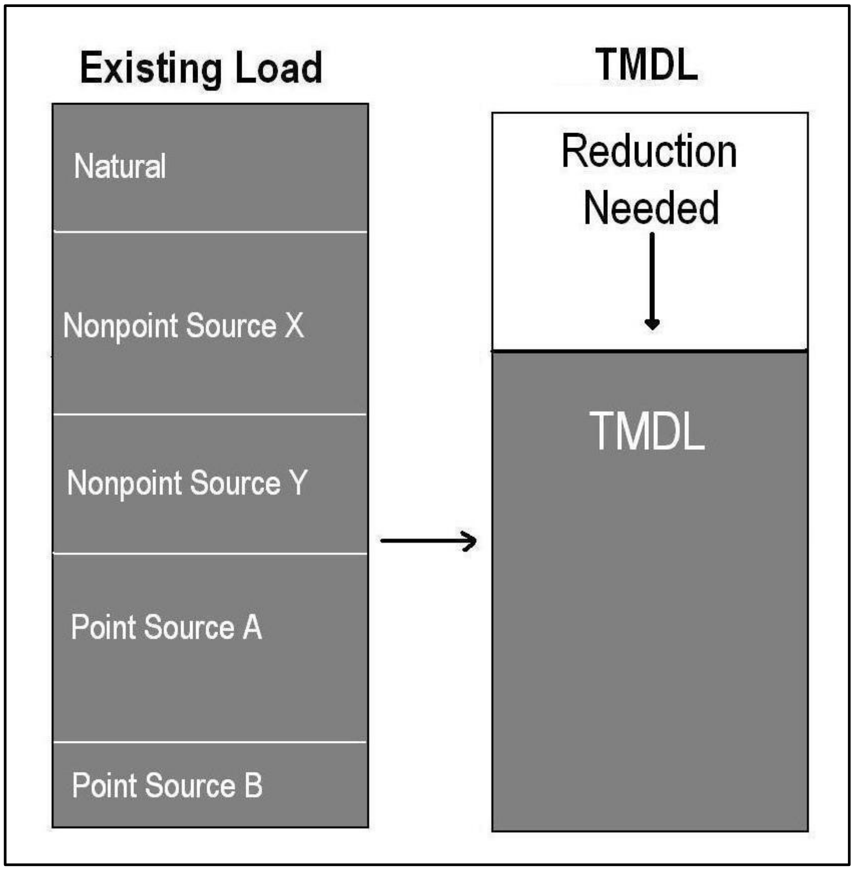


Figure 4-1. Schematic Example of TMDL Development

4.1 DEVELOPING WATER QUALITY 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 as the TMDL targets. For pollutants with narrative water quality standard(s), the targets provide a waterbody-specific 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). Therefore, the targets provide a benchmark by which to evaluate attainment of water quality standards. Furthermore, comparing existing stream conditions to target values allows for a better understanding of the extent and severity of the problem.

4.2 QUANTIFYING POLLUTANT SOURCES

All significant pollutant sources, including natural background loading, are quantified so that the relative pollutant contributions can be determined. Because the effects of pollutants on water quality can vary throughout the year, assessing pollutant sources must include an evaluation of the seasonal variability of the pollutant loading. The source assessment helps to define the extent of the problem by linking the pollutant load to specific sources in the watershed.

A pollutant load is usually quantified for each point source permitted under the Montana Pollutant Discharge Elimination System (MPDES) program. Nonpoint sources are quantified by source categories (e.g., loss of riparian habitat) and/or by land uses (e.g., crop production or land development). These source categories and land uses can be divided further by ownership, such as federal, state, or private. Alternatively, most, or all, pollutant sources in a sub-watershed or source area can be combined for quantification purposes.

Because all potentially significant sources of the water quality problems must be evaluated, source assessments are conducted on a watershed scale. The source quantification approach may produce reasonably accurate estimates or gross allotments, depending on the data available and the techniques used for predicting the loading (40 Code of Federal Regulations (CFR) Section 130.2(I)). Montana TMDL development often includes a combination of approaches, depending on the level of desired certainty for setting allocations and guiding implementation activities.

4.3 ESTABLISHING THE TOTAL ALLOWABLE LOAD

Identifying the TMDL requires a determination of the total allowable load over the appropriate time period necessary to comply with the applicable water quality standard(s). Although "TMDL" implies "daily load," determining a daily loading may not be consistent with the applicable water quality standard(s), or may not be practical from a water quality management perspective. Therefore, the TMDL will ultimately be defined as the total allowable loading during a time period that is appropriate for applying the water quality standard(s) and which is consistent with established approaches to properly characterize, quantify, and manage pollutant sources in a given watershed. For example, sediment TMDLs may be expressed as an allowable annual load.

If a stream is impaired by a pollutant for which numeric water quality criteria exist, the TMDL, or allowable load, is typically calculated as a function of streamflow and the numeric criteria. This same approach can be applied when a numeric target is developed to interpret a narrative standard.

Some narrative standards, such as those for sediment, often have a suite of targets. In many of these situations it is difficult to link the desired target values to highly variable, and often episodic, instream loading conditions. In such cases the TMDL is often expressed as a percent reduction in total loading based on source quantification results and an evaluation of load reduction potential (**Figure 4-1**). The degree by which existing conditions exceed desired target values can also be used to justify a percent reduction value for a TMDL.

Even if the TMDL is preferably expressed using a time period other than daily, an allowable daily loading rate will also be calculated to meet specific requirements of the federal Clean Water Act. Where this occurs, TMDL implementation and the development of allocations will still be based on the preferred time period, as noted above.

4.4 DETERMINING POLLUTANT ALLOCATIONS

Once the allowable load (the TMDL) is determined, that total must be divided among the contributing sources. The allocations are often determined by quantifying feasible and achievable load reductions through application of a variety of best management practices and other reasonable conservation practices.

Under the current regulatory framework (40 CFR 130.2) for developing TMDLs, flexibility is allowed in allocations in that "TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure." Allocations are typically expressed as a number, a percent reduction (from the current load), or as a surrogate measure (e.g., a percent increase in canopy density for temperature TMDLs).

Figure 4-2 illustrates how TMDLs are allocated to different sources using WLAs for point sources and LAs for natural and nonpoint sources. Although some flexibility in allocations is possible, the sum of all allocations must meet the water quality standards in all segments of the waterbody.

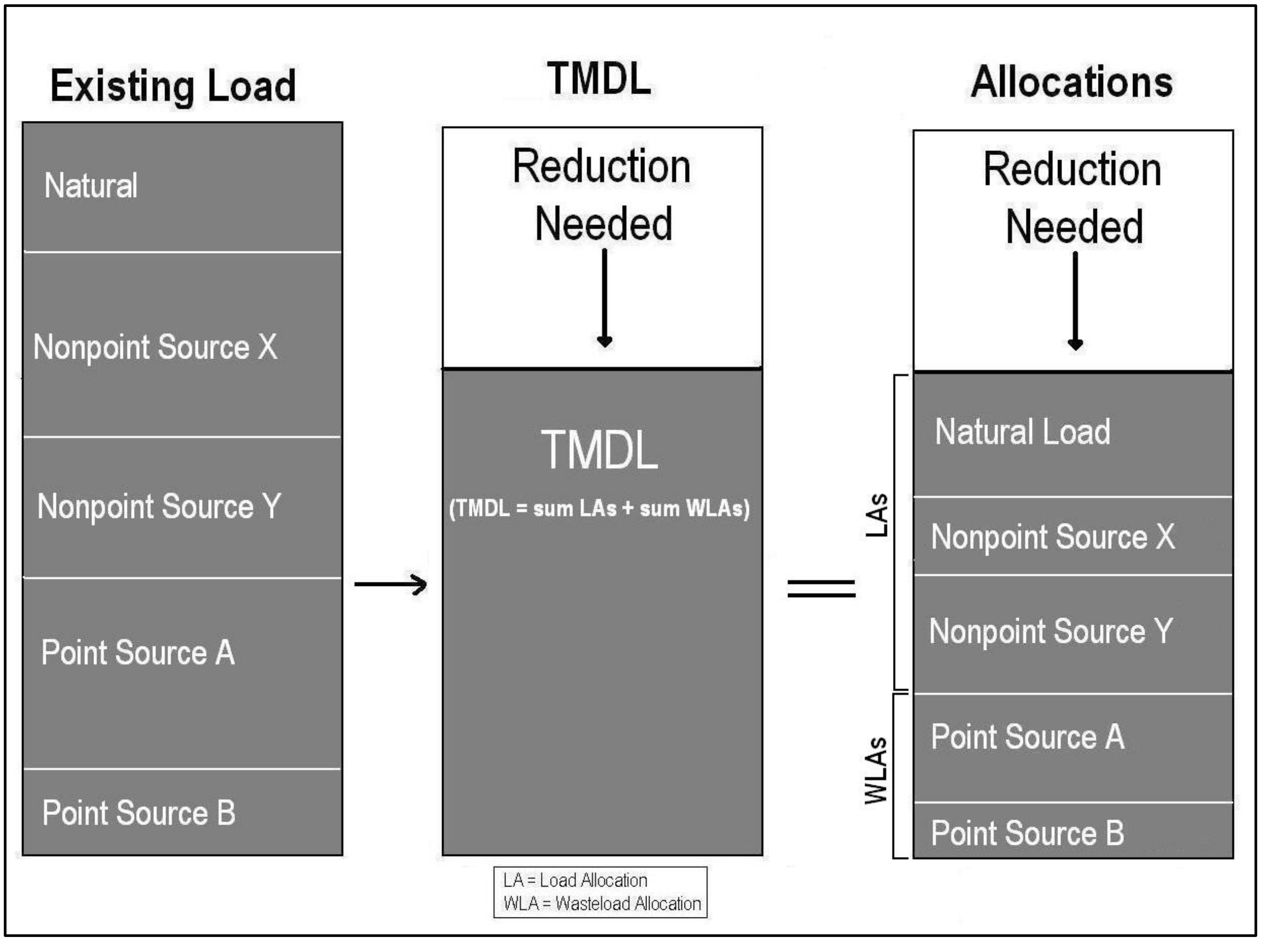


Figure 4-2. Schematic Diagram of a TMDL and its Allocations

TMDLs must also incorporate a margin of safety. The margin of safety accounts for the uncertainty, or any lack of knowledge, about the relationship between the pollutant loads and the quality of the receiving waterbody. The margin of safety may be applied implicitly by using conservative assumptions in the TMDL development process, or explicitly by setting aside a portion of the allowable loading (i.e., a TMDL = WLA + LA + MOS) (U.S. Environmental Protection Agency, 1999). The margin of safety is a required component to help ensure that water quality standards will be met when all allocations are achieved. In Montana, TMDLs typically incorporate implicit margins of safety.

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. The temperature TMDLs in this document 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, Department of Environmental Quality (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 naturally occurring target conditions within the stream reach immediately above the point source. In order to ensure that the water quality standard is achieved below the point source discharge, the WLA is based on the point source's discharge not exceeding the allowable increase above naturally occurring conditions.

4.5 IMPLEMENTING TMDL ALLOCATIONS

The Clean Water Act (CWA) and Montana state law (Section 75-5-703 of the Montana Water Quality Act) require wasteload allocations to be incorporated into appropriate discharge permits, thereby providing a regulatory mechanism to achieve load reductions from point sources. Nonpoint source reductions linked to load allocations are not required by the CWA or Montana statute, and are primarily implemented through voluntary measures. This document contains several key components to assist stakeholders in implementing nonpoint source controls. **Section 7.0** discusses a restoration and implementation strategy by pollutant group and source category, and provides recommended best management practices (BMPs) per source category (e.g., grazing, cropland, urban, etc.). **Section 7.5** discusses potential funding sources that stakeholders can use to implement BMPs for nonpoint sources. Other site-specific pollutant sources are discussed throughout the document, and can be used to target implementation activities. DEQ's Watershed Protection Section helps to coordinate nonpoint implementation throughout the state and provides resources to stakeholders to assist in nonpoint source BMPs. Montana's Nonpoint Source Management Plan (available at http://www.deq.mt.gov/wqinfo/nonpoint/nonpointsourceprogram.mcpx) further discusses nonpoint source implementation strategies at the state level.

DEQ uses an adaptive management approach to implementing TMDLs to ensure that water quality standards are met over time (outlined in **Section 8.0**). This includes a monitoring strategy and an implementation review that is required by Montana statute (see **Section 8.2**). TMDLs may be refined as new data become available, land uses change, or as new sources are identified.

5.0 TEMPERATURE TMDL COMPONENTS

This portion of the document focuses on temperature as an identified cause of water quality impairment in the Beaverhead and Jefferson Rivers. It describes: (1) the mechanisms by which temperature affects beneficial uses of streams; (2) the specific stream segments of concern; (3) information sources used for temperature total maximum daily load (TMDL) development; (4) temperature target development; (5) assessment of sources contributing to excess thermal loading; (6) TMDL development determination; (7) the temperature TMDLs and allocations; (8) seasonality and margin of safety; and (9) uncertainty and adaptive management.

5.1 TEMPERATURE (THERMAL) EFFECTS ON BENEFICIAL USES

Human influences that reduce stream shade, increase stream channel width, add heated water, or decrease the capacity of the stream to buffer solar heat flux all increase stream temperatures. Warmer temperatures can negatively affect aquatic life that depend upon cool water for survival. Coldwater fish species are more stressed in warmer water temperatures, which increases metabolism and reduces the amount of available oxygen in the water. Coldwater fish and other aquatic life may feed less frequently and use more energy to survive in thermal conditions above their tolerance range, which can result in fish kills. 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 the TMDL will address increased summer temperatures as the most likely to cause detrimental effects on fish and aquatic life, human influences on stream temperature, such as those that reduce shade, can lead to lower minimum temperatures during the winter (Hewlett and Fortson, 1982). 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 maximum 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 (**Appendix A**) and subsequently developing temperature TMDLs.

5.2 STREAM SEGMENTS OF CONCERN

The lower segment of the Beaverhead River (MT41B001_020, from Grasshopper Creek to the mouth at the Jefferson River) and the upper Jefferson River (MT41G001_011, from the confluence of the Bighole and Beaverhead Rivers to the confluence with the Boulder River/Jefferson Slough) are on the 2014 Montana impaired waters list as having temperature limiting a beneficial use (**Figure 5-1**). As discussed in **Section 3.1** both segments are classified as B-1, which requires that the streams be maintained suitable for several uses, including salmonid fishes and associated aquatic life. To help put monitoring data into perspective and understand how elevated stream temperatures may affect aquatic life, information on fish presence in the lower Beaverhead and upper Jefferson Rivers and temperature preferences for the most sensitive species are described below.

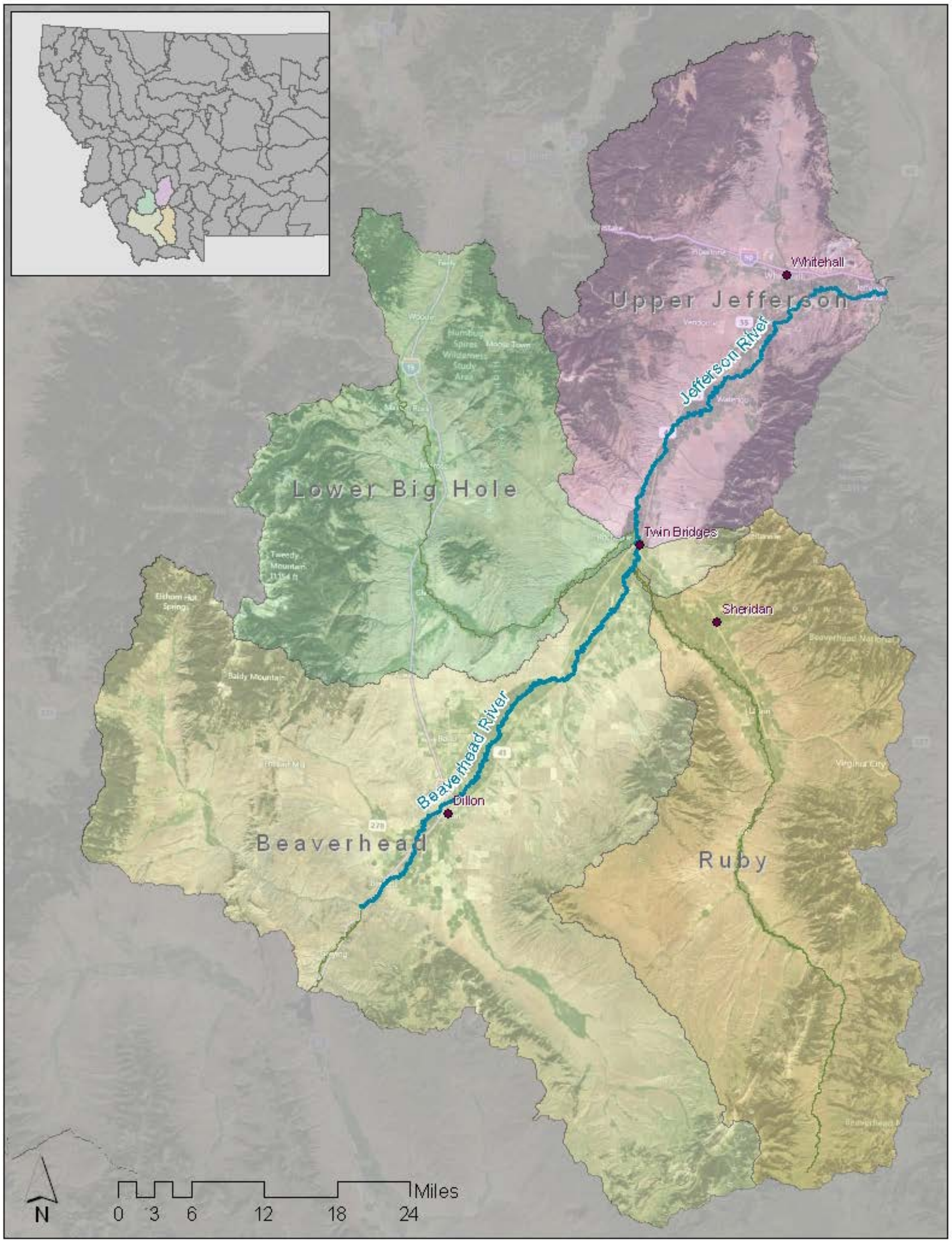


Figure 5-1. Lower Beaverhead and Upper Jefferson River Segments of Concern

5.2.1 Fish Presence in the Lower Beaverhead and Upper Jefferson Rivers

Because different fish species have varying optimal temperature ranges for survival and some are more sensitive than others to elevated stream temperatures, it is important to identify the fish species within each stream segment of concern.

Based on a query of Montana's Fisheries Information System (MFISH) brown trout, longnose dace, mottled sculpin, mountain whitefish, rainbow trout and white suckers are year-round residents found in abundance in the Beaverhead River. Longnose suckers are common year-round residents. Brook trout, burbot, common carp, and mountain sucker are rare in abundance and are year-round residents. Westslope cutthroat trout are rare and their use type is unknown. Arctic grayling are rare in abundance and their use type in the Beaverhead River is primarily migratory.

According to a query of MFISH, mountain whitefish are abundant year-round residents and brown trout, longnose dace, longnose sucker, mottled sculpin, rainbow trout, and white sucker are all common year-round residents in the Jefferson River. Burbot, mountain sucker, northern pike, redside shiner, and stonecat are rare in abundance and year-round residents. Arctic grayling are rare in abundance and they are a fluvial population that are spawning elsewhere. Brook trout are rare in abundance in the Jefferson River and use type is unknown.

Additional information regarding instream flow recommendations in the Beaverhead and Jefferson Rivers is available from Montana Fish, Wildlife, and Parks (FWP). FWP has provided a 2008 evaluation of fish/streamflow relationships for the Jefferson River (See **Attachment A**). Additionally, FWP completed a Jefferson River invertebrate study in 1979 and repeated that study in recent years. The study provides information related to water temperature and streamflow effects on the aquatic invertebrate community, which is available by contacting FWP (Oswald, 1979).

5.2.2 Temperature Levels of Concern in the Lower Beaverhead and Upper Jefferson Rivers

It has been well established that river management has an effect on water temperature (LeBlanc et al., 1997; Meier et al., 2003; Poole and Berman, 2001; Rutherford et al., 1997). For example, healthy riparian areas absorb incoming solar shortwave radiation, reflect longwave radiation, and influence microclimate (i.e., air temperature, humidity, and wind speed). Added streamflow volume (i.e., flow rate) increases the temperature buffering capacity of a waterbody via thermal inertia or assimilative heat capacity. Channel morphology is critical for maintenance of hyporheic flow and minimizes solar gain.

These variables, which are influenced by river management, are important in assessing stream health and associated effects on fish and aquatic life. Critical limits and temperature tolerances of fluvial inhabitants are an effective way to characterize waterbody condition. Temperature tolerances for salmonid fish species present in the Beaverhead River are summarized in **Table 5-1.** Temperatures slightly over 70°F are lethal for 10 percent of the salmonid population (LC_{10}) in an exposure lasting 24 hours[1]. Optimum ranges are nearer 60°. Thus given Department of Environmental Quality's (DEQ) knowledge of the current temperature impairment listings on the Beaverhead and Jefferson Rivers, there are potential impacts to most of the trout species.

Table 5-1. General trout temperature tolerances From DEQ 2011 (R. McNeil, personal communication).[1]

Species	Optimum Range (°F)	LC10 for 24 hours (°F)
Brown trout (adult)	57	75
Rainbow trout (adult)	57	80
Brook trout (adult)	60	77
Cutthroat trout (adult)	56	71

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[1] It should be noted that coldwater fish species have varied temperature requirements that are dependent on life stage. **Table 5-1** should only be used as a rough guide.

5.3 INFORMATION SOURCES AND DATA COLLECTION

As part of this TMDL project, DEQ used several information and data sources to assess temperature conditions in the Beaverhead and Jefferson Rivers:

- DEQ assessment file information
- Temperature related data collection
    - Beaverhead River
        - 2005 Bureau of Reclamation (BOR) stream temperature and flow
        - 2009 riparian shade and channel geometry data
    - Jefferson River
        - 2009 DEQ stream temperature and flow
        - 2009 riparian shade and channel geometry data
- Meteorological and climatic data from nearby observation stations

As discussed in **Appendix A** and **Section 5.4.1**, Montana defines temperature impairment as occurring when human sources cause a certain degree of change over the naturally occurring water temperature (the combination of natural sources and human sources with all reasonable land, soil, and water conservation practices in place). Interpreting the standard is more complex than just comparing measured temperatures to the temperature levels of concern discussed above (and summarized in **Table 5-1**). A QUAL2K water quality model was needed to determine if human sources are causing the allowable temperature change to be exceeded. Model details are presented in **Appendix B** and **C,** but the model summaries and outcomes are provided in **Section 5.5**.

5.3.1 DEQ Assessment Files

DEQ maintains assessment files that provide a summary of available water quality and other existing condition information, along with a justification for impairment determinations.

5.3.2 TMDL Data Collection – Lower Beaverhead River

DEQ's methods for temperature TMDL data collection on the lower Beaverhead River included a combination of characterizing water temperatures throughout the summer and collecting additional streamflow, riparian shade, and channel geometry data (**Figure 5-2.**). This information is collectively used within the QUAL2K model to evaluate impairment and the potential for improvement associated with the implementation of all reasonable land, soil, and water conservation practices. The following sections describe the data collected in the lower Beaverhead River for temperature assessment.

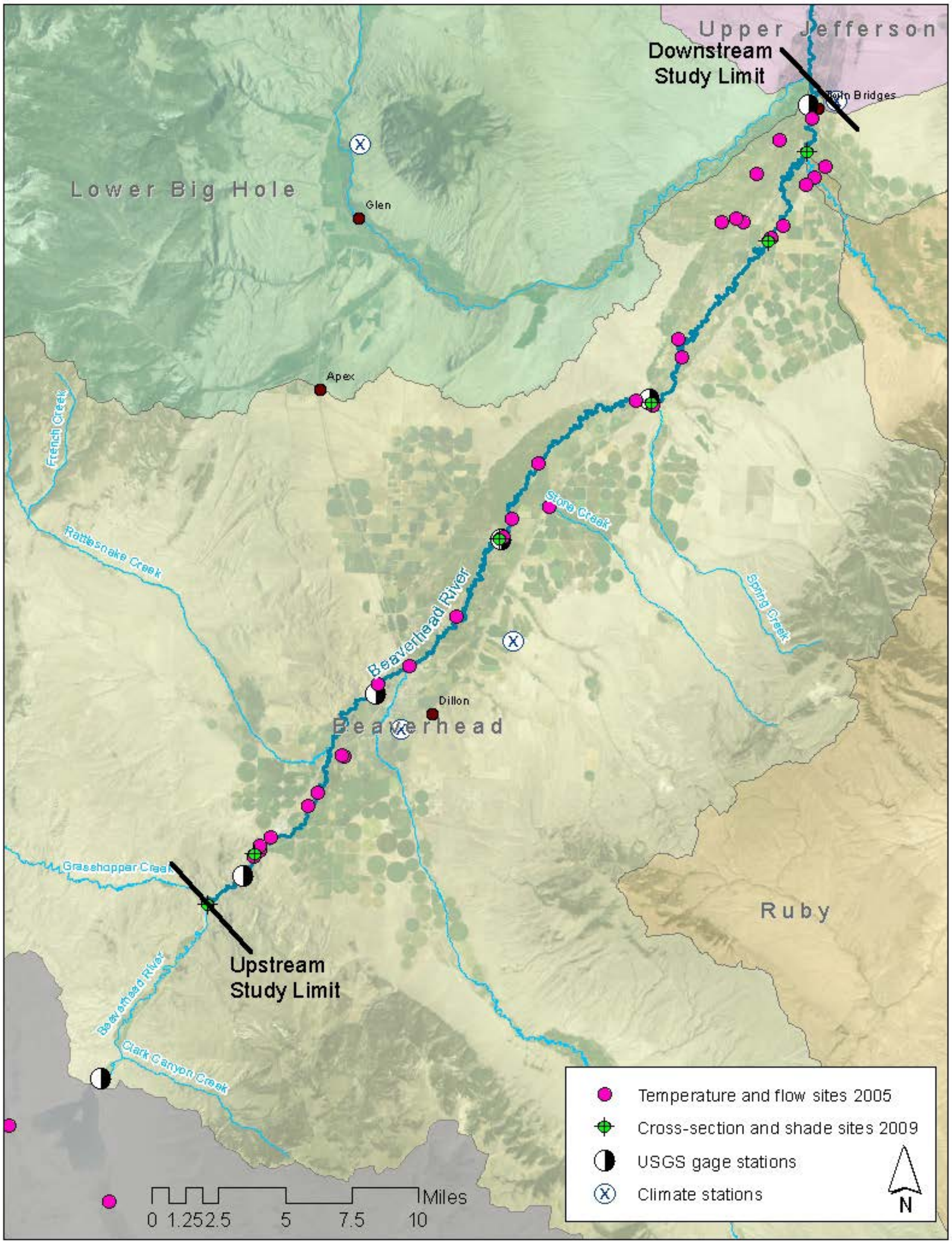

Figure 5-2. Lower Beaverhead River detailed study reach

5.3.2.1 Temperature and streamflow data collection

Temperature and flow data were collected for a water balance study by the Bureau of Reclamation (BOR) in 2005, and these data were used to characterize water quality throughout the summer. Thirty-four discharge and temperature monitoring stations were established in 2005 as part of the BOR water balance effort (Sessoms and Bauder, 2005). The flow measurement and temperature monitoring locations used in this study are identified in **Table 5-2**. Additional information regarding the temperature and flow data collected can be found in **Appendix B**.

Table 5-2. Overview of the monitoring locations on Beaverhead River in 2005

Site Type	Agency	Locations
Mainstem River	USGS	Beaverhead River at Barretts MT
	USGS	Beaverhead River at Dillon MT
	MSU	Beaverhead River at Anderson Lane Bridge
	USGS	Beaverhead River near Twin Bridges MT
	MSU/BOR	Beaverhead River at Giem (Silverbow Lane) Bridge
	MSU	Beaverhead River at Twin Bridges (Madison County Fairgrounds)
Tributaries	MSU	Poindexter Slough
	MSU	Stone Creek near Highway 41 bridge
	MSU	Trout Creek near Point of Rocks
	MSU	California Slough near Silverbow Lane
	MSU	Spring Creek near Silverbow Lane
	MSU	East Bench 41-2 lateral waste way
	MSU	Baker Ditch waste way/Redfield Lane Ditch
	MSU	Schoolhouse Slough at Highway 41 crossing
	MSU	Owsley Slough at Highway 41 crossing
	MSU	Greenhouse Slough at East Bench Road
	MSU	Ruby River at East Bench Road bridge
	MSU	Jacob's Slough at East Bench Road
Diversions	EBID	East Bench Canal
	CCWC	Canyon Canal
	MSU	Smith-Rebich Canal below Barrett's gauging station
	MSU	Outlaw Ditch at Barrett's Diversion Dam
	MSU	Perkins Ditch at Barrett's Diversion Dam
	MSU	Horton Haines Ditch
	MSU	Van Camp Ditch
	MSU	Poindexter Slough Diversion
	MSU	Westside Canal
	MSU	Selway Slough/Ditch
	MSU	Horton Haines Ditch
	MSU	Bishop Ditch
	MSU	1872 Ditch
	MSU	Brown Ditch
	MSU	Co-op Ditch near Point of Rocks
	MSU	Muleshoe Canal
	MSU	Baker Ditch

BOR = Bureau of Reclamation, CCWC = Canyon Canal Water Company, EBID = East Bench Irrigation District, MSU = Montana State University, USGS = U.S. Geological Survey

5.3.2.2 Riparian shading

Characterization of riparian shade was based on a combination of field data and aerial imagery analysis. Shade was estimated using Shadev3.0.xls. Segmentation identical to the QUAL2K model was used (i.e., 36 reaches) and average conditions for each species type, condition, and age class determined during 2009 (Water & Environmental Technologies, 2009) were used in the analysis. Riparian vegetation was assessed to characterize direct solar radiation losses from topography and vegetative shade. The following measurements were collected at 6 locations (18 transects) to support the modeling efforts: (1) vegetation/canopy height, (2) canopy density, (3) channel overhang, and (4) percent shade using a Solar

Pathfinder™. A fiberglass-tape, range-finder, clinometer, canopy densitometer, and Solar Pathfinder™ were used to acquire these attributes. Values were averaged to provide reach-wide estimates for the QUAL2K model. Simulated and observed shade results are shown in **Appendix B**.

5.3.2.3 Channel geometry

Channel geometry (i.e., width and depth) can influence the rate of thermal loading and is a necessary input for the QUAL2K model. Wide, shallow streams transfer heat energy faster than narrow, deep streams. Human activities that alter peak flows or disturb the riparian vegetation, streambanks, and/or stream channel have the potential to alter channel geometry. Therefore, channel geometry can be used to identify areas that may be destabilized and more prone to rapid thermal loading, particularly in locations where shading is minimal. Channel width (wetted and bankfull) was collected at 6 locations (18 transects) in 2009 (**Appendix B).**

5.3.2.4 Meteorological and climatic data

The QUAL2K model requires hourly meteorological data to calculate diurnal heat flux. Four sites had requisite data. These were: (1) Automated Surface Observing Station 242404 Dillon, MT, (2) Dillon Valley Agrimet, (3) Ruby Valley Agrimet, and (4) Jefferson Valley Agrimet. Hourly observations of temperature, wind speed, and dew point were available from each location. Values were averaged to provide mean repeating daily input for the QUAL2K model.

Automated Surface Observing Station number 242404 was closest to the project reach and provides a suitable characterization of long-term climate (Dillon Airport, period of record of 1948-2005). According to site records (Western Regional Climate Center, 2006), July and early August are the most probable time-period when river impairment would occur. Air temperatures approach 80-85°F and coincide with a relatively dry period in the basin.

5.3.3 TMDL Data Collection – Upper Jefferson River

DEQ's methods for temperature TMDL data collection on the upper Jefferson River included a combination of characterizing water temperatures throughout the summer and collecting additional streamflow, riparian shade, and channel geometry data (**Figure 5-3**). This information is collectively used within the QUAL2K model to evaluate impairment and the potential for improvement associated with the implementation of all reasonable land, soil, and water conservation practices. The following sections describe the data collected in the upper Jefferson River for temperature assessment.

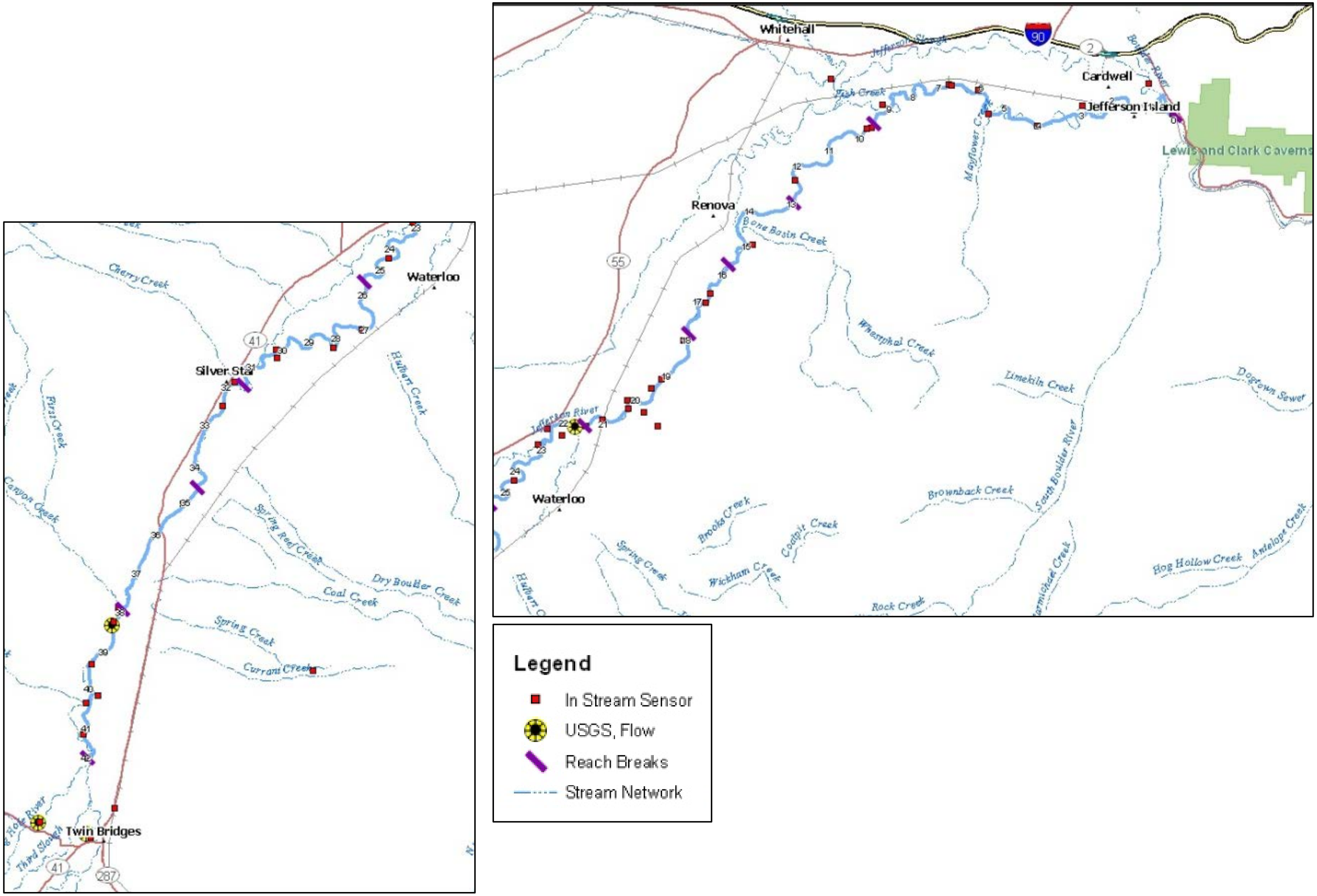

Figure 5-3. Upper Jefferson River detailed study reach

5.3.3.1 Temperature and streamflow data collection

DEQ and Water and Environmental Technologies (WET) collected temperature and flow data in 2009 to characterize water quality throughout the summer. Continuous temperature dataloggers were used to record diurnal variations in water temperature. Forty-nine (49) temperature loggers were deployed in the field; this included 20 mainstem locations, 26 tributaries and irrigation return flows, and three headwater rivers. Of the total deployed, 48 dataloggers were retrieved.

Instantaneous flow was measured at 63 locations (19 mainstem locations, 26 tributaries and irrigation return flows, and 18 irrigation withdrawals). Due to higher than anticipated streamflows during the field effort, it was necessary to adjust pre-selected locations to wadeable sections of the river. A more detailed description of the 2009 data collection effort can be found in **Appendix C.**

5.3.3.2 Riparian shading

Characterization of riparian shade was based on a combination of field data and aerial imagery analysis. Shade was estimated using Shadev3.0.xls. Segmentation identical to the QUAL2K model was used and average conditions for each species type, condition, and age class determined during 2009 (Water & Environmental Technologies, 2009) were used in the analysis. Riparian vegetation was assessed at 24 sites to characterize direct solar radiation losses from topography and vegetative shade. The following measurements were collected to support the modeling efforts: (1) vegetation/canopy height, (2) canopy density, (3) channel overhang, and (4) percent shade using a Solar Pathfinder™ (at 12 of the 24 sites). A fiberglass-tape, range-finder, clinometer, canopy densitometer, and Solar Pathfinder™ were used to acquire these attributes. Values were averaged to provide reach-wide estimates for the QUAL2K model. Simulated and observed shade results are shown in **Appendix C**.

5.3.3.3 Channel geometry

As stated previously, channel geometry (i.e., width and depth) can influence the rate of thermal loading and is a necessary input for the QUAL2K model. Channel width (wetted and bankfull) was collected at 5 locations in 2009 (**Appendix C**).

5.3.3.4 Meteorological and climatic data

The QUAL2K model requires hourly meteorological data to calculate diurnal heat flux within the model. HOBO weather stations collected meteorological data within the river corridor, which were utilized within the model. The hourly air temperature (°C), wind speed (m/s), and dew point (°C) data were compared to the surrounding AGRIMET and RAWS stations located in Whitehall, MT for the model input data (average of hourly results from 8/20/09 – 8/22/09) (**Appendix C**).

5.4 TARGET DEVELOPMENT

The following section describes 1) the framework for interpreting Montana's temperature standard; 2) the selection of target parameters and values used for target TMDL development; and 3) a summary of the temperature target values for the lower Beaverhead and upper Jefferson Rivers.

5.4.1 Framework for Interpreting Montana's Temperature Standard

Montana's water quality standard for temperature is narrative in that it specifies a maximum allowable increase above the naturally occurring temperature to protect fish and aquatic life. Under Montana water quality law, naturally occurring temperatures incorporate both natural sources and human sources that are applying all reasonable land, soil, and water conservation practices. Naturally occurring temperatures can be estimated for a given set of conditions using QUAL2K or other modeling approaches, but because water temperature changes daily and seasonally, no single temperature value can be identified to represent standards attainment. Therefore, in addition to evaluating if human sources are causing the allowable temperature change to be exceeded, a suite of temperature TMDL targets were developed to translate the narrative temperature standard into measurable parameters that collectively represent attainment of applicable water quality standards at all times. The goal is to set the target values at levels that occur under naturally occurring conditions but are conservatively selected to incorporate an implicit margin of safety that helps account for uncertainty and natural variability. The target values are protective of the use most sensitive to elevated temperatures, aquatic life; as such, the targets are protective of all designated uses for the applicable waterbody segments.

For the lower Beaverhead and upper Jefferson Rivers, a QUAL2K model was used to estimate the extent of human influence on temperature by evaluating the temperature change between existing conditions and naturally occurring conditions. The models used the data described in **Sections 5.3.2** and **5.3.3** to simulate existing conditions, and then the models were re-run with riparian shade and water use altered to reflect naturally occurring conditions. If the modeled temperature change between the two scenarios (i.e., existing and naturally occurring) is greater than allowed by the water quality standard (i.e., 0.5-1.0°F, depending on the naturally occurring temperature), this verifies the existing temperature impairments for the lower Beaverhead and Upper Jefferson rivers. Model scenario details and impairment determinations are presented are presented in **Sections 5.5.1** and **5.5.2**, **Source Assessment,** and **Appendices B and C.**

5.4.2 Temperature Target Parameters and Values

The primary temperature target is the allowable human-caused temperature change (i.e., 0.5-1.0°F, depending on the naturally occurring temperature), and the other targets are those parameters that influence temperature and can be linked to human causes (riparian shade, improved streamflow conditions, and lower headwater temperatures; where applicable). All targets are described in more detail below.

5.4.2.1 Allowable human-caused temperature change

The target for allowable human-caused temperature change for the lower Beaverhead and upper Jefferson Rivers links directly to the numeric portion of Montana's temperature standard for B-1 rivers (Administrative Rules of Montana (ARM) 17.30.623(e)): When the naturally occurring temperature is less than 66°F, the maximum allowable increase is 1°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. As stated above, naturally occurring temperatures incorporate natural sources, yet also include human sources that are applying all reasonable land, soil, and water conservation practices.

5.4.2.2 Riparian shade

Increased shading from riparian vegetation reduces sunlight hitting the stream and, thus, reduces the heat load to the stream. Riparian vegetation also reduces near-stream wind speed and traps air against the water surface, which reduces heat exchange with the atmosphere (Poole and Berman, 2001). In addition, lack of established riparian areas can lead to bank instability, which can result in an overwidened channel.

As stated in **Section 5.3**, shade was estimated using Shadev3.0.xls. The river was segmented into different vegetative reaches, identical to those used in the QUAL2K model, and average conditions were applied for each species type, condition, and age class determined during 2009 field work in both the lower Beaverhead and upper Jefferson Rivers. Measured shade, along with dominant vegetation type, height, offset/overhang, canopy density, and channel dimensions were used to validate the model. Values from each vegetation type were averaged to provide reach-wide estimates for the modeling. Simulated shade results are shown in **Appendices B** and **C.** In the shade scenarios (**Section 5.5**), areas with presently diminished shade conditions were changed to a reference condition by increasing all open/grassed sites, barren areas, and any other area with diminished shading vegetation to a reference shade condition based on field measured shade values and Geographic Information System (GIS) analysis.

Lower Beaverhead River

For the lower Beaverhead River, two reference riparian conditions were considered for a target value: where reference willow complex was present along the entire reach and where vigorous cottonwood stands were present due to natural conditions (i.e. no human impacts or native hydrology). Dense willow complex was chosen as the target condition for the lower Beaverhead River because it is likely the best possible condition under the existing hydrology, which is regulated by outflows from the Clark Canyon Reservoir (downstream flow regulation can inhibit the dispersal, germination, and recruitment of cottonwoods). Dense willow complex has an average daily effective shade of 22% (with an average height of approximately 9 feet, overhang of approximately 1.5 feet, density of 73%)**.**

Jefferson River

For the upper Jefferson River, two reference riparian conditions were considered. The first reference condition was defined as improvement to a mixed low level vegetation type. The second reference condition was run as a mixed high level (inclusion of cottonwoods) in which grass/bare areas as well as willow areas and mixed low level areas were increased. The target for the upper Jefferson River was determined to reside between these two reference conditions because some cottonwood recruitment is possible in the Jefferson River. Therefore, mixed low and high level vegetation is considered the reference condition with an average daily effective shade ranging between 16-21% (an average vegetation height of approximately 25.5 feet, overhang of approximately 1.5 feet, density of 42%).

DEQ realizes most healthy riparian buffers are comprised of more than a single category of vegetation, but these riparian vegetation categories were used for two reasons 1) the actual composition of the riparian zone under target shade conditions will vary over time and is too complex to model with QUAL2K, and 2) based on existing vegetation in the watershed and what is known of historical conditions, the effective shade provided by high density willows in the lower Beaverhead River and medium density mixed low and high level vegetation in the upper Jefferson River, were determined to be a reasonable targets. Considering the variability in potential vegetation and shade, these densities were used as a surrogate to represent the average achievable shade condition; effective shade is the result of topography and vegetative height and density, so the target shade condition could be achieved by a combination of vegetation types and densities. Additionally, the effective shade potential at any given location may be lower or higher than the target depending on natural factors such as fire history, soil, topography, and aspect but also because of human alterations to the near-stream landscape including roads and riprap that may not feasibly be modified or relocated. The targets are provided as a quantitative guide for meeting the standard and are intended to represent all reasonable land, soil, and water conservation practices (RLSWCPs). Therefore, if all RLSWCPs are being implemented, then the lower Beaverhead River and the upper Jefferson River will be meeting the riparian shade targets. The targets do not apply to portions where the riparian zone is already at potential or is dominated by vegetation not likely to attain great heights at maturity (e.g., wetland shrub community).

In addition to target vegetation types and densities, the DEQ recommends a buffer width of a minimum of 50 feet to improve effective shade. To help minimize the influence of upland activities on stream temperature, a riparian buffer close to 100 feet is commonly recommended (Ledwith, 1996; Knutson and Naef, 1997; Ellis, 2008). However, several studies have shown that most (85-90%) of the maximum shade potential is obtained within the first 50 feet (Brazier and Brown, 1973; Broderson, 1973; Steinblums et al., 1984) or 75 feet of the channel (CH2M, 2000; Castelle and Johnson, 2000; Christensen, 2000). The Natural Resources Conservation Service (NRCS) Conservation Practice Standard recommends a minimum buffer width of 35 feet, and also includes recommendations to use species with a medium or high shade value and to meet the minimum habitat requirements of aquatic species of concern (Natural Resources Conservation Service, 2011a; 2011b). Based on several literature sources finding that most shade is obtained within a buffer width of 50 feet and that 50 feet is the minimum buffer width for the Montana Streamside Management Zone (Montana Department of Natural Resources and Conservation, 2006), the DEQ recommends a buffer width of a minimum of 50 feet.

5.4.2.3 Instream flow (water use)

Because larger volumes of water take longer to heat up during the day, the ability of a stream to buffer incoming solar radiation is reduced as instream water volume decreases. In other words, a channel with little water will heat up faster than an identical channel full of water, even if they have identical shading and are exposed to the same daily air temperatures.

The effect of water use on instream flow and water temperature was considered. Although Montana standards do not necessarily apply to existing water rights, it is important to assess the cumulative effect of these practices on the overall thermal regime of the river. The simple relationship presented by Brown (1969) suggests that large volume streams are less responsive to temperature changes than low flow streams and will also exhibit smaller diel fluctuations.

Lower Beaverhead River

The modeling scenario (**Section 5.5.1.3**) consisted of a 20% water savings gained through improved irrigation delivery and allowing that water savings to flow down the lower Beaverhead River (any voluntary water savings and subsequent instream flow augmentation must be done in a way that protects water rights).

The goal is to have improved irrigation delivery through best management practices (BMPs) from all water users on the Beaverhead River (BOR, East Bench Irrigation District (EBID), Clark Canyon Water Supply, and others). Some users are already implementing BMPs and there are existing proposals for upgrades for irrigation delivery. The 20% water savings assumption was based on three grant proposals submitted to the state of Montana by the East Bench Irrigation District (EBID). Two of the grants were for lining 2,000 (Montana Department of Natural Resources and Conservation, 2007) and 1,175 (Montana Department of Natural Resources and Conservation, 2009) feet of main canal respectively, which were estimated by EBID to reduce annual leakage by 3,600 and 2,585 acre-feet. The third grant was to replace slide gates at three existing check structures (Montana Department of Natural Resources and Conservation, 2011), which was expected to conserve another 7,855 acre-feet. Hence the total annual water savings by the three proposals was 14,040 acre-feet or 20.8% of the 67,260 acre-feet diverted annually between 1996 and 2005 (except for 2004 when no water was diverted). This value was rounded to 20% for the scenario and reflects the potential improvement through implementing reasonable BMPs. Additional reductions may be feasible through other canal improvements or improvement in irrigation delivery and efficiency in other areas of the watershed, but it is unknown whether these are reasonable or feasible at this time.

Upper Jefferson River

The modeling scenario (**Section 5.5.2.3**) assumes that irrigation delivery improvement and voluntary water reductions during summer low flow conditions by Jefferson River water users could create a water savings of 15% and that the conserved water could be allowed to flow down the upper Jefferson River, thereby increasing instream flow (any voluntary water savings and subsequent instream flow augmentation must be done in a way that protects water rights). The 15% water savings is recommended annually during summer low flow conditions.

For drought years, the Jefferson River Watershed Council (JRWC) and other stakeholders have put together a Drought Management Plan to reduce resource damage and to aid in the equitable distribution of water resources during water critical periods. Implementation of the plan should provide sufficient flow to maintain and potentially improve fish population numbers and is a voluntary effort involving local interests including agriculture, conservation groups, anglers, municipalities, businesses, and government agencies. The first Drought Management Plan was prepared and approved by the Jefferson River Watershed Council in 2000 and revised in 2005. The plan aims to increase flow at the Waterloo Gage (below Fish Creek Canal). The drought management plan goal of maintaining at least 50 cfs at Waterloo has not always been met since the implementation of the plan, but cooperation by water users helped improve flows at this critical location. The Drought Management Plan established flow triggers for directing actions of anglers, water users, and government agencies. The triggers were revised in 2005 based on observations of the previous 5 years of plan implementation. In 2006, a study was prepared for the JRWC and Trout Unlimited (Van Mullem, 2006) to show where additional water savings were possible through changes in canal upgrades and improved canal management. The objective of the JRWC is to continue implementation of the Drought Management Plan in cooperation with Montana FWP, Trout Unlimited, and local irrigators.

Water users in the Beaverhead and Jefferson watersheds are encouraged to work with the United States Department of Agriculture (USDA) Natural Resource Conservation Service, the Montana Department of Natural Resources & Conservation, the local conservation district, and other local land management agencies to review their systems and practices.

5.4.2.4 Headwater Temperature Reduction

Instream water temperature generally tends to increase in the downstream direction from headwaters to lowlands. Increasing temperature in the downstream direction reflects systematic tendencies in parameters critical to water temperature (including width to depth ratios, air temperature, groundwater inflow, and changes in riparian vegetation and topography) (Moore et al., 2005). For example, as streams widen, riparian canopy provides less shade until some point in a river system it provides insignificant shading. Therefore, it is important to maintain cooler naturally occurring temperatures from headwater streams as they provide the base temperatures for the receiving larger order stream.

Effects of headwater inflow depend on the temperature and discharge of each stream and can be characterized by a simple mixing equation. Naturally occurring temperatures for the headwater streams of the Jefferson River were determined using a QUAL2K model for the Beaverhead River (as described in this document), a SNTEMP model for the Ruby River (see Ruby River Temperature TMDL document (2006)), and a Heat Source model for the Big Hole River (see Middle and Lower Big Hole River TMDL document, (2009)). SNTEMP is a simpler model than the QUAL2K, and Heat Source is more complex like the QUAL2K model; however, all three models provide minimum, maximum, and mean temperature outputs for existing conditions and scenario development. Based on these models, naturally occurring headwater temperature targets for the Jefferson River are as follows: Ruby River at mouth = 66.70°F, Beaverhead River at mouth = 72.29°F, Big Hole River at mouth = 77.00°F.

5.4.2.5 Wastewater Treatment Facilities

Wastewater treatment facilities (WWTFs) may influence a stream's water temperature. The temperature TMDL target is performance based for WWTFs and other point source effluents. This target requirement states that these point sources shall not warm the stream individually or in combination by more than the allowable increase in temperature under Montana's temperature standard, which applies to the WWTF in Dillon and any future WWTF that discharge to the lower Beaverhead and upper Jefferson Rivers. This translates to no more than a 1.0°F increase when the receiving water is cooler than 66.5°F, no increase above 67°F when the receiving water is 66 – 66.5°F and no more than a 0.5°F increase under conditions where the receiving water is greater than 66.5°F.

5.4.3 Target Values Summary

The allowable human-caused temperature change is the primary target that must be achieved to meet the standard. Alternatively, compliance with the temperature standard can be attained by meeting the two temperature-influencing targets (i.e., riparian shade and width/depth ratio). In this approach, if all reasonable land, soil, and water conservation practices are installed or practiced, water quality standards will be met. **Table 5-3** summarizes the temperatures targets for the lower Beaverhead and upper Jefferson Rivers.

Table 5-3. Temperature Targets for the lower Beaverhead and upper Jefferson Rivers

Target Parameter	Target Value
Primary Target	
Allowable Human-Caused Temperature Change	If the naturally occurring temperature is less than 66°F, the maximum allowable increase is 1°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.
Temperature-Influencing Targets: Meeting both will meet the primary target	
Riparian Health – Shade	**Beaverhead River** Dense willow complex with an average daily effective shade of 22% (an average height of around 9 ft., overhang of around 1.5 ft., and density of 73%) **Jefferson River** Mixed low and high level vegetation with an average daily effective shade ranging between 16-21% (an average height of around 25.5 ft., overhang of around 1.5 ft., and density of 42%)
Instream flow (water use management)	**Beaverhead River** 20% increase in flow from improved irrigation delivery **Jefferson River** 15% increase in flow from voluntary reductions in use
Reduce headwater temperatures	**Jefferson River** Decrease headwater temperature using the naturally occurring maximum temperature from the three headwaters streams (Ruby River at mouth= 66.70°F, Beaverhead River at mouth = 72.29°F, Big Hole River at mouth = 77.00°F).
Wastewater Treatment Facilities	Individually or in combination no more than a 1.0°F increase when the receiving water is cooler than 66.5°F, no increase above 67°F when the receiving water is 66 – 66.5°F and no more than a 0.5°F increase under conditions where the receiving water is greater than 66.5°F

5.5 SOURCE ASSESSMENT

The source assessment describes the most significant natural, non-permitted, and permitted sources of temperature. As discussed above, the source assessment for the lower Beaverhead and upper Jefferson Rivers largely involved QUAL2K temperature modeling.

5.5.1 Source Assessment Using QUAL2K

QUAL2K is a one-dimensional river and stream water quality model that assumes the channel is well-mixed vertically and laterally. The QUAL2K model uses steady state hydraulics that simulates non-uniform steady flow. Within the model, water temperatures are estimated based on climate data, riparian shading, and channel conditions. Each stream is segmented into reaches within the model that are assigned the same channel and shade characteristics. Segmentation is largely based on the location of field data, tributaries, irrigation withdrawal/returns, and changes in channel conditions or shading. Temperature outputs from the model are given at river station miles that correspond with the end of each modeled reach. Both watersheds have been affected by present and historical grazing in the riparian area, land development/redevelopment, irrigated crop production, streambank modification and destabilization, historical mining, and impacts from flow regulation and modification. Instead of focusing on the potential contribution of all of these sources, the source assessment focused on two factors that can be influenced by human activities and are drivers of stream temperature: instream flow and riparian shade.

5.5.1.2 Lower Beaverhead Assessment Using QUAL2K

A QUAL2K model was used to determine the extent that human-caused disturbances within the lower Beaverhead River have increased the water temperature above the naturally occurring level. The evaluation of model results focuses on the maximum daily water temperatures in the lower Beaverhead River during the summer because those are conditions mostly likely to harm aquatic life, the most sensitive beneficial use.

Within the model, the lower Beaverhead River was segmented into 36 modeled reaches and 3 generalized hydraulic reaches. The water temperature and flow data collected by the BOR in 2005, along with channel measurements, irrigation data, and climate data (**Section 5.3**), were used to calibrate and validate the model. Features of significance were the diversion at Barretts, which withdrew approximately half of the flow in the river, and then numerous smaller diversions that incrementally deplete flow until a minimum is reached near Silver Bow (Giem) Bridge. Gains occur thereafter from sloughs out of the Big Hole River and the Ruby River. Simulated minimum, mean, and maximum daily water temperatures are shown in **Appendix B**. Model error (RE and RMSE) were quite good at 0.01% and 0.91°F. Overall, the river generally increases in temperature (and diurnal flux) from the headwater boundary to mile 12, and then has a short region of cooling coincident with increased flow volume. The addition of the Wastewater Treatment Plant (WWTP) discharge was found to have a very small effect in the middle river.

A baseline scenario and three additional scenarios were modeled to investigate the potential influences of human activities on temperatures in the lower Beaverhead River. The following sections describe those modeling scenarios. Although channel width and depth can influence stream temperatures, the existing channel dimensions were not changed for any of the scenarios because targets for channel width/depth were difficult to ascertain because of a lack of reference data for a system like the

Beaverhead River. A more detailed report of the development and results of the QUAL2K model are included in **Appendix B.**

5.5.1.2.1 Baseline scenario (existing conditions)

The baseline scenario represents stream temperatures under existing shade and channel conditions in August on a hot, dry year and is the scenario that all others are compared against to evaluate the influence of human sources. The simulation results are documented in **Appendix B** and indicate reasonably good calibration for water temperature based on performance statistics of RE and RMSE. Water temperature was shown to increase from the upstream boundary near Barretts until Silver Bow (Giem) Bridge and then decrease thereafter.

Under the baseline scenario, maximum daily temperatures ranged from 71°F at Barretts to 69.9°F at the Westside Canal and then up to 77.1°F at Giem Bridge (**Figure 5-4**). Temperatures generally increase in a downstream direction but reset somewhat by decreasing by approximately 4°F near the mouth at Madison Co. Fairgrounds. The area where temperatures decrease corresponds with where sloughs from the Big Hole River enter into the Beaverhead.

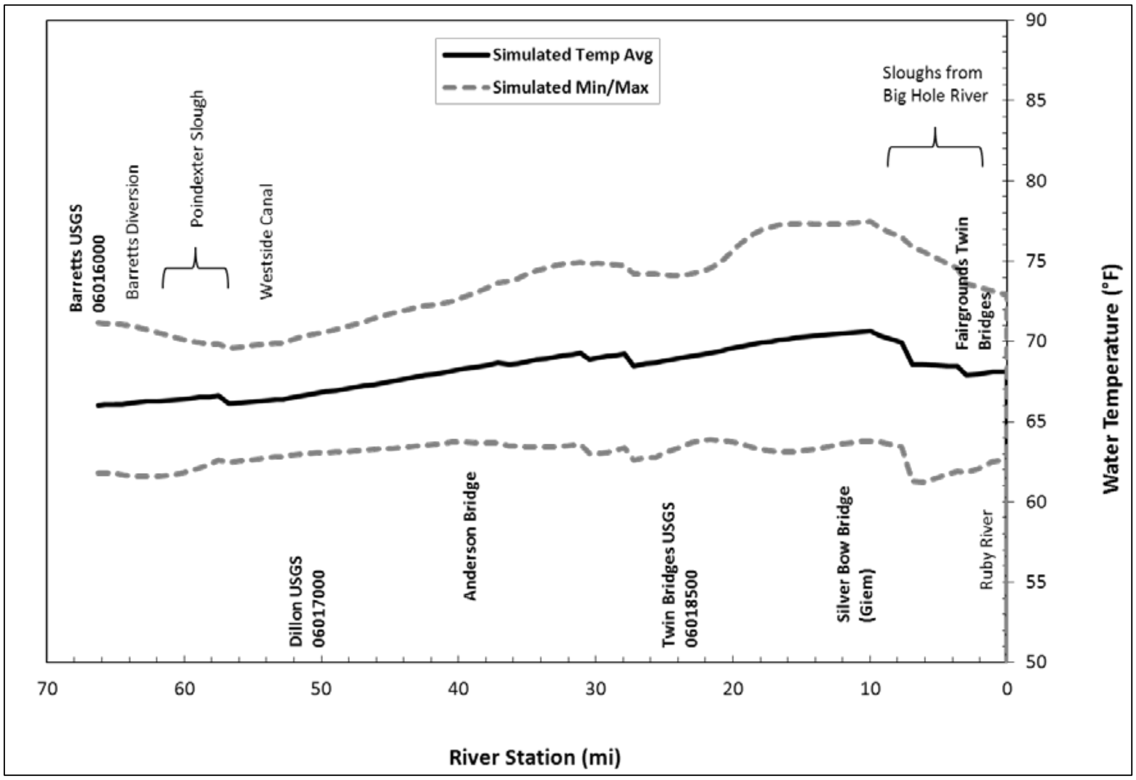

Figure 5-4. Modeled temperatures for the lower Beaverhead River baseline scenario

5.5.1.2.2 Shade scenario

For the shade scenario, the effective shade inputs to the model were set to represent the target shade condition. Two different shade conditions were evaluated: (1) where reference willow canopy was present along the entire reach (which is likely the best possible condition under reservoir hydrology) and (2) where vigorous cottonwood stands were present due to natural conditions (i.e. no human impacts or native hydrology).

Simulations were implemented by simply changing riparian cover conditions in the model. The first shade scenario was changed to “dense willow complex” and the second scenario was done identically, but with “cottonwoods”. The results of these scenarios are shown in **Figure 5-5**. Relative to baseline conditions, the temperature effect of both scenarios decreases the maximum and minimum temperatures over the entire modeling reach. The cottonwood shade scenario, with an effective shade of approximately 43%, resulted in a significant decrease of river temperatures of 5.2° F compared to the willow shade scenario, with an effective shade of 22%, which decreased temperatures less than 1°F. This shows that under the current reservoir regulated hydrology, riparian enhancements will provide limited temperature improvement to the river if implemented (unless continuous cottonwood-planting programs are instated). Tabular results for this scenario (and all others) are shown in **Appendix B**.

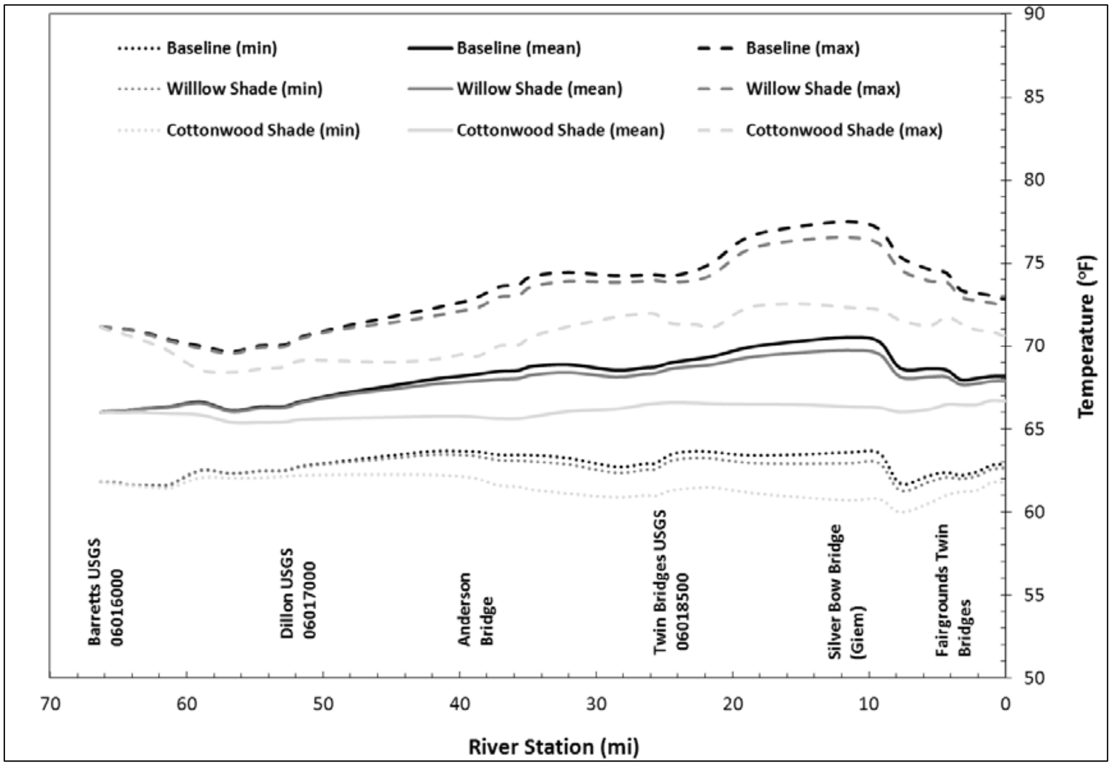

Figure 5-5. Shade scenarios on the lower Beaverhead River

5.5.1.2.3 Increased flow (water use) scenario

The increased flow scenario is used to describe the potential thermal effect of water savings and flow augmentation on water temperatures in the lower Beaverhead River. This scenario assumes that improved water delivery could create a water savings of 20% and that the conserved water could be allowed to flow down the lower Beaverhead River, thereby increasing instream flow. For modeling purposes, the diversion flow rate was reduced by 20%, and the additional water was allowed to flow down the Beaverhead River. Based on model simulations, the 20% savings would lead to maximum reductions of 3°F between miles 10 and 20 (**Figure 5-6**). Minimum temperatures actually increased nearly the same (2.6°F) due to added thermal inertia.

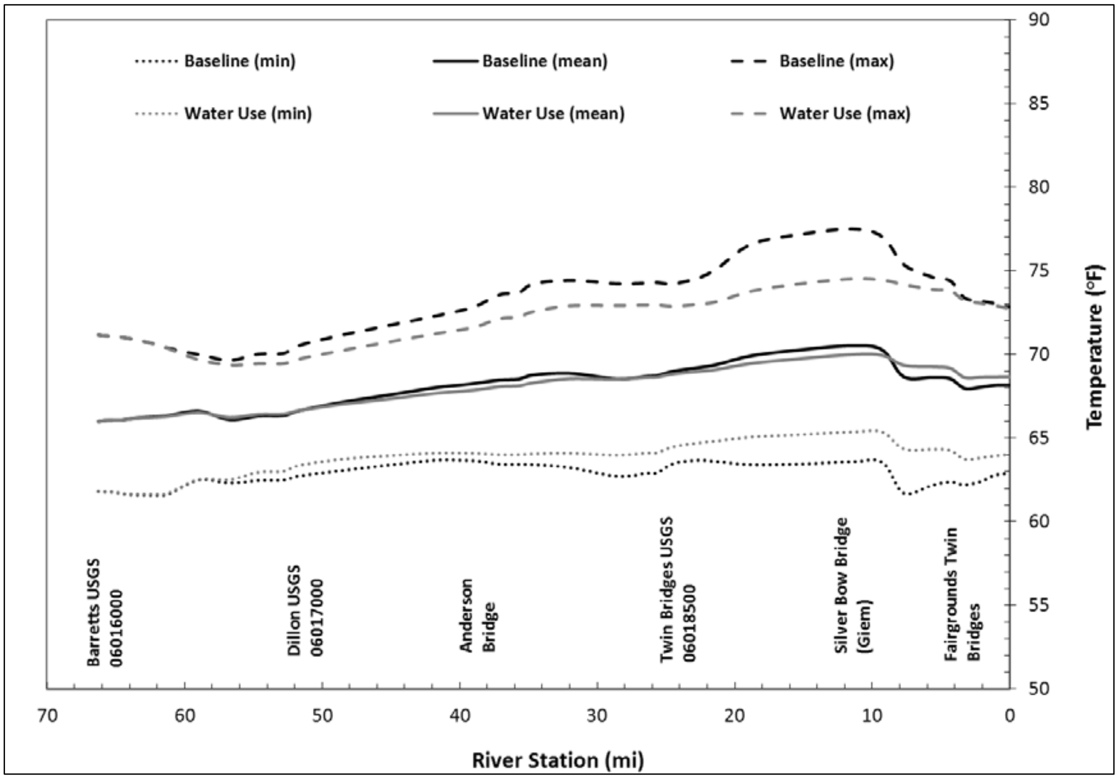

Figure 5-6. Increased flow (water use) scenario on the lower Beaverhead River

5.5.1.2.4 Naturally occurring scenario (full application of BMPs with current land use)

The naturally occurring scenario represents lower Beaverhead River water temperatures when all reasonable land, soil, and water conservation practices are implemented (ARM 17.30.602). Pursuant to 75-5-306, Montana Code Annotated (MCA) “Conditions resulting from the reasonable operation of dams at July 1, 1971” are also considered natural. Thus, this scenario establishes the bar for which the allowable 0.5°F temperature increase is compared (refer to **Section 5.4.2.1**). Assumptions used in the development of the naturally occurring scenario include the following: (1) shade conditions as described in the shade scenario (willow complex) and (2) a 20% reduction in the rate of diverted flow as described in the water use scenario.

Results of the naturally occurring scenario are shown in **Figure 5-7**. The scenario indicates the river is impaired extending from approximately mile 56 downstream to the confluence with the Big Hole River (mile 0). The largest temperature increase over baseline condition is 3.7°F at mile 11.4. The impairment is believed to be primarily related to irrigation based on evaluation of the previous scenarios.

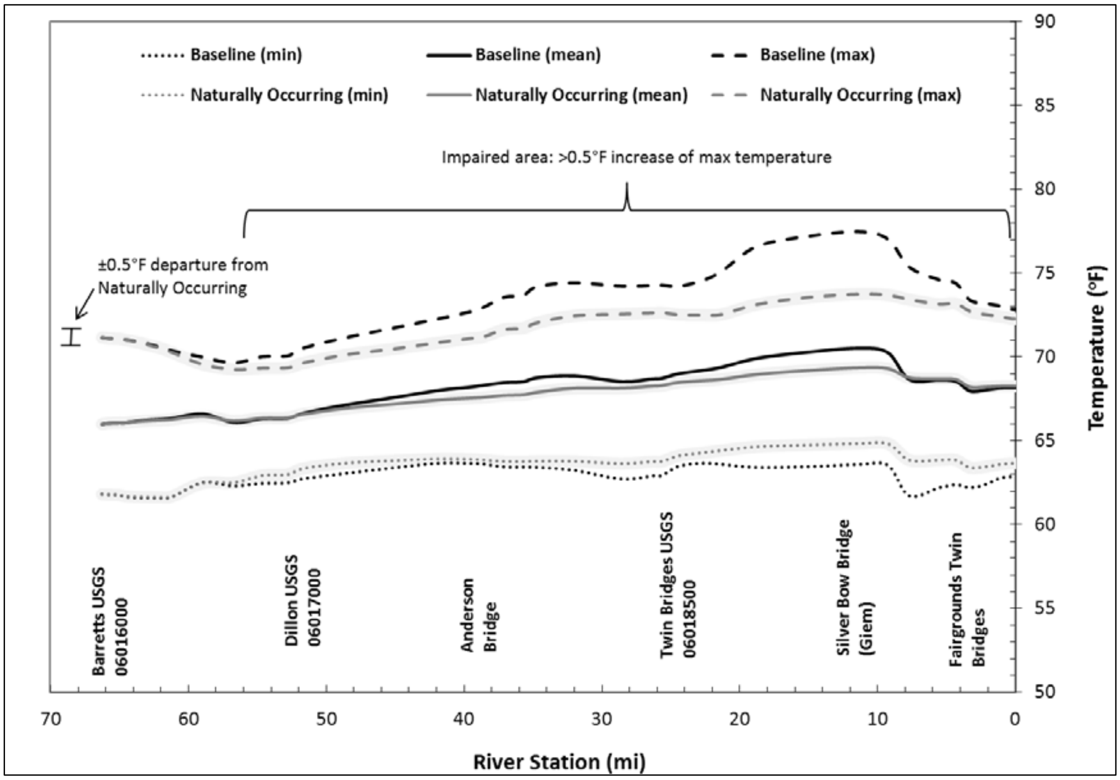

Figure 5-7. The maximum naturally occurring temperature relative to the existing condition (baseline scenario) and the allowed temperature

5.5.2.2 Upper Jefferson Assessment Using QUAL2K

A QUAL2K model was used to determine the extent that human-caused disturbances within the upper Jefferson River have increased the water temperature above the naturally occurring level. The evaluation of model results focuses on the maximum daily water temperatures in the upper Jefferson River during the summer because those are conditions mostly likely to harm aquatic life, the most sensitive beneficial use.

Within the model, the upper Jefferson River was segmented into 10 hydraulic reaches. The water temperature and flow data collected by WET for the DEQ in 2009, along with channel measurements, irrigation data, and climate data (**Section 5.3**), were used to calibrate and validate the model. Examination of the longitudinal temperature profile of the 2009 calibrated model (**Figure 5-8**) of the upper Jefferson River provides important information regarding instream water temperatures and associated river dynamics. Beginning at the upstream boundary (mile 41.2), temperature remains relatively constant until reaching river mile 27, where an increasing trend is noted. This area shows significant off-stream agricultural development on both sides of the river. This area is also a losing stretch of the river. Maximum temperatures reach 73.0°F in this section. The warming trend continues as additional irrigation withdrawals occur and flows decrease until reaching the Willow Springs confluence near mile 19.6. The spring fed tributaries and groundwater inflow through this reach lower the average, maximum, and minimum temperatures. Also, the Point of Rocks geologic outcrop provides topographic shade through this reach, which may also affect river temperatures. Temperatures remain relatively constant for approximately the next 15 miles, but a second increasing trend is noted near the end of the study area, starting at mile 3.9.

The maximum simulated river temperature occurs at mile 21.2 (73°F) where there is significant agricultural development and a losing stretch of the river. A second temperature maximum is at mile 0.0 (73°F) where there is significant agricultural development, as well as several backwater sloughs and oxbow channels. The river enters the LaHood Canyon just downstream of the end of the study area. Overall, the model shows a very consistent temperature profile. This constant profile is a function of the high water year. Overall, a good surface water temperature calibration was achieved based on model statistical efficiency. However, the study was conducted during high flows, which resulted in some hydraulic calibration variations. Once sufficient calibration of the existing condition model was achieved, scenarios for TMDL planning and analysis were developed. The flows used for model calibration represented a relatively high flow condition compared to those experienced over the past decade; as a result, a baseline scenario that simulates low flow conditions was included. Also, several potential land and water management scenarios (modeled from the low flow scenario) are described in the following sections. A more detailed report of the development and results of the QUAL2K model are included in **Appendix C.**

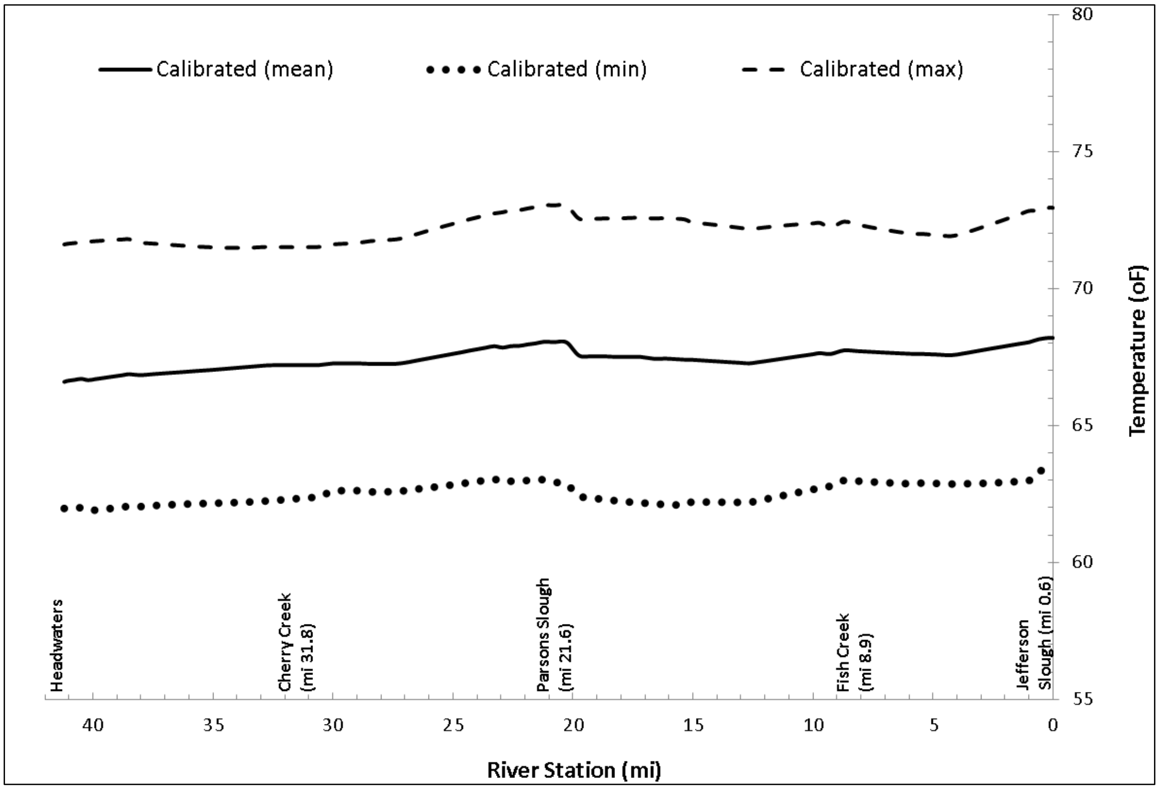

Figure 5-8. Modeled temperatures for the upper Jefferson River calibration

5.5.2.2.1 Baseline scenario using 7Q10 water year (low flow)

The baseline scenario represents stream temperatures under existing shade and channel conditions. The goal of this modeling study was to collect data and model the typical summer time low flow or baseline condition of the upper Jefferson River. However, the 2009 water year experienced significantly higher flows during the model period than the several years preceding the temperature model. As a result, the DEQ developed a baseline scenario that simulated summer time low flow conditions using a 7-day 10-yr low flow or 7Q10 flow condition (**Figure 5-9**). The 7Q10 flow is the lowest 7-day average flow that occurs (on average) once every ten years. More details regarding the 7Q10 flow scenario can be found in **Section C6.1 in Appendix C.**

Under the baseline scenario, maximum temperatures above 77°F occur from above Fish Creek/Jefferson ditch to Willow Springs. The spring fed surface water and groundwater inflow in this reach (around mile 20) reduce average and maximum temperatures at a critical location. Temperatures above 80°F occur between miles 11 to 9, where flow in the river goes down around 12 cfs in a 7Q10 year. Temperatures rise above 77°F again, in the reach above the confluence with the Jefferson Slough. The 7Q10 water year scenario is used as the baseline model for the remaining scenarios, as this flow condition will better show the impact of management scenarios on temperature.

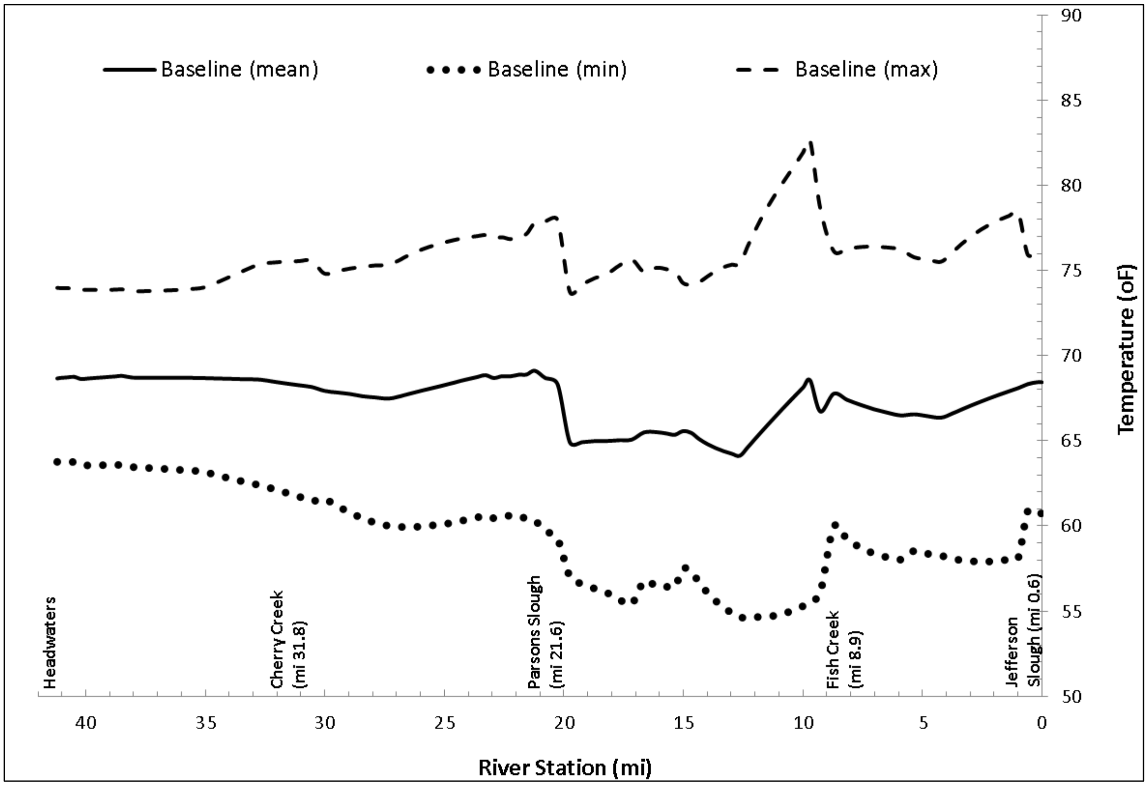

Figure 5-9. Modeled temperatures for the upper Jefferson River baseline scenario

5.5.2.2.2 Shade scenario

For the shade scenario, the effective shade inputs to the model were set to represent the target shade condition based on field measured shade values and GIS analysis. Two different shade conditions were evaluated: (1) where reference mixed low level vegetation is present along the entire reach (all open/grassed sites, barren areas, and any other area with diminished shading vegetation were increased to a reference shade condition) and (2) where reference mixed high level (inclusion of cottonwoods) and mixed low level areas are was present along the entire reach. The potential temperature reduction due to naturally occurring increased shade is somewhere between these two shade conditions with a potential for low level shrubs/willows in some areas and cottonwoods in other areas throughout the upper segment of the river.

Simulations were implemented by simply changing riparian cover conditions in the model. The shade scenario used the averaged shade values (from the two evaluated conditions) to reflect a mix of high and low level vegetation (cottonwoods and shrubs/willows). Existing cottonwoods or mixed high level conditions were not adjusted. The results of these scenarios are shown in **Figure 5-10**. The upgrade from bare, native grass and irrigated grass to a mixed high and low level vegetation shows that the greatest temperature reduction (.71°F) would occur at mile 9.7. Results show that shade is not a major temperature influencing factor unless it is of significant height, due to the wide river channel.

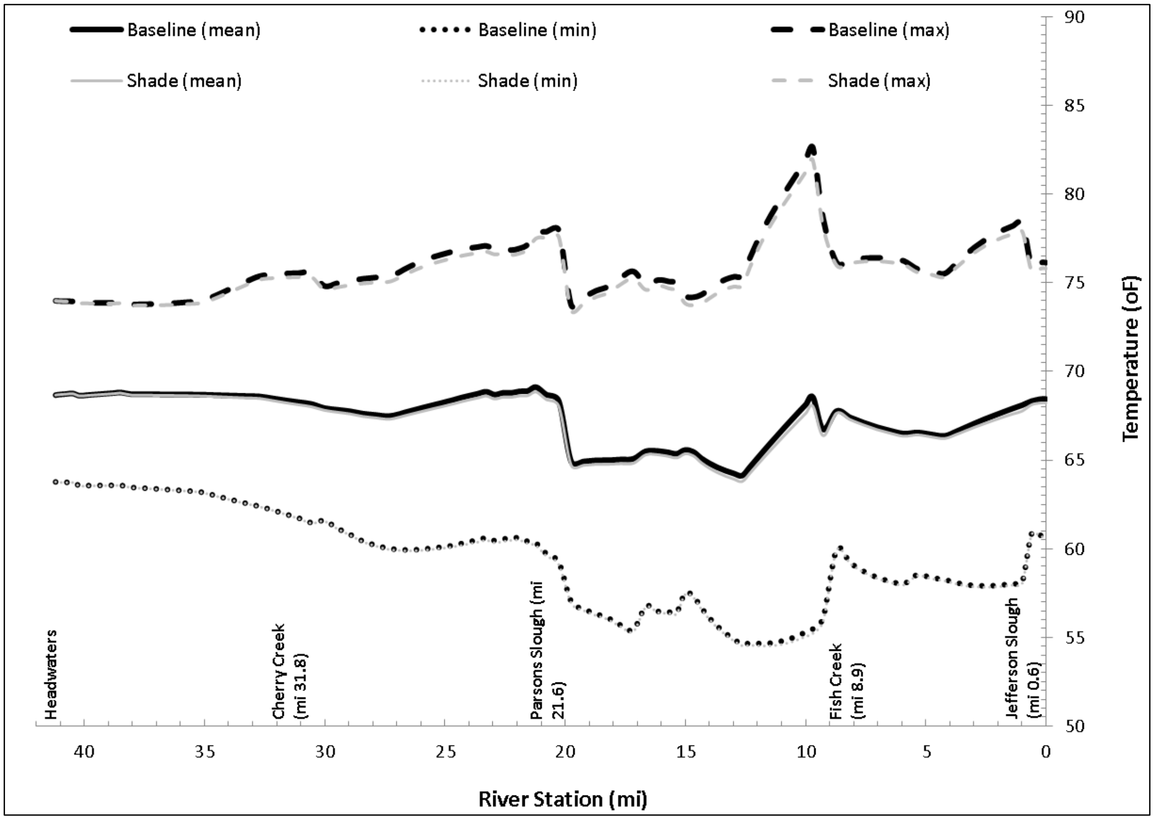

Figure 5-10. Shade scenario on the upper Jefferson River

5.5.2.2.3 Increased flow (water use) scenario

The increased flow scenario is used to describe the potential thermal effect of water savings and flow augmentation on water temperatures in the upper Jefferson River. This scenario assumes that private land owners' voluntary water restrictions during the low flow could create a water savings of 15% and that the conserved water could be allowed to flow down the upper Jefferson River, thereby increasing instream flow. For modeling purposes, the diversion and return flow rates were reduced by 15%, and the additional water was allowed to flow down the upper Jefferson River.

A 15% increase in stream flow shows that the greatest temperature reduction (7.42°F) would occur at mile 9.7 (**Figure 5-11**). The increased flow scenario shows that reducing the amount of water diverted during low flow is a significant contributing factor to maximum temperature reductions. Based on model results, irrigation water savings are an important means to achieve state temperature regulations. However, compliance would be on a voluntary basis by landowners. In addition to these results, water temperatures in the upper Jefferson River would also be beneficially affected by similar improvements in the Ruby, Beaverhead, and Big Hole Rivers.

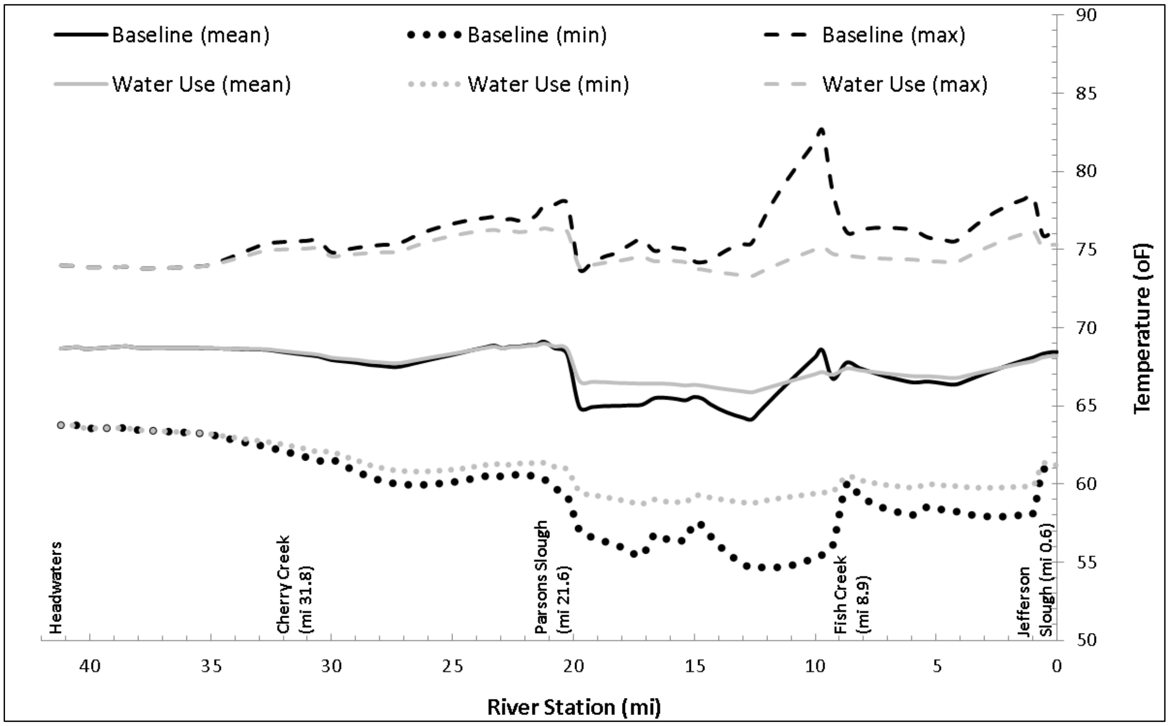

Figure 5-11. Increased flow (water use) scenario on the upper Jefferson River

5.5.2.2.4 Naturally occurring scenario (full application of BMPs with current land use)

The naturally occurring scenario represents upper Jefferson River water temperatures when all reasonable land, soil, and water conservation practices are implemented (ARM 17.30.602). Thus, this scenario establishes the bar for which the allowable 0.5°F temperature increase is compared (refer to **Section 5.4.2.1**). Assumptions used in the development of the naturally occurring scenario include the following: (1) decrease in headwater temperatures (**Table 5-4**), (2) shade conditions as described in the shade scenario (mixed low and high level vegetation type), and (3) a 15% reduction in the rate of diverted flow as described in the water use scenario.

Table 5-4. Parameters used in Headwater Mixing Calculations – Naturally Occurring

River Name	(Q, cfs)	Source data for Q	Tavg °F	Source data for Tavg	Tmax °F	Source data for Tmax
Ruby River	94	*	N/A	Tavg not provided	66.70**	DEQ model, naturally occurring
Beaverhead River	89	*	68.41	DEQ model, naturally occurring scenario	72.14***	DEQ model, naturally occurring
Big Hole River	135	*	71.67	DEQ model, naturally occurring scenario	77.00**	DEQ model, naturally occurring
Jefferson Headwater					**72.59**	**Mixing Calculation**

*Headwater flows were determined as a contributing ratio to the Jefferson River USGS gage at Twin Bridges. Available data for all four USGS gage sites when the Jefferson River was below 600 cfs were from 8/3/2008 through 8/31/2008.

USGS gages:

- 06023000 Ruby River near Twin Bridges, MT
- 06018500 Beaverhead River near Twin bridges, MT
- 06026420 Big Hole R blw Hamilton Ditch nr Twin Bridges, MT
- 06026500 Jefferson River near Twin Bridges MT

**Naturally occurring temperatures for the Ruby and Big Hole Rivers were calculated using models for TMDL development of those rivers (completed in 2006 and 2009 respectively)

***Naturally occurring temperature for the Beaverhead River used in the Jefferson River temperature model was calculated before the completion of the Beaverhead River temperature model. The resulting maximum naturally occurring temperature at the mouth from the Beaverhead River temperature model is 0.15°F above the maximum naturally occurring temperature used in the Jefferson model, which means that the temperature used in the mixing equation results in a slightly more conservative estimate of the naturally occurring temperature of the Jefferson River.

The mixing calculation is as follows:

$$\mathrm{T}_{\max, BeaverheadaboveBigholeRiver} = \frac{Q_{Beaverhead} T_{Beaverhead} + Q_{Ruby} T_{Ruby}}{Q_{Beaverhead} + Q_{Ruby}}$$

$$\mathrm{T}_{\max, JeffersonHeadwater} = \frac{Q_{Beaverhead+Ruby} T_{\max, BeaverheadaboveBigHoleRiver} + Q_{BigHole} T_{BigHole}}{Q_{Beaverhead} + Q_{Ruby} + Q_{BigHole}}$$

Results of the naturally occurring scenario (**Figure 5-12)** suggest that maximum temperatures could be reduced by an average of 1.93°F. Of the 102 output locations within the model, only 1 location met the state of the Montana temperature standard during the baseline (7Q10) scenario (e.g. within the 0.5°F allowable increase). Areas with the greatest potential for improvement occur in several locations: 1) the upper reach as a result of implementation of all reasonable land, soil, and water conservation practices in the Ruby, Beaverhead, and Big Hole (41.2 - 35.08 miles); and 2) various lower reaches largely as a result of water management practices (miles 27-20, 18-15.4, and 14.3-0), with the greatest temperature reduction of 7.91°F at mile 9.7. More information regarding this scenario can be found in **Appendix C.**

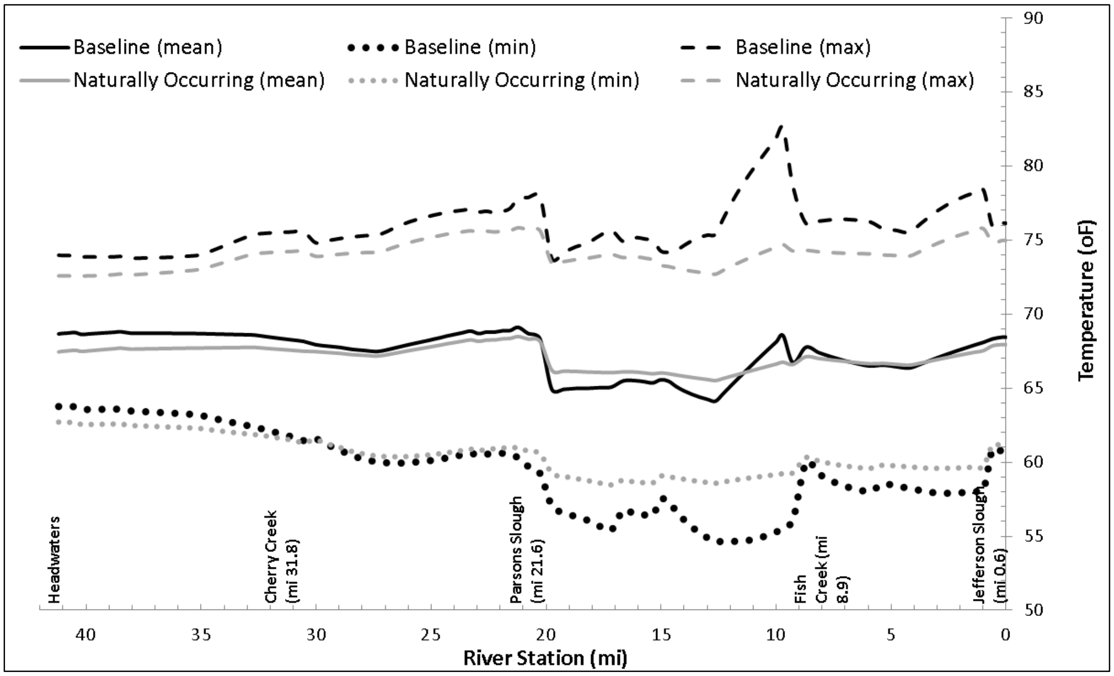

Figure 5-12. The maximum naturally occurring temperature relative to the existing condition (baseline scenario)

5.5.2.3 QUAL2K Model Assumptions

The following is a summary of the significant assumptions used during the QUAL2K model development:

- The lower Beaverhead and upper Jefferson Rivers can be divided into distinct segments, each considered homogeneous for shade, flow, and channel geometry characteristics. Monitoring site locations were selected to be representative of segments of both the lower Beaverhead and upper Jefferson Rivers.
- Stream meander and subsurface flow paths (both of which may affect depth-velocity and temperature) are inherently represented during the estimation of various parameters (e.g., stream slope, channel geometry, and Manning's roughness coefficient) for each segment.
- Weather conditions at the chosen climate stations, which were elevation-corrected, are representative of local weather conditions along the lower Beaverhead and upper Jefferson Rivers. Adjustments made to streamflow and climate for the baseline scenario adequately represent existing conditions on a hot, dry summer.
- Shade Model results are representative of riparian shading along segments of the lower Beaverhead and upper Jefferson Rivers.
- Application of some water conservation measures resulting in a decrease in water withdrawn is reasonable and consistent with the definition of the naturally occurring condition.
- The effective shade provided by the recommended riparian densities is achievable and consistent with the definition of the naturally occurring condition.
- The only tributaries accounted for in the naturally occurring condition scenario were the three major contributors to the Jefferson River: the Big Hole, Ruby, and Beaverhead Rivers. Uncertainties in the models lie within the consideration of improvement to Beaverhead River tributaries and other tributaries to the upper Jefferson, besides the three headwater rivers. The potential for decreasing water temperatures in these streams and the effect the decreased temperatures would have on the lower Beaverhead and upper Jefferson Rivers was not evaluated as part of the model simulations. As such, the QUAL2K modeled naturally occurring

scenarios have the potential for further decreasing the lower Beaverhead and upper Jefferson River temperatures.

5.5.2 Source Assessment of Permitted Point Sources

There are 10 point sources with Montana Pollutant Discharge Elimination System (MPDES) permits in the lower Beaverhead River and 2 in the upper Jefferson River (**Table 5-5**). The majority of the permits listed are either construction permits which are temporary, or permits not in the scope of temperature issues (pesticides), or discharge only in storm events (stormwater and concentrated animal feeding operations permits). The Twin Bridges WWTF discharges to Bayers ditch, which runs for several miles into a series of ditches, therefore having no direct influence on the upper Jefferson River. The only facility with reasonable potential to contribute thermal pollution is the City of Dillon Waste Water Treatment Facility and is examined below (**Section 5.5.2.1**).

Table 5-5. Permitted Point Source in the lower Beaverhead and upper Jefferson Rivers

Facility Name	National Pollutant Discharge Elimination System (NPDES) ID	Permit Type	Waterbody Name
City of Dillon WWTF	MT0021458	MPDES Individual Permit	Beaverhead River
Clark Canyon Hydro US BOR Beaverhead River Dam Alteration	MTB001814	Turbidity Related to Construction (318)	Beaverhead River
Beaverhead Livestock Auction	MTG010176	Concentrated Animal Feeding Operation	Beaverhead River
City of Dillon - Wastewater Treatment Plant Dewatering	MTG070695	Construction Dewatering	Beaverhead River
Beaverhead County Weed Dist. Beaverhead River Corridor Pesticide	MTG870001	Pesticides	Beaverhead River
Barretts Minerals Incorporated	MTR000508	Storm Water - Industrial Activity	Beaverhead River
Clark Canyon Hydro - Clark Canyon Dam Hydroelectric Facility	MTR104018	Storm Water - Construction Activity	Beaverhead River
Dick Anderson - Dillon Wastewater Treatment Plant	MTR105067	Storm Water - Construction Activity	Beaverhead River
RE Miller and Sons - Montana Center for Horsemanship	MTR104116	Storm Water - Construction Activity	Beaverhead River and Blacktail Deer Creek
Tilstra Ranch	MTG010139	Concentrated Animal Feeding Operation	Irrigation ditch to Beaverhead River
Coronado Resources - Madison Project (SW Mining)	MTR000558	Storm Water - Industrial Activity	Tom Benton Gulch and Jefferson River
Twin Bridges Wastewater WWTF	MT0028797	MPDES Individual Permit	Bayers irrigation ditch

Dillon WWTF (MT0021458) Point Source Discharge Assessment

The City of Dillon WWTF discharges to the lower Beaverhead River 49.98 miles from the mouth and has a design flow of .750 million gallons per day (1.16 cfs). To evaluate the effects of temperature, an instantaneous thermal load (in kilocalories per second) can be calculated for the streamflow and WWTF discharge flows per **Equation 5-1** below. Note that this loading equation is applicable to water at a temperature greater than the freezing point of 32°F. The effects of the WWTF discharge can then be calculated by mixing the discharge water with the flow of the Beaverhead River under differing conditions.

To examine the effects of the Dillon WWTF on the Beaverhead River, temperature changes were calculated for two different examples; one on measured instream temperatures and the other on the modeled naturally occurring scenario. The first uses the average August 2004 temperature (61.92°F) measured by the temperature data logger at sampling site BRDM (Beaverhead River at Dillon, MT) upstream of the WWTF and is considered the measured existing conditions example. The second example uses the average naturally occurring scenario temperature (66.6°F) in model reach 12 (where BRDM is located) and is called the modeled naturally occurring scenario example. The temperature value from the naturally occurring scenario is greater than the current condition temperature value because the model was constructed to examine source effects on the period of the month with the warmest stream temperatures. Both examples use the measured maximum August (2010 – 2013) effluent temperature of 69.8°F (**Appendix D**) and effluent design discharge of 1.16 cfs from the WWTF and the measured average August 2005 Beaverhead River streamflow of 164 cfs (flow at station BRDM – **Appendix D**). **Equation 5-1** and a basic mixing equation were used to calculate the effects of the WWTF on instream temperatures in the Beaverhead River.

Equation 5-1: Total Existing Load ($_{\text{instantaneous}}$) = ((T$_{\text{meas}}$) - 32)*(5/9) * Q * 28.3

Where:

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

Measured Existing Conditions Example:
For this example, the thermal load of the Beaverhead River at station BRDM was:

(61.92°F – 32) * (5/9) * 164 cfs * 28.3 = 77,147 kcal/s

The thermal load of the WWTF was:

(69.8°F – 32) * (5/9) * 1.16 cfs * 28.3 = 689 kcal/s

The total thermal load of the Beaverhead River below the WWTF would therefore be:

77,147 kcal/s + 689 kcal/s = 77,836 kcal/s

And the water temperature would be:

(9/5) * ((77,836 kcal/s) / (165.16 cfs * 28.3)) + 32 = 61.98°F

In this case, the WWTF causes an increase of 0.06°F (61.98°F – 61.92°F) in the temperature of the Beaverhead River.

Modeled Naturally Occurring Scenario Example:
For this example, the thermal load of the Beaverhead River at station BRDM was:

(66.6°F – 32) * (5/9) * 164 cfs * 28.3 = 89,214 kcal/s

The thermal load of the WWTF was:

(69.8°F – 32)*(5/9) * 1.16 cfs * 28.3 = 689 kcal/s

The total thermal load of the Beaverhead River below the WWTF would therefore be:

89,214 kcal/s + 689 kcal/s = 89,903 kcal/s

And the water temperature would be:

(9/5) * ((89,903 kcal/s) / (165.16 cfs * 28.3)) + 32 = 66.62°F

In this case, the WWTF causes an increase of 0.02°F (66.62°F – 66.6°F) in the temperature of the Beaverhead River. This value is well below the 0.5°F increase allowed by the standard at the naturally occurring average temperature of 66.6°F.

Because the Dillon WWTF discharges a small amount of effluent relative to the discharge of the Beaverhead River, it has a negligible effect on instream temperatures below the effluent discharge. Maintaining operation of this facility at current levels would appear to cause no significant increase in Beaverhead River temperatures.

5.6 EXISTING CONDITIONS AND COMPARISON TO TARGETS – LOWER BEAVERHEAD AND UPPER JEFFERSON RIVERS

This section includes a comparison of existing data with water quality targets, along with a TMDL development determination for the lower Beaverhead and upper Jefferson Rivers. QUAL2K model results will be compared to the allowable human-caused temperature change to determine if the target is being exceeded.

To evaluate whether attainment of temperature targets has been met, the existing water quality conditions in the lower Beaverhead and upper Jefferson River waterbody segments are compared to the conditions when water quality targets are met. This is done using the QUAL2K model and different scenarios that represent the implementation of all reasonable land, soil, and water conservation practices. This approach provides DEQ with updated impairment determinations used for TMDL development.

5.6.1 Lower Beaverhead River Existing Conditions and Comparison to Targets

The QUAL2K model results indicate that maximum naturally occurring summer temperatures ≥ 66.5°F occur at all Beaverhead River sites (**Figure 5-13**), which means that when water temperatures are the warmest, the allowed increase above the naturally occurring temperature is 0.5°F. Temperature differences between maximum temperatures under the baseline condition and the naturally occurring condition (**Section 5.5.1.2.4**) range from 0.0 to 3.7°F and average 1.3°F (**Figure 5-14**). The allowed increase is being exceeded at 75% of the sites on the Beaverhead River.

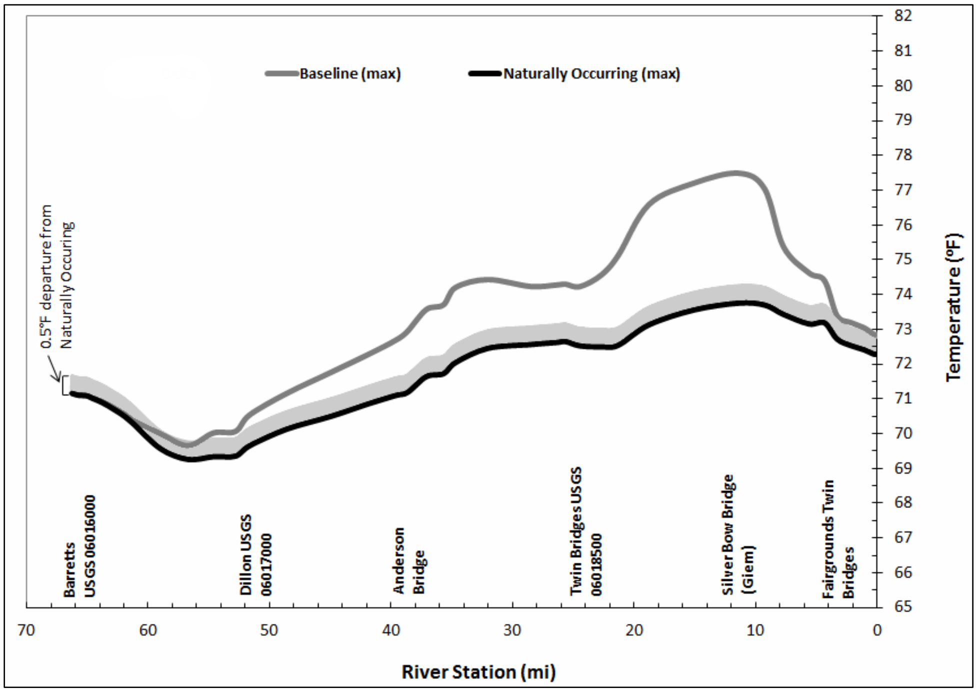

Figure 5-13. Maximum temperatures for QUAL2K Baseline and Naturally Occurring scenarios

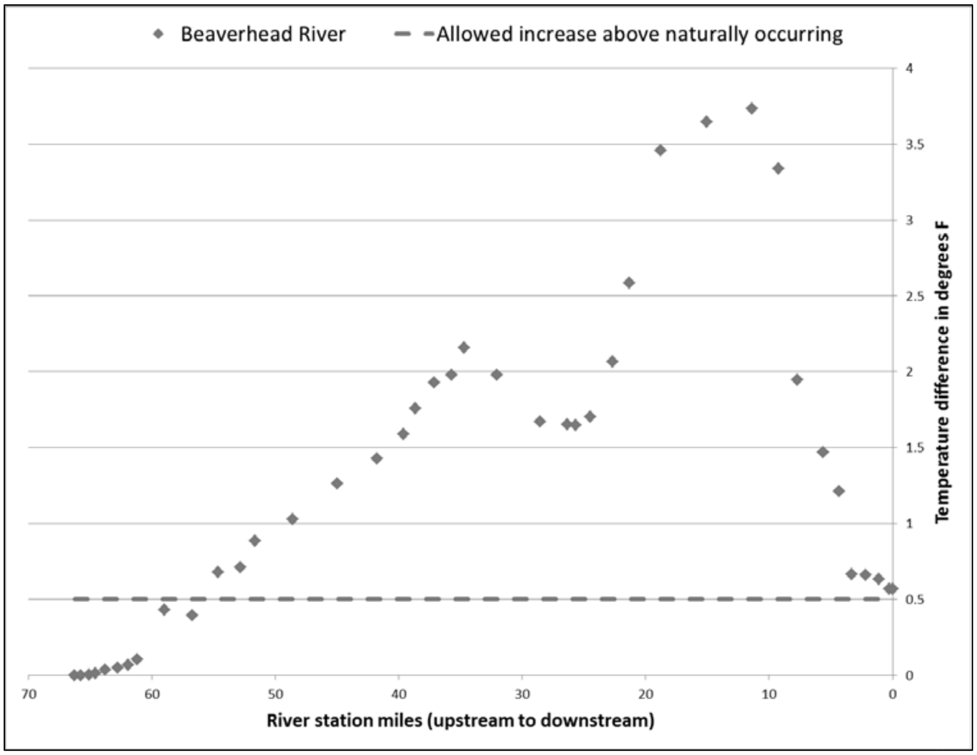

Figure 5-14. Difference between the baseline (existing) condition and the naturally occurring condition (implementation of all reasonable land, soil and water conservation practices) maximum temperatures at river station miles on the Beaverhead River

Aerial photographs were used to identify vegetation breakout reaches, determine the potential riparian vegetation condition for each reach, and determine the reference vegetation category for the

Beaverhead River. Sites were then analyzed in the field in a selected number of study reaches and average effective shade for those sites was assessed. About 20% of the vegetation along the Beaverhead River consists of dense willows, cottonwoods, and small conifers; all of which have effective shade at or above target levels. The other 80% of the river corridor consists of sparse willows, grasses, and sedges (**Table 5-6** and **Appendix B**). The estimated existing average daily effective shade for the Beaverhead River is 14%. For modeling purposes, the average of the results for sites in the dense willows category was then applied to those reaches that were not sampled and were not already at target conditions. Average daily effective shade for the dense willow vegetation classification is 22%.

As described in **Section 5.5.1.2.3.**, the 20% water savings for the increased flow scenario was based on grant proposals submitted by the East Bench Irrigation District regarding irrigation delivery improvements (**Table 5-6**). Based on model simulations, the 20% savings would result in an additional 117 cfs of water in the river and would lead to maximum reductions of 3^{o}F between miles 10 and 20. This scenario indicates that reasonable irrigation delivery improvements can have a significant effect on the overall temperature regime in the river.

Point sources of thermal load to the Beaverhead River are required to meet temperature discharges that are consistent with the appropriate water quality standards. The City of Dillon WWTF (MT0021458) discharge is currently satisfying this target as evaluated in **Section 5.5.2 (Table 5-6)**.

Table 5-6. Existing conditions and comparison to targets

Target Parameter	Existing Condition	Target Value
Allowable Human-Caused Temperature Change	Max Δ of 3.7°F	Δ of <0.5°F (under current maximum temperatures)
Riparian Health - Shade	14%	22%
Instream flow (water use)	Proposals for irrigation delivery improvement	20% water savings kept in the Beaverhead River
WWTF	Δ of <0.05°F	Δ of <0.5°F

Summary and TMDL Development Determination
The human-influenced allowable temperature change target is being exceeded in the Beaverhead River. The riparian vegetation is generally not meeting the shade target, which causes increases in temperature and although there have been proposals for instream flow improvement, the target of a 20% water savings has not yet been met. This information supports the existing impairment listing for the lower Beaverhead River. A temperature TMDL will be developed for this segment.

5.6.2 Upper Jefferson River Existing Conditions and Comparison to Targets

The QUAL2K model results indicate that maximum naturally occurring summer temperatures ≥ 66.5°F occur at all upper Jefferson River sites (**Figure 5-15**), which means that when water temperatures are the warmest, the allowed increase above the naturally occurring temperature is 0.5°F. Temperature differences between maximum temperatures under the baseline condition and the naturally occurring condition (**Section 5.5.2.2.4**) range from 0.3 to 7.9°F and average 1.93°F. The allowed increase is being exceeded at 99% of the modeled output locations on the upper Jefferson River (**Figure 5-16**).

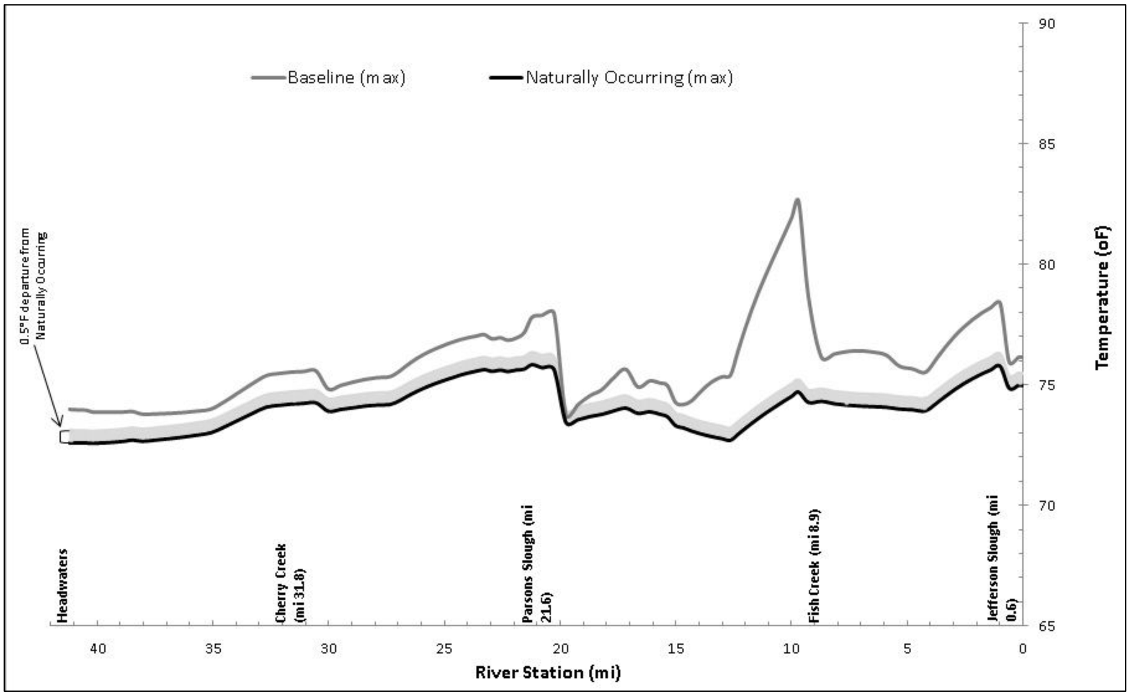

Figure 5-15. Maximum temperatures for QUAL2K Baseline and Naturally Occurring scenarios

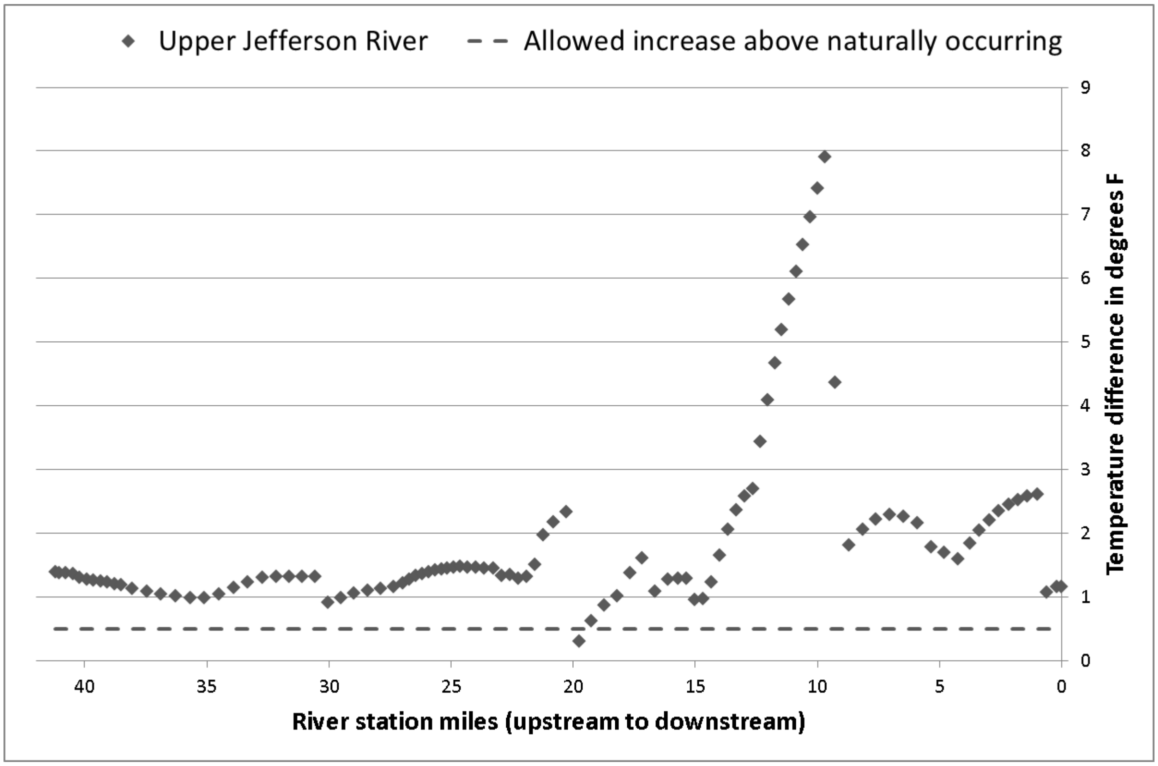

Figure 5-16. Difference between the baseline (existing) condition and the naturally occurring condition (implementation of all reasonable land, soil and water conservation practices) maximum temperatures at river station miles on the upper Jefferson River.

As described in **Section 5.5.2.2.2**, shade parameters were input into ShadeV3.xls at every kilometer and then all nodes within each model reach were averaged into a single average hourly value for the entire reach. The upper Jefferson River has varied vegetation conditions, and aerial photography and field reconnaissance did not show significant vegetation breaks. The estimated existing average daily effective shade for mixed low and high level vegetation is 15%. The upgrade from bare, native grass and irrigated grass to a mix of high and low level vegetation would lead to a maximum temperature reduction of 0.71°F. The target range for average daily effective shade is between 16% and 20% (**Table 5-7** and **Appendix C**).

As described in **Section 5.5.2.2.3.**, the 15% water savings for the increased flow scenario is based on private land owners' voluntary water restrictions during summer low flow conditions (and during drought conditions, as suggested in the Jefferson River drought management plan). According to the plan, when the river drops below 600 cfs, the JRWC encourages voluntary conservation measures by water users and awareness among anglers about stress on fish. When the streamflow drops below 280 cfs at the Twin Bridges gage, FWP will evaluate the need for mandatory fishing closures on the Jefferson. At this level irrigators and municipal water users will be asked to voluntarily reduce their water consumption, and weekly meetings will be coordinated by the JRWC with users to keep people informed and updated about the water flows so as to maintain a minimum of 50 cfs at the Waterloo gage. Fishing closures may remain in effect until the flow at Twin Bridges reaches or exceeds 300 cfs for seven consecutive days. Based on model simulations, a 15% savings would result in an average additional 54.4 cfs in the river and would lead to a maximum reduction of 7.42°F around mile 10. This scenario indicates that reasonable irrigation delivery improvements can have a significant effect on the overall temperature regime in the river.

The naturally occurring scenario includes a reduction in the thermal loads from the three headwaters of the Jefferson River (the Big Hole, Ruby, and Beaverhead Rivers). All three rivers have completed temperature models and the temperature targets for each river are presented below in **Table 5-7**. The Big Hole, Ruby, and Beaverhead Rivers are all currently exceeding target conditions at the mouth. Implementation of all reasonable land, soil, and water conservation practices in these three rivers would significantly reduce headwater temperatures coming into the upper Jefferson River (**Section 5.5.2.2.4)**.

Table 5-7. Existing conditions and comparison to targets

Target Parameter		Existing Condition	Target Value
Allowable Human-Caused Temperature Change		Max Δ of 7.9°F	Δ of <0.5°F (under current maximum temperatures)
Effective Shade		15%	16-20%
Water Use		Drought management plan in place	15% water savings kept in the upper Jefferson River
HEADWATER TEMPERATURE	**Ruby River**	69.96°F (Tmax at mouth)	66.70°F (Tmax at mouth)
	Beaverhead River	72.86°F (Tmax at mouth)*	72.29°F (Tmax at mouth)
	Big Hole River	78.06°F (Tmax at mouth)	77.00°F (Tmax at mouth)

*Note that temperatures at the mouth of the Beaverhead are reduced from upstream temperatures near Giem bridge because of added flow from the Ruby River and Big Hole sloughs.

Summary and TMDL Development Determination

The human-influenced allowable temperature change target is being exceeded in the upper Jefferson River. Riparian vegetation is not meeting the lower end of the shade target range. And, the upper Jefferson River continues to record declining flows during hot and dry summer conditions, even with the drought management plan that is in place calling for voluntary reductions in water use. This information supports the existing impairment listing for the upper Jefferson River. A temperature TMDL will be developed for this segment.

5.7 TEMPERATURE TMDLS AND ALLOCATIONS

Total maximum daily loads (TMDLs) are a measure of the maximum load of a pollutant a particular waterbody can receive and still maintain water quality standards (**Section 4.0**). A TMDL is the sum of wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources. A TMDL includes a margin of safety (MOS) to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving stream. Allocations represent the distribution of allowable load applied to those factors that influence loading to the stream. In the case of temperature, thermal loading is assessed.

5.7.1 Temperature TMDL and Allocation Framework

Because stream temperatures change throughout the course of a day, the temperature TMDL is expressed as the instantaneous thermal load associated with the stream temperature when in compliance with Montana's water quality standards. As stated earlier, the temperature standard for the lower Beaverhead and upper Jefferson Rivers 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 that applies to the lower Beaverhead and upper Jefferson Rivers, relative to naturally occurring temperatures, is depicted in **Figure 5-17**. As stated in **Section 5.5**, maximum daily temperatures in the lower Beaverhead and upper Jefferson Rivers during the baseline scenario are typically greater than 66.5°F, which means the allowable increase caused by human sources during the hottest part of the summer is typically 0.5°F for both rivers.

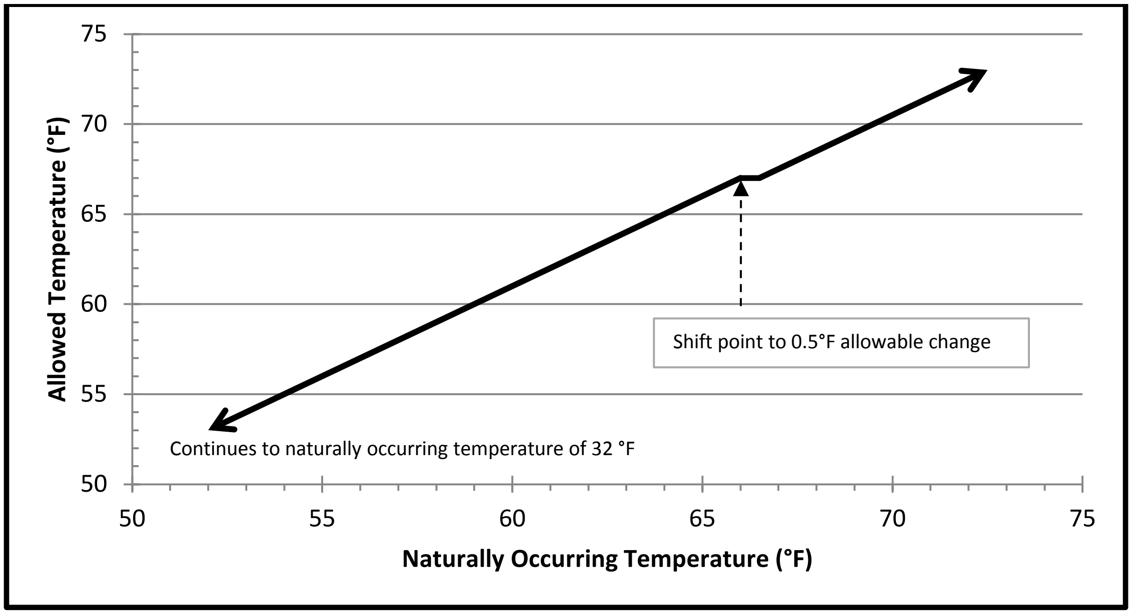

Figure 5-17. Line graph of the temperature standard that applies to lower Beaverhead and upper Jefferson Rivers

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 5-2**. 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 5-17**.

Equation 5-2: $\mathbf{TMDL_{(instantaneous)} = ((T_{NO} + \Delta) - 32)*(5/9) * Q * 28.3}$

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 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 during the daytime 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 5-2**, which provides a load per second, can be converted to a daily load (kcal/day) by multiplying by 86,400 (which is the number of seconds in a day).

Because calculation of the TMDL on any timescale relies on the identification of the naturally occurring condition, which fluctuates over time and within a stream, it generally requires a water quality model. However, the shade, flow, point source, and headwater temperature targets that will be met when all reasonable land, soil, and water conservation practices are applied, and the water conservation efforts that fall under the definition of naturally occurring, are also measurable components of meeting the TMDLs and water quality standard. Meeting the targets described above and applying all reasonable water conservation measures, collectively provide an alternative method for meeting and evaluating the TMDL that more directly translates to implementation than an instantaneous or daily thermal load.

5.7.2 Temperature TMDL and Allocations for the lower Beaverhead River

The numeric temperature TMDL for the lower Beaverhead River is **Equation 5-2.** The load allocation to nonpoint sources is based on **Equation 5-3.** An explicit MOS will be based on the remaining temperature change allowed by the standard after the LA to nonpoint sources is calculated to meet the naturally occurring temperature and the WLAs are calculated based on the design flow (1.16 cfs) of the facilities and the maximum August temperature (69.8°F) of effluent discharge (2010 – 2013). The following example[2] TMDL for the lower Beaverhead River uses the average August flow (164 cfs) measured at station BRDM (at Dillon, MT above the WWTF **Appendix D**) and the modeled naturally occurring average

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[2] The example TMDL provides a load for one point on the river using that specific point's flow and naturally occurring temperature as input to the equation. The load will vary at any given point on the river as flows and temperatures change. Therefore there is not one single, definitive, daily load to provide for the river segment; rather, we provide an example TMDL at a given point on the river using the TMDL equation.

temperature of 66.6°F at this same location. At this temperature, the allowable increase above the naturally occurring temperature is 0.5°F based on the water quality standard for temperature (ARM 17.30.624(e)).

Equation 5-2 is the TMDL.

An example of how to calculate the TMDL at a given point on the river using the parameters described in the paragraph at the beginning of **Section 5.7.2** is provided below:

$$\textbf{TMDL (instantaneous)} = ((66.6 + 0.5) - 32)*(5/9) * (164 + 1.16) * 28.3 = 91{,}144 \text{ kcal/s}$$

Converted to a daily load the TMDL is:

$$\textbf{TMDL} = 91{,}144 \text{ kcal/s} * 86{,}400 \text{ s/day} = 7{,}874{,}802{,}374 \text{ kcal/day}^{*}$$

*resulting daily load is from unrounded instantaneous load

Equation 5-3 is the load allocation.

Equation 5-3: $LA\ (_{instantaneous}) = (T_{NO} - 32)*(5/9) * Q * 28.3$

Where:

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

An example of how to calculate a composite load allocation at a given point on the river using the same parameters as described above (naturally occurring temperature of 66.6°F and flow of 164 cfs (leaving out the discharges from the Dillon WWTF), is provided below:

$$LA_{(instantaneous)} = (66.6 - 32)*(5/9) * 164 * 28.3 = 89{,}214 \text{ kcal/s}$$

Converted to a daily load the LA is:

$$LA = 89{,}214 \text{ kcal/s} * 86{,}400 \text{ s/day} = 7{,}708{,}104{,}960 \text{ kcal/day}^{*}$$

*resulting daily load is from unrounded instantaneous load

In the case of the Beaverhead River, the Dillon WWTF does not appear to have a significant effect on stream temperature (see **Sections 5.5.2**). The WLA for this discharger will be written based on the design flow of the facility (1.16 cfs) and a maximum recorded August effluent temperature (69.8°F) per **Equation 5-4**.

Equation 5-4: $WLA_{(instantaneous)} = (T_{max} - 32)*(5/9) * Q * 28.3$

Where:

T_{max} = *maximum temperate of discharge (°F)*
Q = *design flow discharge in cubic feet per second*
28.3 = conversion factor

The WLA is:

$$\mathbf{WLA_{DILLONWWTF\ (instantaneous)} = (69.8 - 32)*(5/9) * 1.16 * 28.3 = 689\ kcal/s}$$

Converted to a daily load the WLA is:

$$\mathbf{WLA_{DILLONWWTF} = 689\ kcal/s * 86{,}400\ s/day = 59{,}563{,}123\ kcal/day^{*}}$$

[*] resulting daily load is from unrounded instantaneous load

Using **Equation 5-5,** the resulting explicit MOS for this example is:

Equation 5-5: MOS $_{(instantaneous)}$ ***= TMDL - LA - WLA***

$$\mathbf{MOS_{(instantaneous)} = 91{,}144\ kcal/s - 89{,}214\ kcal/s - 689\ kcal/s = 1240\ kcal/s}$$

Converted to a daily load the MOS is:

$$\mathbf{MOS = 1240\ kcal/s * 86{,}400\ s/day = 107{,}134{,}291\ kcal/day^{*}}$$

[*] resulting daily load is from unrounded instantaneous load

The temperature TMDL, load allocation, wasteload allocation, and MOS (based on parameters at a given point on the river) are summarized in **Table 5-8**. The targets in **Section 5.4.3** (**Table 5-3**) 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 5-8**. Implementation of BMPs is necessary to meet the water quality targets for temperature. The source assessment for the lower Beaverhead River indicates that the low instream flow during the time period of concern contributes the most human-caused temperature loading; load reductions should focus on potential improvements to irrigation delivery and efficiency through implementing reasonable BMPs. Meeting load allocations for the lower Beaverhead River may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 7.0**.

Table 5-8. Lower Beaverhead River instantaneous and daily load allocations

Category	Temperature (°F)	Flow (cfs)	Temperature change from baseline (°F)	Allocation (instantaneous load in kcal/s)	Allocation (daily load in kcal/day)
Nonpoint sources and background (LA)	66.60	164	0.00	89,214	7,708,104,960
Dillon WWTF (WLA)	69.80	1.16	0.02	689	59,563,123
Explicit MOS	NA	NA	0.48	1240	107,134,291
Total	NA	165.16	0.50	91,144**	7,874,802,374**

**These values reflect the TMDL expressed as instantaneous (kcal/s) and daily (kcal/day) loads

5.7.3 Temperature TMDL and Allocations for the upper Jefferson River

The numeric temperature TMDL for the upper Jefferson River is **Equation 5-2.** The load allocation to nonpoint sources is based on **Equation 5-3**. An explicit MOS of either 0.5 or 1.0 °F will be used in this waterbody segment depending on the naturally occurring temperature. The following example[3] TMDL for the upper Jefferson River uses a flow of 101 cfs, the modeled 7Q10 flow used in the baseline condition (**Appendix D**), just above Jefferson Slough (mile 0.79) between August 20-22 (the modeled time period) and the modeled naturally occurring average temperature of 67.53°F (just above Jefferson Slough at mile 0.79). At this temperature, the allowable increase above the naturally occurring temperature is 0.5°F based on the water quality standard for temperature (ARM 17.30.624(e)).

Equation 5-2 is the TMDL.

An example of how to calculate the TMDL at a given point on the river using the parameters described in the paragraph at the beginning of **Section 5.7.3** is provided below:

$$\mathbf{TMDL_{(instantaneous)} = ((67.53 + 0.5) - 32)*(5/9) *101 * 28.3 =57{,}214\ kcal/s}$$

Converted to a daily load the TMDL is:

$$\mathbf{TMDL = 57{,}214\ kcal/s * 86{,}400\ s/day = 4{,}943{,}258{,}352\ kcal/day^{*}}$$

*resulting daily load is from unrounded instantaneous load

Equation 5-3 is the load allocation.

An example of how to calculate a composite load allocation at a given point on the river using the same parameters as described above (naturally occurring temperature of 67.53°F and flow of 101 cfs) is provided below:

$$\mathbf{LA_{(instantaneous)} = (67.53- 32)*(5/9) * 101 * 28.3 = 56{,}420\ kcal/s}$$

Converted to a daily load the LA is:

$$\mathbf{LA = 56{,}420\ kcal/s * 86{,}400\ s/day = 4{,}874{,}659{,}152\ kcal/day^{*}}$$

*resulting daily load is from unrounded instantaneous load

The resulting explicit MOS at 101 cfs is:

$$\mathbf{MOS_{(instantaneous)} = 57{,}214\ kcal/s – 56{,}420\ kcal/s = 794\ kcal/s}$$

Converted to a daily load the MOS is:

$$\mathbf{MOS = 794\ kcal/s * 86{,}400\ s/day = 68{,}599{,}200\ kcal/day^{*}}$$

*resulting daily load is from unrounded instantaneous load

The temperature TMDL, load allocation, and MOS (based on parameters at a given point on the river) are summarized in **Table 5-9**. The targets in **Section 5.4.3** (**Table 5-3**) serve as surrogates to the numeric

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[3] The example TMDL provides a load for one point on the river using that specific point's flow and naturally occurring temperature as input to the equation. The load will vary at any given point on the river as flows and temperatures change. Therefore there is not one single, definitive, daily load to provide for the river segment; rather, we provide an example TMDL at a given point on the river using the TMDL equation.

allocations. Meeting these targets will result in meeting the numeric allocations under all conditions including the example in **Table 5-9**. Implementation of BMPs is necessary to meet the water quality targets for temperature. The source assessment for upper Jefferson River indicates that the low in streamflow during the time period of concern contributes the most human-caused temperature loading; load reductions should focus on potential improvements to irrigation delivery and efficiency through implementing reasonable BMPs. Meeting load allocations for the upper Jefferson River may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 7.0**.

Table 5-9. Upper Jefferson River instantaneous and daily load allocations

Category	Temperature (°F)	Flow (cfs)	Temperature change from baseline (°F)	Allocation (instantaneous load in kcal/s)	Allocation (daily load in kcal/day)
Nonpoint sources and background (LA)	67.53	101	0.00	56,420	4,874,659,152
Explicit MOS	NA	NA	0.50	794	68,599,200
Total	NA	101	0.50	57,214**	4,943,258,352**

**These values reflect the TMDL expressed as instantaneous (kcal/s) and daily (kcal/day) loads

5.7.4 Achieving Temperature Allocations

Improvement in riparian health needs significant time before changes can be seen. DEQ does not expect these targets to be met in the short-term; however, changes in land management practices would need to be implemented to meet goals for temperature in the lower Beaverhead and upper Jefferson Rivers. A commitment to those practices is necessary to maintain them. In addition, the targets and allocations presented represent the desired conditions that would be expected in most areas along a stream, but DEQ acknowledges that all sites may not be able to achieve them. The targets and allocations are not intended to be specific to every given point on the river; the intent, rather, is to achieve the TMDLs as a typical condition throughout the lower Beaverhead and upper Jefferson River segments. Note that some areas may also be able to achieve conditions greater than the targets, and the management should strive for the best possible condition given all reasonable land, soil, and water conservation practices in all circumstances.

5.8 SEASONALITY AND MARGIN OF SAFETY

Seasonality and margin of safety are both required elements of TMDL development. This section describes how seasonality and margin of safety (MOS) were applied during development of the lower Beaverhead and upper Jefferson temperature TMDLs.

Seasonality addresses the need to ensure year-round beneficial-use support. Seasonality is addressed for temperature in this TMDL document as follows:

- Temperature monitoring and modeling occurred during the summer, which is the warmest time of the year when instream temperatures are most stressful to aquatic life.
- Effective shade for the lower Beaverhead and upper Jefferson Rivers were based on the August solar path, which is typically the hottest month of the year.
- The maximum daily temperatures were used for the source assessment and impairment characterization because they are most likely to stress aquatic life; however, sources affecting maximum stream temperatures can also alter daily minimum temperatures year-round.

Addressing the sources causing elevated summer stream temperatures will also address sources that could lower the minimum temperature throughout the year.
- Temperature targets, the TMDL, and load allocations apply year round, but it is likely that exceedances occur mostly during summer conditions.

The MOS is included to account for uncertainties in pollutant sources and other watershed conditions, and ensure (to the degree practicable) that the TMDL components and requirements are sufficiently protective of water quality and beneficial uses. The MOS is addressed in several ways for temperature as part of this document:

- Although there is an allowable increase from human sources beyond those applying all reasonable land, soil, and water conservation practices, the surrogate allocations are expressed so human sources must apply all reasonable land, soil, and water conservation practices.
- Montana's water quality standards are applicable to any timeframe and any season. The temperature modeling analysis for the lower Beaverhead and upper Jefferson Rivers investigated stream temperatures during the summer, when effects of increased water temperatures are most likely to have a detrimental effect on aquatic life. Additionally, flow and climatic conditions were slightly adjusted for the upper Jefferson River from the sampling years to represent stream temperatures under more critical conditions than those observed in 2009.
- Compliance with targets and refinement of load allocations are all based on an adaptive management approach (**Section 5.9**) that relies on future monitoring and assessment for updating planning and implementation efforts.

5.9 UNCERTAINTY AND ADAPTIVE MANAGEMENT

Uncertainties in the accuracy of field data, source assessments, water quality models, loading calculations, and other considerations are inherent when evaluating environmental variables for TMDL development. While uncertainties are an undeniable fact of TMDL development, mitigation and reduction of uncertainty through adaptive management approaches is a key component of ongoing TMDL implementation activities. Uncertainties, assumptions, and considerations are applied throughout this document and point to the need for refining analyses when needed.

The process of adaptive management is predicated on the premise that TMDLs, allocations, and their supporting analyses are not static, but are processes subject to periodic modification and adjustment as new information and relationships are better understood. As further monitoring and assessment is conducted, uncertainties with present assumptions and consideration may be mitigated via periodic revision or review of the assessment that occurred for this document. As part of the adaptive management approach, changes in land and water management that affect temperature should be tracked. As implementation of restoration projects that reduce thermal input, or as new sources that increase thermal loading arise, tracking should occur. Known changes in management should be the basis for building future monitoring plans to determine if the thermal conditions meet state standards.

Uncertainty was minimized during data collection because temperature and field data were collected following DEQ sampling protocols (Montana Department of Environmental Quality, 2005a; 2005b). A quality assurance project plan (QAPP) was also completed for the Jefferson and Beaverhead QUAL2K models, but there was more uncertainty associated with the model than with the field data because numerous assumptions had to be made to help simulate existing and naturally occurring conditions. Modeling assumptions are described in in **Appendices B and C.**

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

Any influencing 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 worst case scenario reflective of 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. Implementation and monitoring recommendations presented in **Section 8.2** and **8.3** provide a basic framework for reducing uncertainty and further understanding of the complex issues TMDLs undertake.

6.0 NON-POLLUTANT IMPAIRMENTS

Water quality issues are not limited simply to those streams where total maximum daily loads (TMDLs) are developed. In some cases, streams have not yet been reviewed through the water quality assessment process and do not appear Montana's list of impaired waters, even though they may not be fully supporting all of their beneficial uses. In other cases, a stream may be listed as impaired, but does not require TMDL development because it is determined not to be impaired for a pollutant, but for a non-pollutant (TMDLs are only required for pollutant causes of impairment). Non-pollutant causes of impairment, such as "alteration in streamside or littoral vegetation covers," are often associated with temperature, sediment, or nutrient issues, but may be having a deleterious effect on a beneficial use without a clearly defined quantitative measurement or direct linkage to a pollutant.

Non-pollutant impairments have been recognized by Department of Environmental Quality (DEQ) as limiting their ability to fully support all beneficial uses and are important to consider when improving water quality conditions in both individual streams and watershed areas as a whole. **Table 6-1** shows the non-pollutant impairments in the lower Beaverhead and upper Jefferson Rivers on Montana's 2014 list of impaired waters. They are being summarized in this section to increase awareness of the non-pollutant impairment definitions and typical sources. Additionally, the restoration strategies discussed in **Section 7.0** inherently address some of the non-pollutant listings and many of the best management practices (BMPs) necessary to meet TMDLs will also address non-pollutant sources of impairment. As mentioned above, these impairment causes should be considered during planning of watershed scale restoration efforts.

Table 6-1. Lower Beaverhead and Upper Jefferson Non-pollutant (Pollution) Listings on the 2014 303(d) List

Waterbody ID	Stream Segment	2014 Probable Causes of Impairment
Beaverhead River, Grasshopper Creek to mouth (Jefferson River)	MT41B001_020	Alteration in streamside or littoral vegetative covers
		Low flow alterations
		Physical substrate habitat alterations
Jefferson River, headwaters to confluence of Jefferson Slough	MT41G001_011	Low flow alterations
		Physical substrate habitat alterations

6.1 NON-POLLUTANT CAUSES OF IMPAIRMENT DETERMINATION

Non-pollutant listings are often used as a probable cause of impairment when available data at the time of assessment does not necessarily provide a direct quantifiable linkage to a specific pollutant. In some cases the pollutant and non-pollutant categories are linked and appear together in the cause listings, however a non-pollutant category may appear independent of a pollutant listing. The following discussion provides some rationale for the application of the identified non-pollutant causes to a waterbody, and thereby provides additional insight into possible factors in need of additional investigation or remediation.

Alteration in Streamside or Littoral Vegetation Covers

Alteration in streamside or littoral vegetation covers refers to circumstances where practices along the stream channel have altered or removed riparian vegetation and subsequently affected channel geomorphology and/or stream temperature. This may include riparian vegetation removal for a road or utility corridor, effects of streamside mine tailings or placer mining remnants, or overgrazing by livestock along the stream. As a result of altering the streamside vegetation, destabilized banks from loss of vegetative root mass could lead to overwidened stream channel conditions and elevated sediment loads, in addition to elevated stream temperature from loss of canopy shade.

Physical Substrate Habitat Alterations

Physical substrate habitat alterations generally describe cases where the stream channel has been physically altered or manipulated, such as through the straightening of the channel or from human-influenced channel downcutting, resulting in a reduction of morphological complexity and loss of habitat (riffles and pools) for fish and aquatic life. For example, this may occur when a stream channel has been straightened to accommodate roads, agricultural fields, or through placer mine operations.

Low Flow Alterations

Streams are typically listed for low flow alterations when local water use management leads to flows that would not be typical under naturally occurring flow conditions. This could be related to irrigation practices, dam release operations, or even groundwater use that has subsequently altered stream recharge; which could result in dry channels or extreme low flow conditions harmful to fish and aquatic life.

It should be noted that while Montana law states that TMDLs cannot impact Montana water rights and thereby affect the allowable flows at various times of the year, the identification of low flow alterations or other flow regime alterations as a probable source of impairment does not violate any state or federal regulations or guidance related to stream assessment and beneficial use determination. Subsequent to the identification of this as a probable cause of impairment, it is up to local users, agencies, and entities to improve flows through water and land management.

6.2 MONITORING AND BMPS FOR NON-POLLUTANT AFFECTED STREAMS

In the lower Beaverhead River, two forms of habitat alteration (alteration in streamside or littoral vegetation covers and physical substrate habitat alterations) were linked to the sediment TMDL developed in 2012. The low flow alteration was also addressed in that 2012 document. It is likely that meeting those sediment targets will also equate to addressing the habitat impairment conditions in the lower Beaverhead River. For the upper Jefferson River, which has no developed sediment TMDL (but does have a sediment listing), applying the sediment targets from the Beaverhead River will likely begin to address the habitat impairment condition. Additionally, groundwater protection may be an effective measure to avoid complete dewatering and provide thermal refuge for aquatic life, especially throughout the Upper Jefferson River segment.

Streams listed for *non-pollutants* as opposed to a pollutant should not be overlooked when developing watershed management plans. Attempts should be made to collect sediment, nutrient, and temperature information where data is minimal and the linkage between probable cause, non-pollutant listing, and effects to the beneficial uses are not well defined. Watershed management planning should also include strategies to help increase streamflows, particularly during summer low flow periods for those streams with low flow alteration impairment causes. The monitoring and restoration strategies that follow in **Sections 7.0** and **8.0** are presented to address both pollutant and non-pollutant issues for streams in the lower Beaverhead and Upper Jefferson Rivers, and they are equally applicable to streams listed for the above non-pollutant categories.

7.0 WATER QUALITY IMPROVEMENT PLAN

7.1 PURPOSE OF IMPROVEMENT STRATEGY

This section describes a general strategy and specific on-the-ground measures designed to restore water quality beneficial uses and attain water quality standards in the lower Beaverhead and upper Jefferson Rivers. The strategy includes general measures for reducing loading from each identified significant pollutant source.

This section should assist stakeholders in developing a watershed restoration plan (WRP) that will provide more detailed information about restoration goals within the watershed. The WRP may also encompass broader goals than the water quality improvement strategy outlined in this document. The intent of the WRP is to serve as a locally organized “road map” for watershed activities, prioritizing types of projects, sequences of projects, and funding sources towards achieving local watershed goals. Within the WRP, local stakeholders identify and prioritize streams, tasks, resources, and schedules for applying best management practices (BMPs). As restoration experiences and results are assessed through watershed monitoring, this strategy could be adapted and revised by stakeholders based on new information and ongoing improvements.

7.2 ROLE OF DEQ, OTHER AGENCIES, AND STAKEHOLDERS

The Montana Department of Environmental Quality (DEQ) does not implement total maximum daily load (TMDL) pollutant-reduction projects for nonpoint source activities, but may provide technical and financial assistance for stakeholders interested in improving their water quality by doing such activities. Successful implementation of TMDL pollutant-reduction projects requires collaboration among private landowners, land management agencies, and other stakeholders. DEQ will work with participants to use the TMDLs as a basis for developing locally-driven WRPs, administer funding specifically to help support water quality improvement and pollution prevention projects, and help identify other sources of funding.

Because most nonpoint source reductions rely on voluntary measures, it is important that local landowners, watershed organizations, and resource managers work collaboratively with local and state agencies to achieve water quality restoration goals and to meet TMDL targets and load reductions. Specific stakeholders and agencies that will likely be vital to restoration efforts for streams discussed in this document include:

- Beaverhead Watershed Committee
- Jefferson River Watershed Council
- Beaverhead Conservation District
- Ruby Valley Conservation District
- Jefferson Valley Conservation District
- Water Users on the Beaverhead River (East Bench Irrigation District, Clark Canyon Water Supply Company, and Others)
- Water Users on the Jefferson River (Jefferson Canal Co., Fish Creek Ditch, and Others)
- Natural Resources and Conservation Service (NRCS)
- U.S. Fish & Wildlife Service (USFWS)
- U.S. Environmental Protection Agency (EPA)

- Montana Department of Natural Resources and Conservation (DNRC)
- Montana Fish, Wildlife and Parks (FWP)
- Montana Department of Environmental Quality (DEQ)
- Bureau of Reclamation (BOR)
- Montana Trout Unlimited
- U.S. Army Corp of Engineers
- Montana Department of Transportation
- Montana Bureau of Mines and Geology
- Montana Water Center (at Montana State University)
- University of Montana Watershed Health Clinic
- Montana Aquatic Resources Services
- Montana State University Extension Water Quality Program

7.3 WATER QUALITY RESTORATION OBJECTIVES

The water quality restoration objective for the lower Beaverhead and upper Jefferson Rivers is to reduce pollutant loads as identified throughout this document in order to meet the water quality standards and TMDL targets for full recovery of beneficial uses for all impaired streams. Meeting the TMDLs provided in this document will achieve this objective for both temperature impaired river segments. Based on the assessment provided in this document, the TMDLs can be achieved through proper implementation of appropriate BMPs.

A WRP can provide a framework strategy for water quality restoration and monitoring, focusing on how to meet conditions that will likely achieve the TMDLs presented in this document, as well as other water quality issues of interest to local communities and stakeholders. WRPs identify considerations that should be addressed during TMDL implementation and should assist stakeholders in developing a more detailed adaptive plan in the future. A locally developed WRP will provide more detailed information about restoration goals and spatial considerations but may also encompass broader goals than this framework includes. A WRP would serve as a locally organized “road map” for watershed activities, sequences of projects, prioritizing of projects, and funding sources for achieving local watershed goals, including water quality improvements. The WRP is intended to be a living document that can be revised based on new information related to restoration effectiveness, monitoring results, and stakeholder priorities.

The EPA requires nine minimum elements for a WRP. A complete description can be found at http://www.epa.gov/region9/water/nonpoint/9elements-WtrshdPlan-EpaHndbk.pdf and are summarized here:

1. Identification of the causes and sources of pollutants
2. Estimated load reductions expected based on implemented management measures
3. Description of needed nonpoint source management measures
4. Estimate of the amounts of technical and financial assistance needed
5. An information/education component
6. Schedule for implementing the nonpoint source management measures
7. Description of interim, measurable milestones
8. Set of criteria that can be used to determine whether loading reductions are being achieved over time
9. A monitoring component to evaluate effectiveness of the implementation efforts over time

This document provides, or can serve as an outline, for many of the required elements. Water quality goals for temperature are detailed in **Section 5.0**. These goals include water quality and habitat targets as measures for long-term effectiveness monitoring. These targets specify satisfactory conditions to ensure protection and/or recovery of beneficial uses of waterbodies in the lower Beaverhead and upper Jefferson Rivers. It is presumed that meeting all water quality and habitat targets will achieve the water quality goals for each impaired waterbody. **Section 8.0** identifies a general monitoring strategy and recommendations to track post-implementation water quality conditions and measure restoration successes.

7.4 OVERVIEW OF MANAGEMENT RECOMMENDATIONS

A temperature TMDL was completed for both the lower Beaverhead and upper Jefferson Rivers in this document. A temperature TMDL was written for the Big Hole River (Kron et al., 2009) and for the Ruby River (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2006), among TMDLs for other EPA-approved TMDLs in those watersheds. Eighteen sediment TMDLs were approved in the Beaverhead watershed in 2012. Seven sediment TMDLs were approved for tributaries in the upper Jefferson watershed in 2006. The Beaverhead, Ruby, and Upper Jefferson watersheds all have additional listed waterbody-pollutant combinations that are in need of TMDLs or re-assessment. Other streams in the project areas may be in need of restoration or pollutant reduction, but insufficient information about them precludes TMDL development at this time. The following sub-sections describe some generalized recommendations for implementing projects to achieve the TMDLs. Details specific to each river and therefore which of the following strategies may be most appropriate, are found within **Section 5.0.**

In general, restoration activities can be separated into two categories: active and passive. Passive restoration allows natural succession to occur within an ecosystem by removing a source of disturbance. Fencing off riparian areas from cattle grazing is a good example of passive restoration. Active restoration, on the other hand involves accelerating natural processes or changing the trajectory of succession. For example, historic placer mining often resulted in the straightening of stream channels and piling of processed rock on the streambank. These impacts would take so long to recover passively that active restoration methods involving removal of waste rock and rerouting of the stream channel would likely be necessary to improve stream and water quality conditions. In general, passive restoration is preferable for sediment, temperature, and nutrient problems because it is generally more cost effective, less labor intensive, and will not result in short term increase of pollutant loads as active restoration activities may. However, in some cases active restoration is the only feasible mechanism for achieving desired goals; these activities must be assessed on a case by case basis (Nature Education, 2013).

7.4.1 Temperature Restoration Approach

The goal of the temperature restoration approach is to reduce water temperatures where possible to be consistent with naturally occurring conditions. The most significant mechanism for reducing water temperatures in the lower Beaverhead and Upper Jefferson Rivers is using water conservation measures to maximize water left in the stream. Other factors that will help are: increasing riparian shade, improving overwidened portions of the stream, working with reservoir operations, groundwater protection, tributary flow enhancement, creating seasonal flow objectives, and maintaining conditions where theses creeks are currently meeting the targets. Identification of water sources with relatively high water temperature could also result in developing a prioritized project list of inflows that elevate water temperature.

Increasing instream summer flows can be achieved through a thorough investigation of water use practices and water conveyance infrastructure, and a willingness and ability of local water users to keep more water instream. This TMDL document cannot, nor is it intended to, prescribe limitations on individual water rights owners and users. However, it is understood that increased summer instream flows could improve summer water temperatures, and in addition improve quality and connectivity among instream features used by aquatic life. Local water users should work collectively and with local, state, and federal resource management professionals to review water use options and available assistance programs to create seasonal flow objectives.

Increase in shade can be accomplished through the restoration and protection of shade-providing vegetation within the riparian corridor. This type of vegetation can also have the added benefit of serving as a stabilizing component to streambanks to reduce bank erosion, slow lateral river migration, and buffer pollutants from upland sources from entering the stream. In some cases, this can be achieved by limiting activities in the riparian area (such as grazing, near stream cropping, development, and other near stream activities) or through application of BMPs for those activites. Other areas may require planting, active bank restoration, and protection to establish vegetation.

Recovery of stream channel morphology in most cases will occur slowly over time following the improvement of riparian condition, stabilization of streambanks, and reduction in overall sediment load.

The above approaches give only the broadest description of activities to help reduce water temperatures. The temperature assessment described in **Section 5.0** looked at possible scenarios based on limited information at the watershed scale. Those scenarios showed that improvements in stream temperatures can primarily be made by increasing instream flow during summer months. It is strongly encouraged that resource managers and land owners continue to work to identify all potential areas of improvement and develop projects and practices to reduce stream temperatures in the lower Beaverhead and upper Jefferson Rivers.

7.4.2 Non-Pollutant Restoration Approach

Although TMDL development is not required for non-pollutant listings, they are frequently linked to pollutants, and addressing non-pollutant causes, such as flow and habitat alterations, is an important component of TMDL implementation. Non-pollutant listings within the lower Beaverhead and upper Jefferson Rivers are described in **Section 6.0**. Typically, habitat impairments are addressed during implementation of associated pollutant TMDLs. Therefore, if restoration goals within the two rivers are not also addressing non-pollutant impairments, additional non-pollutant related BMP implementation should be considered.

7.5 RESTORATION APPROACHES BY SOURCE

General management recommendations are outlined below for the major sources of human caused pollutant loads in the lower Beaverhead and upper Jefferson Rivers: riparian and wetland vegetation removal, agricultural sources, and residential development. Applying BMPs is the core of the nonpoint source pollutant reduction strategy, but BMPs are only part of a watershed restoration strategy. For each major source, BMPs will be most effective as part of a comprehensive management strategy. The WRP developed by local watershed groups should contain more detailed information on restoration goals and specific management recommendations that may be required to address key pollutant sources. BMPs are usually identified as a first effort and further monitoring and evaluation of activities and outcomes, as part of an adaptive management approach will be used to determine if further restoration approaches are necessary to achieve water quality standards. Monitoring is an important part of the restoration process, and monitoring recommendations are outlined in **Section 8.0**.

7.5.1 Riparian Areas, Wetlands, and Floodplains

Healthy and functioning riparian areas, wetlands, and floodplains are critical for wildlife habitat, groundwater recharge, reducing the severity of floods and upland and streambank erosion, and filtering pollutants from runoff. The performance of the above named functions is dependent on the connectivity of riparian areas, wetlands, and floodplains to both the stream channel and upland areas. Human activities affecting the quality of these transitional habitats or their connectivity can alter their performance and greatly affect the transport of water, sediments, and contaminants (e.g., channelization, increased stream power, bank erosion, and habitat loss or degradation). Therefore, restoring, maintaining, and protecting riparian areas, wetlands, and floodplains within the watershed should be a priority of TMDL implementation in the lower Beaverhead and upper Jefferson Rivers.

Reduction of riparian and wetland vegetative cover by various land management activities is a principal cause of water quality and habitat degradation in watersheds throughout Montana. Although implementation of passive BMPs that allow riparian and wetland vegetation to recover at natural rates is typically the most cost-effective approach, active restoration (i.e., plantings) may be necessary in some instances. The primary advantage of riparian and wetland plantings is that installation can be accomplished with minimum impact to the stream channel, existing vegetation, and private property.

Factors influencing the appropriate riparian and wetland restoration would include severity of degradation, site-potential for various species, and availability of local sources for native transplant materials. In general, riparian and wetland plantings would promote establishment of functioning stands of native species. The following recommended restoration measures would allow for stabilization of the soil, decrease sediment delivery to the stream, and increase absorption of nutrients from overland runoff:

- Harvesting and transplanting locally available sod mats with an existing dense root mass provides immediate promotion of bank stability and filtering nutrients and sediments
- Seeding with native graminoids (grasses and sedges) and forbs is a low cost activity at locations where lower bank shear stresses would be unlikely to cause erosion
- Willow sprigging expedites vegetative recovery, but involves harvest of dormant willow stakes from local sources
- Transplanting mature native shrubs, particularly willows (*Salix* sp.), provides rapid restoration of instream habitat and water quality through overhead cover and stream shading, as well as uptake of nutrients

Note: Before transplanting *Salix* from one location to another it is important to determine the exact species so that we do not propagate the spread of non-native species. There are several non-native willow species that are similar to our native species and commonly present in Montana watersheds.

In addition to the benefits described above, it should be noted that in some cases, wetlands act as areas of shallow subsurface groundwater recharge and/or storage areas. The captured water via wetlands is then generally discharged to the stream later in the season and contributes to the maintenance of base flows and stream temperatures. Restoring ditched or drained wetlands can have a substantial effect on the quantity, temperature, and timing of water returning to a stream, as well as the pollutant filtering capacity that improved riparian and wetlands provide.

7.5.2 Agriculture

The main agricultural BMP recommendations for the lower Beaverhead and upper Jefferson Rivers focus on maintaining riparian shade through grazing and cropland BMPs; and also through improving instream flow through irrigation management.

7.5.2.1 Grazing

Grazing has the potential to increase temperatures by altering channel width and riparian vegetation, but these effects can be mitigated with appropriate management. Development of riparian grazing management plans should be a goal for any landowner who operates livestock and does not currently have such plans. Private land owners may be assisted by state, county, federal, and local conservation groups to establish and implement appropriate grazing management plans. Riparian grazing management does not necessarily eliminate all grazing in riparian corridors. In some areas however, a more limited management strategy may be necessary for a period of time in order to accelerate reestablishment of a riparian community with the most desirable species composition and structure.

Every livestock grazing operation should have a grazing management plan. The NRCS Prescribed Grazing Conservation Practice Standard (Code 528) recommends the plan include the following elements (Natural Resources Conservation Service, 2010):

- A map of the operation showing fields, riparian and wetland areas, winter feeding areas, water sources, animal shelters, etc.
- The number and type of livestock
- Realistic estimates of forage needs and forage availability
- The size and productivity of each grazing unit (pasture/field/allotment)
- The duration and time of grazing
- Practices that will prevent overgrazing and allow for appropriate regrowth
- Practices that will protect riparian and wetland areas and associated water quality
- Procedures for monitoring forage use on an ongoing basis
- Development plan for off-site watering areas

Reducing grazing pressure in riparian and wetland areas and improving forage stand health are the two keys to preventing nonpoint source pollution from grazing. Grazing operations should use some or all of the following practices:

- Minimizing or preventing livestock grazing in riparian and wetland areas
- Providing off-stream watering facilities or using low-impact water gaps to prevent ‘loafing’ in wet areas
- Managing riparian pastures separately from upland pastures
- Installing salt licks, feeding stations, and shelter fences in areas that prevent ‘loafing’ in riparian areas and help distribute animals
- Replanting trodden down banks and riparian and wetland areas with native vegetation (this should always be coupled with a reduction in grazing pressure)
- Rotational grazing or intensive pasture management that takes season, frequency, and duration into consideration

The following resources provide guidance to help prevent pollution and maximize productivity from grazing operations:

- United States Department of Agriculture (USDA), Natural Resources Conservation Service Offices serving Beaverhead, Jefferson, and Madison Counties are located in Dillon, Whitehall, and Sheridan (find your local USDA Agricultural Service Center listed in your phone directory or on the Internet at www.nrcs.usda.gov)
- Montana State University Extension Service (www.extn.msu.montana.edu)
- DEQ Watershed Protection Section (Nonpoint Source Program): Nonpoint Source Management Plan (http://deq.mt.gov/wqinfo/nonpoint/NonpointSourceProgram.mcpx)

The key strategy of the recommended grazing BMPs is to develop and maintain healthy riparian and wetland vegetation and minimize disturbance of the streambank and channel. The primary recommended BMPs for the lower Beaverhead and upper Jefferson Rivers are limiting livestock access to streams and stabilizing the stream at access points, providing off-site watering sources when and where appropriate, planting native stabilizing vegetation along streambanks, and establishing and maintaining riparian buffers. Although bank revegetation is a preferred BMP, in some instances bank stabilization may be necessary prior to planting vegetation.

7.5.2.2 Flow and Irrigation

Flow alteration and dewatering are commonly considered water quantity rather than water quality issues. However, changes to streamflow can have a profound effect on the ability of a stream to flush sediment and attenuate other pollutants, especially nutrients, metals, and heat. Flow reduction may increase water temperature, reduce available habitat for fish and other aquatic life, and may cause the channel to respond by changing in size, morphology, meander pattern, rate of migration, bed elevation, bed material composition, floodplain morphology, and streamside vegetation if flood flows are reduced (Andrews and Nankervis, 1995; Schmidt and Potyondy, 2004). Restoration targets and implementation strategies recognize the need for specific flow regimes, and may suggest flow-related improvements as a means to achieve full support of water quality beneficial uses. However, local coordination and planning are especially important for flow management because state law indicates that legally obtained water rights cannot be divested, impaired, or diminished by Montana’s water quality law (Montana Code Annotated (MCA) 75-5-705).

Irrigation management is a critical component of attaining both coldwater fishery conservation and TMDL goals. Understanding irrigation water, groundwater, and surface water interactions is an important part of understanding how irrigation practices will affect streamflow during specific seasons.

Some irrigation practices in western Montana are based on flood irrigation methods. Occasionally head gates and ditches leak, which can decrease the amount of water in diversion flows. The following recommended activities could potentially result in notable water savings:

- Install upgraded head gates for more exact control of diversion flow and to minimize leakage when not in operation
- Develop more efficient means to supply water to livestock
- Determine necessary diversion flows and timeframes that would reduce over watering and improve forage quality and production
- Where appropriate, redesign or reconfigure irrigation systems
- Upgrade ditches (including possible lining, if appropriate) to increase ditch conveyance efficiency

Some water from spring and early summer flood irrigation likely returns as cool groundwater to the streams during the heat of the summer. These critical areas could be identified so that they can be preserved as flood irrigation areas. Other irrigated areas which do not contribute to summer groundwater returns to the river should be identified as areas where year round irrigation efficiencies could be more beneficial than seasonal management practices. Winter baseflow should also be considered during these investigations.

7.5.3 Residential/Urban Development

There are multiple sources and pathways of pollution to consider in residential and urban areas. Destruction of riparian areas and stormwater generated from impervious areas and construction sites are discussed below.

7.5.3.1 Riparian Degradation

Residential development adjacent to streams can affect the amount and health of riparian vegetation, the amount of large woody debris available in the stream, and might result in placement of riprap on streambanks (see **Section 7.5.4**). As discussed in the above section on riparian areas, wetlands, and floodplains, substantially degraded riparian areas can affect channel width and shade and do not effectively filter pollutants from upland runoff. Riparian areas that have been converted to lawns or small acreage pastures for domestic livestock may suffer from increased contributions of nutrients, sediment, and bacteria, as well as increased summer stream temperatures, increased channel erosion, and greater damage to property from flooding.

For landowners, conservation easements can be a viable alternative to subdividing land and can be facilitated through several organizations such as The Nature Conservancy, the Trust for Public Land, and FWP. Further information on conservation easements and other landowner programs can be obtained from FWP (http://fwp.mt.gov/fishAndWildlife/habitat/wildlife/programs/landownersGuide.html).

DEQ encourages the consideration of adopting local zoning or regulations that protect the functions of floodplains and riparian and wetland areas where future growth may occur. Requirements for protecting native vegetation riparian buffers can be an effective mechanism for maintaining or improving stream health. Local outreach activities to inform new residential property owners of the effects of riparian degradation may also prevent such activities from occurring, including providing information on: appropriate fertilizer application rates to lawns and gardens, regular septic system maintenance, preserving existing riparian vegetation, native vegetation for landscaping, maintaining a buffer to protect riparian and wetland areas, and practices to reduce the amount of stormwater originating from developed property. Montana's Nonpoint Source Management Plan contains suggested BMPs to address the effects of residential and urban development, and also contains an appendix of setback regulations that have been adopted by various cities and counties in Montana (Montana Department of Environmental Quality, 2012c). Planning guides and informational publications related to wetlands and native plant species in Montana can be found on DEQ's Wetlands Conservation website at: http://deq.mt.gov/wqinfo/Wetlands/default.mcpx.

7.5.3.2 Stormwater

Where precipitation from rain or snowmelt events does not infiltrate soils in urban areas and at construction sites, it drains off the landscape as stormwater, which can potentially increase base temperatures of the receiving waterbody (and can carry pollutants as well). As the percentage of impervious surfaces (e.g., streets, parking lots, roofs) increases, so does the volume of stormwater and pollutant loads delivered to waterbodies. Although stormwater is not currently identified as a significant source of pollutant contributions for the two rivers discussed in this document, stormwater management could be a consideration when identifying water quality improvement objectives within the watershed restoration plan. The primary method to control stormwater discharges is the use of BMPs. Additional information can be found in Montana's Nonpoint Source Management Plan (Montana Department of Environmental Quality, 2012c). A guide to stormwater BMPs can be found on EPA's National Menu of Stormwater Best Management Practices at: http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm. The Montana Water Center also has a website dedicated to stormwater control for construction activities: http://stormwater.montana.edu/.

7.6 POTENTIAL FUNDING AND TECHNICAL ASSISTANCE SOURCES

Prioritization and funding of restoration or water quality improvement projects is integral to maintaining restoration activities and monitoring project successes and failures. Several government agencies and also a few non-governmental organizations fund or can provide assistance with watershed or water quality improvement projects or wetlands restoration projects. Below is a brief summary of potential funding sources and organizations to assist with TMDL implementation.

7.6.1 Section 319 Nonpoint Source Grant Program

DEQ issues a call for proposals every year to award Section 319 grant funds administered under the federal Clean Water Act. The primary goal of the 319 program is to restore water quality in waterbodies whose beneficial uses are impaired by nonpoint source pollution and whose water quality does not meet state standards. 319 funds are distributed competitively to support the most effective and highest priority projects. In order to receive funding, projects must directly implement a DEQ-accepted watershed restoration plan and funds may either be used for the education and outreach component of the WRP or for implementing restoration projects. The recommended range for 319 funds per project proposal is $10,000 to $30,000 for education and outreach activities and $50,000 to $300,000 for implementation projects. All funding has a 40% cost share requirement, and projects must be administered through a governmental entity such as a conservation district or county, or a nonprofit organization. For information about past grant awards and how to apply, please visit http://deq.mt.gov/wqinfo/nonpoint/319GrantInfo.mcpx.

7.6.2 Future Fisheries Improvement Program

The Future Fisheries grant program is administered by FWP and offers funding for projects that focus on habitat restoration to benefit wild and native fish. Anyone ranging from a landowner or community-based group to a state or local agency is eligible to apply. Applications are reviewed annually in December and June. Projects that may be applicable to the lower Beaverhead and upper Jefferson watersheds include restoring streambanks, improving fish passage, and restoring/protecting spawning habitats. For additional information about the program and how to apply, please visit http://fwp.mt.gov/fishAndWildlife/habitat/fish/futureFisheries/.

7.6.3 Watershed Planning and Assistance Grants

The DNRC administers Watershed Planning and Assistance Grants to watershed groups that are sponsored by a conservation district. Funding is capped at $10,000 per project and the application cycle is quarterly. The grant focuses on locally developed watershed planning activities; eligible activities include developing a watershed plan, group coordination costs, data collection, and educational activities. For additional information about the program and how to apply, please visit http://dnrc.mt.gov/cardd/LoansGrants/WatershedPlanningAssistance.asp.

Numerous other funding opportunities exist for addressing nonpoint source pollution. Additional information regarding funding opportunities from state agencies is contained in Montana's Nonpoint Source Management Plan (Montana Department of Environmental Quality, 2012c) and information regarding additional funding opportunities can be found at http://www.epa.gov/nps/funding.html.

7.6.4 Environmental Quality Incentives Program

The Environmental Quality Incentives Program (EQIP) is administered by NRCS and offers financial (i.e., incentive payments and cost-share grants) and technical assistance to farmers and ranchers to help plan and implement conservation practices that improve soil, water, air and other natural resources on their land. The program is based on the concept of balancing agricultural production and forest management with environmental quality, and is also used to help producers meet environmental regulations. EQIP offers contracts with a minimum length of one year after project implementation to a maximum of 10 years. Each county receives an annual EQIP allocation and applications are accepted continually during the year; payments may not exceed $300,000 within a six-year period. For additional information about the program and how to apply, please visit http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/.

7.6.5 Resource Indemnity Trust/Reclamation and Development Grants Program

The Resource Indemnity Trust / Reclamation and Development Grants Program (RIT/RDG) is an annual program administered by DNRC that can provide up to $300,000 to address environmental related issues. RIT/RDG program funds can be used for conducting site assessment/characterization activities such as identifying specific sources of water quality impairment. RIT/RDG projects typically need to be administered through a non-profit or local government such as a conservation district, a watershed planning group, or a county. For additional information about the program and how to apply, please visit: http://dnrc.mt.gov/cardd/ResourceDevelopment/rdgp/ReclamationDevelopmentGrantsProgram.asp .

7.6.6 Montana Partners for Fish and Wildlife

Montana Partners for Fish and Wildlife is a program under the U.S. Fish & Wildlife Service that assists private landowners to restore wetlands and riparian habitat by offering technical and financial assistance. For additional information about the program and to find your local contact for the Beaverhead and Jefferson watersheds, please visit: http://www.fws.gov/mountain-prairie/pfw/montana/.

7.6.7 Wetlands Reserve Program

The Wetlands Reserve Program is a voluntary conservation program administered by the NRCS that offers landowners the means to restore, enhance, and protect wetlands on their property through permanent easements, 30 year easements, or Land Treatment Contracts. The NRCS seeks sites on agricultural land where former wetlands have been drained, altered, or manipulated by human. The landowner must be interested in restoring the wetland and subsequently protecting the restored site. For additional information about the program and how to apply, please visit http://www.nrcs.usda.gov/wps/portal/nrcs/main/mt/programs/easements/wetlands/

7.6.8 Montana Wetland Council

The Montana Wetland Council is an active network of diverse interests that works cooperatively to conserve and restore Montana's wetland and riparian ecosystems. Please visit their website to find dates and locations of upcoming meetings, wetland program contacts, and additional information on potential grants and funding opportunities: http://deq.mt.gov/wqinfo/wetlands/wetlandscouncil.mcpx.

7.6.9 Montana Natural Heritage Program

The Montana Natural Heritage Program is a valuable resource for restoration and implementation information including maps. Wetlands and riparian areas are one of the 14 themes in the Montana Spatial Data Infrastructure. The Montana Wetland and Riparian Mapping Center (found at: http://mtnhp.org/nwi/) is creating a statewide digital wetland and riparian layer as a resource for management, planning, and restoration efforts.

7.6.10 Montana Aquatic Resources Services, Inc.

Montana Aquatic Resources Services, Inc. (MARS) is a nonprofit organization focused on restoring and protecting Montana's rivers, streams and wetlands. MARS identifies and implements stream, lake, and wetland restoration projects, collaborating with private landowners, local watershed groups and conservation districts, state and federal agencies, and tribes. For additional information about the program, please visit http://montanaaquaticresources.org/.

8.0 MONITORING STRATEGY AND ADAPTIVE MANAGEMENT

8.1 MONITORING PURPOSE

The monitoring strategies discussed in this section are an important component of watershed restoration, and a requirement of total maximum daily load (TMDL) implementation under the Montana Water Quality Act (Montana Code Annotated (MCA) 75-5-703(7)), and the foundation of the adaptive management approach. Water quality targets and allocations presented in this document are based on available data at the time of analysis. The scale of the watershed analysis, coupled with constraints on time and resources, often result in necessary compromises that include estimations, extrapolation, and a level of uncertainty in TMDLs. The margin of safety (MOS) is put in place to reflect some of this uncertainty, but other issues only become apparent when restoration strategies are underway. Having a monitoring strategy in place allows for feedback on the effectiveness of restoration activities, the amount of reduction of instream pollutants (whether TMDL targets are being met), if all significant sources have been identified, and whether attainment of TMDL targets is feasible. Data from long-term monitoring programs also provide technical justifications to modify restoration strategies, targets, or allocations where appropriate.

The monitoring strategy presented in this section provides a starting point for the development of more detailed planning efforts regarding monitoring needs; it does not assign monitoring responsibility. Monitoring recommendations provided are intended to assist local land managers, stakeholder groups, and federal and state agencies in developing appropriate monitoring plans to meet the water quality improvement goals outlined in this document. Funding for future monitoring is uncertain and can vary with economic and political changes. Prioritizing monitoring activities depends on funding opportunities and stakeholder priorities for restoration. Once restoration measures have been implemented for a waterbody with an approved TMDL and given time to take effect, Department of Environmental Quality (DEQ) will conduct a formal evaluation of the waterbody’s impairment status and determine whether TMDL targets and water quality standards are being met.

8.2 ADAPTIVE MANAGEMENT AND UNCERTAINTY

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 best management practices (BMPs), have been applied to determine whether compliance with water quality standards has been attained. This aligns with an adaptive management approach that is incorporated into DEQ’s assessment and water quality impairment determination process.

Adaptive management as discussed throughout this document is a systematic approach for improving resource management by learning from management outcomes, and allows for flexible decision making. There is an inherent amount of uncertainty involved in the TMDL process, including: establishing water quality targets, calculating existing pollutant loads and necessary load allocations, and determining effects of BMP implementation. Use of an adaptive management approach based on continued monitoring of project implementation helps manage resource commitments and 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.

For an in-depth look at the adaptive management approach, view the U.S. Department of the Interior's (DOI) technical guide and description of the process at: http://www.doi.gov/archive/initiatives/AdaptiveManagement/. DOI includes **Figure 8-1** below in their technical guide as a visual explanation of the iterative process of adaptive management (Williams et al., 2009).

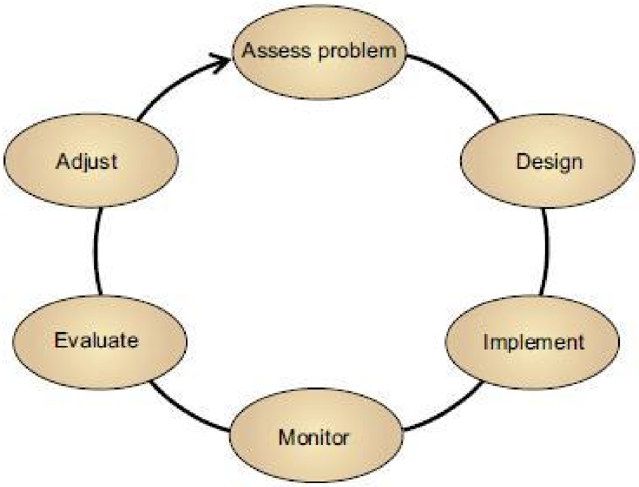

Figure 8-1. Diagram of the adaptive management process

8.3 FUTURE MONITORING GUIDANCE

The objectives for future monitoring in the lower Beaverhead and upper Jefferson Rivers include:

- Strengthen the spatial understanding of sources for future restoration work, which will also improve source assessment analysis for future TMDL review
- Gather additional data to supplement target analysis, better characterize existing conditions, and improve or refine assumptions made in TMDL development
- Gather consistent information among agencies and watershed groups that is comparable to the established water quality targets and allow for common threads in discussion and analysis
- Expand the understanding of streams and nonpoint source pollutant loading throughout the project area beyond those where TMDLs have been developed and address issues
- Track restoration projects as they are implemented and assess their effectiveness

8.3.1 Strengthening Source Assessment

In the lower Beaverhead and upper Jefferson Rivers, the identification of pollutant sources was conducted largely through tours of the watershed, assessments of aerial photographs, the incorporation of geographic information system information, reviewing and analyzing available data, and the review of published scientific studies. In many cases, assumptions were made based on known watershed conditions and extrapolated throughout the project area. As a result, the level of detail often does not provide specific areas on which to focus restoration efforts, only broad source categories to reduce pollutant loads from both of the river segments. Strategies for strengthening source assessments for temperature are outlined below:

- Field surveys to better identify and characterize riparian area conditions and potential for improvement
- Identification of possible areas for improvement in shading along the river corridor, major tributaries, and headwater streams
- Investigation of groundwater influence on instream temperatures, and relationships between groundwater availability and water use
- Assessment of irrigation practices and other water use in and potential for improvements in water use that would result in increased instream flows
- Use of additional collected data to evaluate and refine the temperature targets

8.3.2 Increasing Available Data

While the lower Beaverhead and upper Jefferson Rivers have been studied and monitored over the years, data are still often limited depending on the pollutant of interest. Infrequent sampling events at a small number of sampling sites may provide some indication of overall water quality and habitat condition. However, regularly scheduled sampling at consistent locations, under a variety of seasonal conditions is the best way to assess overall stream health and monitor change. Increasing the number of data logger locations and the number of years of data, including collection of associated flow and shade data, would improve our understanding of instream temperature changes and better identify influencing factors on those changes. Collecting additional stream temperature data in sections with the most significant temperature changes and/or largest spatial gaps between loggers will also help refine the characterization of temperature conditions.

8.3.3 Consistent Data Collection and Methodologies

Data has been collected throughout the lower Beaverhead and upper Jefferson Rivers for many years and by many different agencies and entities; however, the type and quality of information is often variable. Wherever possible, it is recommended that the type of data and methodologies used to collect and analyze the information be consistent so as to allow for comparison to TMDL targets and track progress toward meeting TMDL goals.

DEQ is the lead agency for developing and conducting impairment status monitoring; however, other agencies or entities may work closely with DEQ to provide compatible data. Water quality impairment determinations are made by DEQ, but data collected by other sources can be used in the impairment determination process. The information in this section provides general guidance for future impairment status monitoring and effectiveness tracking. Future monitoring efforts should consult DEQ on updated monitoring protocols. Improved communication between agencies and stakeholders will further improve accurate and efficient data collection.

It is important to note that monitoring recommendations are based on TMDL related efforts to protect water quality beneficial uses in a manner consistent with Montana’s water quality standards. Other regulatory programs with water quality protection responsibilities may impose additional requirements to ensure full compliance with all appropriate local, state, and federal laws.

Data loggers should be deployed at the same locations through the years to accurately represent the site-specific conditions over time, and recorded temperatures should at a minimum represent the hottest part of the summer when aquatic life is most sensitive to warmer temperatures. Data loggers should be deployed in the same manner at each location and during each sampling event, and follow a consistent process for calibration and installation. Any modeling that is used should refer to previous modeling efforts (such as the QUAL2K analysis used in this document) for consistency in model development to ensure comparability. In addition, flow measurements should also be conducted using consistent locations and methodology.

8.3.4 Effectiveness Monitoring for Restoration Activities

As restoration activities are implemented, monitoring is valuable to determine if restoration activities are improving water quality, instream flow, and aquatic habitat and communities. Monitoring can help attribute water quality improvements to restoration activities and ensure that restoration activities are functioning effectively. Restoration projects will often require additional maintenance after initial implementation to ensure functionality. It is important to remember that degradation of aquatic resources happens over many decades and that restoration is often also a long-term process. An efficiently executed long-term monitoring effort is an essential component to any restoration effort.

Due to the natural high variability in water quality conditions, trends in water quality are difficult to define and even more difficult to relate directly to restoration or other changes in management. Improvements in water quality or aquatic habitat from restoration activities will most likely be evident in changes in channel cumulative width/depths, improvements in bank stability and riparian habitat, increases in instream flow, and changes in communities and distribution of fish and other bio-indicators. Specific monitoring methods, priorities, and locations will depend heavily on the type of restoration projects implemented, landscape or other natural setting, the land use influences specific to potential monitoring sites, and budget and time constraints.

As restoration activities begin throughout the project area, pre and post monitoring to understand the change that follows implementation will be necessary to track the effectiveness of specific projects. Monitoring activities should be selected such that they directly investigate those subjects that the project is intended to effect, and when possible, linked to targets and allocations in the TMDL.

8.3.5 Watershed Wide Analyses

Recommendations for monitoring in the lower Beaverhead and upper Jefferson Rivers should not be confined to only those streams addressed within this document. The water quality targets presented in this document are applicable to all streams in the watershed, and the absence of a stream from the state’s impaired waters list does not necessarily imply that the stream fully supports all beneficial uses. Furthermore, as conditions change over time and land management changes, consistent data collection methods throughout the watershed will allow resource professionals to identify problems as they occur, and to track improvements over time.

9.0 STAKEHOLDER AND PUBLIC PARTICIPATION

Stakeholder and public involvement is a component of total maximum daily load (TMDL) planning supported by Environmental Protection Agency (EPA) guidelines and required by Montana state law (Montana Code Annotated (MCA) 75-5-703, 75-5-704) which directs Department of Environmental Quality (DEQ) to consult with watershed advisory groups and local conservation districts during the TMDL development process. Technical advisors, stakeholders and interested parties, state and federal agencies, interest groups, and the public were solicited to participate in differing capacities throughout the TMDL development process in the lower Beaverhead and upper Jefferson Rivers.

9.1 PARTICIPANTS AND ROLES

Throughout completion of the lower Beaverhead and upper Jefferson TMDLs, DEQ worked to keep stakeholders apprised of project status and solicited input from a TMDL advisory group. A description of the participants in the development of the TMDLs in the Thompson Project Area and their roles is contained below.

Montana Department of Environmental Quality

Montana state law (MCA 75-5-703) directs DEQ to develop all necessary TMDLs. DEQ has provided resources toward completion of these TMDLs in terms of staff, funding, internal planning, data collection, technical assessments, document development, and stakeholder communication and coordination. DEQ has worked with other state and federal agencies to gather data and conduct technical assessments. DEQ has also partnered with watershed organizations to collect data and coordinate local outreach activities for this project.

United States Environmental Protection Agency

EPA is the federal agency responsible for administering and coordinating requirements of the Clean Water Act (CWA). Section 303(d) of the CWA directs states to develop TMDLs (see **Section 1.1**), and EPA has developed guidance and programs to assist states in that regard. EPA has provided funding and technical assistance to Montana's overall TMDL program and is responsible for final TMDL approval.

Conservation Districts

The lower Beaverhead and upper Jefferson Rivers fall within Beaverhead, Madison, Silverbow, and Jefferson counties. DEQ provided both the Conservation Districts with consultation opportunity during development of TMDLs. This included opportunities to provide comment during the various stages of TMDL development, and an opportunity for participation in the advisory group discussed below.

TMDL Advisory Group

The Beaverhead and Jefferson TMDL Advisory Groups consisted of selected resource professionals who possess a familiarity with water quality issues and processes in the lower Beaverhead and upper Jefferson Rivers, and also representatives of applicable interest groups. All members were solicited to participate in an advisory capacity per Montana state law (75-5-703 and 704). DEQ requested participation from the interest groups defined in MCA 75-5-704 and included municipalities and county representatives; livestock-oriented and farming-oriented agriculture representatives; timber and mining industry representatives; watershed groups; state and federal land management agencies, tribal representatives; and representatives of fishing-related business, recreation, and tourism interests. The advisory groups also include additional stakeholders with an interest in maintaining and improving water quality and riparian resources.

Advisory group involvement was voluntary and the level of involvement was at the discretion of the individual members. Members had the opportunity to provide comment and review of technical TMDL assessments and reports and to attend meetings organized by DEQ for the purpose of soliciting feedback on project planning. Typically, draft documents were released to the advisory group for review under a limited timeframe, and their comments were then compiled and evaluated. Final technical decisions regarding document modifications resided with DEQ.

Communications with the group members was typically conducted through e-mail and draft documents were made available through DEQ's wiki for TMDL projects (http://montanatmdlflathead.pbworks.com). Opportunities for review and comment were provided for participants at varying stages of TMDL development, including opportunity for review of the draft TMDL document prior to the public comment period.

9.2 RESPONSE TO PUBLIC COMMENTS

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 formal public comment period for the Lower Beaverhead River and Upper Jefferson River Temperature TMDLS was initiated on July 9, 2014 and ended on August 7, 2014. DEQ held two public meetings; the first in Dillon, MT on July 15, 2014 and the second in Whitehall on July 17, 2014. At these two meetings, DEQ provided an overview of the TMDLS, made copies of the document available to the public, and solicited public input and comment on the document. The announcement for those meetings was distributed among the Watershed Advisory Groups and advertised in the following newspapers: the Montana Standard, the Dillon Tribune, and the Whitehall Ledger. This section includes DEQ's response to all public comments received during the public comment period.

Formal written comments were received from two organizations. DEQ evaluates all comments and related information to ensure no critical information was excluded from the document. Excerpts of the public comment letters are provided below. The original comment letters are located in the project files at DEQ and may be reviewed upon request. The response prepared by DEQ follows the comment.

9.2.1 Public Comment Letter 1

Comment 1.1:

Summary

The undersigned are pleased to see the breadth and intensity of scientific diligence conducted in drafting the instant TMDLs. Extensive modeling and site-specific data was used to document existing, baseline, and target TMDL project area conditions. On the whole, we agree with and support the science used in modeling and estimating needed reductions in water segment temperatures in order for the Lower Beaverhead and Upper Jefferson to meet their designated and existing uses.

However, we are concerned that the draft TMDLs fail to provide adequate Margins of Safety or Reasonable Assurances that additional, needed reductions will actually be achieved.

Response 1.1:
Thank you for taking the time to review and comment on the Lower Beaverhead River and Upper Jefferson River Temperature TMDLs. We are pleased that you agree with and support the science used in modeling and estimating needed reductions in the Lower Beaverhead and Upper Jefferson Rivers. **Section 4.4** describes reasonable assurance. In regard to how reductions will be achieved, please see response 1.3.

Comment 1.2:
Specific Concerns
On the whole, the two river segments for which Temperature TMDLs have been prepared evidence the need for extensive riparian buffers and land use improvement, as well as the need to improve seasonal flow. In both the Lower Beaverhead and Upper Jefferson, DEQ analyses made clear that, depending on the relevant river segment, riparian improvements may or may not result in significant improvements and conversely, that increases in river flow would almost always result in temperature improvements.

From the 30,000' perspective, we are concerned that the Lower Beaverhead TMDL shows that the allowable temperature standard is being exceeded at 75% of all sites. Apparently only 20% of existing riparian vegetation meets or exceeds needed target levels (and conversely 80% fails to approach necessary targets). Statistical analysis in the TMDL points to the inescapable conclusion that the best manner by which temperature may be decreased in the Lower Beaverhead is via water efficiency/higher flows, where maximum flow increases could result in a maximum benefit of 3% temperature reduction.

Similarly, but even more disturbing, is the data proffered that shows that 99% of the Upper Jefferson is exceeding its target temperature condition. Data there, similar to the Lower Beaverhead, shows that improvements in riparian vegetation will be even less effective in meeting temperature goals (maximum of a .71% reduction for total implementation of riparian BMPs), while water savings BMPs would optimally result in a maximum of a 7.42% reduction in temperature.

On the whole we agree with the science supporting these findings of needed reductions. However, when it comes time to explain how those reductions are realized, DEQ's draft document relies on an inscrutable, mathematically complex and, in a bizarre twist, TMDLs called "example" TMDLs.[4]

Response 1.1:
In respect to your first comment regarding the use of example TMDLs in the document, your footnote alludes to the fact that an equation is the TMDL, which is correct. This is stated in **Section 5.7.1** and shown in **Equation 1** below. The example TMDL provides a load for one point on the river using that specific point's flow and naturally occurring temperature as input to the equation. The load will vary at any given point on the river as flows and temperatures change. Therefore there is not one single, definitive, daily load to provide for the river segment; rather, we provide an example TMDL at a given point on the river using the TMDL equation. In order to avoid confusion to other stakeholders regarding the language of an "example TMDL", clarifying language has been added in the document (see **Sections 5.7.2** and **5.7.3**).

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[4] Anecdotally, we've never encountered a TMDL named an "example" TMDL. Whereas there is no other equation providing Load Allocations, Waste Load Allocations and Margin of Safety in the draft document, we are forced to assume that those equations are in reality the basis by which the DEQ is rationalizing its TMDLs. We encourage DEQ to clarify its nomenclature and confirm that those equations in **Section 5-34** et seq. are indeed the salient, required TMDLs.

An instantaneous load is computed 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 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.

Equation 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

Comment 1.3:

Specific Concerns (cont.)

These TMDLs' load allocations (LAs) and margins of safety (MOS) are respectively huge, and strain credulity as one reads that all improvements relied upon to achieve necessary reductions are voluntary. In fact, the TMDL relies 100% on voluntary efforts to achieve needed reductions, particularly in terms of the only means that the TMDL document shows has the capacity to make a significant improvement in decreasing temperature violations, e.g. increasing flow.

Therein lies our concern: TMDLs with complete reliance on voluntary, future actions to achieve necessary reductions do not possess sufficient reasonable assurances that load reductions will occur to satisfy water quality standards.

While we understand that DEQ is not statutorily given full authority over non point source management, it and other, partner agencies do possess authority to ratchet down certain controls on land uses which the TMDL documents admits directly affect riverine temperature (e.g. grazing, E&S controls, buffers, etc.) Therefore it is incumbent on DEQ to think outside the box and consider what actions it and partner agencies or authorities may take to enforce the intent of the TMDLs. It is unconscionable and, as experience has shown often unrealistic to rely, on nonbinding, unenforceable mandates to achieve water quality mandates.

We strongly encourage the DEQ to revise the Lower Beaverhead/Upper Jefferson Draft TMDL to incorporate some measure of accountability in lieu of the present, completely voluntary approach.

Response 1.3:

Regarding comments on ensuring that riparian and water quantity goals are met instream, the department supports a voluntary program, per State law (75-5-703, MCA), of reasonable land, soil, and water conservation practices to achieve compliance with water quality standards for nonpoint source (NPS) activities for water bodies that are subject to a TMDL. Because local irrigation management and any subsequent flow alterations are not regulated point sources and there are essentially no applicable nonpoint source regulations for these temperature TMDL's[5], they fall under the nonpoint source program and any subsequent water savings by local stakeholders is realized on a voluntary basis.

However, DEQ does provide technical and financial support to local stakeholders to help carry out these best management practices. DEQ recommends a voluntary approach to water savings, as water quality assessments may not divest, impair, or diminish any water right recognized pursuant to Title 85, according to State law (75-5-705, MCA). DEQ encourages and supports the efforts of local watershed groups and conservation districts to develop Watershed Restoration Plans (WRPs) to achieve these objectives. DEQ will implement TMDLs by providing staff support and providing (where possible) Section 319 funding of the Clean Water Act to those local watershed efforts that pursue NPS controls by developing their own WRPs and using adaptive management strategies. Watershed Restoration Plans can be viewed as a locally developed "road map," complete with identified priority areas and/or activities, as well as timelines for achieving milestones.

9.2.2 Public Comment Letter 2

Comment 2.1:

Page 2-2

The map on this page does not include the USGS gage for the Beaverhead at Twin Bridges. This site was added in recent years to better understand inflows from sloughs and springs originating from the Big Hole and Ruby Watersheds.

Response 2.1:

Site was added to **Figure 2-2**, **Table 2-1**, and **Figure 5-2**.

Comment 2.2:

Page 2-2 (cont)

Clarification of whether the TMDL analysis for the Beaverhead River practically evaluates conditions at the mouth (including numerous diffuse water sources from the Ruby and Big Hole) or the Beaverhead upstream of the Ruby and other water sources would help the reader understand the situation more accurately.

Response 2.2:

Table B3-1 in **Appendix B**, *Beaverhead River Temperature Model*, displays locations of sampling sites for flow and temperature on the Beaverhead River, tributaries, and diversions (including several return flows from the Big Hole River). The DEQ agrees that conditions at the lower end of the impaired segment are complex. The model used the existing calibrated data to estimate what is happening at any given point on the river. Therefore, even though an in-depth study was not performed on irrigation and groundwater return flow, the model does use the existing data along the lower stretch of the Beaverhead River along with monitored irrigation return flow to interpret general conditions of the segment, which is appropriate for the scope of the TMDL.

Comment 2.3:

Page 2-4

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[5] DEQ's voluntary approach is in recognition that there are some regulatory requirements for nonpoint sources. For example, the streamside management zone (SMZ) law provides important riparian protection from commercial timber harvest in forested watersheds, although that particular law has little potential impact for the temperature TMDLs within this document.

The draft discusses flow recovery in early fall related to storms and precipitation. We believe it is important to briefly discuss the relative contribution of reduced irrigation demand, and perhaps more importantly, timing of irrigation return flows related to flow recovery in late summer/early fall. Quantitative data is likely insufficient to provide detailed trends, but more discussion of seasonal irrigation returns related to water temperature might be informative.

Response 2.3:
A very general description of late season irrigation return flows was added to **Section 2.1.2**.

Comment 2.4:
Page 2-5
Impoundments. Although a basic description of impoundments was provided, management of impoundments offer a significant opportunity to influence streamflow and water temperature in a watershed. Two examples of impoundment management to address flow and temperature issues are Painted Rocks Reservoir on the Bitterroot River and Hebgen Lake on the Madison River. For example, Painted Rocks water was purchased for flow and temperature enhancement and pulsed releases from Hebgen are used to reduce water temperature in the lower Madison River. In addition, contrasting Ruby Reservoir management with operation of Clark Canyon Reservoir may offer future management examples that may help improve summer flow and temperature issues.

Response 2.4:
The DEQ agrees that reservoir management in conjunction with irrigation management from water users may help improve summer flow and temperature issues, and has outlined this as a suggestion for meeting targets in **Section 5.4.2.3** and as part of the temperature restoration approach in implementation in **Section 7.4.1**.

Comment 2.5:
Section 5.2.1
Fish Species information is provided, but some detailed reports may also be good references to include in this document. For example, FWP’s instream flow recommendation document contains detailed information for recommending desirable streamflow using the wetted perimeter methodology in the Beaverhead and Jefferson Rivers. In addition, an evaluation of fish/streamflow relationships for the Jefferson River is available in a 2008 report. A Jefferson River invertebrate study conducted in 1979 and repeated in recent years provides information related to water temperature and streamflow effects on the aquatic invertebrate community. We believe these types of data have potential to make the TMDL document more effective and we would be happy to provide this information to you.

Response 2.5:
These references were added into **Section 5.2.1** and the 2008 report was added as an attachment to the TMDL.

Comment 2.6:
Page 5-32
The table showing maximum temperature of the Ruby, Beaverhead and Big Hole has the potential to be misleading. Beaverhead at mouth presumably includes a variety of inflows from sloughs and springs below the Ruby River, which could give the impression that the Beaverhead has cooler water than the Big Hole. Comparing the Beaverhead above the Ruby to the Big Hole probably provides a more accurate assessment of thermal sources for the upper Jefferson River. Understanding these sources accurately

may be important for identifying future remedies. Table B6-1 shows maximum water temperature of the lower Beaverhead near Giem's in 2005 at 77 F (above the Ruby River and Big Hole Sloughs) and maximum temperature of 73 F at the Madison County Fairgrounds. Hence, significant cooling apparently occurs due to inflows to the lower Beaverhead River.

Response 2.6:
The temperatures displayed in **Table 5-7** are the conditions as they come into the Jefferson River, which are the appropriate conditions to input into the model. Temperatures will vary throughout the river, depending on inflows, outflows, changes in riparian vegetation, etc. No changes were made to the table, but a note was added to emphasize that temperature in the Beaverhead River at the mouth is reduced because of added flow from the Ruby River and Big Hole sloughs.

Comment 2.7:
<u>Page 6-2</u>
Low Flow Alteration. The document states that TMDL's cannot impact water rights, but identification of low flow alterations as a probable source of impairment does not violate state or federal regulations. At least for the Jefferson River, we agree that identifying low flow alteration as a source of elevated water temperature is appropriate. For example, the Jefferson River at Twin Bridges USGS gage exceeds 73 F (daily maximum) frequently during drought years, and only occasionally during years with more normal flow conditions. Daily maximum water temperature at Twin Bridges Gage only exceeded 73 F a total of seven days in the five years from 1995 to 1999. During the severe drought of 2000 to 2007, 73 F daily maximum was exceeded between 7 and 30 days per year.

Your recommendation to encourage a 15% voluntary reduction of withdrawals during periods of water shortage might be a positive step to improve water temperature, but potentially including the concept of seasonal flow objectives might be a better method to attempt to manage flows in the system. For example, 4 major canals in the Jefferson have voluntarily reduced diversion of water by over 15% during several years of drought plan implementation, but these efforts can be negated by changes with upstream water sources. Flow is often less than 300 cfs at Twin Bridges, and withdrawals from major canals between Twin Bridges and Waterloo is often near 300 cfs. A 15% reduction of withdrawals (45 cfs) is common during drought years due to difficulty diverting water and due to attempts to maintain a target flow of 50 cfs at Waterloo.

And finally regarding low flow alterations, your data clearly shows water temperature recovery in areas with groundwater recharge (especially in the area downstream of Parson's Bridge). Groundwater protection may be one of the most effective measures to attempt to avoid complete dewatering and to provide thermal refuge for aquatic life throughout the Jefferson River TMDL reach.

Response 2.7:
The 15% voluntary reduction is a starting point with which to run scenarios in the model. Additional savings may be possible through flow management (in all years, not just drought years), especially with seasonal flow objectives. However, performing a detailed study on possible water savings with seasonal management objectives was outside of the scope of this TMDL document. This suggestion however was put into **Section 7.4.1**, as part of the temperature restoration approach. Language regarding groundwater protection was added to **Section 6.2**.

Comment 2.8:
<u>Page 7-3</u>

The document states that water conservation measures may be the best means to reduce water temperature. We agree this is important, but other water management actions might also be included in this discussion such as: reservoir operation, groundwater protection, and tributary flow enhancement. Identification of water sources with relatively high water temperature could also result in developing a prioritized project list of inflows that elevate water temperature. We agree with your statement that increased shade and recovery of channel morphology can provide positive effects for cooling water temperature. We believe this is important for both the mainstem rivers and associated tributaries.

Response 2.8:
These additional management actions were added to the discussion in **Section 7.4.1**.

Comment 2.9
We appreciate the extensive effort needed to develop this TMDL. Water temperature in the Upper Missouri Basin plays a critical role for maintaining high quality fisheries and for preventing the need for frequent fishing closures during periods of high temperature, which reduces angling opportunity.

Response 2.9
Thank you for taking the time to review the document.

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APPENDIX A - REGULATORY FRAMEWORK AND REFERENCE CONDITION APPROACH

This appendix presents details about applicable Montana Water Quality Standards (WQS) and the general and statistical methods used for development of reference conditions.

TABLE OF CONTENTS

LIST OF TABLES

ACRONYMS

Acronym	Definition
ARM	Administrative Rules of Montana
BER	Board of Environmental Review (Montana)
CFR	Code of Federal Regulations
CWA	Clean Water Act
DEQ	Department of Environmental Quality (Montana)
EPA	Environmental Protection Agency (US)
HHC	Human Health Criteria
MCA	Montana Codes Annotated
MCL	Maximum Contaminant Level
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TPA	TMDL Planning Area
TSS	Total Suspended Solids
UAA	Use Attainability Analysis
WQA	Water Quality Act
WQS	Water Quality Standards

A1.0 TMDL DEVELOPMENT REQUIREMENTS

Section 303(d) of the federal Clean Water Act (CWA) and the Montana Water Quality Act (WQA) (Section 75-5-703) requires development of TMDLs for impaired waterbodies that do not meet Montana WQS. Although waterbodies can become impaired from pollution (e.g. low flow alterations and habitat degradation) and pollutants (e.g. nutrients, sediment, metals, pathogens, and temperature), the CWA and Montana state law (75-5-703) require TMDL development only for impaired waters with pollutant causes. Section 303(d) also requires states to submit a list of impaired waterbodies to the U.S. Environmental Protection Agency (EPA) every two years. Prior to 2004, EPA and DEQ referred to this list simply as the 303(d) list.

Since 2004, EPA has requested that states combine the 303(d) list with the 305(b) report containing an assessment of Montana’s water quality and its water quality programs. EPA refers to this new combined 303(d)/305(b) report as the Integrated Water Quality Report. The 303(d) list also includes identification of the probable cause(s) of the water quality impairment (e.g. pollutants such as metals, nutrients, sediment, pathogens or temperature), and the suspected source(s) of the pollutants of concern (e.g. various land use activities). State law (MCA 75-5-702) identifies that a sufficient credible data methodology for determining the impairment status of each waterbody is used for consistency. The impairment status determination methodology is identified in DEQ’s Water Quality Assessment Process and Methods found in Attachment 1 of Montana’s Water Quality Integrated Report (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2012).

Under Montana state law, an "impaired waterbody" is defined as a waterbody or stream segment for which sufficient credible data show that the waterbody or stream segment is failing to achieve compliance with applicable WQS (Montana Water Quality Act; Section 75-5-103(11)). A “threatened waterbody” is defined as a waterbody or stream segment for which sufficient credible data and calculated increases in loads show that the waterbody or stream segment is fully supporting its designated uses, but threatened for a particular designated use because of either (a) proposed sources that are not subject to pollution prevention or control actions required by a discharge permit, the nondegradation provisions, or reasonable land, soil, and water conservation practices or (b) documented adverse pollution trends (Montana WQA; Section 75-5-103(31)). State law and Section 303(d) of the CWA require states to develop all necessary TMDLs for impaired or threatened waterbodies. Neither of the waterbodies being addressed within the scope of this document are listed as threatened.

A TMDL is a pollutant budget for a waterbody identifying the maximum amount of the pollutant that a waterbody can assimilate without causing applicable WQS to be exceeded (violated). TMDLs are often expressed in terms of an amount, or load, of a particular pollutant (expressed in units of mass per time such as pounds per day). TMDLs must account for loads/impacts from point and nonpoint sources in addition to natural background sources and must incorporate a margin of safety and consider influences of seasonality on analysis and compliance with WQS. **Section 4.0** of the main document provides a description of the components of a TMDL.

To satisfy the federal CWA and Montana state law, TMDLs are developed for each waterbody-pollutant combination identified on Montana’s 303(d) list of impaired or threatened waters, and are often presented within the context of a water quality restoration or protection plan. State law (Administrative

Rules of Montana 75-5-703(8)) also directs Montana DEQ to "…support a voluntary program of reasonable land, soil, and water conservation practices to achieve compliance with water quality standards for nonpoint source activities for waterbodies that are subject to a TMDL…" This is an important directive that is reflected in the overall TMDL development and implementation strategy within this plan. It is important to note that water quality protection measures are not considered voluntary where such measures are already a requirement under existing federal, state, or local regulations.

A2.0 APPLICABLE WATER QUALITY STANDARDS

WQS include the uses designated for a waterbody, the legally enforceable standards that ensure that the uses are supported, and a nondegradation policy that protects the high quality of a waterbody. The ultimate goal of this TMDL document, once implemented, is to ensure that all designated beneficial uses are fully supported and all water quality standards are met. Water quality standards form the basis for the targets described in **Section 5.0**. Temperature is the pollutant addressed in this framework water quality improvement plan. This section provides a summary of the applicable water quality standard for temperature.

A2.1 CLASSIFICATION AND BENEFICIAL USES

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

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

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

Descriptions of Montana's surface water classifications and designated beneficial uses are presented in **Table A2-1**. In 2003, Montana added four classes: D, E, F, and G. These classes include ephemeral streams (E-1 and E-2), ditches (D-1 and D-2), seasonal or semi-permanent lakes and ponds (E-3, E-4, E-5) and waters with low or sporadic flow (F-1). The lower Beaverhead and upper Jefferson Rivers are classified as B-1.

Table A2-1. Montana Surface Water Classifications and Designated Beneficial Uses

Classification	Designated Uses
A-CLOSED:	Waters classified A-Closed are to be maintained suitable for drinking, culinary and food processing purposes after simple disinfection.
A-1:	Waters classified A-1 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment for removal of naturally present impurities.
B-1:	Waters classified B-1 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
B-2:	Waters classified B-2 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
B-3:	Waters classified B-3 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
C-1:	Waters classified C-1 are to be maintained suitable for bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
C-2:	Waters classified C-2 are to be maintained suitable for bathing, swimming and recreation; growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
C-3:	Waters classified C-3 are to be maintained suitable for bathing, swimming and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl and furbearers. The quality of these waters is naturally marginal for drinking, culinary and food processing purposes, agriculture and industrial water supply.
I:	The goal of the State of Montana is to have these waters fully support the following uses: drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
D-1:	Waters classified D-1 are to be maintained suitable for agricultural purposes and secondary contact recreation.
D-2:	Waters classified D-2 are to be maintained suitable for agricultural purposes and secondary contact recreation. Because of conditions resulting from low flow regulations, maintenance of the ditch, or geomorphologic and riparian habitat conditions, quality is marginally suitable for aquatic life.
E-1:	Waters classified E-1 are to be maintained suitable for agricultural purposes, secondary contact recreation, and wildlife.
E-2:	Waters classified E-2 are to be maintained suitable for agricultural purposes, secondary contact recreation, and wildlife. Because of habitat, low flow, hydro-geomorphic, and other physical conditions, waters are marginally suitable for aquatic life.
E-3:	Waters classified E-3 are to be maintained suitable for agricultural purposes, secondary contact recreation, and wildlife.

Table A2-1. Montana Surface Water Classifications and Designated Beneficial Uses

Classification	Designated Uses
E-4:	Waters classified E-4 are to be maintained suitable for aquatic life, agricultural purposes, secondary contact recreation, and wildlife.
E-5:	Waters classified E-5 are to be maintained suitable for agricultural purposes, secondary contact recreation, saline-tolerant aquatic life, and wildlife.
F-1:	Waters classified F-1 are to be maintained suitable for secondary contact recreation, wildlife, and aquatic life, not including fish.
G-1:	Waters classified G-1 are to be maintained suitable for watering wildlife and livestock; aquatic life, not including fish; secondary contact recreation; marginally suitable for irrigation after treatment or with mitigation measures.

A2.2 STANDARDS

In addition to the use classifications described above, Montana's WQS include numeric and narrative criteria as well as a nondegradation policy.

Numeric Standards

Numeric surface water quality standards have been developed for many parameters to protect human health and aquatic life. These standards are in the Department Circular DEQ-7 (Montana Department of Environmental Quality, 2012) . The numeric human health standards have been developed for parameters determined to be toxic, carcinogenic, or harmful and have been established at levels to be protective of long-term (i.e., lifelong) exposures as well as through direct contact such as swimming.

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

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

Narrative Standards

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

The narrative standard is applicable to the lower Beaverhead and upper Jefferson River's temperature listings. In addition to the standards below, the beneficial-use support standard for B-1 streams, as defined above, can apply to other conditions, often linked to pollution, limiting aquatic life. These other conditions can include effects from dewatering/flow alterations and effects from habitat modifications.

A2.3 Temperature Standards

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

For waters classified as B-1; from Rule 17.30.622(e) and 17.30.623(e):
A 1^{o} F maximum increase above naturally occurring water temperature is allowed within the range 32^{o} F to 66^{o} F; within the naturally occurring range of 66^{o} F to 66.5^{o} F, no discharge is allowed which will cause the water temperature to exceed 67^{o} F; and where the naturally occurring water temperature is 66.5^{o} F or greater, the maximum allowable increase in water temperature is 0.5^{o} F. A 2^{o} F per-hour maximum decrease below naturally occurring water temperature is above 55^{o} F. A 2^{o} F maximum decrease below naturally occurring water temperature is allowed within the range of 55^{o} F to 32^{o} F.

A3.0 REFERENCE CONDITIONS AS DEFINED IN DEQ'S STANDARD OPERATING PROCEDURE FOR WATER QUALITY ASSESSMENT

DEQ uses the reference condition to evaluate compliance with many of the narrative WQS. The term "reference condition" is defined as the condition of a waterbody capable of supporting its present and future beneficial uses when all reasonable land, soil, and water conservation practices have been applied. In other words, reference condition reflects a waterbodies greatest potential for water quality given historic land use activities.

DEQ applies the reference condition approach for making beneficial use-support determinations for certain pollutants (such as temperature) that have specific narrative standards. Also, Montana WQS do not contain specific provisions addressing detrimental modifications of habitat or flow. However, these factors are known to adversely affect beneficial uses under certain conditions or combination of conditions. The reference conditions approach is used to determine if beneficial uses are supported when flow or habitat modifications are present.

Waterbodies used to determine reference condition are not necessarily pristine or perfectly suited to giving the best possible support to all possible beneficial uses. Reference condition also does not reflect an effort to turn the clock back to conditions that may have existed before human settlement, but is intended to accommodate natural variations in biological communities, water chemistry, etc. due to climate, bedrock, soils, hydrology, and other natural physiochemical differences. The intention is to differentiate between natural conditions and widespread or significant alterations of biology, chemistry, or hydrogeomorphology due to human activity. Therefore, reference conditions should reflect minimum impacts from human activities. It attempts to identify the potential condition that could be attained (given historical land use) by the application of reasonable land, soil, and water conservation practices. DEQ realizes that pre-settlement water quality conditions usually are not attainable.

The following methods may be used to determine reference conditions:

Primary Approach

- Comparing conditions in a waterbody to baseline data from minimally impaired waterbodies that are in a nearby watershed or in the same region having similar geology, hydrology, morphology, and/or riparian habitat.
- Evaluating historical data relating to condition of the waterbody in the past.
- Comparing conditions in a waterbody to conditions in another portion of the same waterbody, such as an unimpaired segment of the same stream.

Secondary Approach

- Reviewing literature (e.g. a review of studies of fish populations, etc., that were conducted on similar waterbodies that are least impaired).
- Seeking expert opinion (e.g. expert opinion from a regional fisheries biologist who has a good understanding of the waterbody's fisheries health or potential).
- Applying quantitative modeling (e.g. applying sediment transport models to determine how much sediment is entering a stream based on land use information, etc.).

DEQ uses the primary approach for determining reference condition if adequate regional reference data are available and uses the secondary approach to estimate reference condition when there is no regional data. DEQ often uses more than one approach to determine reference condition, especially when regional reference condition data are sparse or nonexistent.

A4.0 REFERENCES

Montana Department of Environmental Quality. 2012. Circular DEQ-7: Montana Numeric Water Quality Standards. Helena, MT: Montana Department of Environmental Quality. http://deq.mt.gov/wqinfo/Circulars.mcpx. Accessed 1/15/2013.

Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau. 2012. Montana 2012 Final Water Quality Integrated Report. Helena, MT: Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau. WQPBIMTSR-004f.

APPENDIX B – BEAVERHEAD RIVER TEMPERATURE MODEL

ABSTRACT

The enhanced river water quality model QUAL2K was applied to the Beaverhead River in southwestern Montana by the Montana Department of Environmental Quality (DEQ) to evaluate stream temperature improvement scenarios for a 66 mile reach extending from Barretts to Twin Bridges, MT as part of the temperature Total Maximum Daily Load (TMDL) investigation for the river. Heat transfer principles were used to evaluate a number of scenarios and their effect on diurnal water temperature. A companion model, Shadev3.0.xls was used to evaluate shade. Existing data were used for model development including climatic information from the National Weather Service (NWS) and Bureau of Reclamation AgriMet program, streamflow and temperature data from Montana State University (collected for the Bureau of Reclamation), data from the U.S. Geological Survey, and associated field measurements made by DEQ during 2009. Models were calibrated relatively successfully with mean relative error of 0.01% and root mean squared error of 0.9°F. Following calibration we employed scenario analysis to determine feasible management strategies for the river. We evaluated the following: (1) the effect of riparian vegetation and shading improvement along the stream corridor, (2) morphological changes to the river's width depth ratio, (3) irrigation efficiency improvement and maintenance projects, and (4) natural and naturally occurring conditions. Based on our evaluation, we determined that the Beaverhead River is impaired for water temperature due to a number of reasons, most notably, the cumulative effect of irrigation dewatering and shade removal. Overall, the river is 3.7°F warmer than naturally occurring with the most significant effect being irrigation. Consequently, we recommend that irrigation efficiency be considered as the highest priority for any management plan to meet the state water temperature standard. Other best management practices that should be considered in conjunction with these activities include riparian enhancement (tree planting). The study was commissioned by DEQ as part of our statewide watershed planning work.

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ACRONYMS

Acronym	**Definition**
ARM	Administrative Rules of Montana
ASOS	Automated surface observing Station
BLM	Bureau of Land Management (federal)
BOR	Bureau of Reclamation
CC	Clark Canyon Dam
CCWC	Canyon Canal Water Company
DEQ	Department of Environmental Quality (Montana)
DNRC	Department of Natural Resources & Conservation
EBID	East Bench Irrigation District
EPA	Environmental Protection Agency (US)
FWP	Fish, Wildlife, and Parks
FWS	Fish & Wildlife Service (US)
GWIC	Groundwater Information Center
HUC	Hydrologic Unit Code
MBMG	Montana Bureau of Mines and Geology
MCA	Montana Codes Annotated
MPDES	Montana Pollutant Discharge Elimination System
MSU	Montana State University
NAIP	National Agriculture Imagery Program
NOAA	National Oceanic and Atmospheric Administration
NSDZ	Near Stream Disturbance Zone
NWS	National Weather Service
QA	Quality Assurance
RE	Relative Error
RMSE	Root Mean Squared Error
TMDL	Total Maximum Daily Load
TPA	TMDL Planning Area
USGS	United States Geological Survey
WWTP	Wastewater Treatment Plant

B1.0 BACKGROUND

The river water quality model QUAL2K was applied to the Beaverhead River in southwestern Montana to evaluate stream temperature improvement scenarios for a 66.3 mile reach between Barretts and Twin Bridges, MT. Models were constructed to ascertain the relationship between flow, riparian conditions, river management, and instream water temperature as part of the TMDL. Information on the project background, modeling results, and scenario analyses are contained within the rest of the document.

B1.1 PRIOR STUDIES

Prior investigations into water temperature on the Beaverhead River have suggested that it is impaired for a number of reasons. For example numerous times the river has been greater than 21.1°C (70°F), and twice it has exceeded 25°C (78 and 79°F) (CDM Federal Programs Corporation et al., 2003). Such values are near the upper limit for most salmonid species and are of concern. To compound the issue, the river is dewatered (Montana Department of Fish, Wildlife and Parks, Fisheries Division, 2003). Sections with problems include:

- The upper Beaverhead River, which is periodically dewatered from the Clark Canyon Dam to the West Side Canal (21 miles).
- The lower Beaverhead River, which is chronically dewatered from the West Side Canal to the Big Hole River (39 miles).

In addition to the previous assertions, vegetation losses from the riparian corridor and dam operation have all been speculated as other possible causes of impairment (CDM Federal Programs Corporation et al., 2003). None have ever been validated quantifiably however. As a result, modeling was commissioned by DEQ to identify whether feasible irrigation efficiency improvement or maintenance projects or riparian vegetation or channel morphology improvements as part of the TMDL would have a significant influence on water temperature. We subsequently will use that information to identify management practices, if any, are of merit in meeting the Montana stream temperature standard (ARM 17.30.623(2)(e), 2006).

B1.2 MONTANA'S TEMPERATURE STANDARD (ARM 17.30.623)

Water quality impairment in Montana is currently arbitrated according to the state water temperature standard (ARM 17.30.623(2)(e), 2006). For B-1 waters (which the Beaverhead River is) a maximum allowable increase of 1°F over "naturally occurring" is acceptable when natural temperatures are within the range of 32°F to 66°F. If temperatures are 66.5°F or greater, a 0.5°F increase is allowed (ARM 17.30.623(2)(e), 2006). Hence certain increases are allowed, but with limitations. The standard was originally developed to address point source discharges therefore it is difficult to interpret for nonpoint sources. To fully evaluate its requirements, DEQ must first characterize the departure from "naturally occurring" (which reflects the implementation of "all reasonable soil and water conservation practices") (per ARM 17.30.602) and then recommend best management practices (BMPs) to mitigate the impairment. Modeling is one of the most effective ways to make this determination. Consequently, this document and project were conceptualized to link water temperature with reasonable management conditions along the river corridor).

B1.3 THE EFFECTS OF MANAGEMENT ON WATER TEMPERATURE

It has been well established that river management has an effect on water temperature (LeBlanc et al., 1997; Meier et al., 2003; Poole and Berman, 2001; Rutherford et al., 1997). For example, healthy riparian areas absorb incoming solar shortwave radiation, reflect longwave radiation, and influence microclimate (i.e., air temperature, humidity, and wind speed). Added streamflow volume (i.e., flow rate) increases the temperature buffering capacity of a waterbody via thermal inertia or assimilative heat capacity. Channel morphology is critical for maintenance of hyporheic flow and minimizes solar gain.

These variables that are influenced by river management are important in assessing stream health and associated effects on fish and aquatic life. Critical limits and temperature tolerances for fluvial inhabitants are an effective way to characterize waterbody condition. Temperature tolerances for fish species present in the Beaverhead River are summarized in **Table 1-1.** Temperatures slightly over 70°F are lethal for 10 percent of the salmonid population (LC_{10}) in an exposure lasting 24 hours[1]. Optimum ranges are nearer 60°. Thus given our knowledge about the Beaverhead River, there are potentially impacts to most of the trout species.

Table B1-1. General trout temperature tolerances

From DEQ 2011 (R. McNeil, personal communication).

Species	Optimum Range (°F)	LC_{10} for 24 hours (°F)
Brown trout (adult)	57	75
Rainbow trout (adult)	57	80
Brook trout (adult)	60	77
Cutthroat trout (adult)	56	71

B1.4 RESERVOIR INFLUENCE

The Beaverhead River is also reservoir regulated therefore the operation of upstream storage facilities is a consideration. Clark Canyon Reservoir is at the uppermost end of the project reach and provides nearly all flow in the river. According to Smith (1973), this is a net benefit as the reservoir buffers diurnal temperatures and provides stable cool hypolimnetic water. It also provides flow beyond what may naturally be available. As a result, temperature downstream of the reservoir is significantly better (i.e., cooler and less diurnal flux) than a non-regulated system of similar size. A second consideration is Lima Reservoir (much further upstream) which also partially regulates flow in the Red Rock River, a tributary to Clark Canyon Reservoir. It is less important given its storage volume and proximity to the study area. Consequently, there are further considerations in regard to water temperature management in the Beaverhead River than those stated in previous sections.

B2.0 STUDY AREA DESCRIPTION

The Beaverhead River is located in Beaverhead and Madison counties in southwestern Montana (**Figure B2-1**). The river flows out of Clark Canyon Dam northeasterly for approximately 80 miles past the towns of Dillon and Twin Bridges, MT until ultimately confluencing with the Big Hole River near Twin Bridges.

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[1] It should be noted that coldwater fish species have varied temperature requirements that are dependent on life stage. **Table 1-1** should only be used as a rough guide.

The temperature impairment extends from Grasshopper Creek to the Big Hole River (segment ID MT41B001_020) and is 62.7 miles long (Montana Department of Environmental Quality, 2011). The entire area is part of United States Geological Survey (USGS) Hydrologic Unit Code (HUC) 10020002. **Note:** the 62.7 miles referenced above is a different length than used in model development (as detailed in later sections).

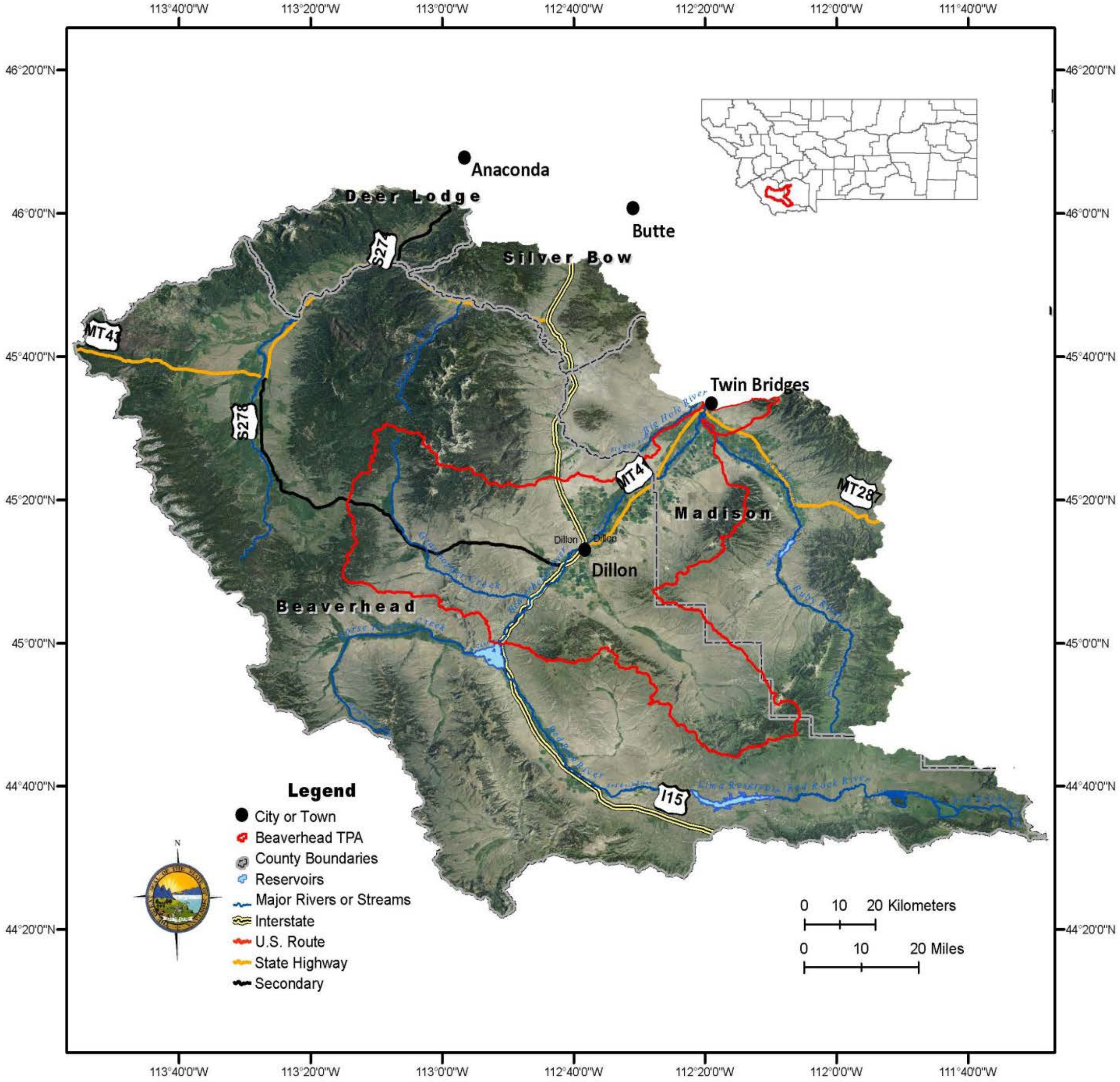

Figure B2-1. Beaverhead River vicinity map showing TPA boundary and associated features

The area being modeled extends from the USGS gage at Barretts (USGS 06016000) to the Highway 41 Bridge near Twin Bridges (Madison County Fairgrounds). This encompasses the available field data. The impairment actually extends slightly upstream to Grasshopper Creek. The study area is most easily accessed via Interstate-15 between Idaho Falls, ID and Dillon, MT, and on Montana Highway 41 between

Dillon and Twin Bridges (**Figure B2-2**). Monitoring sites and USGS gages are also shown and are referenced in future sections.

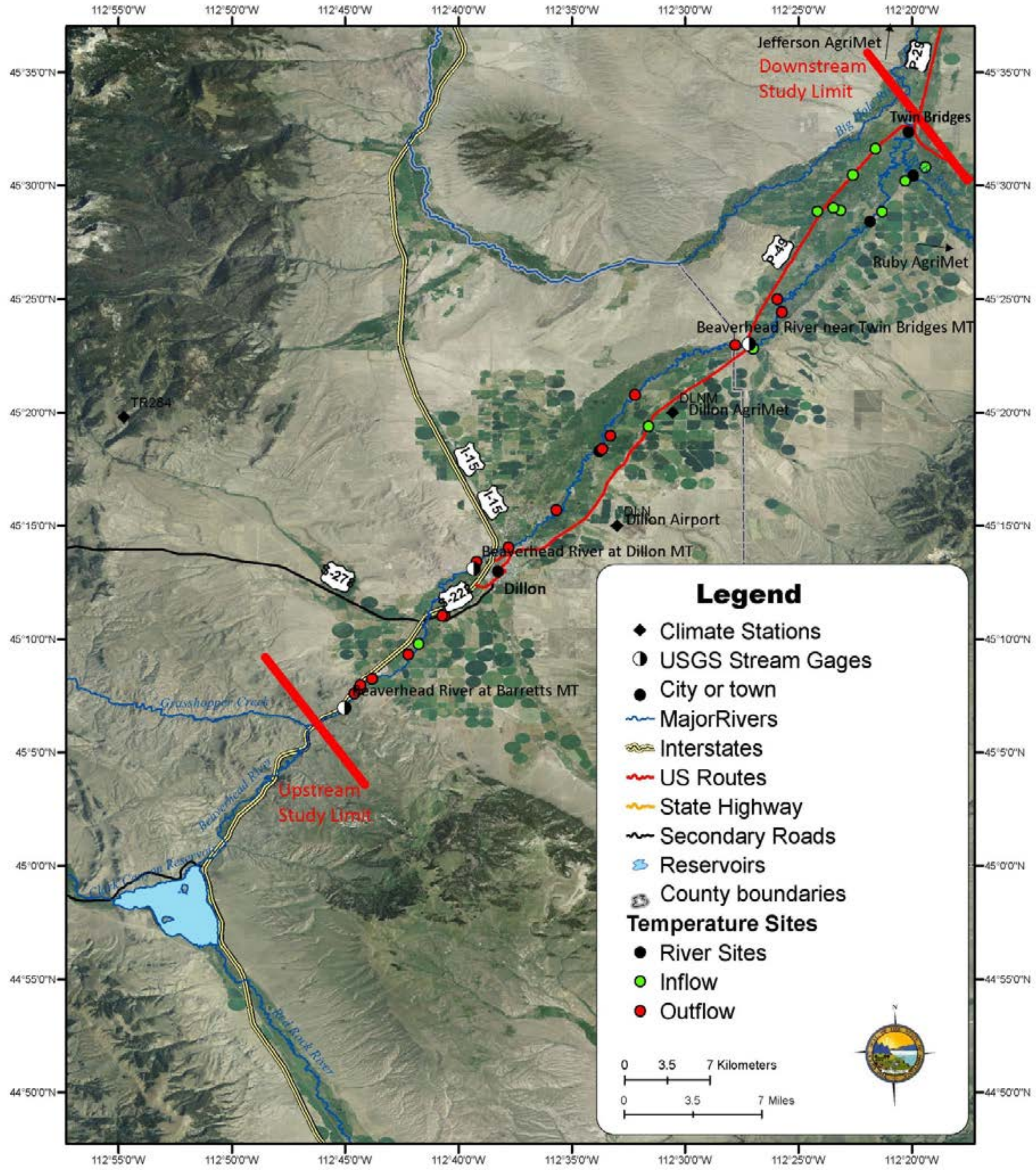

Figure B2-2. Beaverhead River detailed study reach

B2.1 CLIMATE

Climate of the Beaverhead River is inter-continental. Located on the eastern side of the continental divide, it is influenced by relatively dry cells pushed inland by prevailing westerly to northwesterly winds. Systems of low-pressure are most prevalent during the winter months and produce both rain and snow. Pacific highs influence the summer climate and cause long periods of warm and dry weather. Automated surface observing Station (ASOS) number 242404 is most proximal to the project reach and provides a suitable characterization of long-term climate (Dillon Airport, period of record of 1948-2005). According to site records (Western Regional Climate Center, 2006), July and early August are the most probable time-period when river impairment would occur. Air temperatures approach 80-85°F and coincide with a relatively dry period in the basin (**Figure B2-3**, left).

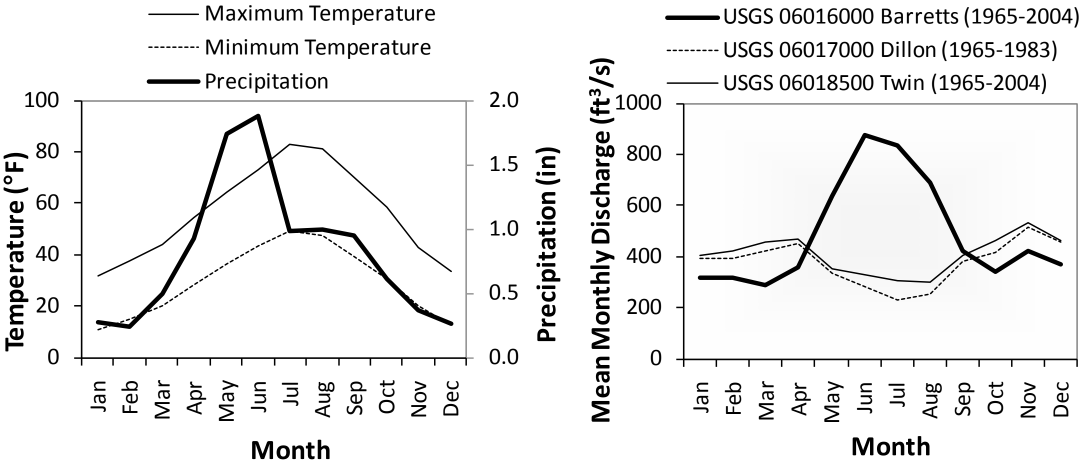

Figure B2-3. Beaverhead River climate and streamflow summary
(Left panel). Monthly temperature and precipitation for the Dillon airport. (Right panel) Mean monthly discharge for gages in the project site. Both climate station and gage locations are shown in **Figure B2-2**.

B2.2 STREAMFLOW

Streamflow in the watershed originates primarily from snowmelt out of the Tendoy and Centennial mountain ranges to the south and east and from the Beaverhead Mountains to west. Precipitation concentrates in these locations to form both major inflows to Clark Canyon Reservoir (Red Rock River and Horse Prairie Creek). Hydrology downstream of the reservoir is entirely regulated. From October to March, water is stored for the upcoming irrigation season. Conservation pool releases then occur from April through September to meet irrigation demands.

The U.S. Geological Survey (USGS) operates three gages on Beaverhead River (**Figure B2-3**, right panel). These include: (1) USGS 06016000 Beaverhead River at Barretts MT (upstream of all major diversions), (2) USGS 06017000 Beaverhead River at Dillon MT, and (3) USGS 06018500 Beaverhead River near Twin Bridges MT. The hydrograph at all locations is influenced by irrigation. Annual streamflow in the upper watershed has a pronounced yet shifted hydrograph peak of about 800 ft^3/s in July (during the irrigation season due to storage releases) whereas streamflow in the lower river shows an inverted hydrograph from cumulative diversions (flows between 200 and 500 ft^3/s). Minimum discharges usually occur during late summer months and often result in late-season shortages of irrigation water.

B2.3 GROUNDWATER

Groundwater is abundant in the project area and potentiometric surface maps indicate the flow path is generally from the uplands towards the floodplains, and then northeast along the Beaverhead River (Uthman and Beck, 1998). The uppermost tertiary aquifer is believed to have the most interaction with the river resulting in both gaining and losing reaches. Near Dillon, the river is thought to be gaining.

Groundwater accretion comprises a large part of this baseflow. The upper reaches are characterized as losing (Uthman and Beck, 1998).

Historical hydrogeologic data suggest groundwater resources in the basin are stable. The construction of Clark Canyon Dam (CC) caused the water table in the vicinity of the East Bench irrigation canal to rise as much as 100 feet [Botz 1967 as cited in Uthman and Beck (1998)], however, groundwater elevations are now seasonally stable. In some places, drain tiles have been installed to help route groundwater. Changes are related to artificial recharge from the dam and leakage through the canals, and further detail on the hydrogeology of the project site is found in Uthman and Beck (1998).

B2.4 IRRIGATION AND LAND USE

Land use in the Beaverhead River valley is primarily irrigated agriculture. Crops consist of alfalfa and grass hay (U.S. Department of Agriculture, 2011) and production consists of 2 or 3 cuttings per year which are then either sold as hay or are used to winter cattle. Water for irrigation is provided by two main companies; the East Bench Irrigation District (EBID) whose major diversion is located approximately three miles below Grasshopper Creek at Barretts (eleven miles below Clark Canyon Reservoir), and the Clark Canyon Water Supply Company which is on the west side of the river and consists of a number of smaller ditch companies or private irrigation shareholders. In total, each unit provides full irrigation service to 28,055 and 33,706 acres respectively (U.S. Department of the Interior, Bureau of Reclamation, 2006a).

About 46 percent of the watershed is under private ownership. Another 39 percent is under federal management, and 15 percent is stewarded by the state (including FWP managed lands and surface waters) (CDM Federal Programs Corporation et al., 2003). Most of the federal lands are in the higher elevations whereas the lower elevations are mostly private (with some BLM and State Trust Lands). The condition of these areas is highly variable. Riparian corridors vary from healthy native vegetation stands in some instances to severely impacted locations elsewhere. In most places, willow and aspen communities were historically present, but have been removed through human activity (BLM, 2003 as cited in CDM et al., (2003)).

B2.5 FISH AND AQUATIC LIFE

Despite being one of the better fisheries in the state, the Beaverhead River has declined over the years. The upper and mid-river has suffered from reductions in fish populations for nearly a decade as a result of persistent drought (R. Oswald, personal communication as cited in CDM et al., (2003)). Conditions have not improved much until recently. Limited releases from Clark Canyon Reservoir during the winters of 2002-2003 (<27 ft^3/s) were mostly to blame. These depressed trout populations through reductions in wetted stream perimeter, feeding habitat, macroinvertebrate prey food, spawning sites, and protective woody debris (R. Oswald, personal communication as cited in CDM et al., (2003)). The size, health, and vigor of the trout population in the Beaverhead River was cumulatively affected.

The lower river (Anderson Lane, Mule Shoe, and Twin Bridges sections, downstream of Dillon) has suffered from low fish densities for a long time (since the 1970s). This is believed to be related to a variety of habitat problems including altered flow regimes, heavy bedload transport, channel atrophy, excessively high summer temperatures, and bank instability from a lack of woody riparian vegetation (Oswald (2000) and Oswald and Brammer (1993) as cited in CDM et al., (2003)). The lower river is in poor condition subsequently, and will likely benefit from a temperature TMDL.

B3.0 DATA SUMMARY

A data summary has been prepared to overview some of the information collected by other agencies in support of the modeling. Most of the review is focused on the data collected by Montana State University (MSU) (Sessoms and Bauder, 2005) for Bureau of Reclamation (BOR) water contract renegotiations. These were the primary data used in the model development. Since some of this data happened to be an indirect measure (i.e., the dataloggers just happened to record temperature), a short section is provided here to ensure that the data is valid for TMDL planning purposes.

B3.1 OVERVIEW

Thirty-four discharge and temperature monitoring stations were established in 2005 as part of the Bureau of Reclamation (BOR) water balance effort (Sessoms and Bauder, 2005). Monitoring instrumentation was Tru-track WT-VO capacitance meters which are voltage output water height probes that log both water height and temperature. Stage is measured with a temperature corrected accuracy of ±1%, and water temperatures are measured within ±0.5°F. Thus the absolute accuracy of these instruments is 2% and 1.0°F respectively. Each logger was housed in a stilling well and logged at one-hour intervals.

Flow measurements were made with Marsh-McBirney Model 2000 Flo-Mate portable flow meters to rate the gaging sites. Discharges were correlated with Tru-track stage heights to establish site rating curves and were visited approximately once per month from April 4 to October 24. Standard operating procedures were used in the collection of the data as outlined in the “Water Measurement Manual” (U.S. Department of the Interior, Bureau of Reclamation, 2001) or USGS Water Supply Paper 2175 Measurement and Computation of Streamflow (Rantz, 1982)[2]. EBID uses flumes for their discharge measurements, which according to Sessoms and Bauder (2005) are sufficiently accurate for use as well.

The flow measurement and temperature monitoring locations used in this study are identified in **Table B3-1**. From **Figure B2-2** it is apparent that many sites are not located directly on the main river, but are on its periphery (i.e., the easiest locations to measure). From a water temperature perspective this is not ideal as the potential arises (however unlikely that it is) that changes could occur between the diversion point and the logger location. This concern is further compounded by the fact that there was no formal quality documentation for the work (personal communication, H. Sessoms, 2006). Hence a quality assurance (QA) assessment was completed to ensure this data met our requirements.

B3.2 QUALITY ASSESSMENT OF PREVIOUSLY COLLECTED DATA

The first phase of QA consisted of completing spot checks of temperature at several locations during the fall of 2005. A Horiba Water Quality Checker U-10 (accuracy ±0.5°F) was used. Field measured temperatures were correlated with the date and time of the datalogger recording for comparison. Results are shown in **Figure B3-1** (Left panel). As evidenced by the good correlation between field temperature and recorded temperature at the logger, the MSU data appears to have good accuracy and precision over the study reach. Sites that received field QA included: (1) Beaverhead River at Madison

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[2] These are the two primary sources for such flow measurement activities.

County Fairgrounds, (2) Jacobs Slough, (3) Ruby River, (4) Greenhouse Slough, (5) East Bench 41-2 Lateral Wasteaway, (6) Beaverhead River at Giem Bride, (7) Spring Creek, (8) California Slough, (9) Schoolhouse Slough, (10) Owsley Slough, (11) Coop Ditch, and (12) Beaverhead River at Anderson Lane Bridge.

Table B3-1. Overview of the monitoring locations on Beaverhead River in 2005.

Site Type	Agency	Locations
Mainstem River	USGS	Beaverhead River at Barretts MT
	USGS	Beaverhead River at Dillon MT
	MSU	Beaverhead River at Anderson Lane Bridge
	USGS	Beaverhead River near Twin Bridges MT
	MSU/BOR	Beaverhead River at Giem (Silverbow Lane) Bridge
	MSU	Beaverhead River at Twin Bridges (Madison County Fairgrounds)
Tributaries	MSU	Poindexter Slough
	MSU	Stone Creek near Highway 41 bridge
	MSU	Trout Creek near Point of Rocks
	MSU	California Slough near Silverbow Lane
	MSU	Spring Creek near Silverbow Lane
	MSU	East Bench 41-2 lateral waste way
	MSU	Baker Ditch waste way/Redfield Lane Ditch
	MSU	Schoolhouse Slough at Highway 41 crossing
	MSU	Owsley Slough at Highway 41 crossing
	MSU	Greenhouse Slough at East Bench Road
	MSU	Ruby River at East Bench Road bridge
	MSU	Jacob’s Slough at East Bench Road
Diversions	EBID	East Bench Canal
	CCWC	Canyon Canal
	MSU	Smith-Rebich Canal below Barrett’s gauging station
	MSU	Outlaw Ditch at Barrett’s Diversion Dam
	MSU	Perkins Ditch at Barrett’s Diversion Dam
	MSU	Horton Haines Ditch
	MSU	Van Camp Ditch
	MSU	Poindexter Slough Diversion
	MSU	Westside Canal
	MSU	Selway Slough/Ditch
	MSU	Horton Haines Ditch
	MSU	Bishop Ditch
	MSU	1872 Ditch
	MSU	Brown Ditch
	MSU	Co-op Ditch near Point of Rocks
	MSU	Muleshoe Canal
	MSU	Baker Ditch

BOR = Bureau of Reclamation, CCWC = Canyon Canal Water Company, EBID = East Bench Irrigation District, MSU = Montana State University, USGS = U.S. Geological Survey

A similar correlation was made between the USGS temperature monitor on the mainstem river and the Co-op ditch Tru-track (very close proximity to the USGS gage) in order to verify that the logger temperature (even though some distance from the river) is similar to that of the mainstem river (**Figure B3-1**, Right panel). In this instance, there seems to be a potential issue due to a consistent positive bias.

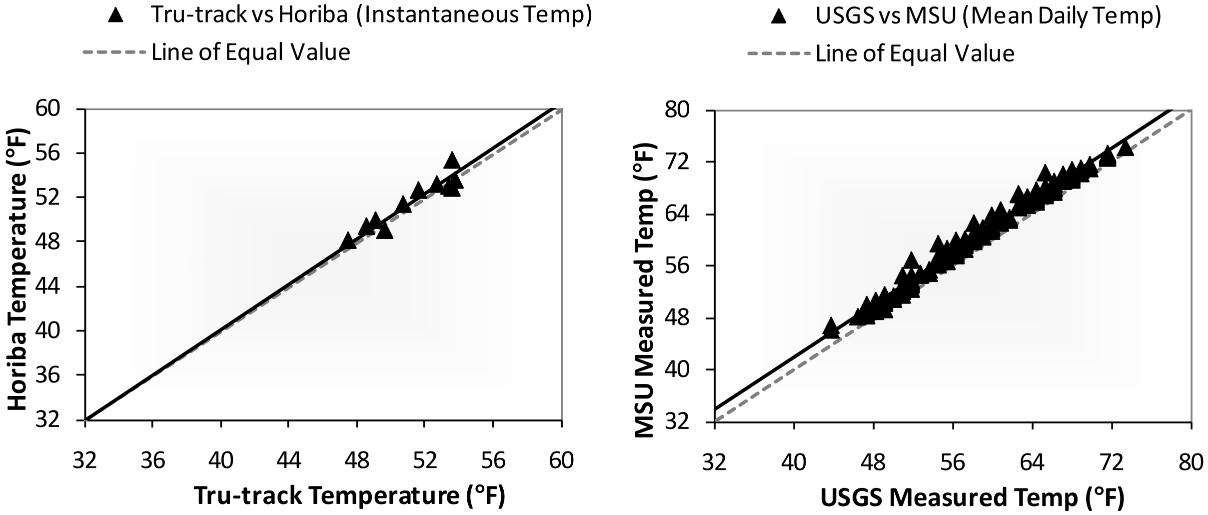

Figure B3-1. Temperature QA comparisons for the Beaverhead River

(Left panel). MSU Tru-track vs. DEQ Horiba at multiple sites. (Right panel) MSU Tru-track vs. USGS gage.

After further review of the data supporting **Figure B3-1** (Right panel), it was identified that the MSU comparison site (Co-op canal) had a hot spring in it (i.e., 80°F in October noted by field personnel). It therefore is a poor comparison site. Consequently we cannot verify our assumption whether outgoing ditch temperatures truly reflect the mainstem river. We will address this concern later through the use of the model. To correct the Co-op Tru-track site, we did a simple adjustment as shown in **Figure B3-2** which required a constant shift of -2°F.

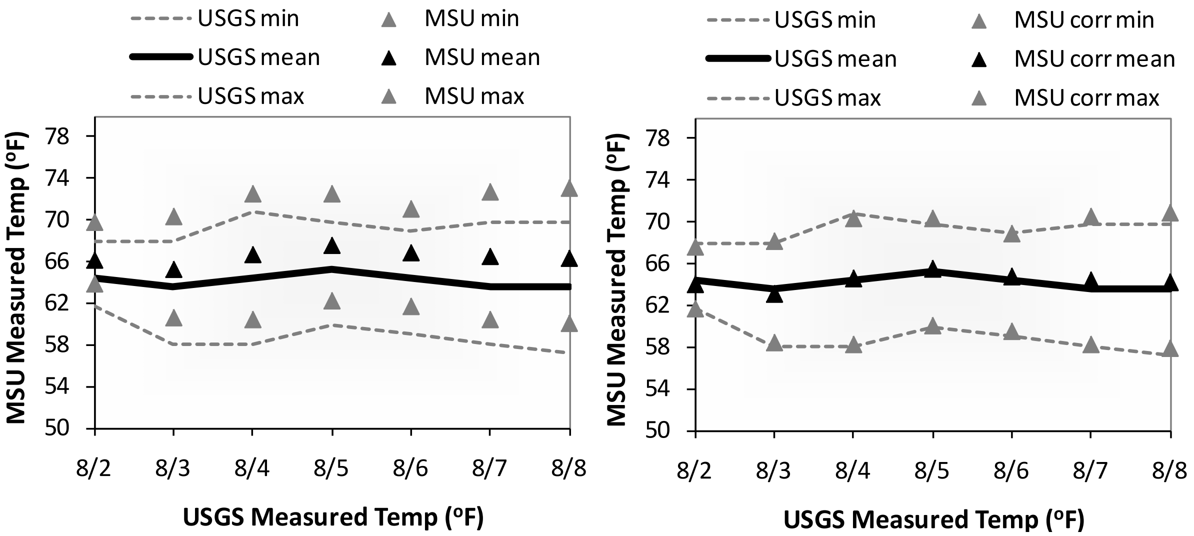

Figure B3-2. Correction of Co-op canal data for influence of hot spring

(Left panel). Uncorrected Co-op canal data. (Right panel). Corrected data.

QA of the flow data is shown in **Figure B3-3**. We compared daily USGS, BOR, and MSU flow measurements. Most discharge measurements appear to be reasonable according to the line of equal value as only minor deviations occur between USGS and BOR observations[3]. For example, residuals were not greater than 15% at any time which indicate a suitable fit (Sauer and Meyer, 1992). Deviation between the MSU and BOR data, however, is more concerning. MSU discharge estimates at Anderson Bridge are nearly 40% different than the BOR data[4]. Giem Bridge provided much better results (approximately 15% low) somewhat affirming the quality of the data.

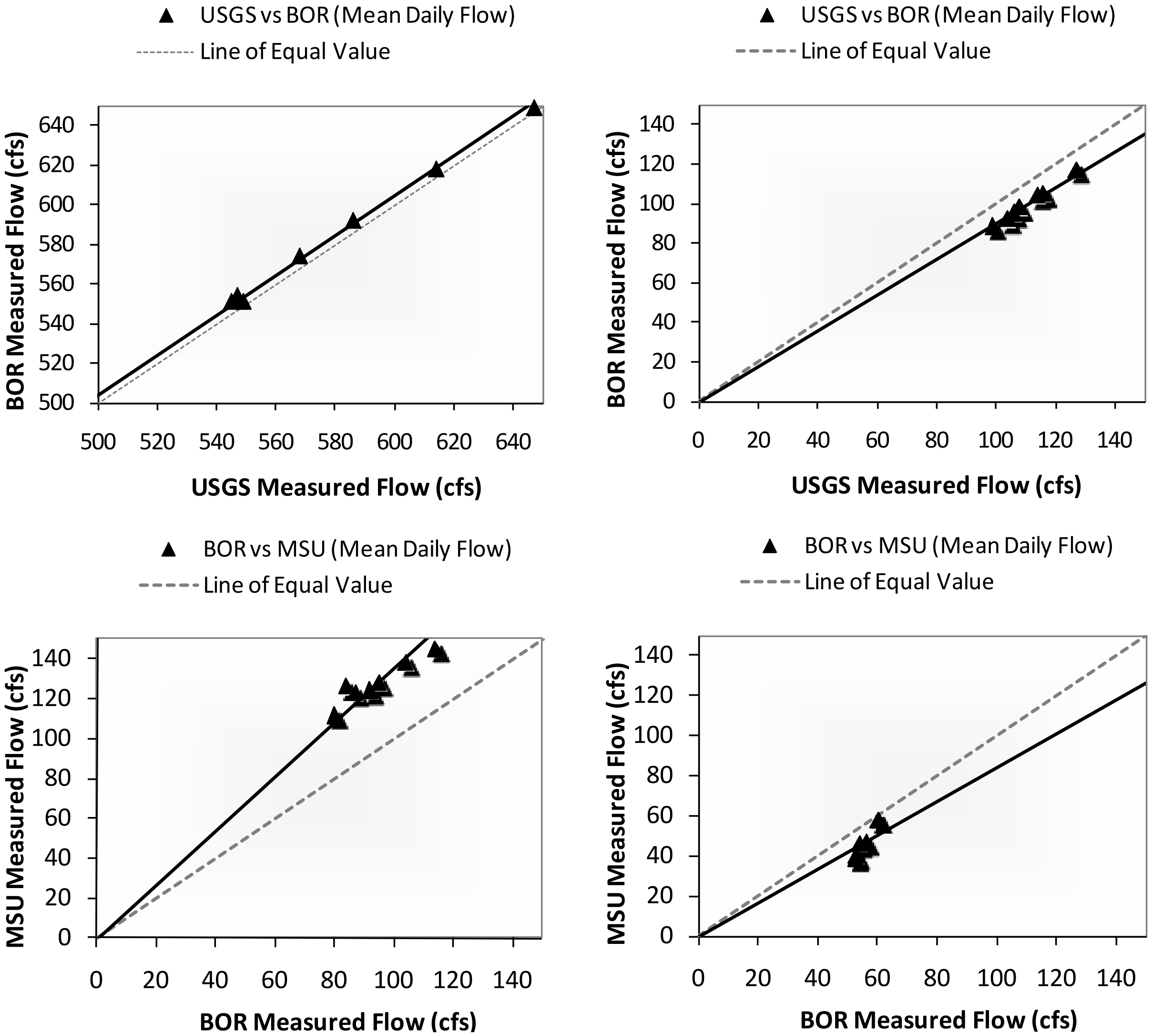

Figure B3-3. Quality assessments between USGS, BOR, and MSU discharge measurements
(Top left and right panels). Comparisons between Barretts and Twin Bridges for USGS and BOR sites. (Bottom left and right panels). Same but between MSU and BOR for Anderson and Giem Bridge.

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[3] Mean daily discharge for these locations were obtained electronically via the National Water Information System (NWIS) and BOR Hydromet websites (U.S. Geological Survey, 2006; U.S. Department of the Interior, Bureau of Reclamation, 2006b).

[4] This site had nuisance weeds/algae which apparently interfered with the flow measurement.

B3.3 SUMMARY

Based on the data in this section (in regard to both temperature and flow), DEQ feels comfortable in proceeding with the modeling assuming that the concerns and limitation of the data are adequately addressed in their use. As such, any questionable information will be scrutinized and validated prior to use. In cases of unexplainable or grossly erroneous data, these will be removed from the analysis entirely. Any data concerns from this point on will be noted in the text.

B4.0 MODELING APPROACH

DEQ selected a mechanistic modeling approach to evaluate the relationship between management activities and water temperature on the Beaverhead River. The enhanced river quality model QUAL2K (Q2K) was selected for analysis due to a number of reasons including its frequency in application for TMDL planning, fairly standardized heat flux algorithms, and endorsement by EPA (Rauch et al., 1998; Wool, 2009). Shadev3.0 was used as a companion model to identify hourly changes in shade from topographic and riparian shade. Each tool is briefly described in this section.

B4.1 QUAL2K DESCRIPTION

Q2K is a steady-state one-dimensional river model that simulates the movement of water and heat flux in completely mixed systems. It is applicable to rivers where the major transport mechanisms of advection and dispersion are significant along the longitudinal direction of flow, with the assumption that lateral and vertical water temperature gradients are negligible. By operating the model in a quasi-dynamic mode, the user has the ability to study the diurnal variation of temperature on an hourly or sub-hourly time scale. Q2K allows multiple waste discharges, withdrawals, tributary flows, and incremental inflow and outflow to be positioned anywhere along the channel, and includes sediment heat flux routines and reach variable meteorology. Consequently it is a significant improvement over the original QUAL2E model (Brown and Barnwell, Jr., 1987). Q2K is limited to periods where both streamflow and input heat loads are steady-state and input data requirements are shown in **Table B4-1**.

Table B4-1. QUAL2K input requirements

Data Type	Input Requirement[1]
Meteorology	1. Hourly air temperature 2. Hourly dew point temperature 3. Hourly wind speed 4. Hourly percent cloud cover 5. Atmospheric turbidity coefficient 6. Reach latitudes and longitudes
Hydrology	1. Discharge data for headwaters, and point and nonpoint sources 2. Temperature data for headwaters, and point and nonpoint sources
Hydraulics	1. Stream network configuration 2. Reach lengths and elevations 3. Transport function (rating curves, etc.)
Shade	1. Hourly percent shade for each reach

[1] Most of the input variables in **Table 4-1** can readily be acquired through existing field measurement programs. Their use in development of the model are described in **Section B5.0**.

B4.2 CONCEPTUAL REPRESENTATION

A river in Q2K is represented as a series of reaches and elements where point sources (e.g., tributaries) and nonpoint source inflows (e.g., groundwater) or withdrawals are present (**Figure B4-1**). Reaches are homogeneous stretches of river that have similar aspect, shading, or hydraulic characteristics, whereas the element is the fundamental computational unit of the model. Reach stationing determines the placement of the point and nonpoint source inflows. Additional information regarding Q2K can be found in Chapra, et al., (Chapra et al., 2008b).

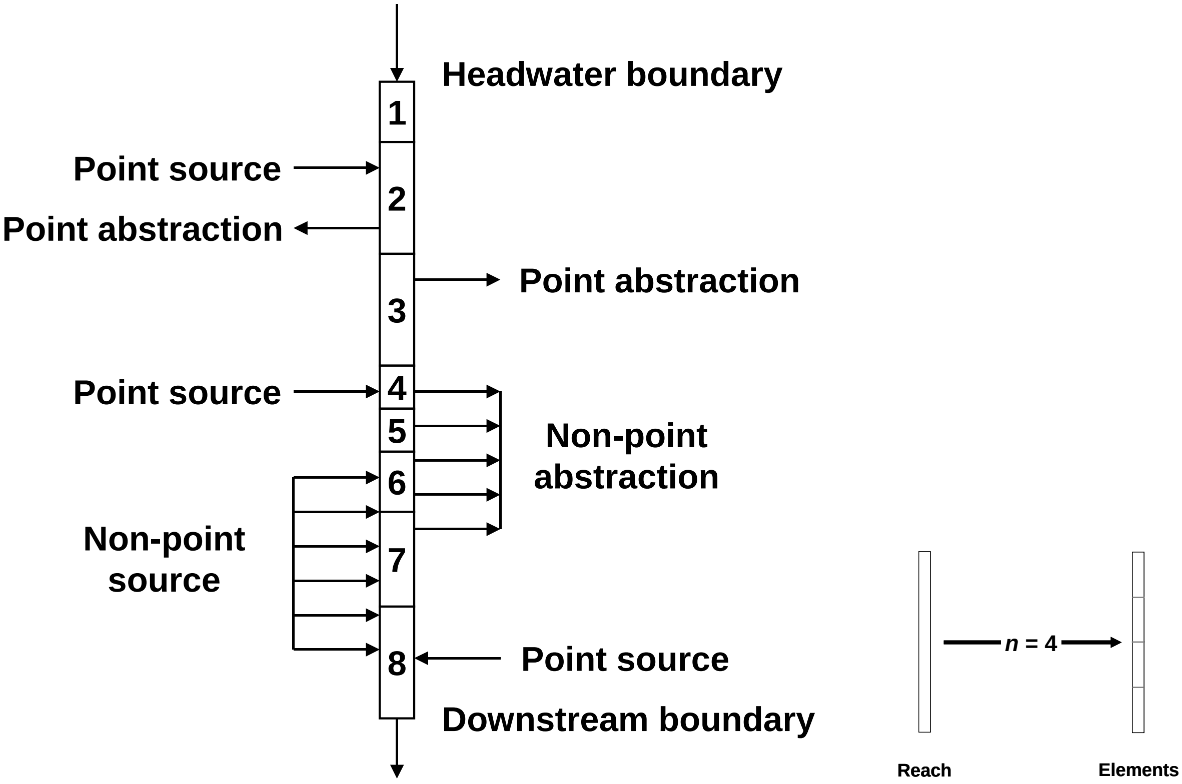

Figure B4-1. Conceptual representation of a river reach within QUAL2K
Taken from Chapra, et al., (2004). Please refer to the modeling documentation for further discussion.

B4.3 HEAT BALANCE

The heat balance in Q2K is written as **Equation B4-1**, where for each control volume *i* (an element) the change in temperature T_i [°C] is computed according to t = time [d], E'_i = the bulk dispersion coefficient between reaches i and $i + 1$ [m^3/d], $W_{h,i}$ = the net heat load from point and nonpoint sources into reach *i* [cal/d], ρ_w = the density of water [g/cm^3], C_{pw} = the specific heat of water [cal/(g °C)], $J_{h,i}$ = the air-water heat flux [cal/(cm^2 d)], and $J_{s,i}$ = the sediment-water heat flux [cal/(cm^2 d)] (Chapra et al., 2008b). This is shown graphically in **Figure B4-2**.

(Equation B4-1)

$$\frac{dT_i}{dt}=\frac{Q_{i-1}}{V_i}T_{i-1}-\frac{Q_i}{V_i}T_i-\frac{Q_{ab,i}}{V_i}T_i+\frac{E'_{i-1}}{V_i}\left(T_{i-1}-T_i\right)+\frac{E'_i}{V_i}\left(T_{i+1}-T_i\right)$$
$$+\frac{W_{h,i}}{\rho_w C_{pw} V_i}\left(\frac{\text{m}^3}{10^6\ \text{cm}^3}\right)+\frac{J_{h,i}}{\rho_w C_{pw} H_i}\left(\frac{\text{m}}{100\ \text{cm}}\right)+\frac{J_{s,i}}{\rho_w C_{pw} H_i}\left(\frac{\text{m}}{100\ \text{cm}}\right)$$

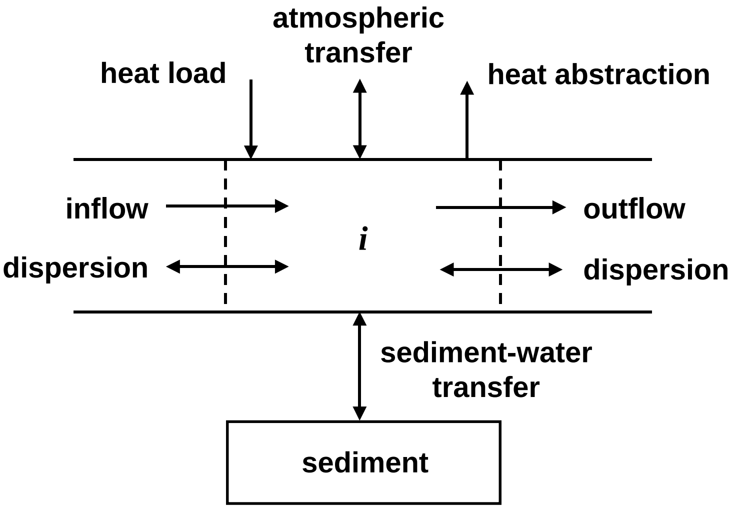

Figure B4-2. Graphical representation of the heat balance within a Q2K model element
Reproduced from Chapra, et al., (Chapra et al., 2008b).

The surface heat exchange is modeled as a combination of five processes including solar shortwave radiation, atmospheric longwave radiation, conduction from air and sediments, and advective heat input from water inflows. This is shown in **Equation B4-2**, where $I(0)$ = net solar shortwave radiation at the water surface, J_{an} = net atmospheric longwave radiation, J_{br} = longwave back radiation from the water, J_c = conduction, and J_e = evaporation. All fluxes are expressed as cal/cm^2/d.

(Equation B4-2) [5]

$$J_h = I(0) + J_{an} - J_{br} - J_c - J_e$$

A graphical rendition of surface heat exchage is also shown in **Figure B4-3**. Heat losses include longwave radiation, conduction to air and bed sediments, and evaporation and outflow from the river. Heat gains include both radiation and non-radiation terms.

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[5] Shortwave radiation within the model is determined as a function of latitude and longitude of the modeled reach. It is attenuated by atmospheric transmission, cloud cover, reflection, and topographic and vegetative shading. Water and atmospheric longwave radiation are calculated according to the Stefan-Boltzmann law and conduction and evaporation are calculated using the Brady, Graves, and Geyer method and Dalton's Law (Chapra et al., 2008b). Air and water temperature, wind speed, and the saturation vapor pressure (relative humidity) are all required as well.

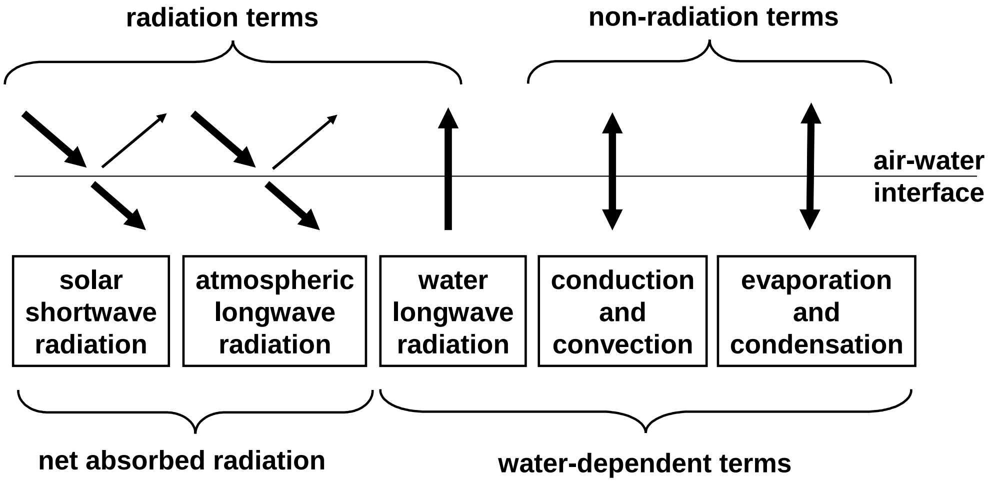

Figure B4-3. Surface heat exchange in Q2K model
Reproduced from Chapra, et al., (2008b)

B4.4 ASSUMPTIONS AND LIMITATIONS

Q2K has a number of assumptions and limitations. Those critical to temperature assessment such as in the Beaverhead River include the following:

- Negligible water temperature gradients (i.e., the channel is assumed to be well-mixed both vertically and laterally).
- Steady flow and heat load conditions (i.e., river hydrology, hydraulics, and boundary conditions are assumed to be steady state).
- Diurnally uniform meteorological forcings (i.e., climatic conditions are assumed uniform over the project reach both spatially and temporally).

A final assumption implicit in the model is that diversion water temperatures measured by MSU are representative of the temperature of the Beaverhead River (in order to calibrate the model). We were unable to prove this in **Section B3.2**. However the assumption is valid given the relative proximity of these sites to the diversion point from the river. We provide further justification in **Section B6.0**.

B4.5 SHADE MODEL (SHADEV3.0.XLS)

Shade for Q2K was simulated in Shadev3.0.xls. This software is a visual basic for applications package developed by the Oregon Department of Environmental Quality and adapted by Washington Ecology (Pelletier, 2007) to determine shade from both topography and vegetation using solar time and position, aspect, position, and vegetation characteristics of a channel (**Figure B4-4**). Required field data for the shading calculation include: (1) tree canopy height, (2) density, (3) overhang, (4) stream reach aspect, (5) wetted channel width, (6) near stream disturbance zone (NSDZ) width, (7) channel incision, and (8) topographic shading (**Table B4-2**). These values were collected by a DEQ contractor in 2009.

Similar to Q2K, Shadev3.0.xls has a number of assumptions. These include: (1) that vegetative parameters (tree height, density, and overhang) are considered uniform over the project reach for a particular species type and age class (2) that calculation of solar position (e.g. azimuth and altitude) is accurate for each Julian day at the respective modeling latitude and longitude, and (3) that topographic angle can accurately be estimated using ArcGIS viewshed. Further information regarding Shadev3.0.xls can be found in Boyd and Kasper (2003) and Pelletier (2007).

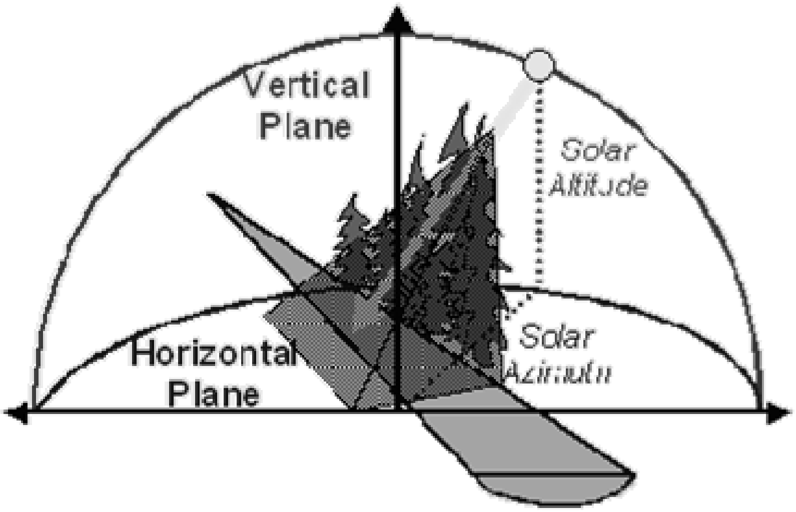

Figure B4-4. Conceptual representation of Shadev3.0.xls
Diagram taken from Boyd and Kasper (2003).

Table B4-2. ShadeV3.0.xls model input requirements.

Data Type	Specific Input Requirement
Solar Position	1. Latitude and longitude of reach 2. Date and time
Stream Morphology	1. Aspect 2. Channel width 3. Near stream disturbance zone (NSDZ) width 4. Incision
Vegetation	1. Canopy height 2. Canopy density 3. Overhang
Geographic	1. Topographic angle

B5.0 MODEL SETUP AND DEVELOPMENT

The Q2K model setup and development is described in this section. Included is a brief summary of the analysis period, details on the physical model construction, and other information related to model development.

B5.1 MODELING ANALYSIS PERIOD SELECTION

The analysis period was based on critical limiting conditions (i.e., the time of year when temperature impairment is most likely to occur). Review of 5 years of temperature data at USGS 06018500 Beaverhead River near Twin Bridges gage (2000-2004) suggests this period occurs somewhere between July and August (**Figure B5-1**, left panel). Temperature data collected during 2005 (the year the model will be developed) corroborate these findings (**Figure B5-1**, right panel). Accordingly, the period of

August 4-7, 2005 was used for Q2K development, at or when conditions are likely to impair water temperature.

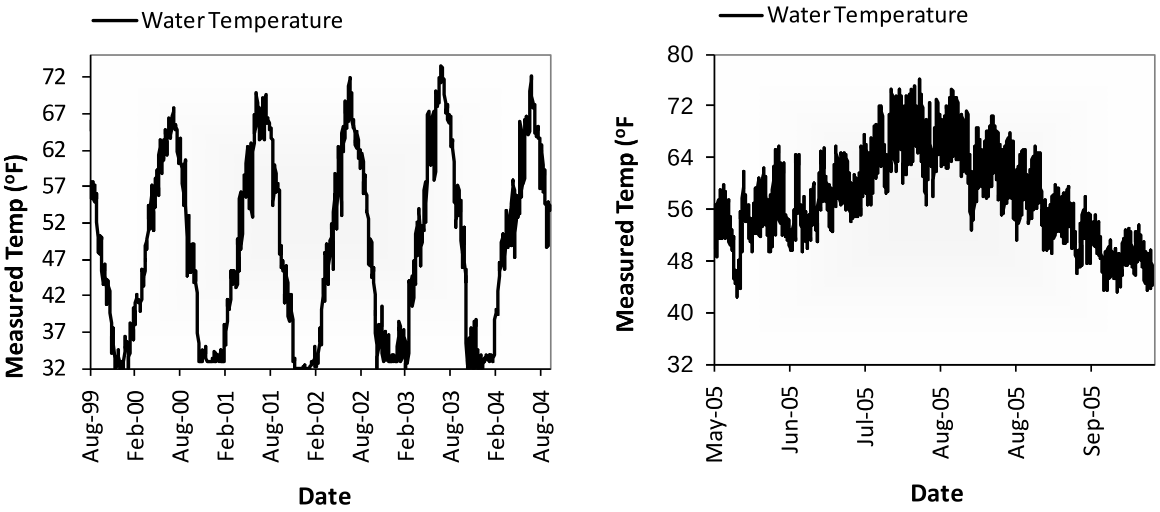

Figure B5-1. Water temperature data used to determine the model analysis period
(Left panel). USGS temperature data from 1999-2004. (Right panel) Data from 2005 at Anderson Bridge. The most critical limiting period occurs sometime in July or August.

Data were then compiled over the period of interest. MSU discharge data were readily available in MS Excel spreadsheets and required very little reduction. USGS, BOR, and NOAA data were downloaded from each agency's website and assembled into individual data files. All units were converted to standard international (S.I.) and were aggregated into a format for modeling (i.e., mean repeating day time-series which are consistent with the requirements of Q2K). In other words, input data were averaged over the study period into a single daily time-series of climate, discharge, and temperature.

B5.2 COMPARISON WITH HISTORICAL CONDITIONS

A comparison of the analysis period with historical conditions is shown in **Figure B5-2**. Both climate (as represented by mean daily air temperature and precipitation) and streamflow (as annual hydrograph) were evaluated. The meteorological conditions during August were very similar to that of the climatic normals (1970-2001) (National Oceanic and Atmospheric Administration, 2011) (**Figure B5-2**, left) and streamflow was below average, between the 5th and 25th percentile. Thus the conditions are very close to those that would be expected during critical low flow conditions.

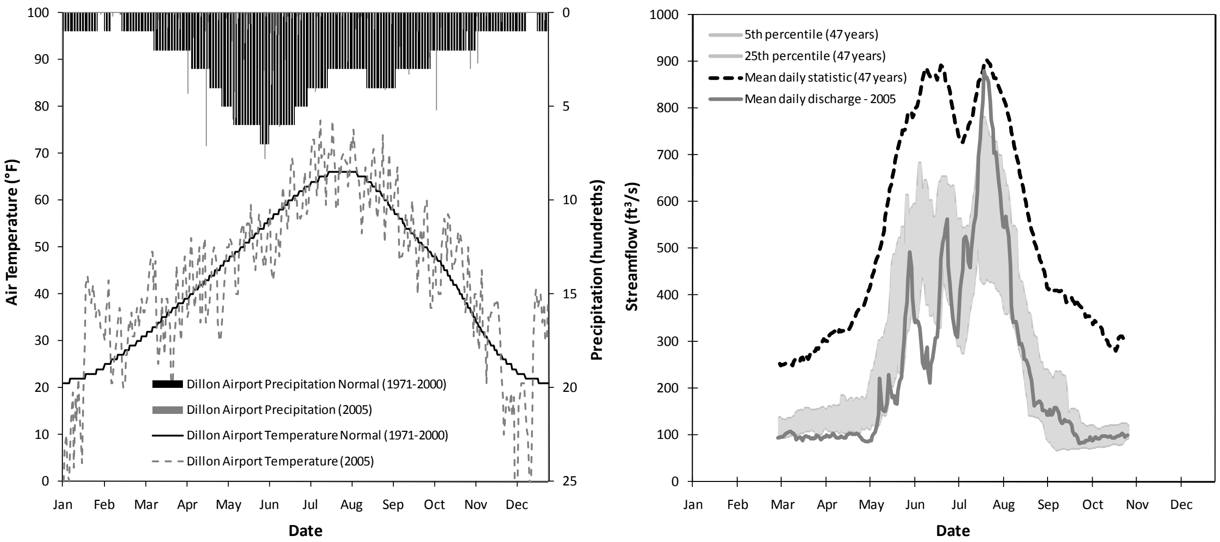

Figure B5-2. Conditions encountered during 2005 compared to historical data
(Left panel) Climatological data. (Right panel) Streamflow hydrology. For flow, only March through October is shown as the gage was not operated during the winter months for most of the period of record.

Water temperature data for this period is shown in **Figure B5-3**. Upon examination, a number of general interpretations can be made. First, temperatures are fairly similar in the mainstem river, but show a slight increase from approximately 65°F at Barretts to 68°F near Twin Bridges (mean daily temperatures are reported in the figure). On the whole, incoming tributaries tend to be cooler than the river, whereas the sloughs and Ruby River (in the lower watershed) are nearly the same temperature or perhaps slightly cooler. Probably the biggest difference in the figure is flow. Mean daily discharges ranges from over 550 ft^3/s in the upper river to nearly 50 ft^3/s in the lower reaches. From up- to down-stream, the profile is characteristic of heavy irrigation depletion followed by a number of irrigation returns. Slough inflow from Spring Creek, California Slough, Schoolhouse Slough, Charlton Slough, Greenhouse Slough, etc. (most of these are from the Big Hole River) and the Ruby River nearly quadruple the flow over a very short extent. This perhaps somewhat attenuates the temperature effect.

Additionally from **Figure B5-3** it should be apparent that ascertaining the relationship between river management and water temperature from simply looking at data is difficult. While a 3°F increase in water temperature does occur (in combination with flow depletion), we have no way of knowing whether the increase is natural or human-caused, or the extent thereof. Water quality models will therefore be used to: (1) better formalize the mechanistic relationship between variables such as flow, water temperature, and others, (2) determine whether this increase in temperature is natural or anthropogenic, (3) understand the cause-effect relationships of management activities and observed stream temperature, and (4) provide recommendations, if any, that can be implemented to meet the temperature standard in the river.

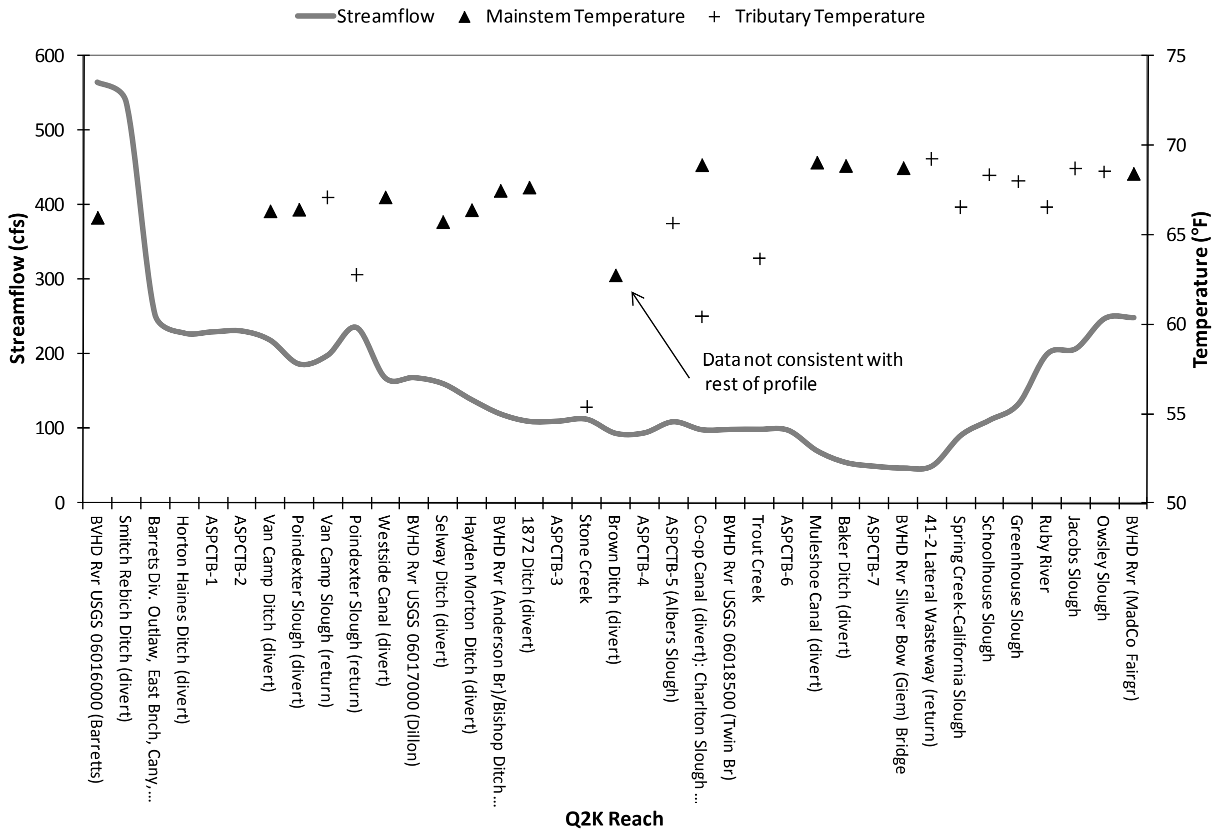

Figure B5-3. Longitudinal discharge and water temperature relationships for the Beaverhead River. Water temperature data are reflective of the mean daily temperature.

B5.3 MODEL PHYSICAL DESCRIPTION AND SEGMENTATION

The Beaverhead River Q2K model reflects the physical mechanics of advection and dispersive heat transport for the river. The model was segmented to describe: (1) major inflows and outflows identified by Sessoms and Bauder (2005), (2) the USGS and BOR gage sites, (3) aspect and vegetation breaks, and (4) other important features identified by DEQ. In total, 36 reaches were discretized with an average approximate reach length of three miles. These are shown in **Figure B5-4** (Left panel). They also coincide with the Q2K reaches shown in **Figure B5-3**.

Although 36 different reaches were identified (as indicated by the dark black lines on the river plan drawing) there was insufficient information to describe all of these hydraulically. The paucity of river width and depth data necessitated a much simpler hydraulic representation. As a result only 3 generalized hydraulic regions were used which correspond to the USGS gaging sites (also shown in **Figure B5-4**, Left panel). The stationing of tributaries, other inflows, and outflows is shown in **Figure B5-4** (Right panel). These are more directly addressed in **Section B5.5**. More information on the model hydraulics is contained within **Section B5.6**.

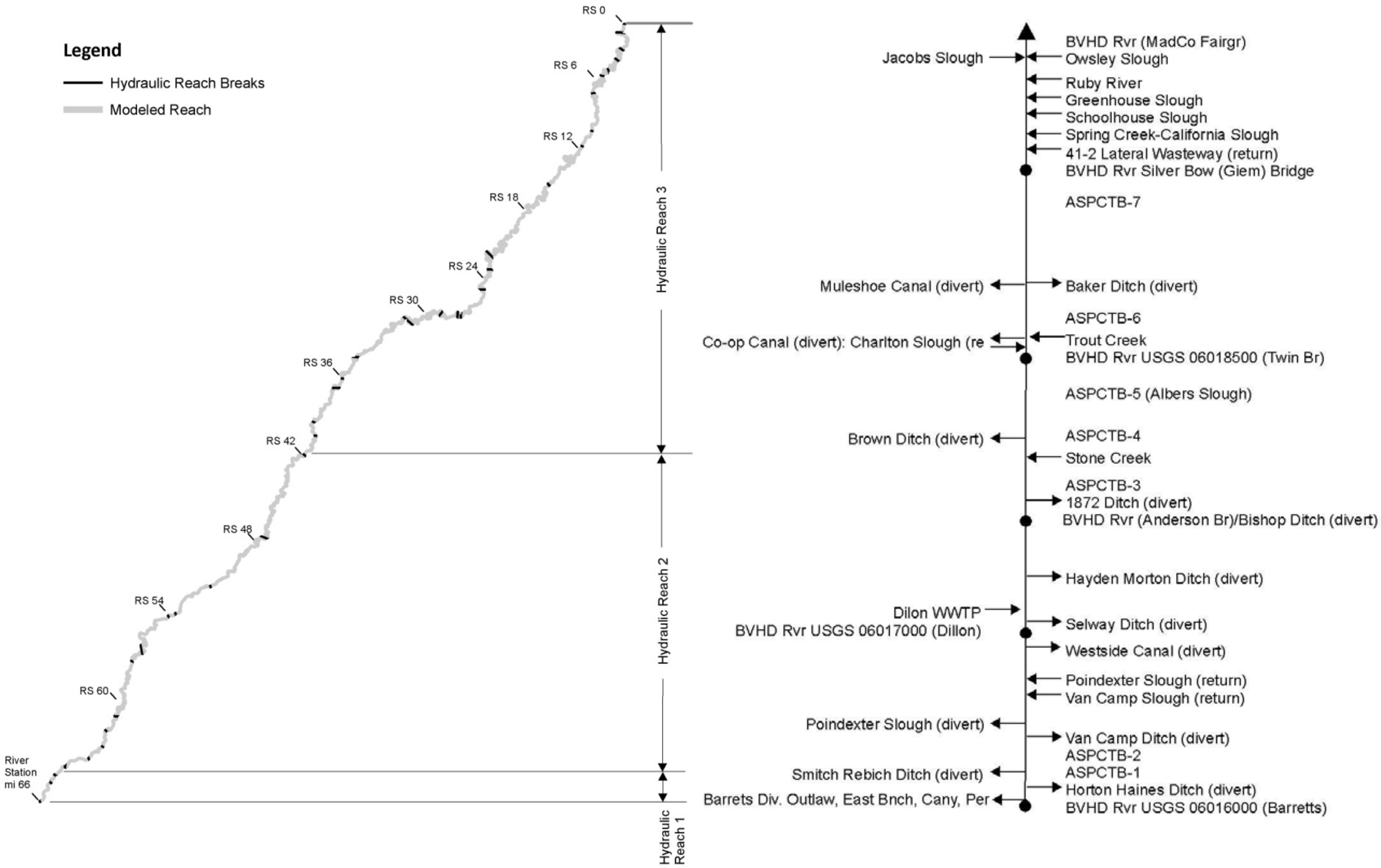

Figure B5-4. Q2K model segmentation and spatial inflow/outflow summary for Beaverhead River.
(Left panel) Model segmentation and hydraulic reach assignments for the Q2K model (based on USGS gages). (Right panel) Inflow outflow summary where inflows are denoted with an incoming arrow, outflow as outgoing arrows, and circles as mainstem river gage sites. The side in which the inflow or outflow originates on the figure (i.e., left/right) has no physical meaning.

B5.4 METEOROLOGICAL DATA

Q2K requires hourly meteorological data to calculate diurnal heat flux within the model. Four sites have requisite data. These are: (1) ASOS 242404 Dillon, MT, (2) Dillon Valley Agrimet, (3) Ruby Valley Agrimet, and (4) Jefferson Valley Agrimet. Hourly observations of temperature, wind speed, and dew point were available from each location and are shown in **Figure B5-5**. They were averaged[1] to provide mean repeating day input for Q2K (**Figure B5-6**).

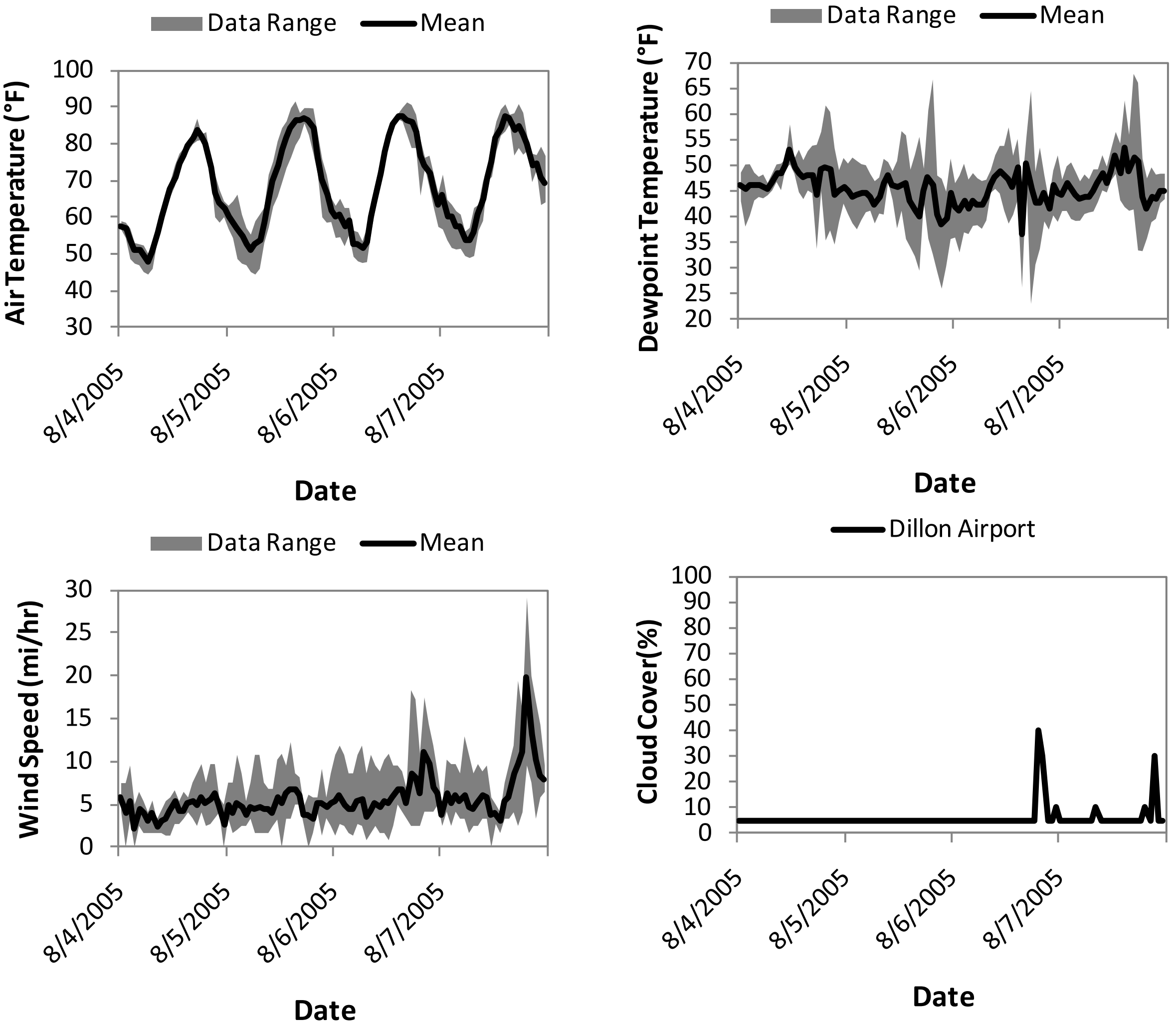

Figure B5-5. Hourly meteorological data summary for August 4-7th, 2005 summer period. (Top left/right panel). Air and dew point temperature [°F]. (Bottom left/right panel). Wind speed [mi/hr] and cloud cover [%]. It should be noted that the model actually requires input in SI units.

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[1] All sites were within close proximity to the watershed, therefore the average of the four sites were used. Only one site, (Dillon ASOS) had information regarding cloud cover.

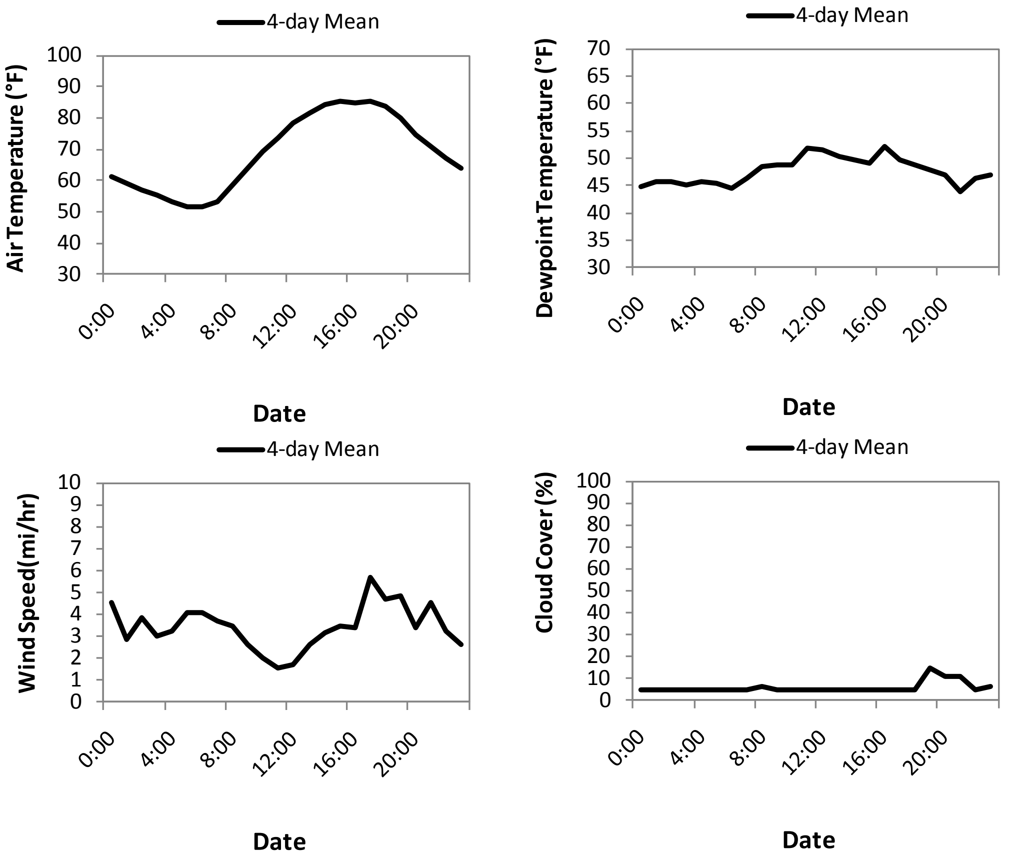

Figure B5-6. Mean repeating day meteorological data summary for August 4-7th, 2005 summer period. These data reflect the aggregation of the time-series in **Figure B5-5**. In other words, values at 6:00 a.m., 7:00 a.m., and so on were averaged to provide a single day's time-series.

Wind speed data were corrected to an appropriate height using the power-law profile (Linsley et al., 1982) (**Equation B5-1**), where: *v* = mean wind speed at conversion height, v_1= measured wind speed at some standard height, *z* = conversion height, z_1 = standard measurement height, and *k* = exponent.

$$\frac{v}{v_1} = \left(\frac{z}{z_1}\right)^k$$

(Equation B5-1)

The height of the anemometer at Dillon is 33 ft (10 m) (personnel communication, National Weather Service, Great Falls, 2006). Agrimet sensor heights are approximately 6.5 ft (2 m) (personal communication T. Grove, BOR, 2006). A value of *k*= 0.18 was used for the Dillon ASOS (airport) and 0.25 for the AgriMet sites (grass field) to make the adjustment to the 7 meter height required by Q2K.

B5.5 HYDROLOGY

A steady-state flow balance was used to define the hydrology in the model (**Equation B5-2**), where Q_i = outflow from reach *i* into reach *i* + 1 [m^3/d], Q_{i-1} = inflow from the upstream reach *i* – 1 [m^3/d], $Q_{in,j}$= total inflow into the reach from point and nonpoint sources [m^3/d], and $Q_{ab,i}$= total outflow from the reach due to point and nonpoint abstractions [m^3/d]. All major inflow and outflow components were field measured. A graphical version of this balance is shown in **Figure B5-7**.

(**Equation B5-2**)

$$Q_i = Q_{i-1} + Q_{in,i} - Q_{ab,i}$$

Inflow and outflow locations in the water balance were based on the channel centerline digitized by DEQ using aerial photography from 2005 National Agriculture Imagery Program (NAIP) while nonpoint sources and abstractions were modeled as line sources. A tabular version of the water balance for the model analysis period is shown in **Table B5-1**.

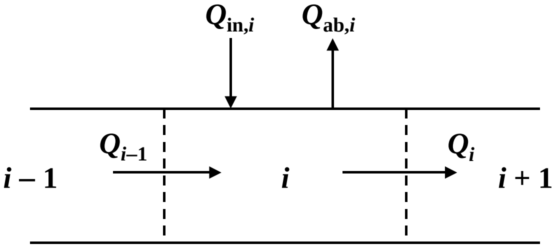

Figure B5-7. QUAL2K steady-state water balance for a given element.
Reproduced from Chapra, et al., (2008a).

Table B5-1. Beaverhead River steady-state water balance.
Data for the period of August 4-7th, 2005.

Location	Description	Surface Water (m^3/s)[1]	Groundwater (m^3/s)
BVHD00	Observed - BVHD Rvr USGS 06016000 (Barretts)	564.6	17.8
BVHD01	Smith Rebich Ditch (divert)	-27.7	
BVHD02	Barretts Diversions (divert)	-285.4	
BVHD03	Horton Haines Ditch (divert)	-25.7	
BVHD04	ASPCTB-1	0	
BVHD05	ASPCTB-2	0	
BVHD06	Van Camp Ditch (divert)	-13.2	
BVHD07	Poindexter Slough (divert)	-33.1	
BVHD08	Van Camp Slough (return)	6.9	
BVHD09	Poindexter Slough (return)	36.2	
BVHD10	Westside Canal (divert)	-72	
TOTAL		150.6	
BVHD11	Observed - BVHD Rvr USGS 06017000 (Dillon)	168.4	
*Includes Outlaw, East Bench, Canyon Canal, and Perkins Diversions			
BVHD12	Selway Ditch (divert)	-5.4	-15.7
BVHD13	Hayden Morton Ditch (divert)	-16.5	
++++++	Bishop Ditch (divert)	-11.1	
TOTAL		135.4	
BVHD14	Observed - BVHD Rvr (Anderson Br)	119.7	
*Bishop ditch diversion occurs directly upstream of Anderson Bridge			

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[1] Recall that all flow estimates were based on the MSU water balance during 2005 (Sessoms and Bauder, 2005).

Table B5-1. Beaverhead River steady-state water balance.
Data for the period of August 4-7th, 2005.

Location	Description	Surface Water (m^3/s)[1]	Groundwater (m^3/s)
BVHD15	1872 Ditch (divert)	-10.5	5.5
BVHD16	ASPCTB-3	0	
BVHD17	Stone Creek	1.7	
BVHD18	Brown Ditch (divert)	-19.1	
BVHD19	ASPCTB-4	0	
BVHD20	ASPCTB-5 (Albers Slough)	13.5	
BVHD21	Co-op Canal (divert)	-23.6	
++++++	Charlton Slough (return)	11.6	
TOTAL		93.4	
BVHD22	Observed - BVHD Rvr USGS 06018500 (Twin Br)	98.9	
*Charlton Slough Return occurs directly downstream of the Co-op Canal			
BVHD23	Spring-Trout Creek	0.4	-10.9
BVHD24	ASPCTB-6	0	
BVHD25	Muleshoe Canal (divert)	-26.5	
BVHD26	Baker Ditch (divert)	-14.8	
BVHD27	ASPCTB-7	0	
TOTAL		58.0	
BVHD28	Observed - BVHD Rvr Silver Bow (Giem) Bridge	47.0	
BVHD29	41-2 Lateral Wasteway (return)	1.5	18.2
BVHD30	Spring Creek-California Slough-Redfield Ditch	36.7	
BVHD31	Schoolhouse Slough	16.9	
BVHD32	Greenhouse Slough	20.5	
BVHD33	Ruby River	64.4	
BVHD34	Jacobs Slough	5.3	
BVHD35	Owsley Slough	38.2	
TOTAL		230.6	
BVHD36	Observed - BVHD Rvr (MadCo Fairgr)	248.9	

BVHD$_{ij}$ is the Beaverhead reach number in the Q2K model
ASPCTB denotes reach break due to aspect change

B5.6 HYDRAULICS

The movement of water through the model was represented using rating curves[1]. These relate mean velocity and depth to discharge in the form of a power equation (**Equation B5-3** and **Equation B5-4**), where *H*=depth [m] and *U*=velocity [m/s] are related to discharge (*Q*)[m/s] through the empirical coefficients and exponents *a* and *b* and α, and β [all unitless].

Equation B5-3. $U = aQ^b$

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[1] The rating curve approach was selected for the hydraulic parameterization due the paucity of hydraulic data (cross-sectional geometry, top width, etc.). We regressed discharge with mean channel velocity and width to come up with coefficient and exponent estimates for the river.

Equation B5-4. $H = \alpha Q^{\beta}$

Computed *U* and *H* are then used to determine the cross-sectional area (A_c) and average reach top width (*B*) which are the primary attributes of interest for temperature modeling (**Equation B5-5** and **Equation B5-6**) (Chapra, et al., (2008b)).

Equation B5-5. $A_c = \frac{Q}{U}$

Equation B5-6. $B = \frac{A_c}{H}$

Data to determine the coefficients and exponents described previously are available from the USGS gages (i.e., Barretts [upper], Dillon [middle], and Twin Bridge [lower]). The values *a* and *b* and α, and β were determined through least-square regression and were assigned the hydraulic regions identified previously in **Figure B5-4**. Estimates were found to be consistent with the literature (Barnwell, Jr. et al., 1989; Flynn and Suplee, 2010b; Leopold and Maddock, Jr., 1953) (**Table B5-2**) and the sum of b and β was less than or equal to 1.

Table B5-2. Beaverhead River rating curve coefficients and exponents.

Equation	Exponent	Typical value	Range[1]	Beaverhead Values
$U = aQ^b$	b	0.43	0.4-0.6	Upper=0.43, Middle=0.46, Lower=0.37
$H = \alpha Q^{\beta}$	β	0.45	0.3-0.5	Upper=0.43, Middle=0.35, Lower=0.41

[1]From the following: (Barnwell et al., 1989; Flynn and Suplee, 2010a; Leopold and Maddock, 1953).

We also measured bankfull width and wetted width properties during 2009 (4 sites) to benefit the model calibration. A summary of reach properties determined through this work are shown in **Table B5-3**. Rating curves for the sites are in **Figure B5-8**[1.]

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[1] It should be noted that additional data became available on the river after the initial modeling. This came in the form of a HEC-RAS model developed by the Bureau of Reclamation (BOR) for the purpose of sediment flushing flow analysis. The analysis extent was from Clark Canyon Dam to Barretts (Klumpp, 2010), however the model had insufficient cross-sectional geometry (only three surveyed sections) which were actually provided by DEQ. Since this did not provide any additional information beyond what DEQ had already obtained, we did not use the HEC-RAS information.

Table B5-3. Beaverhead River Q2K reach properties.

Reach ID	Reach Label	Reach Length (mi)	River Station (mi)	Latitude	Longitude	Upstream Elevation (ft)	Downstream Elevation (ft)	Rating Curve Info.			
								U coef	Exp	*H* coef	Exp
BVHD01	Smith Rebich Ditch	1.0	65.3	45.13	112.74	5269	5249	0.18	0.43	0.34	0.43
BVHD02	Barretts, East Bnch, Cany, etc.	0.0	64.9	45.13	112.74	5249	5246	0.18	0.43	0.34	0.43
BVHD03	Horton Haines Ditch	1.0	64.3	45.14	112.73	5246	5243	0.20	0.46	0.46	0.35
BVHD04	ASPCTB-1	1.0	63.3	45.14	112.71	5243	5220	0.20	0.46	0.46	0.35
BVHD05	ASPCTB-2	1.0	62.3	45.15	112.70	5220	5207	0.20	0.46	0.46	0.35
BVHD06	Van Camp Ditch	1.0	61.6	45.15	112.70	5207	5197	0.20	0.46	0.46	0.35
BVHD07	Poindexter Slough	1.0	60.8	45.16	112.70	5197	5184	0.20	0.46	0.46	0.35
BVHD08	Van Camp Slough	4.0	57.2	45.18	112.69	5184	5144	0.20	0.46	0.46	0.35
BVHD09	Poindexter Slough	1.0	56.3	45.20	112.68	5144	5141	0.20	0.46	0.46	0.35
BVHD10	Westside Canal	3.0	53.0	45.21	112.67	5141	5108	0.20	0.46	0.46	0.35
BVHD11	USGS 06017000 (Dillon)	0.0	52.7	45.22	112.66	5108	5098	0.20	0.46	0.46	0.35
BVHD12	Selway Ditch	2.0	50.7	45.50	112.35	5098	5069	0.20	0.46	0.46	0.35
BVHD13	Hayden Morton Ditch	4.0	46.6	45.25	112.61	5069	5020	0.20	0.46	0.46	0.35
BVHD14	Anderson Br/Bishop Ditch	6.0	40.2	45.30	112.58	5020	4954	0.20	0.46	0.46	0.35
BVHD15	1872 Ditch	1.0	39.0	45.31	112.56	4954	4941	0.19	0.37	0.37	0.41
BVHD16	ASPCTB-3	1.0	38.3	45.32	112.56	4941	4928	0.19	0.37	0.37	0.41
BVHD17	Stone Creek	2.0	35.9	45.33	112.55	4928	4905	0.19	0.37	0.37	0.41
BVHD18	Brown Ditch	0.0	35.5	45.34	112.54	4905	4902	0.19	0.37	0.37	0.41
BVHD19	ASPCTB-4	2.0	33.9	45.35	112.53	4902	4882	0.19	0.37	0.37	0.41
BVHD20	ASPCTB-5 (Albers Slough)	4.0	30.2	45.37	112.51	4882	4852	0.19	0.37	0.37	0.41
BVHD21	Co-op Canal: Charlton Slough	3.0	26.9	45.38	112.48	4852	4829	0.19	0.37	0.37	0.41
BVHD22	USGS 06018500 (Twin Br)	1.0	25.9	45.38	112.46	4829	4823	0.19	0.37	0.37	0.41
BVHD23	Trout Creek	0.0	25.5	45.38	112.45	4823	4821	0.19	0.37	0.37	0.41
BVHD24	ASPCTB-6	2.0	23.5	45.39	112.44	4821	4803	0.19	0.37	0.37	0.41
BVHD25	Muleshoe Canal	2.0	22.0	45.40	112.43	4803	4797	0.19	0.37	0.37	0.41
BVHD26	Baker Ditch	1.0	20.7	45.41	112.43	4797	4783	0.19	0.37	0.37	0.41
BVHD27	ASPCTB-7	7.0	13.2	45.44	112.41	4783	4724	0.19	0.37	0.37	0.41
BVHD28	Silver Bow (Giem) Bridge	4.0	9.6	45.46	112.38	4724	4708	0.19	0.37	0.37	0.41
BVHD29	41-2 Lateral Wasteway	1.0	8.9	45.48	112.36	4708	4706	0.19	0.37	0.37	0.41
BVHD30	Spring Creek-California Slough	2.0	6.6	45.49	112.35	4706	4678	0.19	0.37	0.37	0.41
BVHD31	Schoolhouse Slough	2.0	4.7	45.51	112.35	4678	4655	0.19	0.37	0.37	0.41
BVHD32	Greenhouse Slough	1.0	4.0	45.51	112.35	4655	4642	0.19	0.37	0.37	0.41

Table B5-3. Beaverhead River Q2K reach properties.

Reach ID	Reach Label	Reach Length (mi)	River Station (mi)	Latitude	Longitude	Upstream Elevation (ft)	Downstream Elevation (ft)	Rating Curve Info.			
								U coef	Exp	*H* coef	Exp
BVHD33	Ruby River	1.0	2.7	45.52	112.34	4642	4641	0.19	0.37	0.37	0.41
BVHD34	Jacobs Slough	1.0	1.7	45.52	112.34	4641	4639	0.19	0.37	0.37	0.41
BVHD35	Owsley Slough	1.0	0.5	45.53	112.33	4639	4637	0.19	0.37	0.37	0.41
BVHD36	BVHD Rvr (MadCo Fairgr)	1.0	0.0	45.54	112.34	4637	4636	0.19	0.37	0.37	0.41

Reach lengths based on digitized centerline 2005 NAIP Imagery

Up- and down-stream elevations taken from USGS DEM

U = Velocity *H* = Depth

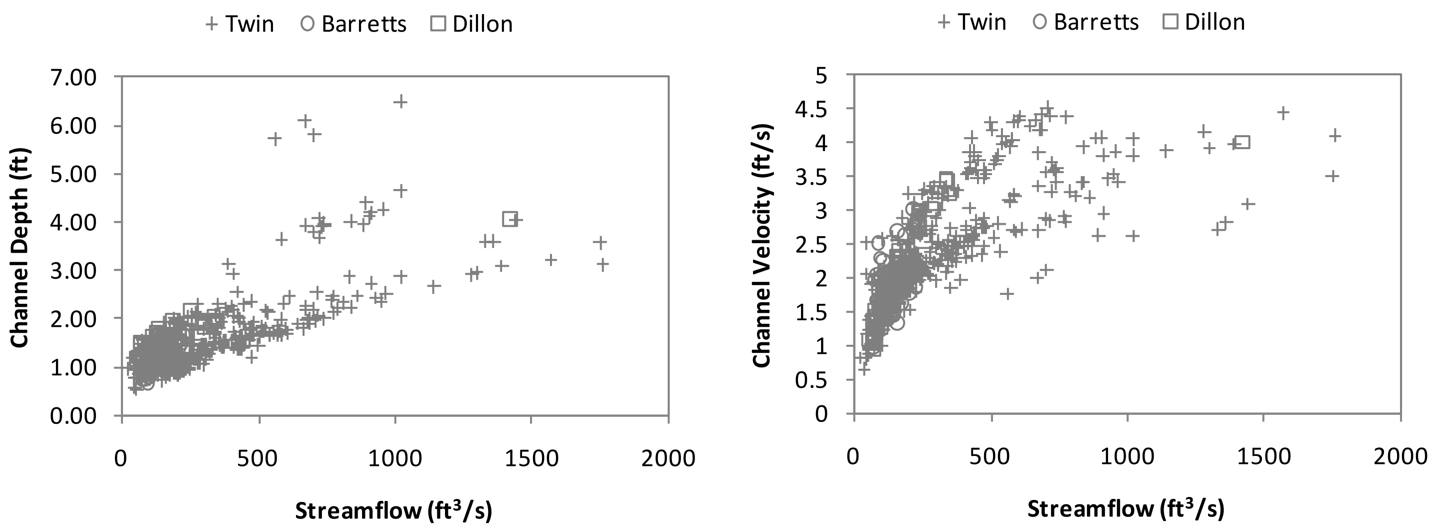

Figure B5-8. Rating curve compilation for gages on the Beaverhead River.

Data from USGS 06016000 Beaverhead River at Barretts MT, USGS 06017000 Beaverhead River at Dillon MT, and USGS 06018500 Beaverhead River near Twin Bridges MT.

B5.7 SHADE

Shade was estimated using Shadev3.0.xls. Segmentation identical to the Q2K model was used (i.e., 36 reaches) and average conditions for each species type, condition, and age class determined during 2009 (Water & Environmental Technologies, 2009) were used in the analysis (**Table B5-4**). Shade was also measured along with dominant vegetation type, height, offset/overhang, canopy density, and channel dimensions to validate the model.

Table B5-4. Shade and morphological data for the Beaverhead River.

Location	Dominant Veg. Type	Topo. + Veg. Shade (%)	Overhang (ft)	Veg. Height (ft)	Density (%)	Wetted Width (ft)
Upstream of Grasshopper Creek (BHS-6)	Willow	2.4	0	7	77	69
Barrett's campground (BHS-5)	Cottonwood	8.3	0	66	68	49
Anderson Lane (BHS-4)	Grass-sedge	0.9	0	3	18	42
Highway 41 (BHS-3)	Willow	0.3	0	13	12	43
Silverbow Lane (BHS-2)	Grass-sedge	0.6	0	3	53	64
DS confluence with Ruby (BHS-1)	Grass-sedge	0.1	0	2	65	75

Note: only the dominant vegetation at each site shown.

Values from **Table B5-4** were averaged to provide reach-wide estimates for the modeling (**Table B5-5**). Simulated shade results are shown in **Figure B5-9** (against observed data) and mean daily values are quite low, less than 10%. Subsequently shade is not of great importance to the heat balance on the Beaverhead River. This will be reiterated in later sections. **Table B5-6** identifies the input parameters used in the calculation.

Table B5-5. Beaverhead River riparian shade conditions from aerial assessment and 2009 field data.

Code	Source	Description	Height (m)	Density %	OH (m)
700	DEQ	willow complex - sparse	2.5	63	0.1
701	DEQ	willow complex - dense	2.7	73	0.4
702	DEQ	dmd (cottonwood) - medium, sparse	15.0	68	0.0
703	DEQ	grass/rush/sedge riparian	0.6	61	0.0
704	DEQ	50% willow 50%grass-sedge	1.6	62	0.0
705	DEQ	css - conifer, small, sparse	15.0	68	0.0

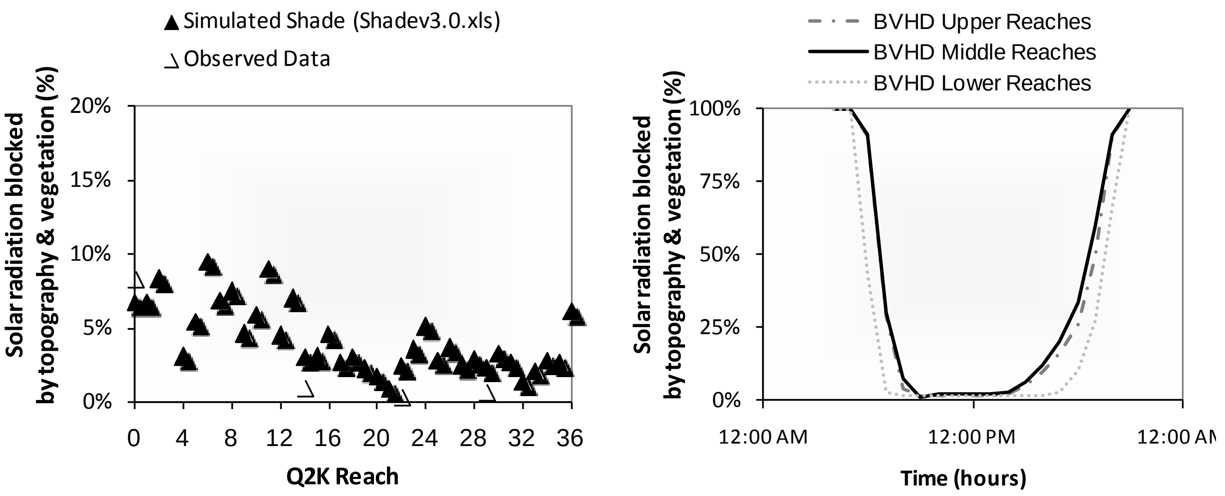

Figure B5-9. Simulated and observed longitudinal shade on the Beaverhead River.
(Left panel) Simulated and observed longitudinal shade from the Shadev3.0.xls model. Note that the simulated values pattern the field measurements well. (Right panel). Diurnal shade for one of the reaches. Shade from both vegetation and topography was considered.

Table B5-6. Shadev3.0.xls input parameters.

Reach	ID	Aspect from N	NSDZ (bfull)	B (est)	NSDZ	θ W	θ S	θ E	LB	RB
BVHD01	Smitch Rebich Ditch (divert)	25	25.0	19.0	3.0	10	6	6	701	701
BVHD02	Barretts, East Bnch, Cany, etc.	30	18.5	14.0	2.0	9	5	5	701	700
BVHD03	Horton Haines Ditch (divert)	40	16.5	12.0	2.0	10	2	5	700	702
BVHD04	ASPCTB-1	75	15.5	12.0	2.0	3	1	3	700	703
BVHD05	ASPCTB-2	50	15.0	11.0	2.0	2	2	4	700	703
BVHD06	Van Camp Ditch (divert)	10	16.5	12.0	2.0	2	2	3	700	700
BVHD07	Poindexter Slough (divert)	30	18.5	14.0	2.0	2	2	3	700	700
BVHD08	Van Camp Slough (return)	15	19.5	15.0	2.0	2	2	3	700	700
BVHD09	Poindexter Slough (return)	50	20.0	15.0	3.0	2	1	3	700	700
BVHD10	Westside Canal (divert)	40	18.5	14.0	2.0	4	2	3	700	700
BVHD11	USGS 06017000 (Dillon)	70	19.5	15.0	2.0	11	2	2	702	700
BVHD12	Selway Ditch (divert)	60	17.0	13.0	2.0	5	2	2	700	701
BVHD13	Hayden Morton Ditch (divert)	40	15.5	12.0	2.0	2	2	3	700	700
BVHD14	(Anderson Br)/Bishop Ditch	25	17.5	13.0	2.0	1	2	2	704	704
BVHD15	1872 Ditch (divert)	30	16.0	12.0	2.0	1	3	1	703	703
BVHD16	ASPCTB-3	350	15.0	11.0	2.0	2	1	1	703	703
BVHD17	Stone Creek	35	17.5	13.0	2.0	2	3	1	703	703
BVHD18	Brown Ditch (divert)	25	17.5	13.0	2.0	2	3	1	703	703
BVHD19	ASPCTB-4	35	20.5	15.0	3.0	2	2	2	703	703
BVHD20	ASPCTB-5 (Albers Slough)	50	21.0	16.0	3.0	2	2	2	703	703
BVHD21	Co-op Canal: Charlton Slough	80	22.0	17.0	3.0	2	2	2	703	703
BVHD22	USGS 06018500 (Twin Br)	90	21.0	16.0	3.0	2	2	2	700	700
BVHD23	Trout Creek	110	20.0	15.0	3.0	4	1	2	701	704
BVHD24	ASPCTB-6	40	19.5	15.0	2.0	2	1	2	700	704
BVHD25	Muleshoe Canal (divert)	30	17.5	13.0	2.0	1	1	1	703	703
BVHD26	Baker Ditch (divert)	355	20.5	15.0	3.0	2	1	1	703	704
BVHD27	ASPCTB-7	35	18.0	14.0	2.0	1	1	2	703	703

Table B5-6. Shadev3.0.xls input parameters.

Reach	ID	Aspect from N	NSDZ (bfull)	B (est)	NSDZ	θ W	θ S	θ E	LB	RB
BVHD28	Silver Bow (Giem) Bridge	30	17.0	13.0	2.0	3	1	2	703	703
BVHD29	41-2 Lateral Wasteway (return)	30	21.0	16.0	3.0	3	2	1	703	705
BVHD30	Spring Creek-California Slough	355	20.0	15.0	3.0	1	3	1	703	703
BVHD31	Schoolhouse Slough	30	18.0	14.0	2.0	2	3	1	703	703
BVHD32	Greenhouse Slough	65	19.5	15.0	2.0	3	2	1	703	703
BVHD33	Ruby River	40	20.5	15.0	3.0	2	3	1	703	703
BVHD34	Jacobs Slough	0	23.0	17.0	3.0	2	3	1	703	703
BVHD35	Owsley Slough	330	25.0	19.0	3.0	3	2	2	703	703
BVHD36	BVHD Rvr (MadCo Fairgr)	20	25.0	19.0	3.0	2	3	2	701	703

θ = Degrees, N = North, E = East, W = West
NSDZ = Near Stream Disturbance Zone

B5.8 BOUNDARY CONDITIONS

Surface water boundary conditions were specified for remaining tributary and point source inputs using field data. They were averaged over the analysis period similar to other data. Temperature at each location was varied as a sinusoid per the Q2K documentation (Chapra et al., 2008b) which necessitated specification of mean daily temperature, time of maximum, and range (**Figure B5-10**, left panel). A comparison of how the approximation correlated with measured data is shown in **Figure B5-10** (right panel). A summary of all tributary boundary conditions are shown in **Table B5-7**.

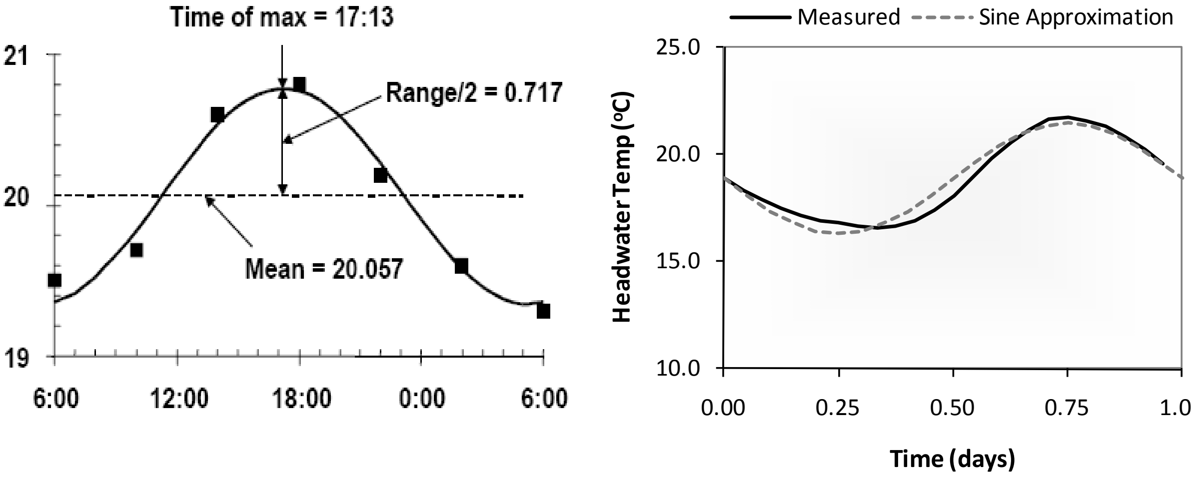

Figure B5-10. Comparison of diurnal sinusoid with respect to field data
(Left panel). Methodology used to approximate diurnal conditions. (Right panel) Sinusoid approximation at one location in the model network. Note that the estimates are very close to the observed diel cycle in the river.

Table B5-7. Beaverhead River boundary conditions.

Name	Location (mi)	Abstraction (ft^3/s)	Inflow (ft^3/s)	mean (°F)	range/2 (°F)	Time of max
USGS 06016000 (Barretts)	66.3	Headwater boundary condition				
Smith Rebich Diversion	65.3	27.7	n/a	n/a	n/a	n/a
Barretts Diversion Dam	64.9	285.4	n/a	n/a	n/a	n/a
Horton Haines Diversion	64.4	25.7	n/a	n/a	n/a	n/a

Table B5-7. Beaverhead River boundary conditions.

Name	Location (mi)	Abstraction (ft^3/s)	Inflow (ft^3/s)	mean (°F)	range/2 (°F)	Time of max
Van Camp Diversion	61.8	13.2	n/a	n/a	n/a	n/a
Poindexter Slough (divert)	60.8	33.1	n/a	n/a	n/a	n/a
Van Camp Slough (return)	57.2	n/a	6.9	67	36	5:30 PM
Poindexter Slough (return)	56.3	n/a	36.2	63	37	4:00 PM
Westside Canal Diversion	53.0	72	n/a	n/a	n/a	n/a
USGS 06017000 (Dillon)	52.7	0	n/a	n/a	n/a	n/a
Selway Ditch (divert)	50.6	5.4	n/a	n/a	n/a	n/a
Hayden Morton Ditch (divert)	46.6	16.5	n/a	n/a	n/a	n/a
BVHD Rvr Anderson/Bishop Ditch	40.2	11.1	n/a	n/a	n/a	n/a
1872 Ditch (divert)	39.0	10.5	n/a	n/a	n/a	n/a
Stone Creek	35.9	n/a	1.7	55	38	4:30 PM
Brown Ditch (divert)	35.5	19.1	n/a	n/a	n/a	n/a
ASPCTB-5 (Albers Slough)	30.2	n/a	13.5	66	40	5:30 PM
Co-op Canal (divert)	26.9	23.6	n/a	n/a	n/a	n/a
Charlton Slough (return)	26.9	n/a	11.6	60	41	5:00 PM
BVHD Rvr USGS 06018500 (Twin Br)	25.8	0	n/a	n/a	n/a	n/a
Trout Creek	25.5	n/a	0.4	64	41	5:00 PM
ASPCTB-6	23.5	0	n/a	n/a	n/a	n/a
Muleshoe Canal (divert)	21.9	26.5	n/a	n/a	n/a	n/a
Baker Ditch (divert)	20.7	14.8	n/a	n/a	n/a	n/a
ASPCTB-7	13.2	n/a	n/a	n/a	n/a	n/a
BVHD Rvr Silver Bow (Giem) Bridge	9.6	n/a	n/a	n/a	n/a	n/a
41-2 Lateral Wasteway (return)	8.9	n/a	1.5	69	36	5:00 PM
Spring Creek-California Slough	6.5	n/a	36.7	67	41	5:30 PM
Schoolhouse Slough	4.7	n/a	16.9	68	39	6:00 PM
Greenhouse Slough	3.9	n/a	20.5	68	38	5:30 PM
Ruby River	2.6	n/a	64.4	67	38	6:00 PM
Jacobs Slough	1.7	n/a	5.3	69	40	4:00 PM
Owsley Slough	0.5	n/a	38.2	69	38	6:00 PM
BVHD Rvr (MadCo Fairgr)	0.0	n/a	0	32	32	n/a

B5.9 GROUNDWATER TEMPERATURE

The last consideration in model development is groundwater temperature, which according to Smith and Lavis (1998) can account for large temperature changes in smaller streams (7-9° F). Uthman and Beck (1998) previously demonstrated localized areas of groundwater influx occur in the Beaverhead River and we wished to reflect these appropriately in the model. Therefore the groundwater temperature for the Beaverhead River was calculated using two approaches: (1) from mean annual air temperature as recommended by Theurer, et al., (1984) and (2) through evaluation of the Montana Ground Water Information Center (GWIC) database records. From the first method, mean annual temperature at Dillon ASOS 242404 was 43°F (6°C). The GWIC database indicates a slightly warmer estimate; 51°F based on examination of wells within one mile laterally of the river (**Table B5-8**). We use the GWIC data due to its applicability to the project site and similarity with other locations in the state.

Table B5-8. Groundwater data used in accretion flow determination.
Data from Montana Bureau of Mines and Geology (MBMG) GWIC database[10].

Sample	GWIC ID	Latitude	Longitude	Aquifer	Depth (ft)	Agency	Sample Date	Water Temp. (°F)
1996Q0408	151328	45.234	-112.599	110ALVM	41	MBMG	9/21/1995	46
1996Q0375	109401	45.232	-112.606	111ALVM	29	MBMG	9/14/1995	54
1996Q0379	109402	45.233	-112.617	111ALVM	30	MBMG	9/14/1995	52
1996Q0378	109436	45.228	-112.627	111ALVM	55	MBMG	9/14/1995	54
1994Q5009	145389	45.228	-112.634	110ALVM	0	DNRC	11/14/1993	45
1991Q5000	109444	45.219	-112.636	111ALVM	60	USGS	8/21/1991	48
1996Q0410	109444	45.219	-112.636	111ALVM	60	MBMG	9/21/1995	51
1996Q0409	151329	45.214	-112.673	110ALVM	84	MBMG	9/21/1995	51
1991Q5001	149185	45.214	-112.672	110ALVM	124	USGS	8/22/1991	49
1994Q0353	133400	45.208	-112.674	110ALVM	85	USGS	8/27/1993	50
1994Q0357	133402	45.208	-112.674	110ALVM	20	USGS	8/27/1993	50
1994Q0503	133403	45.218	-112.654	110ALVM	31	USGS	9/15/1993	53
2004Q0138	133390	45.191	-112.673	110ALVM	18	MBMG	9/17/2003	52
1994Q0505	133398	45.181	-112.702	110ALVM	92	USGS	9/14/1993	51
1994Q0522	133394	45.164	-112.686	110ALVM	49	USGS	9/2/1993	52
1994Q0355	133396	45.153	-112.704	110ALVM	51	USGS	8/28/1993	49
1994Q0515	133409	45.140	-112.714	110ALVM	53	USGS	9/1/1993	57
1994Q0502	133397	45.134	-112.730	110ALVM	51	USGS	9/14/1993	49
2004Q0176	133397	45.134	-112.730	110ALVM	51	MBMG	10/1/2003	51

B5.10 WASTEWATER TREATMENT FACILITY INFLUENT

The last input consideration was the Dillon, MT wastewater treatment plant (WWTP). Inflow was determined from MPDES permit records for the month of August 2005 and consisted of a flow rate of 450,000 gallons per day and a temperature of 67.3 °F. There was insufficient data to prescribe temperature from the Dillon WWTP in the model, so data from Darby, MT (a similar lagoon system) was used instead.

B6.0 MODEL CALIBRATION

The calibration involved adjustment of the model representation to reflect the observed data from Sessoms and Bauder (2005). Fourteen locations were used for the calibration. These were: (1) Barrets Diversion Dam, (2) Van Camp Ditch, (3) Poindexter Slough (diversion), (4) Westside Canal, (5) Selway Ditch, (6) Hayden Morton Ditch, (7) Beaverhead River at Anderson Bridge, (8) 1872 Ditch, (9) Brown Ditch, (10) Co-op Canal, (11) Muleshoe Canal, (12) Bishop Canal, (13) Silver Bow (Giem) Bridge, and (14) Madison County Fairgrounds. Model calibration procedures are described in detail elsewhere (American

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[10] A screening procedure was used to filter un-representative wells out of the GWIC database. This included the following:

1. Sorting on geologic code - keeping only ALVM
2. Sorting on date - removing data that is not +/- 2 months of study date
3. Removing data older than 20 years
4. Removing data with null temperature values (0.0 degrees)
5. Removing data greater than 2 standard deviations from the mean.

Society for Testing and Materials, 1984; Reckhow and Chapra, 1983; Thomann, 1982). Details specific to the Beaverhead River are described in the following sections.

B6.1 EVALUATION CRITERION

Two statistical methods were selected to evaluate the sufficiency of the Beaverhead River model. These were relative error (RE) and root mean squared error (RMSE). RE is a measure of the percent difference between observed and predicted ordinates. It was calculated as shown in **Equation B6-1**, where *RE* = relative simulation error, T_o = observed temperature, and T_s = simulated temperature. RE should be less than ±5.0% at all locations (or ±1°F respectively). Overall system RE should approach 0%.

(Equation B6-1)

$$RE = \frac{\left(T_s - T_o\right)}{T_o}$$

Root mean squared error (RMSE) was also used which is a common objective function for water quality model calibration (Chapra, 1997; Little and Williams, 1992). It compares the difference between the modeled and observed ordinates and uses the squared difference as the measure of fit. Thus a difference of 10 units between the predicted and observed values is one hundred times worse than a difference of 1 unit. Squaring the differences also treats both overestimates and underestimates by the model as undesirable. The root of the average difference is then taken. Calculation of RMSE is shown in **Equation B6-2** (Diskin and Simon, 1977), where *n*=the number of observations being evaluated.

(Equation B6-2)

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{i_n}[T_o(i) - T_s(i)]^2}$$

B6.2 RESULTS AND DISCUSSION

The results and discussion regarding the Beaverhead River Q2K model calibration are presented below.

B6.2.1 Hydrology

Simulated and observed hydrology are shown in **Figure B6-1**. There was no model error (RE and RMSE were 0% and 0°F) because we directly implemented the steady-state water balance outlined in **Section B5.0**. Features of significance were the diversion at Barretts which withdrew approximately half of the flow in the river and then numerous smaller diversions that incrementally deplete flow until it a minimum is reached near Silver Bow (Giem) Bridge. Gains occur thereafter from sloughs out of the Big Hole River and the Ruby River. The lowest flow was approximately 50 ft^3/s.

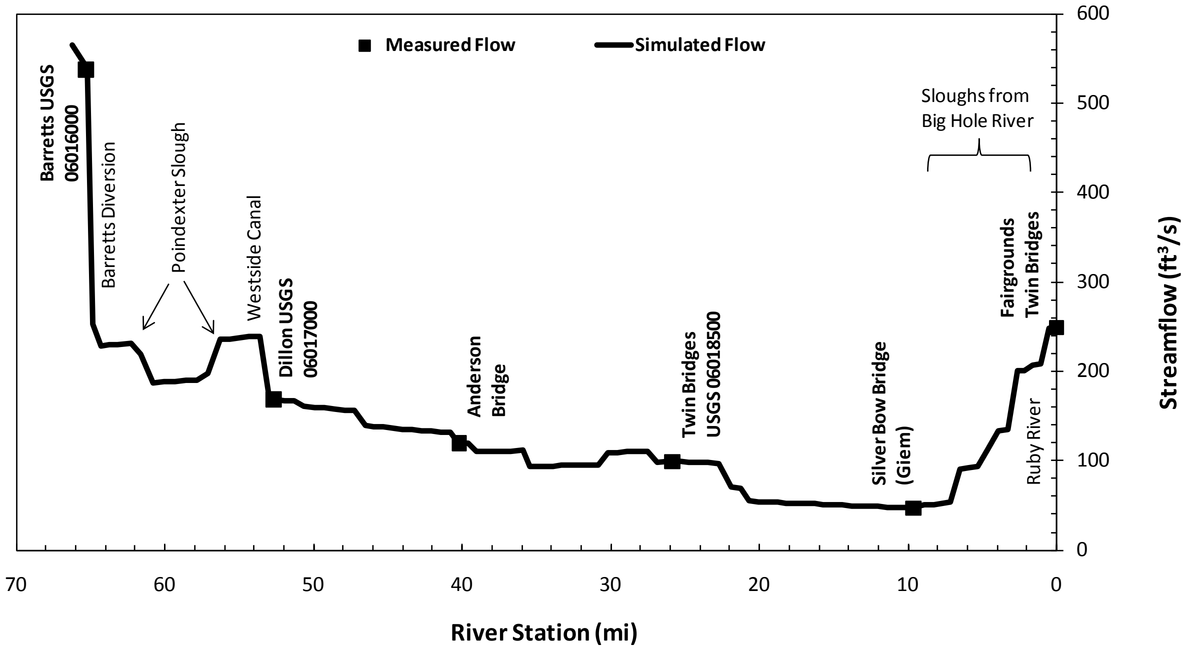

Figure B6-1. Streamflow calibration for the Beaverhead River.
Longitudinal plot of streamflow over the August 4-7, 2005 calibration period.

B6.2.2 Hydraulics

A plot of simulated channel wetted width is shown in **Figure B6-2**. RE and RMSE for the simulation were 4.5% and 12.7 ft respectively, which is adequate for our purposes. Hydraulic calibration involved adjustment of both depth and velocity coefficients until the observed and simulated indicators of (1) observed diel maximum and minimum peaks at each calibration node and (2) simulated wetted widths were in agreement. From examination of our results, it appears as if the model represents channel attributes reasonably. Observed values in the figure were taken from field data as well as analysis of rating curves for each of the USGS gage sites[11]. Only a very basic summary of hydraulics is presented here given the limited data in the watershed.

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[11] Channel wetted widths were determined from the rating curves described in **Section B5.5** which were then applied to the flow conditions during 2005 to estimate velocity, depth, and wetted width using a wide rectangular channel approximation.

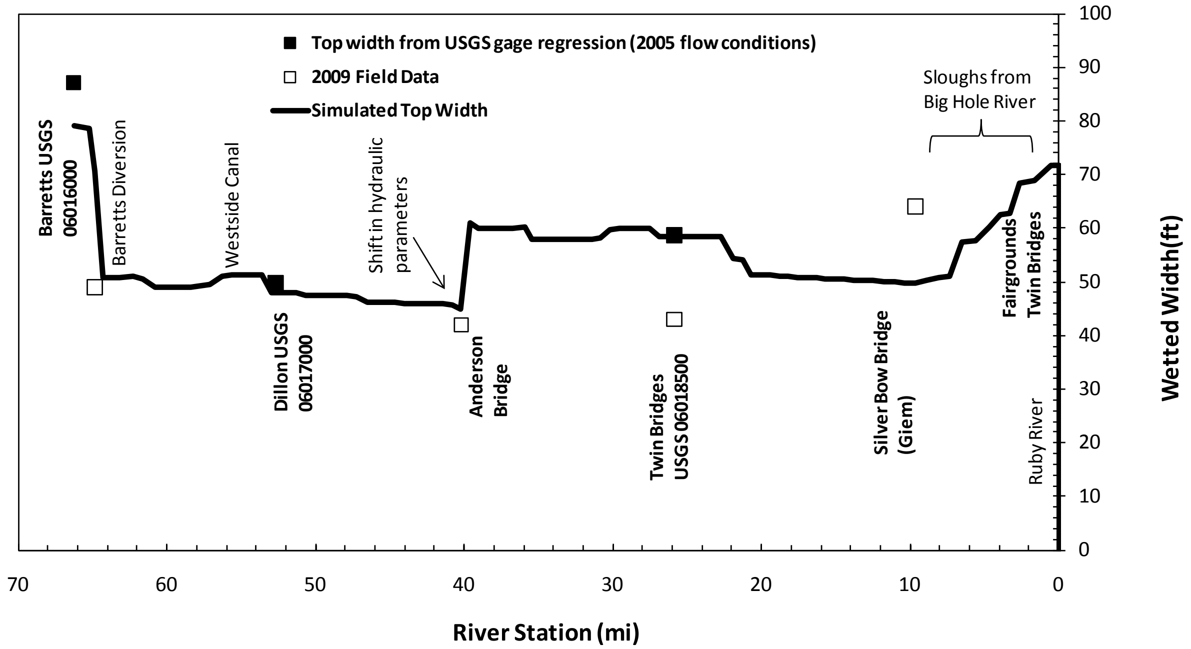

Figure B6-2. Simulated Beaverhead River hydraulics.
Longitudinal plot of over the August 4-7, 2005 calibration period.

B6.2.3 Water Temperature

Simulated minimum, mean, and maximum daily water temperatures are shown in **Figure B6-3**. RE and RMSE were quite good at 0.01% and 0.91°F, which included the exclusion of one data point which was clearly in error[12] (mile 46.6). Overall, the river generally increases in temperature (and diurnal flux) from the headwater boundary to mile 12, and then has a short region of cooling coincident with increased flow volume. The addition of the WWTP discharge was found to have a small effect in the middle river and actually caused a decrease in maximum temperatures of less than 0.05°F for several miles downstream (i.e., the WWTP effluent is cooler than the river).

In summary, very little calibration was needed to accurately simulate water temperature after physical constraints in the previous sections were addressed (i.e., hydrology and hydraulics). The calibration mainly involved adjustment of influent nonpoint source water temperature by attributing it to either groundwater (cold water) or unaccounted return flow (warm water). The procedure for ascribing the relative relationship was determined by modifying the percentage of each component until temperature simulations were within the desired criterion. Composite statistics for the temperature simulation are provided in **Table B6-1**.

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[12] According to several authors (Barnwell, Jr. et al., 1989; Theurer et al., 1984) temperature loggers are easily affected by local environmental conditions and model users should be skeptical of observed data when major unexplained differences between observed and simulated values occur. Selway ditch (mi 50.6) and Hayden Morton ditch (mi 46.6) and are two such examples.

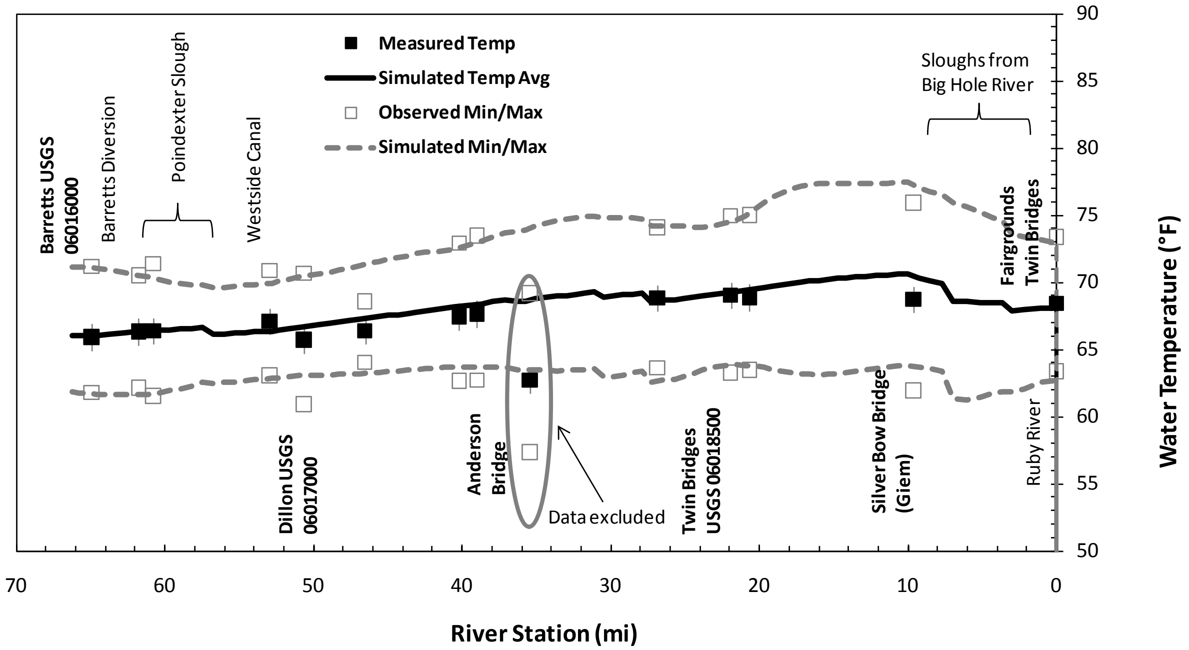

Figure B6-3. Simulated and observed water temperatures for the Beaverhead River during 2005.

Table B6-1. Calibration statistics for each calibration node

Calibration Node	Distance x(mi)	Mean Temp (°F)	Min Temp (°F)	Max Temp (°F)	RE			Error		
					Mean	Min	Max	Max	Min	Max
Barretts	64.9	66.1	61.7	71.0	0.00	0.00	0.00	0.02	0.02	0.02
Van Camp	61.8	66.3	61.7	70.4	0.00	-0.01	0.00	0.00	0.27	0.03
Poindexter	60.8	66.4	61.8	70.2	0.00	0.00	-0.02	0.00	0.05	1.41
Westside Canal	53.0	66.4	62.8	69.9	-0.01	0.00	-0.01	0.50	0.07	0.97
Selway Ditch	50.6	66.8	63.0	70.5	0.02	0.03	0.00	1.17	4.49	0.03
Hayden Morton	46.6	67.3	63.3	71.4	0.01	-0.01	0.04	0.87	0.62	8.03
Anderson Bridge	40.2	68.3	63.7	72.8	0.01	0.02	0.00	0.72	1.08	0.01
1872 ditch	39.0	68.4	63.7	73.0	0.01	0.02	-0.01	0.56	0.92	0.21
Brown ditch	35.5	68.7	63.4	74.2	Data excluded from analysis					
Co-op canal	26.9	68.6	62.8	74.2	0.00	-0.01	0.00	0.05	0.76	0.01
Muleshoe canal	21.9	69.3	63.9	74.6	0.00	0.01	-0.01	0.06	0.39	0.16
Baker Ditch	20.7	69.5	63.8	75.4	0.01	0.00	0.01	0.42	0.10	0.15
Giem Bridge	9.6	70.4	63.7	77.1	0.02	0.03	0.01	2.63	3.23	1.20
Madison Co. Fair.	0.0	68.1	62.6	73.0	0.00	-0.01	-0.01	0.09	0.61	0.20
				Averages	**RE = 0.01**			**RMSE = 0.91**		

B7.0 WATERSHED MANAGEMENT SCENARIOS

The calibrated Q2K model was subsequently used to determine the impact of potential watershed management alternatives on the flow and temperature regime of the Beaverhead River. Six different management scenarios were evaluated: (1) baseline conditions; (2) two improved riparian habitat scenarios, (3) an increased flow scenario, (4) a naturally occurring condition scenario, and (5) an unmodified hydrology scenario. Results of the model simulations are described below and will be used to determine the amount of stream temperature impairment, and the relative effectiveness of management changes on the warm weather temperatures in the river.

B7.1 BASELINE

The baseline scenario describes existing conditions in the watershed and is merely a reflection of the calibration. In review, baseline modeling was completed during drought and in low flow conditions. The simulation results have been documented in prior sections and indicate reasonable good water temperature calibration based on performance statistics of RE and RMSE. Water temperature was shown to increase from the upstream boundary near Barretts until Silver Bow (Giem) Bridge and then decrease thereafter. Simulated values from the baseline form the basis for which all other scenarios will be compared.

B7.2 IMPROVED RIPARIAN HABITAT SCENARIO

Enhanced riparian conditions were simulated on the Beaverhead River to evaluate the influence of shade along the river corridor. Previous work suggests shade could be a possible contributor to river impairment and could potentially be improved. Consequently, two different shade conditions were evaluated: (1) where reference willow canopy was present along the entire reach (which is likely the best possible condition under reservoir hydrology) and (2) where vigorous cottonwood stands were present due to natural conditions (i.e. no human impacts or native hydrology).

Simulations were implemented by simply changing riparian cover conditions in the model. For example in the first scenario, shade was changed to “dense willow complex” which effectively provided more shade for the river. The second scenario was done identically, but with cottonwoods. The results of these scenarios are shown in **Figure B7-1**. Relative to baseline conditions, the temperature effect of both scenarios decreases the maximum and minimum temperatures over the entire modeling reach. The cottonwood shade scenario resulted in a significant decrease of river temperatures of 5.2 ^{o}F compared to the willow shade scenario which decreased temperatures less than 1^{o}F. This shows that under the current reservoir regulated hydrology, riparian enhancements will provide limited temperature improvement to the river if implemented (unless continuous tree-planting programs are instated). Tabular results for this scenario (and all others) are shown in **Table B7-1** at the end of this section.

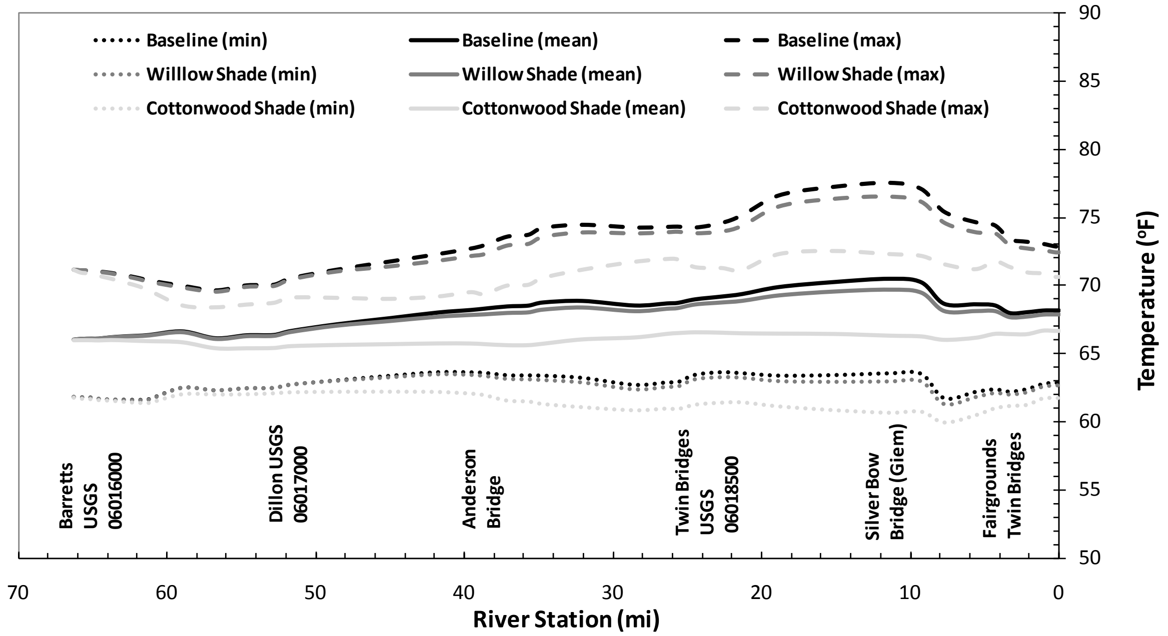

Figure B7-1. Simulated reference shade conditions for the Beaverhead River.

B7.3 INCREASED FLOW SCENARIO

The effect of water use on instream flow and water temperature was considered. Although Montana standards do not necessarily apply to existing water rights, it is important to assess the cumulative effect of these practices on the overall thermal regime of the river. The simple relationship presented by Brown (1969) suggests that large volume streams are less responsive to temperature changes than low flow streams and will also exhibit smaller diel fluctuations. The scenario consisted of keeping the 20% water savings gained through improved irrigation delivery and allowing that water savings to flow down the lower Beaverhead River (any voluntary water savings and subsequent instream flow augmentation must be done in a way that protects water rights).

The 20% water savings was based on three grant proposals submitted to the state of Montana by the East Bench Irrigation District (EBID). Two of the grants were for lining 2,000 (Montana Department of Natural Resources and Conservation, 2007) and 1,175 (Montana Department of Natural Resources and Conservation, 2009) feet of main canal respectively which were estimated by EBID to reduce annual leakage by 3,600 and 2,585 acre-feet. The third grant was to replace slide gates at three existing check structures (Montana Department of Natural Resources and Conservation, 2011) which was expected to conserve another 7,855 acre-feet. Hence the total annual water savings by the three proposals was 14,040 acre-feet or 20.8% of the 67,260 acre-feet diverted annually between 1996 and 2005 (except for 2004 when no water was diverted) was. This value was rounded to 20% for the scenario and reflects the potential improvement through implementing reasonable BMPs. Additional reductions may be feasible through other canal improvements or improvement in irrigation delivery and efficiency in other areas of the watershed, but it is unknown whether these are reasonable or feasible at this time.

Results of the increased flow scenario are shown in **Figure B7-2**. Based on model simulations, the 20% savings would result in an additional 117 ft^3/s of water in the river and would lead to maximum reductions of 3°F between miles 10 and 20. Minimum temperatures actually increased nearly the same

(2.6°F) due to added thermal inertia. This scenario indicates that reasonable irrigation delivery improvements can have a significant effect on the overall temperature regime in the river.

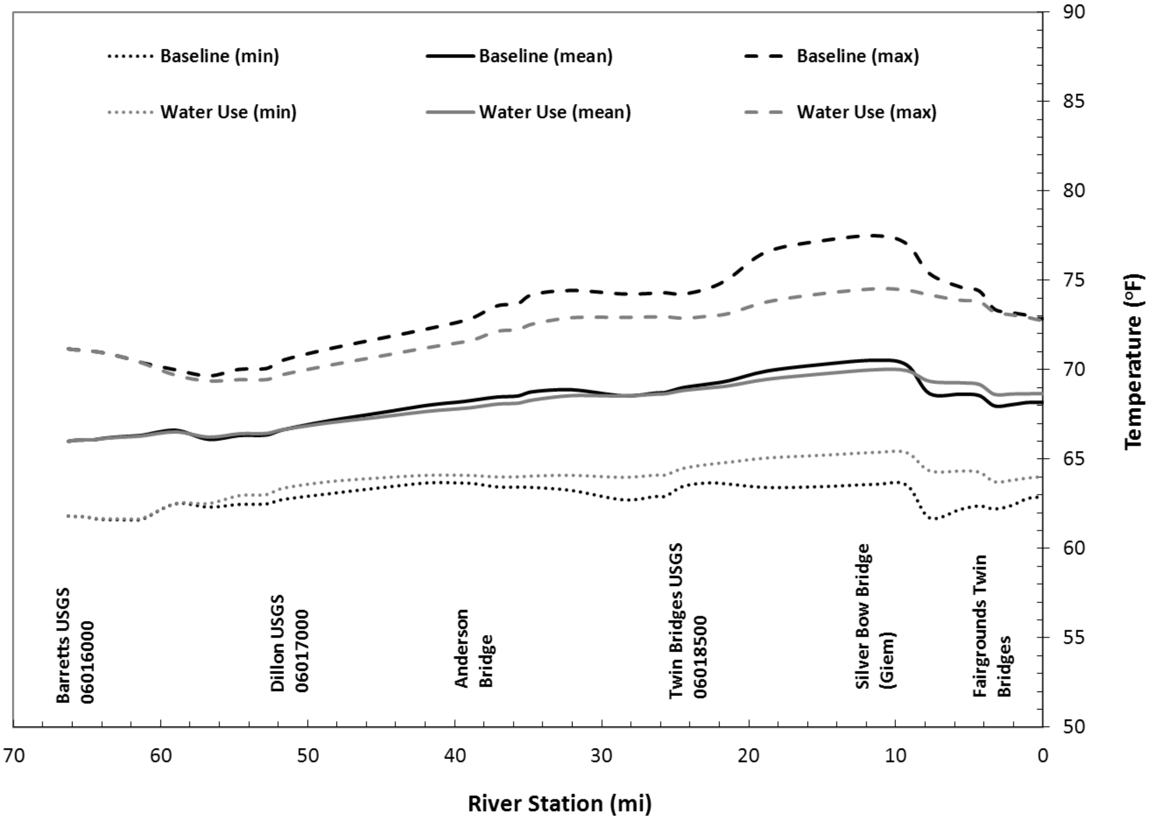

Figure B7-2. Increased flow (water use) scenario on the lower Beaverhead River

B7.4 NATURALLY OCCURRING CONDITION SCENARIO

The naturally occurring scenario represents lower Beaverhead River water temperatures when all reasonable land, soil, and water conservation practices are implemented (**ARM 17.30.602**). Pursuant to 75-5-306, Montana Code Annotated (MCA) "Conditions resulting from the reasonable operation of dams at July 1, 1971" are also considered natural. Thus, this scenario establishes the bar for which the allowable 0.5°F temperature increase is compared (refer to **Section B1.2**). Assumptions used in the development of the naturally occurring scenario include the following: (1) shade conditions as described in the shade scenario (willow complex) and (2) a 20% reduction in the rate of diverted flow as described in the water use scenario.

Results of the naturally occurring scenario are shown in **Figure B7-3**. The scenario indicates the river is impaired extending from approximately mile 56 downstream to the confluence with the Big Hole River (mile 0). The largest temperature increase over baseline condition is 3.7°F at mile 11.4. The impairment is believed to be primarily related to irrigation based on evaluation of the previous scenarios.

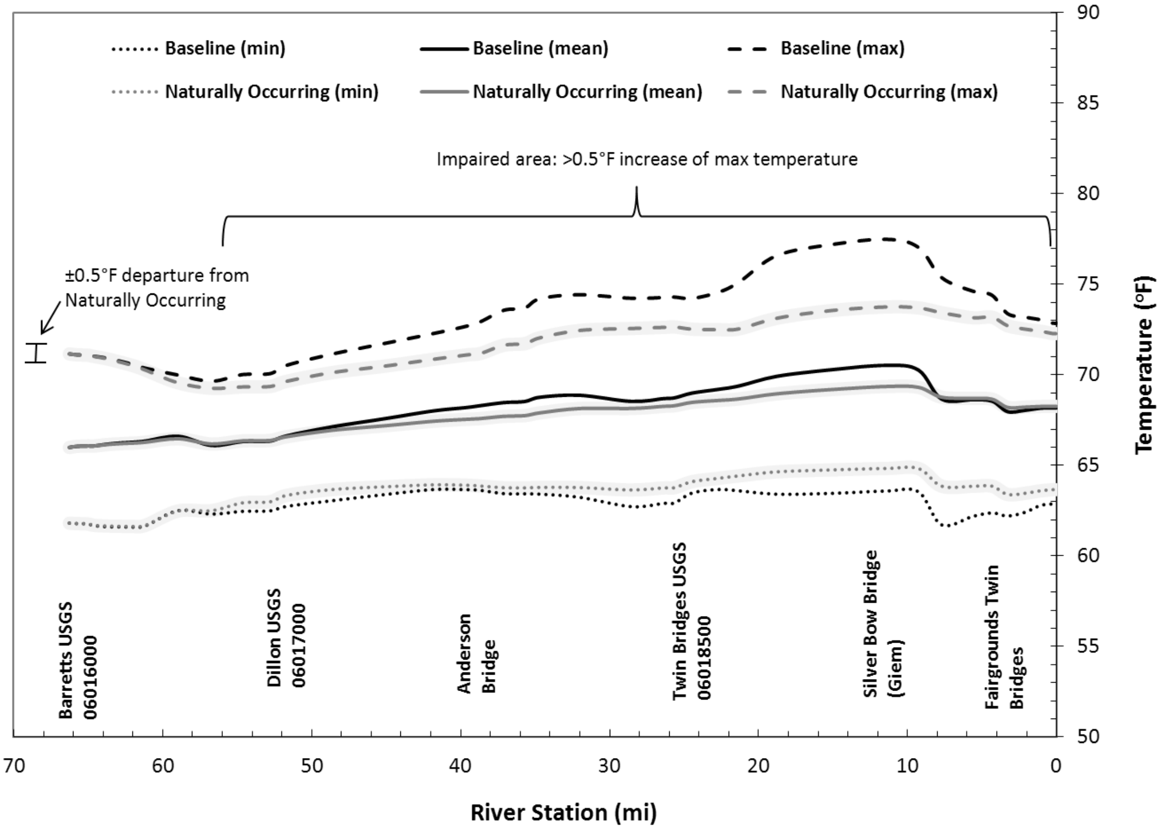

Figure B7-3. The maximum naturally occurring temperature relative to the existing condition (baseline scenario) and the allowed temperature

B7.5 UNMODIFIED HYDROLOGY SCENARIO

The unmodified hydrology scenario reflects the temperature regime that would be expected absent of the influence of humans. While this scenario is clearly not realistic from a socio-economic implementation standpoint, it does allow us to characterize the extent of departure from original hydrologic conditions and evaluate the maximum potential improvement in the watershed. It also may be helpful in future resource conservation efforts. For the purpose of this study, unmodified hydrology was defined as the removal of all human influences that affect the river. Unmodified hydrology scenario assumptions included the following: (1) reference shade conditions by incorporating 50% willows and 50% cottonwoods along the river, (2) decreased width to depth ratios (3) no irrigation or consumptive water use, (4) removal of CC and Lima dam, and (5) removal of the Dillon WWTP discharge.

Evaluation of unmodified hydrology first required estimation of original flows within the river. The CC dam began altering the flow regime in the study area in 1964. Prior to 1964 the river was still modified to a lesser extent by the Lima dam upstream. The annual median hydrograph from the USGS Beaverhead at Barretts gage (#06016000) both pre- and post-construction of the CC dam is shown in **Figure B7-4**. Several other unregulated streams/rivers in the project vicinity are also shown (Grasshopper Creek, USGS 06015500 and the Big Hole River near Melrose, USGS 06025500) for comparative purposes[13]. The dam extends the period of high flow into the latter parts of the summer months to supply irrigation water which subsequently provides additional flow that would otherwise not be present. To estimate this increase, the influence of storage in the Lima Reservoir[14] (which was constructed in 1902) was removed from the pre-Clark Canyon dam hydrograph at Barrets. The result was that the original flow during the modeling period (August 5th) is likely around 180 ft^3/s, or about 32% of the existing flow (564.4 cfs).

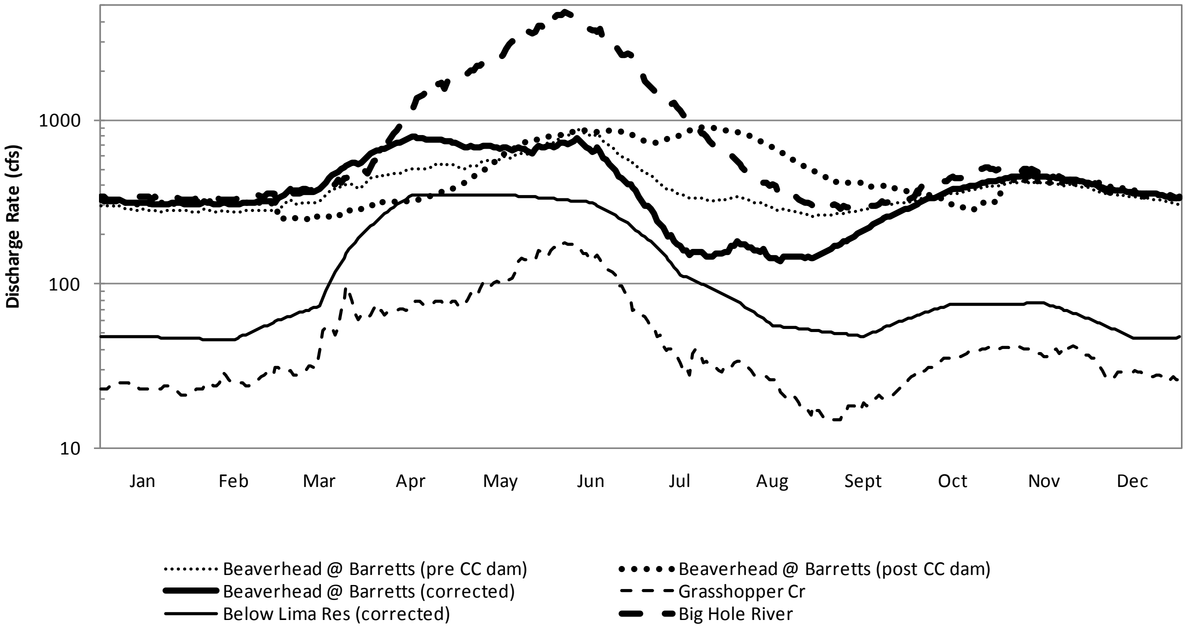

Figure B7-4. Median discharge rates corrected for dam influences.

Results of the unmodified hydrology scenario are shown in **Figure B7-5**. Clearly the river's thermal regime has been significantly altered and the cumulative effect is very apparent. The results show a significant improvement (decrease) of the maximum temperatures throughout most of the modeling reach, with a maximum temperature decrease of 6.4°F at mile 11.4. If the unmodified hydrology scenario only accounted for dam removal, the results would show temperature increases as compared to baseline.

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[13] Each gage station has irrigation diversions above them, so the hydrographs are not considered unaltered, but are applicable to comparison to the Beaverhead River.

[14] The Lima reservoir storage was based on monthly average values of inflow versus outflow from 1989-2011 as recorded by the BOR. The BOR records are only monthly averages and these were interpolated linearly to provide an estimated daily corrections for storage in this analysis.

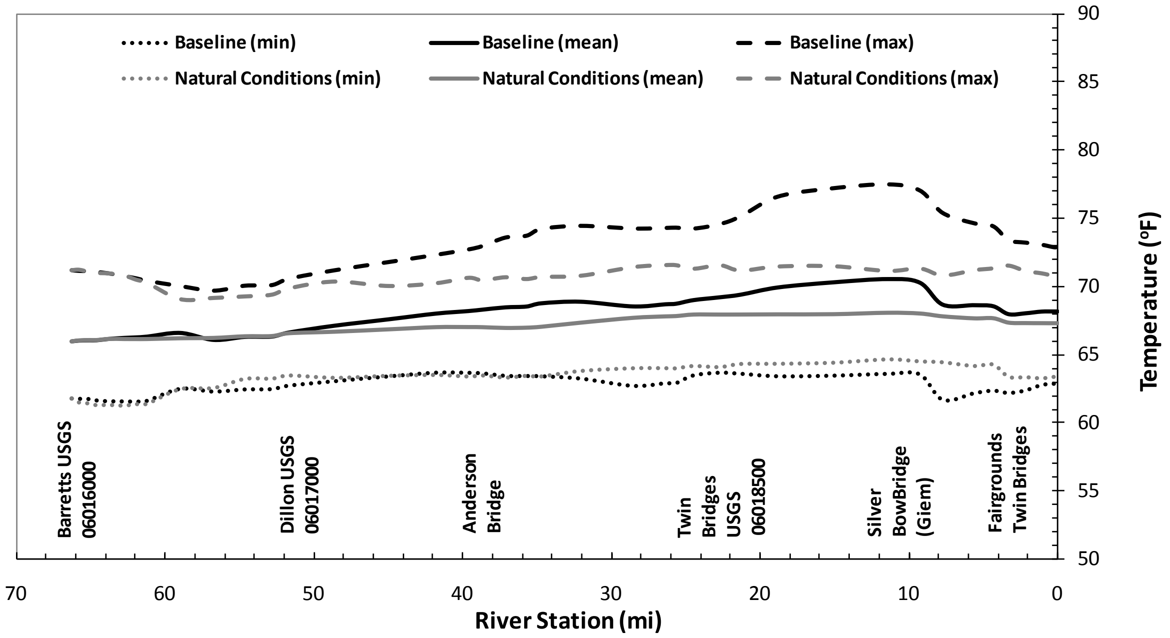

Figure B7-5. Simulated unmodified hydrology conditions on the Beaverhead River.

B7.6 SCENARIO SUMMARY

All of the scenarios detailed in this section are summarized below (**Figure B7-6**). In every situation, water temperature improvements were gained, the most significant being those related to the water volume (i.e., flow). Future conservation efforts should therefore focus on prioritizing restoration efforts with these in mind. A tabular summary of the findings are shown in **Table B7-1**.

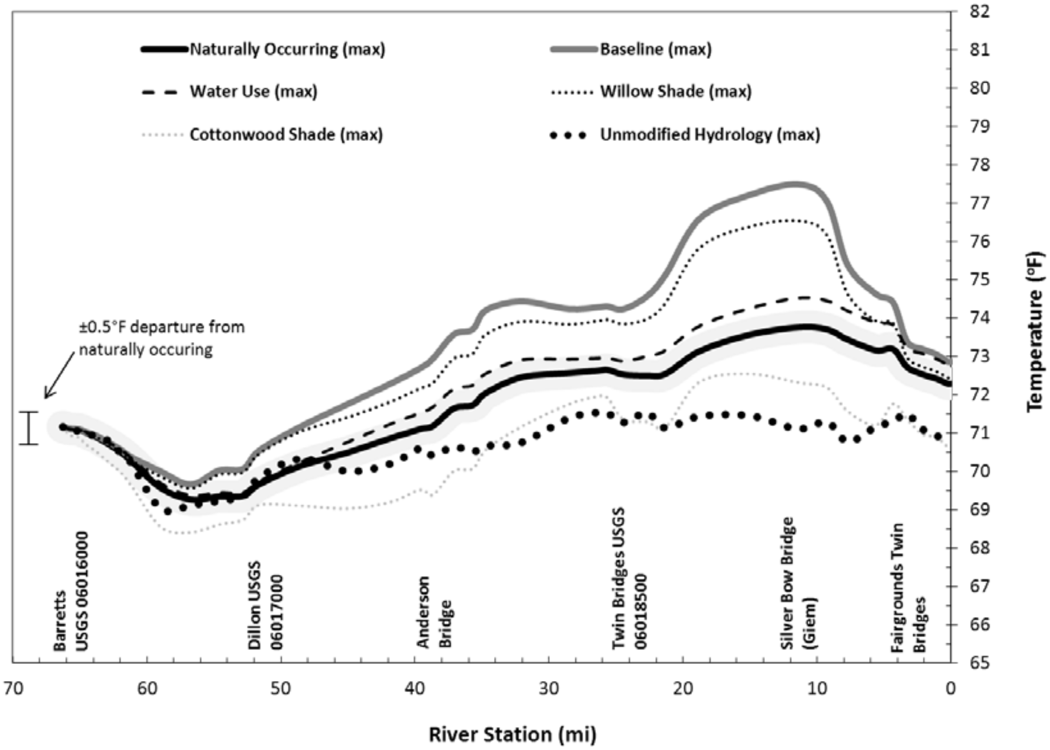

Figure B7-6. Comparison of management scenarios on the Beaverhead River.

Table B7-1. Summary of the management scenario analysis for the Beaverhead River.

Scenario	Mean Temp (°F)	Min Temp (°F)	Max Temp (°F)	Mean ΔT decrease (°F)	Min ΔT decrease (°F)[1]	Max ΔT decrease (°F)
Baseline	67.9	61.6	77.5	NA	NA	NA
Willow Shade	67.6	61.3	76.5	0.4	0	1.0
Cottonwood Shade	66.1	60.0	72.5	2.4	0	5.2
Increased Flow (Water Use)	67.9	61.6	74.5	0.9	0	3.0
Naturally Occurring	67.6	61.6	73.8	1.3	0	3.7
Unmodified Hydrology	67.1	61.3	71.5	2.2	-0.1	6.4

[1] Negative values indicate an increase of temperature compared to baseline.

B8.0 CONCLUSION

Water temperature modeling was completed on the lower Beaverhead River such that the mechanistic relationship between instream water temperature, riparian conditions, and water management practices could be established for the summer critical low-flow period. Through scenario analysis, it was shown that flow alteration was the most crucial management component influencing water temperature in the basin. Existing water temperatures are up to 3.7°F warmer than naturally occurring conditions, and are up to 6.4°F higher than the unmodified hydrological condition. Thus the key management recommendation originating from this study is to protect and reestablish instream flows to the extent possible. Other management scenarios were evaluated to identify the most effective means of the improving water temperature in the river. Decreasing irrigation diversions through better delivery efficiency appears to be the most effective method available. However, riparian improvement could also be used in conjunction with improved irrigation delivery and efficiency to a greater benefit. If riparian improvements were realized, it would reduce the amount of water savings needed from irrigation delivery and efficiency to fully mitigate the current temperature impairment.

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APPENDIX C – UPPER JEFFERSON RIVER TEMPERATURE MODEL

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C1.0 INTRODUCTION

This report details a temperature monitoring and modeling project completed on the Upper Jefferson River mainstem. The Jefferson River (waterbody # MT41G001_010, 83.6 miles from the headwaters to the mouth) is listed as impaired due to temperature on the 2014 303(d) List. This river is listed as a B-1 use class, which is regulated by the Administrative Rules of Montana (ARM 17.30.623 (2) (e)) to meet the following temperature conditions:

(1) A maximum allowable increase of 1 °F above naturally occurring temperatures within the range of 32° to 66° F;
(2) No discharge is allowed which will cause the water temperature to exceed 67ºF within the naturally occurring range of 66ºF to 66.5ºF; and
(3) Where the naturally occurring water temperature is 66.5ºF or greater, the maximum allowable increase in water temperature is 0.5ºF.

A temperature model calibrated with July 2009 field data was used to document existing temperature conditions and typical low flow conditions, and to simulate scenarios using various land and water management practices which would reduce temperature in the Upper Jefferson River to meet B-1 classification requirements.

Listed tributaries for temperature impairments, Big Pipestone Creek (waterbody MT41G002_010, 24.4 miles), and the Boulder River (waterbody MT41E001_030, MT41E001_22, 45.6 miles, which discharge into the Jefferson River within the study area, were not explicitly modeled as a part of this study. Big Pipestone Creek discharges to Whitetail Creek, and the combined flow discharges to the Jefferson Slough. The Boulder River discharges into the Jefferson Slough prior to its confluence with the Jefferson River.

C2.0 PROJECT STUDY AREA

The Jefferson River originates from three headwaters: Ruby River, Beaverhead River and the Big Hole River which drain approximately 7,632 mi^2 of high and mid-elevation topography. The Ruby River and Beaverhead River originate from the Ruby River Reservoir and the Clark Canyon Dam, respectively. The Big Hole River is free of any mainstem water impoundments. The entire watershed is part of United States Geological Survey (USGS) Hydrologic Unit Code (HUC) 10020005 and consists of predominantly of wide alluvial valleys that are constrained at a number of locations by narrowing geological outcrops. Currently, all 83.6 miles of the Jefferson River are listed as impaired for thermal modification (Montana Department of Environmental Quality, 2014). However, given the size of the watershed, the study area has been broken into two distinct planning segments: (1) the upper TMDL planning area (TPA) which extends from the headwaters to the Boulder River/Jefferson Slough, and (2) the lower TPA which extends from Boulder River to the confluence with the Missouri River.

This study is focused on the Upper Jefferson River TPA extending from the headwaters to downstream of the confluence with the Boulder River/Jefferson Slough. The Upper Jefferson River within the study area flows approximately 42 miles past the towns of Silver Star, Waterloo, Whitehall, and Cardwell. The project site is most easily accessed via MT-41 and MT-55 between Whitehall and Twin Bridges and via Point of Rocks Road between Waterloo and Whitehall **Exhibit C1**.

C2.1 CLIMATE

The Upper Jefferson River encompasses a geographic area of approximately 734 mi^2. The average annual rainfall in the Jefferson River Valley (as opposed to the mountainous portions of the watershed) is 9.65 inches and the average annual snowfall is 11 inches (Water & Environmental Technologies, 2006). The 1956 Jefferson County Water Resource Survey (WRS) notes that July and August are sunny, clear, and warm with occasional showers and thunderstorms. The WRS study noted that winds can be strong in the Jefferson River Valley. Cooperative observation station Whitehall, Montana (COOP ID 248910) indicates that from the 1961 – 1990 time period, July and August received 19% of the total precipitation with the heaviest precipitation in May and June (37% of total 10.52 inches). Average minimum and maximum air temperatures during 1961-1990 range from 47.1 ºF to 84.2ºF in July and August (Western Regional Climate Center, 2009).

C2.2 SURFACE WATER

Watershed hydrology is predominately snowmelt-driven and there are two operational USGS gauging stations in the study area. These include: (1) USGS 06026500 *Jefferson River below Twin Bridges, MT*, and (2) USGS 06027600 *Jefferson River at Parsons Bridge near Silver Star, MT*. Typically, spring snowmelt begins in early April, peaks in June, and then rapidly declines in July and August toward baseflow. Tributary inflow to the Upper Jefferson River is dependent on snowmelt and precipitation. The watershed includes two spring fed tributaries: Parsons Slough and Willow Springs. Important tributaries in the study reach include Hell's Canyon Creek, Fish Creek and the Boulder River/Jefferson Slough.

C2.3 GROUNDWATER

A recent groundwater study conducted in a subset of the TPA area was the Groundwater Study of the Waterloo Area (Water & Environmental Technologies, 2006) commissioned by Trout Unlimited for the area near Parsons Slough and Willow Springs, east of the Jefferson River channel. The study showed that the Jefferson River benefited from spring fed tributaries and groundwater inflow in the Waterloo area. Heavy irrigation withdrawals from major ditches at times exceeded surface flows at Twin Bridges, and groundwater and tributary inflow was a primary factor in maintaining streamflow through the middle reaches of the Jefferson.

For this study area, the principal water-bearing formation was unconsolidated alluvium. The alluvial deposits include valley fill, alluvial fan gravels and glacial deposits resulting from outwash derived from either a glacier or glacier dammed lakes. The full alluvium thickness is not well known as wells drilled in the area are generally completed when sufficient water is encountered, well above the alluvial bottom. Information reviewed from driller logs show a coarsening downward sequence consisting of silty clay, sand and coarse gravels.

The water bearing material is characterized as an unconfined aquifer with the water table depth varying throughout the valley. The greatest water table depth within the study area is on the Parrot Bench and ranges from 80 to 180 feet below ground surface (bgs), shallowing westward toward the valley center to depths of 1 to 10 feet bgs. In the Waterloo study area, groundwater flows to the north at an average gradient of 11.7 feet per mile (0.002%).

The Jefferson River Watershed Council (JRWC) has requested that the Upper Jefferson River Watershed be included as a basin study area as part of the MBMG Groundwater Investigation Program approved during the 2009 legislative session. There are several long-term wells in the project study area that are sampled by the MBMG as part of its statewide monitoring network.

C2.4 IRRIGATION AND DOMESTIC WATER USE

Land ownership in the Upper Jefferson River watershed is 57% private, 28% Forest Service, and 15% Bureau of Land Management and State land combined. The primary land use is rangeland and forested areas, with 15% classified as agricultural use. The majority of agricultural production in the valley is irrigated land (Jefferson River Watershed Council, 2011). The Jefferson River Basin is a closed basin due to over-appropriation of water rights. The Jefferson River Watershed Council has enacted a voluntary drought management program with a critical low water level at Parson's Bridge of 50 cfs.

The majority of agricultural lands within the project study area are irrigated through shares from three major canals: the Parrot, Fish Creek, and Creeklyn. A small percentage of lands are irrigated by smaller diversions along the Jefferson River or through groundwater irrigation wells. The Parrot ditch is the largest delivery canal on the Jefferson River, flowing along the Parrot Bench, at the eastern edge of the study area. The Parrot Ditch is 26 miles long, serves approximately 9,000 irrigated acres, and carries over 200 cfs during the irrigation season. Combined diversions from these three canals often exceed 300 cfs.

Past irrigation practices were primarily flood irrigation, but over time a large percentage of land has been converted to sprinkler methods in an attempt to increase production and efficiency, and to reduce water usage and labor. Over 70% of the irrigated lands in the Jefferson Valley are now irrigated with sprinkler or center pivot systems. Where flood irrigation systems rarely applied water with greater than 50% efficiency, the application efficiency for center pivot systems is commonly 70 to 75% (Van Mullem, 2006). There are a number of smaller ditches throughout the project area that still provide flood irrigation to pasture and hay ground. These ditches generally flow from smaller diversions on the Jefferson River downstream of the Parrot Ditch, or from lateral ditches off the Parrot. There are also several old river channels or slough channels along the river bottom, some of which are used for irrigation or serve as return flow conduits.

C3.0 FIELD METHODS AND MATERIALS

A multi-disciplinary field team from WET, DEQ, Trout Unlimited and MFWP deployed instream temperature loggers from 7/27/2009 through 7/31/2009, and collected field measurements from 8/16/2009 through 8/21/2009 to characterize continuous water temperature, meteorological data (e.g. air temperature, dew point, wind speed, and cloud cover.), and the associated water balance in support of the modeling effort. The intensive one-week synoptic flow monitoring program was supplemented with information from temperature loggers deployed in tributaries, return flows, headwater and mainstem channel water columns, and from a project-specific HOBO weather station. Additional information was obtained from the USGS National Water Information Program, Remote Automated Weather Station (RAWS) program, and Bureau of Reclamation AGRIMET network to provide comprehensive data regarding the project reach.

C3.1 SITE SELECTION

Sites for discharge, temperature monitoring and shade characterization were identified by assessment of aerial images and USGS topographical maps to capture areas where stream temperature may be influenced by changes in land cover/land use and streamflow (via irrigation ditches, tributaries, and return flows). In addition, a riparian inventory of the Jefferson River was completed in 2002, which characterized the channel, riverbanks, and vegetation, and was used to assist with sample site selection. Irrigation diversions were identified through aerial images, Montana Water Resource Surveys (WRS) for Jefferson County (1956), Silver Bow County (1955) and Madison County (1965), the WET Ground Water Report (2006) and the Van Mullem Report (2006).

In total, 19 mainstem locations, 26 tributaries and irrigation return flows, and 18 irrigation withdrawals were monitored in the field. Twenty-four (24) sites were assessed for vegetative shade and 12 of these sites were also monitored with a Solar Pathfinder ™. Approximately 56% of the flow measurement sites and approximately 90% of the shade sites were accessed by watercraft, while the remainder were accessed by land.

C3.2 TEMPERATURE DATA

Continuous temperature dataloggers were used to record diurnal variations in water temperature. Temperature loggers used in the Upper Jefferson River modeling study were Optic StowAway® model number WTA32-05+37. The StowAway® is a completely sealed underwater temperature logger with capability to record continuous readings from 0.5 seconds to 9 hours. Temperature measurements were collected at 15-minute increments, and were read on the hour for model input/calibration purposes. Logger calibration checks were completed by DEQ both pre- and post deployment, and were deemed acceptable. Loggers have a NIST traceable temperature accuracy of ±0.2°C, therefore the absolute accuracy is 0.4ºC. Loggers were in the field for approximately three months (late July through early October 2009).

Forty-nine (49) temperature loggers were deployed in the field; this included 20 mainstem locations, 26 tributaries and irrigation return flows, and three headwater rivers. Of the total deployed, 48 dataloggers were retrieved. The duplicate logger to the USGS gage downstream of Parsons Bridge could not be located (JEF-M-21.8). The logger JEF-M-20.7 (Joe Adams' boat launch) was found to be out of the water for a significant portion of the field week. The datalogger JEF-M-21 (railroad bridge overpass accessed from Loomont Road), is in close proximity to JEF-M-20.7 and was used to describe the mainstem temperature for this reach.

C3.3 DISCHARGE DATA

Instantaneous flow was measured at 63 locations (19 mainstem locations, 26 tributaries and irrigation return flows, and 18 irrigation withdrawals). Due to higher than anticipated streamflows during the field effort, it was necessary to adjust pre-selected locations to wadable sections of the river. Stream discharge was measured with a *Marsh McBirney Flo-Mate 2000™* current velocity meter and standard USGS area-velocity method at all sites. Four *Marsh McBirney Flo-Mate 2000™* current velocity meters were used in the field. Velocity output for the meters was verified to be within ±10% on the first day of the field effort. Results were ±6.4% (1.40, 1.44, 1.47, and 1.49 ft/sec).

The streamflow measurements were within 5% of the USGS measurements with the exception of JEF-M-38.3 (11%). There is a note on the field form at site JEF-M-38.3 that the tape measure was strung at a slight angle to the channel, which may explain the difference (**Table C1**).

Table C1. Accuracy Results for Field Collected Data – Stream Discharge

Date and Time	Location	Field (CFS)	Established Equipment Result	Relative Percent Difference
8/18/09, 13:00	BGH-H-F	437.76	USGS, 446 CFS	2%
8/18/09, 11:54	RUB-H-F	133.41	USGS, 140 CFS	5%
8/18/09, 11:00	BHD-H-F	418.63	USGS, 439 CFS	5%
8/20/09, 09:50	JEF-M-38.3	732.83	USGS, 818 CFS	11%
8/19/09, 16:00	JEF-M-21.8	579.32	USGS, 554 CFS	4%

C3.4 MORPHOLOGICAL AND SHADE DATA

River morphology and riparian vegetation data were assessed in the field to characterize direct solar radiation losses from topography and vegetative shade. The following measurements were collected to support the modeling efforts: (1) bankfull and wetted channel width, (2) vegetation/canopy height, (3) canopy density, (4) channel overhang, and (5) percent shade at specified transects. A fiberglass-tape, range-finder, clinometer, canopy densitometer, and Solar Pathfinder™ were used to acquire these attributes.

C3.5 CLIMATE DATA

Climate was field-monitored so that measurements in the river corridor could be correlated with that of surrounding RAWS, AGRIMET, and HOBO weather stations. Air temperature and wet bulb depression were measured with a U.S. Weather Bureau type sling phsychrometer having accuracy of ±0.5 °C. Wind speed was measured with a Dwyer hand-held wind meter (±0.2 m/s for low scales and ±1.3 m/s for high scales). Observations of cloud cover were also recorded. All measurements were collected four times daily.

C4.0 MODEL DEVELOPMENT

C4.1 MODEL DESCRIPTION

QUAL2K v2_11b8 (Q2K) is a one-dimensional (channel is well-mixed vertically and laterally), steady state temperature model (Chapra et al., 2008). Q2K v2.11b8 utilizes a Microsoft Excel graphical interface and is programmed with Visual Basic for Applications (VBA). The components of the heat balance are simulated on a diel time scale. Calculations include solar shortwave radiation, downwelling atmospheric longwave IR radiation, evaporation and air convection/conduction, and sediment heat exchange.

Input parameters required to simulate the heat flux across the air-water interface include air temperature, wind speed, dew point temperature, and cloud cover. These parameters interact with shade, river morphology, and adjacent tributaries to provide a comprehensive description of mass/heat transfer and advection/dispersion throughout the simulated system. Springs, tributaries, and return flows are assumed to be mixed instantaneously, and reach-specific rating curves are used to estimate flow velocity and depth and associated hydraulics for a given discharge. Groundwater infiltration or depletion is input on a reach-specific basis.

C4.2 SHADE INPUT AND GIS PREPROCESSING

Shade.xls utilizes a Microsoft Excel graphical interface and is programmed with Visual Basic for Applications (VBA) that calculates the topographic and vegetative shade for equidistant nodes specified by the user. The interface is designed to conform to Q2K formatting. Forcing functions required to simulate the effective shade at each node include: type of vegetation, vegetation density, angle of topographical shade from water surface, aspect of water flow, wetted width, and bankfull width. A spatially explicit ArcView3.2 GIS pre-processor called TTools for efficient calculation of morphologic and shading attributes at river scales (Boyd and Kasper, 2003) was utilized to determine the type of vegetation at each node and the angle of topographical shade from the water surface. Fundamental input data required for implementation of TTools includes: (1) site topography in the form of a digital elevation model (DEM), (2) digitized channel morphology (e.g. bankfull width and centerline), (3) digitized riparian vegetation shapefile, and (4) user-defined vegetation characteristics. The 10-m USGS National Elevation Dataset (NED) was used for calculation of topographic characteristics. Channel centerline, bankfull width, and riparian vegetation classification were all digitized by using 2004 National Agricultural Imagery Program (NAIP) photography at a scale of 1:5,000. Project coordinate system and datum were Montana State-Plane NAD83 and NAVD88.

TTools includes a longitudinal and radial sampling algorithm that calculates site-specific morphologic and shading characteristics such as channel width and slope, topographic shade, and vegetative shade at user defined nodes (*i* and *i*+1) along the channel centerline. A node distance of 1000-m was used in the case of the Upper Jefferson.

The height, density, and overhang were determined by averaging all field entries for each specific vegetation type and calibrated with Shade.xls results to Solar Pathfinder™ effective shade results. The following vegetation classifications and shade input parameters are shown in **Table C2**. An example of the vegetation classification layer developed by TTools is shown in **Figure C1**. Blank vegetation description is used to populate unused columns within the Shade.xls excel program for each node. Three field teams characterized shade parameters; differences in best professional judgment of sparse or dense cottonwoods may account for similar vegetation densities.

Table C2. Shade.xls Input Parameters for Vegetation Type

Vegetation Description	Height (m)	Density (%)	Overhang (m)
Upland Native Grass	1.3	14%	0.1
Irrigated Wetland Grass	0.5	24%	0.2
Mixed High Level	12.6	48%	0.8
Mixed Low Level	3.0	36%	0.2
Cottonwood Dense	16.3	54%	0.0
Cottonwood Sparse	13.9	52%	0.0
Willow Dense	4.2	62%	0.1
Willow Sparse	2.6	46%	0.1
Bare	0.0	0%	0.0
Blank	0.0	0%	0.0

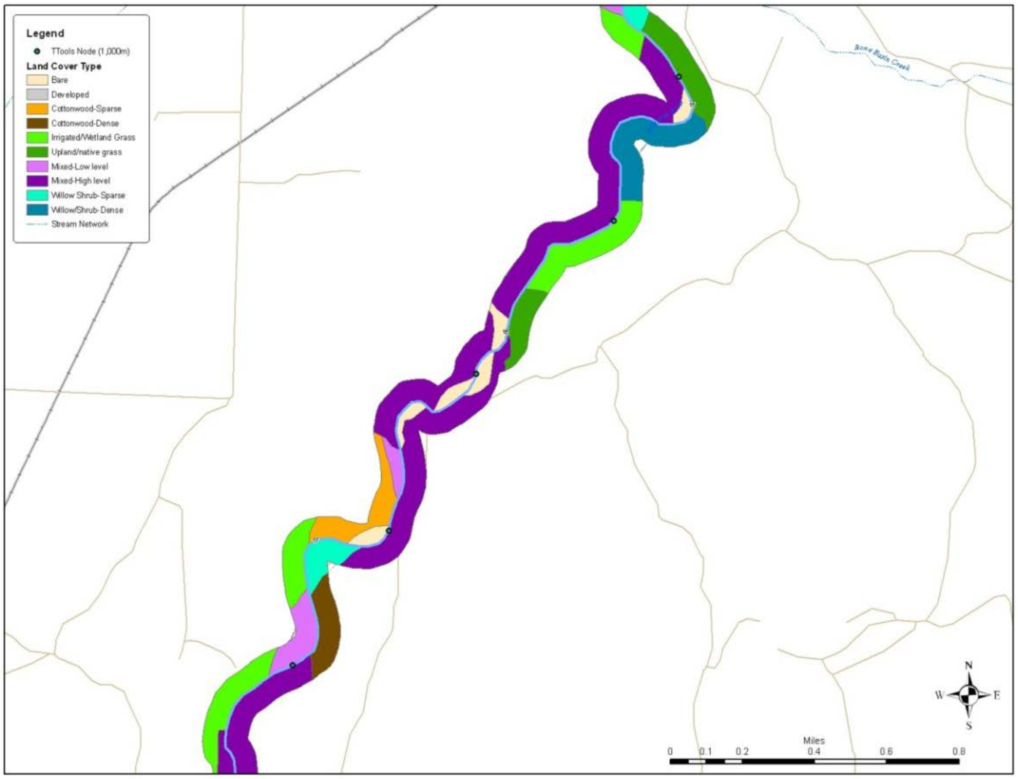

Figure C1. TTools Vegetation Classification

C4.3 SIMULATION PERIOD AND GLOBAL CONTROL SPECIFICATIONS

The ideal model simulation period would occur with the critical limiting period, i.e., where standards are most likely to be exceeded and under steady-state climatic and hydrologic conditions. Based on a review of water temperature data at USGS 06026500 *Jefferson River below Twin Bridges, MT*, this period most frequently occurs in late July, when air temperatures are the highest, when the photoperiod is sufficiently long, and when the hydrograph has sufficiently recessed. The field data collection was pre-scheduled to this time when the photoperiod is long and the river levels reach baseflow.

A review of the seasonal maximum and seven day maximum of temperature logger results between 7/29/2009 and 9/30/2009 are summarized in **Table C3**. Seasonal maximum temperatures occurred in early or late August, depending on river location. The seasonal maximum temperature dates appear to be affected by the location in the upper half or lower half of the river, whereas the 7-day average occurred in late July for almost all temperature logger locations. After evaluating the logger data, a three day average temperature from August 20-22, 2009 was used in the model. This date overlapped with a majority of seasonal maximum temperature results and the loggers with the most days over 70°F, as well as two days of field measurements.

Control information specified during initial modeling efforts was: (1) number of days (2) calculation time steps, and (3) integration solution method. It was determined that the model ran adequately with a run time of three days, calculation step of 0.08 hours, and the Euler Method (default). The time of travel for the existing conditions was approximately one day whereas the time of travel in a 7-day 10-year low flow event is approximately two days; thus this time step exceeds the time of travel in all scenarios.

Table C3. Upper Jefferson River - Mainstem 2009 Temperature Data Summary: Data period 7/29/2009 – 9/30/2009

Site ID	Start	Stop	Seasonal Max.		7-Day Averages (ºF)				Days> 70F
			Date	Value	Date	Max	Min	ΔT	
RUB-H-T	7/28/09	9/30/09	8/1/09	69.8	7/30/09	67.7	60.7	7.0	0
BGH-H-T	7/28/09	9/30/09	8/3/09	73.1	8/21/09	70.5	61.8	8.7	16
BHD-H-T	7/28/09	9/30/09	8/3/09	72.5	7/29/09	70.5	61.3	9.1	8
JEF-M-41.2-T	7/29/09	9/30/09	8/3/09 & 8/4/09	72.7	7/29/09	70.3	61.8	8.5	7
JEF-M-39.5-T	7/29/09	9/30/09	8/4/09	73.8	7/29/09	70.7	62.0	8.7	13
JEF-M-38.3-T	7/29/09	9/30/09	8/4/09	73.7	7/29/09	70.6	62.3	8.3	9
JEF-M-35.2-T	7/29/09	9/30/09	8/4/09	73.1	7/30/09	70.5	62.9	7.6	10
JEF-M-35.2-T	Duplicate				8/1/09	70.5	63.0	7.4	Duplicate
JEF-M-32.4-T	7/29/09	9/30/09	7/31/09 & 8/4/09	73.1	7/30/09	70.6	63.3	7.3	13
JEF-M-27.1-T	7/29/09	9/30/09	8/4/09	73.1	7/29/09	70.5	62.9	7.6	9
JEF-M-24.5-T	7/29/09	9/30/09	8/22/09	73.1	7/29/09	70.6	63.4	7.3	14
JEF-M-21-T	7/29/09	9/30/09	8/22/09	72.5	7/29/09	70.1	63.2	6.9	7
JEF-M-19.2-T	7/29/09	10/1/09	8/4/09 & 8/21/09 & 8/22/09	72.5	8/21/09	69.9	61.0	8.9	12
JEF-M-15.9-T	7/29/09	10/1/09	8/4/09 & 8/21/09 & 8/22/09	72.9	7/30/09	70.2	62.9	7.3	9
JEF-M-15.9-T	Duplicate				8/21/09	70.2	61.7	8.5	Duplicate
JEF-M-12.1-T	7/29/09	10/1/09	8/22/09	72.8	7/30/09	70.2	63.2	7.0	11
JEF-M-9.5-T	7/29/09	9/29/09	8/22/09	72.8	7/29/09	70.5	62.9	7.6	11
JEF-M-9.5-T	Duplicate				7/30/09	70.5	63.3	7.1	Duplicate
JEF-M-7.2-T	7/29/09	9/29/09	8/22/09	73.1	7/29/09	70.6	63.0	7.6	13
JEF-M-7-T	7/29/09	9/29/09	8/22/09	73.2	7/29/09	70.7	62.9	7.8	16
JEF-M-3.9-T	7/28/09	9/29/09	8/22/09	73.7	7/29/09	71.3	63.5	7.8	20
JEF-M-3.9-T	Duplicate				8/1/09	71.3	64.1	7.2	Duplicate
JEF-M-1.4-T	7/29/09	9/30/09	8/4/09 & 8/22/09	73.4	7/29/09	71.1	63.6	7.5	19
JEF-M-0-T	7/29/09	9/30/09	8/4/09 & 8/22/09	73.7	7/29/09	71.1	63.4	7.7	20

C4.4 HYDROLOGY AND MASS TRANSFER INPUT

Hydrology and mass transfer data from the 2009 field effort were used to define the overall water balance and associated boundary conditions in the model. As shown in **Figure C2**, mean daily discharge at the USGS gage near Twin Bridges (06026500) for August 16 - 22, 2009 was approximately 789 cfs. This flow was calculated as the 7Q1.6 (63% probability of non-exceedance) based on the available years of record (1958-1972 and 1994-2009, Thomann and Mueller).

Temperature records were not available for the 2009 year at the USGS gage site near Twin Bridges. However, the temperature results from the USGS gage near Parson's Bridge (06027600) were available and are shown on **Figure C3.** The translucent yellow box on **Figures C2** and **C3** indicates the selected 3-day model period. The 2009 model period shows a warmer mean daily temperature than the mean value from 2006 – 2009 as shown in **Figure C3**.

The model application was developed for the 3-day period of August 20-22, 2009. The translucent yellow box on **Figures C2** and **C3** indicates the 3-day model period. Locations of all hydrology/mass transfer monitoring sites are shown in **Exhibit C1**.

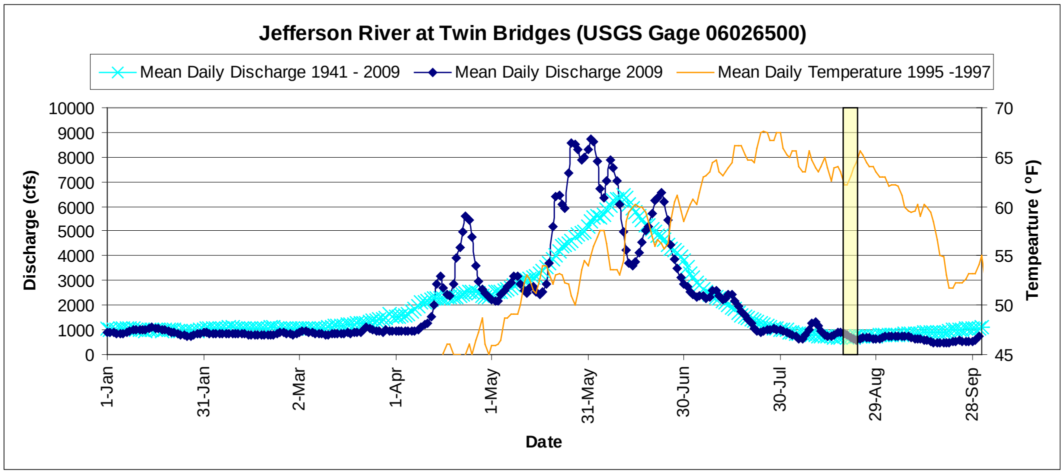

Figure C2. Summary of mean daily discharge, temperature, and associated statistics for the USGS gage near Twin Bridges, MT (USGS 06026500)

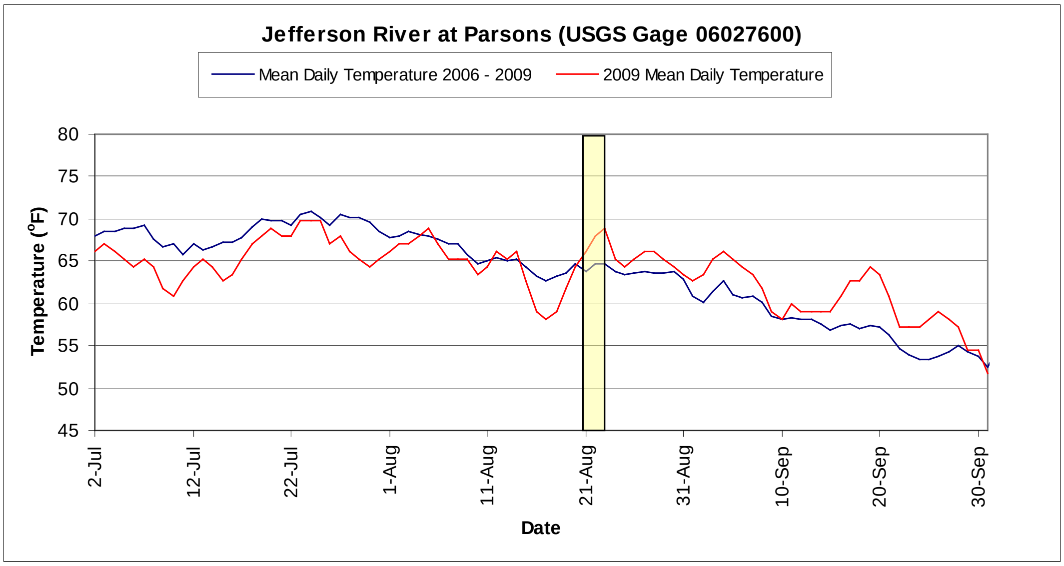

Figure C3. Summary of mean daily water temperature, and temperature statistics for the USGS gage at Parsons Bridge, MT (USGS 06026500).

A steady state upstream flow boundary condition was assumed for the use of Q2K to model temperature conditions. All tributary and irrigation exchanges were also considered steady-state. The average hourly temperature across the 3-day modeling period was entered into the model at the upstream boundary. All tributary and return flow temperature inputs consisted of the mean, range/2, and time of max for the average hourly value over the 3-day modeling period. Groundwater temperature was adjusted within published groundwater temperatures in order to best fit observed and simulated water column temperatures. Further discussion is included in **Section 5.4**.

Significant areas of split flow (greater than one mile) were not entered into the Q2K model. The split flow at mile 7 showed similar temperature trends in both channels, as shown on **Figure C4**, sites M-7 and M-7.2.

Box and whisker plots from all Jefferson River mainstem sites, incoming tributaries, and irrigation return flows are shown in **Figure C4**. The location of each temperature logger site is included in **Exhibit C2**. While minimums and maximums vary throughout the watershed, it is recognized that irrigation return flows (encapsulated in yellow translucent boxes) often have a much larger temperature range and associated quartiles, compared to that of natural tributary flow (encapsulated with blue translucent boxes). Specific to the model period, the increased temperature range was not entirely a function of flow volume in each return flow. The travel time and distance are mostly likely the other contributing parameters.

The temperature datalogger for the mainstem JEF-M-20.7 was out of the water for the first portion of the week. Thus, this specific box plot is not for the full seven day time period.

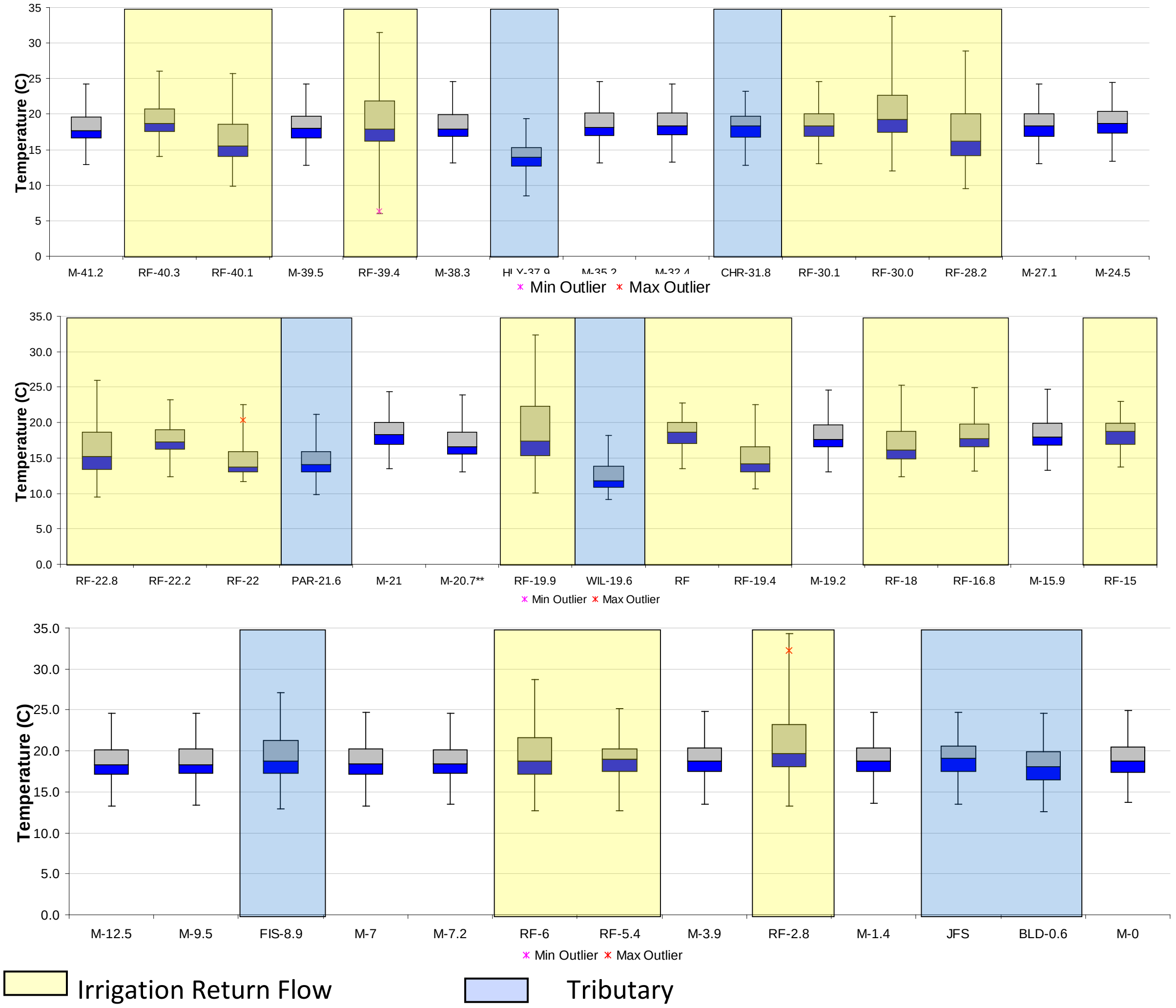

Figure C4. Box and Whisker Plots for 8/18/2009 through 8/24/2009

Flow measurements throughout the watershed were collected from 8/16/2009 through 8/21/2009. A water balance was created between each mainstem flow measurement to determine the groundwater influence. The water balance included seventeen mainstem reaches along the Upper Jefferson River and incorporated all known irrigation withdrawals and return flows, as well as tributary inflows. The model is divided into ten reaches as discussed in **Section C4.5, Figures C5** and **C6**); as a result, groundwater abstraction or inflow was combined at the reach breaks for model input data. Groundwater gain/loss was validated for the study reach within the WET 2006 report. The WET report included mainstem Jefferson River flow monitoring from above the Parrot Canal to below the Willow Spring confluence. Based on these data collected in 2005, a course level water balance was developed. The 2005 water balance identified similar gaining and losing reach locations as determined in this 2009 study; however it should be noted that flow conditions and monitoring reaches were different for each study. The 8/20/2009 water balance is shown in **Table C4.**

Table C4. Water Balance - Upper Jefferson River updated to 8/20/2009

UPPER JEFFERSON RIVER WATER BALANCE 8/18 - 8/21/09 Corrected to 8/20/2009			
		m3/s	**GWH20 EST**
JEF-M-41.2		**830.029**	
JEF-RF-40.3		4.319	
JEF-RF-40.1		22.140	**-19.597**
	TOTAL	**856.488**	**LOSING**
JEF-M-39.5		**836.890**	
JEF-RF-39.4		0.635	
JEF-D-38.8		-2.472	
JEF-D-38.6		-5.984	**-27.641**
	TOTAL	**831.541**	**LOSING**
JEF-M-38.3	**USGS gage 06026500**	**803.903**	
HCY-37.9	Hells Canyon	7.005	
JEF-D-37		-13.125	
JEF-D-36.3	Creeklyn Ditch	-45.180	**-60.015**
	TOTAL	**752.600**	**LOSING**
JEF-M-35.2		**757.685**	
JEF-D-35	Parrot Ditch	-169.075	
JEF-D-34.2		0.000	**84.446**
	TOTAL	**523.510**	**GAINING**
JEF-M-32.4		**607.956**	
CHR-31.8	Cherry Ck.	0.170	
JEF-D-30.5		-68.086	
JEF-RF-30.1		71.202	
JEF-RF-30.0		0.499	
JEF-RF-28.2		5.803	
JEF-2-28.1		-10.000	**39.790**
	TOTAL	**607.544**	**GAINING**
JEF-M-27.1		**647.334**	
JEF-D-26.7		-0.780	
JEF-D-25.1		-15.865	**-2.413**
	TOTAL	**630.689**	**LOSING**
JEF-M-24.5		**628.276**	
JEF-RF-23.8	(Redirected to 22.8)	0.000	
JEF-RF-22.8	Hirschy	11.686	
JEF-RF-22.2		1.027	
JEF-RF-22		3.000	
JEF-D-21.9	Fish Ck. Ditch	-87.717	**-29.372**
	TOTAL	**556.272**	**LOSING**
JEF-M-21.8	**USGS gage 06027600**	**526.900**	
PAR-T-21.6		1.249	**20.997**
	TOTAL	**528.149**	**GAINING**

UPPER JEFFERSON RIVER WATER BALANCE 8/18 - 8/21/09 Corrected to 8/20/2009			
		m3/s	**GWH20 EST**
JEF-M-21		**N/A**	
JEF-M-20.7		**549.146**	
JEF-RF-19.9		2.758	
WIL-T-19.6	Willow	20.913	
JEF-RF		4.993	
JEF-RF-19.4		2.132	**79.844**
	TOTAL	**579.942**	**GAINING**
JEF-M-19.2		**659.786**	
JEF-RF-18		3.240	
JEF-D-18		-42.781	
JEF-RF-16.8		39.435	**-55.073**
	TOTAL	**659.680**	**LOSING**
JEF-M-15.9		**604.607**	
JEF-RF-15		22.143	
JEF-D-14.6	Temple Ranch	-1.961	
JEF-D-14.6	Fish Creek	-37.640	
JEF-D-14.6	Slaughterhouse Slough	-33.120	**21.197**
	TOTAL	**554.029**	**GAINING**
JEF-M-12.5	**After Renova**	**575.226**	
JEF-D-12.1	(dry)	0.000	**-36.784**
	TOTAL	**575.226**	**LOSING**
JEF-M-9.5	**Koontz Bridge**	**538.442**	
FIS-T-8.9		76.777	
JEF-D-7.6		-8.201	**96.038**
	TOTAL	**607.018**	**GAINING**
JEF-M-7 SPLIT		**322.886**	
JEF-M-7.2 SPLIT		**380.170**	
JEF-RF-6	near Mayflower Bridge	0.137	
JEF-RF-5.4		23.148	**-23.359**
	TOTAL	**726.341**	**LOSING**
JEF-M-3.9		**702.982**	
JEF-D-3.5	pump, 0 flow 8/18	0.000	
JEF-RF-2.8		0.324	**100.175**
	TOTAL	**703.306**	**GAINING**
JEF-M-1.4	**near Jefferson Island**	**803.481**	
JFS-F		39.113	
Bld culvert		1.478	
BLD - 0.6		157.668	**-117.142**
	TOTAL	**1001.740**	**LOSING**
JEF-M-0	**near Lahood**	**844.007**	

Ideal model conditions would have a steady state flow condition (less than 10%) throughout the field and model simulation time periods. In order to best represent steady state conditions, each mainstem flow was corrected to a single date: 8/20/2009. This correction was performed based on the two USGS sites with continuous monitoring data for all four dates, and one mainstem site that was measured for flow on two consecutive days. The corrected values to 8/20/2009 enabled a better determination of the influence of groundwater between each reach.

The groundwater gain or loss between each mainstem measurement is shown on **Figure C5**. Groundwater gain or loss is described in the model based on user-defined Q2K reaches (further described in **Section C4.5**); the reaches with groundwater inflow are shown with translucent yellow boxes on **Figure C5.**

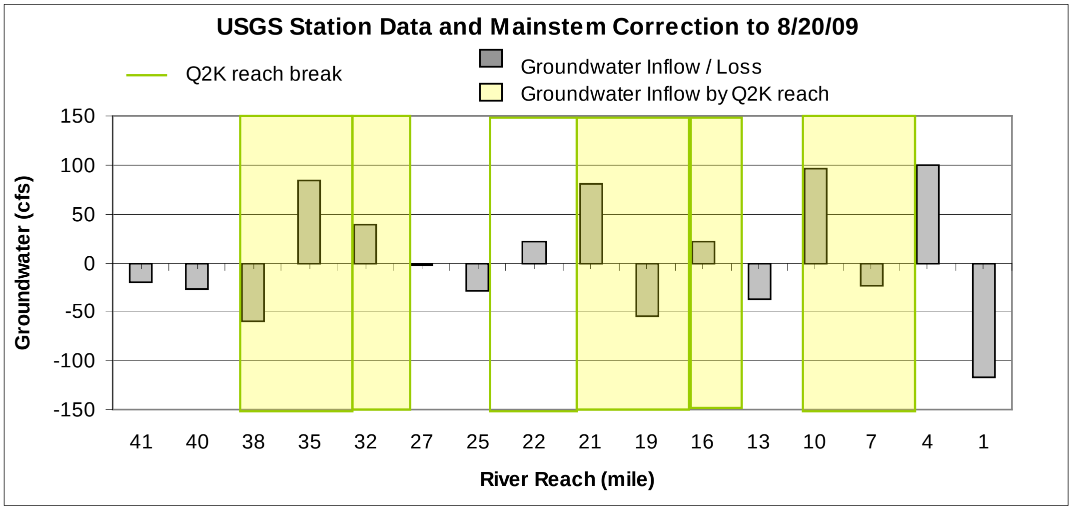

Figure C5. Groundwater Gain and Loss in the Q2K model

The Jefferson Slough was monitored for flow and temperature both upstream (station JFS) and downstream of the confluence with the Boulder River (station BLD-0.6). The Jefferson Slough shows a similar temperature range to the nearby Jefferson mainstem measurement (JEF-M-1.4) for the 2009 water year. Flow measurements are included in **Table C4**, however, only the combined Boulder and Jefferson Slough datum (BLD-0.6) were utilized in the model and for groundwater quantity calculations.

Temperature loggers were deployed at the effluent locations for the Twin Bridges and Whitehall wastewater lagoons. Neither effluent discharged directly to the Jefferson River; as a result, they were not included in the model.

C4.5 REACH BREAKS AND HYDRAULIC INPUT

Reach Breaks

Hydraulic data (depth and velocity) are calculated from reach-specific rating curves. Reach breaks were defined based on major channel elevation breaks and aspect changes from the 10-m DEM, as well as tributaries and major ditch locations (**Figure C6**). Each entry (blue diamond) is the intersection of the Jefferson River with a contour line. Several locations have the same elevation due to river meanders through the same contour line. This highlights the imprecision of using the 10-meter DEM.

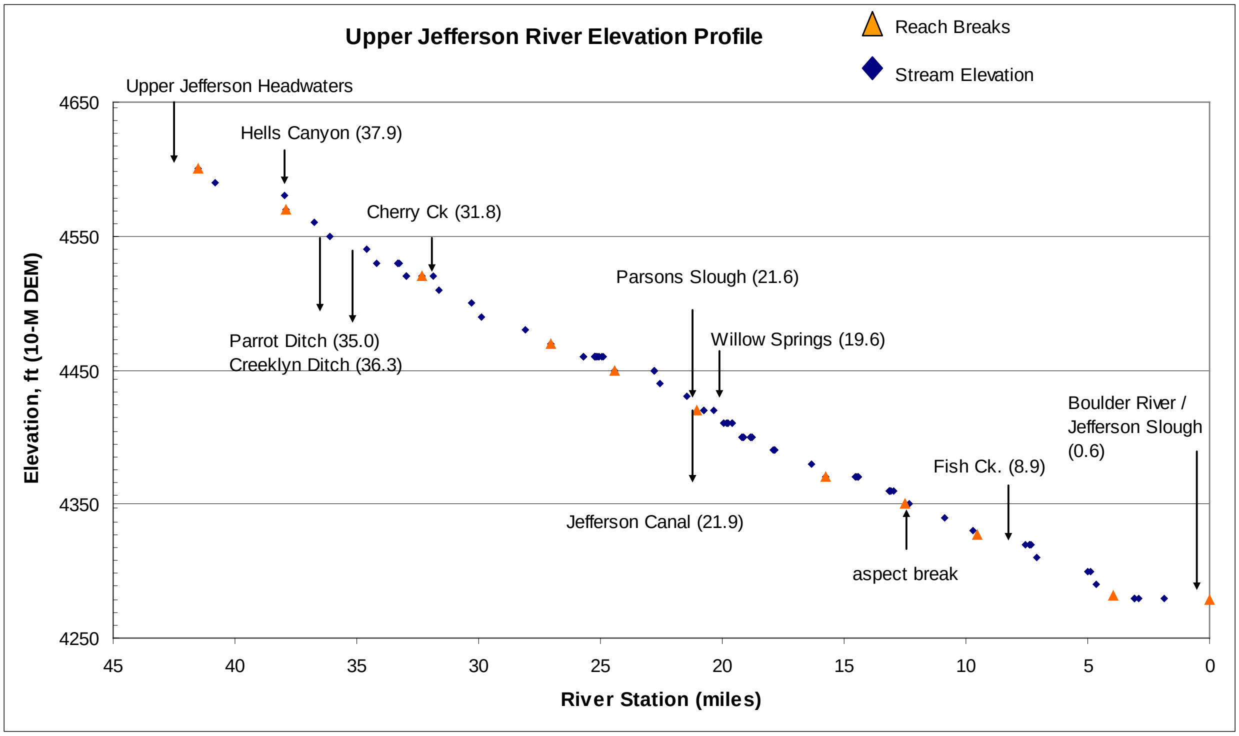

Figure C6. Upper Jefferson River Profile and Q2K Model Reach Breaks

The Q2K model was divided into ten reaches as shown above. Each reach was divided into ten elements in order to interpolate results at the same station as field measured locations and to compare output to the baseline model with a larger dataset. Thus there are 100 elements in the model. Elements are smaller river sections of uniform length within an existing reach break. Elements are utilized within the Q2K program to decrease the distance between output variables (width, depth, velocity, flow, and temperature).

Hydraulic Input

The Q2K model allows the user to utilize rating curves to describe the velocity and depth at each reach based on weir geometry, rating curves or Manning's Equation. This model utilized rating curves; exponent values were calculated based on the available velocity, discharge, and a wide river approximation from USGS gage 06026500 Jefferson River below Twin Bridges, MT. Two USGS gages are located within the project reach; however the USGS 06027600 (Jefferson River at Parsons Bridge nr Silver Star), MT had only four years of discharge data as compared to sixteen years of field measurements at the Twin Bridges site (06027500). As a result, the exponent values from USGS gage 06026500 were used for all Q2K reaches in the model.

Depth for each field measurement was calculated as the cross-sectional area divided by wetted width (Leopold and Maddock, Jr., 1953). The resulting rating curves (based on metric units) have the following power equations and r-squared values:

Velocity: $U = 0.1918Q^{0.4000}$ $R^2 = 0.7177$
Depth: $H = 0.1570Q^{0.4537}$ $R^2 = 0.8526$

A reach-specific coefficient was determined based on field-measured wetted width, velocity, flow, and depth for each mainstem flow measurement. The average velocity was calculated as the flow divided by area; the average depth was determined from area divided by wetted width. Field data was not adjusted for the hydraulic calculations; field collected discharge was corrected to a single day in order to calculate a water balance as discussed in **Section C4.4**. The Microsoft Excel add-in SOLVER was used to solve for the depth and velocity rating curve coefficients based on set values for the rating curve exponents, wetted width, average velocity, discharge, and average depth. Results are shown in **Table C5**.

Table C5. Reach Specific Rating Curves

Mainstem Site	Wetted Width, WW (ft)	Average Depth H=A/WW (ft)	Average Velocity U=Q/A (ft/sec)	Discharge, Q (ft^3/sec)	Velocity Rating Curve Coefficient (metric)	Depth Rating Curve Coefficient (metric)
JEF-M-41.2	176.0	1.59	3.18	889.8	0.2665	0.1122
JEF-M-39.5	169.0	1.70	3.12	897.2	0.2604	0.1197
JEF-M-38.3	153.0	2.05	2.34	732.8	0.2120	0.1576
Q2K Model input values (Twin Bridges Rating Curve)					**0.1918**	**0.1570**
JEF-M-35.2	218.0	1.09	2.93	692.6	0.2715	0.0857
JEF-M-32.4	166.2	1.61	2.43	650.1	0.2312	0.1308
Q2K Model input values (Twin Bridges Rating Curve)					**0.1918**	**0.1570**
JEF-M-27.1	150.0	1.46	2.96	647.3	0.2815	0.1189
Q2K Model input values (Twin Bridges Rating Curve)					**0.1918**	**0.1570**
JEF-M-24.5	154.0	1.67	2.44	628.3	0.2356	0.1378
Q2K Model input values (Twin Bridges Rating Curve)					**0.1918**	**0.1570**
JEF-M-21	160.0	1.34	2.70	579.3	0.2689	0.1148
JEF-M-20.7	133.0	1.65	2.50	549.1	0.2538	0.1452
Q2K Model input values (Twin Bridges Rating Curve)					**0.1918**	**0.1570**
JEF-M-19.2	160.0	1.30	3.19	663.4	0.3004	0.1049
JEF-M-15.9	128.5	1.82	2.59	604.6	0.2529	0.1530
Q2K Model input values (Twin Bridges Rating Curve)					**0.1918**	**0.1570**
JEF-M-12.1	171.0	2.08	1.41	500.4	0.1485	0.1904
Q2K Model input values (average of JEF-M-12.1 and JEF-M-9.5)					**0.2341**	**0.1763**
JEF-M-9.5	96.0	1.94	3.28	612.4	0.3197	0.1622
Q2K Model input values (average of JEF-M-12.1 and JEF-M-9.5)					**0.2341**	**0.1763**
JEF-M-7	105.0	1.73	2.67	485.3	Split flow	Split flow
JEF-M-7.2	134.5	2.98	1.04	416.1	Split flow	Split flow
JEF-M-3.9	148.5	2.01	2.68	799.4	0.2343	0.1488
Q2K Model input values (results from JEF-M-3.9)					**0.2343**	**0.1488**
JEF-M-1.4	179.0	1.50	2.60	699.0	0.2397	0.1183
JEF-M-0	192.0	2.25	2.09	904.9	0.1743	0.1575
Q2K Model input values (average of JEF-M-1.4 and JEF-M-0)					**0.2070**	**0.1379**

Use of the Twin Bridges rating curve coefficient versus a best fit coefficient constrained by field data was calibrated by comparison of the model output to field collected temperature, wetted width, depth and velocity. These comparisons are further discussed in the results section.

C4.6 CLIMATE INPUT

Project specific meteorological data from the HOBO Weather Station was utilized within the model. The hourly air temperature (°C), wind speed (m/s), and dew point (°C) data is compared to the AGRIMET and

RAWS stations located in Whitehall, MT in **Figures C7 – C9** for the model input data (average of hourly results from 8/20/09 – 8/22/09). Field measurements taken from within the river corridor are also shown on the charts where available.

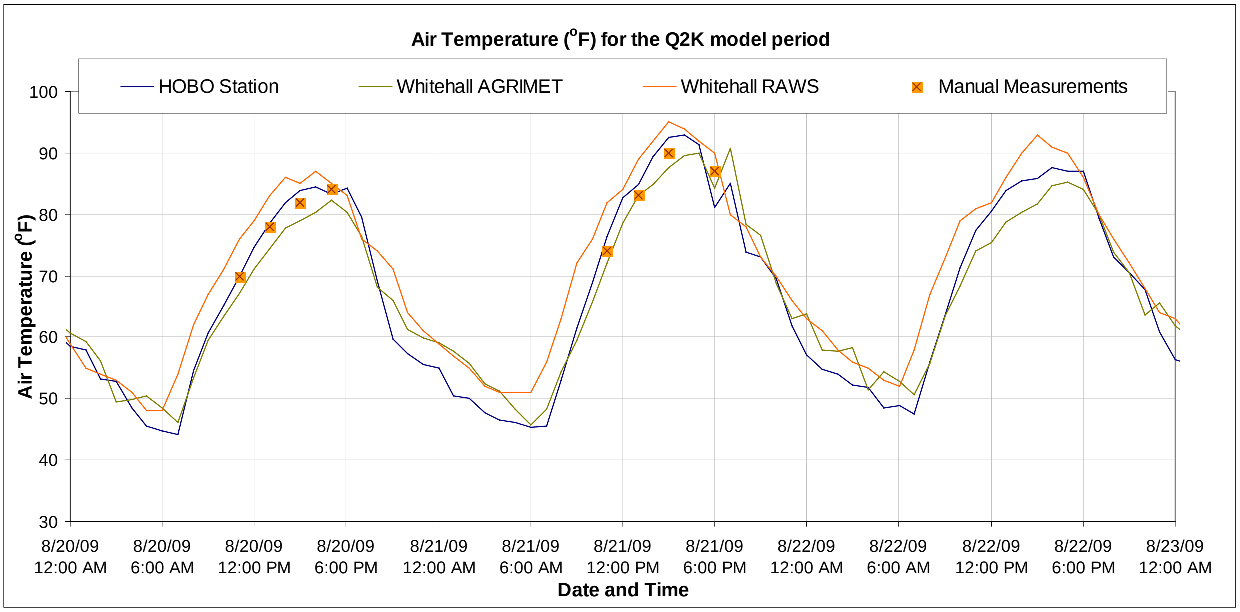

Figure C7. Weather Stations and Field Data Results: Air Temperature

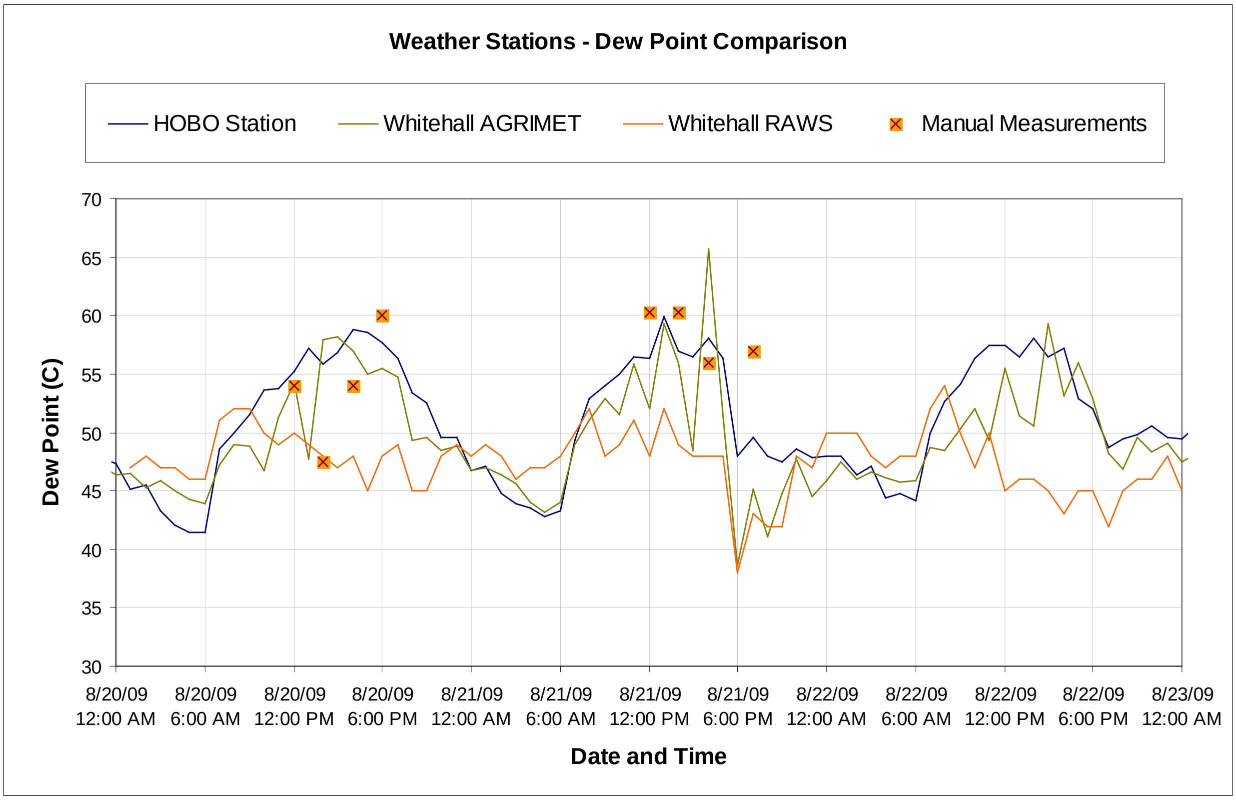

Figure C8. Weather Stations and Field Data Results: Dew Point

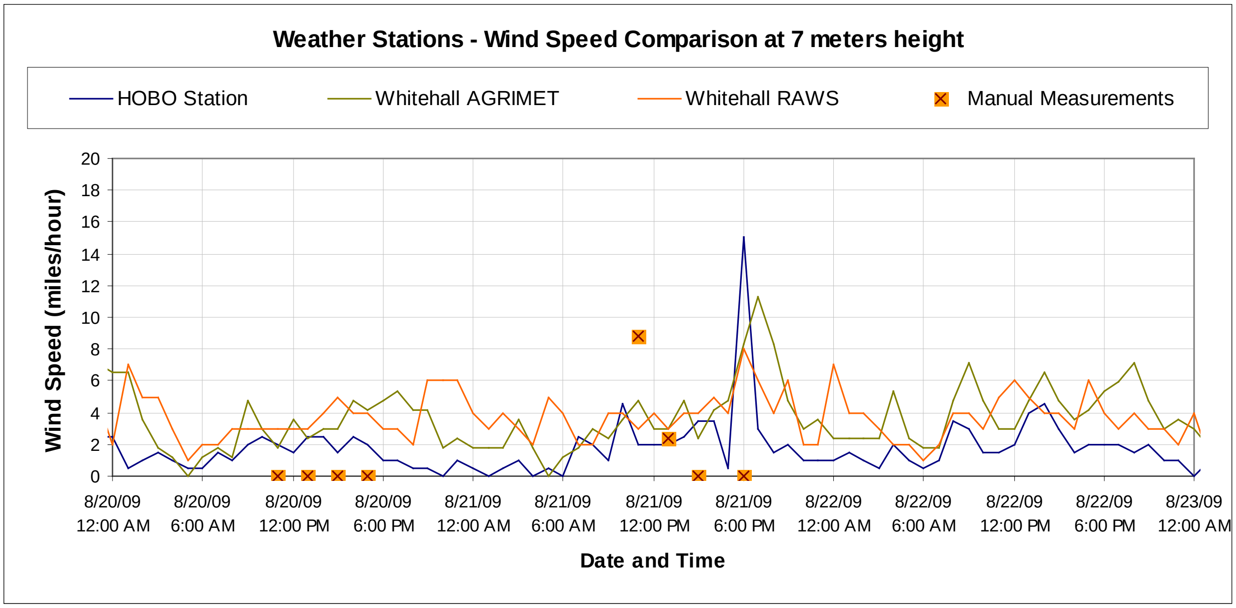

Figure C9. Weather Stations and Field Data Results: Wind Speed

Of all inputs (temperature, wind speed, and dew point temperature), wind speed was found to vary the most between locations. With the exception of the brief thunderstorm on the evening of 8/21/09, the wind speed was lowest at the HOBO station. Due to the proximity of the HOBO weather station to the river channel, it most likely best represents the actual conditions in the study area. The wind speed was corrected to seven meters for the HOBO and AGRIMET stations in **Figure C9**. This correction was generated based on Q2K input requirements.

Cloud cover was estimated from the Solar Radiation (W/m^2) that was blocked during the model period. Solar radiation (W/m^2) was collected hourly at the HOBO weather station. Cloud cover was calculated as follows:

$$\text{Cloud Cover} = \frac{S_{\max(8/18/19-8/22/09)} - \overline{S_{average(8/20/09-8/22/09)}}}{S_{\max(8/18/19-8/22/09)}} \quad (1)$$

where:

S = solar radiation (W/m^2)

An alternative cloud cover calculation was entered into the model to diminish the effect of the storm on the evening of 8/21/2009. The effect on the model output was indiscernible.

C4.7 MODEL EVALUATION CRITERIA

Following model input development, performance statistics were selected to assess minimum, maximum and average temperature predictions from Q2K v2.11b8. The first criterion was percent bias (PBIAS), which is a measure of the average tendency of the simulated temperatures to be larger or smaller than an observed value. Optimal PBIAS is 0.0 while a positive value indicates a model bias toward overestimation. A negative value indicates bias toward underestimation. PBIAS is calculated as follows:

$$PBIAS = \frac{\sum_{i=1}^{n}(T_{isim} - T_{iobs})}{\sum_{i=1}^{n}(T_{iobs})} \times 100 \qquad (2)$$

where:

PBIAS = deviation of temperature in percent
T_{iobs} = observed temperature (ºC)
T_{isim} = simulated temperature (ºC)

DEQ has defined acceptable model bias (PBIAS) as less than or equal to ±5%.

The second evaluation criterion used in the Upper Jefferson River modeling is the sum of squared residuals (SSR), which is a commonly used objective function for hydrologic model calibration, and standard error (SE). Sum of square residuals (SSR) compares the difference between the modeled and observed ordinates, and uses the squared differences as the measure of fit. As an example, a difference of 2°C between the predicted and observed temperature value is four times worse than a difference of 1°C. Squaring the differences also treats both overestimates and underestimates by the model as undesirable. The equation for calculation of SSR is shown below (Diskin and Simon, 1977).

$$SSR = \sum_{i=1}^{n}(T_{iobs} - T_{isim})^2 \quad (3)$$

where:

SSR = sum of squared residuals

The standard error is described as the standard deviation of the residual error. The residual is defined as the difference between the observed and simulated value.

C4.8 SENSITIVITY ANALYSIS AND MODEL UNCERTAINTY

Model uncertainty was assessed using a simple one-at-a-time (OAT) sensitivity analysis with parameter perturbations of ±10% and ±30%. The OAT methodology ensures that changes in output can unambiguously be attributed to the changes in model input. Parameter sensitivity is typically expressed as a normalized sensitivity coefficient (NSC) as shown below (Brown and Barnwell, Jr., 1987).

$$\text{NSC} = \left| \frac{\Delta Y_o / Y_o}{\Delta X_I / X_I} \right| \quad (4)$$

where:

NSC = normalized sensitivity coefficient
ΔY_o = change in the output variable Y_o
ΔX_i = change in the input variable X_i

NSCs for model parameters in Q2K v2_11b8 are shown in **Table C6**. NSCs are taken as the average results of the four sensitivity runs (±10% and ±30% perturbations) for minimum, average, and maximum temperatures for two locations on the Jefferson: mile 0.0 and mile 21.9.

Table C6. Summary of parameter sensitivity for the Upper Jefferson River Q2K v2.11b8 model

Parameter	Rank	NSC
Headwater T (°C)	1	0.32
Tributary and Irrigation Return Mean T (°C)	2	0.26
Tributary and Irrigation Return Time of Max T (time)	3	0.26
Tributary Mean T (°C)	4	0.14
Rating Curves – coefficient	5	0.13
Air T (°C)	6	0.13
Dew Point T (°C)	7	0.08
Headwater Q (cms)	8	0.06
Groundwater T (°C)	9	0.06
Groundwater Q (cms)	10	0.03
Tributary and Irrigation Return Q (cms)	11	0.02
Tributary and Irrigation Return T Range/2 (°C)	12	0.01
Hourly Effective Shade (%)	13	0.01
Vegetation Density (%, shade.xls)	14	0.00
Cloud Cover (%)	15	0.00

Results indicate that inputs directly related to mass transfer (headwater, tributary and irrigation return flow temperatures) are highly sensitive in the Upper Jefferson River watershed. Tributary and irrigation return mean temperature was highly sensitive, yet the flow and temperature range adjustments were less sensitive. This is likely a result of the high water year and higher discrepancy between mainstem and tributary / irrigation return inflows. Parameters related to flow routing (rating curves) and meteorological forcing data were also sensitive to the model output. With the exception of rating curves, the eight highest ranking parameters are well known (directly measured in the field). This model was qualified as a moderately-certain project for the existing conditions.

C4.9 MODEL CALIBRATION PROCEDURE

The Upper Jefferson River Q2K model was calibrated based on the evaluation criteria identified previously. Meteorological input data were first assessed for reasonable representation based on DEQ's experience on other rivers (Beaverhead and Big Hole). Meteorological input data was then evaluated with field measurements and the Whitehall AGRIMET and RAWS stations. Unaltered results from the HOBO weather station were deemed adequate for all reaches in the Upper Jefferson River for the model period. Model calibration features as provided within Q2K were best fit between simulated temperature output and observed temperatures: solar shortwave radiation model (Bras, atmospheric turbidity coefficient of 2.0), downwelling atmospheric longwave IR radiation (Brutsaert) and evaporation and air convection/conduction model (Brady-Grave-Geyer). The following sediment heat parameters were adjusted for a cobble bed: sediment thermal thickness (10 cm), sediment thermal diffusivity (0.0127 cm^2/s), sediment density (1.6 g/cm^2) and sediment heat capacity (0.5 cal/g ºC).

Groundwater temperatures were best fit between simulated temperature output and observed temperatures for groundwater temperature values ranging between 9ºC to 15 ºC (further discussed in **Section C5.4**). The rating curves were the model input data with the most impact on the temperature profile. All data were adjusted within a reasonable range so that agreement between observed and simulated values occurred. Final calibrated reach parameters are shown in **Attachment C**. Subsequent PBIAS and SSR values for the temperature calibration are described in the Results and Discussion section.

C4.10 MODEL VALIDATION / CONFIRMATION

After calibration, a model should be validated or confirmed against an independent dataset. This effectively demonstrates that the model performs adequately over a range of conditions beyond that which it was calibrated to (Bartholow, 1989; Reckhow and Chapra, 1983; Chapra, 1997). For the Jefferson River, independent data outside of the 2009 field effort do not exist for validation purposes largely due to the dynamic conditions encountered in the watershed. As a result, auxiliary lines of evidence were evaluated in a “low-level” confirmation exercise. This included: an assessment of appropriate instream water temperature responses to varying climatic and headwater conditions.

C5.0 RESULTS & DISCUSSION

C5.1 HYDROLOGY

Simulated streamflow for the August 20-22, 2009 modeling period is shown in **Figure C10**. Inspection of the observed and predicted flow shows good agreement. Hydrology is within ±7.3% at all monitoring nodes (not including JEF-M-19.2 (30.8 km), JEF-M-3.9 (6.3 km), and split flow at JEF-M-7 and JEF-M-7.2 (11 km)). The two non-braided sites, JEF-M-19.2 and JEF-M-3.9, likely under-predict the observed flow due to linear addition of groundwater influx or depletion across long reaches built into this particular Q2K model. Mean prediction PBIAS and standard error were -0.13% and 1.06 cms respectively (comparing daily simulated flow values with instantaneous field-measurements). Surface water hydrology is clearly a function of the combined influence of tributary inflow, irrigation withdrawal and return flow, split channel flow (e.g. braiding), and localized groundwater inflow. Major surface water inflows occur at Hells Canyon, Waterloo (Willow/Parsons), Fish Creek and the Boulder River/Jefferson Slough areas. River reaches with groundwater inflow are shown with translucent yellow rectangles on **Figure C10**.

The results in **Figure C10** and model evaluation statistics were computed from corrected data to a single date of 8/20/09 as described in **Section C4.4.** A few trends are noticed in **Figure C10** for unnamed irrigation control that should be further explained. Q2K applies groundwater linearly over the entire reach whereas tributaries, and irrigation diversions and return flows cause immediate changes to the mainstem flow. A sharp dip is shown near 30 miles (50 km): this is due to a diversion (JEF-D-30.5, 68.1 cfs) followed by a return flow (JEF-M-30.1, 71.2 cfs) within 0.4 miles. The second un-named but significant diversion occurs at kilometer 28.87 (JEF-D-18, 42.8 cfs) near Temple Ranch and the Renova Structure.

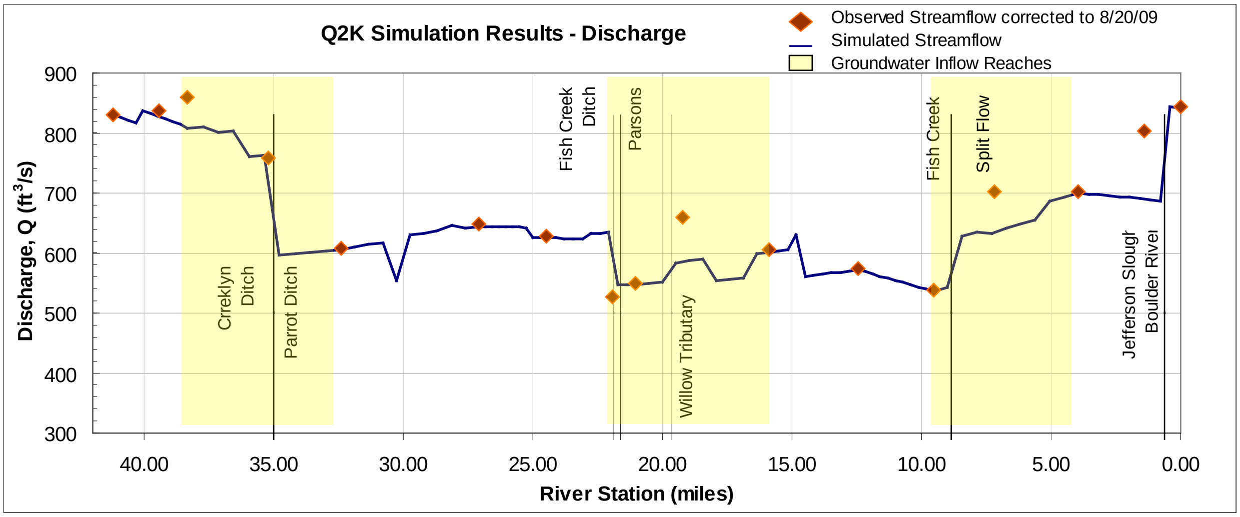

Figure C10. Observed versus Simulated Discharge

C5.2 HYDRAULICS

Correct simulation of river hydraulics ensures that the air-water interface and associated water column are exposed to an accurate duration and area of meteorological inputs within the model. For confirmation purposes, a comparison of model hydraulics against measured field data is shown in **Figures C11 - C12**. Relatively good agreement is seen between observed and simulated wetted widths. Differences between velocity and depth have a higher PBIAS, which is likely due to the high flow conditions experienced in 2009. Wadeable sites selected for streamflow measurements were often not representative of the channel across the entire reach. Mean PBIAS for computed channel velocities, wetted widths, and associated depths were -18.5%, 0.06%, and 35.7%, respectively. Standard errors were 0.56 ft/s, and 24.11 and 0.32 feet, respectively. These values are adequate given the field conditions in a high water year, as well as the simplified hydraulic portion of the Q2K model as compared to more detailed hydraulic models.

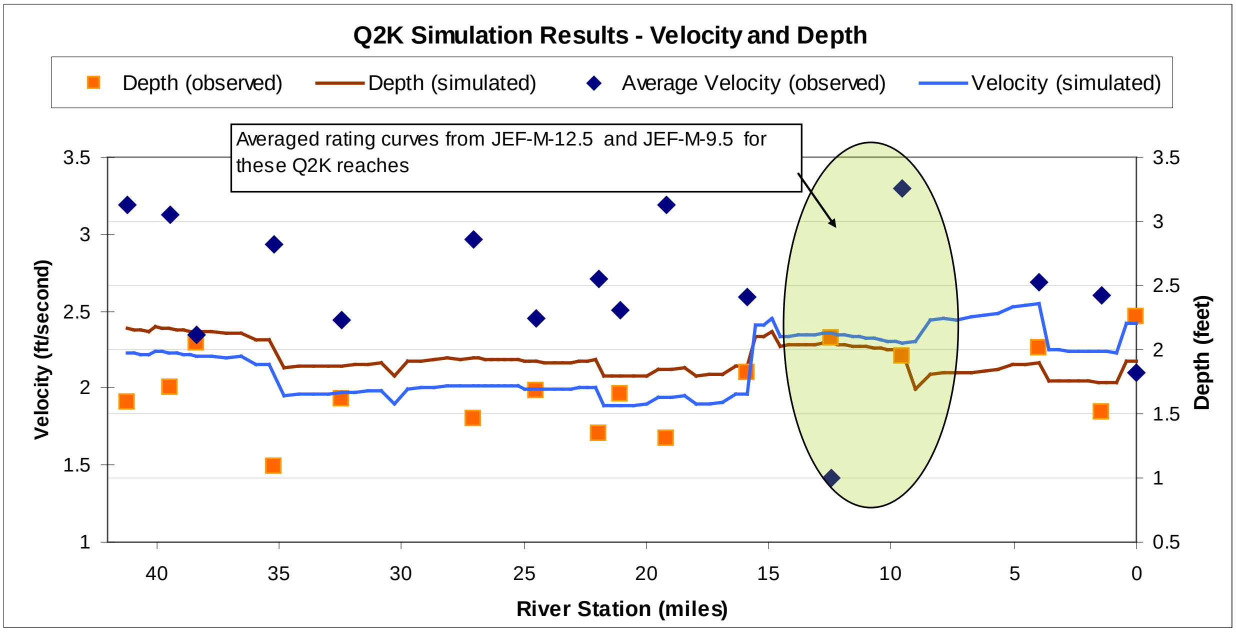

Figure C11. Observed versus Simulated Velocity and Depth

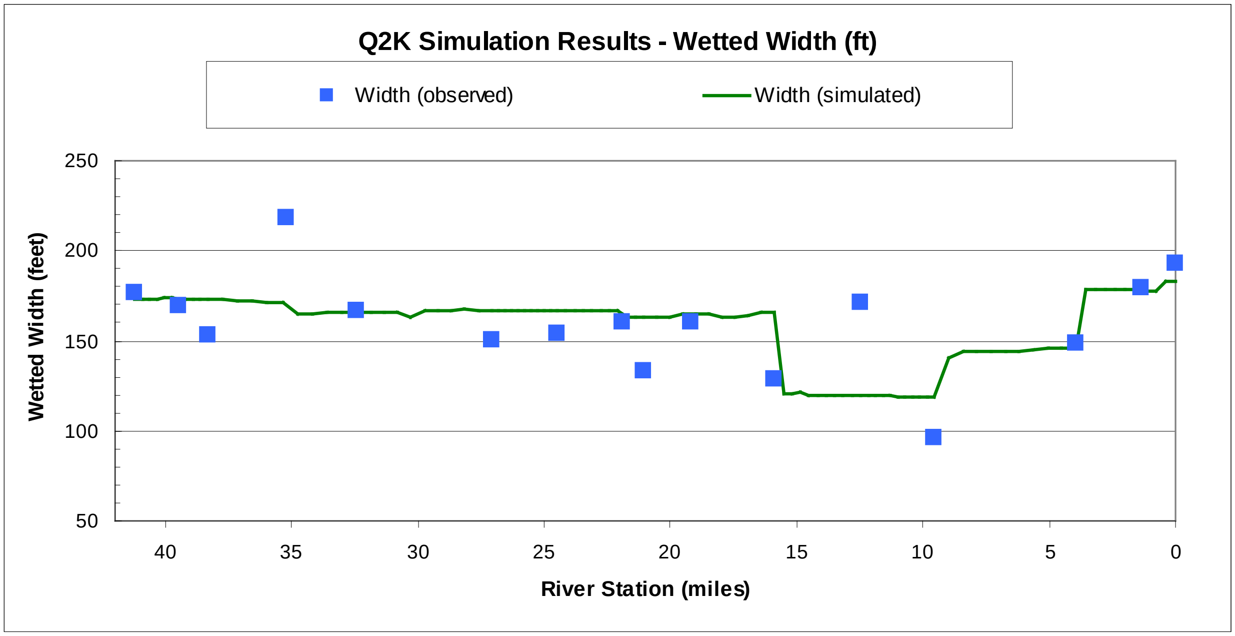

Figure C12. Observed versus Simulated Wetted Width

C5.3 SHADE

Simulated stream shade includes shading from both topography and vegetation and integrates the effects of channel aspect, offset, and width at a particular model node. Shade.xls outputs hourly effective shade and daily effective shade. Daily effective shade predictions ranged from 0% to 13.2% as compared to 0% to 13% at field-measured individual stations. Overall simulation PBIAS was 29% with a standard error (in % shade) of 2.4%. While these numbers are not within ideal model ranges, when compared to site-specific observations taken with a solar pathfinder, model simulation values are within reason (**Figure C13**). Discrepancies between simulated and observed values exemplify the difference between measured point values and averages over the 1,000-m distance step. There are three Solar Pathfinder results at each field-measured site. These are the averages from 25%, 50% and 75% of the wetted width from the right bank at each of three transects. The uncorrected shade results utilize vegetation density as averaged from all field data. The corrected shade results utilize vegetation density that is decreased to increase fit with field data. The solid line shows average effective shade across all nodes within each Q2K reach. The use of shade data on a reach basis in Q2K indicates why one-at-a-time sensitivity analysis for vegetation density and shade input parameters were low-ranking.

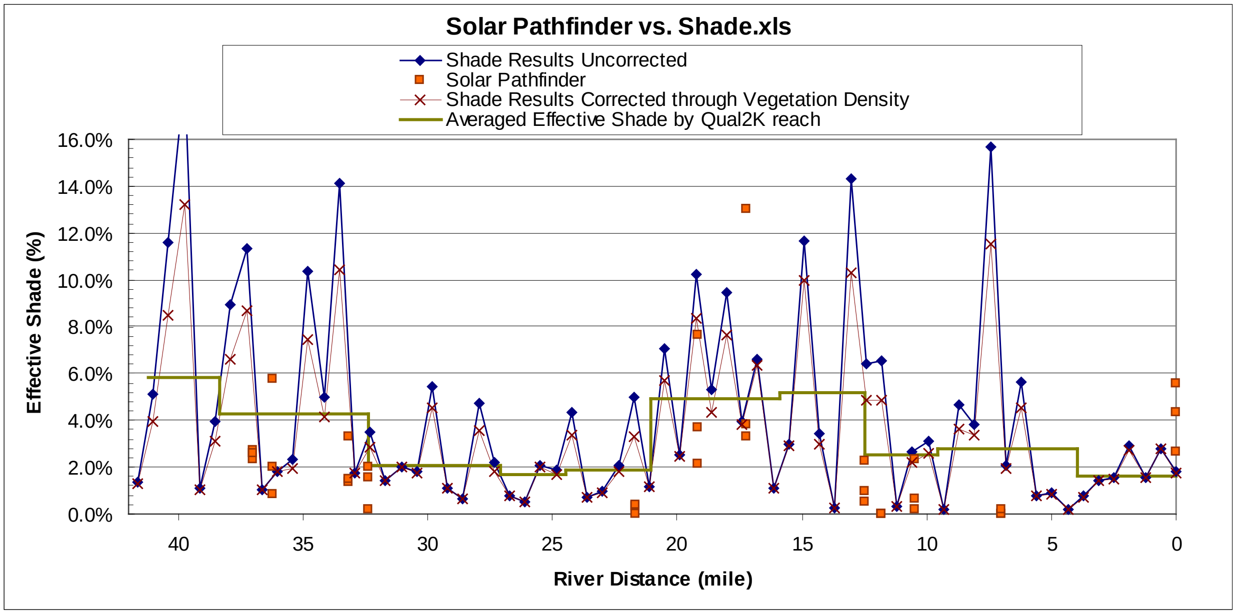

Figure C13. Shade Results versus Solar Pathfinder Measurements

C5.4 WATER TEMPERATURE

Computed and observed minimum, mean, and maximum water temperatures for the August 20-22, 2009 modeling period are shown in **Figure C14**.

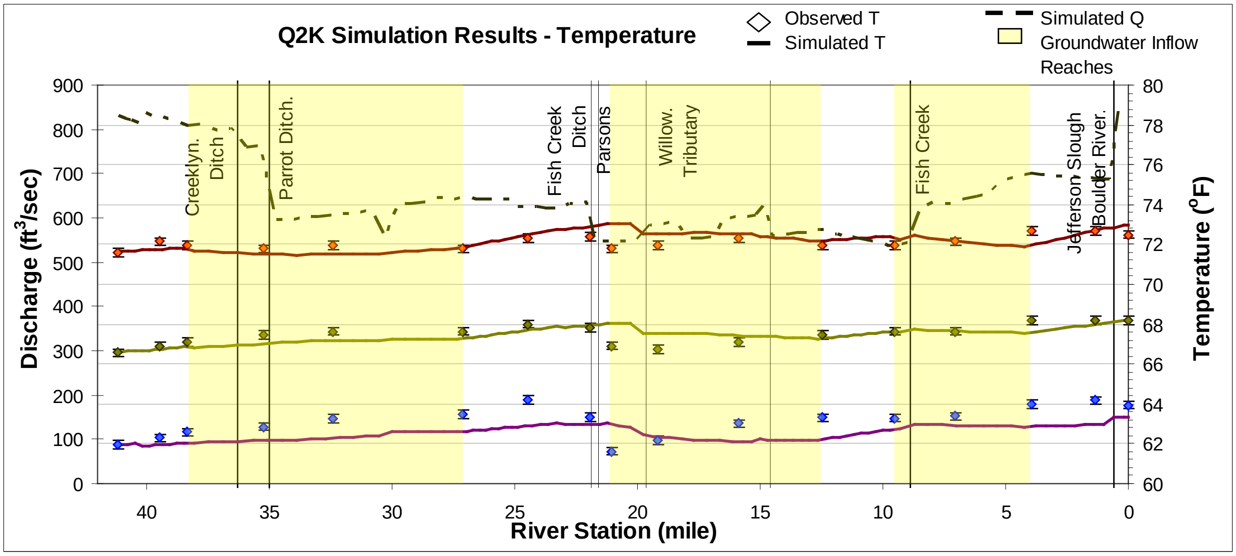

Figure C14. Modeled vs. Observed Water Temperature

Overall, there is very good agreement between the simulated and observed values for minimum, maximum, and mean temperatures. Diurnal plots are included in **Figure C15** for mainstem locations approximately every ten miles. The simulated values are provided for a single 24 hour day in the Q2K model. These simulated results are repeated across the three day model period for the charts below.

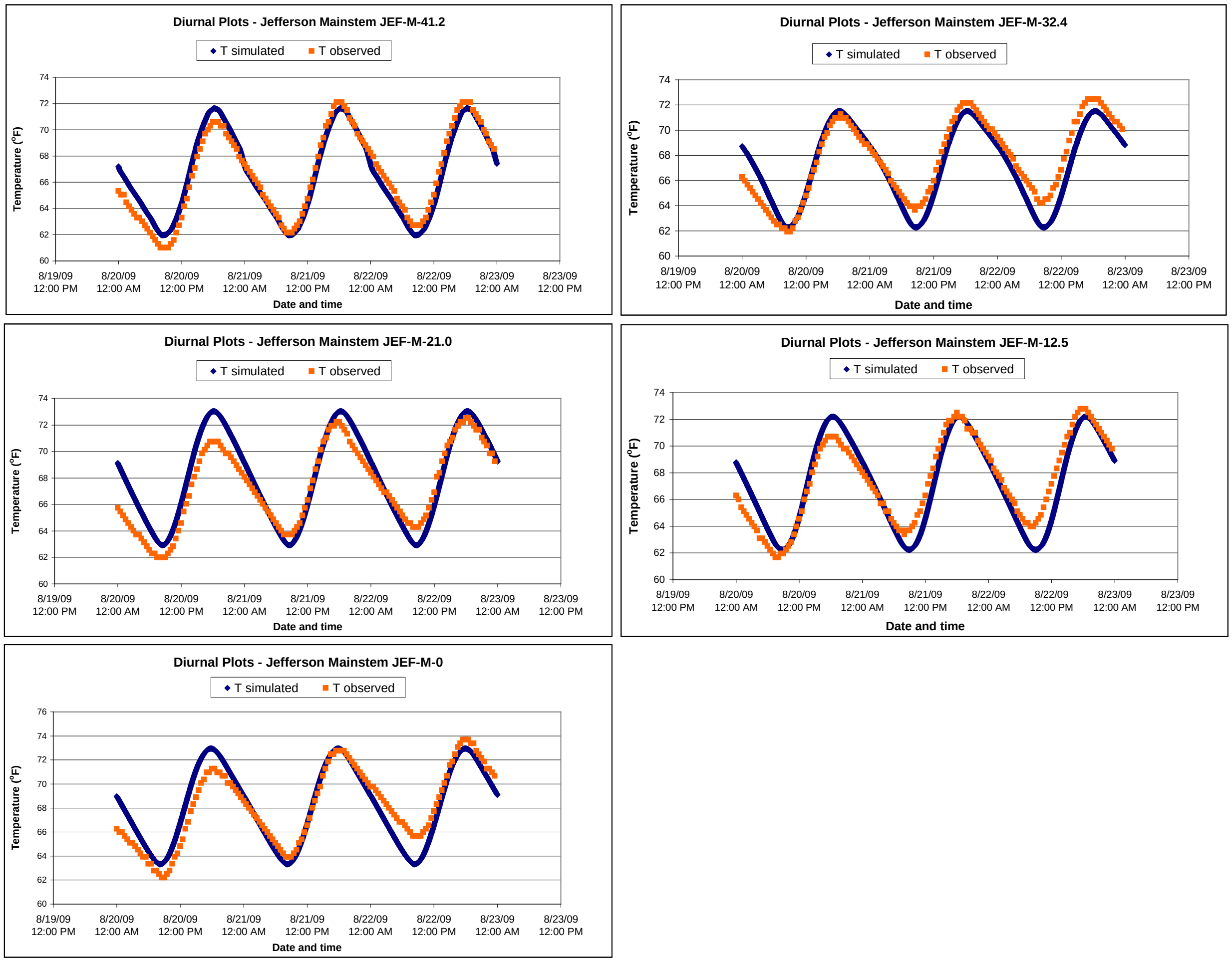

Figure C15. Diurnal Temperature Plots for 3-Day Model Period on Jefferson Mainstem

Calibration statistics were determined by combining the mean, minimum and maximum simulated and observed values for each mainstem location. Results are as follows: PBIAS was largely negligible (-0.53%), SSR = 1.92 and standard error = 0.53°F. Individual calibration statistics for average, minimum and maximum temperatures are shown in **Table C7**.

Table C7. Individual Station Calibration Statistics

Statistics	Average Temperature	Minimum Temperature	Maximum Temperature	Average Result
Percent Bias (%)	-0.08	-1.81	0.29	-0.53
SSR	0.96	3.66	1.13	1.92
Standard Error (ºF)	0.43	0.63	0.47	0.52

Examination of the longitudinal temperature profile of the Upper Jefferson River provides important information regarding instream water temperatures and associated river dynamics. Beginning at the upstream boundary (mile 41.2), temperature remains relatively constant until reaching river mile 27, where an increasing trend is noted. This area shows significant off-stream agricultural development on both sides of the river. This area is also a losing stretch of the river. Maximum temperatures reach 73.0°F in this section. The warming trend continues as additional irrigation withdrawals occur and flows decrease until reaching the Willow Springs confluence near mile 19.6. The spring fed tributaries and groundwater inflow through this reach lower the average, maximum and minimum temperatures. Also, the Point of Rocks geologic outcrop provides topographic shade through this reach which may also affect river temperatures. Temperatures remain relatively constant for approximately the next 15 miles, but a second increasing trend is noted near the end of the study area, starting at mile 3.9.

The maximum simulated river temperature occurs at mile 21.2 (73°F) where there is significant agricultural development and a losing stretch of the river. A second temperature maximum is at mile 0.0 (73°F) where there is significant agricultural development, as well as several backwater sloughs and oxbow channels. The river enters the LaHood Canyon just downstream of the end of the study area. Overall, the model shows a very consistent temperature profile. This constant profile is a function of the high water year.

In calibration of the longitudinal profile of surface water temperature, groundwater inflow temperature was found to vary depending on nearby springs or geothermal activity. Data collected for the WET report (2006) included groundwater temperatures near Willow Springs and Parson's Bridge. For the same model period (Aug 20 – Aug 22), groundwater temperatures were stable within 0.5°F and water temperatures were as follows: monitoring wells Willow-8 (53°F), Willow-10 (55.5°C) and Parsons-1 (51.7°C). Known hot springs are located near Silver Star (mile 31.7) and along Point of Rocks Road (mile 15.9). In areas where large alluvial groundwater systems converged (reaches 38.3 – 27.1 miles), a temperature of 53.6°F was used. In reaches downgradient of Willow Springs, temperatures of 48.2°F (reach 21.1 – 15.8 miles), and 51.8°F (reach 15.8 – 12.5 miles) were used. A temperature of 59.0°F was used where both regional groundwater flow and hot springs occur, throughout reach 9.6 – 3.9 miles. These groundwater temperatures are within ranges queried from the Groundwater Information Center (GWIC) database. The GWIC database showed a range of 45.7 to 64.8°C in nearby wells. Groundwater inflow temperatures were adjusted to available field data in those reaches where previous studies have been conducted.

Overall, a good surface water temperature calibration was achieved based on model statistical efficiency. The primary drawback to model calibration activities was the high flows in which the study was conducted, which resulted in some hydraulic calibration variations. Once sufficient calibration of the existing condition model was achieved, scenarios for TMDL planning and analysis were developed. The flows used for model calibration represented a relatively high flow condition compared to those experienced over the past decade; as a result, a scenario was created to include the 7Q10 flow event, with a limited validation.

C6.0 SCENARIO ANALYSIS

A number of scenarios were developed as part of this study so that watershed managers can provide reasonable recommendations for meeting water quality criteria in the river. Vegetation losses along the riparian corridor, irrigated crop production, and hydrostructures (dams and diversions) have all been cited as causes for elevated water temperature in the Jefferson River (Montana Department of Environmental Quality, 2008). In addition to these identified causes, impacts from tributaries and other inflows to the river are potential causes for impairment.

Although it is known that human activities are impacting the Upper Jefferson River, little has been done to associate management activities in the river corridor with instream temperatures. As a result, this report developed modeling scenarios to address the following: (1) 7Q10 low flow or "baseline" conditions, (2) a naturally occurring scenario in which all reasonable land, soil, and water conservation practices are applied (ARM 17.30.602 (3) a shade scenario in which reference condition shade is applied across the study area, and (4) improved irrigation water practices. A detailed description of assumptions for each scenario is included in each subsection. The 7Q10 scenario, and therefore all subsequent scenarios because the 7Q10 is the baseline scenario, were updated in 2014 to incorporate climate data from 2013, which was very near to a 7Q10 year (370 cfs for a period of time during August, 2013).

C6.1 SCENARIO 1: 7Q10 WATER YEAR – BASELINE SCENARIO

The goal of this modeling study was to collect data and model the typical summer time low flow or baseline condition of the Upper Jefferson River. The 2009 water year experienced significantly higher flows during the model period than in the past several years. As a result, it was necessary to develop a baseline scenario that simulated conditions during a 7-day 10-yr low flow condition (e.g. statistically a condition that would happen every ten years).

It was determined that the 7Q10 flow was an appropriate representation of low flow conditions. The 7Q10 flow is the lowest 7-day average flow that occurs (on average) once every ten years. The 7Q10 flow for the July – October time period (as stated in the USGS Statistical Summaries of Streamflow for gage 06026500 Jefferson River near Twin Bridges, MT) is 387 cfs. The 2009 existing conditions model (830 cfs) was altered by changing the following parameters:

- Headwater flow was decreased to 387 cfs (53% reduction). All tributary inputs (Point Sources worksheet) were decreased by 50% including Hells Canyon Creek, Cherry Creek, Fish Creek and the Boulder River/Jefferson Slough. Willow Springs and Parsons Slough are influenced by springs; as a result, flows were not adjusted.

- Headwater average temperature was increased to 68.7ºF, based on available temperature data from recent 7Q10 flow conditions. Hourly temperature inputs were based on the same diurnal pattern as exhibited in the 2009 existing conditions model.

- Groundwater gaining reaches (Diffuse Sources worksheet) were decreased by 25% and groundwater losing reaches were decreased by 50%.

- Climate data averaged from August 17-19, 2013 were used from the Jefferson AgriMet site, where wind was adjusted down x0.32 (Flynn and Suplee, 2013).

- The minimum, maximum, and average verification temperatures for the baseline 7q10 condition were calculated based on three days of record (August 17-19, 2013) at USGS gaging stations 06026500 (Jefferson River near Twin Bridges MT) and at 06027600 (Jefferson River at Parsons Bdg nr Silver Star, MT). These dates were selected to evaluate the 7Q10 scenario with post-hoc data because 2013 approximated a 7Q10 flow, and no test of the model had been made under those conditions.

Maximum temperatures above 80ºF occur between miles 10.9 to9.7. The Q2K model output results are shown are shown in **Table C8**. The Scenario 1 - Baseline 7Q10 water year is utilized as the baseline model for the remaining scenarios, as this flow condition better displays the impact of management scenarios on temperature.

Table C8. Temperature Changes – Scenario 1: Baseline 7Q10 Condition

Condition	Location	(Q, cfs)	T_{min}	T_{avg}	T_{max}
Scenario 1: Baseline 7Q10	Parson's Bridge (mi. 21.9)	52.2	60.61	68.88	76.94
2009 Existing Conditions		547.2	62.99	67.96	72.92
*Scenario Change (ºF)			**-2.38**	**0.92**	**4.02**
Scenario 1: Baseline 7Q10	Outlet – (mile 0.0)	178.3	60.74	68.44	76.14
2009 Existing Conditions		841.5	63.32	68.20	72.95
*Scenario Change (ºF)			**-2.58**	**0.24**	**3.19**
Average deviation of all model nodes			**-3.15**	**-0.02**	**3.81**
Greatest temperature increase (and location) from 2009 condition			**1.80** (headwaters)	**2.07** (headwaters)	**10.22** (mile 9.7)

*A negative number indicates that the baseline condition is cooler than the existing condition, and a positive number indicates the baseline condition is warmer than the existing condition.

C6.2 SCENARIO 2: NATURALLY OCCURRING CONDITION SCENARIO

The naturally occurring condition scenario defines water temperature conditions resulting from the implementation of all reasonable land, soil, and water conservation practices (LSWCP), e.g. where best management practices are implemented as outlined in ARM 17.30.602. Essentially, "naturally occurring" establishes the bar for which the allowable 0.5°F temperature increase is compared to, and effectively determines if a waterbody is meeting or exceeding a temperature standard. The following changes were made to the 7Q10 baseline model in the naturally occurring scenario:

- Decrease headwater temperature. Determine headwater temperature from a mixing calculation using naturally occurring maximum temperature from three headwaters streams (**Table C9**, Results: T_{min} =62.71, T_{avg} = 67.44, T_{max} =72.59°F).
- Increase all open/grassed sites, barren areas, and any other area with diminished shading vegetation to a reference shade condition (averaged shade from Scenarios 3a and 3b).
- Incorporate a 15% irrigation efficiency improvement for all diversions and return flows (Scenario 4).

Table C9. Parameters used in Headwater Mixing Calculations – Naturally Occurring

River Name	(Q, cfs)	Source data for Q	Tavg °F	Source data for Tavg	Tmax °F	Source data for Tmax
Ruby River	94	*	N/A	Tavg not provided	66.70**	DEQ model, naturally occurring
Beaverhead River	89	*	68.41	DEQ model, naturally occurring scenario	72.14***	DEQ model, naturally occurring
Big Hole River	135	*	71.67	DEQ model, naturally occurring scenario	77.00**	DEQ model, naturally occurring
Jefferson Headwater					**72.60**	**Mixing Calculation**

*Headwater flows were determined as a contributing ratio to the Jefferson River USGS gage at Twin Bridges. Available data for all four USGS gage sites when the Jefferson River was below 600 cfs were from 8/3/2008 through 8/31/2008.

USGS gages:

- 06023000 Ruby River near Twin Bridges, MT
- 06018500 Beaverhead River near Twin bridges, MT
- 06026420 Big Hole R blw Hamilton Ditch nr Twin Bridges, MT
- 06026500 Jefferson River near Twin Bridges MT

Combined flows for the three rivers add up to be less than the 7Q10, but is acceptable for calculating mixing equations.

**Naturally occurring temperatures for the Ruby and Big Hole Rivers were calculated using models for TMDL development of those rivers (completed in 2006 and 2009 respectively)

***Naturally occurring temperature for the Beaverhead River used in the Jefferson River temperature model was calculated before the completion of the Beaverhead River temperature model. The resulting maximum naturally occurring temperature at the mouth from the Beaverhead River temperature model is 0.15°F above the maximum naturally occurring temperature used in the Jefferson model, which means that the temperature used in the mixing equation results in a slightly more conservative estimate of the naturally occurring temperature of the Jefferson River.

The mixing calculation is as follows:

$$T_{JeffersonHeadwater} = \frac{(Q_{Beaverhead} * T_{Beaverhead}) + (Q_{Ruby} * T_{Ruby}) + (Q_{BigHole} * T_{BigHole})}{Q_{Beaverhead} + Q_{Ruby} + Q_{BigHole}}$$

Baseline (7Q10) and naturally occurring scenario results, along with associated water temperatures near Parson's Bridge (21.9 miles) and at the downstream boundary of the study area (0.0 miles) are shown in **Table C10**.

Table C10. Temperature Changes – Scenario 2: Naturally Occurring

Condition	Location	T_{min}	T_{avg}	T_{max}
Naturally Occurring Scenario	Parson's Bridge (mi. 21.9)	60.97	68.34	75.62
Baseline		60.61	68.88	76.94
*Scenario 2 Change (ºF)		**0.36**	**-0.54**	**-1.32**
Naturally Occurring Scenario	Outlet – (mile 0.0)	61.09	67.94	74.97
Baseline		60.74	68.44	76.14
*Scenario 2 Change (ºF)		**0.35**	**-0.50**	**-1.17**
Average deviation of all model nodes		**1.04**	**-0.29**	**-1.93**
Greatest temperature reduction (and location) from 7Q10 baseline		**-1.06** (headwaters)	**-1.79** (mile 13.4)	**-7.91** (mile 9.7)

*A negative number indicates that the scenario temperature is cooler than the baseline temperature, and a positive number indicates the scenario temperature is warmer than the baseline

Results of the naturally occurring scenario suggest that maximum temperatures could be reduced by an average of 1.93°F. Of the 102 output locations within the model, only 1 location met the state of the Montana temperature standard during the baseline (7Q10) scenario (e.g. within the 0.5°F allowable increase). Areas with the greatest potential for improvement occur in several locations: 1) the upper reach as a result of implementation of all reasonable land, soil, and water conservation practices in the Ruby, Beaverhead, and Big Hole rivers (41.2 - 35.08 miles); and 2) various lower reaches largely as a result of water management practices (miles 27-20, 18-15.4, and 14.3-0), with the greatest temperature reduction of 7.91°F at mile 9.7.

C6.3 SCENARIO 3: SHADE/VEGETATION IMPROVEMENT

During the field reconnaissance, the riparian corridor varies between being in relatively good condition and having eroding banks, grazing impacts, and riparian clearing to accommodate irrigated agriculture. A hypothetical shading scenario was run to characterize the maximum possible influence of shade on instream temperature. The following assumptions were made in the shade scenario: (1) all open/grassed sites, barren areas, and any other area with diminished shading vegetation were increased to a reference shade condition, and (2) all other conditions were held constant.

Two reference shade conditions were evaluated. The first reference condition was defined as improvement to a mixed low level vegetation type. The second reference condition was defined as a mixed high level (inclusion of cottonwoods) in which grass/bare areas as well as willow areas and mixed low level areas were increased. The potential temperature reduction due to naturally occurring increased shade is somewhere between these two shade conditions with a potential for low level shrubs/willows in some areas and cottonwoods in other areas throughout the upper segment of the river. Thus an arithmetic average of the shade from the two reference conditions was used in the model.

As stated in Section 5.3, shade parameters were input into Shade.xls at every kilometer and then all nodes within each model reach were averaged into a single average hourly value for the entire reach. The Upper Jefferson River TPA has varied vegetation conditions, and aerial photography and field reconnaissance did not show significant vegetation breaks. Thus the averaging method is appropriate; however, the long reaches within this Q2K model do not allow for assessment of localized conditions.

Simulations were implemented by simply changing riparian cover conditions in the model. The shade scenario used the averaged shade values (from the two evaluated conditions) to reflect a mix of high and low level vegetation (cottonwoods and shrubs/willows). Existing cottonwoods or mixed high level conditions were not adjusted. Scenario results, along with associated instream water temperatures near Parson's Bridge (mile 21.9), and at the downstream boundary of the study area (mile 0.0) are shown in **Table C11**.

Table C11. Temperature Changes – Scenario 3: Shade/Vegetation Improvement

Condition	Location	T_{min}	T_{avg}	T_{max}
Shade Scenario	Parson's Bridge (mi. 21.9)	60.49	68.62	76.65
Baseline		60.61	68.88	76.94
*Scenario 3 Change (ºF)		**-0.12**	**-0.26**	**-0.29**
Shade Scenario	Outlet – (mile 0.0)	60.68	68.22	75.81
Baseline		60.74	68.44	76.14
*Scenario 3 Change (ºF)		**-0.06**	**-0.22**	**-0.33**

Table C11. Temperature Changes – Scenario 3: Shade/Vegetation Improvement

Condition	Location	T_{min}	T_{avg}	T_{max}
Average deviation of all model nodes		**-0.08**	**-0.20**	**-0.30**
Greatest temperature reduction (and location) from 7Q10 baseline		**-0.26** (mile 9.7)	**-0.51** (mile 9.7)	**-0.71** (mile 9.7)

*A negative number indicates that the scenario temperature is cooler than the baseline temperature, and a positive number indicates the scenario temperature is warmer than the baseline

The upgrade from bare, native grass and irrigated grass to a mixed high and low level vegetation shows that the greatest temperature reduction (0.71°F) would occur at mile 9.7. Results show that shade is not a major temperature influencing factor unless it is of significant height, due to the wide river channel. However, it should be noted that shade is an important part of a healthy river system, as healthy riparian vegetation not only provides thermal protection but also improves bank stability and fish habitat.

C6.4 SCENARIO 4: IMPROVED WATER MANAGEMENT PRACTICES

The water management practices scenario describes the thermal effect of improved irrigation management on the Upper Jefferson River. Although Montana standards do not necessarily apply to consumptive water use, it is important to assess the cumulative effect of these practices on the overall thermal regime of the river. The following changes were made to the 7Q10 baseline model in the improved water management practices scenario:

- Irrigation diversions and return flows in the Upper Jefferson were decreased 15% to account for private land owners' voluntary water restrictions during the 7Q10 flow.

Naturally occurring and improved water management scenario results, along with associated instream water temperatures near Parson's Bridge (35.25 km) and at the downstream boundary of the study area (0 km) are shown in **Table C12**.

Table C12. Temperature Changes – Scenario 4: Improved Water Management

Condition	Location	T_{min}	T_{avg}	T_{max}
Water Use Scenario	Parson's Bridge (mi. 21.9)	61.35	68.84	76.17
Baseline		60.61	68.88	76.94
*Scenario 4 Change (ºF)		**0.74**	**-0.04**	**-0.77**
Water Use Scenario	Outlet – (mile 0.0)	61.21	68.19	75.30
Baseline		60.74	68.44	76.14
*Scenario 4 Change (ºF)		**0.47**	**-0.25**	**-0.84**
Average deviation of all model nodes		**1.49**	**0.27**	**-1.29**
Greatest temperature reduction (and location) from 7Q10 baseline		**0.00** (headwaters to mile 36.9)	**-1.38** (mile 9.7)	**-7.42** (mile 9.7)

*A negative number indicates that the scenario temperature is cooler than the baseline temperature, and a positive number indicates the scenario temperature is warmer than the baseline

A 15% increase in streamflow shows that the greatest temperature reduction (7.42°F) would occur at mile 9.7. The increased flow scenario shows that reducing the amount of water diverted during low flow is a significant contributing factor to maximum temperature reductions, however it does raise minimum temperatures throughout the segment. Based on model results, irrigation water savings are an important means to achieve state temperature regulations. However, compliance would be on a voluntary basis by landowners. In addition to these results, water temperatures in the Upper Jefferson River would also be beneficially affected by similar improvements in the Ruby, Beaverhead, and Big Hole Rivers.

C7.0 CONCLUSION

Water temperature monitoring was conducted on the Upper Jefferson River during the 2009 field season and temperature modeling activities were completed using Q2K and Shade.xls. The calibrated 2009 existing conditions model showed daytime peak temperatures exceeded 70ºF during a flow event of 830 cfs. This report also developed a 7Q10 baseline flow event from the calibrated 2009 existing conditions model (post-audited and updated with 2013 data), in order to simulate multiple low flow conditions experienced over that past decade. Several scenarios were developed to define the impact of specific watershed management changes on Jefferson mainstem temperatures; also, a naturally occurring scenario was developed that simulates temperature conditions with the implementation of all reasonable land, soil, and water conservation practices. Each management change scenario is compared to a 7Q10 baseline scenario in **Table C13.**

Table C13. Summary of Scenario Results: Average Temperature Change across all Q2K Elements from 7Q10 Baseline

Scenario	Average Temperature (ºF) Difference from 7Q10 Baseline Model across all Q2K elements		
	Minimum	Average	Maximum
Scenario 2: Naturally Occurring	1.04	-0.29	-1.93
Scenario 3: Shade/Vegetation Improvement – Mixed Low and High Level averaged	-0.08	-0.20	-0.30
Scenario 4: Improved Water Management	1.49	0.27	-1.29

*A negative number indicates that the scenario temperature is cooler than the baseline temperature, and a positive number indicates the scenario temperature is warmer than the baseline

The scenario analysis shows that the establishment of a reference shade condition consisting of mixed low and high level vegetation would reduce the maximum instream temperatures by an average of 0.3ºF and up to 0.71ºF at river station 9.7 miles.

The water management scenarios (Scenario 4) shows significant reductions in maximum river temperature. A 15% water conservation scenario (Scenario 4) would reduce the maximum temperature by 1.29 ºF on average throughout the reach and up to 7.42ºF at river station 9.7 miles (near Koontz Bridge), and efforts should be focused on achieving this target.

Areas with the greatest improvement between the 7Q10 baseline simulation results and the naturally occurring scenario occur in several locations:

1. The upper reach (41.2 - 35.08 miles) as a result of the implementation of all reasonable land, soil, and water conservation practices in the Ruby, Beaverhead and Big Hole Rivers, and
2. Various lower reaches (miles 27-20, 18-15.4, and 14.3-0) largely as a result of water management practices.

Watershed management activities should be prioritized to address these most impacted sections first, with activities on other sections of the river completed at a later time. It is important to point out that for water temperature, the location of the impacted section may not necessarily coincide with the location where the critical management action needs to be undertaken. In this regard, additional modeling of proposed management practices should be completed to prioritize which results in the most improvement for the least cost.

Q2K modeling results of Scenarios 1-4, along with the Shade.xls file, and 2009 field data can be found in the WQPB library at the DEQ.

C8.0 REFERENCES

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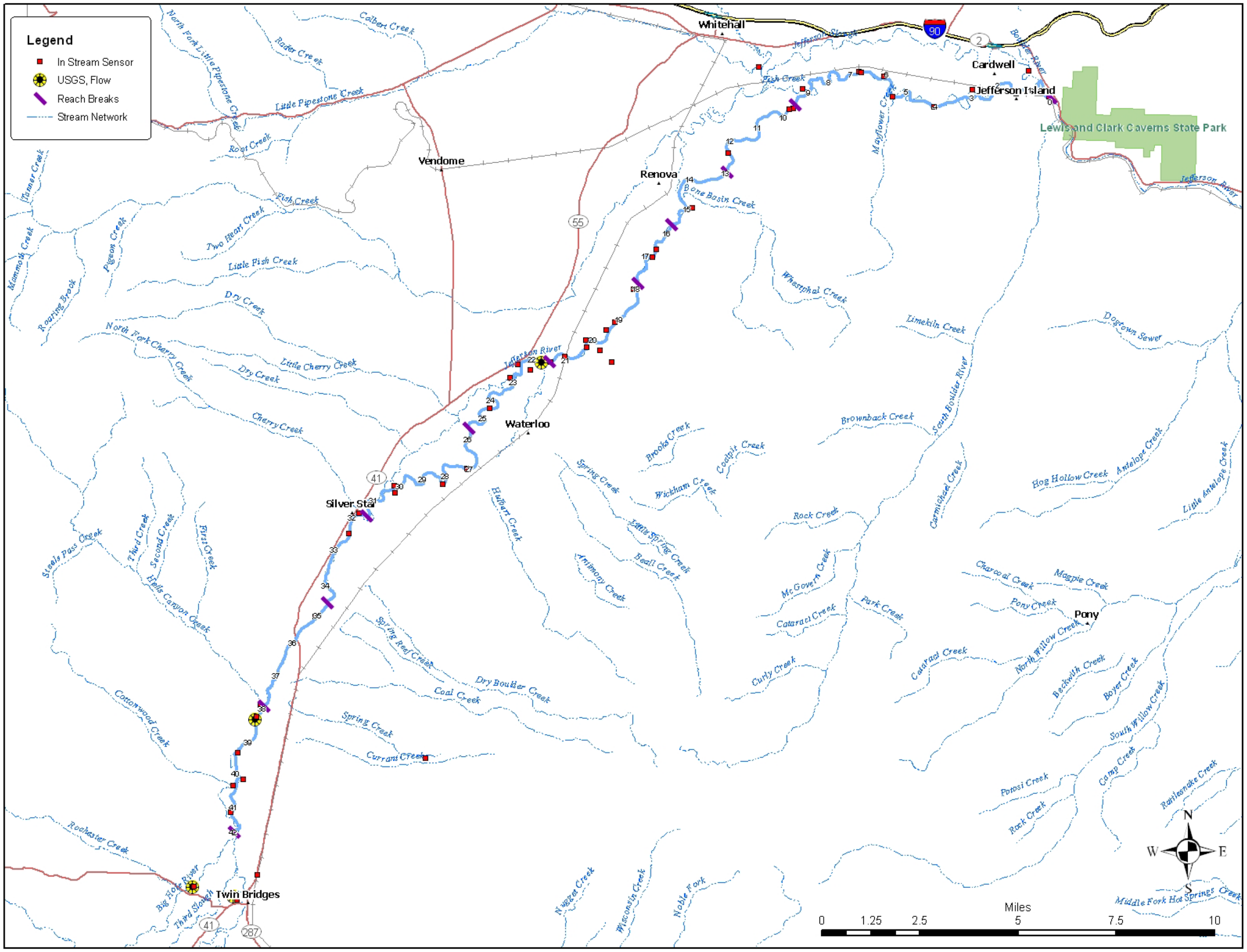
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Waterloo
Silver Star
Twin Bridges
Pony
Jefferson River
Jefferson Slough
Boulder River
Big Hole River
Fish Creek
Mayflower Creek
Bone Basin Creek
Whitetail Creek
Little Pipestone Creek
Colbert Creek
Ryder Creek
North Fork Little Pipestone Creek
Root Creek
Two Heart Creek
Little Fish Creek
Dry Creek
North Fork Cherry Creek
Little Cherry Creek
Cherry Creek
Tanner Creek
Mammoth Creek
Pigeon Creek
Roaring Brook
Steels Pass Creek
Third Creek
Second Creek
First Creek
Hells Canyon Creek
Cottonwood Creek
Rochester Creek
Third Slough
Hurlburt Creek
Spring Creek
Spring Reef Creek
Dry Boulder Creek
Coal Creek
Currant Creek
Brooks Creek
Cockpit Creek
Wickham Creek
Little Spring Creek
Beall Creek
Antimony Creek
Brownback Creek
South Boulder River
Carmichael Creek
Limekiln Creek
Dogtown Sewer
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McGovern Creek
Cataract Creek
Park Creek
Curly Creek
Hog Hollow Creek
Antelope Creek
Little Antelope Creek
Charcoal Creek
Magpie Creek
Pony Creek
North Willow Creek
Beckwith Creek
Boyer Creek
South Willow Creek
Camp Creek
Rattlesnake Creek
Potosi Creek
Nugget Creek
Wisconsin Creek
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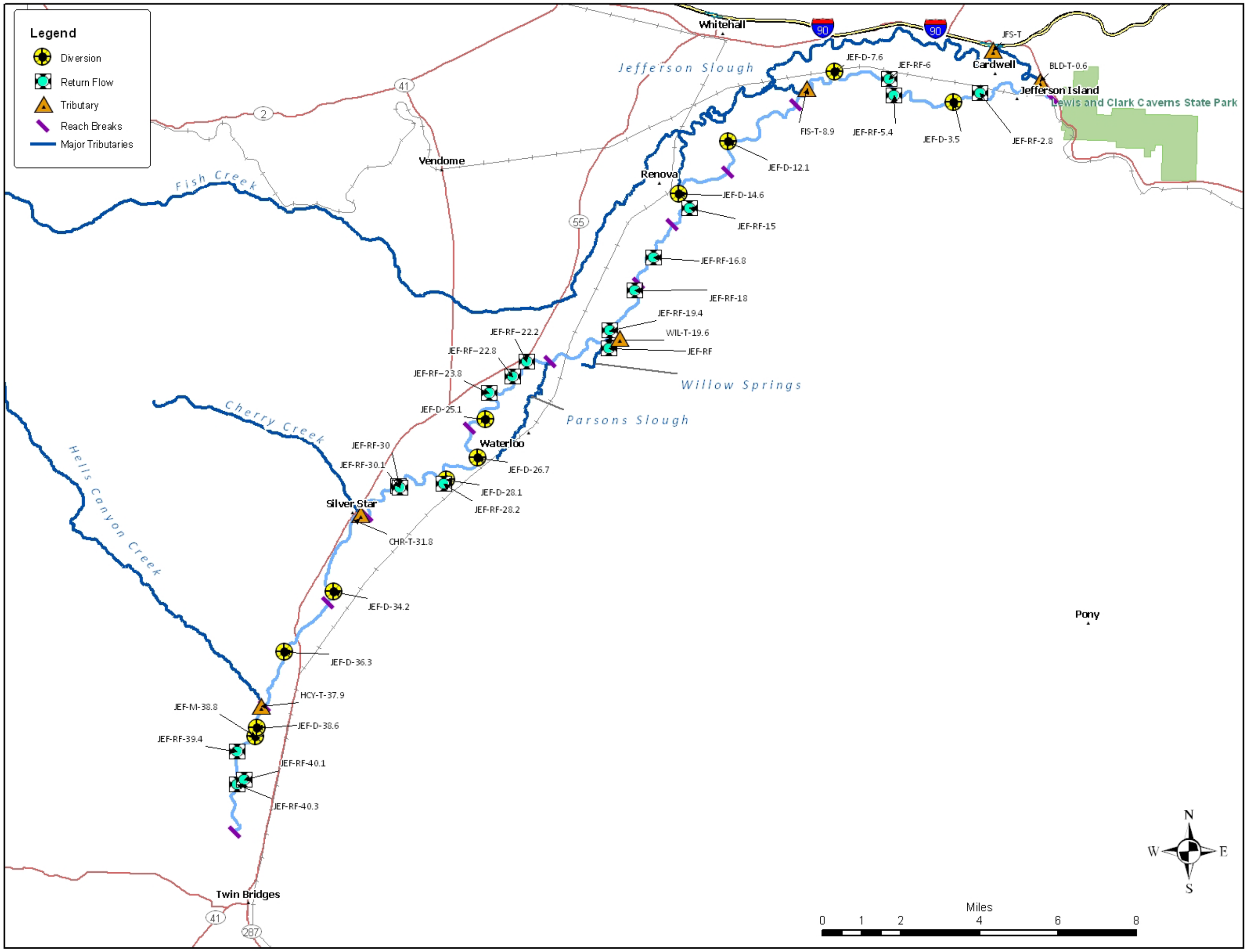
EXHIBIT C2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Lewis and Clark Caverns State Park
Jefferson Slough
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JEF-RF-6
FIS-T-8.9
JEF-RF-5.4
JEF-D-3.5
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Fish Creek
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JEF-RF–23.8
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Parsons Slough
Cherry Creek
Waterloo
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CHR-T-31.8
Hells Canyon Creek
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JEF-D-36.3
HCY-T-37.9
JEF-M-38.8
JEF-D-38.6
JEF-RF-39.4
JEF-RF-40.1
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APPENDIX D – TEMPERATURE AND FLOW DATA

This appendix displays the data used in the source assessment (**Tables D1 and D2**) for the Dillon WWTF (**Section 5.5.2**) and example TMDLs for the lower Beaverhead and upper Jefferson Rivers (**Sections 5.7.2 and 5.7.3**).

D1.0 DILLON WWTF DMR DATA 2010-2013

Table D1. Dillon WWTF effluent water temperature in °F

Monitoring Period Start Date	Monitoring Period End Date	Statistical Base Long Desc	DMR value
12/1/2013	12/31/2013	Instantaneous Maximum	41.9
12/1/2013	12/31/2013	Instantaneous Minimum	34.34
11/1/2013	11/30/2013	Instantaneous Maximum	41.54
11/1/2013	11/30/2013	Instantaneous Minimum	38.12
10/1/2013	10/31/2013	Instantaneous Maximum	51.26
10/1/2013	10/31/2013	Instantaneous Minimum	44.6
9/1/2013	09/30/2013	Instantaneous Maximum	66.02
9/1/2013	09/30/2013	Instantaneous Minimum	59.36
8/1/2013	08/31/2013	Instantaneous Maximum	68.54
8/1/2013	08/31/2013	Instantaneous Minimum	66.02
7/1/2013	07/31/2013	Instantaneous Maximum	71.06
7/1/2013	07/31/2013	Instantaneous Minimum	68.9
6/1/2013	06/30/2013	Instantaneous Maximum	64.04
6/1/2013	06/30/2013	Instantaneous Minimum	58.1
5/1/2013	05/31/2013	Instantaneous Maximum	59
5/1/2013	05/31/2013	Instantaneous Minimum	52.34
4/1/2013	04/30/2013	Instantaneous Maximum	50.9
4/1/2013	04/30/2013	Instantaneous Minimum	42.62
3/1/2013	03/31/2013	Instantaneous Maximum	38.84
3/1/2013	03/31/2013	Instantaneous Minimum	33.98
2/1/2013	02/28/2013	Instantaneous Maximum	35.96
2/1/2013	02/28/2013	Instantaneous Minimum	32.18
1/1/2013	01/31/2013	Instantaneous Maximum	33.44
1/1/2013	01/31/2013	Instantaneous Minimum	32.72
12/1/2012	12/31/2012	Instantaneous Maximum	36.5
12/1/2012	12/31/2012	Instantaneous Minimum	33.62
11/1/2012	11/30/2012	Instantaneous Maximum	44.78
11/1/2012	11/30/2012	Instantaneous Minimum	36.68
10/1/2012	10/31/2012	Instantaneous Maximum	57.74
10/1/2012	10/31/2012	Instantaneous Minimum	42.8
9/1/2012	09/30/2012	Instantaneous Maximum	60.62
9/1/2012	09/30/2012	Instantaneous Minimum	56.84
8/1/2012	08/31/2012	Instantaneous Maximum	69.26
8/1/2012	08/31/2012	Instantaneous Minimum	64.58
7/1/2012	07/31/2012	Instantaneous Maximum	71.24
7/1/2012	07/31/2012	Instantaneous Minimum	62.96
6/1/2012	06/30/2012	Instantaneous Maximum	66.56
6/1/2012	06/30/2012	Instantaneous Minimum	54.86

Table D1. Dillon WWTF effluent water temperature in °F

Monitoring Period Start Date	Monitoring Period End Date	Statistical Base Long Desc	DMR value
5/1/2012	05/31/2012	Instantaneous Maximum	60.26
5/1/2012	05/31/2012	Instantaneous Minimum	51.26
4/1/2012	04/30/2012	Instantaneous Maximum	53.6
4/1/2012	04/30/2012	Instantaneous Minimum	45.86
3/1/2012	03/31/2012	Instantaneous Maximum	44.78
3/1/2012	03/31/2012	Instantaneous Minimum	33.8
2/1/2012	02/29/2012	Instantaneous Maximum	33.62
2/1/2012	02/29/2012	Instantaneous Minimum	33.26
1/1/2012	01/31/2012	Instantaneous Maximum	33.8
1/1/2012	01/31/2012	Instantaneous Minimum	33.44
12/1/2011	12/31/2011	Instantaneous Maximum	33.98
12/1/2011	12/31/2011	Instantaneous Minimum	33.44
11/1/2011	11/30/2011	Instantaneous Maximum	33.8
11/1/2011	11/30/2011	Instantaneous Minimum	42.98
10/1/2011	10/31/2011	Instantaneous Maximum	58.46
10/1/2011	10/31/2011	Instantaneous Minimum	48.38
9/1/2011	09/30/2011	Instantaneous Maximum	62.42
9/1/2011	09/30/2011	Instantaneous Minimum	58.64
8/1/2011	08/31/2011	Instantaneous Maximum	68
8/1/2011	08/31/2011	Instantaneous Minimum	65.66
7/1/2011	07/31/2011	Instantaneous Maximum	103.64
7/1/2011	07/31/2011	Instantaneous Minimum	74.48
6/1/2011	06/30/2011	Instantaneous Maximum	72.14
6/1/2011	06/30/2011	Instantaneous Minimum	56.84
5/1/2011	05/31/2011	Instantaneous Maximum	60.08
5/1/2011	05/31/2011	Instantaneous Minimum	45.14
4/1/2011	04/30/2011	Instantaneous Maximum	46.22
4/1/2011	04/30/2011	Instantaneous Minimum	43.7
3/1/2011	03/31/2011	Instantaneous Maximum	41.18
3/1/2011	03/31/2011	Instantaneous Minimum	33.98
2/1/2011	02/28/2011	Instantaneous Maximum	35.6
2/1/2011	02/28/2011	Instantaneous Minimum	34.34
1/1/2011	01/31/2011	Instantaneous Maximum	39.56
1/1/2011	01/31/2011	Instantaneous Minimum	35.6
12/1/2010	12/31/2010	Instantaneous Maximum	36.5
12/1/2010	12/31/2010	Instantaneous Minimum	35.42
11/1/2010	11/30/2010	Instantaneous Maximum	51.8
11/1/2010	11/30/2010	Instantaneous Minimum	36.86
10/1/2010	10/31/2010	Instantaneous Maximum	59
10/1/2010	10/31/2010	Instantaneous Minimum	49.28
9/1/2010	09/30/2010	Instantaneous Maximum	59
9/1/2010	09/30/2010	Instantaneous Minimum	57.2
8/1/2010	08/31/2010	Instantaneous Maximum	69.8
8/1/2010	08/31/2010	Instantaneous Minimum	62.6
7/1/2010	07/31/2010	Instantaneous Maximum	68
7/1/2010	07/31/2010	Instantaneous Minimum	65.66
6/1/2010	06/30/2010	Instantaneous Maximum	68

Table D1. Dillon WWTF effluent water temperature in °F

Monitoring Period Start Date	Monitoring Period End Date	Statistical Base Long Desc	DMR value
6/1/2010	06/30/2010	Instantaneous Minimum	50
5/1/2010	05/31/2010	Instantaneous Maximum	57.56
5/1/2010	05/31/2010	Instantaneous Minimum	48.02
4/1/2010	04/30/2010	Instantaneous Maximum	52.52
4/1/2010	04/30/2010	Instantaneous Minimum	42.08
3/1/2010	03/31/2010	Instantaneous Maximum	43.16
3/1/2010	03/31/2010	Instantaneous Minimum	34.52

D2.0 FLOW DATA FOR STATION BRDM ON THE BEAVERHEAD RIVER 2005

Table D2. Report For Water Year 2005

Run 06/02/2006 08:49		Station Identification: BRDM - Beaverhead River at Dillon, MT						Parameter code: QD - Daily Mean Total Discharge (cfs)				
Day	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**Jul**	**Aug**	**Sept**
1	55.20	96.83	74.64	69.53	50.78	76.14	43.89	44.14	160.80	107.28	206.27	128.43
2	56.42	94.32	80.96	68.83	42.54	70.93	44.84	43.23	165.77	122.27	196.91	119.80
3	56.07	104.18	78.22	66.87	41.56	60.13	44.20	42.04	133.22	120.24	175.06	112.63
4	55.57	103.12	76.42	66.81	40.50	64.43	44.43	39.68	107.55	116.54	177.81	116.70
5	58.44	101.93	83.22	66.87	41.65	64.30	47.17	39.00	102.52	113.45	168.16	121.17
6	57.41	101.21	82.78	66.87	59.75	64.47	44.27	49.67	108.55	135.10	158.45	121.49
7	55.34	100.61	83.06	66.87	38.70	66.51	42.82	42.07	119.89	142.98	181.95	115.01
8	54.25	99.10	85.63	66.87	38.70	68.12	43.81	42.49	133.01	154.04	178.00	90.99
9	52.85	98.10	85.34	66.87	38.70	67.86	42.81	48.93	111.38	187.07	175.82	82.19
10	53.01	95.13	87.34	66.87	40.05	69.20	42.17	104.79	94.80	194.14	170.15	86.29
11	55.83	94.58	92.66	66.87	80.56	69.23	42.11	158.60	95.51	198.75	168.72	96.89
12	54.25	94.13	91.48	66.87	78.60	70.24	41.88	115.37	106.68	180.58	167.73	95.96
13	55.68	88.59	88.76	66.87	77.68	68.75	43.11	89.88	161.69	155.37	177.44	89.73
14	54.84	87.48	85.76	66.87	78.81	62.43	44.57	96.15	128.07	152.95	182.32	85.88
15	54.39	89.35	86.29	66.87	56.46	63.68	47.54	90.33	90.03	131.72	194.01	64.55
16	62.91	91.93	85.12	66.87	38.88	59.23	53.74	90.15	94.44	122.97	186.87	53.84
17	68.19	91.21	82.47	69.92	59.03	50.68	54.42	133.50	89.59	114.22	178.15	58.50
18	74.10	91.93	83.75	66.87	46.92	47.94	59.64	142.58	82.82	134.03	180.08	57.28
19	77.27	93.47	85.89	66.89	62.07	49.39	77.87	126.36	87.31	128.92	164.49	51.10
20	78.80	93.27	82.31	66.87	76.96	50.38	88.59	117.32	92.04	134.62	159.73	49.40
21	82.40	83.14	98.35	66.87	69.88	50.83	82.53	120.43	60.09	148.79	158.84	50.89
22	82.89	84.48	79.57	66.87	69.72	49.39	73.26	108.82	86.88	164.88	158.45	58.78
23	87.71	88.67	95.78	64.10	71.17	50.77	68.93	92.54	-----	209.87	162.99	60.76
24	84.38	93.20	60.73	57.59	71.46	49.92	72.03	77.22	132.40	210.51	156.32	66.31
25	82.06	97.67	53.27	52.47	72.93	50.05	73.48	66.51	141.67	223.48	151.62	66.54
26	81.84	91.98	62.10	50.83	73.66	49.18	67.35	45.04	157.54	241.97	142.24	67.71
27	83.37	85.39	83.26	46.88	74.94	47.78	55.11	47.00	203.25	207.71	121.01	64.16
28	94.67	80.24	64.02	45.64	74.17	50.98	48.17	53.85	177.19	205.60	114.29	62.39
29	107.32	92.45	65.54	44.50		51.27	48.40	86.06	141.85	207.25	113.25	65.97
30	102.62	71.64	67.58	44.80		47.75	46.02	105.64	130.76	207.28	119.94	64.71
31	100.57		70.15	43.51		44.27		117.86		197.54	125.86	

Table D2. Report For Water Year 2005

<table>
<tr><td colspan="3">Run 06/02/2006 08:49</td><td colspan="5">Station Identification: BRDM - Beaverhead River at Dillon, MT</td><td colspan="5">Parameter code: QD - Daily Mean Total Discharge (cfs)</td></tr>
<tr><td>Day</td><td>Oct</td><td>Nov</td><td>Dec</td><td>Jan</td><td>Feb</td><td>Mar</td><td>Apr</td><td>May</td><td>June</td><td>Jul</td><td>Aug</td><td>Sept</td></tr>
<tr><td colspan="13"></td></tr>
<tr><td>Min</td><td>52.85</td><td>71.64</td><td>53.27</td><td>43.51</td><td>38.70</td><td>44.27</td><td>41.88</td><td>39.00</td><td>60.09</td><td>107.28</td><td>113.25</td><td>49.40</td></tr>
<tr><td>Max</td><td>107.32</td><td>104.18</td><td>98.35</td><td>69.92</td><td>80.56</td><td>76.14</td><td>88.59</td><td>158.60</td><td>203.25</td><td>241.97</td><td>206.27</td><td>128.43</td></tr>
<tr><td>Avg</td><td>70.34</td><td>92.64</td><td>80.08</td><td>62.23</td><td>59.51</td><td>58.27</td><td>54.31</td><td>83.14</td><td>120.60</td><td>163.62</td><td>163.64</td><td>80.87</td></tr>
<tr><td>T KAF</td><td>4.325</td><td>5.513</td><td>4.924</td><td>3.826</td><td>3.305</td><td>3.583</td><td>3.231</td><td>5.112</td><td>6.937</td><td>10.060</td><td>10.062</td><td>4.812</td></tr>
<tr><td>T CFS</td><td>2181</td><td>2779</td><td>2482</td><td>1929</td><td>1666</td><td>1806</td><td>1629</td><td>2577</td><td>3497</td><td>5072</td><td>5073</td><td>2426</td></tr>
</table>

D3.0 7Q10 MODELED FLOW DATA FOR THE JEFFERSON RIVER 8/20-8/22

Table D3. Baseline condition - Jefferson River 7Q10 flow used in QUAL2K model

River station mile	Flow in CFS		River station mile	Flow in CFS		River station mile	Flow in CFS
41.19	386.7		25.52	151.8		11.89	26.1
40.91	384.3		25.26	151.7		11.60	24.3
40.62	382.0		25.00	135.7		11.30	22.5
40.34	379.6		24.74	135.6		11.01	20.6
40.05	390.5		24.48	135.4		10.72	18.8
39.77	388.1		24.14	135.0		10.43	16.9
39.48	385.7		23.79	134.6		10.13	15.1
39.20	383.7		23.45	134.2		9.84	13.3
38.91	381.3		23.11	133.8		9.55	11.4
38.63	379.0		22.76	139.2		8.99	16.9
38.34	374.2		22.42	138.8		8.43	60.7
37.75	373.6		22.07	140.4			
37.16	362.3		21.73	52.2			
36.56	364.1		21.39	53.0			
35.97	320.8		21.04	52.6			
35.38	322.6		20.53	54.5			
34.78	155.3		20.01	56.3			
34.19	157.2		19.49	83.0			
33.60	159.0		18.97	85.9			
33.01	160.8		18.46	87.7			
32.41	162.7		17.94	48.5			
31.88	165.7		17.42	50.3			
31.35	168.7		16.90	52.2			
30.82	171.7		16.39	73.8			
30.28	106.6		15.87	75.6			
29.75	145.4		15.53	77.2			
29.22	148.4		15.19	78.8			
28.69	151.4		14.85	91.4			
28.15	157.3		14.51	20.3			
27.62	150.3		14.17	21.9			
27.09	153.3		13.83	23.5			
26.83	153.2		13.49	25.1			
26.57	152.3		13.15	26.6			
26.31	152.1		12.81	28.2			
26.05	152.0		12.47	29.8			
25.79	151.9		12.18	28.0			

ATTACHMENT A – EVALUATION OF FISHERY TRENDS IN THE JEFFERSON RIVER DRAINAGE RELATED TO CHANGES IN STREAMFLOW PATTERN AND HABITAT RESTORATION ACTIVITIES

EVALUATION OF FISHERY TRENDS IN THE JEFFERSON RIVER DRAINAGE RELATED TO CHANGES IN STREAMFLOW PATTERN AND HABITAT RESTORATION ACTIVITIES

Ron Spoon
Montana Department of Fish, Wildlife & Parks
March 2008

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

Information in this report is a product of over 20 years of attention provided to one of Montana's great rivers. Compiling information to better understand the water and fishery resource is intended to help citizens in the valley make decisions on the fate of the Jefferson River. Once dubbed the "Forgotten Fork" of the headwaters of the Missouri, the past eight years of citizen involvement to protect and improve habitat have raised the profile of the river, and it is clear that the river can no longer be considered forgotten or dismissed. The commitment of volunteers in watershed groups, water user associations, Trout Unlimited boards, Conservation Districts, and other numerous landowners and citizens has made the Jefferson Valley a better and healthier place. Since 1979, a handful of fishery technicians have helped collect the information presented in this report. Their skill and hard work has been critical for improving our understanding of the river.

INTRODUCTION

CHAPTER I

FISHERY AND STREAMFLOW TRENDS IN THE JEFFERSON RIVER – 1979 TO 2007

Evaluation of annual stream flow and fishery trends in the Jefferson River demonstrate that the fishery is influenced by low flow conditions during periods of drought. Population estimates for brown trout in three sections of the river from 1979 to 2007 indicate that the fishery declined during low flow periods, and surveys of other fish species also show that drought conditions impact all fish species resident to the Jefferson River. Monitoring of fish response to tributary enhancement projects from 1986 to 2007 indicate that such projects have significant potential to improve the trout population of the Jefferson River if adequate seasonal flow is maintained in the mainstem Jefferson River.

The Jefferson River is approximately 80 miles in length. The river originates at the confluence of the Big Hole and Beaverhead Rivers near Twin Bridges, and joins with the Madison River near Three Forks, Montana (Figure 1). The average width of the Jefferson River is about 197 feet, and the gradient averages 7.3 feet per mile. The river substrate is primarily composed of gravel and cobble, and the river typically meanders throughout a broad floodplain dominated by cottonwood.

Throughout its length, the Jefferson River and associated tributaries are extensively used as a source of irrigation water. Streamflow gaging near the headwaters show a mean annual flow of 2,014 cfs. Mean monthly flow ranges from 856 cfs (August) to 6,050 cfs (June). Base winter flow averages 1,070 cfs. Stream flow gaging reflects the severe summer dewatering of the Jefferson River, and flow depletion is considered one of the primary limiting factors for maintaining a desirable sport fishery for trout.

Another factor that significantly influences the sport fishery is the relative scarcity of healthy tributaries providing cold, clean water to the mainstem Jefferson River. The shortage of healthy tributaries results in few locations for successful trout spawning and juvenile trout rearing areas needed to provide recruitment of new fish to the system.

Since mainstem flow depletion and a shortage of quality tributaries are believed to be the primary limiting factors for the Jefferson River trout fishery, evaluation of flow enhancement and tributary restoration projects are the primary topics of investigation in this report. The Jefferson River Watershed Council and Trout Unlimited began an important partnership with MDFWP for this evaluation and restoration project beginning in 1999 and 2001, respectively.

METHODS

Fish Sampling

JEFFERSON RIVER

Fish sampling in the Jefferson River was primarily conducted during the spring when flow was sufficient to operate a boom-mounted electrofishing unit and a jet boat. A Coffelt Model VVP-15 electrofisher powered by a 4500 watt generator was used to create an electric field with direct current. Captured fish received a fin clip for Mark/Recapture identification, and were weighed, measured, and released. Marking fish for conducting Mark/Recapture estimates was typically conducted by making at least three downstream passes of the electrofishing boat: left bank, right bank, and mid channel to attempt to obtain a complete and unbiased sample of the entire river channel. Recapture runs for a sampling section were conducted at least seven days after the marking runs to allow for fish re-distribution, and when multiple recapture runs were needed to obtain population estimates, sampling was conducted with replacement of marked fish (ie. no fin clipping was conducted during recapture runs to ensure that fish were not included in subsequent runs).

Sampling time was recorded at each electrofishing stop to the nearest minute using a watch or stop watch. Recording actual electrofishing time (not including travel time) allowed estimation of catch-per-unit-effort (CPUE) for various species of fish during the population estimate procedure. In addition to recording the number of trout captured by the netter at each stop, the netter also estimated the number of other fish species observed in the electrofishing field and provided the information to the boat operator using hand signals. Thus, CPUE for trout was based on number of trout netted and delivered to the live well and CPUE for other species (typically mountain whitefish, suckers, and other species) was based on number of fish observed but not captured by the netter.

TRIBUTARIES

Evaluation of spawning and juvenile trout rearing in tributaries were primarily based on counting redds and conducting one-pass CPUE surveys using a backpack electrofishing unit. Determining spawning use of a tributary was conducted by walking upstream and recording the number of redds counted near the expected end of spawning activity. Streams with extensive spawning or concentrated redd construction received multiple redd counts to help identify occupied (new) redds or unoccupied (old redds) to provide a more accurate redd count.

Juvenile trout CPUE surveys were typically conducted with one electrofishing pass of the entire stream channel. The survey attempted to capture all trout to obtain a count and to measure length of fish. Non-game fish were generally not captured and classified as abundant, common, or rare. The number of young-of-the-year (YOY) trout captured per 100 seconds of shocking time was calculated by simply dividing the number of rainbow trout <120 mm and brown trout <130 mm by the shocking time.

Streamflow Measurement:

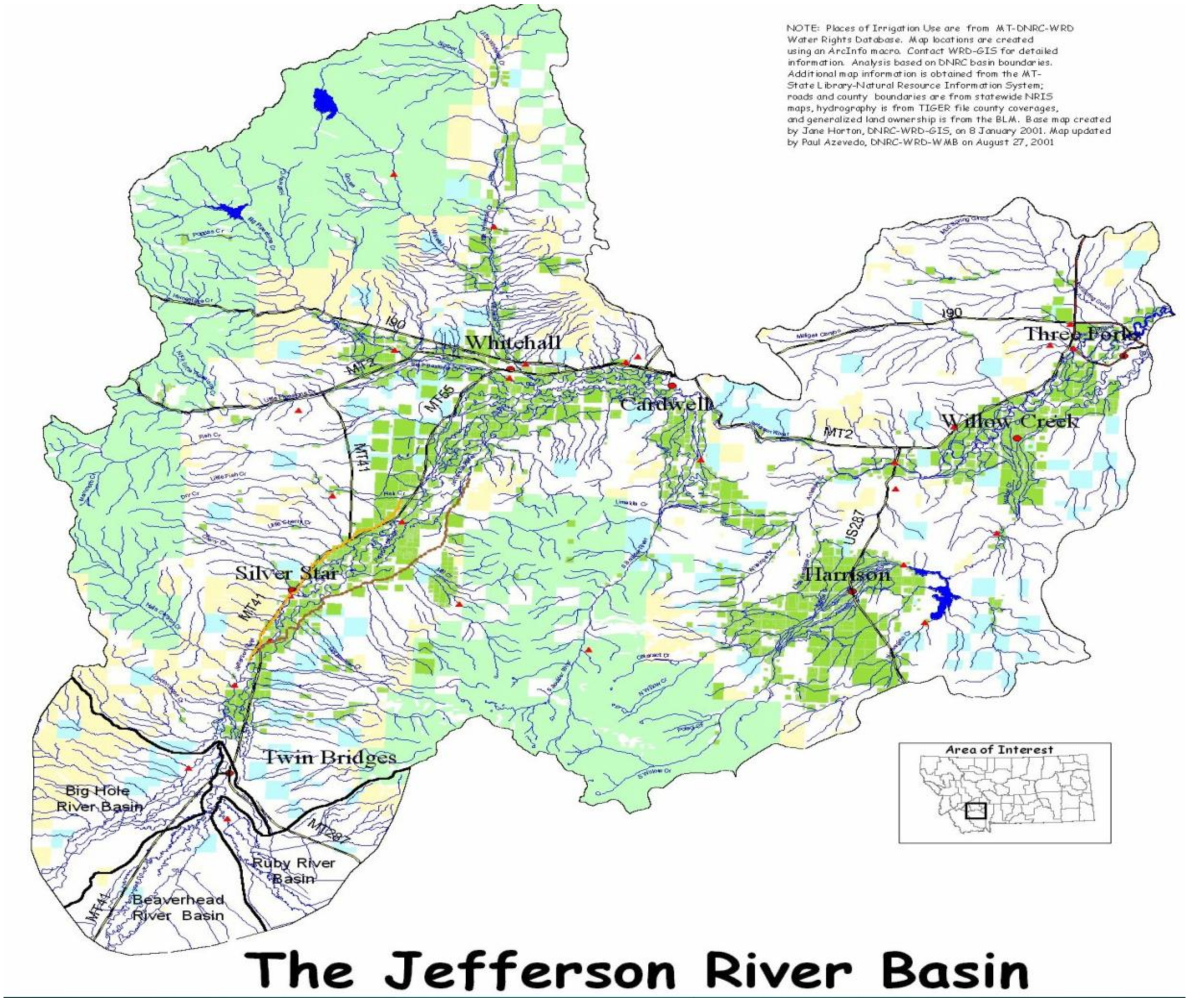
Streamflow data presented in this report were generally obtained from United States Geological Survey (USGS) records. Long-term USGS gage records prior to 1999 for the Jefferson are available for two sites: Jefferson River near Twin Bridges (06026500) is located near the headwaters and Jefferson River near Three Forks (06036650) is located near the mouth of the river. Additional flow monitoring was conducted by MDFWP near the most severely dewatered reach of the Jefferson River below Parson's Bridge (Waterloo). Flow monitoring near Waterloo was conducted using standard USGS methods and flow readings were related to staff gage elevations during low flow periods (mid-July through September). Stage readings gradually became more continuous when an Aqua-Rod was installed from 2000 to 2005. Flow monitoring at Waterloo was conducted by USGS (06027600) starting in 2006, and seasonal data is available for low flow periods in July, August and September.

In 1996, the Twin Bridges gage was reactivated by MDFWP, USGS and DNRC to improve understanding of inflow patterns of the Upper Jefferson Basin. Continuous flow monitoring is conducted near the mouth of the Jefferson River at Three Forks since 1979. Occasional stream flow measurements were gathered by MDFWP near the most severely dewatered reach of the river near Waterloo during the 1990's. Additional streamflow and water temperature measurements are presented in this report. Data were collected using standard cross section methods and a Marsh-McBirney Flow Meter.

Jefferson River Study Area

The Jefferson River flows for about 80 miles from the confluence of the Big Hole and Beaverhead Rivers near Twin Bridges to its mouth near Three Forks (Figure 1). The average width of the river is about 197 feet, and the gradient averages 7.3 feet per mile. River substrate consists primarily of gravel and cobble.

The drainage area of the Jefferson River Basin above the USGS gage at Three Forks is over 9,500 square miles (USGS, Gustofson 2003). The drainage area of the Big Hole River, Beaverhead River (including Red Rock River), and Ruby River is 2802 sq. miles, 3,783 sq. miles, and 989 sq. miles, respectively. The Big Hole River basin has no large impoundments for water storage, the Ruby River basin is influenced by Ruby Reservoir, and the Beaverhead River basin contains Lima Reservoir and Clark Canyon Reservoir. The Jefferson Basin HUC contains 1340 sq. miles and 893 miles of perennial steam, with a mean elevation of 5640 ft (Gustofson 2003).


NOTE: Places of Irrigation Use are from MT-DNRC-WRD Water Rights Database. Map locations are created using an ArcInfo macro. Contact WRD-GIS for detailed information. Analysis based on DNRC basin boundaries. Additional map information is obtained from the MT-State Library-Natural Resource Information System; roads and county boundaries are from statewide NRIS maps, hydrography is from TIGER file county coverages, and generalized land ownership is from the BLM. Base map created by Jane Horton, DNRC-WRD-GIS, on 8 January 2001. Map updated by Paul Azevedo, DNRC-WRD-WMB on August 27, 2001

The Jefferson River Basin

Figure 1. Map of the Jefferson Basin.

RESULTS

Based on long term streamflow monitoring of the Jefferson River at two USGS gaging stations and one seasonal station at Parson's Bridge (Waterloo), it is clear that drought conditions beginning in 1999 or 2000 have resulted in significantly reduced flows at all monitoring locations in the Jefferson Basin compared to earlier records. During the period 1979 to 2007, mean annual flow and mean August flow of the Jefferson River at Three Forks was generally above average from 1979 to 1984 and 1996 to 1998, and well below average from 1985 to 1995 and from1999 through 2007 (Figure 2). The trend for mean annual flow is mirrored by the trend of mean August flow near the mouth of the Jefferson River at Three Forks, indicating that a poor water year generally results in both lower peak flows during spring and lower base flow during summer.

The flow trend near the headwaters of the Jefferson River near Twin Bridges provides a longer period of record compared to the Three Forks Gage, but has periods with data gaps. The mean August flow for the Twin Bridges gage was estimated to be 788 cfs. From 2000 to 2007, the mean August flow was generally about 50% (about 400 cfs) less than the long term average, and the unusual pattern of continuous low flow years is apparent (Figure 3). Occasional years of extremely low flow during the period of record can be expected, but the 8 consecutive years of low flow from 2000 to 2007 appear to be unprecedented.

Flows at all measurement locations of the Jefferson River reflect the severe dewatering that occurs during summer seasons. The lowest flow in the river generally occurs in the general area between Silver Star and Waterloo. When summer flow is less than about 400 cfs at Twin Bridges, flow near Waterloo is often less than 100 cfs and sometimes less than 20 cfs. The drought plan established for the Jefferson River, which was written in 1999, attempts to maintain streamflow over 50 cfs at the Waterloo gaging station (See Chapter V for a discussion of the drought plan and an evaluation of flow trends during the 2000 to 2007 period).

The health of the Jefferson River is severely impacted during periods of drought when inflows to the river near Twin Bridges (the approximate confluence of the Big Hole, Ruby, and Beaverhead Rivers) fall below 400 to 500 cfs. The reach of the Jefferson River located between Twin Bridges and Waterloo contains about 800 cfs of water right claims, and four large canals routinely monitored in this area frequently divert about 350 cfs during the irrigation season. The frequent occurrence of low flow throughout the Jefferson River is a product of the significant appropriation of water for irrigation in the upper 20 miles of river, and the additional irrigation withdrawals spaced throughout the remaining 60 miles of river.

The quantity of water needed to maintain a healthy aquatic community and an abundant sport fishery was quantified in MDFWP's *Application for Reservations of Water in the Missouri River Basin above Fort Peck Dam* in 1989. The wetted perimeter method was used to recommend a minimum flow request of 1,100 cfs. Based on this method of surveying cross-sectional measurements to develop the relationship between streamflow and the quantity of river channel covered with water, there were two flows identified where rapid loss of river channel area occurs when flows decrease: upper inflection point was 1,100 cfs and lower inflection point was 550 cfs. Thus, flows decreasing below 1,100 cfs result in the increased exposure of the river channel, and flows decreasing below 550 cfs result in a very rapid loss of aquatic habitat. During "normal" flow years, there is typically enough water to maintain a recommended flow of 1,100 cfs at many locations in the Jefferson River, but during drought years, flow is often well below recommended levels.

Flow trends for the Jefferson River presented in Figures 2 and 3 indicate that the recent drought is severe based on relatively recent data of the past 30 to 40 years. Gaging data for the Jefferson River, however, do not extend back to the 1930's when drought conditions were generally considered to be most severe. Long term gaging stations in the lower Big Hole (Melrose) and the Upper Missouri River (Toston) indicate that the current flow trend since 2000 is more severe than previous drought years experienced in the upper Missouri River basin (Figure 4).

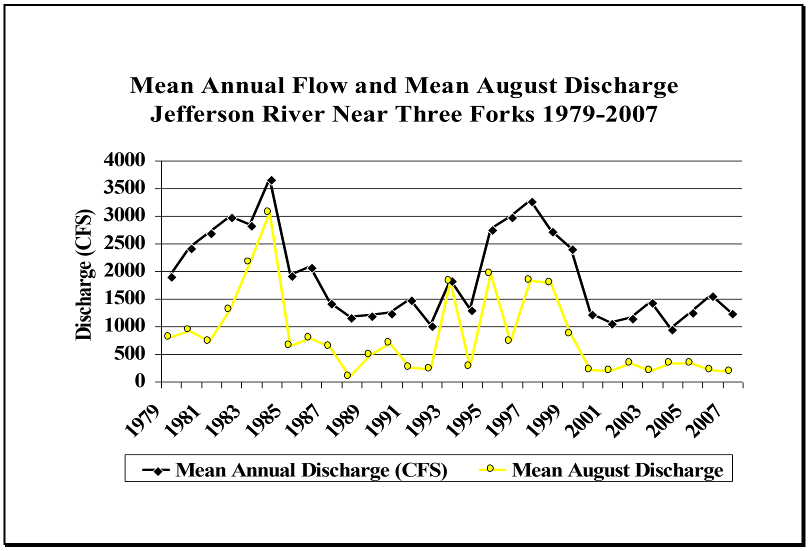


Figure 2. Comparison of mean annual flow and mean August flow of the Jefferson River at the Three Forks USGS gaging station near Three Forks.

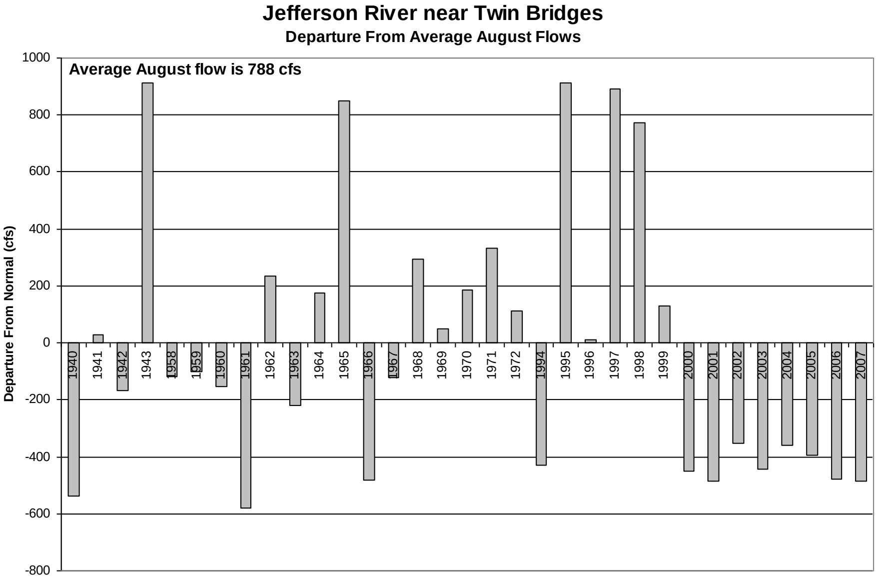


Figure 3. Departure from "normal" stream flow of the Jefferson River at the USGS gaging station near Twin Bridges.

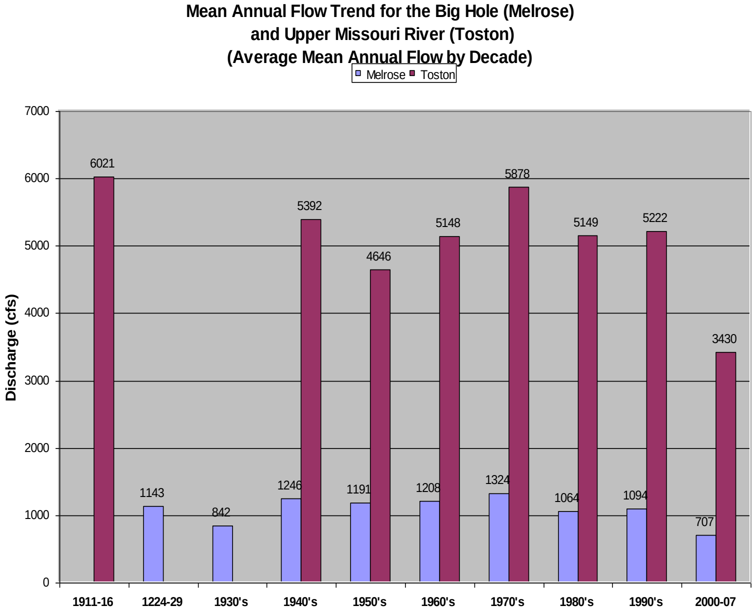


Figure 4. Comparison of long term mean annual flow above and below the Jefferson River (Average Mean Annual Flow by Decade).

Stream flow in the upper Jefferson River have been monitoried at the Twin Bridges gaging station for 33 years since the beginning of the period of record in 1940. Flow monitoring at Waterloo was only been monitored during occasional years during 1988 and a few select water years in the 1990's to confirm the extent of dewatering at this critical location. Daily flow records have been collected at Waterloo from 2000-2007 and a comparison of stream flow at Twin Bridges and Waterloo during 2000 illustrates the significant irrigation withdrawl between these two locations (Figure 5). In addition, Figure 5 illustrates the extreme departure between the desirable instream flow recommendation of 1,100 cfs and the flow level during drought conditions at both Twin Bridges and Waterloo gaging locations.

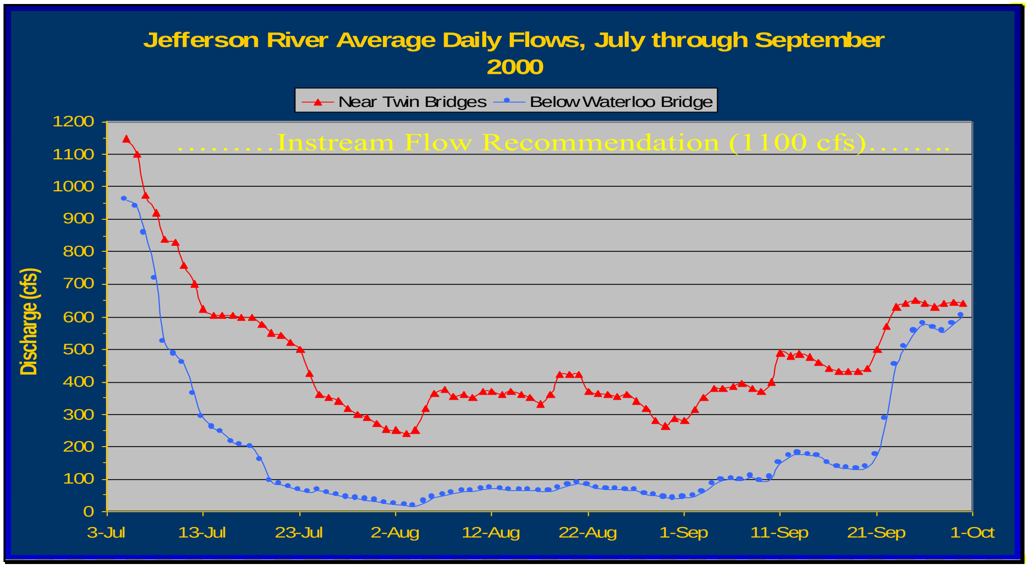


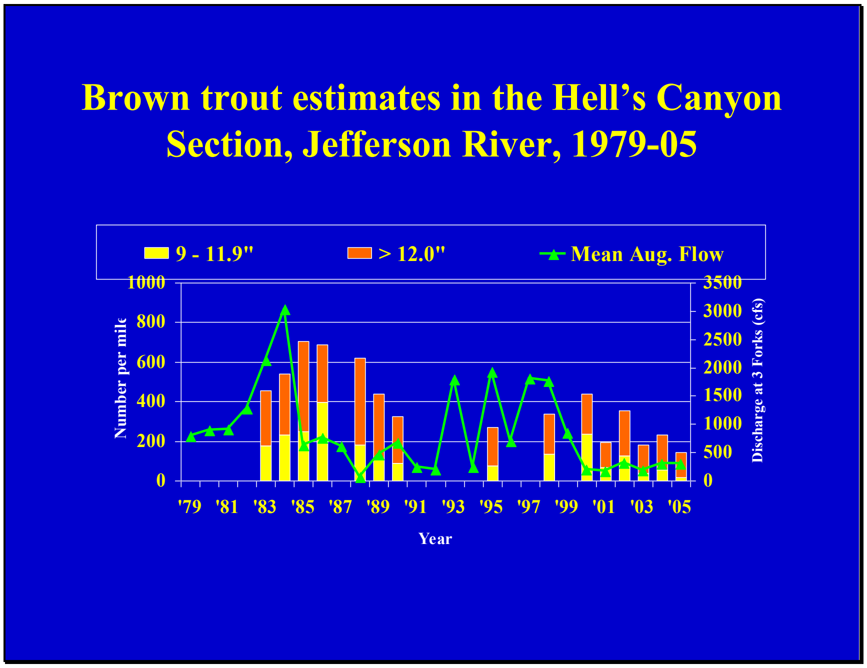
Figure 5. Summer flow trend of the Jefferson River at Twin Bridges and Waterloo during 2000 in relation to the instream flow recommendation of 1,100 cfs.

Fishery Trends in the Jefferson River

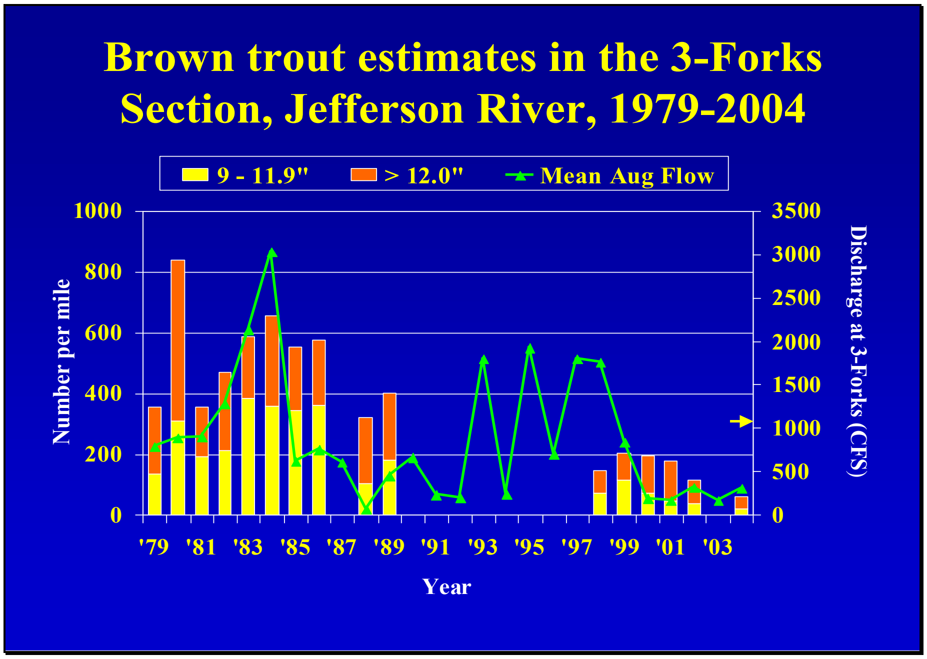
Fisheries data presented in subsequent sections of this report indicate that trout and other species of fish have declined significantly during these extreme flow conditions observed since 2000. Other variables such as spawning habitat limitations, water quality, fish mortality due to angling, impacts on physical habitat quality, bird predation on fish, and others probably influence the fishery of the Jefferson River, but the loss of flow during the summer period appears to have the most significant impact on the fishery.

Spring electrofishing surveys provide reliable brown trout population estimates for two long-term study sections established in the late 1970's (Hells Canyon Section and Three Forks Section). An additional section was added in 2000 in the mid-section of the river where flow depletion is most severe (Waterloo Section) (Figure 6; page 16). In addition, a fourth section was added in 2006 near the Sappington Springs to monitor fish response to habitat improvements in the lower segment of the Jefferson River.

Long-term study sections near Hells Canyon (upper river) and Three Forks (lower river) demonstrated declining brown trout populations in response to drought conditions in the mid to late 1980's (Figures 7 and 8). Brown trout abundance increased in the Hells Canyon Section in response to improved flow conditions in the mid-1990's, but brown trout abundance did not increase in the lower river during this time frame. The absence of a positive population response to increasing flow from 1993 to 1998 at Three Forks indicates that other factors such as recruitment limitations are affecting this reach of the Jefferson River.



Brown trout estimates in the Hell's Canyon Section, Jefferson River, 1979-05



Brown trout estimates in the 3-Forks Section, Jefferson River, 1979-2004

Figures 7 and 8. Brown trout population trends related to mean August flow at the Three Forks Gaging Station (1979 to 2005).

Brown Trout Response to Low Flow Conditions – 2000-2007

Brown trout abundance has declined in each of the three population monitoring sections in response to the severe summer flow depletions beginning in the late 1990's. Adult brown trout populations (fish over 12" total length) at Hells Canyon, Waterloo, and Three Forks sections have declined by about 40 to 60% percent between 2000 and 2007 (Figure 9). The Hells Canyon and Three Forks Sections were last sampled in 2005 and 2004, respectively.

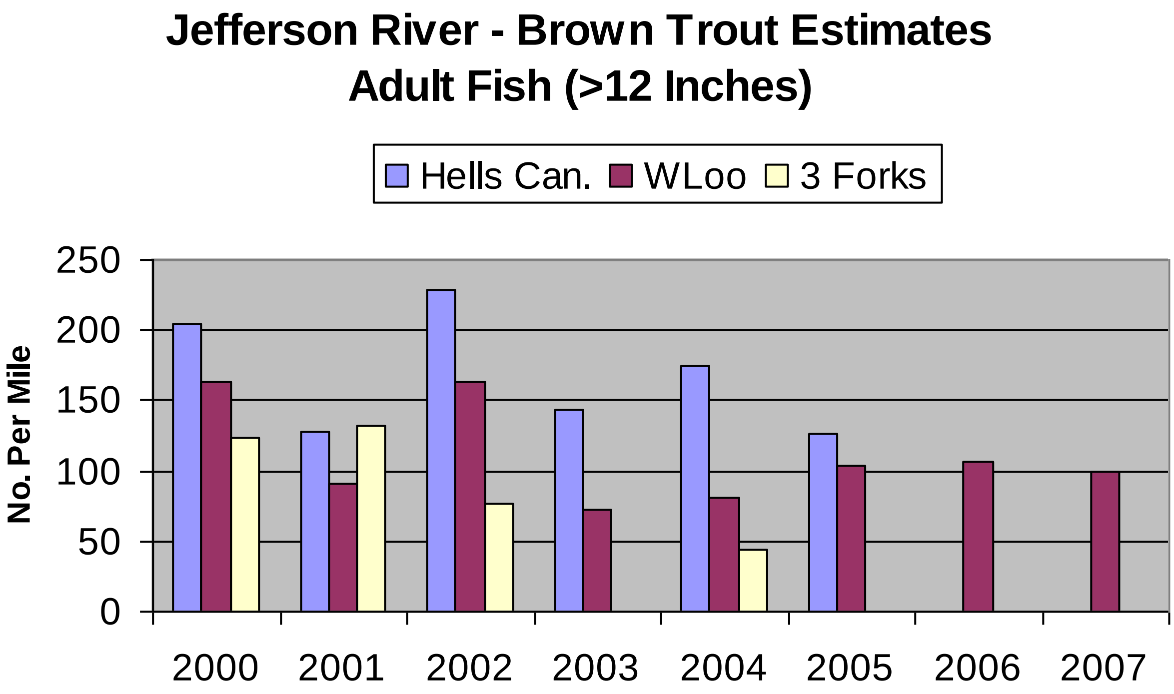


Figure 9. Comparison of adult brown trout population trends in three sections of the Jefferson River during the severe drought period of 2000 to 2007.

Young brown trout (age II fish between 9 and 11.9") also declined at each of the three sampling sections, and the reduction in numbers appears to be more severe than the adult fish over 12" in length (Figure 10). It appears that low stream flow during drought impacts juvenile brown trout in the Jefferson River more than it impacts the adult population. Improved flow during the 1993-1998 period indicates that juvenile trout abundance recovered in the Hell's Canyon Section more quickly than adult brown trout after favorable summer flow conditions (Figure 7).

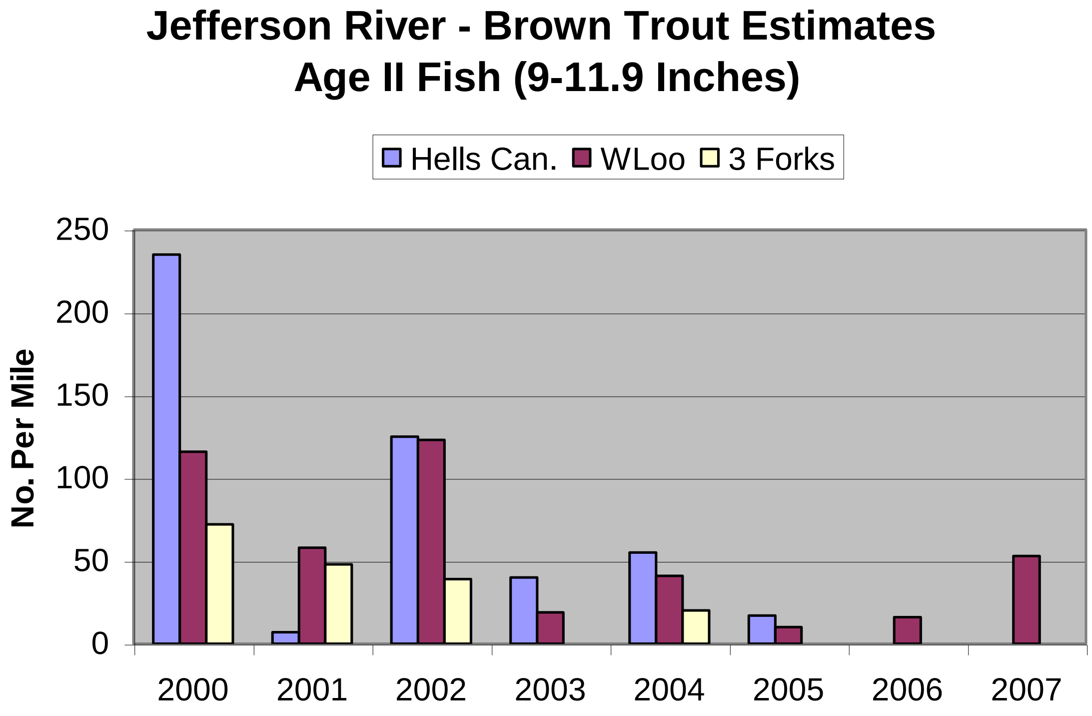


Figure 10 . Comparison of age II brown trout population trends in three sections of the Jefferson River during the severe drought period of 2000 to 2007.

Although the direct causes of reduced survival of young fish is not known, it is possible that young brown trout dependant on shoreline cover are forced to move into concentrated pool habitat during drought conditions and may be subjected to predation or other sources of mortality. After the extremely low flow year of 1988, the number of adult brown trout at the Hells Canyon Section was relatively unchanged, but the number of fish less than 12” was significantly reduced (Figure 7).

The instream flow recommendation of 1,100 cfs maintains a desirable wetted perimeter with water in contact with shoreline cover, which is important for brown trout survival. Summer streamflow in the upper river near Hells Canyon was often below 400 cfs, and flow near Waterloo was often less than 100 cfs from 2000 to 2007. Shoreline rearing habitat was very limited during each of these years.

Although a general decline has been observed throughout all sections during the severe drought period representing the upper, middle, and lower river, it is noteworthy that the most severe dewatering of the middle river near Waterloo has not experienced continued declines in numbers in the past three years (since 2005). Implementation of the drought plan, which attempts to maintain critical flows near Waterloo has been effective at preventing complete dewatering of this reach of the river. See Chapter V for a summary of the drought plan, and Appendix A for a table of discharge measurements near Waterloo.

Rainbow Trout Population Estimates

Spring-time population surveys provide reliable indices of brown trout abundance because movement of fish appears to be minimal during the population estimate procedure, which takes 10 to 14 days to complete. Spring estimates for rainbow trout are influenced by spawning movements of adult rainbow trout, and these data have a known bias resulting from adult fish moving to and from spawning areas during the population estimate process. Therefore, population estimate results for adult rainbow trout are not included in this report.

Despite movements of adult and some sub-adult rainbow trout, there is some useful trend information that can be obtained from these population surveys at the Hells Canyon Section (upper river) and the Waterloo Section (middle river). Rainbow abundance in the Three Forks Section (lower river) is not sufficient to show meaningful trends.

Population estimates for rainbow trout less than 12.0 inches in length (mostly non-spawning fish) in the Waterloo Section declined after the beginning of the severe drought conditions starting in 2000 and began to rebound in 2004 (Figure 11). A reduction in the rainbow trout population after 2000 was similar to that observed for brown trout, but the improved numbers of rainbow trout after 2003 indicates that rainbow trout abundance can be improved during years with low summer streamflow. Projects to enhance two spawning/rearing tributaries in this monitoring section were completed from 2004 to 2007.

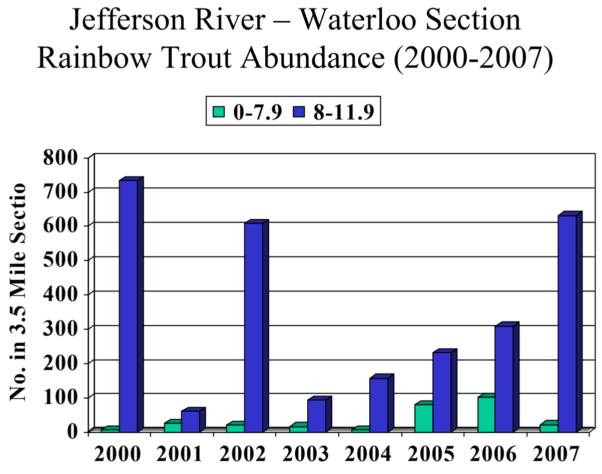


Figure 11. Rainbow trout population trend in the Waterloo Section during consecutive years of severe drought (2000-2007). Number of rainbow trout in size group (0-8.9") is the total numbered captured; the number (8-11.9 inches) is a mark recapture population estimate.

Rainbow trout abundance for fish less than 12 inches in the Hells Canyon Section also show a significant decline between 2000 and 2004, presumably due to the flow decline during this period (Figure 12). Although current rainbow trout abundance appears reduced due to drought conditions, rainbow trout were not abundant during the improved flow conditions of the 1980's. There was an apparent increase in the rainbow fishery from the mid-1980's to the late 1990's. Some factors influencing the rainbow trout fishery in this reach during this increase is the implementation of a catch and release fishing regulation, implementation of the Hells Canyon Water Lease and Fish Screen Project in 1996, and relatively good flow conditions in the Jefferson River.

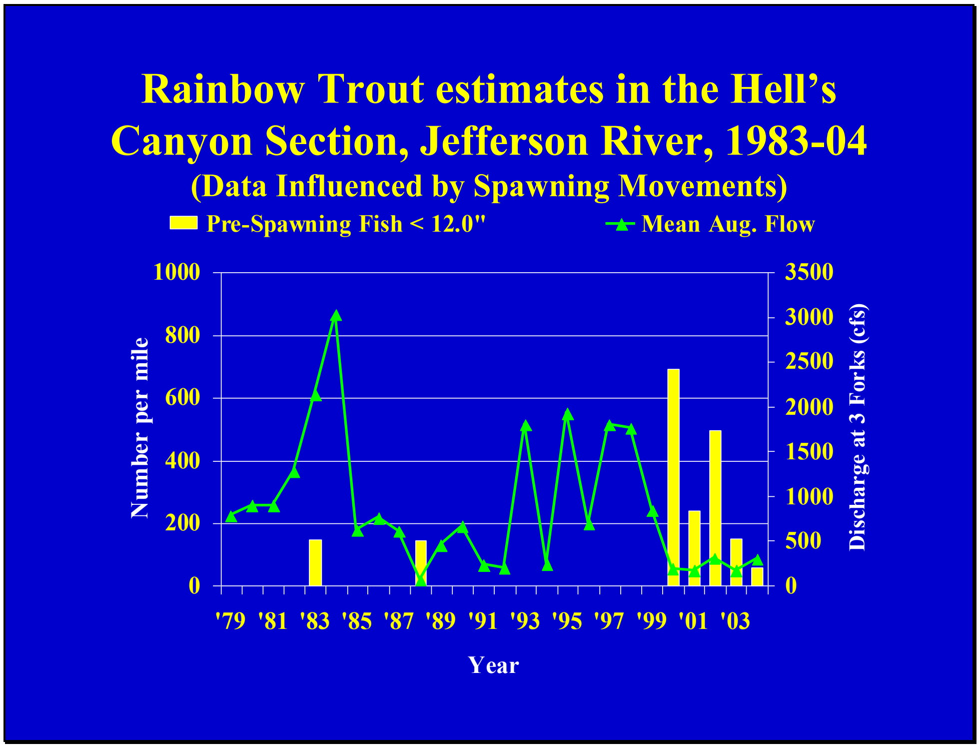


Figure 12. Long term trend of rainbow trout abundance in the Hells Canyon Section of the Jefferson River related to mean August flow.

Brown trout have been the dominant trout species in the Jefferson River during the 1980's and 1990's. Although it appears that both brown and rainbow trout are impacted by low flow conditions, the improved recruitment of rainbow trout due to tributary enhancement projects provides a new component to the trout fishery that may buffer the fishery from severe population declines during periods of change. The positive population response of the rainbow fishery in the Waterloo Section during low flow conditions is an example of the benefits of developing an alternative trout fishery (Figure 11).

Catch-Per-Unit-Effort Surveys

Population estimates at defined locations over a period of time are useful for determining population trends at specific locations, but these data can miss important dynamics of the fishery at other locations throughout the river. In 2000, FWP conducted an extensive survey of other reaches of the river using one electrofishing pass and determining the number of fish captured per unit time of sampling.

Catch-per-effort (CPUE) surveys in 2000 provide a wide view of fish distribution throughout the Jefferson River, and this sampling occurred in reaches of the river that had no previous fish inventory information (Figure 6). The longitudinal fishery trend from CPUE data show that rainbow trout abundance appears to be linked to recruitment from two spawning tributaries. The largest number of rainbow captured per unit effort was observed near the mouths of Hells Canyon and Willow Springs, which are the two primary spawning and rearing tributaries for rainbow trout in the Jefferson basin (Figure 13).

Observations for other fish species were also obtained during the CPUE survey. Mountain whitefish were the most common fish observed during this sampling in 2000, followed by sucker species, brown trout and rainbow trout (Figure 14).

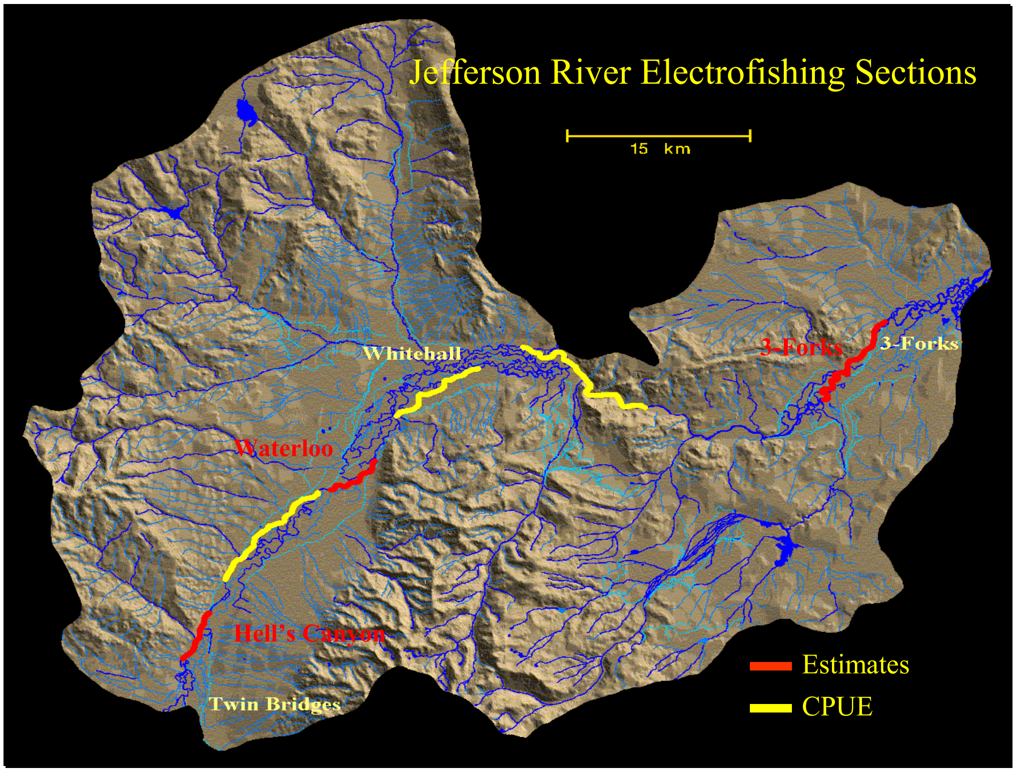
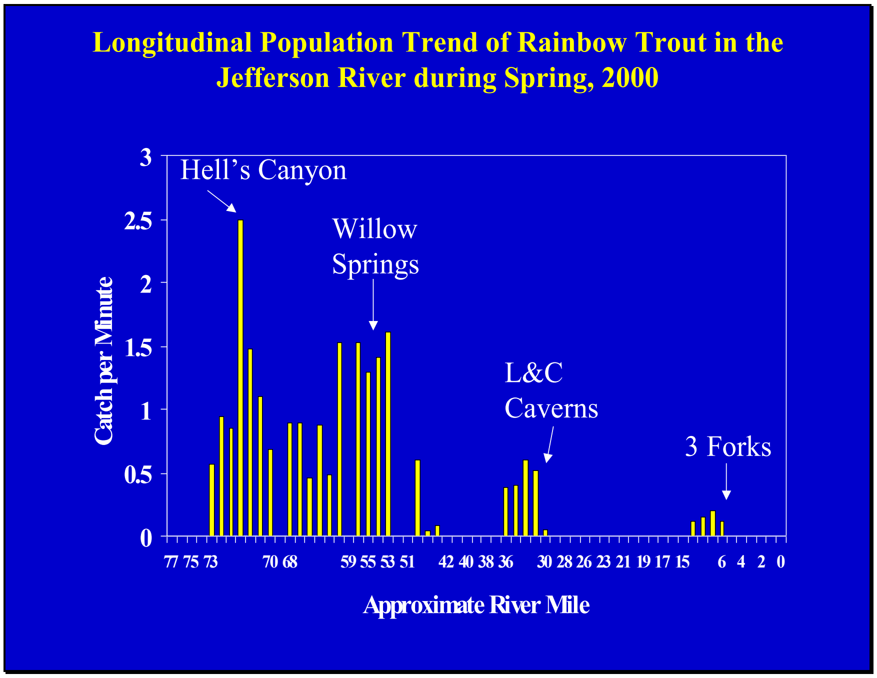
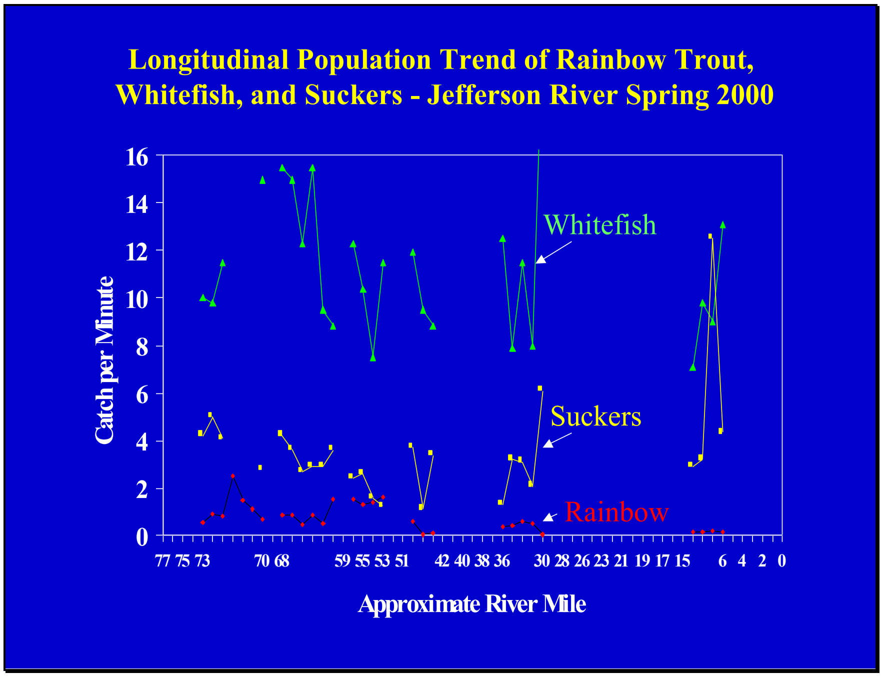


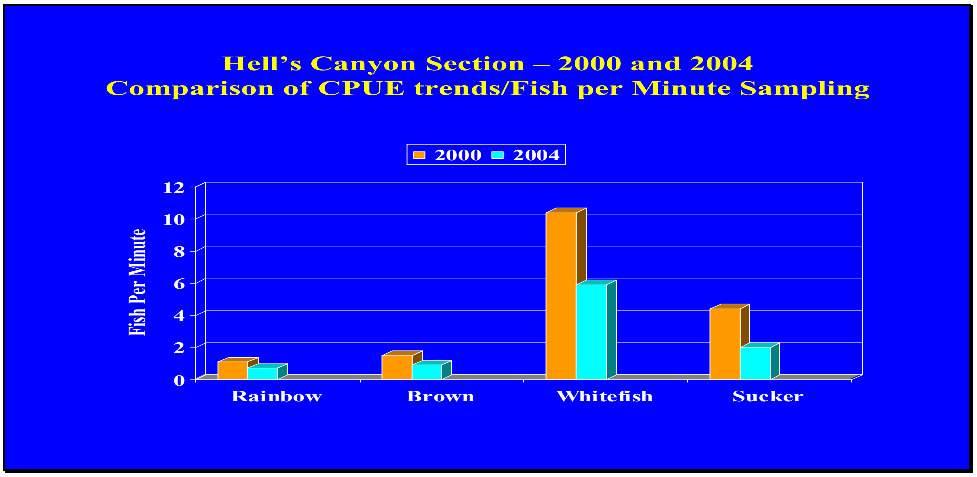
Figure 6. Map showing three long-term population estimate sections and three reaches of the Jefferson River where single pass, CPUE data was collected during 2000.

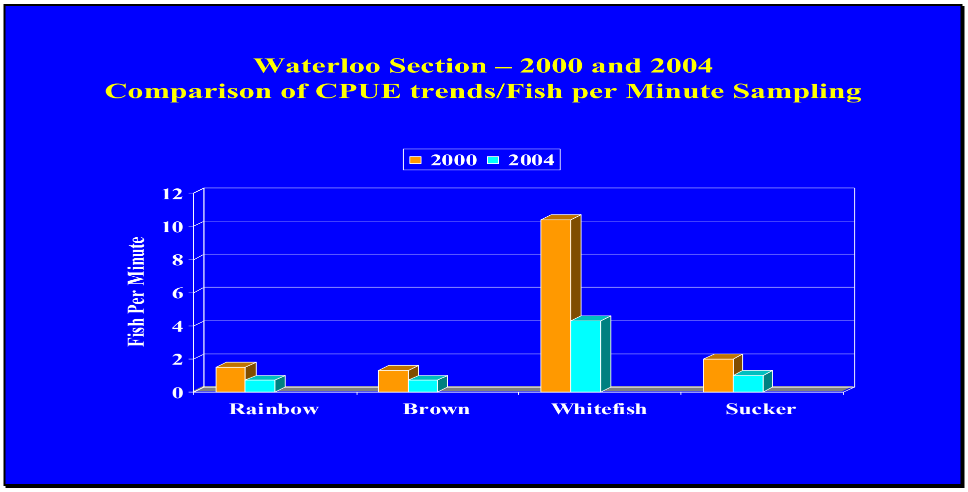
Although CPUE sampling techniques do not provide estimates of fish abundance, these surveys do provide a relative measure of abundance that appears to be sensitive to drought impacts. A comparison of CPUE results for brown and rainbow trout show a decline in numbers using population estimate techniques (Figures 7 and 8). Declining abundance of mountain whitefish and sucker species were also documented in all there study sections using CPUE sampling between 2000 and 2004 (Figures 15, 16, 17).

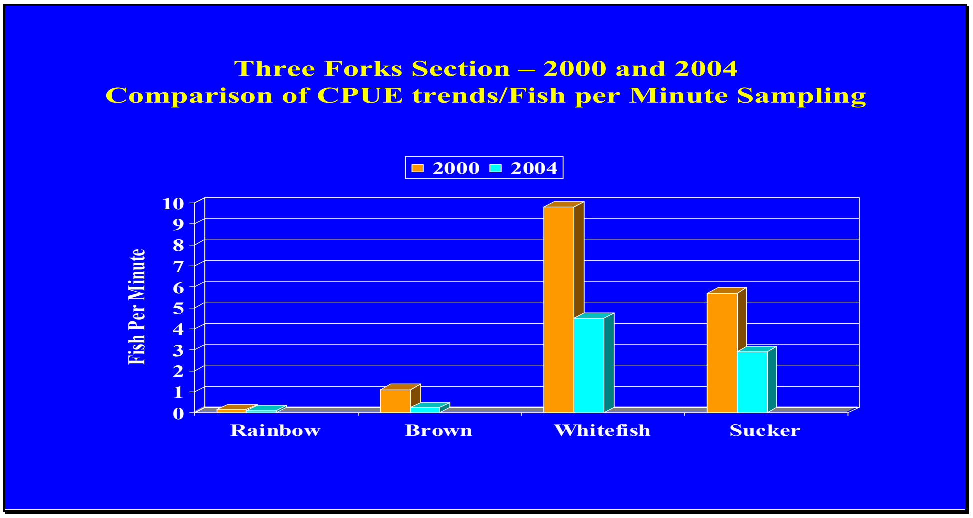




Figures 13 and 14. CPUE sampling results in the Jefferson River during 2000.







Figures 15, 16 and 17. Comparison of CPUE trends for four fish species in three Study Sections of the Jefferson River (2000-2004).

CPUE data improved understanding of important recruitment sources of brown and rainbow trout in the Jefferson River, and provided quantitative data for non-trout species during the drought event beginning in 2000. Flow conditions resulting in reductions of brown and rainbow trout populations were documented with population estimate data, but CPUE data indicated that these conditions were also resulting in population effects on mountain whitefish and sucker populations (Figures 15, 16, and 17). Since mountain whitefish and sucker species are not likely to have significant angling- related mortality, documentation of declines in whitefish and sucker abundance from 2000 to 2004 further reflect the cause of fish population reductions to be largely related to drought impacts.

COMPARISON OF CPUE AND POPULATION ESTIMATE TRENDS

Comparing results of population estimates conducted in the Waterloo Section to CPUE trends determined concurrently with population estimate sampling indicated that CPUE reliably assessed basic fish population trends (Figure 18). With the possible exception of an outlier in 2002, CPUE and population estimate results closely mirror the trends and relative magnitude of population response during the 2000 to 2007 period. Raw numbers used in the population estimate and CPUE procedure are presented in Table 1. The relatively high recapture rate in the population estimate procedure (R/C ratio for brown trout over 12" averaged 29%) probably accounts for the trend of CPUE closely matching the population estimate result. Relatively low electrofishing efficiency (R/C ratios of less than 10%) would likely result in a poor relationship between mark-recapture estimates of fish abundance and CPUE results.

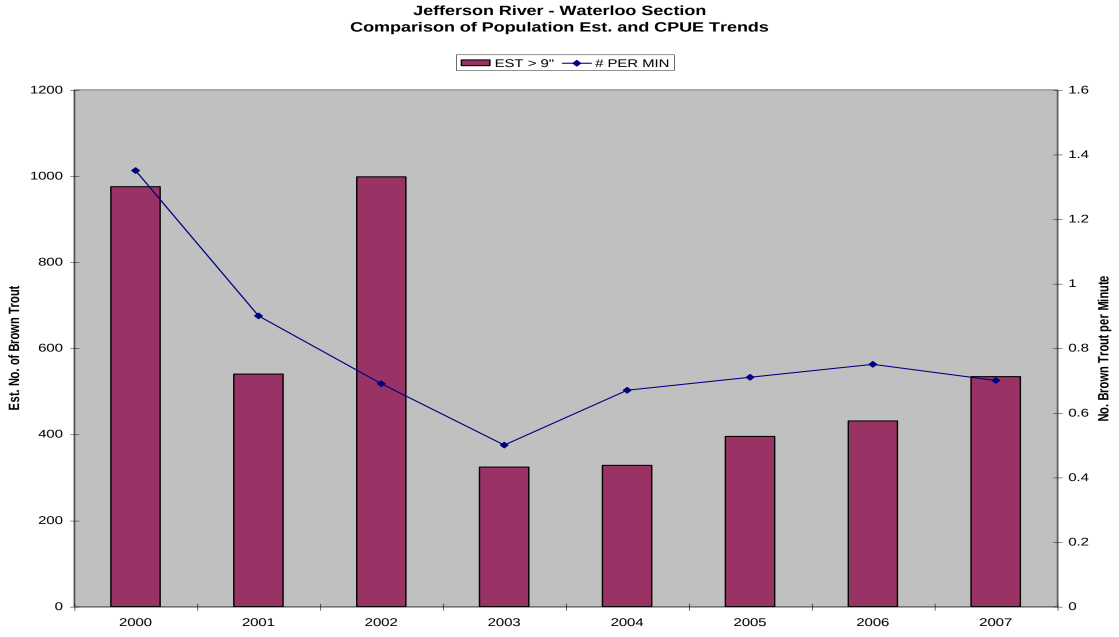


Figure 18. Comparison of Population Estimate and CPUE trends for brown trout in the Waterloo Section of the Jefferson River (2000-2007).

Table 1. Raw data for population estimate and CPUE comparisons at the Waterloo Section of the Jefferson River (2000-2007).

JEFFERSON RIVER AT WATERLOO; 3.5 MILE SECTION; SPRING SAMPLING FOR BROWN TROUT

YEAR	SIZE	POP EST	SD	CPUE	MARK	CAP	RECAP	R/C	# NEW
2000	0-8.9				17	10	0		27
	9-11.9	405	72		123	58	17	29%	
	>12.0	570	56		220	123	47	38%	
	ALL BNT			1.35/MIN					
2001	0-8.9	779	293		64	59	4		119
	9-11.9	203	63		48	24	5	21%	
	>12.0	337	38		114	76	32	42%	
	ALL BNT			0.90/MIN					
2002	0-8.9	83	40		7	20	1		26
	9-11.9	431	174		35	47	3	6%	
	>12.0	567	98		93	126	20	16%	
	ALL BNT			0.69/MIN					
2003	0-8.9	179	93		14	23	1		36
	9-11.9	74	36		14	9	1	11%	
	>12.0	250	25		90	101	36	36%	
	ALL BNT			0.50/MIN					
2004	0-8.9	62	27		4	24	1		27
	9-11.9	144	40		34	28	6	21%	
	>12.0	284	28		101	108	38	35%	
	ALL BNT			0.67/MIN					
2005	0-8.9	219	97		21	29	2		48
	9-11.9	35	6		18	14	7	50%	
	>12.0	360	49		118	81	26	32%	
	ALL BNT			0.71/MIN					
2006	0-8.9	747	309		40	72	3		109
	9-11.9	56	15		18	17	5	29%	
	>12.0	375	90		68	59	10	17%	
	ALL BNT			0.75/MIN					
2007	0-8.9	164	108		10	14	0		24
	9-11.9	184	45		48	33	8	24%	
	>12.0	350	79		68	60	11	18%	
	ALL BNT			0.70/MIN					

CHAPTER II
Projects to Enhance Trout Spawning and Rearing Habitat

Based on prior observations of the importance of tributary spawning and rearing and monitoring of fish trends throughout the river, a primary goal of enhancing spawning habitat received increased focus from 2000 to 2007. Spawning and juvenile rearing habitat in tributaries of the Jefferson River are most often limited by flow limitations, over-widened channels due to land use, high sediment impacting spawning substrate, and fish passage problems. Spawning habitat enhancement projects intended to correct these problems were conducted for the following tributaries from 2000 to 2007:

Willow Springs
Parson's Slough
Boulder River
Antelope Creek
Hamilton Spring Creek
Hell's Canyon Creek
Sappington Springs
Fish Creek

An example of one tributary enhancement project is shown in Figure 19. The design considerations for tributary enhancement are primarily based on providing increased areas with clean gravel for trout egg deposition and providing suitable streamflow during egg incubation and juvenile out-migration. Although improved habitat for resident fish also occurs in some of these projects, creation of numerous pools and adult holding water habitat is intentionally minimized during design of most projects to maximize spawning/rearing benefits.

Implementing habitat enhancement projects requires significant effort to identify willing landowners, write grants, prepare stream enhancement designs, apply for permits, review water rights, conduct before and after project monitoring, and others. Trout Unlimited and FWP shared many of the tasks and few projects would have been completed between 2001 and 2007 without the partnership between these two entities.

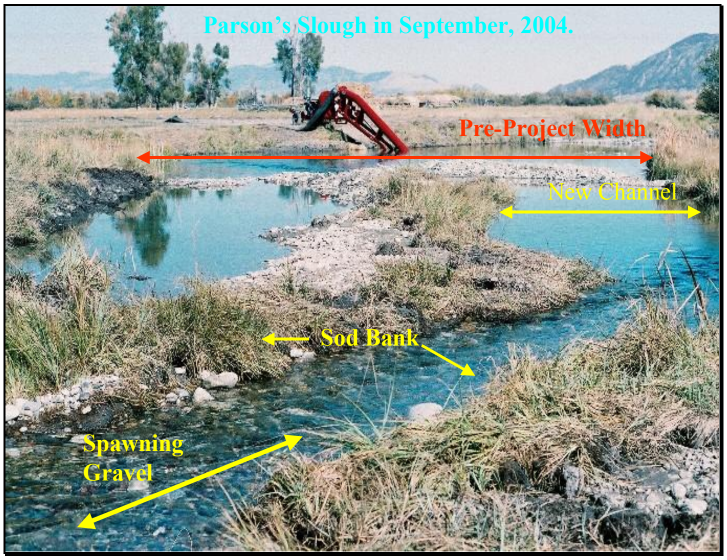


Figure 19. Example of project to enhance trout spawning/rearing habitat.

CHAPTER III

EVALUATION OF FISHERY TRENDS IN TRIBUTARIES TO THE JEFFERSON AND UPPER MISSOURI RIVER RELATED TO CHANGES IN STREAMFLOW PATTERN AND HABITAT RESTORATION ACITITIES (1990-2007)

Both the Jefferson and Missouri Rivers are impacted by low summer streamflow, and monitoring of the mainstem fisheries generally show a relationship between fish numbers and major shifts in summer flow. Another factor that significantly influences the sport fishery is the relative scarcity of healthy tributaries providing cold, clean water to the mainstem Jefferson River. The shortage of healthy tributaries results in few locations for successful trout spawning and juvenile trout rearing areas needed to provide recruitment of new fish to the system. Since mainstem flow depletion and a shortage of quality tributaries are believed to be the primary limiting factors for the Jefferson and Upper Missouri River trout fisheries, these aspects of the fishery and the associated habitat are the primary topics of interest for fisheries monitoring.

This report summarizes results from electrofishing surveys on 16 spawning tributaries of the Missouri River and Jefferson River. The relatively simple and inexpensive technique of making a one pass electrofishing run and calculating the Catch-Per-Unit-Effort (CPUE) was used to determine basic trends in the number of juvenile trout residing in these spawning and nursery tributaries.

Monitoring results of fish response to tributary enhancement projects from 1986 to 2007 indicate that such projects have significant potential to improve the trout population of the Jefferson River. Results of Catch-Per-Unit-Effort (CPUE) electrofishing surveys are presented for nine tributaries of the Jefferson River. Similar monitoring of seven tributaries of the Missouri River is also included in this report to provide an expanded sample size to evaluate broad trends in juvenile trout abundance.

METHODS

This report summarizes results from 16 tributaries over a number of years beginning in 1992. A single pass using a backpack electrofishing unit was used to collect fish and the distance and time sampled was recorded. Fish were captured using a dip net and a measurement of total length was recorded. In most cases, a two-person crew (electrofisher and dip netter) was used to sample the entire channel during the summer or fall period.

Sampling sections were generally located near the mouths of streams or near typical spawning locations of fish migrating from the mainstem river. The sections were typically 100 to 300 feet in length, and sampling time was generally 800 to 2000 seconds in duration. The technique generally took minimal effort, and 2 or 3 streams could be surveyed per day. The same location was sampled each year (Figure 12; page 37).

The streams selected for sampling was based on known observations of spawning fish migrating into these tributaries from the mainstem rivers, or to evaluate the number of juvenile trout present in the section before and after projects were implemented to enhance spawning attributes of tributaries. The basic assumption of this sampling method is that CPUE trends determined in the late summer and fall reflect the relative quality of these streams related to spawning and rearing potential.

An example of the potential use of this sampling technique is to determine abrupt changes in juvenile density due to major changes in habitat or fish survival (eg. dewatering due to drought, rainbow trout mortality due to disease, or fish response due to habitat improvements and imprinting of eggs or fry). The technique was not assumed to be appropriate for detecting small changes in fish populations or year class strength. Since fall electrofishing surveys for juvenile trout (young-of-the-year) reflect success of spawning activity, egg incubation success, and rearing conditions during summer after fry emerge from redds, this technique provides a broad assessment of the suitability of the spawning stream for a portion of the year. Since rainbow trout spawn from March through April in most of these streams, CPUE of rainbow trout juveniles during November provide an assessment of the stream's ability to support reproduction from March through November of a given year. Since brown trout spawn in October and November, CPUE trends for juvenile brown trout during the following November provide an assessment of the suitability of the stream for spawning and rearing for approximately the previous 12 months.

The abundance of juvenile trout determined near the mouth of these 16 spawning tributaries is generally considered to reflect hatching and survival of fish produced in the tributary, and not a result of juvenile trout migrating into a specific tributary from a mainstem river. However, it is known that juvenile trout from the mainstem river can migrate into these tributaries and influence the CPUE trend. For example, an electrofishing survey of an artificial spawning channel of the Missouri River (Crow Creek Spawning Channel) found more brown trout juveniles than rainbow trout despite the fact that the channel was dry during the brown trout spawning period. These fish presumably migrated into the channel from the Missouri River during the summer.

Both the Jefferson and Missouri Rivers are impacted by low summer streamflow, and monitoring of the mainstem fisheries generally show a relationship between fish numbers and major shifts in summer flow. Another factor that significantly influences the sport fishery is the relative scarcity of healthy tributaries providing cold, clean water to the mainstem Jefferson River. The shortage of healthy tributaries results in few locations for successful trout spawning and juvenile trout rearing areas needed to provide recruitment of new fish to the system.

RESULTS

CATCH-PER-UNIT-EFFORT ELECTROFISHING

Electrofishing surveys were conducted in several trout spawning tributaries (16 streams) of the Missouri River and Jefferson River from 1992 through 2007. A single pass using a backpack electrofishing unit during the late summer or fall provides a relative index of the number of juvenile trout residing in each tributary. The technique does not provide an estimate of total numbers of fish, but can provide general trends in response to changes in habitat, flow and species composition. Significant changes in fish numbers resulting from habitat enhancement can be detected using this technique, and tables showing trends of brown trout and rainbow trout are presented in this summary. Based on general observations in several streams over a number of years, it appears that catch rates of 0 to 1.0 juvenile fish per 100 seconds indicates low spawning/rearing success. Catch rates of 1.0 to 3.0 fish per 100 seconds indicates moderate spawning/rearing success, and catch rates exceeding 3.0 fish per 100 seconds indicates that significant spawning and rearing occurred in the stream during a specific year. The best spawning/rearing tributaries in the study area occasionally yielded 8 to 10 trout per 100 seconds during exceptional production years.

Several tributaries of the Missouri River show a trend of decreasing abundance of rainbow trout juveniles after the severe drought beginning in about 2000 (Table 1). Another finding of this evaluation was that the abundance of rainbow trout juveniles increased after imprinting fish and or eggs and conducting enhancement of spawning habitat in at least three of the streams sampled. Examples of this response to imprinting and/or habitat enhancement are presented in this summary. In addition, trout population estimate information for the Waterloo Section of the Jefferson River indicated that improved recruitment of juvenile rainbow trout provided potential benefits of tributary restoration to the fishery in the mainstem river where rainbow trout estimates showed an increasing population (Figure 6). The increased numbers of rainbow trout was most apparent for small fish less than 8 inches in length (Figure 7). Both Willow Springs and Parson’s Slough enter the Jefferson River in the Waterloo monitoring section (Figure 3).

Since the ratio of brown trout to rainbow trout juveniles is an unbiased result of the CPUE survey (electrofishing efficiency is likely very similar for the two species), relatively small changes in the ratio of brown trout and rainbow trout are likely to be detected. Two streams with long term CPUE trends of both brown and rainbow trout show relatively stable brown trout numbers during periods of changing rainbow trout abundance (Figures 8 and 9). One stream (Confederate Creek) experienced a near complete loss of brown trout during the period (Figure 10), and one stream showed a significant decline of both trout species since 1992 (Figure 11).

Table 1. Summary of catch-per-unit-effort (CPUE) electrofishing surveys of juvenile **rainbow trout** in selected spawning tributaries of the Jefferson River and Missouri River. The CPUE value for each stream represents the number of age 0 **rainbow trout** (<120 mm) captured per 100 seconds of electrofishing during the period, 1992 to 2006.

Creek Name	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07
Willow Springs	1.5	---	2.4	5.0	---	---	6.1	9.1	---	9.8	4.3	1.8	3.1	6.3	3.8	10
Hells Canyon	5.6	---	---	3.0	3.8	4.0	2.6	1.6	---	3.3	4.7	6.2	5.5	7.2	3.0	2.9
Parson’s Slough												0.0	1.6	0.2	9.4	2.4
Sappington Spring															2.4	2.6
Antelope Creek													0.2		0.2	0.1
Hamilton Spring														0.1	0	--
Fish Creek														0.1		
Sl. House Slough														0.0		
Willow Creek																0.0
Missouri River Tributaries:																
Beaver Creek	0.3	---	---	5.8	2.2	6.7	2.5	2.1	---	3.5	---	---	1.2	0.6		1.1
Deep Creek	0.8	---	---	1.8	0.8	---	3.9	3.0	---	0.0	0.3	---	0.6	0.1	0.1	0.1
Dry Creek	---	---	---	2.2	---	---	3.6	0.0	---	0.0	---	---	2.5	0.4	0.0	0.0
Magpie Creek	---	---	---	4.7	2.6	---	---	---	--	---	0.1	---	0.16	0.0	9.8	--
Confederate Creek	7.4	4.4	---	6.6	3.8	2.6	2.8	3.0	---	11.4	2.1	2.6	3.0	0.3	0.4	2.2
Marsh Creek				1.1				0.2				0.0			0.1	0.6
Big Springs				1.9											2.1	5.1

Table 2. Summary of catch-per-unit-effort (CPUE) electrofishing surveys of juvenile **brown trout** in selected spawning tributaries of the Jefferson River and Missouri River. The CPUE value for each stream represents the number of **brown trout** (<130 mm) captured per 100 seconds of electrofishing during the period, 1992 to 2005.

Creek Name	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07
Willow Springs	1.5	---	1.3	0.9	---	---	2.5	0.5	---	3.2	0.6	0.5	0.4	0.1	0.9	2.2
Hells Canyon	3.4	---	---	1.4	0.5	0.7	0.7	1.8	---	0.6	2.4	0.4	0.6	2.0	2.4	1.1
Parson’s Slough												0.08	1.2	0.4	0.3	2.1
Sappington Spring															3.1	2.6
Antelope Creek													1.3		1.5	0.9
Hamilton Spring														0.1	0.1	--
Fish Creek														1.0		
Sl. House Slough														2.2		
Willow Creek																0.1
Missouri River Tributaries																
Beaver Creek	0.2	---	---	0.0	0.5	0.04	0.07	0.0	---	0.2	---	---	0.9	0.0	--	0.0
Deep Creek	3.6	---	---	0.3	0.3	---	0.3	1.4	---	0.0	0.3	---	0.7	0.6	0.1	0.0
Dry Creek	---	0.0	0.0	---	---	0.0	0.0	0.0	---	0.0	0.0	---	0.0	1.0	0.0	0.0
Magpie Creek	---	---	0.0	---	0.0	---	---	---	--	---	0.0	---	0.0	0.0	0.0	--
Confederate Creek	3.9	3.5	---	0.2	0.06	0.1	0.3	0.6	---	0.0	0.8	0.1	0.0	0.2	0.2	0.0
Marsh Creek				0.1		0.1		1.8				0.9			0.6	4.6
Big Springs				1.2											0.2	0.5

TABLE SUMMARY: Jefferson River Tributaries

Willow Springs: Initial habitat improvement took place in 1987 and additional improvements were made in April 2005. No rainbow trout were observed in this tributary in the mid-1980's, and the first spawning took place in 1991 (three years after imprinting rainbow trout from Hell's Canyon Creek). Fry production after habitat improvement and imprinting was significantly improved by the project, and an increase in the number of rainbow trout residing in the Jefferson River near Willow Springs was observed throughout the 1990's. Redd counts for rainbow trout spawning in Willow Springs show a progressive increase since 1991 (Figure 2) and a general increase in juvenile rainbow trout accompanied the increased number of redds (Figure 8). The abundance of age 0 rainbow trout frequently exceeded 3.0 fish per 100 seconds, which was among the highest density of all tributaries surveyed. Four years of egg collection (approximately 10,000 eggs per year) from the Willow Springs spawning run (2004 – 2007) have not impacted juvenile rainbow trout abundance based on CPUE result.

Hells Canyon: Prior to 1991, when rainbow trout began spawning in Willow Springs (see above), Hells Canyon Creek was the only major rainbow trout spawning tributary for the upper Jefferson River. Abundance of juvenile rainbow trout appeared to decline in the late 1990's during early observations of Whirling Disease effects, but numbers recovered from 2000 to 2005 (Figure 9). A project to install a fish screen and to implement a water lease on an irrigation canal was completed in the fall of 1996 after dewatering impacts and fish loss to the irrigation system was documented. Water lease requirements have been met since project was implemented in 1996. Rainbow trout fry numbers have maintained a level near the long-term average despite Whirling Disease and the severe drought of 2000-2006. The water lease has maintained sufficient flow in the stream to allow rearing of large numbers of young rainbow trout as shown by the catch-per-unit-effort table. Installation of a fish screen has prevented the loss of thousands of juvenile trout each year. Information on this evaluation, including flow measurements, is presented in the water leasing report. The abundance of brown and rainbow trout juveniles have fluctuated since 1992, but numbers have not significantly declined despite drought conditions, in part, because of the water lease agreement.

Parson's Slough: Habitat improvement and imprinting rainbow trout eggs resulted in the first juvenile rainbow trout observed in this spring creek in 2004. Successful imprinting of rainbow trout eggs from Willow Springs in 2006 resulted in one of the highest catch rates of juvenile rainbow trout observed in any tributary surveyed in the Missouri River and Jefferson River. Additional habitat improvement was conducted during 2007 in Parson's Slough using funds from FFIP and other sources. The trend for brown trout is positive, and rainbow trout returning to Parson's Slough after imprinting was first documented in 2006. See pages 29-33 for more detailed results.

Sappington Spring: This small (<5 cfs) spring was constructed during fall 2005 to provide spawning and rearing habitat for brown and rainbow trout resident to the Jefferson River. One brown trout redd was observed soon after construction in 2005 and

5 redds were observed in 2006. No rainbow trout redds were observed in spring 2006. Rainbow trout eggs from Willow Springs were imprinted in 2006 and 2007, and moderate abundance of juvenile brown and rainbow trout was observed in the fall CPUE survey (Tables 1 and 2).

Antelope Creek: Elimination of an irrigation canal and habitat enhancement were implemented in fall/winter of 2005. Five brown trout redds were observed in the project area in 2006. CPUE survey results before and after the project showed similar numbers of brown and rainbow trout after the first two years (2006 and 2007) of project completion (Table 1 and 2).

Fish Creek: Brown trout fry were present, but not common, in the proposed enhancement reach and rainbow trout fry were rare prior to restoration (2005). Brown trout spawning was documented in the enhancement reach during fall 2007, and post project CPUE sampling in 2008 will be conducted to evaluate fish survival.

Slaughterhouse Slough: Brown trout fry were present in this slough (side channel) near the Piedmont Bridge crossing in 2005, but no rainbow trout fry were observed. Continued restoration of Fish Creek and improved flow conditions in Slaughterhouse Slough is expected to provide improved habitat for rainbow trout. Continued monitoring will determine the need for rainbow trout imprinting.

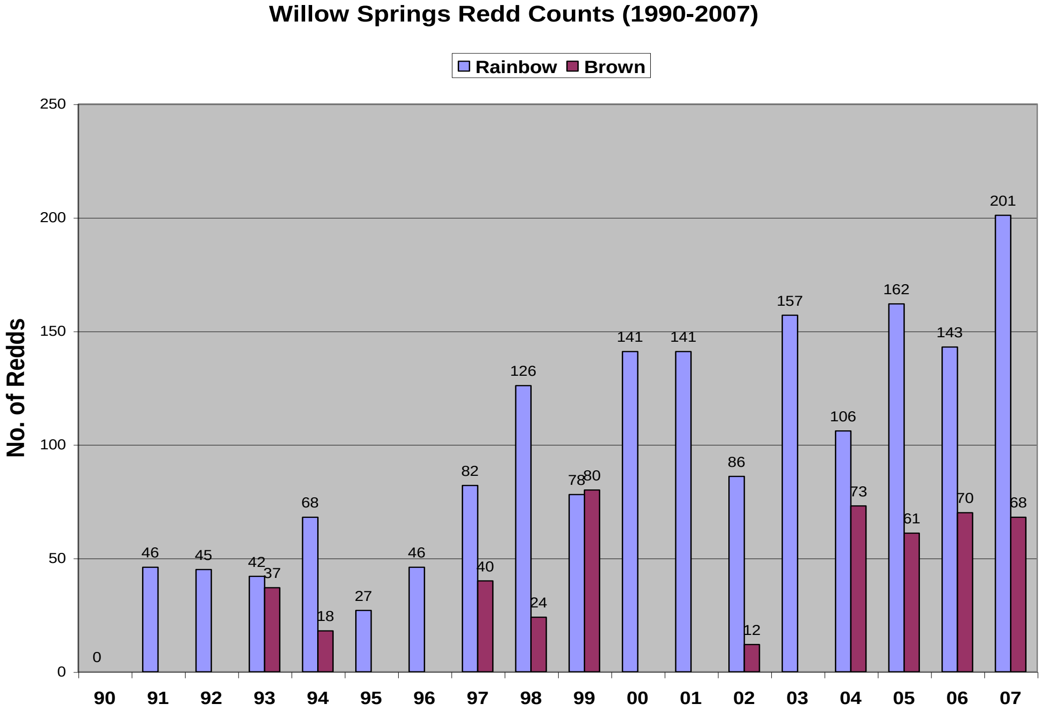


Figure 1. Brown and rainbow trout redd counts in Willow Springs from 1990 to 2007.

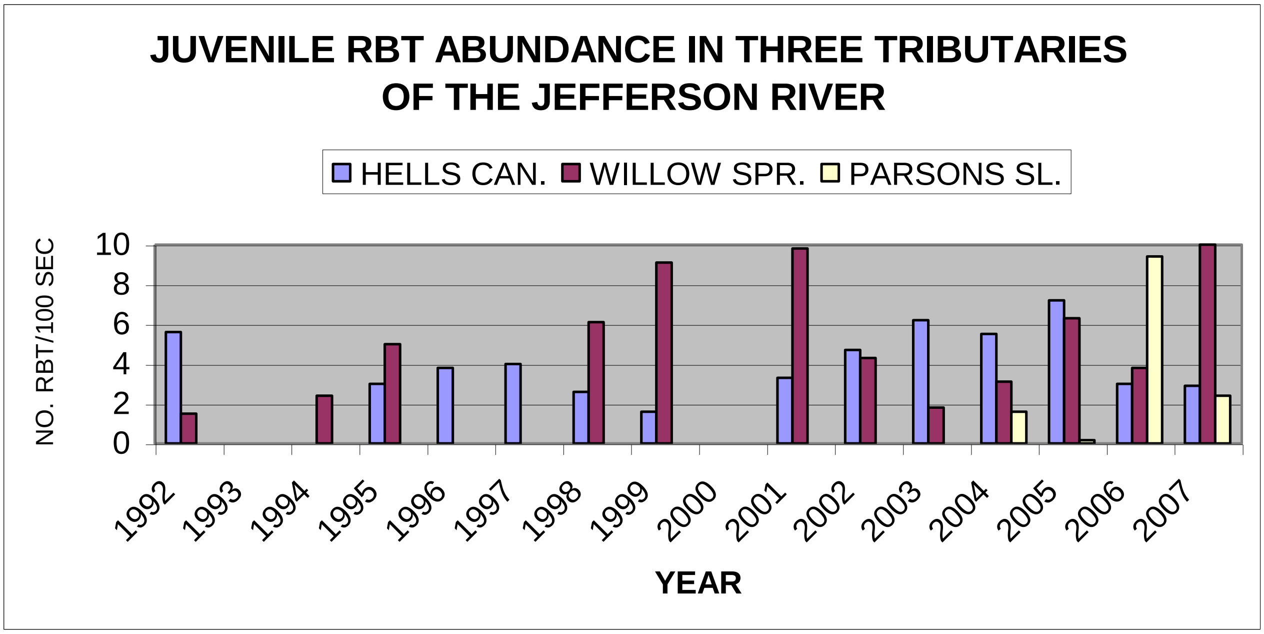


Figure 2. Juvenile rainbow trout Catch-per-Unit-Effort trends for three tributaries to the Jefferson River (HCAN=Hells Canyon Creek, WSPR=Willow Springs, PARS=Parson's Slough).

Willow Creek: The first CPUE survey was conducted in 2007. Low density of brown trout juveniles and no rainbow trout juveniles were observed. Willow Creek is influenced by seasonal flow releases from Harrison Lake, and future sampling will determine the potential recruitment value of this tributary.

Hamilton Spring Creek: Low densities of both trout species were observed in 2005 and 2006 after imprinting rainbow trout eggs. High sediment loading appears to impact egg survival and future monitoring is needed to evaluate benefits from a riparian fence installation.

THE PARSON'S PROJECT

Parson's Slough enters the Jefferson River about one mile downstream of Parson's Bridge. Habitat enhancement work to improve spawning and rearing attributes of this small tributary was initiated by a private landowner, Trout Unlimited, and MDFWP in 2003.

A fall electrofishing survey was conducted above Loomont Lane was initiated during fall 2003. A very low number of brown trout juveniles and no rainbow trout were observed in 2003. This sampling confirmed the need for initiating rainbow trout imprinting of the spring creek in a similar manner to work conducted in Willow Springs in the late 1980's. Both Willow Springs and Parson's Slough are streams heavily influenced by groundwater and spring seepage, and the streams were wide, shallow and the stream bottom was dominated by large amounts of fine sediment. Both streams were modified to narrow the channel, protect streambanks from livestock, and in some cases appropriately sized gravel was added to the system.

Phase I of Parson's Slough habitat enhancement took place during summer/fall 2004 above Loomont Lane. Imprinting of rainbow trout eggs from the Willow Springs spawning run was initiated in 2004. Imprinting was conducted in 2004, 2005, and 2006. Phase II of the habitat enhancement project was conducted during February and March of 2007 from Loomont Lane to the mouth of Parson's Slough. About 0.27 miles of habitat is located below Loomont Lane and 0.85 miles of habitat is located above Loomont Lane.

Rainbow Trout Spawning Observations:

No rainbow trout redds were observed in 2004 and 2005. In 2006, the first documented rainbow trout spawning occurred when nine redds were counted: 3 redds below Loomont Lane and 6 redds above Loomont Lane. A total of 32 redds were counted in 2007: 14 redds below Loomont Lane and 18 redds above Loomont Lane.

Brown Trout Spawning Observations:

On 1 December 2004, we counted 16 brown trout redds (6 below Loomont Lane, and 10 within the newly constructed habitat above Loomont Lane). On 23 November 2005, we counted 26 total redds in Parson's Slough (11 below Loomont Lane, and 15 above Loomont Lane). In 2006, 51 brown trout redds were counted: 13 redds below Loomont Lane and 38 above Loomont Lane). Three counts during November 2007 found a total of 64 brown trout redds (29 below Loomont Lane and 35 redds above Loomont Lane.

Fall Electrofishing to monitor fry production:

Rainbow trout fry were not present prior to imprinting based on sampling in 2003. During fall 2004, significant numbers of rainbow trout fry were observed indicating the imprint planting during the summer was very successful. This success was evident during Jefferson River electrofishing in April 2005, when rainbow trout yearlings were about 4 times more abundant than previously observed in the Waterloo Section. Rainbow trout fry were present, but not common in 2005, indicating that 2005 imprinting was not very successful as suspected when observing high fry mortality in hatching boxes. The successful imprint of rainbow trout fry in 2006 resulted in a very high density of YOY rainbow trout during the fall survey (Table 3). As a result of the high number of juvenile rainbow trout observed in 2006 and the presence of the first documented rainbow trout spawning during 2006, no additional imprinting of rainbow trout eggs from Willow Spring was conducted in 2007. The relatively high number of juvenile rainbow trout observed during fall 2007 was a product of natural reproduction with no supplementation of imprinted fish.

Brown trout fry above Loomont Lane was very low in 2003. Sampling in 2004 and 2005 was conducted below Loomont Lane and brown trout fry abundance was similar during the two years (Table 3). After additional channel modification was conducted in 2007, the number of brown trout fry observed during the fall was the highest observed during the study period.

Table 3. Juvenile trout abundance in Parson's Slough during the fall (2003-07).

	Brown Trout/100 Seconds	Rainbow/100 Seconds
2003	0.16	0
2004	1.6	1.9
2005	1.5	0.2
2006	0.3	9.4
2007	2.1	2.4

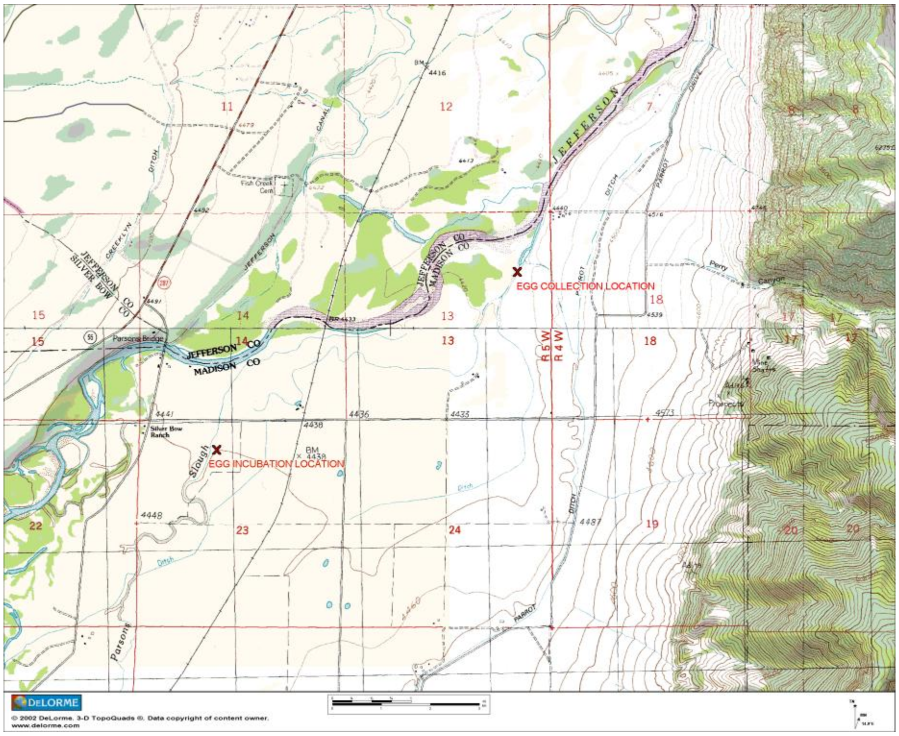
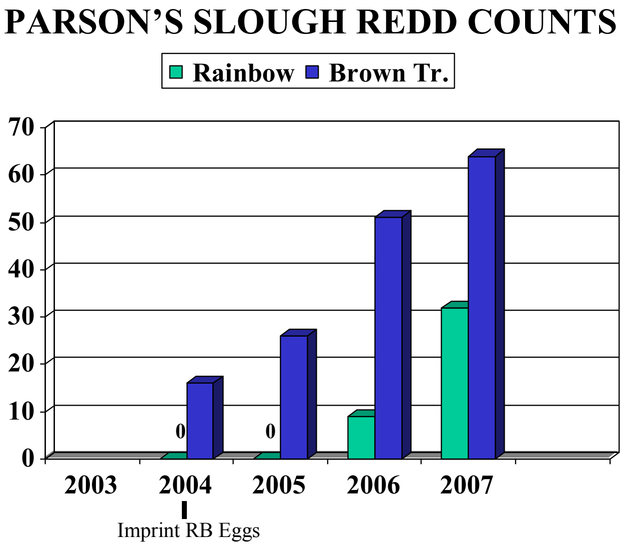
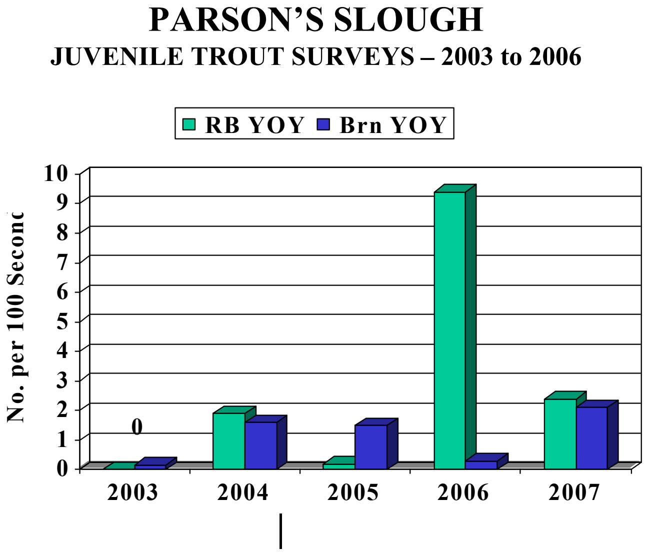


Figure 3. Map of Parson's Slough and Willow Springs showing rainbow trout egg collection location (Willow Springs) and egg incubation location (Parson's Slough).



Imprint RB Eggs
Hab. Imp. – Phase I



RB Egg Imprint
Hab. Imp. – Phase I

Figures 4 and 5. Brown and rainbow trout redd count results and juvenile trout CPUE trends (2003-2007).

Rainbow Trout Population Trend in the Waterloo Section, Jefferson River (2000 to 2007)

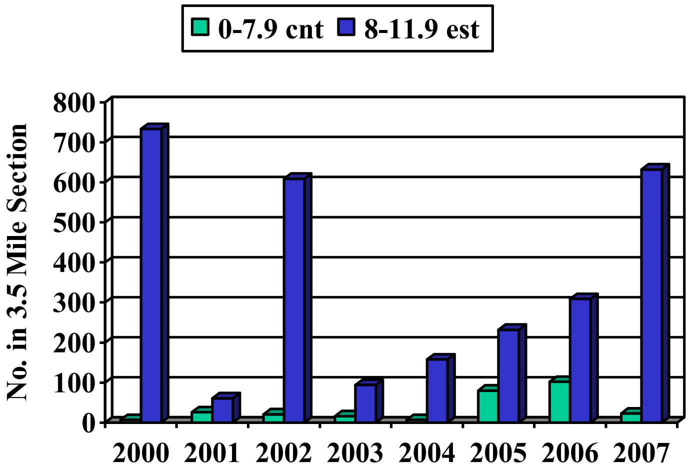


Figure 6. Rainbow trout abundance in the Waterloo Section of the Jefferson River during springtime electrofishing. Yearling rainbow trout (0 to 7.9 inches) represent the total number captured during the survey and age II trout (8 to 11.9 inches) represent the estimated number using Mark/Recapture techniques. Rainbow trout over 12 inches were not included due to bias resulting from spawning movements.

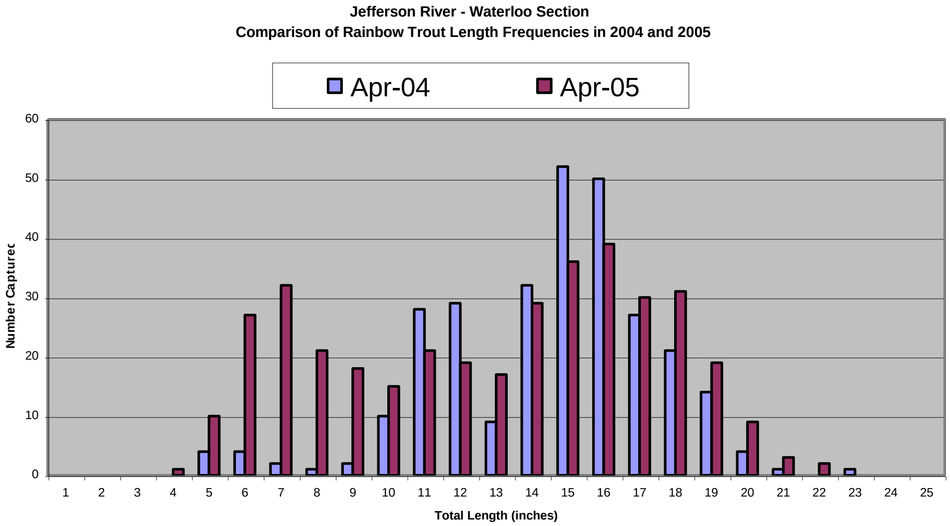


Figure 7. Length frequency of rainbow trout in the Waterloo Section (2004-05).

Missouri River/Canyon Ferry Reservoir Tributaries

Catch rates of juvenile trout were also monitored for several tributaries in the Missouri River/Canyon Ferry Reservoir complex to evaluate spawning and rearing success. See Tables 1 and 2 to review trends in abundance. The most extensive fishery monitoring of Missouri River tributaries was conducted in Deep Creek and Confederate Creek and these results are presented in more detail in the Toston Mitigation report.

Beaver Creek: Severe flow limitations have reduced rainbow fry abundance during the recent drought (no habitat or flow improvement has been conducted). The CPUE tables show catch rates of less than 1 trout per 100 seconds of sampling during most years after 2000 and fish abundance was generally reduced compared to the pre-2000 sampling.

Deep Creek: Fry migration and adult spawning surveys have also been conducted (see a more detailed evaluation of Deep Creek in this report). Low streamflow has reduced rainbow trout fry abundance compared to the mid-1990's, and effects of Whirling Disease also appear to impact spawning success based on the declining trend in CPUE and the frequent observations of fish with deformities.

Dry Creek: Juvenile rainbow trout are completely absent during some years, and at moderate levels during other years. Supplemental water delivered for egg incubation has variable success in this stream. Streamflow is very low during fall and winter and brown trout generally do not spawn successfully in Dry Creek.

Magpie Creek: Rainbow spawners pass upstream of the fish ladder in most years. Abundance of juvenile rainbow trout above the ladder is much reduced from levels observed in the mid-1990's and no rainbow trout were observed in 2005. Surprisingly, an extremely high number of juvenile rainbow trout were observed above the fish ladder in 2006, indicating favorable fish passage and high spawning success (Table 1).

Confederate Creek: Juvenile rainbow trout abundance has maintained a level near the long-term average in recent years, despite the severe drought. Brown trout abundance has declined in recent years and virtually no brown trout redds have been observed in this stream in the past five years. Habitat improvement was conducted in 1991.

Marsh Creek: Juvenile brown and rainbow trout abundance has remained low throughout the years of sampling. No habitat improvement has been conducted in this stream, but future potential exists to provide spawning and rearing for trout due to a spawning run that occasional enters the system.

Big Springs: An artificial spawning channel was constructed at Big Springs in September 1994. About 20 to 40 brown trout redds and over 50 rainbow trout redds have been counted annually for the past 13 years. CPUE surveys were conducted during three years: juvenile rainbow trout were common with an increasing trend and brown trout were less abundant with a decreasing trend.

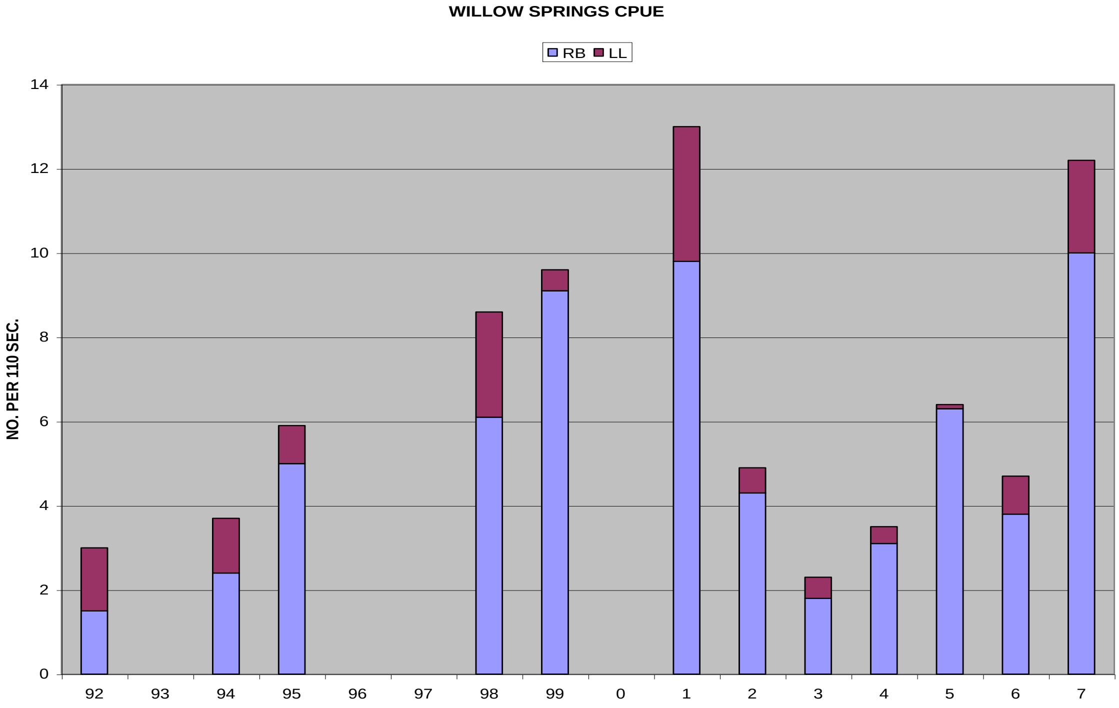


Figure 8. Brown and rainbow trout CPUE trend in Willow Springs (1992-2007).

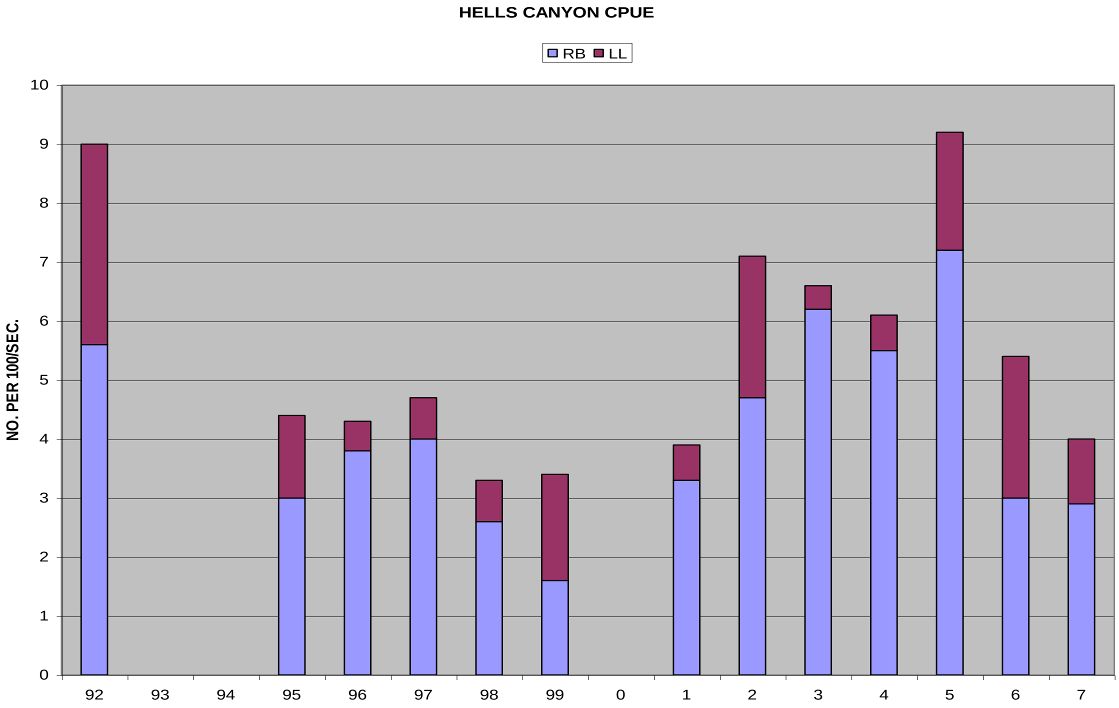


Figure 9. Brown and rainbow trout CPUE trend in Hells Canyon Creek (1992-2007).

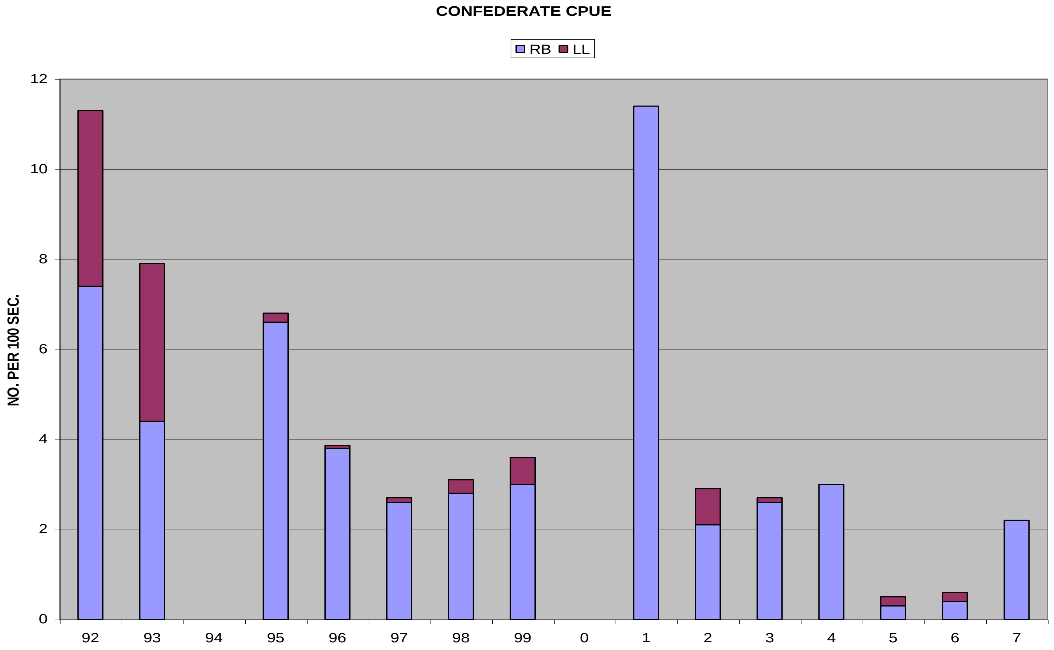


Figure 10. Brown and rainbow trout CPUE trend in Confederate Creek (1992-2007).

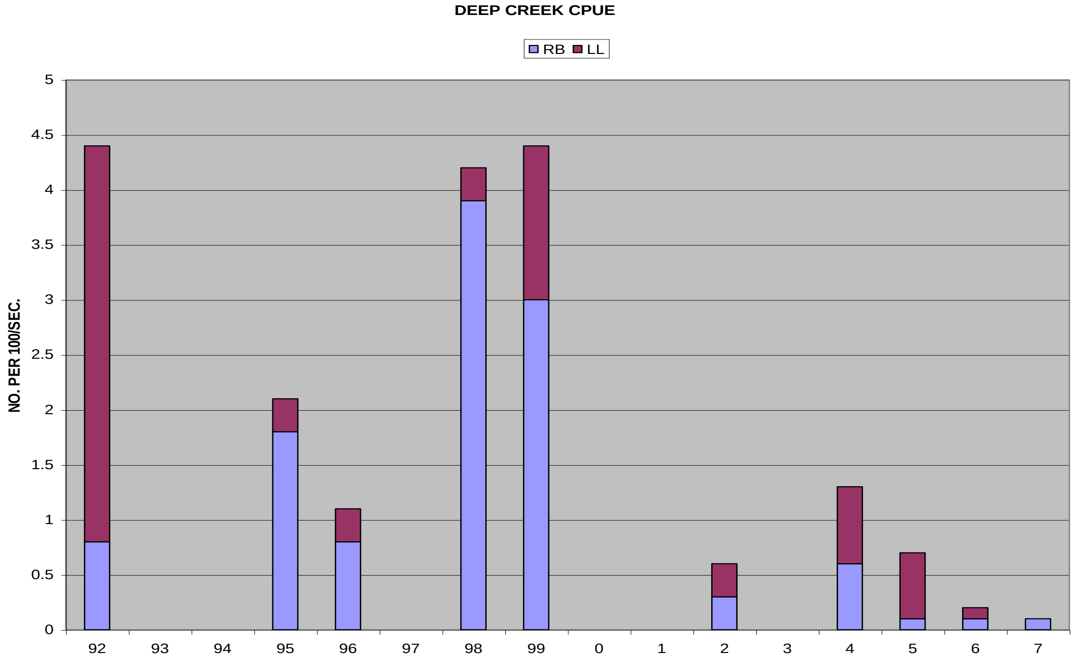


Figure 11. Brown and rainbow trout CPUE trend in Deep Creek (1992-2007).

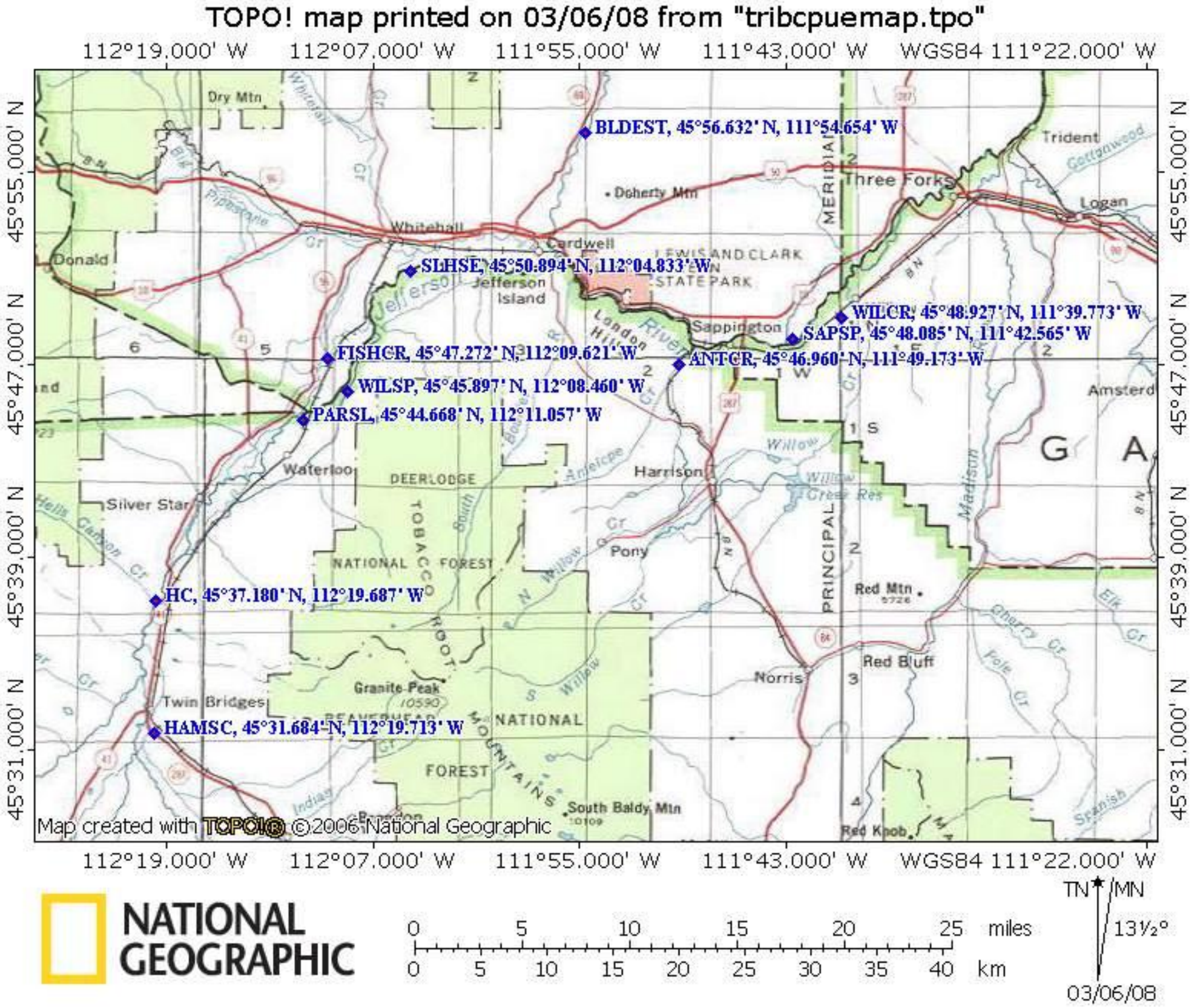


Figure 12. Location of CPUE sampling sections for tributaries of the Jefferson River.

Summary of Tributary Evaluations

Catch-per-unit-effort (CPUE) sampling of several tributaries over a long period of time provided information to assess the spawning and nursery function of streams. Some streams showed a measurable decline in juvenile abundance due to low flow conditions (Deep Creek, Beaver Creek). Hells Canyon Creek and Willow Springs did not experience similar declines in juvenile trout abundance during the same period. The water lease in Hells Canyon Creek and the relatively stable flow regime of Willow Springs may have helped avoid fish loss during the series of low flow years starting in 2000. CPUE sampling was effective for evaluating success of imprint planting at Willow Springs, Parson's Slough, and Sappington Springs, and the sampling method established a baseline of juvenile trout abundance for several other streams in the project area.

CHAPTER IV

Boulder River Fishery Evaluation

Monitoring of fish population abundance, spawning movements of brown trout, and redd construction by brown trout was conducted in the Boulder River in 2007. The Boulder River from Cold Springs to the confluence with the Jefferson River (about 13 miles) contains a resident brown trout fishery and provides significant spawning habitat for a migratory run of spawning brown trout resident to the Jefferson River. Monitoring of this reach of the Boulder River was conducted in 2007 to evaluate the status of this fishery and determine feasibility of improving the fishery using habitat enhancement methods.

A mark recapture population estimate was conducted in a 1.66 mile reach of the river on 11 April 2007 (Figure 1). Ninety-one percent of trout fishery was comprised of brown trout, with total of 296 brown trout and 28 rainbow trout were captured during the survey. The sampling section contained 328 brown trout per mile of stream for fish over 9.0 inches in total length (age II and older fish). No estimate of rainbow trout was calculated due to small sample size and the presence of spawning fish presumed to be migrating through the sampling section.

Evaluation of the Brown Trout Spawning Run

Fish Trapping at Shaw Diversion

The Shaw Diversion is located about 4 miles upstream of the mouth of the Boulder River. This diversion is a seasonal barrier to upstream fish movement due to the placement of boards on the concrete diversion, and a fish ladder was placed in the diversion in 2001. Capture of spawning brown trout was attempted during 2007 to document fish passage around the diversion and to determine the timing and extent of the brown trout spawning run during the fall migration period.

Trapping began on 9 September 2007, and the first fish was captured on 27 September. The majority of brown trout moved through the trap between 9 October and 31 October, and no fish entered the trap after 10 November. The trap was operated for 50 days, and 45 brown trout and 4 mountain whitefish were captured during the effort. A total of 38 brown trout received floy tags inserted behind the dorsal fin for future evaluation of spawning movements. Size of brown trout entering the trap ranged from 9.7 to 22.5 inches total length. The sex ratio of brown trout was 21 males: 21 females and 3 non-spawning fish.

Irrigation boards were removed from the structure in early October and an unknown percentage of fish were able to move through the diversion without entering the fish trap. Thus, the capture of 45 brown trout only represents a small, unknown percentage of the spawning run. An extensive survey of brown trout redd construction was conducted following the trapping operation to determine the size of the spawning run migrating into the Boulder River.

Boulder River Redd Count--2007

Ten reaches of the Boulder River was walked during November to count brown trout redds and estimate the total number of redds in the lower 13 miles of the river (Table 1).

Table 1. Boulder River Redd Count During November, 2007.

SECTION	RIVER MILES	# of REDDS	REDDS/MILE
Cold Spr to Ford	0.0-0.71 (0.71 Miles)	80	112.7 Redds/Mile
Ford to Gavin Bridge	0.71-1.56 (0.85 Miles)	30	**35.3*** Redds/Mile
Bridge to Gavin Cabin	1.56-2.11 (0.55 Miles)	20	**36.4*** Redds/Mile
Cabin to Rt Bank Slough	2.11-2.90 (0.79 Miles)	45	**57.0*** Redds/Mile
Slough to County Bridge	2.90-5.33 (2.43 Miles)	---	No Count (Est. 43.6/Mile)
County Bridge to Diversion	5.33-9.13 (3.8 Miles)	---	No Count (Est. 43.6/Mile)
Diversion to Ctwd Bridge	9.13-9.48 (0.35 Miles)	16	**45.7*** Redds/Mile
Ctwd Bridge to Old Highway	9.48-11.10 (1.62 Miles)	28	17.3 Redds/Mile
Old Highway to Railroad	11.10-12.33 (1.23 Miles)	22	17.9 Redds/Mile
Railroad to Jefferson R.	12.33-13.13 (0.80 Miles)	0	Low Gradient (0 Redds/Mile)
Cold Springs to Mouth of Boulder River	0- 13.13 Miles	241 Counted + 272 Estimated = **513 Total Redds**	Redd Cnt. Estimated from Mile 2.9 to 9.13

- Average Redds Per Mile based on these four reaches to estimate number of redds per mile in 6.23 miles of river where a redd count was not conducted in 2007.

The redd count survey found that a total of 513 brown trout redds were constructed in the 13.1 mile reach of the Boulder River between Cold Springs and the confluence with the Jefferson River. About 7 miles of river was walked during the redd count, and redd counts were extrapolated for the remaining 6.2 miles that was not walked during the survey. Based on redd counts in nearby reaches, it was assumed that 43.6 redds per mile were constructed in the reaches not surveyed.

Relatively few redds were observed in the lower 3 miles of the river near the confluence with the Jefferson River, with a maximum of 17.9 redds per mile observed in this area. From the I-90 crossing to about 0.7 miles below Cold Springs, the number of redds per mile ranged from 45.7 to 57.0 redds per mile. The largest concentration of brown trout redds were observed in the 0.7 mile reach below Cold Springs, where 112.7 redds per mile were observed. The spring water entering the Boulder River appears to be the most desirable location for spawning fish.

Comparison of Fish Abundance in 1974 and 2007

Fish sampling was conducted in four sections of the Boulder River in 1974. Low numbers of brown trout were observed near Elkhorn Bridge, the Carey Ranch, and near Negro Hollow Bridge, ranging from 39 to 52 brown trout per 1000 feet of stream (7 to 10 brown trout per mile). Brown trout abundance increased below Cold Springs, and an estimate section at Shaw Ranch showed 242 brown trout per 1000 feet (46 brown trout per mile) for age I fish and older. Estimates were conducted in late summer and no mention of rainbow trout was found in the previous records.

The population estimate conducted in April of 2007 was not conducted precisely at the previous Shaw Ranch section due to access issues and the uncertain boundaries of the previous population estimate section. Since the 2007 population estimate was conducted in the spring to eliminate potential spawning movement bias, the late summer estimate of 1974 cannot be directly compared to results from 2007 sampling. Despite the potential errors from section boundaries and seasonal timing, it appears that brown trout abundance has increased from about 46 brown trout per mile in 1974 to 328 brown trout per mile in 2007.

Rainbow trout observations in the lower Boulder were not recorded in the 1974 fishery summary for the Boulder River, and it is assumed that either no rainbow trout were present at this time, or relatively few fish were present and no population estimate was conducted due to low sample size. Therefore, it is not known whether the capture of 28 rainbow trout captured in the 1.66 mile section in 2007 represents a significant change in the population of rainbow trout.

Figure 1. Map of lower Boulder River showing trap location at Shaw Diversion, the population estimate section, and the Cold Springs, which is the upper extent of the redd count conducted in 2007.

CHAPTER V

STREAMFLOW PROTECTION AND ENHANCEMENT EFFORTS FOR THE JEFFERSON RIVER

The Jefferson River is designated as a Chronically Dewatered stream by MDFWP because of the frequent occurrence of low stream flow during the summer irrigation season. Relatively low summer stream flow of the lower Big Hole, Ruby and Beaverhead Rivers often results in low stream flow of the Upper Jefferson River, and the appropriation of approximately 800 cfs of water right claims in the upper 25 miles of the Jefferson River can result in very low flows during years with below average snowpack and rainfall. During the extreme drought conditions of 1988, the Jefferson River had almost no water flowing over riffles, and the USGS measured about 3 cfs of flow near Waterloo below Parson’s Bridge.

At least four important steps have been taken to attempt to resolve the chronic dewatering of the Jefferson River.

1. The upper Missouri River Basin was closed to new appropriation of water claims in 1993. This action provided protection for instream flow and for existing water users by reducing or eliminating new and competing claims for additional water use in the basin;

2. A drought management plan for the Jefferson River was written in 1999 to attempt to voluntarily share the burden of water shortages during drought years. Existing water users attempt to coordinate withdrawals to informally share the remaining water and leave a portion of the water savings in the Jefferson River to protect aquatic life;

3. A cooperative effort between MDFWP, DNRC, JRWC and Trout Unlimited was initiated in 2001 to improve understanding of irrigation canal infrastructure to improve efficiency of water use to benefit both water users and the instream flow of the Jefferson River;

4. A study groundwater resources in the Waterloo area was conducted in 2004 and 2005 to improve understanding and management of groundwater resources in a portion of the Jefferson Valley. Protection of groundwater resources is believed to be key in the future recovery of aquatic resources in the Jefferson River Basin.

JEFFERSON RIVER DROUGHT MANAGEMENT PLAN
(ABSTRACT)

Purpose:

The purpose of the Drought Management Plan is to reduce resource damage and to aid in the equitable distribution of water resources during water critical periods. The plan is a voluntary effort involving local interests including agriculture, conservation groups, anglers, municipalities, businesses, and government agencies.

The first Drought Management Plan was prepared and approved by the Jefferson River Watershed Council on 25 July, 2000. The plan was implemented for five years (2000 through 2004) and increased flow at the target location (Waterloo Gage below Fish Creek Canal) was documented by monitoring river and irrigation canal flows during the period. The drought management plan goal of maintaining at least 50 cfs at Waterloo was not always met during these years, but cooperation by water users helped improve flows at this critical location. Prior to developing the drought plan, the Jefferson River was severely dewatered at this location during dry years, and in 1988, only 5 cfs was measured at the Waterloo Gage location.

Drought Management Plan Triggers:

The 2000 version of the Drought Management Plan established flow triggers for directing actions of anglers, water users, and government agencies. The triggers were revised in February 2005 based on observations of the previous 5 years of plan implementation. As of 2007, the current drought plan triggers are listed below.

Triggers: The following prescribed actions are to occur when the river flow drops below the following levels or when maximum daily water temperature exceeds 73 degrees F for three consecutive days at the Twin Bridges Gaging Station (06026500):

600 cfs: The 600 cfs trigger flow at the Twin Bridges Gage serves to alert water users and anglers of declining flow conditions and requests voluntary water conservation measures and angler awareness of stress caused by fishing during periods of low flow and high water temperature. A press release will be issued to inform the public of low flow conditions on the Jefferson River.

280 cfs: Montana Dept. of Fish, Wildlife & Parks will evaluate the need for a mandatory fishing closure throughout the Jefferson River at this flow level at the Twin Bridges Gage. Voluntary reduction of irrigation and municipal water use is also initiated when the river drops below 280 cfs, and weekly meetings with water users will be coordinated by JRWC. The meetings will update water users on inflows to the river, ditch withdrawals, and status of the flow at the Waterloo Gage to attempt to maintain a minimum flow of 50 cfs at Waterloo. The angling closure will remain in effect until flows reach or exceed 300 cfs for seven consecutive days at the Twin Bridges Gage.

73 Degrees F: Independent of stream flow level, Montana Dept. of Fish, Wildlife & Parks can implement a mandatory time of day closure to prohibit angling throughout the Jefferson River between the hours of 2:00 PM to 12:00 AM (midnight) when maximum daily water temperature equals or exceeds 73 degrees F (23 degrees C) for three consecutive days. Lifting of summer temperature restrictions will be conducted on September 15 unless an earlier/later date is designated by the FWP Commission.

DROUGHT PLAN EVALUATION (2000-2008)

The evaluation of the effectiveness of the Drought Management Plan was conducted throughout the first eight years of implementation (2000 – 2008). Monitoring flow of four large irrigation canals and several locations of the Jefferson River was used to determine the ability to maintain critical stream flow in the river while providing sufficient irrigation water to water users. Implementation of the plan was challenged by the unprecedented drought conditions from 2000 to 2008. Long term flow records were not available for stations located on the Jefferson River, but flow records for the Big Hole (Melrose Gage) and the Upper Missouri River (Toston Gage) indicate that the eight consecutive drought years starting in 2000 were the lowest on record when compared to previous averages (Figure 1).

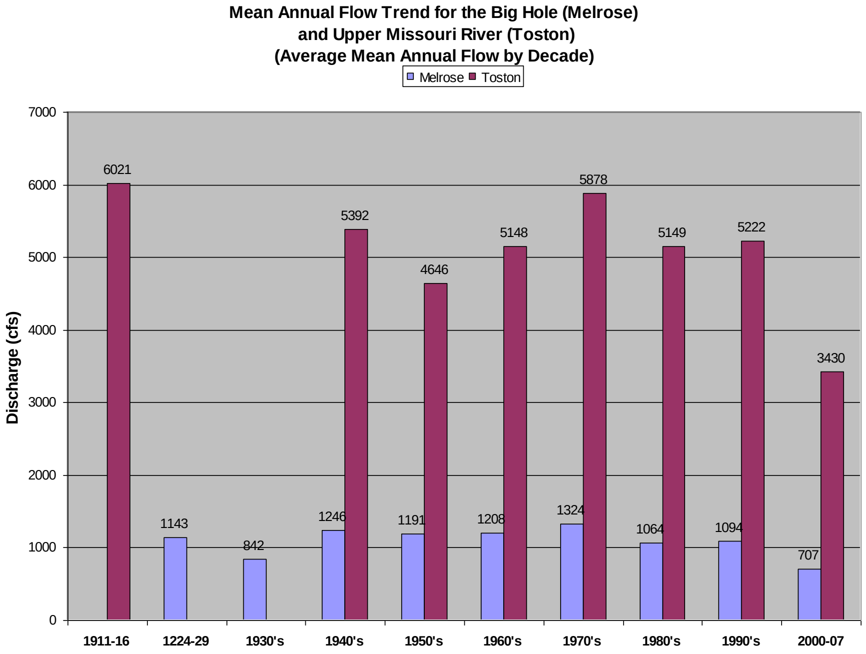


Figure 1. Long term trend of mean annual flow for the Big Hole and Missouri River USGS gaging stations located at Melrose and Toston.

The primary method for attempting to coordinate water use by the four major irrigation canals in the upper Jefferson River was to conduct weekly meetings during the summer months when flow at the USGS gage at Twin Bridges was critically low (less than 280 cfs). The purpose of the weekly meetings was to attempt to maintain 50 cfs at the Drought Management Plan (DMP) target location at Waterloo (below Parson’s Bridge). Four major canals (Creeklyn Ditch, Parrot Ditch, Fish Creek Canal, and Jefferson Canal) and several small ditches withdraw water between the mouth of Hell’s Canyon Creek and Parson’s Bridge (Figure 2).

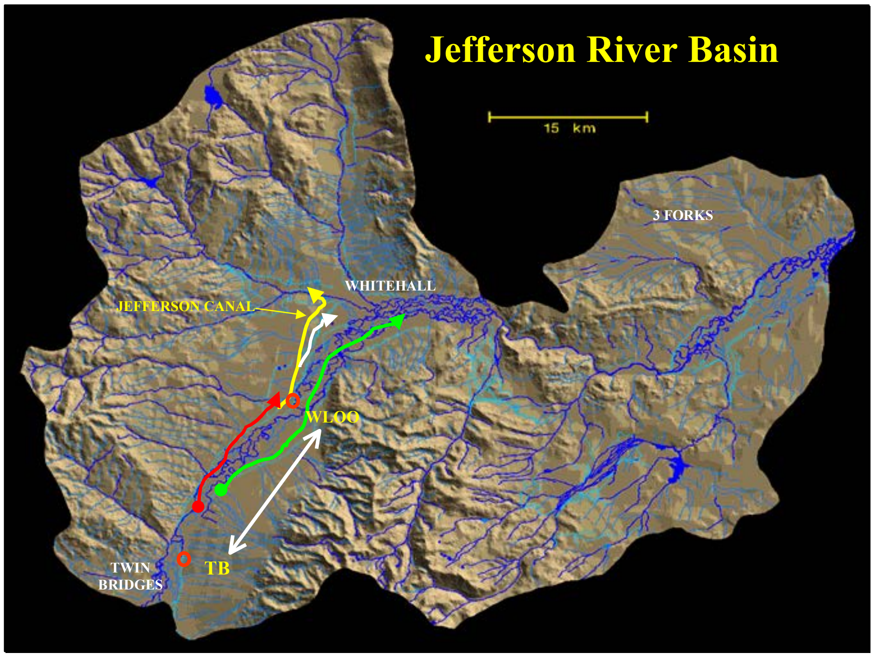


Figure 2. Map of the four major canals participating in the Drought Management Plan (Creeklyn Ditch: Red, Parrot Ditch: Green, Jefferson Canal: Yellow, and Fish Creek Canal: White).

Maintenance of the flow target of 50 cfs at Waterloo was not accomplished for several days during most years between 2000 and 2007 (Figure 3). Weekly meetings held with water users, agency representatives and Trout Unlimited during periods when flow was less than 280 cfs at Twin Bridges and often less than 100 cfs at Waterloo were conducted to attempt to voluntarily reduce ditch withdrawals to maintain the flow above 50 cfs at the Waterloo Gage.

When one or more of the ditches were able to provide some water to improve flow in the Jefferson River, other ditches attempted to lower headgates to attempt to pass the water downstream to the Waterloo Gage. Another example of actions taken during weekly water user meetings, was to agree to modify irrigation diversion structures to attempt to improve ditch flows for a specific period, and to refrain from additional measures to obtain water later in the summer.

During periods when the Jefferson River was extremely low (less than 280 cfs at Twin Bridges and less than 50 cfs at Waterloo), and air temperature was high during critical growing periods, the result of the weekly meeting often resulted in no possible action to improve flow at Waterloo. Weather forecasts and summaries of flow trends from upstream sources were discussed during such meetings. During the eight years of DMP meetings with water users, irrigation withdrawal was never increased when flow at Waterloo was less than 50 cfs.

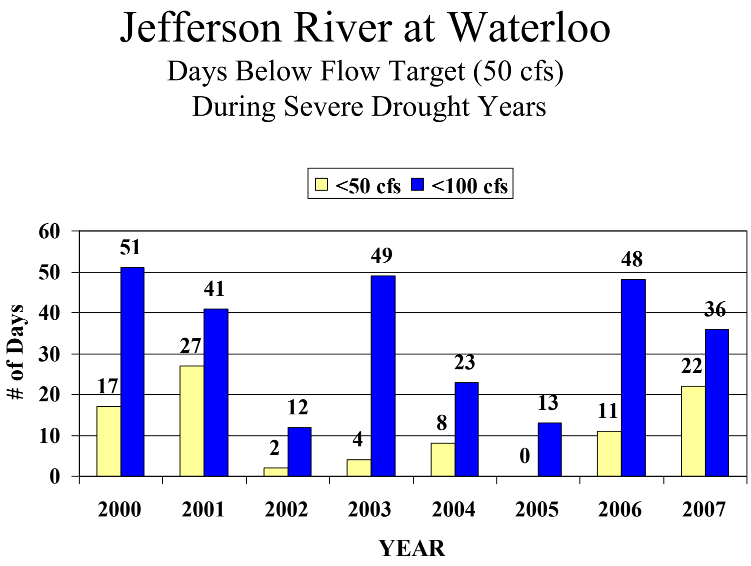


Figure 3. Number of days that Waterloo flow target of 50 cfs was not reached from 2000 to 2007. Days less than 100 cfs also included for reference.

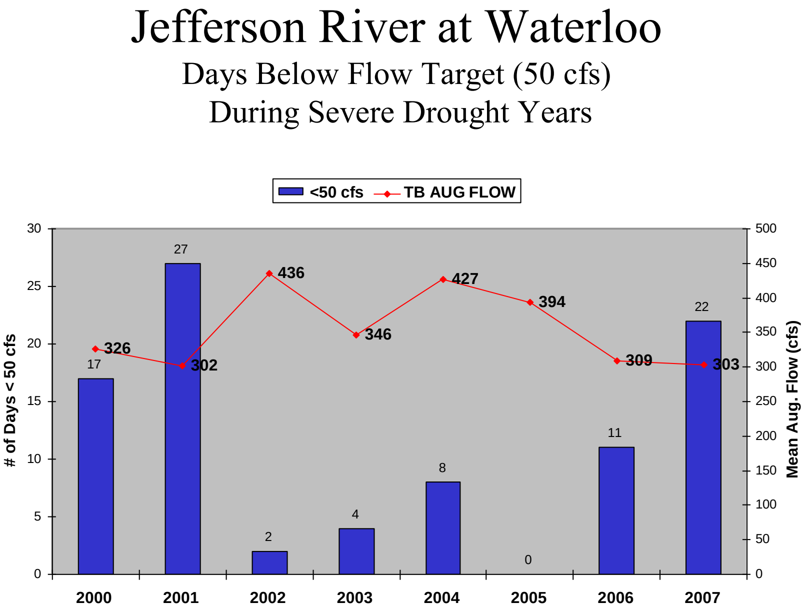


Figure 4. Number of days that Waterloo flow target of 50 cfs was not reached compared to mean August flow at the USGS gage near Twin Bridges.

The number of days that flow at Waterloo was less than 50 cfs ranged from 11 to 27 days during years when mean August flow at Twin Bridges was approximately 300 cfs (Figure 4). When mean August flow at Twin Bridges was near or above 400 cfs, the number of days that flow at Waterloo was less than 50 cfs ranged from 0 days and 8 days.

When mean August flow at Twin Bridges exceeded 400 cfs from 2000 to 2007 the number of days that flow was less than 50 cfs at Waterloo was relatively low, and the percentage of water at Twin Bridges that reached the target at Waterloo was relatively high (Figure 5). A relatively constant percentage of 16 to 17 % of the Twin Bridges flow was observed during 5 years when the Twin Bridges flow was about 300 to 350 cfs. During the three years when mean August flow at Twin Bridges was approximately 400 cfs, the percentage of water that reached Waterloo was 32 to 34 %.

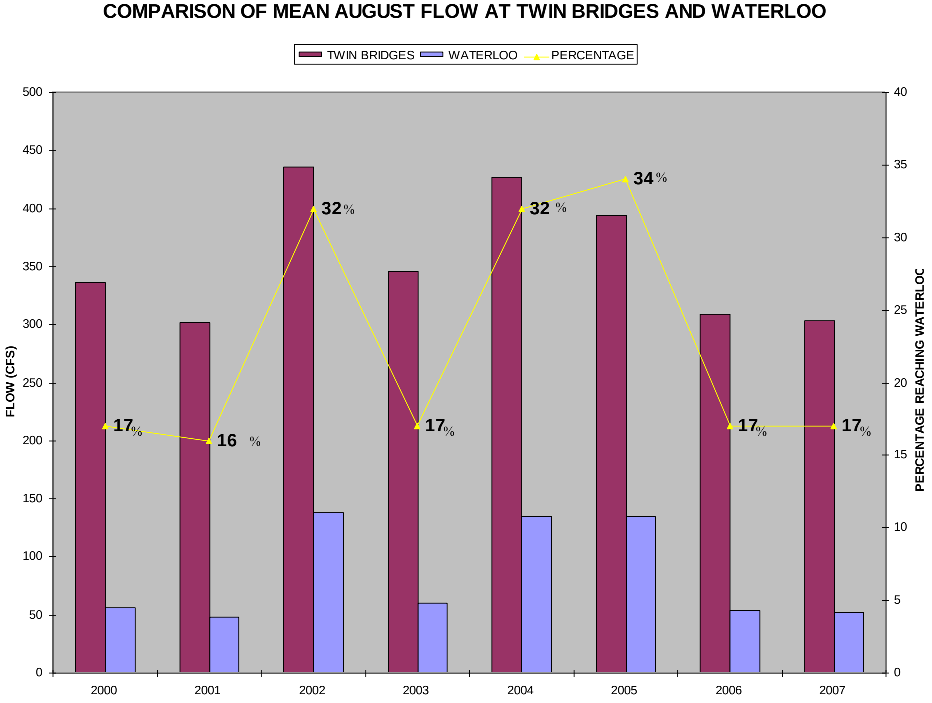


Figure 5. Comparison of mean August flow at Twin Bridges and Waterloo and the percentage of flow reaching Waterloo (2000-2007).

Based on evaluations of flow trends at Twin Bridges and Waterloo from 2000 to 2007, it appears that a flow of approximately 400 cfs at Twin Bridges is a critical stage for preventing dewatering of the upper Jefferson River. When flow at Twin Bridges exceeds 400 cfs, a relatively high percentage of flow reaches Waterloo and the risk of dewatering the river between Silver Star and Waterloo is reduced.

An important component of the implementation of the DMP from 2000 to 2007 was monitoring withdrawals by irrigation canals. Staff gages were placed near the headgate of Creeklyn Ditch, Parrot Ditch, and the combined headgate of Fish Creek and Jefferson Canal. Rating curves were established for each canal and staff gage readings were collected at least once per week during the mid-July to late September period.

Data for individual canals were not published during the evaluation to maintain the privacy of water users, but total flow of the combined ditch withdrawals of all four canals range from about 250 cfs to 400 cfs (Figure 6). Despite the extremely dry conditions and hot temperatures of 2007, the total ditch withdrawal in 2007 was lower than previous years indicating that effectiveness of the DMP coordination was relatively high after several years of effort implementing the plan (Figure 6).

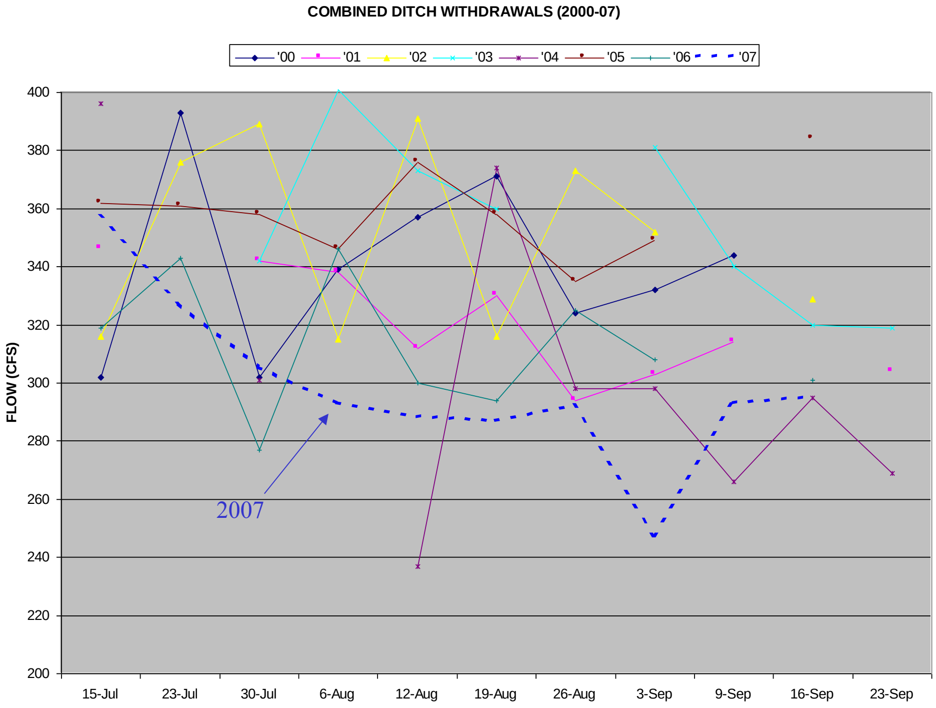


Figure 6. Combined ditch withdrawals from four irrigation canals participating in the DMP from 2000 to 2007.

Averaging weekly data from 2000 to 2007 for all canals indicated that the trend for irrigation withdrawal through the mid-July to late September period was relatively stable (Figure 7). Thus, water diversion during the relatively high demand by plants in mid-July was similar (about 350 cfs) to water diversion in September (about 300 cfs). The weekly withdrawals of canals during 2007 showed reduced late season water diversion compared to the average diversion of water from 2000 to 2007 (Figure 8).

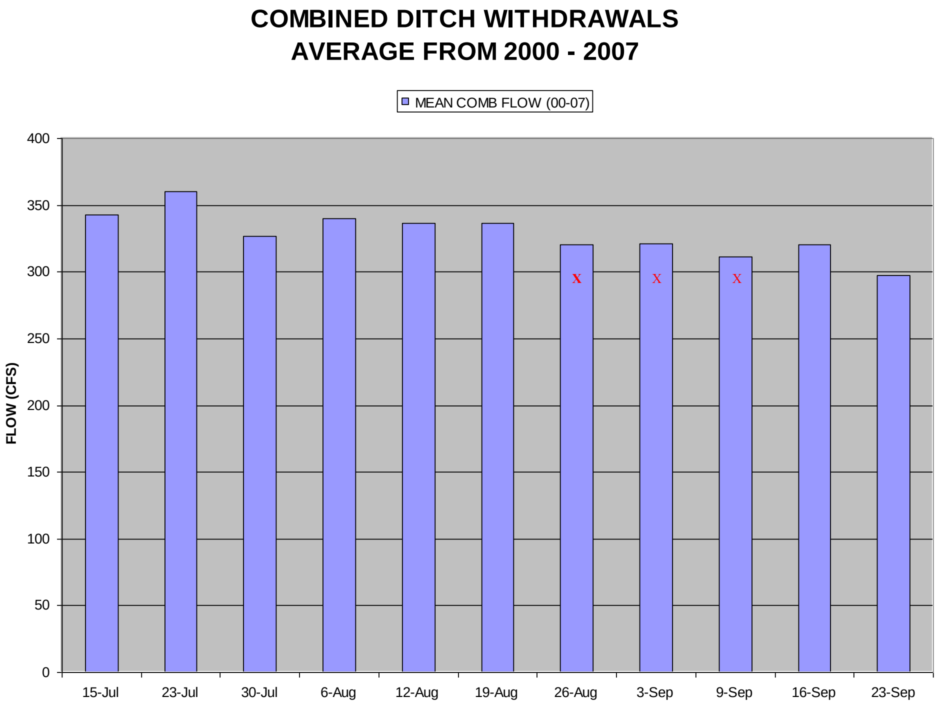


Figure 7. Average water diversion for four canals during eight years of monitoring during 11 weeks of the irrigation season.

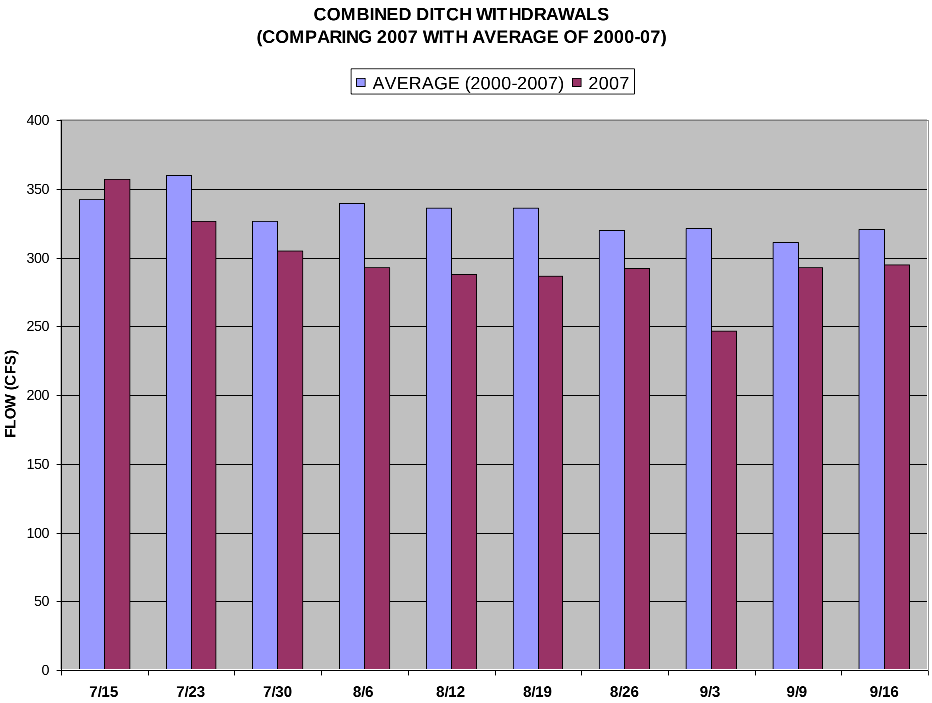


Figure 8. Comparison of average weekly water diversion for four canals during 8 years of monitoring (2000-2007) compared to weekly withdrawals during 2007.

The canal withdrawal trend in 2007 indicated a potential improvement in the ability of the DMP to maintain the 50 cfs flow target at Waterloo during years when the late season flow shortage was severe. From 2000 to 2007, most years experienced continued flow shortage in late August and early September, which resulted in additional days of flow less than 50 cfs at Waterloo despite reduced water demand by irrigated crops. For example, in 2000 flow at Twin Bridges remained above 350 cfs during most of August and a late season decline in late August created concern that the river would be dewatered after several weeks of attempting to maintain 50 cfs at the target (Figure 9). A similar pattern was observed during most years between 2000 and 2007.

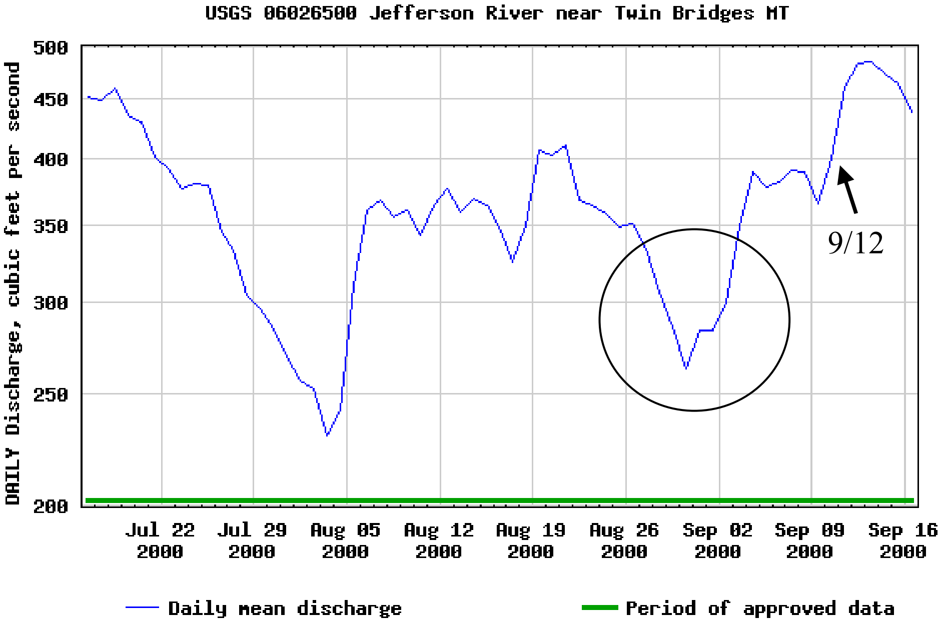


Figure 9. An example of the late August "hole" in the summer hydrograph of the Jefferson River near Twin Bridges (2000). September 12th was the date that flow recovered to at least 400 cfs.

A review of the summer hydrograph of the Jefferson River at Twin Bridges showed that the date that flows recover to at least 400 cfs was relatively consistent from 2000 to 2007 (Table 1). The predictable increase in flow in September always resulted in at least 400 cfs by 16 September. The reliable flow in September may be important to water users voluntarily reducing withdrawals during the summer and having the flexibility to increase withdrawals after mid-September for fall irrigation of pasture..

Table 1. Date range that flow of the Jefferson River at Twin Bridges exceeded 400 cfs (2000-2007).

Year	2000	2001	2002	2003	2004	2005	2006	2007
Date flow > 400 cfs	9/12	9/7	8/28	9/15	8/23	9/12	9/15	9/16

Daily flow was monitored at Waterloo (below Parson's Bridge) during the summer low flow period from 2000 through 2007 to evaluate the success of the DMP in maintaining the 50 cfs flow target (Figure 10). Flow monitoring was conducted by the JRWC from 2000 through 2005, and by USGS in 2006 and 2007. Daily data for this site is tabulated in Appendix A.

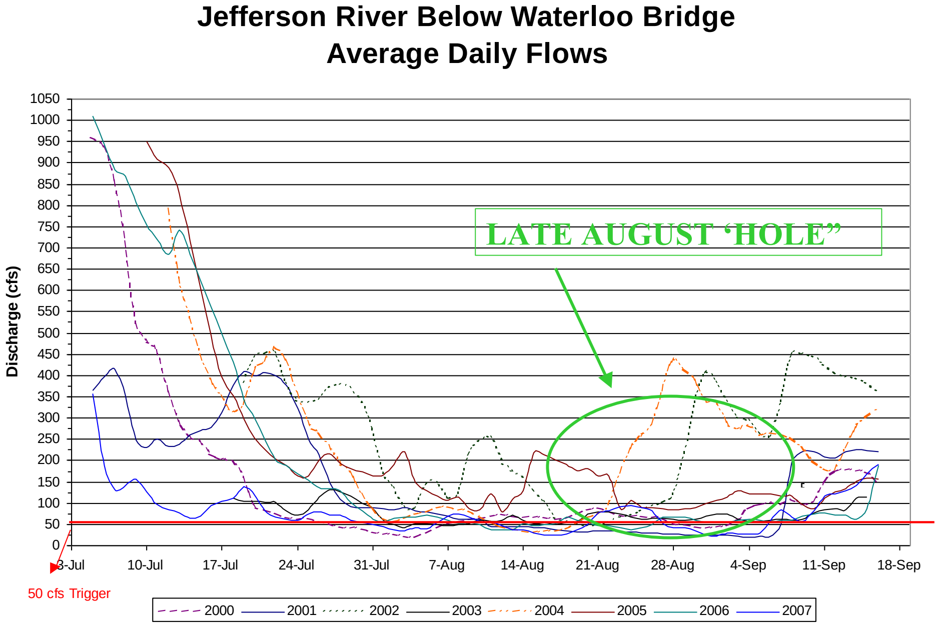


Figure 10. Average daily flow of the Jefferson River at Waterloo compared to the 50 cfs flow target (2000-2007).

The DMP has also monitored flow at several other locations to attempt to document the current flow situation and look for new opportunities to enhance water supply in the Jefferson River. Flow monitoring of the Big Hole, Ruby and Beaverhead Rivers was conducted to better understand the sources of water reaching the headwaters of the Jefferson River. In 2007, flow monitoring of inflows to the Jefferson River was conducted at four locations: Mouth of the Big Hole (USGS gage), Mouth of Beaverhead River (JRWC aqua-rod), Ruby River at Seyler Lane (JRWC staff gage), and the Beaverhead River at Twin Bridges (USGS gage) (Figure 11).

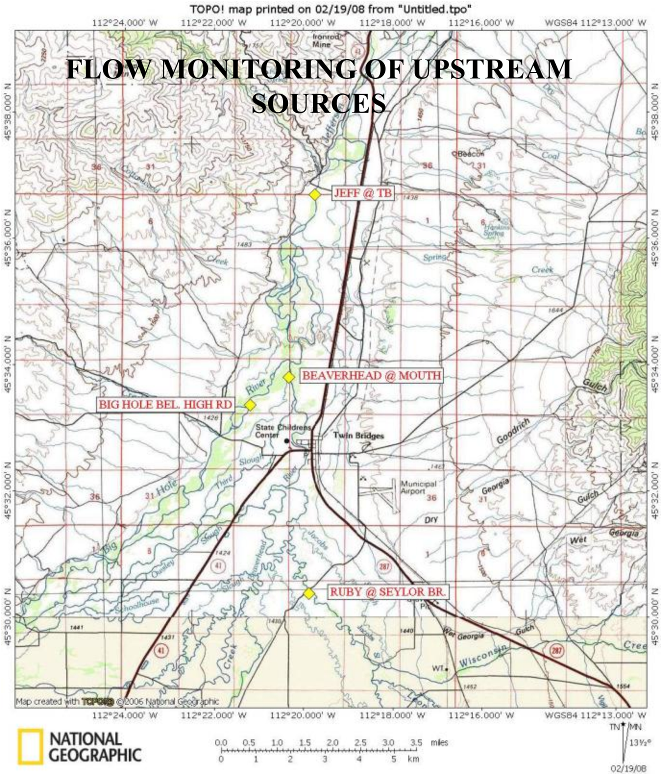


Figure 11. Location of flow monitoring stations above the Jefferson River in 2007.

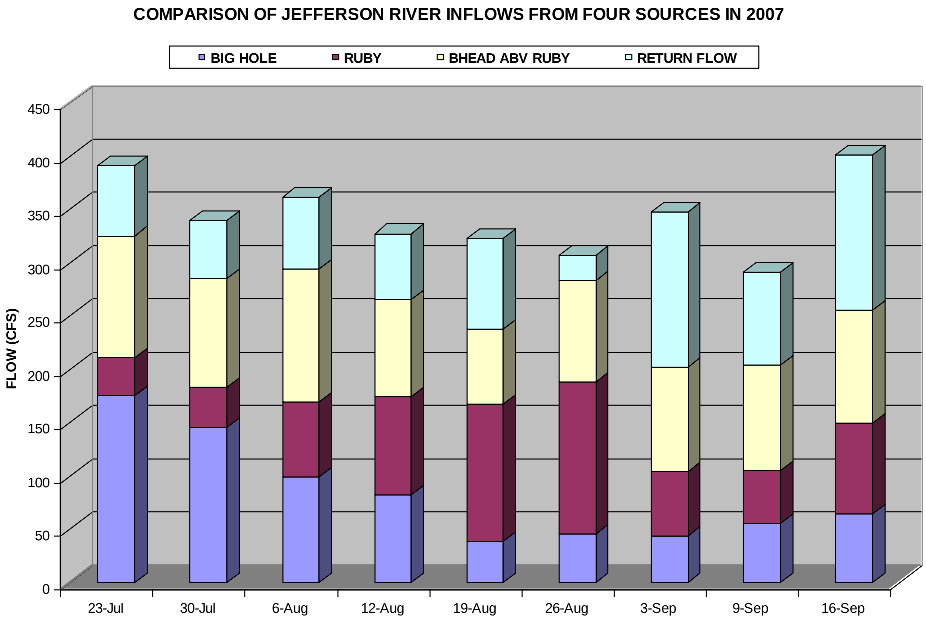


Figure 12. Comparison of Jefferson River inflow from four sources in 2007.

Flow data collected in 2007 indicated that, despite the small size of the drainage area, the Ruby River provided important flow for the upper Jefferson River during the critical period of late August (Figure 12). The Big Hole River near the mouth provided relatively little water to the Jefferson River in late August, but the ditches and sloughs entering the Beaverhead River near Twin Bridges (identified as "return flow") provided significant flow for the lower Beaverhead River. Flow of the Beaverhead River above the confluence with the Ruby River was relatively low considering the large size of the watershed and the presence of Clark Canyon Reservoir.

Monitoring of the Jefferson River stream flow downstream of the Waterloo Gage was intermittently sampled during the 2000 to 2007 period. In 2007, flow at Kountz Bridge and Cardwell was significantly higher than the low flow measured at Waterloo on August 22 (Figure 13). The increased flow downstream of Waterloo was a result of groundwater inflow, spring creek tributaries, and return flow from Parrot Canal, and these sources of water appeared to allow fish survival in the most severely dewatered reach of the Jefferson River. Brown and rainbow trout population estimates conducted during April in this reach of the river indicated that fish numbers declined after the 2000 flow event and have remained stable or increased in recent years (Figures 14 and 15). Mountain whitefish and suckers have also declined in this area since 2000 (Figure 16).

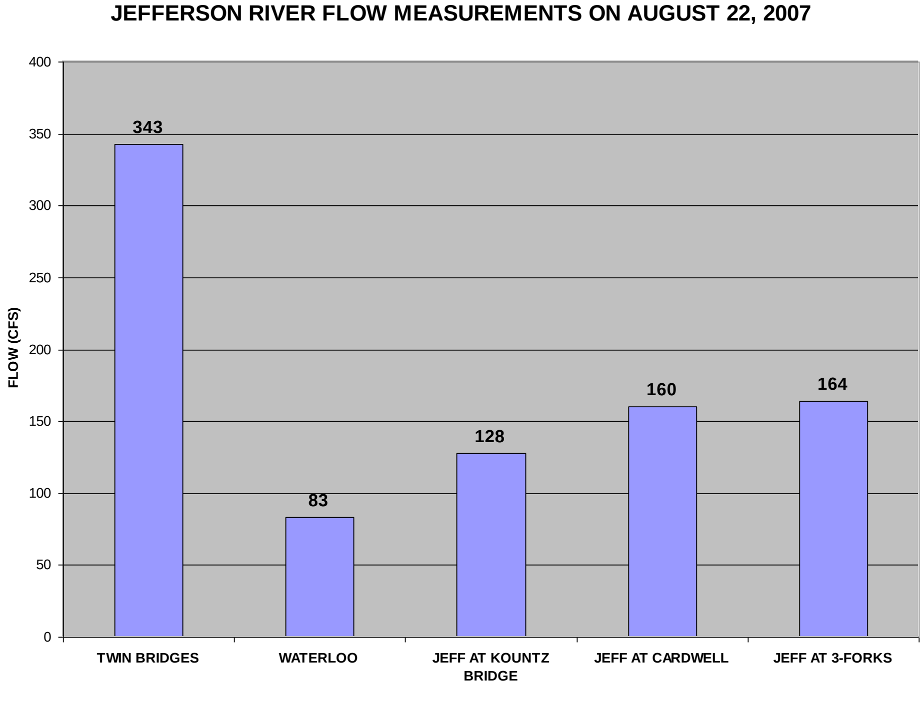
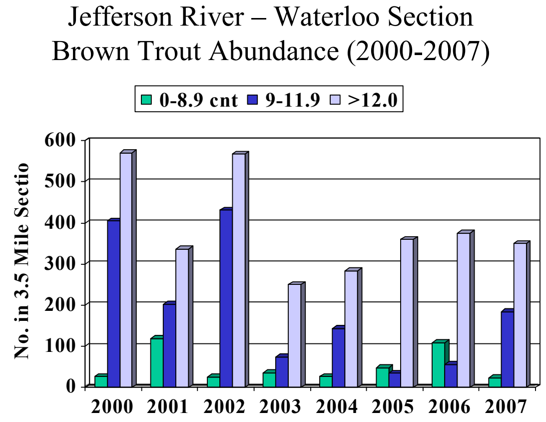
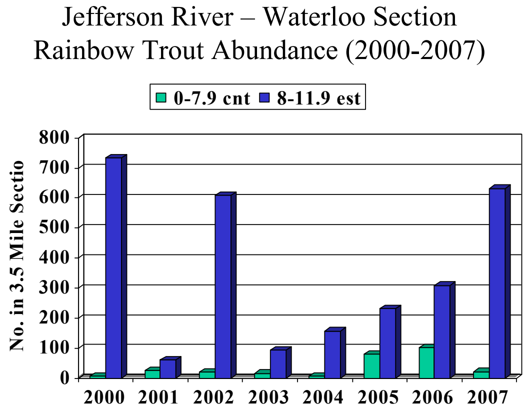
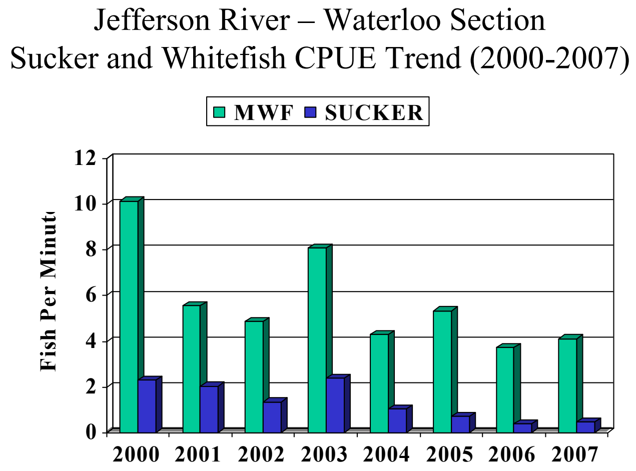


Figure 13. August 22, 2007 flow measurements at 5 locations of the Jefferson River.





Figures 14 and 15. Brown and rainbow trout population estimates in the Waterloo Section of the Jefferson River (2000 – 2007).



Jefferson River – Waterloo Section
Sucker and Whitefish CPUE Trend (2000-2007)

Figure 16. Mountain Whitefish and Sucker trend in the Waterloo Section of the Jefferson River (2000-2007) based on catch per minute of sampling.

Summary of Drought Plan Evaluation

Extensive flow monitoring of the Jefferson River and irrigation canals participating in the drought plan show that water supply during the 2000 to 2007 implementation period was the lowest on record and probably represents the worst case scenario for water supply. Despite the challenging conditions, the Jefferson River did not experience the degree of dewatering experienced in past drought years (particularly 1988), when little or no coordination was attempted to maintain critical summer flows in the Jefferson River.

Although the flow target of 50 cfs at Waterloo was frequently not met during the 2000 to 2007 irrigation seasons, it appears that drought plan implementation resulted in more water at Waterloo than would have been present without the weekly coordination with water users dictated by the DMP. It is not precisely known how much water was "donated" voluntarily by water users, but previous comparisons of water diversion before and after 2000 by DNRC indicate that four major canals diverted about 30 to 50 cfs less water after the DMP was implemented in 2000.

The fishery declined abruptly in the Waterloo Section after the initial summer of severe drought in 2000. Stable or increasing numbers of brown and rainbow trout in the Waterloo Section (the most severely dewatered reach of the Jefferson River) indicate that average August flow at Waterloo is adequate to prevent major fish kill events and continued loss of the fishery.

Coordination with existing water users has been the most effective activity for improving stream flow in the Jefferson River. Improving irrigation efficiency by lining canals for long term improvements in efficiency or temporarily sealing the canals with Canal Seal continues to have potential for reducing ditch withdrawals during critical periods. Other improvements of ditch infrastructure to improve canal management, such as replacing headgates or blow-off structures also have potential to improve flows in the river. In 2008, several projects to improve irrigation structures on the Parrot Canal are being implemented to improve ditch operation. Fund raising, project coordination, and project oversight of this work is being coordinated by Trout Unlimited.

The Jefferson River Drought Management Plan has evolved in the past 8 years. The most recent review of the DMP occurred in February and March, 2008. The proposed modifications to the drought plan that resulted from public meetings in 2008 included:

- Continue to coordinate with upstream watershed groups to enhance inflows to the upper Jefferson River from the Ruby, Big Hole, and Beaverhead River;
- Increase scrutiny of new or expanded water use in the Jefferson Valley by improving understanding of the DNRC water right process;
- Expand the extent of the Drought Plan Reach from Waterloo to Cardwell to attract new, downstream interests into the DMP process;
- Review fishing closure triggers and examine potential for splitting fishing closures into selected reaches of the river rather than the entire Jefferson.
- Continue to attempt to maintain a flow target of 50 cfs at Waterloo and examine methods to reduce the number of days that flow is less than 50 cfs.

CHAPTER VI
FISH LOSS TO IRRIGATION CANALS

Introduction

It is widely known that fish move into various irrigation canals of the Jefferson River during the irrigation season. Prior to 2001, the extent of fish entrainment in canals was not well understood, and sampling of the Creeklyn Ditch was initiated from 2001 to 2007 to better understand the significance of fish loss in one irrigation canal.

The Creeklyn Ditch diverts water from the Jefferson River approximately 4 miles south of Silver Star Montana (T2S R6W S 23) and terminates near Fish Creek (T1S R5W S 11). Total length of the Ditch is approximately 11 miles and flow rate ranges from 60 to 90 cubic feet per second (cfs). The ditch operates from April through November and is usually shut down for one week in early July for control of aquatic vegetation.

Creeklyn Ditch was selected to begin evaluation of fish loss because of its proximity to a major spawning tributary and the fact that no screening devices are in place to prevent fish from entering the ditch. The intake of Creeklyn Ditch is about 2 miles downstream of Hells Canyon Creek, which is a major spawning tributary to the Jefferson River. The proximity of this canal to an important trout spawning and rearing tributary made it likely that Creeklyn Ditch would have a relatively high rate of fish entrainment.

Two fish sampling methods were used to capture fish in Creeklyn Ditch. Use of a backpack electrofishing unit was used to capture fish in the canal during periods when ditch flow was significantly reduced, and operation of a screw trap was used to count downstream migration of fish during normal ditch operations. Electrofishing was occasionally conducted during the early July shut down, and was done within a week of the November shut down at the end of the irrigation season. The screw trap was operated from 26 June to 20 September, 2001. Temperature was also monitored in two locations of the canal from 17 July to 18 October, 2001.

Fish Captured Using the Screwtrap

The screwtrap was placed approximately 600 feet downstream of the headgate and efficiency tests revealed that the trap sampled about 30-40% of the flow. Several checks revealed that the cone rotated at 4 revolutions per minute (RPM), and since little variation was noted in this rate therefore further checks were not done. The trap was checked 32 times between 6/26-9/20 2001. Flow to the ditch was shut off from 1 July to 8 July to control aquatic vegetation. On 9 occasions the trap was found to be jammed with debris and not operational.

Species captured at the trap included rainbow trout, brown trout, redside shiners, longnose dace, sucker spp and mountain whitefish. Total numbers of each species captured is presented in Table 1.

Table 1. Species and number of fish captured in the screw trap at Creeklyn Ditch in 2001.

Species	Total Captured
Rainbow Trout	110
Brown Trout	9
Longnose Dace	1740
Sucker spp.	2000
Mottled Sculpin	28
Redside Shiner	46

Electrofishing Surveys

Electrofishing was conducted on 2 July 2001 and in the fall on 12 and 15 October and 2 November. This was done to evaluate longitudinal distribution of fish in the Creeklyn ditch, further evaluate fish loss, and attempt to rescue fish and return them to the Jefferson River.

Summer Sampling during Drawdown

Four sections of the Creeklyn Ditch were sampled with backpack electrofishing gear on July 2, 2001 one day after ditch drawdown. The headgate section extended from the headgate downstream to the screwtrap. The highway section extended from the screwtrap to the highway crossing. Silver Star and Highway JCT 55/41 were 4.3 and 8.5 miles below the headgate, respectively. The majority of fish captured or observed died due to high air and water temperature. The highest concentration of fish was captured in the 1800 ft section below the headgate, and no fish were captured in the 55/41 Highway Junction. The lack of observed fish near the Highway 55 Junction (8.5 miles below the headgate) may have been influenced by the rapid loss of water during drawdown and the abundant vegetation in the canal (Table 2).

Table 2. Total numbers of fish captured in four sections of the canal on 2 July 2001.

Species	**Headgate 1800 feet 2519 seconds**	**Highway 1200 feet 1728 seconds**	**Silver Star 3600 feet 1241 seconds**	**55/41 JCT 450 feet 240 seconds**
Brown	27	23	7	0
Rainbow	12	4	12	0
MWF	14	7	427	0
Dace	1310	420	80	0
Suckers	410	180	50	0
Red Side	1040	550	0	0
Sculpin	340	100	0	0
Total Fish	3153	1284	576	0

Total fish numbers decreased steadily as distance from the headgate increased, which may be due to fish swimming upstream as flow decreased in the ditch. The notable exception was mountain whitefish, which were observed in large numbers in the Silver Star Section, which was about 4 miles below the headgate

Fall Sampling-- End of Season Shutdown

Headgate and highway sections of Creeklyn Ditch were sampled on Oct-12, Oct-15 and Nov-2. Emphasis on this shocking effort was placed on rainbow and brown trout. A total of 276 rainbow trout and 64 brown trout were captured during the 3 sampling days between the highway and the headgate. Rainbow trout ranged in length from 62-249 mm in length, 92% of rainbow trout captured were young of the year (< 120 mm). Brown Trout ranged from 68-490 mm in length and 40% of those captured were YOY (<130 mm).

Water Temperature

Temperatures were monitored with electronic continuous recording temperature probes at the screw trap and the Highway 55-41 Junction from July 17 through October 18, 2001. Temperatures exceeded 65 F on 48 days at the lower site and 51 days at the upper site. Temperatures did not appear to differ significantly between the two sites..

Annual Comparisons of Fall Sampling

From 2001 through 2007, evaluation of fish loss at Creeklyn Ditch was continued by sampling the 3100 ft reach of the canal from the headgate to the highway crossing with the backpack electrofishing unit during the fall shutdown. Trout were collected during this sampling effort to determine trends in abundance through the 7 year period, and to return fish to the Jefferson River.

Rainbow trout were more abundant in the canal than brown trout during most years, and the number of trout captured in the relatively short reach of the canal below the headgate appeared to be significant (Table 3). The large number of trout near the headgate, however, should not be extrapolated over the 11 miles of ditch in order to estimate total fish loss because fish appeared to concentrate near the headgate during reduced flow.

Considering the difficulty in determining the total number of fish moving into the canal, another approach was used to assess the impacts of fish loss. This approach was to rescue fish from the canal and mark the fish released back to the river to determine the percentage of the river fishery that was comprised of “rescued” fish. In the past 3 years (2005-2007), all trout were given a permanent mark by clipping the entire adipose fin for later identification in the Jefferson River. A total of 1025 rainbow trout and 368 brown trout were marked during this effort. Sampling of the Jefferson River near the release location of fish rescued from Creeklyn Ditch during April 2007 indicated that about 5% of the rainbow trout in the 2 mile reach of the river near the release site were marked with an adipose clip. Since the majority of the rainbow trout rescued and marked with an adipose clip were age 0 at the time of the rescue, most fish captured in the river with adipose clips were 9.0 to 10.9 inches long in 2007. We observed 5 clipped fish in the Jefferson River out of a sample of 50 rainbow trout between 9 and 10.9 inches in length in 2007, indicating that 10% of this size group was comprised of fish rescued from Creeklyn Ditch. More detailed results of this evaluation will be presented in a future report. Preliminary findings indicate that the fish rescue effort may be a benefit to the river population and that the loss of fish to Creeklyn Ditch reduces the trout population within about 2 miles of the headgate.

The size of brown and rainbow trout captured in the canal each fall provided a consistent measure of the growth of YOY fish during the sampling period (2001-2007). The mode length for rainbow trout decreased over the period for rainbow trout from about 95 mm (3.7 inches) in 2001 to about 80 mm (3.1 inches) in 2007 (Table 4). The mode for YOY brown trout 125 mm (4.9 inches) remained consistent throughout the sampling period (Table 5). Growth and condition of YOY trout captured during the fall was favorable, indicating that the ditch provided a favorable rearing environment.

The number of rainbow trout over 300 mm (11.8 inches) captured in the ditch during the fall rescue was always less than 3 fish per year. Larger brown trout were more common than rainbow trout with 0 to 12 brown trout over 300 mm (11.8 inches) captured from 2001 to 2007. Two of the six larger brown trout (>300 mm) captured in Creeklyn Ditch in 2007 were recaptured adipose clipped fish from 2005 or 2006.

Table 3. Fish rescue in Creeklyn Ditch (3100 ft from Highway to Headgate) during October/November 2001 – 2007.

YEAR	Effort (seconds)	No. Rainbow	No. Brown Trout
2001	3155	184	39
2002	4423 (1st pass) 3121 (2nd pass)	80 25	15 48
2003	4323	100	46
2004	6800	346	28
2005	7710	422 (ad.clip)	174 (ad.clip)
2006	5708	242 (ad.clip)	78 (ad.clip)
2007	6995	361 (ad.clip)	116 (ad.clip)

Note: Other Species sampled in ditch.
Longnose dace (abundant)
Sculpin (abundant)
Sucker spp. (common)
Redside Shiner (common)
Mountain Whitefish (present)
Carp (rare)

Table 4. Length Frequency of Rainbow Trout Captured during November fish sampling in Creeklyn Ditch (2001-2007).

Min. Length	Max. Length	2001	2002	2003	2004	2005	2006	2007
0	9							
10	19							
20	29							
30	39							
40	49							2
50	59		2	3		6	3	5
60	69	6	0	10	8	32	35	35
70	79	39	12	19	34	79	85	91
80	89	43	21	23	68	120	47	104
90	99	49	28	24	61	102	31	48
100	109	40	12	5	58	42	9	20
110	119	14	13	1	51	16	4	12
120	129	8	2	2	24	6	0	14
130	139	0	4	1	8	1	0	4
140	149	1	0	1	12	0	2	4
150	159	1	1	1	4	1	4	1
160	169	0	0	2	2	1	4	2
170	179	1	1	2	0	5	2	7
180	189	0	3	1	1	4	4	3
190	199	0	0	1	6	2	1	1
200	209	0	0	1	1	0	2	4
210	219	1	0	3	1	2	4	0
220	229	3	0		2	0	2	1
230	239	0	2		2	0	0	3
240	249	2	0		0	0	0	0
250	259	0	0		0	0	0	0
260	269	0	0		0	1	0	0
270	279	1	0		1	0	1	0
280	289	0	0		0	0	0	0
290	299	0	4		0	1	0	0
300	499	1	0		2	1	2	0

Table 5. Length Frequency of Brown Trout Captured during November fish sampling in Creeklyn Ditch (2001-2007).

Min. Length	Max. Length	2001	2002	2003	2004	2005	2006	2007
0	9							
10	19							
20	29							
30	39							
40	49							
50	59							
60	69							1
70	79					2	1	1
80	89	2		2	1	6	1	4
90	99	1		2		4	5	14
100	109	3	3	2		6	7	15
110	119	7	10	8	3	25	8	21
120	129	8	12	6	6	47	6	27
130	139	5	7	7	4	34	8	14
140	149	3	8	3	7	31	4	9
150	159	1	9	3	4	7	3	2
160	169		3		2	3	1	2
170	179		1		1			
180	189							
190	199						1	
200	209							
210	219			1				
220	229						2	
230	239	1		1		1	2	
240	249	2		2			2	
250	259						2	
260	269					1	1	
270	279	1	1	1			2	
280	289	1		1			7	
290	299	3		1		1	5	
300	399	10	8	4		3	6	6
400	499	2	1	1			3	

CHAPTER VII

Water Temperature Measurements in the Jefferson River and Associated Tributaries on July 31, 2007

On July 31, 2007 water temperature was measured at a variety of locations in the Jefferson River and tributaries to determine site-specific water temperature trends from approximately Sappington Springs to Hell's Canyon Creek. Water temperature was recorded using a Taylor thermometer. The survey began near Sappington Springs and proceeded upstream during the day. Water temperature measurements near Sappington Springs were first recorded at approximately 1200 hrs and the last measurement of the day was recorded at 1900 hours. Therefore, measurements between Sappington and approximately Whitehall were taken before daily maximum temperature was reached (about 1800 hrs), and measurements upstream of Whitehall were taken after the daily maximum temperature was reached.

This day was selected for the survey because the date is generally near the maximum water temperature of the Jefferson River, which generally occurs in late July/early August, and because the day was typical of hot, sunny conditions with above average conditions. Thus, these results provide a general view of near maximum water temperatures for several locations of the Jefferson River.

In addition to collecting water temperature readings in flowing riffle areas where water mixing has occurred, some additional measurements of the water surface or the bottom of pools were also taken to determine general trends for water temperature in various locations of the river. Multiple water temperature measurements were also taken at established USGS gaging stations to verify results of continuous water temperature measurement stations.

JEFFERSON RIVER WATER TEMPERATURE AND FLOW TREND

Data collected at three USGS gaging stations located near the headwaters (Twin Bridges Gage), at the most severely dewatered location upstream of Whitehall (Parson's Bridge Gage), and near the mouth of the Jefferson (Three Forks Gage), confirm the general understanding that water temperature increases from the headwaters to the mouth of the Jefferson River (Table 1). Data collection to identify more specific trends in water temperature have not been conducted in a systematic manner in the past. During 2008, more detailed evaluations of water temperature trends in the Jefferson River will be conducted as a part of the ongoing TMDL program for the Jefferson River, and the data gathered in 2007 was intended to help guide the upcoming temperature evaluation.

Table 1. Temperature and flow data at three USGS gaging stations for July 31, 2007.

LOCATION	FLOW (CFS)	MAX. TEMP.	MIN. TEMP	MEAN TEMP
TWIN BR.	319	24.5 (76.1)	18.5 (65.3)	21.4 (70.5)
PARSON'S BR	51	26.4 (79.5)	18.7 (65.7)	N/A
THREE FORK	168	26.8 (80.2)	21.6 (70.9)	23.8 (74.8)

A general pattern of reduced stream flow and elevated water temperature since 2000 is apparent by looking at data from the USGS gaging station for the Jefferson River at Twin Bridges. From 1995 through 1999, the Jefferson River experienced higher peak flows and higher summer flows compared to the past eight years of severe drought (2000 to 2007) (Figure 1).

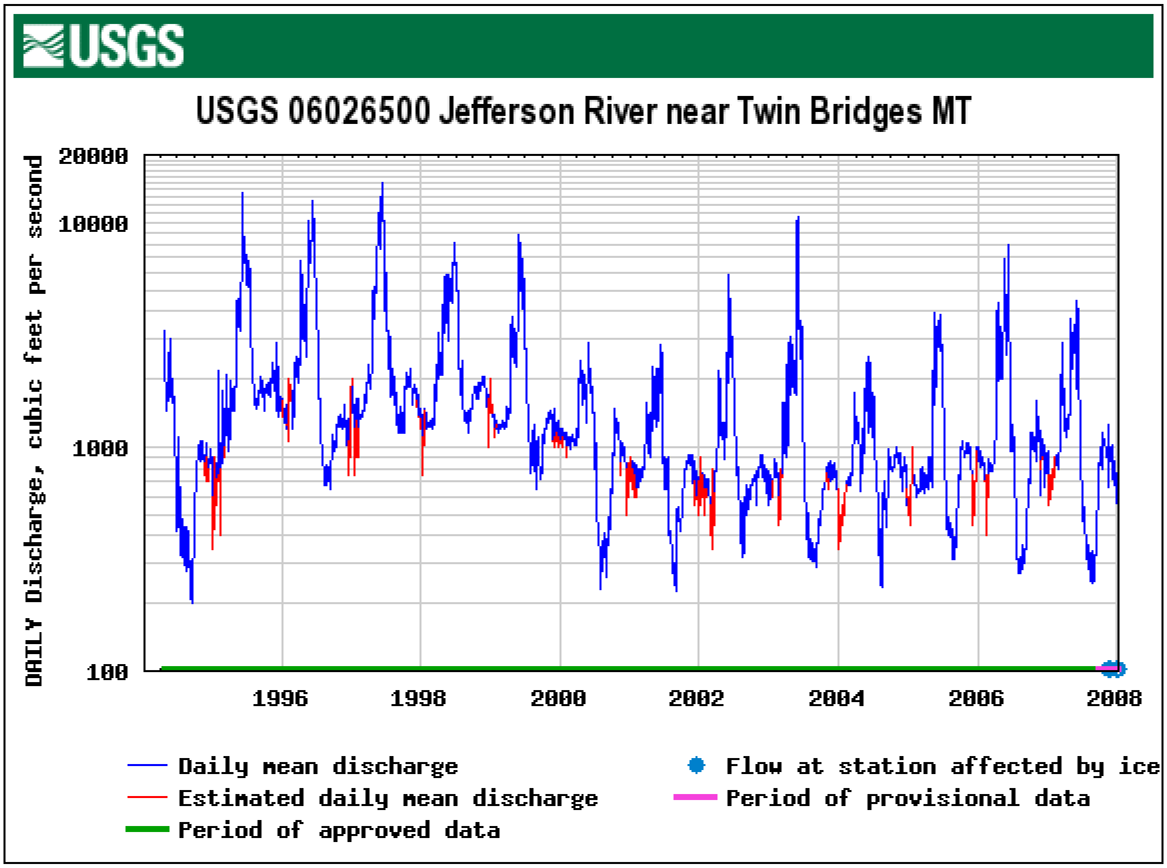


Figure 1. Stream flow pattern of the Jefferson River near Twin Bridges from 1994 to 2008.

Water temperature data from 1996 through 2007 at the Twin Bridges gage appears to closely reflect the reduced stream flow pattern, and years with relatively low flow generally result in relatively high water temperature. Daily maximum water temperature rarely exceeded 23 to 24 C (73.4 to 75.2 F) during the summers of 1996 to 1999 (Figure 2). Compared to the late 1990's, an increase in daily maximum water temperature was observed from 2000 to 2007 with readings sometimes exceeding 24 to 25 C (75.2 to 77.0 F).

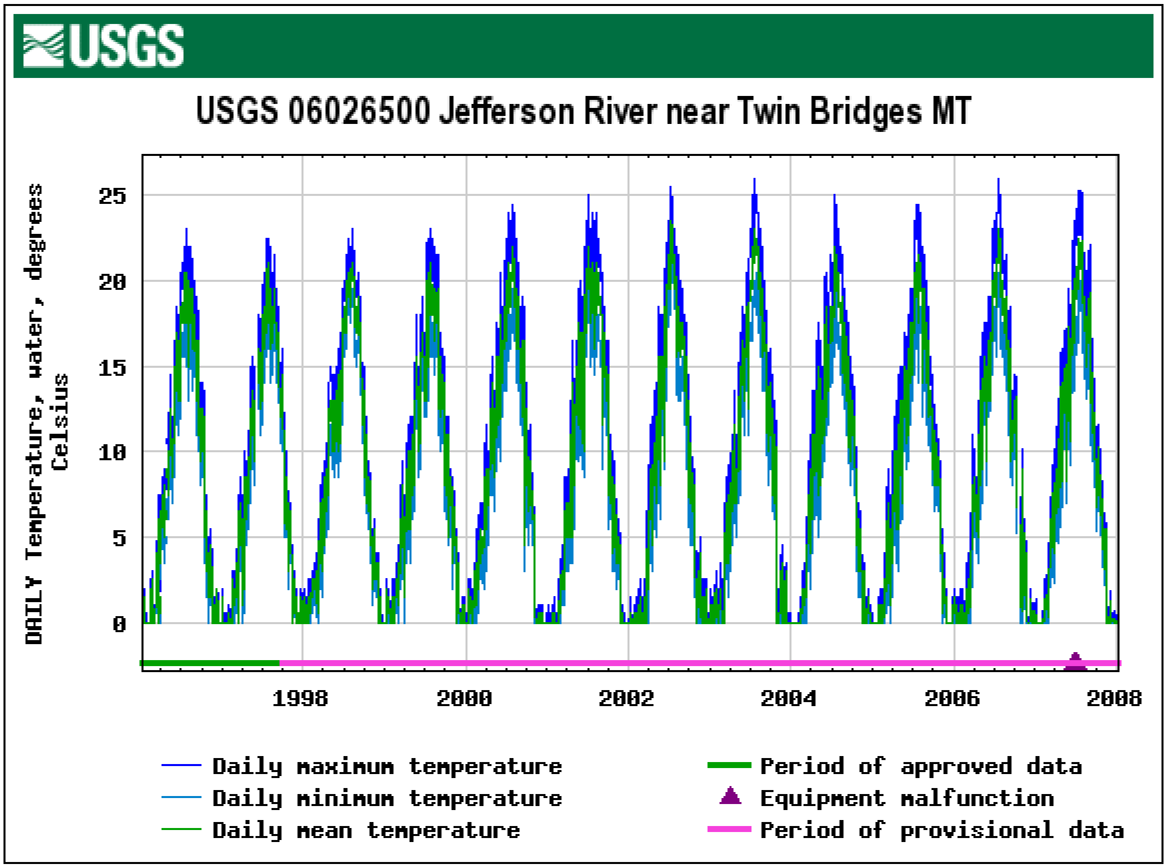


Figure 2. Daily maximum, minimum and mean water temperature of the Jefferson River near Twin Bridges.

RESULTS OF 2007 FIELD SURVEY OF WATER TEMPERATURE

During the summer of 2007, a more detailed understanding of the water temperature status of the Jefferson River was initiated. This survey was intended to expand knowledge of temperature trends beyond the three gaging stations established on the Jefferson River and to prepare for a more detailed evaluation of water temperature planned by DEQ, JRWC, TU and FWP during 2008.

Thirty measurements of water temperature between Sappington Springs and Hell's Canyon Creek on July 31, 2007 clearly show that some springs, sloughs and tributaries entering the Jefferson River provide water that is cooler than the mainstem Jefferson River (Figure 3). Sappington Springs, Willow Springs, Parson's Slough, the North Boulder River, and Hell's Canyon Creek represent the five coolest water temperature measurements during the survey. The warmest water temperature measurements were also obtained away from the mainstem Jefferson River, with Pipestone Creek and the mouth of Jefferson Slough being the two highest recorded measurements. Whitetail Creek was dry and no measurement was obtained at this relatively warm source of water.

On 31 July, temperature of the Jefferson River mainstem ranged from about 72 F to 78 F. The coolest measurement was observed near Cardwell FAS (72.1 F at 1326 hrs) and the warmest measurement was observed near Waterloo and Silver Star (over 78 F at 1700 to 1800 hrs).

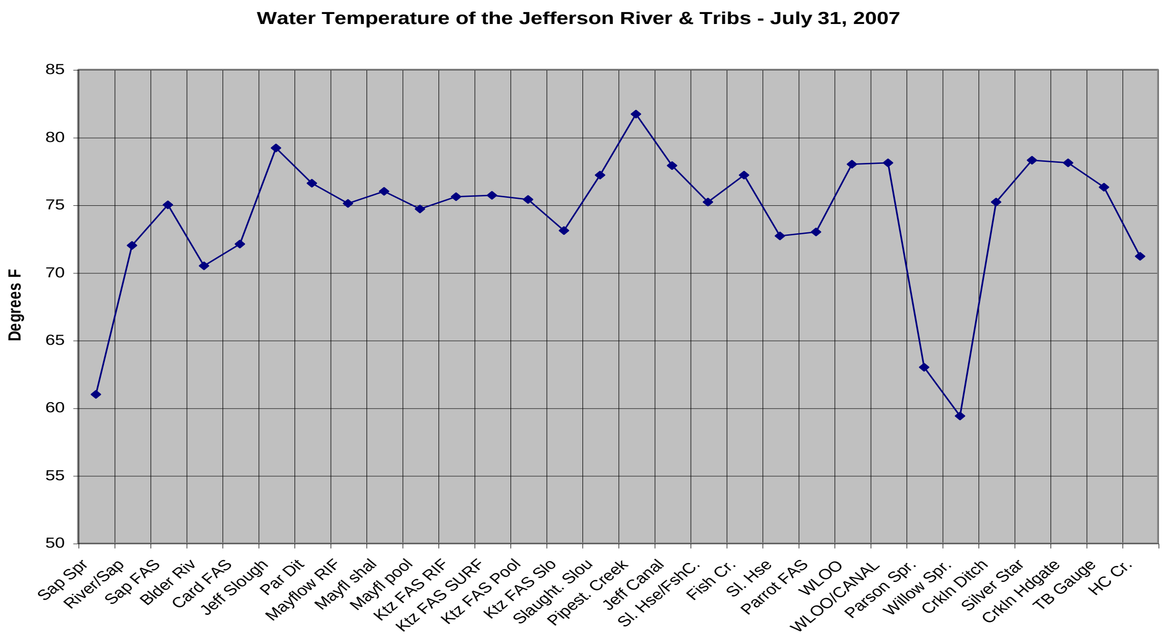


Figure 3. Water temperature measurements at 30 locations along the Jefferson River and associated tributaries and irrigation canals on July 31, 2007.

Water temperature at major canals was also measured during during the survey. The lower end of Parrot Ditch (near Kountz Road) was 76.6 F at 1359 hrs, the lower end of Jefferson Canal (near Whitehall) was 77.9 at 1555 hrs, the lower end of the Fish Creek Canal was 77 F at 1615, and the lower end of Creeklyn Ditch was 75.2 F at 1757. Creeklyn Ditch appeared to be cooler at the bottom of the ditch compared to temperature at the point of diversion. The lower canal temperature measured at 75.2 F (1757 hrs), and the temperature at the headgate measured at 78.1 F (1820) (Figure 4).

The finding at Creeklyn Ditch indicates that the narrow cross-section of canals can sometimes result in less thermal input, which may help maintain cooler temperature. Wide cross-sections, low velocity, and poor riparian growth along canals may increase thermal input and result in elevated water temperature at points of return flow.

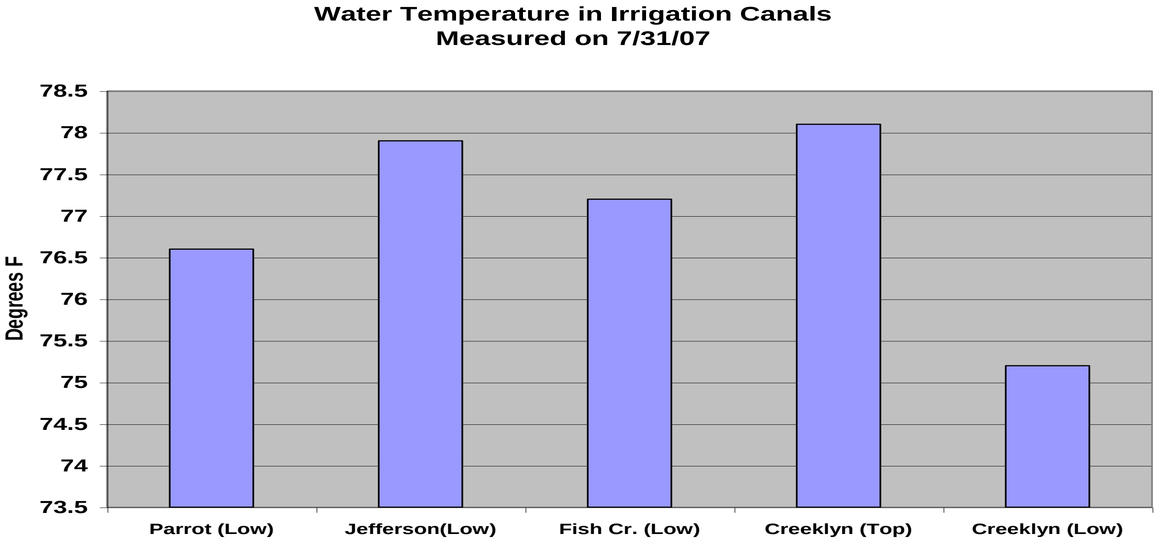


Figure 4. Water temperature measurements in four irrigation ditches on July 31, 2007.

COMPARISON OF USGS GAGING DATA TO FIELD MEASUREMENTS

Three USGS gaging stations record water temperature of the Jefferson River: Three Forks Gage, Parson's Bridge (Waterloo) Gage, and Twin Bridges Gage. Field measurements collected on July 31, 2007 were conducted at the gaging stations to determine the consistency of water temperature measurements of field measurements and gaging station recorders, and determine whether gaging station temperature "probes" reflected water temperature trends throughout the river channel.

Maximum water temperature of the Twin Bridges gage on 31 July was recorded at 76.1 F. The temperature probe was located approximately 3 inches below the water surface in moving water. Field measurements at this location were very similar to the USGS reading. A water temperature measurement of 76.7 F adjacent to the probe was obtained at 1845 hours. The Twin Bridges gage is used to determine the flow and temperature fishing restrictions in the Jefferson River Drought Management Plan. When daily maximum water temperature exceeds 73 F at the Twin Bridges Gage for three consecutive days, fishing may be restricted to morning hours.

Maximum water temperature of the Parson's Slough (Waterloo) Gaging Station on 31 July was recorded at 80.6 F at 1600 hours. Hourly readings from 1300 hours to 2000 hours are presented in Table 1. The USGS temperature probe was located 6 inches below the water surface.

Table 2. Comparison of water temperature recorded at Parson's Slough Gaging Station, Jefferson River, to Field Check (F.C.) measurements at three locations near the gage (near the temperature probe, surface of pool near the probe, and a the bottom of river channel).

TIME	USGS GAGE (DEGREES F)	F.C. AT GAGE (DEGREES F)	F.C. WATER SURFACE (DEGREES F)	F.C. POOL BOTTOM (DEGREES F)
1300	74			
1400	76.3			
1500	78.3			
1600	80.6			
1700	80.2	77.7	78.4	74.3
1800	77.9			
1900	75.9			
2000	75.7			

The USGS gage recording was 2.5 degrees higher than the field check measurement taken near the probe. The field check measurements also indicated that the water surface temperature was elevated as expected, but also indicated that the bottom of the pool (approximately 5 ft depth) was significantly cooler than readings at waters surface or near the gaging station temperature sensor.

AIR TEMPERATURE DURING JULY 31, 2007 SURVEY

Air temperature recorded during the survey with the Taylor thermometer was 90 F at 1200 hours, 92 F at 1600 hours, and 80.6 F at 1900 hours. Temperature Data for surrounding areas (Dillon, Helena, Bozeman) from the NOAA Online Weather Data Website confirm that the date of the survey represented relatively hot conditions for assessing the near maximum water temperatures for the Jefferson River (Table 3).

Table 3. Air temperature data for July 31, 2007 obtained from NOAA.

Location	Max. Temperature on 7/31 (Observed 7/31/07)	Normal Max. Temperature for 31 July
Dillon	89	83
Bozeman	100	86
Helena	96	85

TEMPERATURE CRITERIA FOR ANGLING RESTRICTIONS

Beginning in 2005, FWP and JRWC began using water temperature criteria to restrict angling during warm conditions (afternoon and evening). FWP can implement the temperature restriction when daily maximum water temperature exceeds 23 C (73 F) for three consecutive days. Prior to the 2000 to 2007 drought, temperature rarely exceeded the criteria for three consecutive days (Table 4). In contrast, during the low flow period of the past eight years, the criteria was frequently met during the last two weeks of July.

Table 4. Water temperature trends relative to criteria for drought-related fishing closures. Data was provided by the USGS gaging station at Twin Bridges.

DATE	**# DAYS > 23 C**	**RANGE OF DATES MAX TEMP > 23C**	**Tmax**
1995	0	N/A	18.5
1996	2	27, 28 July	23.0
1997	0	N/A	22.5
1998	2	12, 13 August	23.0
1999	3	27, 28, 30 July	23.0
2000*	16	July 12, 13, 14, 16, 21, 22, 23, 24, 25, 27, 28, 29, 30, 31, August 1, 2	24.5 (7/28-31)
2001*	17	June 28, 29, July 1, 2, 3, 8, 9, 11, 12, 24, 25, 26, 27, August 5, 6, 7, 8	24.5 (7/8)
2002*	16	June 25, 26, 27, July 8, 9, 10, 11, 12 13, 14, 15, 17, 18, 21, 23, 24	25.5 (7/12)
2003*	32	July 7, 10, 11,12,13, 14, 15, 16, 17, 18,19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, August 1, 2, 3, 4, 7, 9, 10, 13, 20	26.0 (7/23-24)
2004*	7	July 14, 15, 16, 17….19, 20, 21	25.0 (7/17)
2005*	13	July 12..14, 15..18, 19, 20, 21..23, 24..Aug 4, 5, 6, 7	24.5 (7/21-23)
2006*	18	July 4..8..15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25..26, 27, 28, 29, 30	26.0 (7/23,24)
2007*	30	July 1, 2, 3, 4, 5, 6, 7, 8, 9..12, 13 14, 15, 16, 17, 18, 19, 20, 21, 22, 23.. 25, 26, 27, 28, 29, 30, 31..Aug 2, 3	25.3 (7/22)

* FWP drought fishing closure policy would be implemented during these years due water temperature exceedence of threshold of 23 C (73 F) for three consecutive days. In 1999, the three days exceeding 23.0 were not consecutive.

DISCUSSION

Based on data collected at existing USGS gaging stations, it is clear that water temperature has increased during the low flow period beginning in about 2000. Brown trout populations have declined in the Jefferson River during the same period and it is not known whether loss of habitat, elevated water temperature, or other causes are responsible for reduced brown trout numbers. Events where significant fish mortality was observed due to high temperature and associated low dissolved oxygen have been rare based on casual observations of the river during hot summer conditions. One large fish kill observed in 2003 between Sappington Bridge and Williams Bridge occurred during very warm conditions in late July indicated that primarily mountain whitefish were affected by the warm conditions. A few hundred mountain whitefish were observed near Sappington Bridge and a few dozen mountain whitefish were observed near Williams Bridge on July 22, 2003. No dead trout were observed on this date, but the survey was not extensive and other species were likely affected to some degree.

Since fish have the ability to migrate to deep pools or other areas of refuge during the severe conditions, it is important to identify areas where fish can survive drought conditions during the most severe period of the summer (approximately July 15 to Aug 15). Knowledge of such areas may help direct management practices by water users to rely on relatively warm sources of water for irrigation, and attempt to maximize instream use of relatively cool water sources.

For example, previous work on the Jefferson River has shown that springs in the Waterloo area (eg. Parsons Slough and Willow Springs) provide cool water for the Jefferson River in the most severely dewatered reach of the river. These sources are approximately 15 degrees F cooler than the Jefferson River. The 2007 survey identified a few other sources of tributary or slough inflows that had different temperature regimes compared to the Jefferson River. A small slough entering the river near Kountz bridge was 2 degrees F cooler than the river. The mouth of the Jefferson Slough was approximately 4 degrees F warmer than the Jefferson River. Some tributaries are cooler than the river (Hells Canyon, North Boulder River) and some are warmer than the river (Pipestone Creek) (Figure 3).

Each of the above examples provide some management possibilities to improve conditions in the Jefferson River. Relatively cool sources of water should receive protection from additional irrigation use, and relatively warm sources of water need to be evaluated for potential improvements of channel morphology to reduce thermal input (the Jefferson Slough channel is very wide with low gradient and relatively high water temperature was measured near the mouth).

Site specific temperature refuge for fish was sometimes apparent from the 2007 survey. Water temperature at the Parson's Slough gage (Waterloo) varied by approximately 4 degrees F when comparing surface, riffle, and pool substrate temperature. The pool was 5 ft deep and about 4 degress F cooler than the water surface. In contrast to the Waterloo observation, temperature readings near Kountz Bridge found the surface water to be very similar to the pool substrate temperature. It is not known if the lack of temperature stratification near Kountz Bridge was due to water mixing, lack of groundwater inflows, or other variables.

The proposed study by DEQ to evaluate infra-red temperature readings on a large scale basis along the Jefferson River will be very helpful for determining opportunities to improve water temperature in the Jefferson River.

CHAPTER VIII
FISHING PRESSURE AND ANGLER USE OF THE JEFFERSON RIVER

Information presented in this report regarding fish population trends indicate that insufficient streamflow is the likely limiting factor for fish abundance in the Jefferson River. An unknown number of fish are also lost or removed from the population due to angling mortality during both high flow years and drought years. Some portion of fish mortality is due to direct harvest by anglers, and some unknown percentage of fish mortality is due to catch and release mortality. To date, there has never been a formal, comprehensive creel census evaluation on the Jefferson River to better understand these sources of fish mortality.

Mortality of fish during drought years is generally believed to be higher than years with normal or high flow due to habitat loss, stress on fish due to elevated temperature and reduced habitat quality, and increased predation loss to a variety of predators (birds, fish, mammals, etc.). Likewise, angling during low flow conditions probably has more potential to impact the fishery due to high water temperature and the concentration of fish during the declining available habitat as the river shrinks in size. See Figure 1 for an example of fishing during drought conditions.

Figure 1. Photograph of an angler fishing in a concentrated pool habitat in the Jefferson River near Waterloo on August 4, 2000.

Angling restrictions imposed during implementation of the Drought Management Plan (2000-2007) were intended to reduce angler-related mortality during stressful drought conditions. Complete fishing closures implemented when flow is less than 280 cfs (90% exceedence flow for August) at Twin Bridges apply to the entire river, and time-of-day restrictions based on elevated water temperature (maximum daily water temperature exceeds 73 F for three consecutive days) also results in closing fishing for the entire Jefferson River from 2 pm to midnight. The rationale for applying fishing restrictions to the entire river was to reduce stress on the fishery in both severely dewatered areas as well as relatively healthy reaches of river where fish may congregate during severe conditions.

Fishing regulations for trout in the Jefferson River have become progressively more restrictive in the past 20 years (Table 1). Catch and release fishing for rainbow trout was initiated in 1986 in an attempt to improve the rainbow trout fishery by restricting harvest. Compared to other catch and release regulations in Montana, which generally restrict gear to artificial lures, the Jefferson River catch and release regulation was a relatively rare format that allowed continued use of bait. Based on an evaluation of rainbow trout and brown trout with visible hook scars during selected years before and after the catch and release regulation was implemented, there appeared to be more trout with hook scars after the regulation was imposed (Figure 2). There was a general trend of higher hook scar percentages for rainbow trout compared to brown trout, which may be due to the catch and release regulation for rainbow trout, the higher catch rates of rainbow trout, or a combination of factors.

"Hoot-owl" fishing restrictions based on reducing fishing activity during warm, afternoon hours typically prohibited fishing from noon to midnight from 2000 to 2006. In 2007, the temperature restriction was changed to prohibit fishing from 2 pm to midnight, which provided an additional two hours of fishing opportunity during low water conditions (Table 1).

Table 1. Summary of Fishing Regulation Changes from 1986 to 2007.

YEAR	CHANGE IN FISHING REGULATION
1986	Catch and Release Regulation for rainbow trout. Allows use of bait.
1998	Catch and release for rainbow trout in spawning streams due to Whirling Disease (statewide issue)
2000	First implementation of fishing closure due to drought plan
2002	Reduction of brown trout limit from 5 to 3 (only 1 over 18") due to drought impacts.
2003	Catch/Release Regulation for rainbow trout maintained despite an effort to allow youth anglers to harvest one fish.
2004	Refine drought plan to close fishing at 280 cfs rather than 250 cfs, and add temperature trigger of 3 days over 73 F.
2007	Extend hours of hoot-owl closure from noon to 2 pm allowing two additional hours of fishing during temperature restriction.

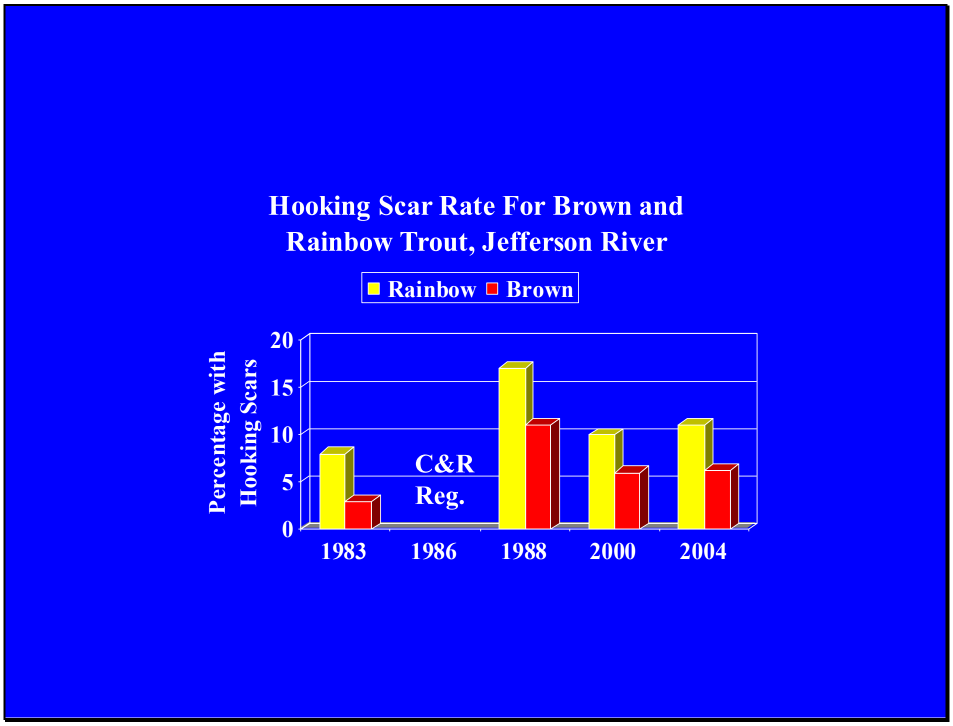


Figure 2. Percentage of brown and rainbow trout with visible hook scars in the Jefferson River before and after 1986 when catch and release fishing regulation was initiated for rainbow trout

CREEL CENSUS

Formal creel census work and angler surveys have not been conducted during the duration of this study. During March 1999, the local Game Warden conducted an informal survey of anglers during routine enforcement patrols. He conducted 38 interviews with anglers, and observed that 24 brown trout and 9 rainbow trout were caught. About 58% of the brown trout were kept by anglers, and due to catch and release regulation for rainbow trout, no rainbow were kept. A total of 64 hours of angling was included in the 38 interviews resulting in a catch rate of 0.38 brown trout per hour and 0.14 rainbow trout per hour.

The informal census in March of 1999 does not give a broad picture of angling success in the Jefferson River because it did not provide a large sample size of interviews throughout the river, or throughout the fishing season. A more detailed creel census would be needed to determine the potential effects of angler harvest on trout populations. Another factor affecting the magnitude of angling mortality of trout in the Jefferson River is fishing pressure. Angling pressure surveys conducted by MDFWP shows that fishing pressure declined from a high of about 25,000 angler days in the mid-1980's to a low of about 5000 anglers days in 2005 (Figure 3). Comparing fishing pressure to mean annual flow of the Jefferson River indicates that years with low stream flow tend to result in fewer angler days. The reduced angling pressure in response to lower stream flow is likely due to a combination of lower stream flow causing reduced fish populations, and the fact that lower stream flow levels during the summer fishing season results in less desirable conditions for floating and fishing the river.

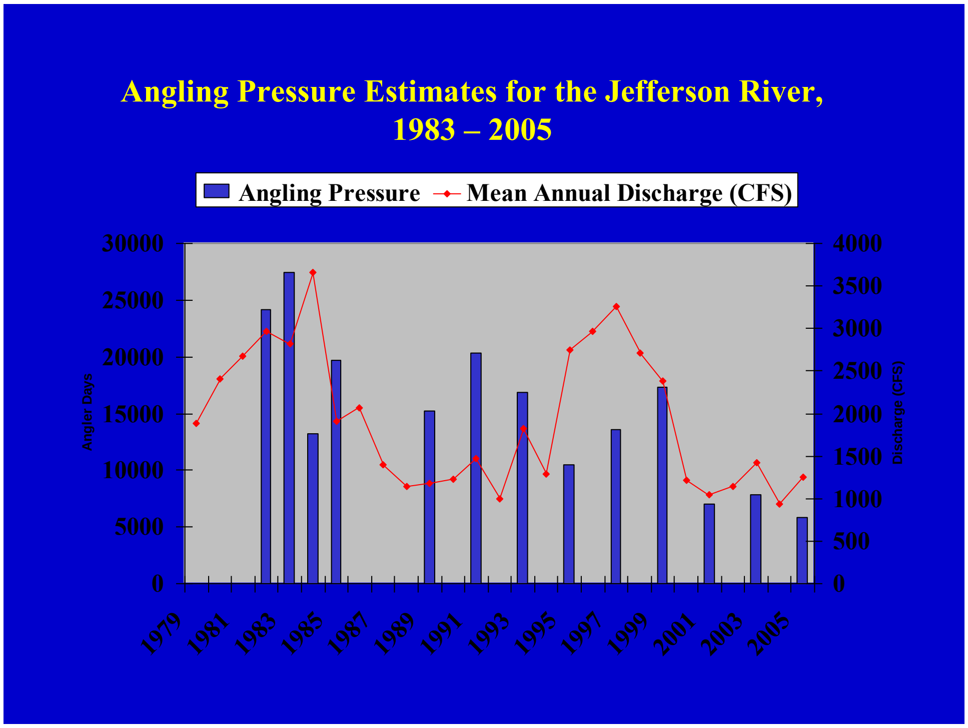
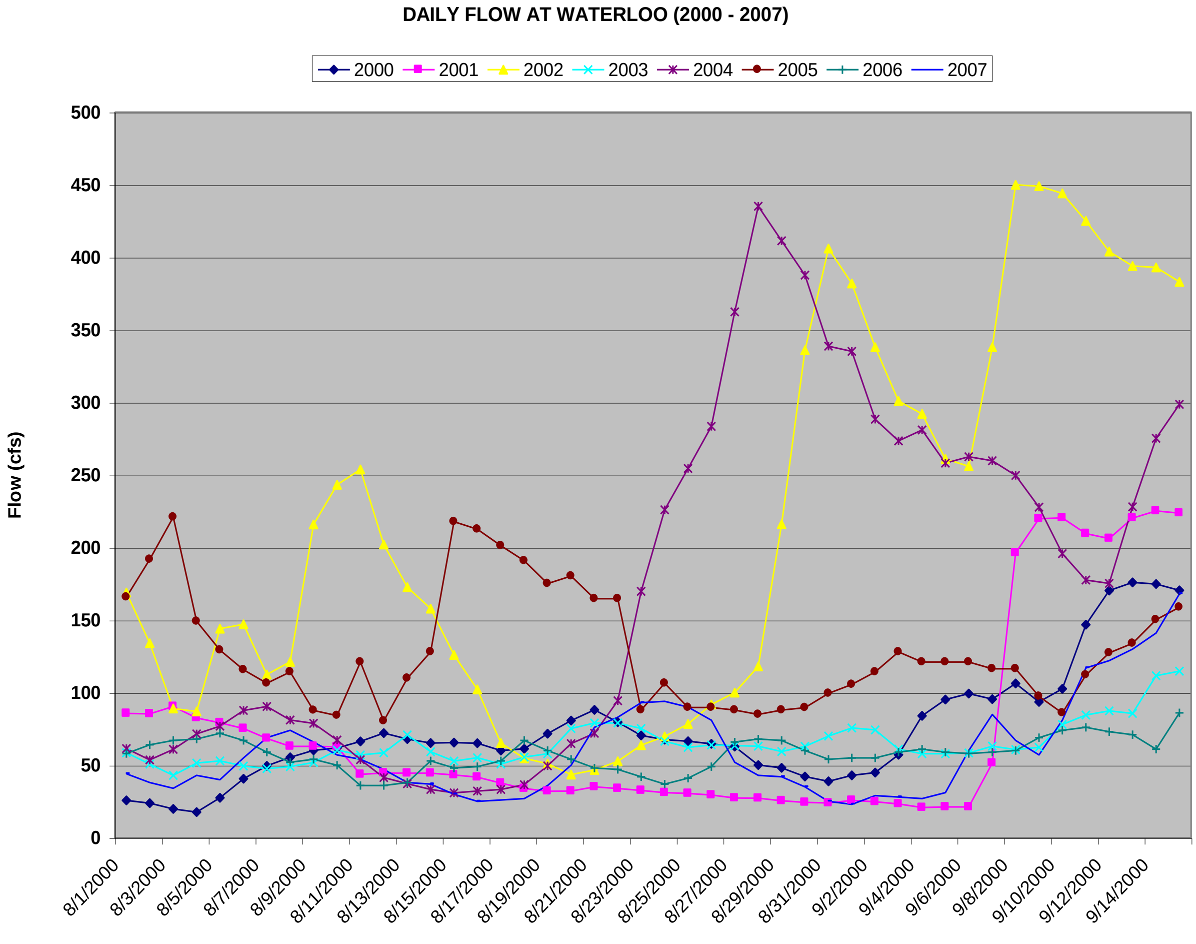


Figure 3. Mean annual flow and angling pressure trends for the Jefferson River.

Appendix A: Daily Flow Records at Waterloo (2000-2007)

SEASONAL DATA COLLECTED BY JRWC FROM 2000 THROUGH 2005
AND BY USGS IN 2006 AND 2007



DAILY FLOW DATA AT WATERLOO
(July through August 8th)

Jefferson River below Waterloo Bridge, Days below benchmarks:

Note: Bold - Data correlated w/Twin USGS Flows
Aquarod Down During This Time
2006-07 Based on USGS Gauge installed J
2001-2005: DNRC Stilling Well/Staff Gauge

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Days < 100	51	41	12	49	23	13	48	36
Days < 50	17	27	2	4	8	0	11	22
Low Flow	17.6	20.8	43.5	43	30.9	85	36	23

Average Daily Flows Below Waterloo Bridge

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
25-Jun								821
26-Jun								746
27-Jun								672
28-Jun								621
29-Jun		331.20						576.0
30-Jun		365.52						545.0
1-Jul		337.11					979.0	530.0
2-Jul		311.61					1130.0	539.0
3-Jul		282.14					1080.0	487.0
4-Jul		287.49					1030.0	456.0
5-Jul	958.24	365.87					1010.0	357.0
6-Jul	936.96	396.00					943.0	188.0
7-Jul	855.58	413.42					884.0	131.0
8-Jul	712.88	351.50					870.0	141.0
9-Jul	520.78	247.95					807.0	156.0
10-Jul	482.31	229.85				**950.8**	754.0	126.0
11-Jul	456.23	251.89				**909.2**	721.0	98.0
12-Jul	358.95	233.87			790.60	**888.40**	684.0	85.0
13-Jul	289.74	238.42			628.20	**825.90**	741.0	76.0
14-Jul	256.58	260.22			534.50	**718.60**	686.0	65.0
15-Jul	243.09	270.02			448.00	**605.10**	623.0	70.0
16-Jul	212.89	277.44			390.90	**494.80**	561.0	94.0
17-Jul	201.80	313.67			351.20	**398.00**	500.0	104.0
18-Jul	196.30	378.48		112.20	312.40	**353.20**	431.0	111.0
19-Jul	158.74	409.11	381.80	104.40	330.90	**297.00**	343.0	138.0
20-Jul	92.23	400.18	441.20	103.60	407.50	**253.20**	301.0	119.0
21-Jul	82.16	406.74	450.00	101.00	431.60	**225.10**	247.0	82.0
22-Jul	74.70	399.15	450.90	102.20	464.60	**204.30**	201.0	66.0
23-Jul	64.82	376.70	378.60	83.00	433.70	**189.70**	189.0	63.0
24-Jul	59.14	322.39	340.40	71.30	356.30	**162.60**	168.0	59.0
25-Jul	63.28	251.38	335.10	85.60	289.30	**164.70**	154.0	74.0
26-Jul	53.77	214.28	342.50	114.70	261.40	**202.20**	136.0	80.0
27-Jul	48.73	148.26	368.70	131.50	233.10	**216.80**	134.0	73.0
28-Jul	42.46	109.77	377.20	125.80	196.20	**193.90**	128.0	71.0
29-Jul	39.00	90.87	369.80	117.40	171.40	**181.40**	102.0	60.0
30-Jul	36.10	88.32	335.00	98.40	118.00	**173.10**	83.0	54.0
31-Jul	30.88	88.19	271.00	86.70	83.40	**163.70**	62.0	50.0
1-Aug	25.67	85.65	169.00	58.50	61.40	**165.80**	58.0	44.0
2-Aug	23.76	85.35	134.00	50.70	53.60	**191.80**	64.0	38.0
3-Aug	19.84	90.37	89.00	43.00	60.90	**220.90**	67.0	34.0
4-Aug	17.60	82.51	87.00	51.50	71.50	**149.10**	68.0	43.0
5-Aug	27.47	79.14	144.00	52.90	76.90	**129.30**	72.0	40.0
6-Aug	40.63	75.29	147.00	49.40	87.70	**115.80**	67.0	55.0
7-Aug	49.49	68.44	112.50	47.60	90.40	**106.40**	59.0	69.0
8-Aug	55.46	62.98	121.20	49.00	81.10	114.20	52.0	74.0

DAILY FLOW DATA AT WATERLOO CONTINUED.

5-Aug	27.47	79.14	144.00	52.90	76.90	**129.30**	72.0	40.0
6-Aug	40.63	75.29	147.00	49.40	87.70	**115.80**	67.0	55.0
7-Aug	49.49	68.44	112.50	47.60	90.40	**106.40**	59.0	69.0
8-Aug	55.46	62.98	121.20	49.00	81.10	114.20	52.0	74.0
9-Aug	60.13	62.90	215.90	51.80	78.80	87.70	54.0	66.0
10-Aug	61.79	62.69	243.20	60.30	67.30	84.10	50.0	57.0
11-Aug	66.29	43.59	253.70	57.00	53.70	121.00	36.0	54.0
12-Aug	72.12	44.55	202.00	58.60	41.50	80.50	36.0	47.0
13-Aug	68.05	44.44	172.60	70.90	37.20	109.80	38.0	38.0
14-Aug	65.22	44.44	157.90	59.20	33.30	128.00	53.0	37.0
15-Aug	65.46	43.19	126.00	52.80	30.90	**217.80**	48.0	30.0
16-Aug	65.11	41.71	102.20	55.10	32.20	**212.60**	49.0	25.0
17-Aug	60.06	37.59	65.20	50.80	33.20	**201.20**	53.0	26.0
18-Aug	61.30	33.95	54.70	55.60	36.50	**190.80**	67.0	27.0
19-Aug	71.63	32.03	51.00	57.90	49.50	**175.10**	60.0	36.0
20-Aug	80.69	32.12	43.50	75.20	64.90	**180.30**	54.0	50.0
21-Aug	88.10	34.96	46.70	79.10	71.90	**164.70**	48.0	76.0
22-Aug	79.65	33.86	52.70	79.10	94.40	**164.70**	47.0	83.0
23-Aug	70.50	32.62	63.80	75.20	169.70	**88.00**	42.0	93.0
24-Aug	67.55	31.10	69.80	66.50	226.00	**106.40**	37.0	94.0
25-Aug	66.45	30.49	78.40	62.20	254.50	**89.70**	41.0	90.0
26-Aug	64.74	29.35	91.80	63.90	283.40	**89.70**	49.0	81.0
27-Aug	62.80	27.40	100.00	63.50	362.40	**87.90**	66.0	52.0
28-Aug	50.06	27.24	118.00	63.10	435.10	**85.00**	68.0	43.0
29-Aug	48.15	25.39	216.00	59.40	411.30	**87.90**	67.0	42.0
30-Aug	42.09	24.40	336.00	62.90	387.70	89.60	60.0	35.0
31-Aug	38.82	23.96	406.00	70.00	338.70	99.40	54.0	25.0
1-Sep	42.99	25.75	382.00	75.70	335.10	105.60	55.0	23.0
2-Sep	44.84	24.70	338.00	74.30	288.40	114.20	55.0	29.0
3-Sep	57.19	23.21	301.00	61.00	273.40	128.00	59.0	28.0
4-Sep	83.96	20.80	292.00	57.90	281.00	121.00	61.0	27.0
5-Sep	95.24	21.22	261.00	57.80	258.10	121.00	59.0	31.0
6-Sep	99.30	21.19	256.00	58.40	262.50	121.00	58.0	60.0
7-Sep	95.55	51.49	338.00	63.00	259.80	116.40	59.0	85.0
8-Sep	106.31	196.32	450.00	60.70	249.60	116.40	60.0	67.0
9-Sep	93.55	219.82	449.00	62.30	227.80	97.40	69.0	57.0
10-Sep	102.62	220.43	444.00	78.00	195.70	85.90	74.0	81.0
11-Sep	146.75	209.52	425.00	84.50	177.50	112.00	76.0	117.0
12-Sep	170.32	206.11	404.00	87.40	175.20	127.40	73.0	122.0
13-Sep	175.96	220.26	394.00	85.60	228.00	133.90	71.0	130.0
14-Sep	174.83	225.23	393.00	111.60	275.20	150.20	61.0	141.0
15-Sep	170.50	223.66	383.00	114.80	298.60	158.80	86.0	168.0
16-Sep	146.74	221.07	359.00		319.50	157.10	189.0	191.0
17-Sep	135.41	222.93	373.00		324.80	161.20	264.0	188.0
18-Sep	132.41	219.43	469.00		314.80	187.60	272.0	208.0
19-Sep	129.97	212.81	477.00		352.00	207.30	293.0	241.0
20-Sep	136.23	208.42	457.00		512.80	222.00	313.0	298.0
21-Sep	173.44	210.14	453.00		792.20	238.20		382.0
22-Sep	282.72	203.20	424.00		883.80	258.00	386.0	415.0
23-Sep	451.48	206.53	416.00		871.40	265.10	438.0	440.0
24-Sep	504.57	205.92	404.00		827.90	376.70		532.0
25-Sep	554.58	208.58	410.00		825.30	459.90	466.0	614.0
26-Sep	575.90	196.16	427.00		789.90	469.80	471.0	641.0
27-Sep	564.03	187.78	447.00		797.20	483.80	462.0	
28-Sep	554.16	190.57	472.00		757.30	467.10	475.0	
29-Sep	576.59	207.94	468.00		740.90	464.90	469.0	
30-Sep	600.92	223.04	474.00		729.60	452.10	477.0	

Average Seasonal Flow	149.6	150.5	249.7	73.7	231.6	215.6	206.9	77.7