NWE-2188-4228

Ms. Kimberly D. Bose
Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

February 28, 2023

Re: NorthWestern Energy files updated Five Year (2018-2022) Madison River Flushing Flow Program Report per Project 2188 Article 419

Dear Secretary Bose,

NorthWestern Energy (NWE) respectfully submits it's updated Project 2188 Madison River Flushing Flow Program Report (Report) pursuant to License Article 419 of the Missouri-Madison Hydroelectric Project. The Report, as directed by FERC Order dated July 3, 2018, is an update to the previous Five Year Report filed on March 1, 2018.

The Report includes analysis of flushing flow data collected from 2018 to 2022, and compares that data to historical flushing flow data. The report suggests that the Upper Madison River (Hebgen Dam to Madison Dam) is meeting its targets for the percent of fine sediment (particle size less than 0.84 mm) in the streambed during most years under flushing flow and non-flushing flow conditions. The Lower Madison River (Madison Dam to mouth) does not appear to consistently meet its targets for the percent of fine sediment (particle size less than 0.84 mm) found in the streambed during years of either flushing flow or non-flushing flow conditions. The Report found that river flows in the Lower Madison River, as measured at the USGS Stream Gage 06041000 (Madison River bl Ennis Lake nr McAllister MT), need to be in excess of 6,800 to 7,600 cfs for a flushing flow to have the potential to reduce fine sediment in the streambed.

Project 2188 License Article 403 requires that NWE "limit flows at USGS Gage No. 06038800 near Kirby Ranch to no more than 3,500 cfs to minimize erosion of the Quake Lake outlet". Under normal water years, Madison River tributary inputs between Kirby Ranch and Ennis Lake do not provide enough flow to make up the additional 3,300 cfs to reach the 6,800 cfs target below Ennis Lake. In recent history, the only two times that Madison River flows below Ennis Lake exceeded 6,800 cfs were under emergency operations in 2011 and 2022 when the 3,500 cfs limit at Kirby Ranch was exceeded due to dam safety concerns.

The Report recommends that when the difference in flow between the USGS Stream Gage 06038800 (Madison River at Kirby Ranch nr Cameron MT) and the USGS Stream Gage 06041000 (Madison River bl Ennis Lake nr McAllister MT), exceeds 3,300 cfs, then a flushing flow should be pursued. At times when this condition exists, NWE will endeavor to release a 3-

day flushing flow from Hebgen Dam and will limit Madison River flows at Kirby Ranch to no more than 3,500 cfs per Project 2188 License Article 403.

NWE proposes to continue to monitor macroinvertebrates and McNeil sediment cores annually at the four long-term monitoring sites, Kirby Ranch, Ennis Campground, Norris Bridge, and Greycliff Fishing Access Site. This annual monitoring will help NWE track sediment trends and biological health through the monitoring of sediment sensitive macroinvertebrates in the Madison River over time. NWE proposes to discontinue salmonid redd counts as a part of the Madison River Flushing Flow Program monitoring. The original intent and purpose of the redd counts was to identify sites where salmonids were actively spawning and to use those areas to direct NWE where to collect McNeil sediment core samples and macroinvertebrates. The Report identifies that the locations of these spawning sites have remained consistent since the redd monitoring started in 2013, and there is no further need to monitor salmonid redds for the purposes of identifying spawning sites.

The Report states that the magnitude of the flushing flows in the Lower Madison River should be in excess of 6,800 to 7,600 cfs to flush fine sediment from the streambed. Under regulated conditions, 7,600 cfs in the Lower Madison River has a recurrence interval ranging from 10 to 25 years. Therefore, given the infrequency of flushing flow events in the Madison River, NWE proposes to develop an updated Madison River Flushing Flow Program Report on a ten year interval to capture any flushing flow events that may have occurred in the previous ten year period.

Northwestern Energy consulted with Montana Department of Environmental Quality (MDEQ), Montana Fish, Wildlife, and Parks (MFWP), US Fish and Wildlife Service (USFWS), US Bureau of Land Management (BLM), and US Forest Service (USFS) in the preparation and filing of the Missouri-Madison Hydroelectric Project Article 419 Madison River Flushing Flow Program Report. Signatures of approval for this updated report are included on page 3. Verbal approval of the Report was received from BLM, but a signature approval was not received prior to filing.

Sincerely,

Mary Gail Sullivan

Director, Environmental and Lands

CC:	Andrew Welch, NWE	Jake Chaffin, USFS	Keenan Storrar, DEQ
	Jon Hanson, NWE	Mary Erickson, USFS	Eileen Ryce, FWP
	John Tabaracci, NWE	Chris Boone, BLM	Matt Jaeger, FWP
	Jordan Tollefson, NWE	Adam Zerrenner, USFWS	

By signature of approval below, the MDEQ, MFWP, USFWS, BLM, USFS approve the updated License Article 419 Madison River Flushing Flow Program Report for the Missouri-Madison Hydroelectric Project (2188):

By: Keenan Storrar

Title: 401 water quality certification coordinator

Representing Montana Department of Environmental Quality

Date: 2/23/2023

By:

Title: Fish Chief

Representing Montana Department of Fish, Wildlife and Parks

Date: 2/24/23

By:

Title: Montana Ecological Services Office Supervisor

Representing U.S. Fish and Wildlife Service

Date: Feb. 21, 2023

By: MARY ERICKSON Digitally signed by MARY ERICKSON Date: 2023.02.28 07:06:05 -07'00'

Title: Forest Supervisor - Custer Gallatin National Forest

Representing U.S. Forest Service

Date: 2/28/23

By: ____________________

Title: ____________________

Representing U.S. Bureau of Land Management

Date: ____________________

From: Boone, Christopher T
To: Tollefson, Jordan
Subject: Re: [EXTERNAL] RE: Madison Flushing Flow Draft Report Available For Review
Date: Tuesday, February 21, 2023 3:53:03 PM

Yes, I can, if not my DSD will

From: Tollefson, Jordan <Jordan.Tollefson@northwestern.com>
Sent: Tuesday, February 21, 2023 12:38 PM
To: Boone, Christopher T <ctboone@blm.gov>
Subject: Re: [EXTERNAL] RE: Madison Flushing Flow Draft Report Available For Review

Thanks for reviewing it Chris. I think the report actually came out pretty good with the 20 years of data that we now have. Would you be able to sign that FERC filing letter on behalf of BLM and send it back to me when you get a chance?

Jordan

Sent from Workspace ONE Boxer

On February 21, 2023 at 9:31:58 AM MST, Boone, Christopher T <ctboone@blm.gov> wrote:

CAUTION: This Email is from an EXTERNAL source outside of NorthWestern Energy.
The Original Sender of this email is ctboone@blm.gov.
Are you expecting the message? Is this different from the message sender displayed above?
Do not click on links or open attachments unless you are sure you recognize the sender and you know the contents are safe.
If you believe the email to be malicious and/or phishing email, please use the **Report Phish** button.

Got your message too late, however, I reviewed it and have no comments, not that you would take any

thanks

From: Tollefson, Jordan <Jordan.Tollefson@northwestern.com>

Sent: Tuesday, February 21, 2023 9:20 AM
To: Chaffin, Jake - FS <jake.chaffin@usda.gov>; Boone, Christopher T <ctboone@blm.gov>; Shallcross, Alden T <ashallcross@blm.gov>; Boyd, James W <james_boyd@fws.gov>; Storrar, Keenan <Keenan.Storrar@mt.gov>; Duncan, Mike <Mike.Duncan@mt.gov>; Trevor.Watson@mt.gov <Trevor.Watson@mt.gov>; Jaeger, Matt <mattjaeger@mt.gov>; tlohrenz_contact <tlohrenz@mt.gov>
Cc: Welch, Andrew <Andrew.Welch@northwestern.com>; Hanson, Jonathan (Jon) <Jon.Hanson@northwestern.com>; Sullivan, Mary Gail <MaryGail.Sullivan@northwestern.com>
Subject: [EXTERNAL] RE: Madison Flushing Flow Draft Report Available For Review

This email has been received from outside of DOI - Use caution before clicking on links, opening attachments, or responding.

Good morning fellow Madison River partners,

The comments that we have received over the course of the 30-day comment period have been addressed and an updated final version of the Madison River Flushing Flow Report is being finished today. Once we get that completed, I will send you all a link to download for your records. NorthWestern Energy is looking for signature approvals form USFS, MFWP, USFWS, DEQ, and BLM to help us finalize this report and file it with FERC this week. To assist us with this filing, please have the representative from your agency sign in the signature blocks of the attached letter for concurrence with the filing of the report and return a copy to me. If you have any questions or concerns, please let me know as soon as possible. Thanks!

Jordan

Jordan Tollefson
Hydro Compliance Professional
Jordan.Tollefson@NorthWestern.com
O (406) 443-8907
C (406) 565-3879
208 N Montana Avenue, Suite 200
Helena, MT 59601

From: Tollefson, Jordan
Sent: Tuesday, February 7, 2023 1:40 PM
To: Chaffin, Jake - FS <jake.chaffin@usda.gov>; 'Chris Boone (ctboone@blm.gov)' <ctboone@blm.gov>; Shallcross, Alden <ashallcross@blm.gov>; 'James Boyd (James_Boyd@fws.gov)' <James_Boyd@fws.gov>; Storrar, Keenan <Keenan.Storrar@mt.gov>; 'Duncan, Mike' <Mike.Duncan@mt.gov>; 'Trevor.Watson@mt.gov' <Trevor.Watson@mt.gov>; 'Jaeger, Matt' <mattjaeger@mt.gov>; Travis Lohrenz <tlohrenz@mt.gov>
Cc: Welch, Andrew <Andrew.Welch@northwestern.com>; Hanson, Jonathan (Jon) <Jon.Hanson@northwestern.com>; Sullivan, Mary Gail <MaryGail.Sullivan@northwestern.com>
Subject: RE: Madison Flushing Flow Draft Report Available For Review

Thank you for taking the time to review and provide NorthWestern with comments on the Madison River Flushing Flow Report. As a reminder, the deadline to submit comments is Friday February 17th. Following the close of the comment window, NorthWestern and Kleinschmidt will address and incorporate comments received from you all. For the formal filing of this plan with FERC, NorthWestern is requesting agency signature approval from Montana DEQ, FWP, USFS, BLM, and the USFWS. Attached you will find our FERC filing letter that will accompany the report with the signature blocks for each agency representative. I am planning to file the report with FERC by Friday February 24th, so please respond with your respective agency’s approvals before that date. As always, don’t’ hesitate to reach out to me if you have any questions. Thank you!

Jordan

Jordan Tollefson
Hydro Compliance Professional
Jordan.Tollefson@NorthWestern.com
O (406) 443-8907
C (406) 565-3879
208 N Montana Avenue, Suite 200
Helena, MT 59601

From: Tollefson, Jordan
Sent: Monday, January 16, 2023 2:52 PM

To: 'Chaffin, Jake - FS' <jakechaffin@fs.fed.us>; 'Chris Boone (ctboone@blm.gov)' <ctboone@blm.gov>; Hanson, Jonathan (Jon) <Jon.Hanson@northwestern.com>; 'James Boyd (James_Boyd@fws.gov)' <James_Boyd@fws.gov>; 'Stringer, Allison - FS' <astringer@fs.fed.us>; Welch, Andrew <Andrew.Welch@northwestern.com>; Storrar, Keenan <Keenan.Storrar@mt.gov>; 'Duncan, Mike' <Mike.Duncan@mt.gov>; 'Trevor.Watson@mt.gov' <Trevor.Watson@mt.gov>; Stagnoli, Robert "Jake" <Robert.Stagnoli@northwestern.com>; Benski, Chris <Chris.Benski@northwestern.com>; 'Jaeger, Matt' <mattjaeger@mt.gov>; Travis Lohrenz <tlohrenz@mt.gov>
Cc: 'Clair Yoder' <Clair.Yoder@kleinschmidtgroup.com>; Stuart Beck <Stuart.Beck@kleinschmidtgroup.com>; 'Nightengale, Tim' <Tim.Nightengale@stantec.com>
Subject: Madison Flushing Flow Draft Report Available For Review

Good afternoon Madison River partners,

NorthWestern Energy and Kleinschmidt Associates have recently completed a draft of the Madison River Flushing Flow Program Report 2018-2022, and the report is available for your review and comment. The report details the data collected during the 2018-2022 timeframe as a part of our flushing flow program and provides recommendations for the program moving forward. To download a copy of the report, please click the link found below:

https://send.northwesternenergy.com/link/CTzqfQq4ibvybsSYeCX7Ck

NorthWestern is requesting that any comments be provided to us by **no later than Friday February 17th**. We have a deadline of filing this report with comments incorporated and with signatures from agency representatives before March 1st, so your timeliness in review is greatly appreciated. I’d also like to set up a meeting with you all before the end of January to discuss the highlights of this report and hopefully answer any questions that you may have. Please take a second to fill out the Doodle poll at the link found below to let me know what your availability is to meet via Zoom.

https://doodle.com/meeting/participate/id/e36QYrRd

As always, if you have any questions, please don’t hesitate to reach out. Hope you all have a great week!

Jordan

Jordan Tollefson
Hydro Compliance Professional
Jordan.Tollefson@NorthWestern.com
O (406) 443-8907
C (406) 565-3879
208 N Montana Avenue, Suite 200
Helena, MT 59601

Flushing Flow Needs in the Madison River, Montana 2018 through 2022

Streambed and Aquatic Invertebrate Monitoring Results and Comparison with Results from 1994 through 2017

FERC No. 2188 – Article 419 of Project 2188 License

Prepared for:

NorthWestern Energy

Prepared by:

Kleinschmidt Associates

February 2023

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACRONYMS

C	
cfs	Cubic feet per second
CPOM	coarse particulate organic matter
E	
EPA	Environmental Protection Agency
F	
FERC	Federal Energy Regulatory Commission
FPOM	fine particulate organic matter
G	
GPS	Global Positioning System
H	
HBI	Hilsenhoff Biotic Index
HWY	Highway
M	
MDEQ	Montana Department of Environment Quality
MDHES	Montana Department of Health and Environ-Mental Sciences
MMRMA	Missouri-Madison River Multimetric
MTI	Metals Tolerance Index
N	
NWE	NorthWestern Energy
P	
PPLM	PPL Montana
R	
R2	Resource Consultants, Inc.
S	
So	sorting coefficient
SOP	Standard Operating Practice
U	
USGS	U.S. Geological Survey

1.0 INTRODUCTION

On September 27, 2000, the Federal Energy Regulatory Commission (FERC) issued a license to PPL Montana (PPLM) for the Missouri-Madison Hydroelectric Project, FERC Project No. 2188. This license regulates nine hydroelectric facilities on the Missouri and Madison rivers in central Montana. Two of these facilities are on the Madison River (Hebgen and Madison) and the remaining seven are on the Missouri River (Hauser, Holter, Black Eagle, Rainbow, Cochrane, Ryan, and Morony). Article 419 (Appendix A) of the new license required PPLM to file a plan to coordinate and monitor flushing flows in the upper Madison River downstream of Hebgen Dam.

In response to a request from PPLM, R2 Resource Consultants, Inc. (R2) prepared a plan to coordinate and monitor flushing flows (R2 2003a). This plan, prepared in consultation with agencies, required the annual collection of substrate core samples and geomorphic and macroinvertebrate data with a review and analysis of the results every five years to determine flushing flow needs.

Data reports were subsequently prepared at five-year intervals (R2 2003b; R2 2008; R2 2013, and R2 2018). The current plan for implementing flushing flows in the Madison River was issued by FERC on June 13, 2013 (FERC 2013). NorthWestern Energy (NWE) purchased the hydro facilities from PPLM in 2014 and the FERC license was subsequently transferred to NWE. Kleinschmidt Associates (formerly R2) was contracted by NWE to prepare the 2022 data report. Construction activities at Hebgen were given priority over pursuing controlled release of flushing flows between 2012 to 2017 in order to maximize the short construction window. This report is focused on analysis of data collected between 2018 through 2022 and a comparison with data previously collected.

1.1 Background

Madison River flows are controlled, to a large extent, by operation of Hebgen Dam. The Hebgen development has no power-generating facilities and primarily serves as a storage reservoir for downstream projects. The reservoir impounds about 380,000 acre-feet of usable storage. In 1959, an earthquake caused a major landslide across the Madison River about five miles downstream of Hebgen Dam. The landslide impounded a section of the Madison River. This impoundment, known as Quake Lake, was approximately 174 feet deep, when it was initially created. The lake is shallower now as a result of erosion of the outlet.

To limit erosion of the outlet from Quake Lake, NWE is required by the FERC License to limit the maximum releases from Hebgen Dam to 3,500 cfs (as determined near Kirby Ranch, U.S. Geological Survey [USGS] Gage 06038800) using available storage capacity in Hebgen Reservoir. The 3,500 cfs limitation was first documented in a Memorandum of Understanding with U.S. Forest Service (Montana Power Company 1976). A recent study was conducted by the USGS (2012) to look at lateral and vertical channel movement and potential for bed-material movement on the Madison River downstream from Quake Lake. Results of this study suggest that the 3,500 cfs limitation effectively limits erosion at the outlet from Quake Lake.

Prolonged exposure to excessive high flows would lead to erosion and undermining of the outlet structure of Quake Lake. The volume of material that blocked the Madison River below Hebgen Dam and formed Quake Lake has been estimated to be in excess of 37 cubic yards (USGS 1964). This volume of material would become an excessive source of sediment to the Madison River downstream from Quake Lake. The erosion and transport of this sediment to the Madison River downstream from Quake Lake would increase turbidity levels, disrupt the geomorphic integrity of the Madison River, and increase the risk of downstream flooding. Thus, it is important to maintain the structural integrity of the outlet of Quake Lake.

The 3,500 cfs constraint on flows in the Madison River near Kirby Ranch is supported by observations of the outlet of Quake Lake, when high flows were released from Hebgen Dam in 1970 and 1993. In 1970, flow releases from Hebgen Dam peaked at 4,500 cfs. Although concurrent flows were not measured near Kirby Ranch, large boulders were moved in the Quake Lake spillway, and Highway 287 was washed out just downstream from Quake Lake. In 1993, flow releases from Hebgen Dam peaked at 3,500 cfs and the resultant flows through the Quake Lake outlet as recorded near Kirby Ranch peaked at 5,030 cfs. Erosion was observed in the outlet channel of Quake Lake. Thus, to limit further erosion of the outlet of Quake Lake, the 3,500 cfs maximum flow constraint near Kirby Ranch should be maintained and is a requirement of the FERC license.

Madison Dam is located on the Madison River 63 miles downstream of Hebgen Dam as shown in Figure 1-1. The powerhouse, with an installed capacity of 12.68 megawatts, is located about 1.5 miles downstream of the dam. The project currently is, and will continue to be, primarily operated as a run-of-the-river facility.

NWE, through operation of Hebgen Dam, has the capability of releasing flows to both the upper Madison River (between Hebgen Dam and Ennis Lake) and the lower Madison River (between Madison Dam and the confluence with the Jefferson and Gallatin rivers). Flow releases from Hebgen Dam are designed to satisfy downstream minimum flow requirements below Hebgen Dam, near Kirby Ranch, and below Madison Powerhouse. This study plan is focused on the determination of the need for flushing flows, and the development of a plan for releasing flushing flows while still meeting current operational constraints of Hebgen Dam.

The Flushing Flow Program was designed to maintain spawning gravel quality for salmonids in the Madison River. Excessive levels of fine sediments in spawning gravel may suffocate salmonid eggs during the incubation period and impair the emergence of fry from the gravel matrix.

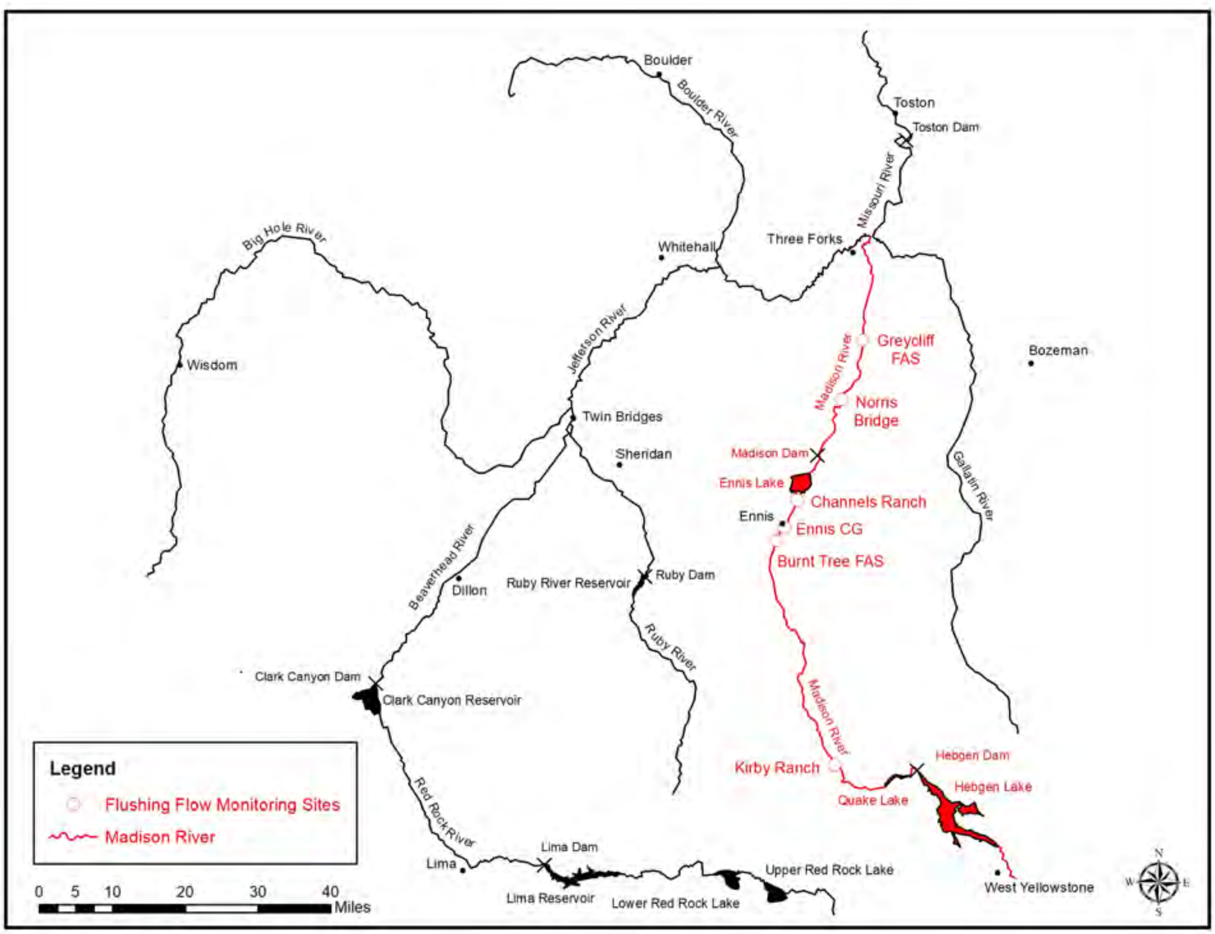


Figure 1-1 Hebgen Dam and Madison Dam located on Madison River, Montana.

1.2 Summary of Previous Studies

A series of studies designed to address the need for flushing flows in the Missouri and Madison rivers was initiated in 1992. The initial study, conducted by EA Engineering, Science, and Technology (EA 1992), involved the collection of field data from nine locations, three on the Madison River and six on the Missouri River. In a subsequent study performed by R2 (1994a), the data collected by EA were analyzed and a draft streambed-monitoring plan was developed for further monitoring of flushing flow needs on the Missouri and Madison rivers. Seven sites were suggested for future monitoring, four on the Madison River and three on the Missouri River.

Streambed and aquatic invertebrate monitoring were performed at two sites on the Madison River (Norris Bridge and Greycliff Fishing Access) by R2 in 1994 (R2 1994a, R2 1994b, and R2 1994c). At each site; channel cross-sections and water surface elevations were surveyed; flows were measured; pebble count surveys were performed and McNeil samples collected; embeddedness was assessed; and macroinvertebrate samples were collected via a modified Hess Sampler and a kick-screen. Results of the study suggested that further monitoring should be performed at the Norris Bridge and Greycliff Fishing Access sites, as well as other sites located upstream from Madison Dam. A draft streambed-monitoring plan was subsequently developed for further monitoring of flushing flow needs on the upper and lower Madison River.

In 1995, a three-year streambed-monitoring program was initiated at four sites on the Madison River. Two sites were selected on the upper Madison River (Kirby Ranch and Ennis) and two sites on the lower Madison River (Norris Bridge and Greycliff Fishing Access). The streambed at these sites were monitored in 1995, 1996, and in 1997 and the results were reported by R2 (R2 1996, R2 1997, and R2 2000). During the course of these studies, the protocol for collecting and analyzing data was refined based on agency input and for consistency with similar studies performed on the Missouri River. Important elements of the data collection program included: cross-section surveys; embeddedness measurements; scour chain monitoring; McNeil samples; modified Hess samples; and kick-net samples.

Between the 1995 and 1996 data collection sessions, a flushing flow occurred in June 1996. Daily flow releases from Madison Dam over a three-day period averaged about 7,600 cfs. Analyses of McNeil samples indicated that there was a significant reduction in the percentage of fines in the samples collected from the Norris Bridge and Greycliff

Fishing Access sites. A similar reduction was not observed at the Kirby Ranch and Ennis sites because the percentage of fines in those samples was low even before the flushing flow occurred. At the end of these studies (R2 2000), further monitoring was recommended at five-year intervals, beginning in 2002.

A comprehensive set of field data, including substrate core samples, geomorphic surveys, and macroinvertebrate samples, were collected in September 2002. These data were analyzed and compared with hydrologic and water temperature records, as well as the results of previous studies. Results of this study were reported by R2 (2003b).

Annual substrate core samples were collected and analyzed by PPLM in 2003, 2004, 2005, and 2006, and a comprehensive set of field data, including substrate core samples, geomorphic surveys, and macroinvertebrate samples, were collected in September 2007. These field data were analyzed and compared with additional hydrologic and water temperature records, and the results of previous studies. Flushing flows were released from Hebgen Dam in 2006, 2008, and 2010. Although the peak flows in the lower Madison River in 2006 did not reach the magnitudes that occurred in 1996, changes in the cross-sectional shape of Transect 3 at the Ennis Campground Site between 2002 and 2007 suggest that the flushing flows were sufficient to mobilize streambed sediments in the upper Madison River. A comprehensive summary of monitoring results from 1994 through 2007 was compiled by R2 (2008).

Annual substrate core samples were collected and analyzed by PPLM in 2008, 2009, 2010, 2011, and 2012. In addition, macroinvertebrate samples were collected and analyzed by Dan McGuire (McGuire 2012) in 2008, 2009, 2010, and 2011. These results and the combined results from monitoring efforts since 1994 were reviewed within the context of the previously developed plan to coordinate and monitor flushing flows in the Madison River (R2 2003a). Recommended changes to the plan were developed (R2 2013).

Construction activities at Hebgen were given priority over pursuing the controlled release of flushing flows between 2012 to 2017 in order to maximize the short construction window. Redd surveys, macroinvertebrate samples, McNeil gravel samples, and scour chain data were collected from 2013 through 2017 and summarized in the Flushing Flow Needs Report (R2 2018). The 2018 report summarized and presented data collected from 2013 through 2017 and compared with results collected from 1994 through 2012.

A sediment mobility assessment of the Madison River was recently performed by Applied Geomorphology (Pioneer Technical Services 2022). The study was focused on the following four locations:

1. Pine Butte – located near the Kirby Ranch Site.
2. Varney – located between the Kirby Ranch and Ennis Campground sites.
3. Norris – located near the Norris Bridge Site
4. Greycliff – located near the Greycliff Fishing Access Site.

At each of these four sites, the grain size distributions of streambed sediments were characterized, hydraulic analyses were performed using the HEC-RAS model, and hydrologic analyses were performed to develop flow duration and flood frequency curves.

At each site, sediment data were collected from two types of areas: an active bed zone with relatively small and mobile gravel; and a coarse bed zone with relatively large and immobile gravel. Wolman pebble count surveys were performed to characterize the grain size distributions of the active bed and the coarse bed. McNeil gravel samples were collected from the active bed zone where spawning was known to occur from the redd surveys.

Hydraulic conditions were analyzed at each of the four sites by developing and calibrating a HEC-RAS 1D model. The models were used to derive a relationship between shear stress and discharge at each site. In addition, a HEC-RAS 2D model was used to develop maps to show how the shear stress was distributed at the Norris Bridge Site.

The shear stress relationship was used to estimate the discharge needed to mobilize the streambed and the flow duration curve was used to estimate the duration of mobilization at each site. Results of the analysis suggest that the median grain size of the active layer would be mobilized on average: 323 days per year at the Pine Butte Site; 357 days per year at the Varney Site; 59 days per year at the Norris Bridge Site; and 364 days per year at the Greycliff Fishing Access Site.

The estimates of duration of mobility seem unusually long for a gravel bed river. They were based on the results obtained from the 1D HEC-RAS model which uses a single value of shear stress for each transect which is averaged for each site. In contrast, the 2D model enables the development of a map of shear stress that illustrates how shear stress varies for each site.

The blue curve (shown in Figure 1-2) is the shear stress rating curve derived from the HEC-RAS 1D model at the Norris Bridge Site. The critical shear stress for mobility is 0.359 psf. This intersects the blue curve at a discharge of 2,250 cfs. This is what was presented in the report. The HEC-RAS 2D model suggests that the shear stress in the surveyed redd locations is less than the shear stress obtained from the HEC-RAS 1D model (green points shown in Figure 1-2). These points suggests that the shear stress in the surveyed redd locations is 41 percent of the shear stress obtained from the HEC-RAS (orange curve shown in Figure 1-2). The critical shear stress for mobility (0.359 psf) intersects the orange curve at a discharge of 9,800 cfs. This value would exceed the magnitude of the 100-year flood and suggests that the substrate at the Norris Bridge Site is well-armored

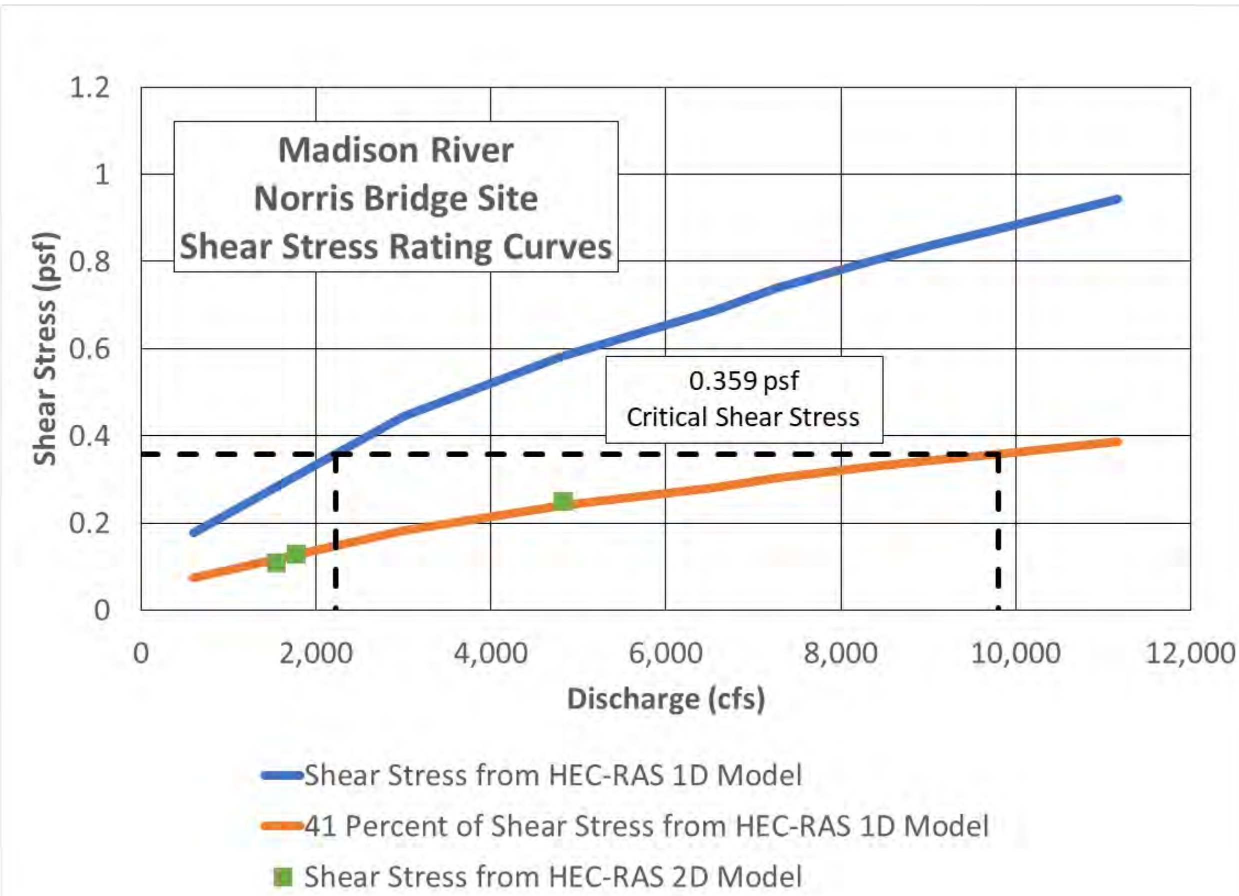


Figure 1-2 Shear Stress versus Discharge and the Critical Discharge for Mobility at the Norris Bridge Site, Madison River.

At the Pine Butte Site, the critical flow for mobilization of gravel is estimated to be 4,000 cfs if the average shear stress in the redd location is assumed to be 41 percent of the reach-averaged shear stress (Figure 1-3). This value exceeds the 3,500 cfs limit and suggests that gravel at this location would be rarely mobilized with current operational constraints.

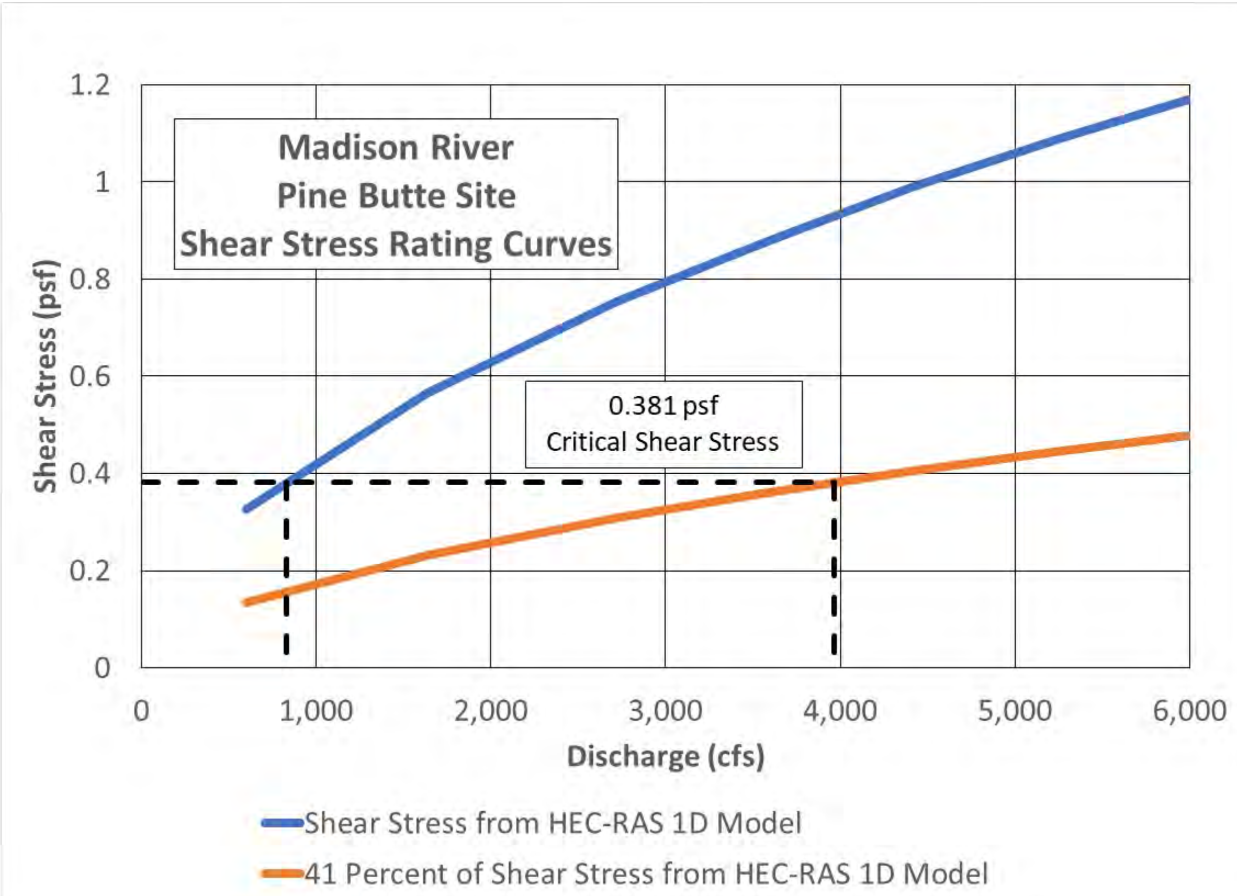


Figure 1-3 Shear Stress versus Discharge and the Critical Discharge for Mobility at the Pine Butte Site, Madison River.

The critical flow for mobilization is estimated to be 1,200 cfs at the Varney site (Figure 1-4). Gravels would be mobilized 54 percent of the time (197 days per year on average). This amount suggests that sediment released to the river from the landslide is still working its way through the system.

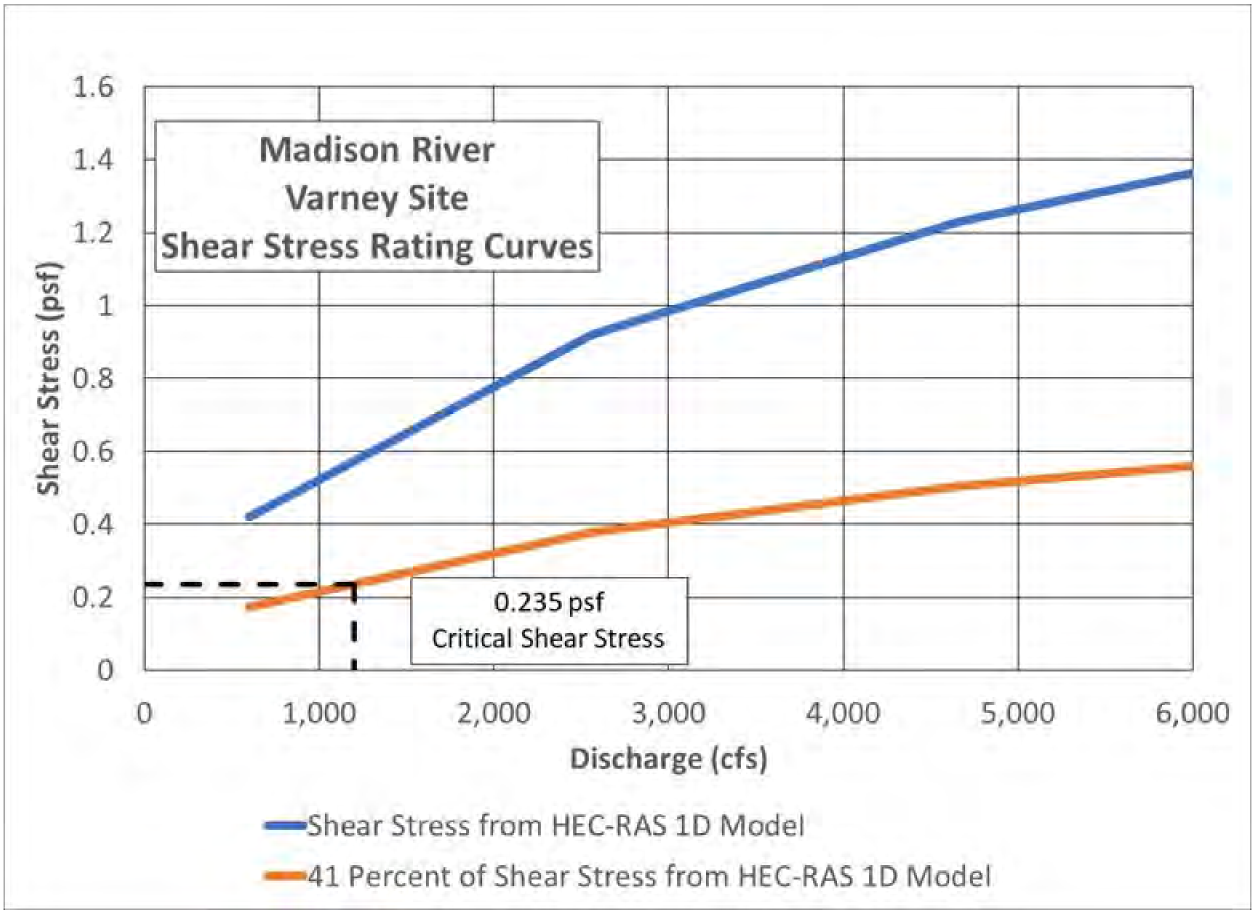


Figure 1-4 Shear Stress versus Discharge and the Critical Discharge for Mobility at the Varney Site, Madison River.

The critical flow for mobilization of gravel at the Greycliff Fishing Access Site is estimated to be 3,000 cfs (Figure 1-5). This flow would be exceeded about 7 percent of the time (about 26 days per year on average).

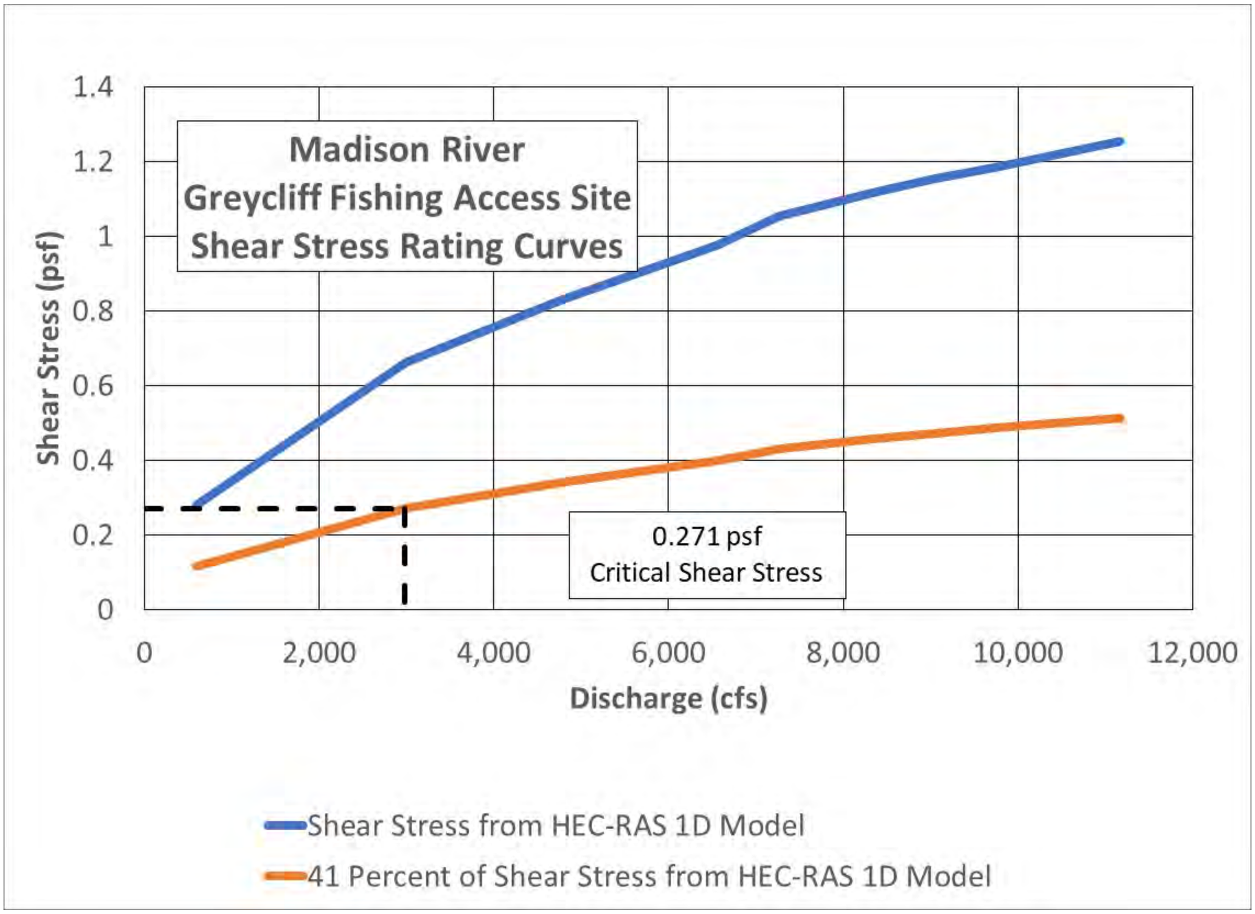


Figure 1-5 Shear Stress versus Discharge and the Critical Discharge for Mobility at the Greycliff Fishing Access Site, Madison River.

Methods developed by the U.S. Forest Service (USFS 2004) were also used to estimate duration of mobility. Previous studies of sediment transport in gravel bed rivers in the western United States were reviewed. Two types of transport were identified:

1. **Phase 1 Transport** – This phase involves the transport of sand and fine gravel on the surface of the stream bed without disrupting the armor layer. The U.S. Geological Survey (USGS 1975) found that Phase 1 Transport begins at about 0.4 times bankfull flow for streams in the Salmon River drainage in Idaho. This type of transport would not be effective in flushing fine sediment from substrate below the armor layer because the armor layer would not be mobilized.

2. **Phase 2 Transport** – This phase is associated with coarse sediment movement from the coarse surface layer and underlying channel bed. As the coarse surface layer is mobilized, underlying fine sediment becomes available for transport. This phase is important for flushing fine sediments and the effectiveness of the flushing flow will depend on both the magnitude and duration of the flush. Phase 2 Transport has been found to begin at 0.6 to 1.0 times bankfull flow in gravel bed rivers (Jackson 1981; Pitlick 1994; Carling 1995; Petts and Maddock 1996; Ryan and Troendle 1996; Whitaker 1997; Ryan et al. 2002; Trush et al. 2000; Ryan et al. 2005).

The 2-year flood is often used to represent a bankfull discharge condition. The 2-year flood was estimated to be 2,715 cfs in the Madison River at Kirby Ranch (USGS Gage 06038800) under regulated conditions (Pioneer Technical Services 2022). Phase 2 Transport at Kirby Ranch is estimated to begin at 2,172 cfs (0.8 times bankfull flow). From the flow duration curves derived by Pioneer Technical Services (2022), Phase 2 Transport is estimated to occur 26 days per year under average conditions in the Madison River at Kirby Ranch (USGS Gage 06038800).

In the Madison River near Cameron (USGS Gage 06040000), the 2-year flood was estimated to be 4,663 cfs under regulated conditions (Pioneer Technical Services 2022). Phase 2 Transport in the Madison River near Cameron is estimated to begin at 3,730 cfs (0.8 times bankfull flow). Phase 2 Transport is estimated to occur 11 days per year under average conditions in the Madison River near Cameron (USGS Gage 06040000).

The 2-year flood was estimated to be 4,820 cfs in the Madison River below Ennis Lake (USGS Gage 06041000) under regulated conditions (Pioneer Technical Services 2022). Phase 2 Transport in the Madison River below Ennis Lake is assumed to begin at 3,856 cfs (0.8 times bankfull flow). Phase 2 Transport is estimated to occur 7 days per year under average conditions in the Madison River below Ennis Lake (USGS Gage 06041000).

There is variation in the different estimates of duration of mobility. Differences can be attributed to spatial variability of sediment grain size and shear stress. The variability of these two parameters can be large and make it challenging to accurately calculate duration of mobility.

1.3 2018–2022 Data

Data collected since the previous plan was submitted include the following:

- **Redd Surveys** – performed in the spring and fall at Kirby Ranch, Ennis Campground, Norris Bridge, and Greycliff Fishing Access.
- **Macroinvertebrate Samples** – collected in the summer at Yellowstone National Park, Hebgen Dam, Kirby Ranch, Ennis Campground, Madison Powerhouse, Norris Bridge, and Greycliff Fishing Access.
- **McNeil Gravel Samples** – collected in the fall at Kirby Ranch, Ennis Campground, Norris Bridge, and Greycliff Fishing Access.
- **Scour Chains** – Surveyed and removed from Ennis Campground, Norris Bridge, and Greycliff Fishing Access in 2018

1.4 Operational Constraints at Hebgen Dam

Flushing flows, when released from Hebgen Dam, are subject to the following constraints:

1. Minimum flows of 150, 600, and 1,100 cfs must be provided in the Madison River below Hebgen Dam, near Kirby Ranch, and below Madison Powerhouse, respectively.
2. The flow in the Madison River near Kirby Ranch must be kept below 3,500 cfs to limit erosion from the outlet of Quake Lake.
3. The reservoir level of Hebgen must be filled to at least elevation 6,530.26 ft by June 20th and to full pool (elevation 6,534.87 ft by late June or early July).
4. Flow releases from Hebgen Dam cannot be changed by more than 10% per day.

2.0 REVIEW OF MONITORING METHODS

Substrate composition of the Madison River are currently monitored at the four locations (Kirby Ranch, Ennis, Norris Bridge, and Greycliff Fishing Access) shown in Figure 2-1. Substrate core samples, macroinvertebrate data, and redd surveys are currently collected annually at all four locations. Collectively, these four sites are intended to provide a representative indicator of the overall condition of the Madison River below Hebgen Dam. The methods used to collect and analyze data from these four sites are described herein.

2.1 Data Collection

To maximize visibility, accessibility, and worker safety in the stream channel, each of the four sediment core sites are visited during the low flow period in late August or September. Stable flows are provided by NWE when field data are collected. Streamflow records are obtained from the USGS for the gages on the Madison River below Hebgen Lake (Gage No. 06038500) and below Ennis Lake (Gage No. 06041000). Macroinvertebrate data are collected in the month of August. Available water temperature records are obtained from the Madison River below Ennis Lake during the summer period. Redd surveys are conducted both in the spring (typically late April or early May) and fall period (typically October and November). Previous data collection efforts are described in the 2018 Report on the flushing flows of the Madison River for the 2013 through 2017 period (R2 2018).

2.1.1 Sediment Characteristics

Sediment core samples are collected annually. The composition of substrates within each sediment monitoring location is sampled using a 12-inch diameter core sampler, designed after a 6-inch version developed by McNeil and Ahnell (1964) as shown in Figure 2-1. At each site, samples are collected from five locations, representative of salmonid spawning gravel areas. Substrate samples are collected to a depth of 8 inches below the streambed level. The samples encompass an area of the streambed that is 12 inches in diameter and 8 inches high; samples weigh approximately 60 pounds each (dry weight). Beginning in 2013, sediment cores were co-located at previously recorded salmonid spawning locations. Scour chains were installed in May, 2018 and removed in August, 2018 and then discontinued.

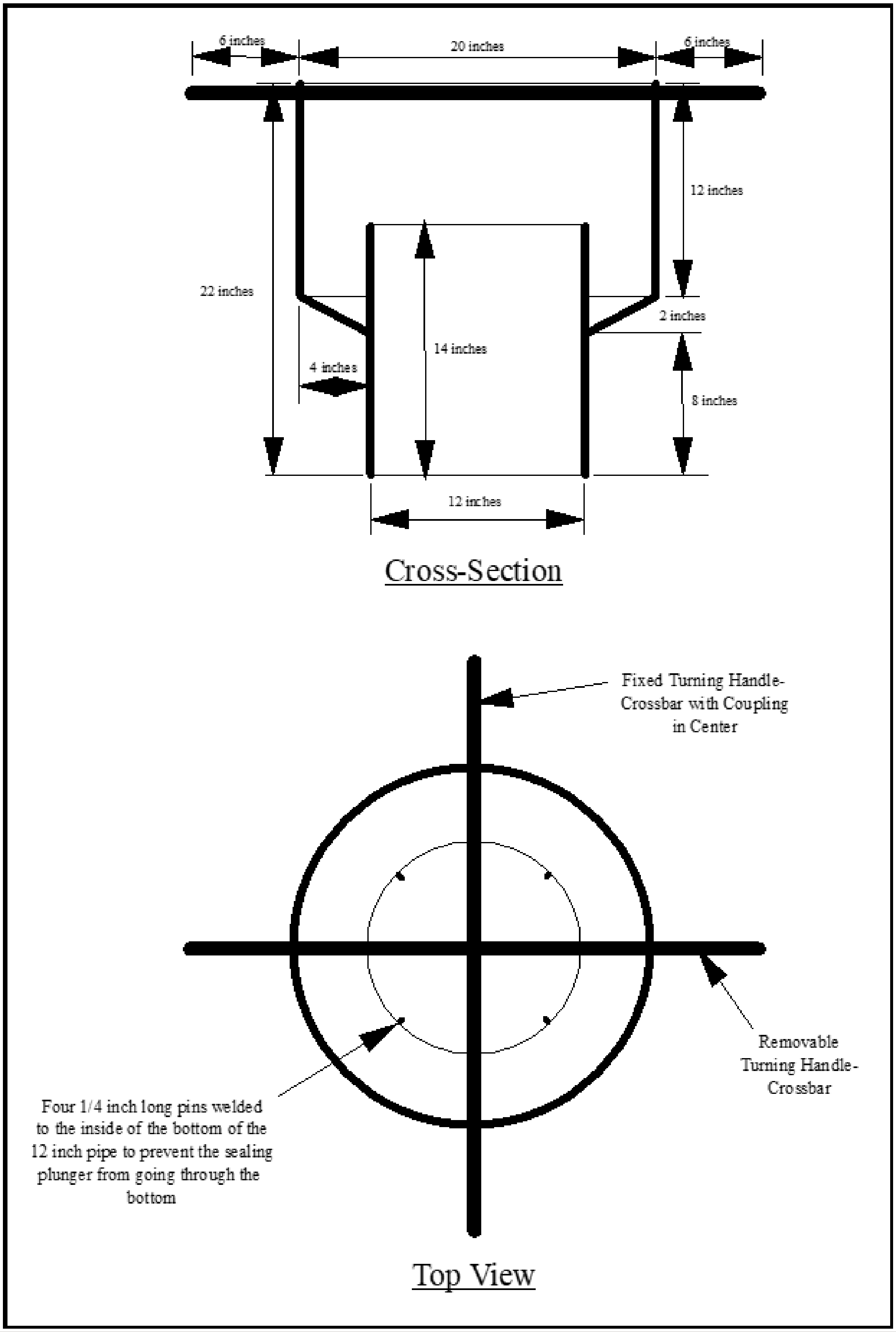


Figure 2-1 Schematic of 12-Inch Diameter Substrate Sampler, Modeled after the Original 6-Inch Diameter Sampler Developed by McNeil and Ahnell (1964).

2.1.2 Aquatic Macroinvertebrate Sampling

Macroinvertebrate sampling was conducted for the Madison River Flushing Flow program in 1996-1997, 2002, and 2007. During this same time period, macroinvertebrates were also collected for the Madison/Missouri Water Quality program, at seven sites in the Madison River (Table 2-1). Beginning in 2008, macroinvertebrate sampling for the Madison/Missouri Water Quality and the Madison River Flushing Flow programs were consolidated. Both studies are improved by implementation of a consistent sampling design and development of a more comprehensive database.

Table 2-1 Period of Record for Madison River Aquatic Macroinvertebrate Monitoring Sites.

Madison River Stations	Water Quality Program	Madison River Stations
YNP	1995-2022	
HWY 287	1996-2008	
Hebgen	1995-2022	
Kirby Ranch	2008-2022	1996-97, 2002, 2007
Ennis Campground	1997-2022	1996-97, 2002, 2007
Madison Powerhouse	1995-2022	
Norris Bridge	2000-2006, 2008-2022	1996-97, 2002, 2007
Greycliff Fishing Access	2000-2006, 2008-2022	1996-97, 2002, 2007

Five macroinvertebrate samples are collected at each site using the modified kick-net procedure described by Hauer et al. (1991). This sampling technique is standard for NWE studies on the Madison and Missouri rivers (Northwestern 2021). To better characterize the benthic fauna at each site, sampling effort was partitioned among wadeable habitats at each site. Four samples were stratified by depth (shallow/deep) and water velocity (slow/fast). The fifth sample was taken from the most abundant (typical) habitat type at the site.

Each sample is taken with a kick-net with a 0.5 m by 0.2 m rectangular opening and 800-µm mesh netting. Within a selected habitat, a sampling grid (delineating a 0.25 m^2 area) is randomly placed on the stream. Samples are collected in the substrate by hand scrubbing cobbles and vigorously kicking and agitating smaller substrate particles within the 0.25 m^2 plot while holding the kick net directly downstream. The contents of the net are then transferred to labeled containers and preserved in 95% ethanol. Surface substrate size composition within the sampled plot is visually estimated. In addition, water depth is recorded and mean water column velocity is measured with a current meter.

Processing of the benthic macroinvertebrate samples is consistent with the techniques and procedures used for NWE annual macroinvertebrate monitoring on the Madison and Missouri rivers (McGuire 1999), using the EPA Rapid Bioassessment Protocols (Plafkin et al. 1989) to obtain a 300-organism fixed-count subsample. The use of a fixed-count subsample standardizes kick sample data and allows quantitative comparisons to a reference condition (Barbour and Gerritsen 1999).

Macroinvertebrates are identified to taxonomic levels specified in the Montana Department of Environment Quality (MDEQ) Rapid Bioassessment Protocols SOPs (MDEQ 1998) using the most recent published taxonomic literature.

2.1.3 Hydrologic Data

Daily streamflow data and annual instantaneous peak flow data are obtained from the U.S. Geological Survey (USGS). Streamflow data are obtained from the USGS gages located on the Madison River below Hebgen Lake (Gage No. 06038500), at Kirby Ranch (USGS Gage 06038800), and below Ennis Lake (Gage No. 06041000).

2.1.4 Redd Surveys

Redd surveys were conducted at all four sites in the spring (Rainbow Trout) and in the fall (Brown Trout). Redd surveys were monitored according to the following schedule:

- Kirby Ranch
  - Spring – 2013, 2015, 2016, 2017, 2019, 2020, 2021, 2022
  - Fall – 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, and 2021
- Ennis Campground
  - Spring – 2013, 2015, 2016, 2017, 2019, 2020, 2021, and 2022
  - Fall – 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, and 2021
- Norris Bridge
  - Spring – 2013, 2015, 2016, 2017, 2019, 2020, 2021, and 2022
  - Fall – 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, and 2021
- Greycliff Fishing Access
  - Spring – 2013, 2015, 2016, 2017, 2020, 2021, and 2022
  - Fall – 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, and 2021
- Burnt Tree

- Spring – 2021
- Fall – 2020, 2021

- Channels Ranch
  - Fall – 2020, 2021
  - Spring – 2021

The location of each redd was recorded with GPS. The dimensions of each redd (depth, length, and width) were measured.

2.2 Data Analysis

The channel morphology, sediment, macroinvertebrate, streamflow, and water temperature data are collected annually to characterize conditions and analyzed every five years to compare with flushing flow releases in the upper Madison and/or lower Madison reaches to assess impact and effectiveness. The methods for performing these analyses are described in this section.

2.2.1 Sediment Characteristics

Particle grain size distributions are determined based on dry weight using sieve analyses. The following sieve sizes are used:

Sieve Size	Sieve Size	Sieve Size
5″ (127 mm)	3/8″ (9.5 mm)	#10 (2.00 mm)
4″ (102 mm)	5/16″ (7.9 mm)	#20 (0.84 mm)
2 ½″ (63.5 mm)	¼″ (6.35 mm)	#35 (0.50 mm)
1 ¼″ (31.8 mm)	#4 (4.75 mm)	#230 (0.062 mm)
5/8″ (15.9 mm)	#5 (4.00 mm)	

The grain size distribution of each sample is analyzed to determine five characteristic grain sizes ($D_{15.9}$, D_{25}, D_{50}, D_{75}, and $D_{84.1}$). The geometric mean diameter (Dg), sorting coefficient (So), and Fredle Index (Fi) is then determined from the following equations:

$$Geometric\ mean\ diameter = D_g = \sqrt{D_{15.9} * D_{84.1}}$$

$$Sorting\ Coefficient = S_o = \sqrt{\frac{D_{25}}{D_{75}}}$$

$$Fredle\ index\ =\ F_i\ =\ \frac{D_g}{S_o}$$

The percentage of each sample finer than 0.84 mm and 6.4 mm is also determined.

Three statistical analyses were conducted to compare the recent data collected at Channels Ranch and Burnt Tree with the other Upper Madison River sites and to evaluate the long-term trends in percent fines at the Upper and Lower Madison River sites in conjunction with the flushing flow program.

The four Upper Madison River sites (Ennis, Kirby, Channels Ranch, and Burnt Tree) were compared for the overlapping period of record (2020-2022) using Analysis of Variance (ANOVA) and Tukey multiple comparisons to evaluate if the recent data collected at Channels Ranch and Burnt Tree were different from the Ennis and Kirby sample locations. The purpose of this comparison was to evaluate whether the sediment data from the Channels Ranch and Burnt Tree locations were duplicative of the data already being collected at Ennis and Kirby and could be discontinued from further monitoring efforts. Data were evaluated for approximate normality and initial results showed that residuals were skewed (Shapiro-Wilks p-value for 0.84mm = 0.004 and for 6.4 mm = 0.014), so a logit transformation was used to yield an approximate normal distribution (Shapiro-Wilks p-value for 0.84mm= 0.35 and for 6.4 mm = 0.28). The logit transformation was calculated as a function of the natural log of the proportion of fines (i.e., $\ln(p/(1-p))$, p= percent fines/100).

Differences between the longer-term records for the Upper and Lower Madison River sites and differences in the percent fines measured during flushing versus non-flushing years were investigated using linear models. The logit transformation was applied to the percent fines data to approximate normality in residuals. After transformation, several outliers (one for <0.84 mm and five for <6.4 mm) were still evident, so models were fit both with and without these values. The model results were consistent with and without the outliers. Initial exploratory models indicated similar levels of linear increasing trends for the 0.84 mm metric, but potential differences for the 6.4 mm metric. Therefore, both linear models included a factor for site, linear trend, and a factor for with and without flushing flow (i.e., FF=No/Yes), and interaction between trend and flushing flow. An additional factor for interaction between trend and site was included for the 6.4 mm model. The years prior to 1998 were not included in these models. Initial exploratory models identified signs of autocorrelation among years (i.e., a plot of year vs residuals had a cyclical pattern), so a random effect for year was added to the model. Models were fit using package nlme (Pinheiro and Bates 2022) in R (R Core Team 2022).

Two model comparison methods were used: Akaike's information criteria (AIC, corrected for sample size), and likelihood ratio F-tests. The AIC criteria is used to compare model likelihoods with penalties for increased complexity and smaller sample sizes. Of the models tested, the model with the lowest AIC is said to be the model with the most information or highest model weight. If the model with the second-lowest AIC is more than 2 units different, then the weight of evidence for the top model is roughly twice the weight of the second-best model (Burnham and Anderson 2002). Differences of less than 2 units between models is considered weak evidence for the top model while differences larger than 2 are considered strong evidence.

A third investigation explored whether higher Madison River peak flows resulted in lower levels of percent fines at each site. This investigation used the linear model fit for site and year and evaluated whether an additional predictor for continuous or two-level factor for peak flow described additional variability in the data. Models using only the predictor for peak flow were also fit. Models were fit separately for the Upper River sites (compared to peak flow at USGS Gage 06038800 Madison River at Kirby Ranch) and the Lower River sites (compared to peak flow at USGS Gage 06041000 Madison River bl Ennis Lake nr McAllister).

2.2.2 Aquatic Macroinvertebrates

The total number of macroinvertebrates per sample is extrapolated from the percentage of the sample used to obtain approximately 300 organisms. A total of 30 metrics were used to quantify community structure, taxonomic composition, and functional feeding groups. Unless explicitly stated, all metric values were based on 300-count subsamples. The following metrics and biotic indices were calculated for each invertebrate sample collected in the Madison River:

Community Structure Metrics

Community Density – Extrapolated from sample counts to estimated number per 1.0 m^2. Provides a relative measure of macroinvertebrate community standing crop. Kick-net samples are considered semi-quantitative because burrowing organisms and those tightly attached to substrates tend to be under-collected. Nevertheless, kick-net sampling can provide approximate density estimates for each site.

Taxa Richness – The number of different types, or taxa, of invertebrates occurring in a given ecosystem or sample. Taxa richness generally increases with increasing water quality and/or habitat diversity and is used as a relative measurement of the health of the benthic invertebrate community. The mean taxa richness for the five samples at each site and the total taxa richness for the site are reported.

Shannon-Weaver Diversity Index – A commonly used index of ecological diversity (Pielou 1966; Ricklefs 1979) that combines the number of taxa present in a sample with the relative abundance of taxa in that sample. The Shannon-Weaver Index (Weber 1973) is calculated as follows:

$$H = -\sum p_i \, \boldsymbol{ln} \, p_i$$

where p_i is the proportion of each taxa in a sample. This diversity index increases as the number in a sample increases and the distribution of taxa in a sample is more uniform. The maximum value of H for a sample is a function of the number of taxa in a sample and the uniformity of the taxa distribution, where common taxa contribute to a relatively high fraction of this index, and rare taxa contribute a relatively low fraction of this index.

Percent Relative Abundance of Dominant Taxon – The percent contribution of the numerically dominant taxon to the total number of invertebrates present in a sample. A community dominated by a single species may indicate environmental stress.

<u>Community Composition Metrics</u>

EPT Richness – The number of distinct taxa within the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). The EPT Richness index summarizes taxa richness within the insect orders containing many pollution-sensitive species. EPT Taxa Richness values generally increase with increasing water quality. Both mean and total EPT taxa richness values were determined.

Percent Relative Abundance of EPT – The percent abundance of the insect orders Ephemeroptera, Trichoptera, and Plecoptera in a sample.

Percent Relative Abundance of Chironomidae – The insect family Chironomidae (midges) includes several highly tolerant species (Lenat 1983). A disproportionate number of Chironomidae may indicate environmental stress.

Ratio of Baetidae to Ephemeroptera – The percent contribution of the family Baetidae to the total abundance of mayflies. The family Baetidae includes many of the most pollution tolerant mayflies (Hubbard and Peters 1978). Environmental stress is often indicated when baetids comprise most of the mayfly fauna.

Ratio of Hydropsychinae to Trichoptera – The percent contribution of the caddisfly subfamily Hydropsychinae to total caddisfly abundance. Members of this subfamily (primarily Hydropsyche, Ceratopsyche, and Cheumatopsyche) are generally more tolerant of pollutants than most caddisflies (Harris and Lawrence 1978). Environmental stress is often indicated when these are the predominant caddisflies at a site.

Ordinal Relative Abundance – The percent relative abundances of six major taxonomic groups: Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Diptera, and Non-insects. The relative abundance of major taxonomic groups provides information on a stream community's structure and the relative contribution of the populations to the total fauna (Barbour et al. 1999).

Functional Feeding Group Relative Abundance – Each aquatic invertebrate taxon was placed in one of five functional food groups, which identify its trophic status (i.e., food requirements). The functional food group categories were: 1) scapers/grazers, which feed upon attached algae or periphyton; 2) shredders, which feed upon coarse particulate organic matter (CPOM) such as leaves; 3) collectors, which feed upon fine particulate organic matter (FPOM); 4) filter feeders, which feed upon FPOM within the water column; and 5) predators. Invertebrate functional food groups were taken from MDEQ's RBP (MDEQ 1998).

<u>Biotic Indices</u>

Modified Hilsenhoff Biotic Index – The modified Hilsenhoff Biotic Index (HBI; Hilsenhoff 1987) is used to portray the overall pollution tolerance of the benthic invertebrate community as a single value (Plafkin et al. 1989). Tolerance values range from 0 to 10, with 0 describing very little or no tolerance to organic pollution, and 10 describing very high tolerance to organic pollution. The HBI is calculated as:

$$HBI = \frac{\sum x_i t_i}{n}$$

where x_i is number of individuals within a given taxon, t_i is the tolerance value for this taxon, and n the total number of organisms in a sample. Tolerance values used for this study were obtained from MDEQ's RBP (MDEQ 1998).

Metals Tolerance Index – (McGuire 1993) Metals tolerance values range from 0 to 10, with 0 describing low tolerance to metals pollution, and 10 describing very high tolerance to metals pollution. The calculation of this index is based on Hilsenhoff's biotic index and is calculated as:

$$MTI = \frac{\sum_{i=1}^{n} x_i \ t_i}{n}$$

where x_i is number of individuals with a given taxon, t_i is the metals tolerance value for this taxon, and n the total number of organisms in a sample. Tolerance values used for this study were obtained from MDEQ's RBP (MDEQ 1998).

<u>Sediment Indices</u>

Six metrics have been used to evaluate sediment/ macroinvertebrate relationships in the Madison River:

Number of Sediment-Tolerant Taxa

Number of Sediment- Intolerant Taxa

Relative Abundance (%) of Sediment-Tolerant Taxa

Relative Abundance (%) of Sediment-Intolerant Taxa

Estimated Percentage Surface Fines (<0.06 mm)

Estimated Percentage of Sand (<2 mm)

These metrics are based on differential tolerances of stream-dwelling macroinvertebrate taxa to fine sediments. Sediment tolerance and optimal values have been calculated for many stream dwelling macroinvertebrate taxa found in the western United States by Yuan (2006), Huff et al. (2006), and Relyea et al. (2001). Taxa richness and relative abundance metrics are categorical classifications (tolerant/intolerant) and use pooled data (all replicates combined). Estimates of surface fines and sand are calculated based on taxa optima using the formula:

$$\textit{Percent substrate} = (\sum x_i \, t_i) / n$$

where x_i is number of individuals within a given taxon, t_i is the optimal value for this taxon, and n the total number of organisms in a sample for which optima have been established.

Optimum fine sediment (< 0.06 mm) values are from Huff et al. (2006) while sand substrate (< 2 mm) optima are from Yuan (2006). Application of these metrics to the Madison River is exploratory. These data establish a baseline for the Madison River, but macroinvertebrate-based criteria have not been developed.

<u>Multimetric Bioassessment</u>

Missouri-Madison River Multimetric Assessment (MMRMA) – The multimetric approach quantifies attributes of community composition, structural, and functional organization into a single number estimate of biological integrity (Barbour et al. 1995). This index is a mathematical combination of six metrics that measures the overall response of the community to environmental alteration and stressor conditions (Karr et al. 1986). The most appropriate multimetric assessment for this investigation was developed from NWE annual biomonitoring on the Missouri and Madison rivers. The metrics and rating criteria for estimating biointegrity (Table 2-2) were developed using Madison and Missouri River data collected from 1994-1998 (McGuire 1999). The number of macroinvertebrate taxa (distinct types) is a reliable measure of overall environmental condition for most streams (Hellawell 1978; Plafkin et al. 1989). Consequently, the multimetric assessment is heavily weighted with species richness metrics (total taxa richness, EPT richness, and Shannon diversity). Community composition is characterized by EPT richness, and the relative abundances (percentages) of EPT and chironomids in the sample. The Biotic Index is based on the indicator organism approach to water quality assessment and was developed to measure organic pollution. The MMRMA score ranges 0 to 30 and is reported as a percentage of the possible maximum score, ranging from 0 to 100%. High scores (> 75%) are characteristic of minimally impacted stream reaches.

Table 2-2 Metrics and Criteria for the Missouri-Madison River Multimetric Assessment (MMRMA) used to assess trends in Madison and Missouri River Benthic Macroinvertebrate Assemblages McGuire (1999).

Metric	Scoring Criteria					
	5	4	3	2	1	0
Taxa richness	>32	32-28	27-23	22-18	17-13	<13
EPT richness	>16	16-13	12-9	8-5	4-1	0
Shannon diversity	>3.3	3.3-3.1	3.0-2.8	2.7-2.5	2.4-2.2	<2.2
Biotic index	<4.1	4.1-4.6	4.7-5.2	5.3-5.8	5.9-6.4	>6.4
% EPT	>70	70-61	60-51	50-41	40-31	<31
% Chironomidae	<21	21-25	26-30	31-35	36-40	>40

Assessment score calculated as the sum of metric scores divided by the maximum possible score.
All values are per 300 organism subsample.

2.2.3 Streamflow Analysis

Annual instantaneous peak flows and annual maximum three-day averaged flows are determined for the Madison River below Hebgen Lake (Gage No. 06038500) and below Ennis Lake (Gage No. 06041000). The annual maximum three-day averaged flow is particularly meaningful with regard to flushing flows in the lower Madison (R2 2000).

2.2.4 Redd Surveys

The total number of redds was determined for Kirby Ranch, Ennis Campground, Norris Bridge, Greycliff Fishing Access, Burnt Tree, and Channels Ranch. Annual total redd counts were determined for the spring and fall monitoring sessions.

3.0 REVIEW OF MONITORING RESULTS

This section presents the results of previous channel morphology surveys along with current sediment sampling, aquatic macroinvertebrate sampling, sediment/macroinvertebrate correlation analyses, streamflow assessment, and water temperature evaluations.

3.1 Sediment Characteristics

3.1.1 Sediment Results

Previous channel morphology and sediment characteristics data no longer collected are provided in the 2018 Report on the flushing flows of the Madison River for the 2013 through 2017 period (R2 2018). This section includes a comparison of upper and lower river sites sediment data collected between 2018 through 2022 with the previous data. The upper river sites include Kirby Ranch and Ennis Campground while the lower river sites include Norris Bridge and Greycliff Fishing Access sites. Trends in percent fines less than 0.84 mm and less than 6.4 mm, Fredle Index, and geometric mean grain size are shown in Figure 3-1, Figure 3-2, Figure 3-3, and Figure 3-4, respectively. The Burnt Tree and Channels Ranch data are not included in the summary of the Upper Madison River sites since these data have only been collected for 2020-2022. A summary comparing the median sediment characteristics for the Upper Madison River sites to the Burnt Tree and Channels Ranch sites for 2020-2022 is provided in Table 3-1. This table shows little variation between the new measurement locations (i.e., Burnt Tree and Channels Ranch) with the existing Upper Madison River sites (i.e., Kirby Range and Ennis Campground).

The percent fines less than 0.84 mm is important for assessing survival of the egg phase during incubation. An excessive quantity of sediment finer than 0.84 mm can reduce the permeability of a gravel matrix and potentially deprive the eggs in a redd of dissolved oxygen needed for survival. McNeil and Ahnell (1964) performed laboratory studies of gravel permeability and found that as percent fines less than 0.833 mm in the gravel increased, the permeability of the gravel matrix decreased. Kondolf (2000) compiled the results of previous investigations of embryo survival of Coho Salmon and Rainbow Trout. The percent fines less than 0.83 mm was determined for the 50% survival level. It was found that 50% survival was associated with percent fines ranging from 7.5% to 21% with a median level of 12%. The median percent fines less than 0.84 mm are 7.5 percent in the Upper Madison River and 12.7 percent in the Lower Madison River (Figure 3-1). The quality of spawning gravel, as measured by percent fines less than 0.84 mm is higher in the Upper Madison River and lower in the Lower Madison River.

The percent fines less than 6.4 mm is important for assessing survival of the alevin phase during incubation. Alevins need space within the gravel matrix to move and eventually emerge from the substrate. An excessive quantity of sediment finer than 6.4 mm can block the interstitial spaces within the gravel matrix and potentially trap the alevins within the substrate, preventing their emergence. Kondolf (2000) also compiled the results of previous investigations of survival to emergence of Chinook Salmon, Cutthroat Trout, Kokanee, Rainbow Trout, and steelhead. The percent fines less than 6.35 mm was determined for the 50% survival level. It was found that 50% survival was associated with percent fines ranging from 15% to 40%, with a median level of 30%. The median percent fines less than 6.4 mm are 19.9 percent in the Upper Madison River and 30.8 percent in the Lower Madison River (Figure 3-2). The quality of spawning gravel, as measured by percent fines less than 6.4 mm is higher in the Upper Madison River and lower in the Lower Madison River.

Lotspeich and Everest (1981) determined survival-to-emergence for Coho Salmon and steelhead as related to the Fredle index using data reported by Phillips et al. (1975). Results of the study indicate that 50% survival-to-emergence is associated with a Fredle index of about 2.7 mm. The median Fredle Index values are 6.9 mm in the Upper Madison River and 2.3 mm in the Lower Madison River (Figure 3-3). The quality of spawning gravel, as measured by the Fredle Index is higher in the Upper Madison River and lower in the Lower Madison River.

Shirazi and Seim (1979) collected and analyzed the results of embryo survival studies of Coho Salmon, Cutthroat Trout, Sockeye Salmon, and steelhead. Results of the study indicate that 50% embryo survival would be associated with a geometric mean diameter of 10.8 mm. The median Geometric Mean Diameter values are 15.3 mm in the Upper Madison River and 7.7 mm in the Lower Madison River (Figure 3-4). The quality of spawning gravel, as measured by the Geometric Mean Diameter is higher in the Upper Madison River and lower in the Lower Madison River.

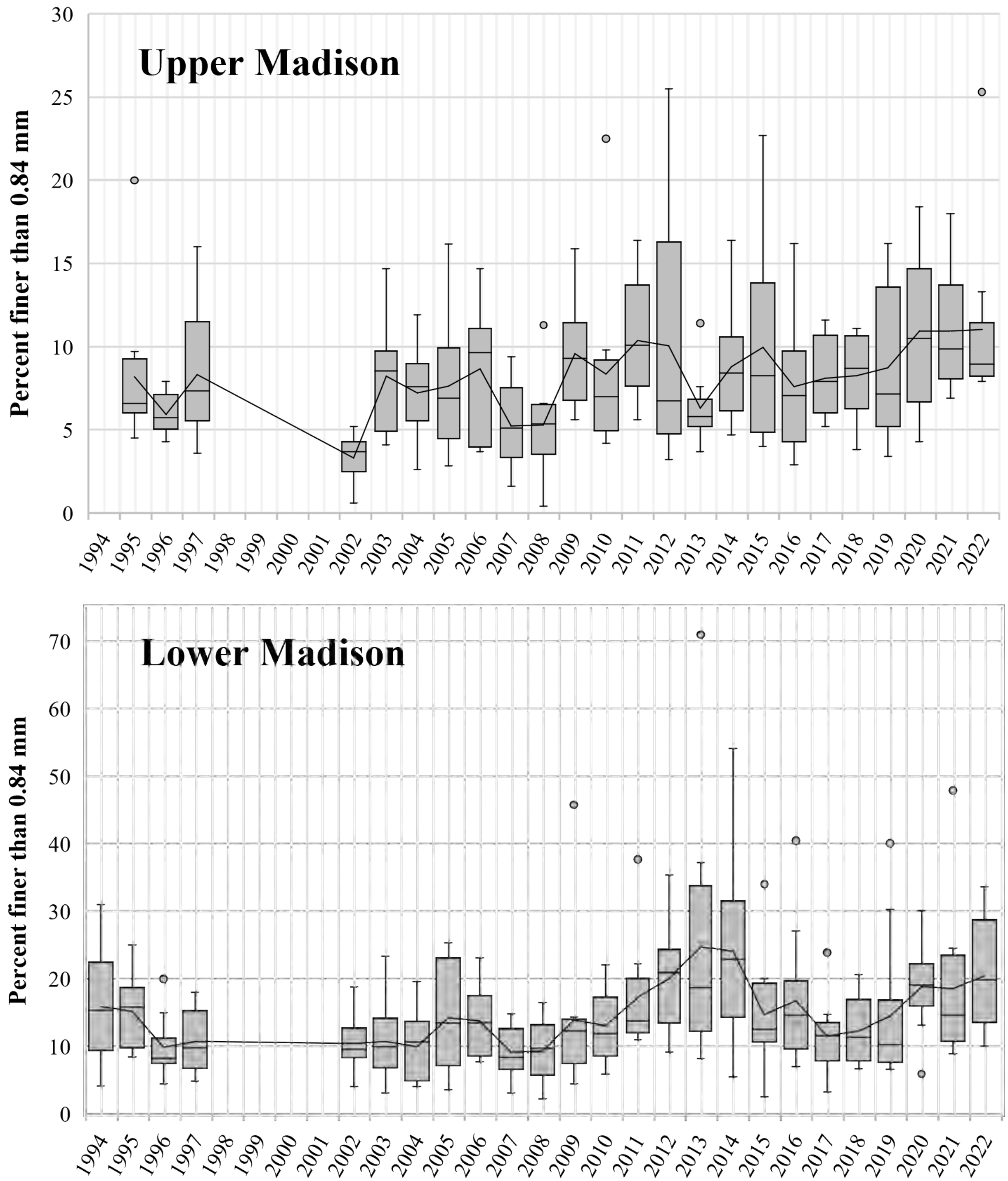
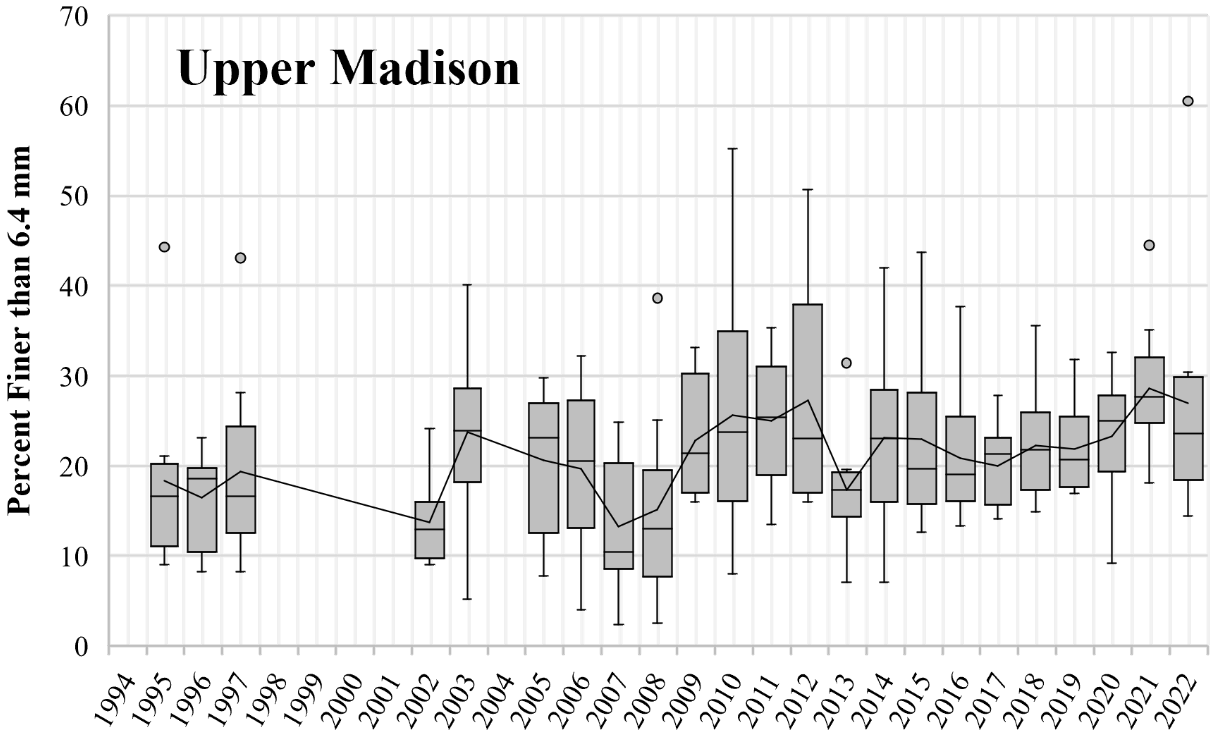


Figure 3-1 Trends in Percent Fines Less than 0.84 mm of Spawning Gravel Samples Collected from the Upper and Lower Reaches of the Madison River.



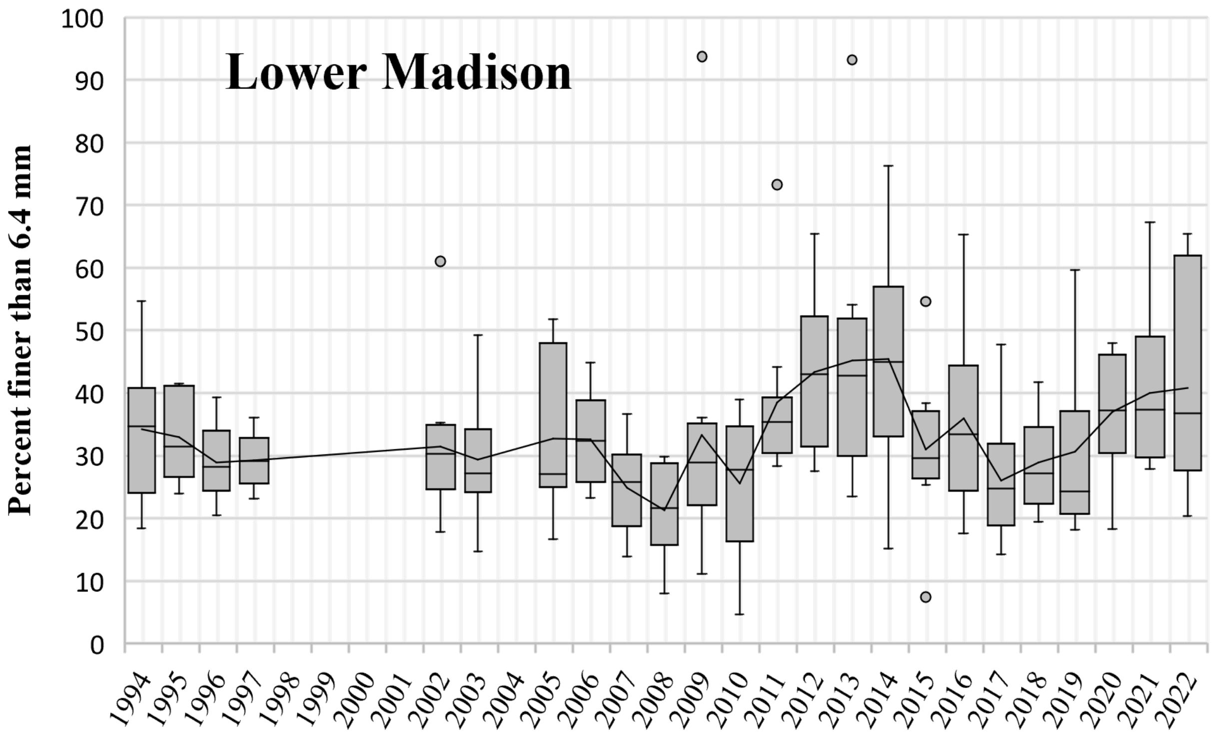


Figure 3-2 Trends in Percent Fines Less than 6.4 mm of Spawning Gravel Samples Collected from the Upper and Lower Reaches of the Madison River.

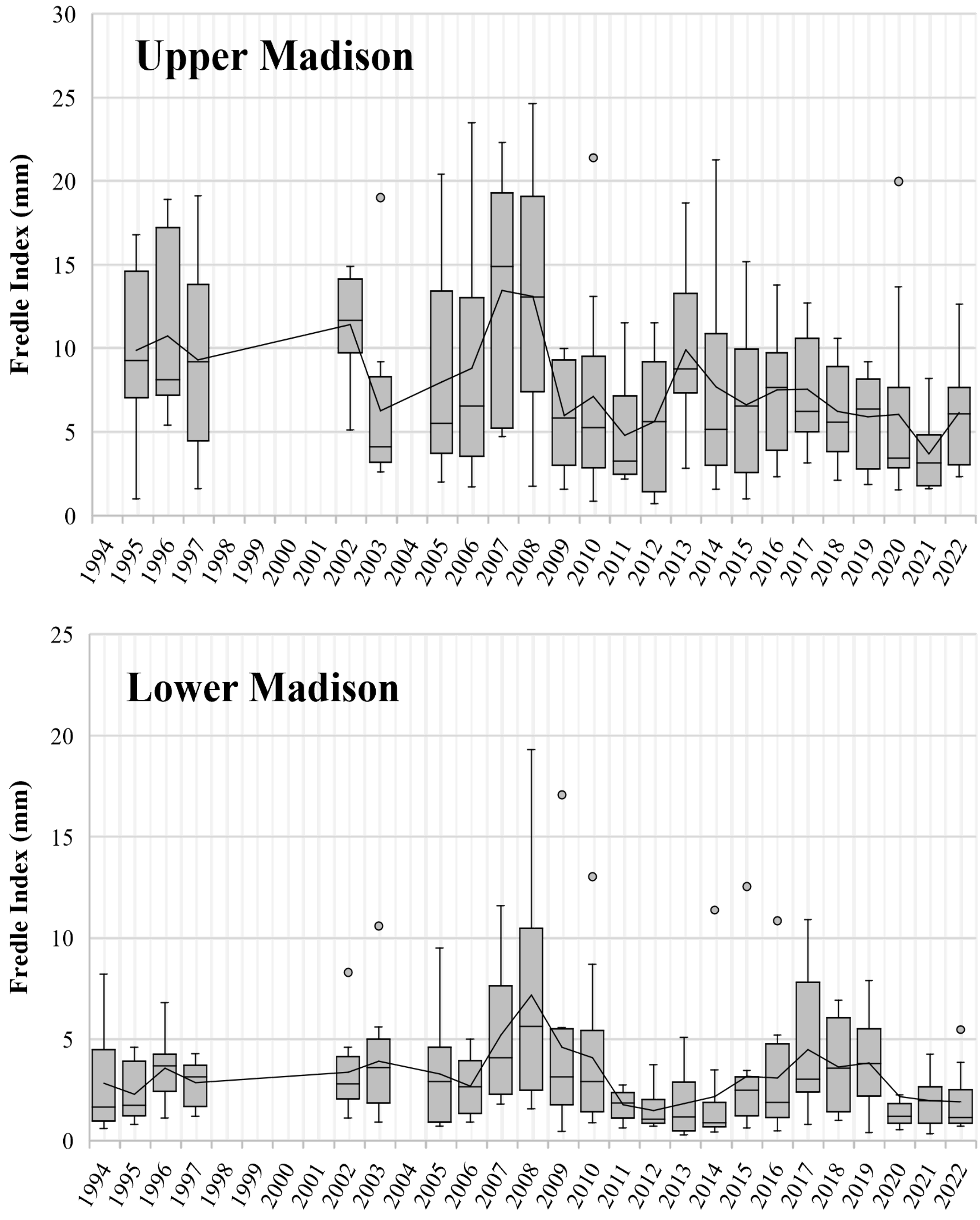
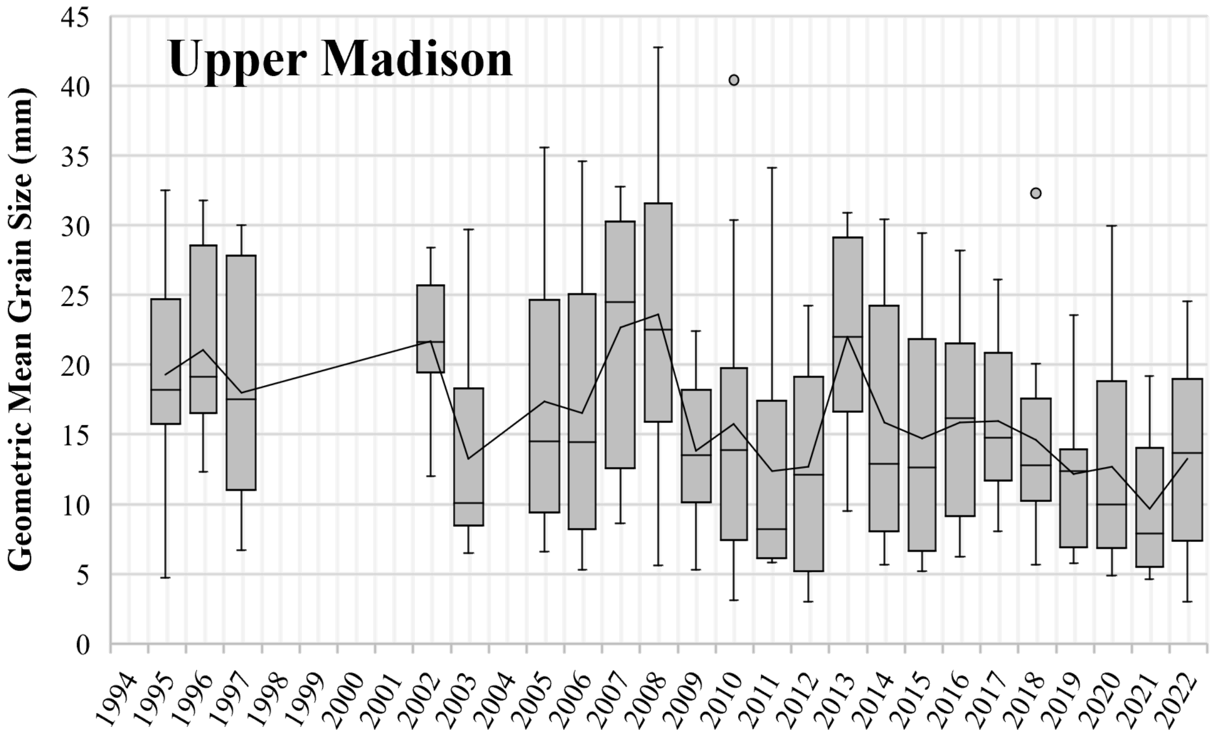


Figure 3-3 Trends in the Fredle Index Computed from Spawning Gravel Samples Collected from the Upper and Lower Reaches of the Madison River.



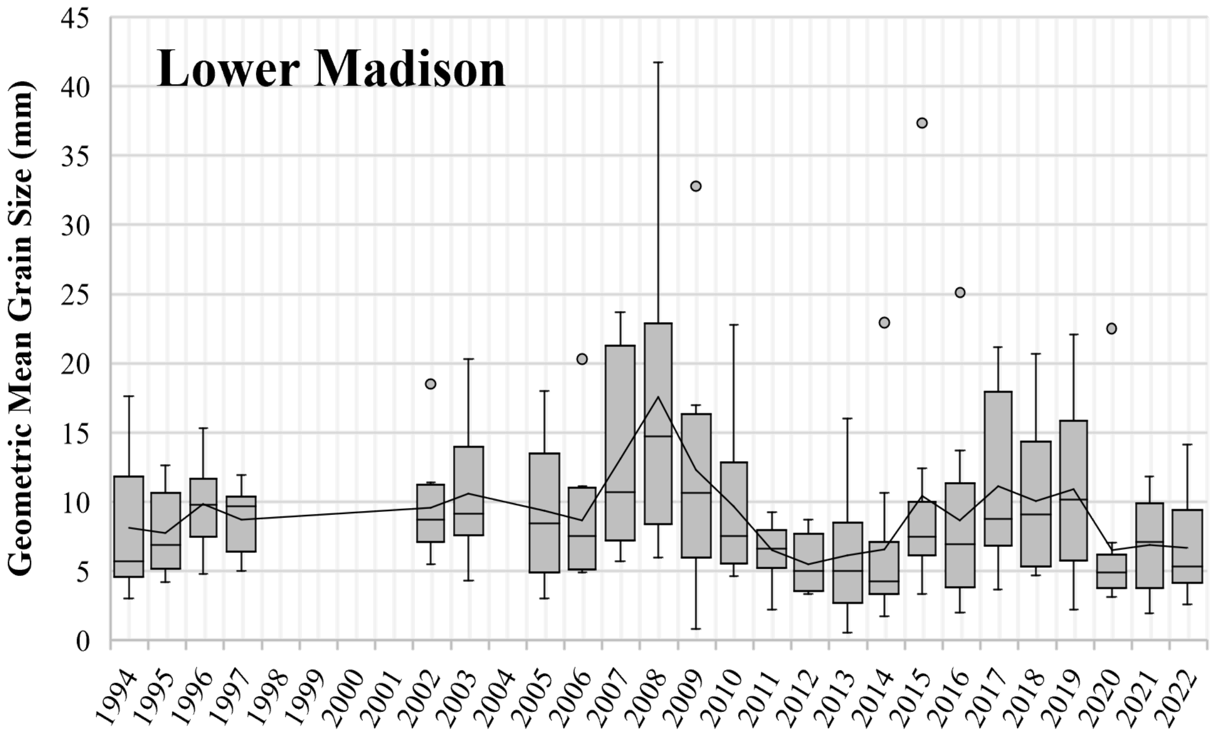


Figure 3-4 Trends in the Geometric Mean Grain Size of Spawning Gravel Samples Collected from the Upper and Lower Reaches of the Madison River.

Table 3-1 Comparison of Median Sediment Characteristics between the Upper Madison River Sites with Channels Ranch and Burnt Tree sites for 2020 through 2022.

Year/Location	% Finer than 0.84mm	% Finer than 6.4 mm	Fredle Index (mm)	Geometric Mean Grain Size (mm)
2020				
Upper Madison	10.5	25.0	3.4	10.0
Channels Ranch	7.5	22.4	4.9	14.7
Burnt Tree	10.2	24.3	4.0	10.7
2021				
Upper Madison	9.9	27.7	3.1	7.9
Channels Ranch	8.6	23.5	4.8	11.4
Burnt Tree	8.8	24.9	3.8	11.2
2022				
Upper Madison	9.0	23.6	6.1	13.7
Channels Ranch	7.2	17.7	8.4	16.7
Burnt Tree	9.4	27.0	3.5	10.9

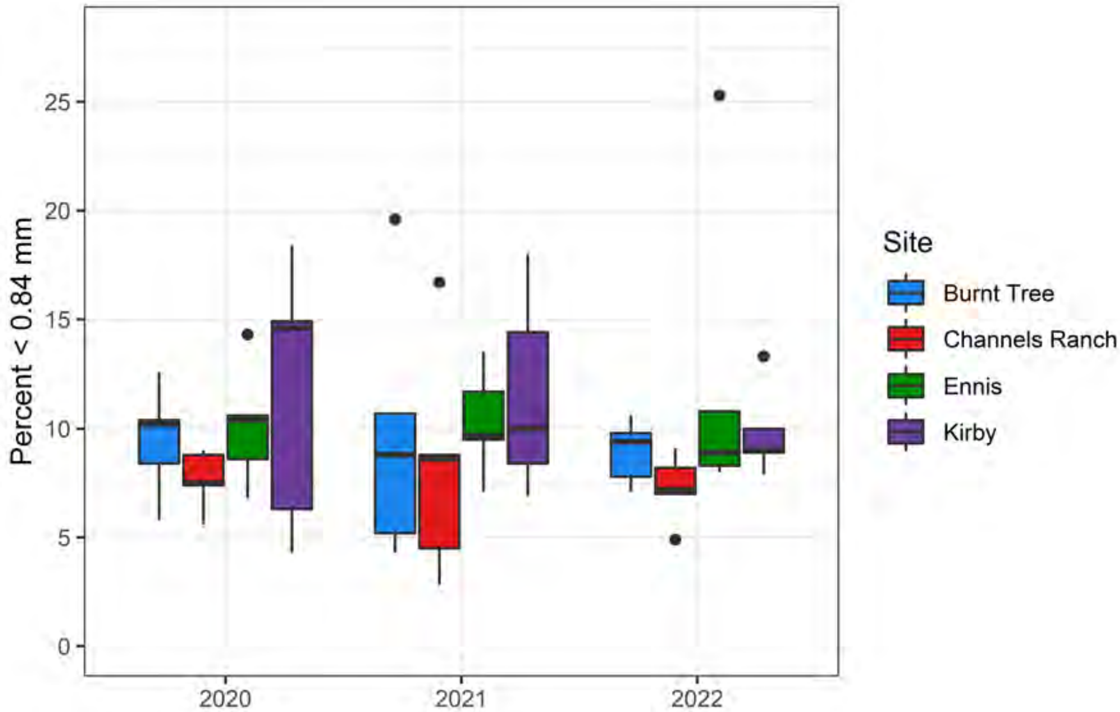
3.1.2 Sediment Statistical Analysis

Results of the three statistical analyses conducted on the percent fines data are provided below. The results from the comparison of the Channels Ranch and Burnt Tree data with the other two Upper Madison River sites are presented first followed by the analysis of the percent fines data in conjunction with the flushing flow program.

The comparison of the four upper Madison River sites showed weak evidence of differences among sites (Table 3-2; p-value = 0.07). The ANOVA was followed by Tukey multiple comparisons. The Tukey tests indicated weak evidence that the percent finer than 0.84 mm are lower at Channels Ranch than that at Ennis (p=0.064) and Kirby (p = 0.071), and that the percent finer than 6.4 mm are lower at Channels Ranch and Kirby than at Ennis (p = 0.066, and p = 0.047, respectively). These results suggest the evidence is weak that there are any differences among sites, and any potential differences for the two added sites are showing less percent fines than the regularly sampled sites of Kirby and Ennis. Box plots comparing the percent files at the four locations for the 2020-2022 period are provided in Figure 3-5.

Table 3-2 Results of the ANOVA Comparing the Four Upper Madison River Sites (Ennis, Kirby, Channels Ranch, and Burnt Tree). Data were Transformed using a Logit Function.

Predictors	Degrees of Freedom	Sum of Squares	Mean Squared Error	F Value	p-value
% Finer than 0.84mm					
Site	3	1.5	0.51	2.49	0.071
Year	2	0.0039	0.0020	0.0095	0.99
Site: Year Interaction	6	0.13	0.022	0.11	1.0
Residuals	48	9.9	0.21		
% Finer than 6.4mm					
Site	3	1.9	0.64	2.9	0.044
Year	2	0.23	0.11	0.51	0.60
Site: Year Interaction	6	0.40	0.067	0.31	0.93
Residuals	48	10.6	0.22		



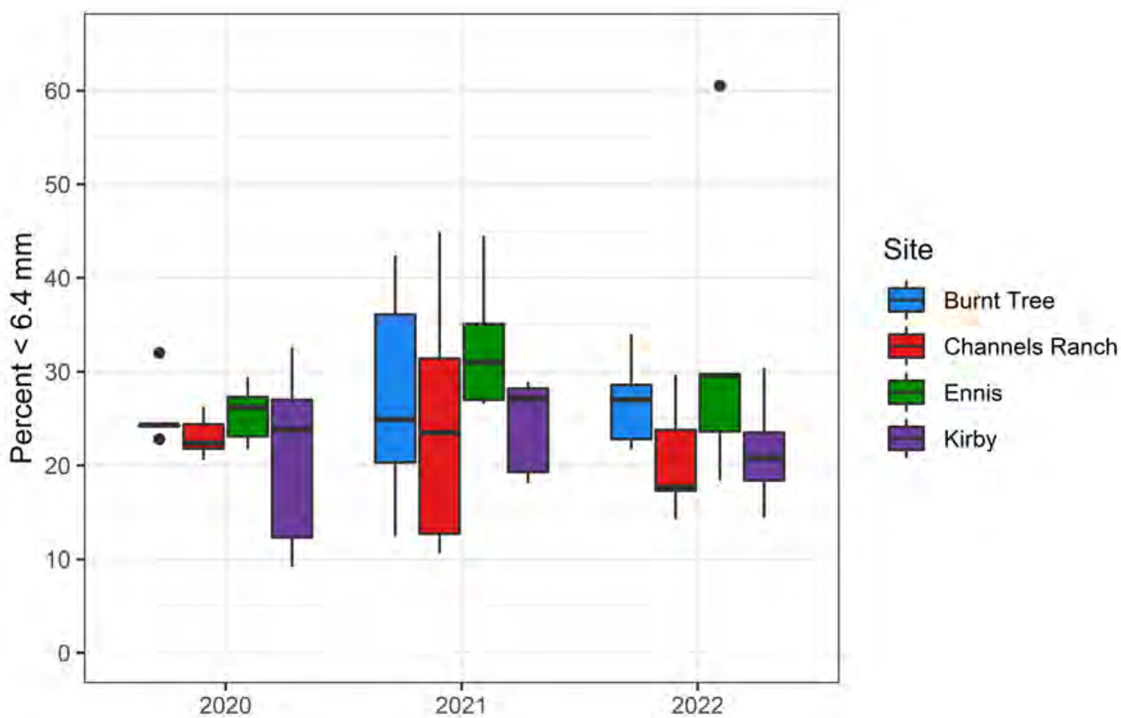


Figure 3-5 Boxplots Showing Distribution of Percent Fines Results of 0.84 mm (top) and 6.4mm (bottom) by Site and Year for Four Upper Madison River Sites Sampled in 2020-2022. The Box Represents the Interquartile Range and the Horizontal Line within the Box Represents the Median. Observed Data Outside 1.5* the Interquartile Range are Shown as Points.

Results from the evaluation of the long-term record at the four consistently sampled sites (i.e., Kirby, Ennis, Norris, and Greycliff) using a linear model (without outliers) are provided in Table 3-3 (F-test results). For both dependent variables (i.e., 0.84 and 6.4 mm), the F-test comparison indicates that there is a significant linear trend through time and there is an overall difference in percent fines among sites (i.e., sites have different intercepts, but the flushing flow factor and interactions were not significant. These results were consistent with the AIC comparisons (not shown), meaning that the model including only Site and Year (trend) had the lowest AIC and the second model in both cases had less than half of the weight of this best model. Thus, there was no evidence of lower percent fines or different trends in years with flushing flows.

The trend models fit for percent fines using the site and year variables are displayed in Figure 3-6. Overall, the models showed an increasing trend in percent fines at both the 0.84 and 6.4 level ($p = 0.0012$, $p = 0.018$, respectively). Tukey multiple comparisons showed differences in percent fines among sites between the Lower versus Upper Madison River sites (i.e., the Lower Madison River sites have higher percent fines than the Upper Madison River sites, $p<0.0001$). The model did not show a difference in percent fines at the 0.84mm level between the two Upper Madison River sites (Kirby and Ennis, $p = 0.53$) or the two Lower Madison River sites (Norris and Greycliff, $p=0.31$). There was also no difference at the 6.4mm level between the two Lower Madison River sites ($p = 0.99$), but there was a significant difference between the two Upper Madison River sites for percent fines less than 6.4mm ($p = 0.0003$).

Table 3-3 Linear Model F-Test Results. Data were Transformed using a Logit Function.

Predictors	Degrees of Freedom (numerator)	Degrees of Freedom (denominator)	F Value	p-value
% Finer than 0.84mm				
Site	3	392	39.9	<.0001
Year	1	18	14.8	0.0012
FF	1	18	0.054	0.82
Site: FF Interaction	3	392	0.92	0.43
% Finer than 6.4mm				
Site	3	328	40.1	<.0001
Year	1	15	7.0	0.018
FF	1	15	0.45	0.51
Site: FF Interaction	3	328	0.33	0.81
Site: Year Interaction	3	328	0.79	0.50

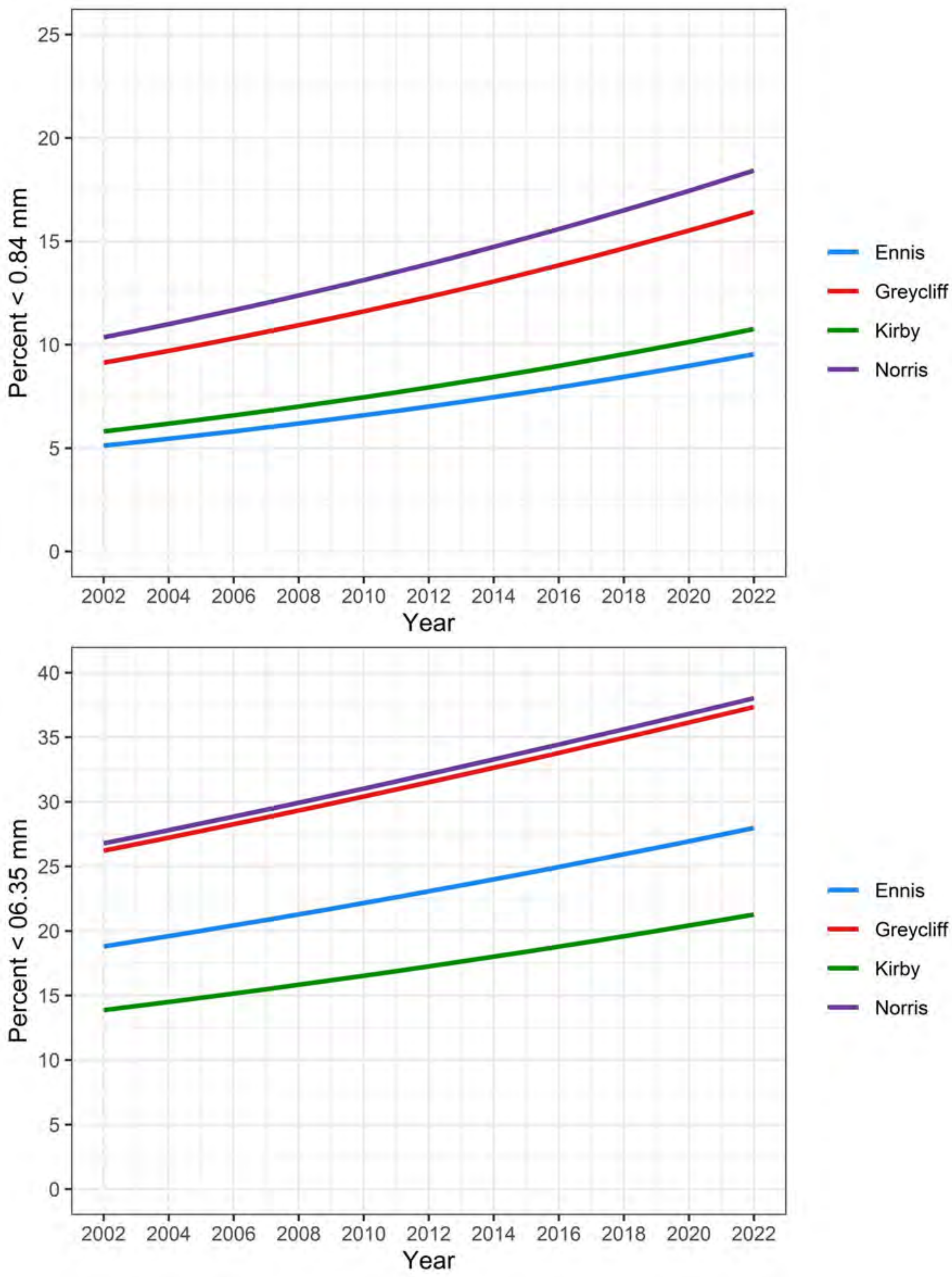


Figure 3-6 Model Fit to Percent Fines Less than 0.84 mm (top) and Less than 6.4 mm (bottom) Showing Increasing Trend through Time and Differences Among Sites. A Factor for Flushing Flow Years vs Non-Flushing Flow Years was not Significant.

The investigation of relationships between annual peak flow and percent fines was conducted separately for the Upper and Lower Madison River sites. Figure 3-7 shows the relationships between peak flow and the two transformed sediment metrics for the upper (top plots) and lower (bottom plots) Madison River sites. The lines are local regression smoothers meant to help see trends. From the plots in Figure 3-7, no obvious trends are identified, but statistical models were developed to investigate relationships further.

For the upper sites, peak flow at Kirby was included in the statistical model, either as a continuous variable or as a factor with years separated by low peak flows less than 3,000 cfs versus higher peak flows greater than 3,000 cfs. A peak flow value of 3,000 cfs was selected as a cutoff point between the low and high flow factor to provide approximately equal numbers of years in each category. The percent fines dependent variables were logit transformed to approximate normality. Models were fit both with and without potential outliers and differences are noted. For the 0.84 mm metric, the flow factor (low/high) predictor provided more information according to the AIC criteria. The original model showed significant interaction between the peak flow factor and site ($p < 0.03$), so models were fit separately for the two Upper Madison River sites (Table 3-4). For the Kirby site, peak flow was not a significant predictor (partial F-test p-value=0.8), and adding the factor to the model increased AIC (i.e., there is a decrease in evidence for that model). For the Ennis site with all data included, the result was the same: peak flow was not significant (partial F-test p-value = 0.26 and AIC increases with peak flow in the model). With the outlier (percent fines less 0.84 = 0.4) removed, the partial F-test p-value was 0.095, and the model including the peak flow factor had slightly lower AIC, indicating some (weak) evidence for the influence of peak flow. However, in this case, the model would predict higher percent fines less than 0.84mm in years with higher peak flows which is opposite of the intention of the flushing flow program.

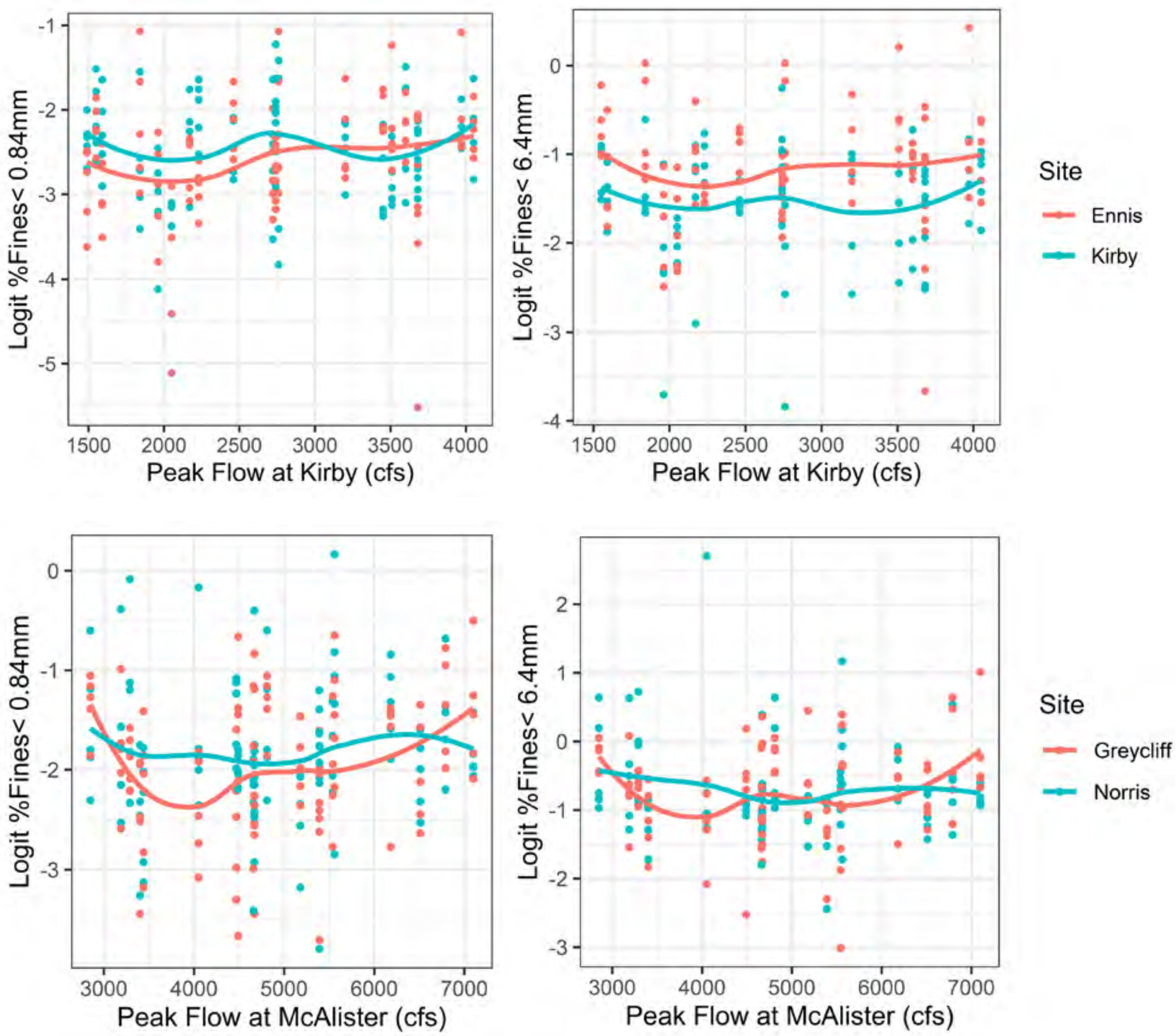


Figure 3-7 Scatter Plots showing Relationship Between peak Flow in the Madison River and Observed Percent Fines (logit-transformed). Plots on the left are for fines less than 0.84mm and plots on the right are for fines less than 6.4 mm. Overlaid lines are local regression smoothers for each site.

For percent fines less than 6.4 mm at the Upper Madison River sites, there was no evidence of an effect of the peak flow factor when the outliers (percent fines less than 6.4 mm <3) were retained, nor evidence of interaction between site and the peak flow factor. With the outliers removed, there was weak evidence of interaction (p-value=0.06), so the sites were modeled separately (Table 3-4). For the Kirby site, with the outliers removed, the partial F-test was not significant (p=0.14), but the model including the peak flow factor had slightly lower AIC, indicating some weak evidence for the influence of peak flows. For the Ennis site, adding the peak flow factor to the model provided no additional information (AIC increased by 0.59) and peak flow was not a significant predictor (partial F-test p = 0.31). Therefore, there may be a small benefit of flows greater than 3,000 cfs to percent fines less than 6.4 mm at the Kirby site, but the evidence for this influence is not strong with overlapping confidence intervals. For example, in 2012 the model prediction with the low-flow factor was 18.7% of the sediment was less than 6.4 mm (approximate 95% confidence interval 17 to 21%), and the model prediction with the high-flow factor was 16.5% of the sediment was less than 6.4 mm (approximate 95% confidence interval 14 to 19 percent.)

For the Lower Madison River sites, peak flow at McAllister was included as a continuous variable or as a factor with years separated by low peak flows less than 5,000 cfs and higher peak flows greater than5,000 cfs. A peak flow value of 5,000 cfs was selected as a cutoff point between the low and high flow factor to provide approximately half of the years in each category. For all lower river comparisons, the continuous predictor provided more information according to the AIC criteria. As before, there were several potential outliers for the 6.4mm metric, so models were run with and without these points, which had fines greater than 90% or less than 5%. There was no evidence of an effect of peak flow adding information to the sediment models for the Lower Madison River sites (Table 3-5). There was no interaction among sites and the peak flow variable, so sites were not tested separately. For the 0.84 metric, the F-test p-value for the peak flow effect was 0.48, and AIC increased by 1.8 with peak flow in the model. For the 6.4 mm metric (with outliers removed), the F-test p-value for the peak flow predictor was 0.99, and model AIC increased by 2 when the peak flow predictor was included in the model. The results were similar when outliers were included. There is no evidence of a relationship between peak flow at McAllister and percent fines observed in the Lower Madison River.

Table 3-4 Peak Flow Linear Model F-Test Results for the Upper Madison River Sites. Data were Transformed using a Logit Function.

Predictors	Degrees of Freedom (numerator)	Degrees of Freedom (denominator)	F Value	p-value
% Finer than 0.84mm				
Kirby				
Year	1	17	15.9	0.001
Peak Flow (PF) >3000	1	17	1.6	0.22
Year: PF Interaction	1	17	0.062	0.81

Predictors	Degrees of Freedom (numerator)	Degrees of Freedom (denominator)	F Value	p-value
Ennis (all data)				
Year	1	17	4.04	0.061
Peak Flow (PF) >3000	1	17	1.37	0.26
Year: PF Interaction	1	17	0.076	0.79
Ennis (outlier removed)				
Year	1	17	4.2	0.056
Peak Flow (PF) >3000	1	17	3.1	0.095
Year: PF Interaction	1	17	0.57	0.46
% Finer than 6.4mm				
Kirby (outliers removed)				
Year	1	14	16.0	0.0013
Peak Flow (PF) >3000	1	14	2.5	0.14
Year: PF Interaction	1	14	0.039	0.85
Ennis (outliers removed)				
Year	1	14	1.53	0.24
Peak Flow (PF) >3000	1	14	1.12	0.31
Year: PF Interaction	1	14	0.097	0.76

Table 3-5 Peak Flow Linear Model F-Test Results for the Lower Madison River Sites. Data were Transformed using a Logit Function. Results Shown for 6.4mm have Outliers Removed.

Predictors	Degrees of Freedom (numerator)	Degrees of Freedom (denominator)	F Value	p-value
% Finer than 0.84mm				
Site	1	187	2.6	0.11
Year	1	18	11.3	0.0035
Peak Flow	1	18	0.52	0.48
Site: PF Interaction	1	187	0.141	0.71
% Finer than 6.4mm				
Site	1	158	0.18	0.68
Year	1	15	3.1	0.097
Peak Flow	1	15	0.0003	0.99
Site: PF Interaction	1	158	1.8	0.18

3.2 Aquatic Macroinvertebrates

Macroinvertebrate sampling results for August sampling from 2018 through 2022, and temporal trends since 2012, are discussed below. The macroinvertebrate samples were collected and analyzed by Montana Biological Survey. Detailed results of each macroinvertebrate sample analyzed from the 2018-2022 period, including taxa counts, calculated metric values, and their associated means and standard deviations can be found in the annual macroinvertebrate reports to NWE (McGuire and Stagliano 2018; Stagliano 2019, 2020, 2021, 2022, 2023).

3.2.1 2018-2022 Macroinvertebrate Summary

Aquatic macroinvertebrate data from the five-year period of 2018–2022 are presented and compared. Inference is also drawn from comparable macroinvertebrate data obtained during NWE annual 2188 Madison River biomonitoring beginning in 1996. Discussion of the most relevant metrics is presented in this section.

3.2.1.1 Macroinvertebrate Metrics

Changes in the structure, composition, and pollution tolerance of Madison River macroinvertebrate communities through time were evaluated based on selected metrics using data at the same study sites collected since the last flushing flow report, from 2017–2022. All metric values are based on site averages of 300-count subsamples for the five samples collected at each site in each monitoring year (McGuire and Stagliano 2018; Stagliano 2019, 2020, 2021, 2022, 2023).

Community Compositions

The relative abundance of major macroinvertebrate groups at each site since 2017 is depicted in Figure 3-8 through Figure 3-11. The Kirby site had large proportions of non-insects, mainly snails, in most years, but these were lower in 2017 and 2018. The lower relative abundance of Mollusca in these years was accompanied by increases in Trichoptera at the site. Since 2019, non-insects have since increased to greater than 50% of the total relative abundance, thus reducing EPT taxa compositions into the 30% to 40% range (Figure 3-8). There has been small fluctuation in the contribution of Ephemeroptera over the past six years, rising in 2018, falling in 2019 and 2020, and slowly rising again through 2022 (Figure 3-8).

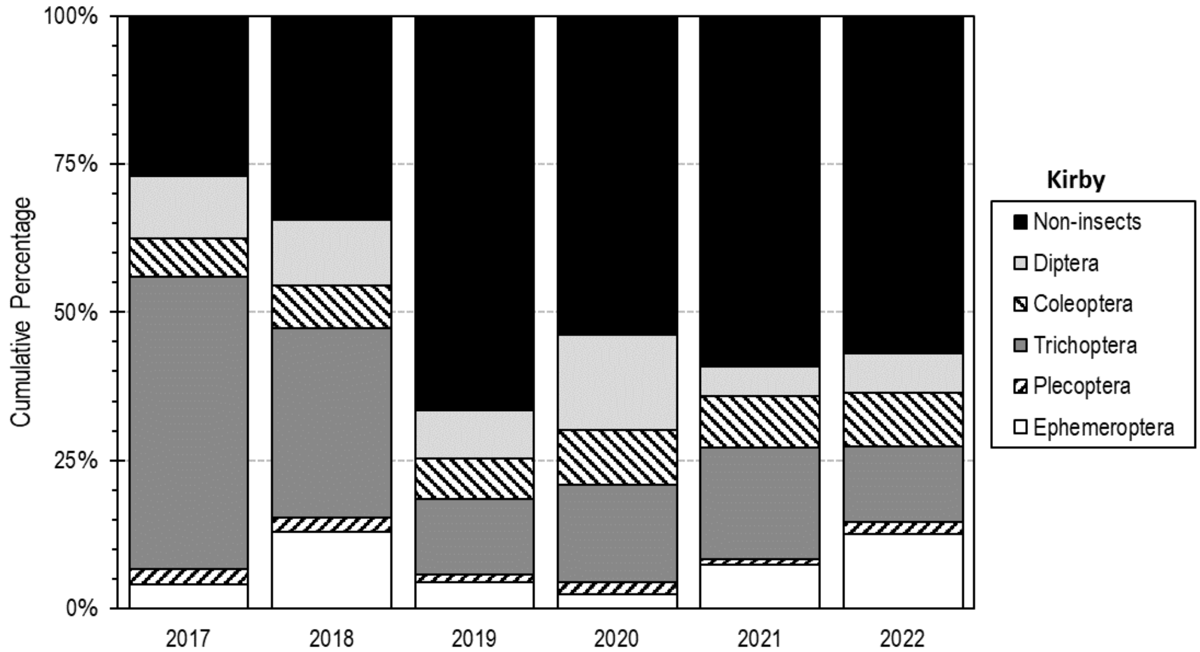


Figure 3-8 Community Compositions by Ordinal Relative Abundances of Six Major Taxonomic Groups at the Kirby Station on the Madison River, Montana for August Surveys from 2017-2022.

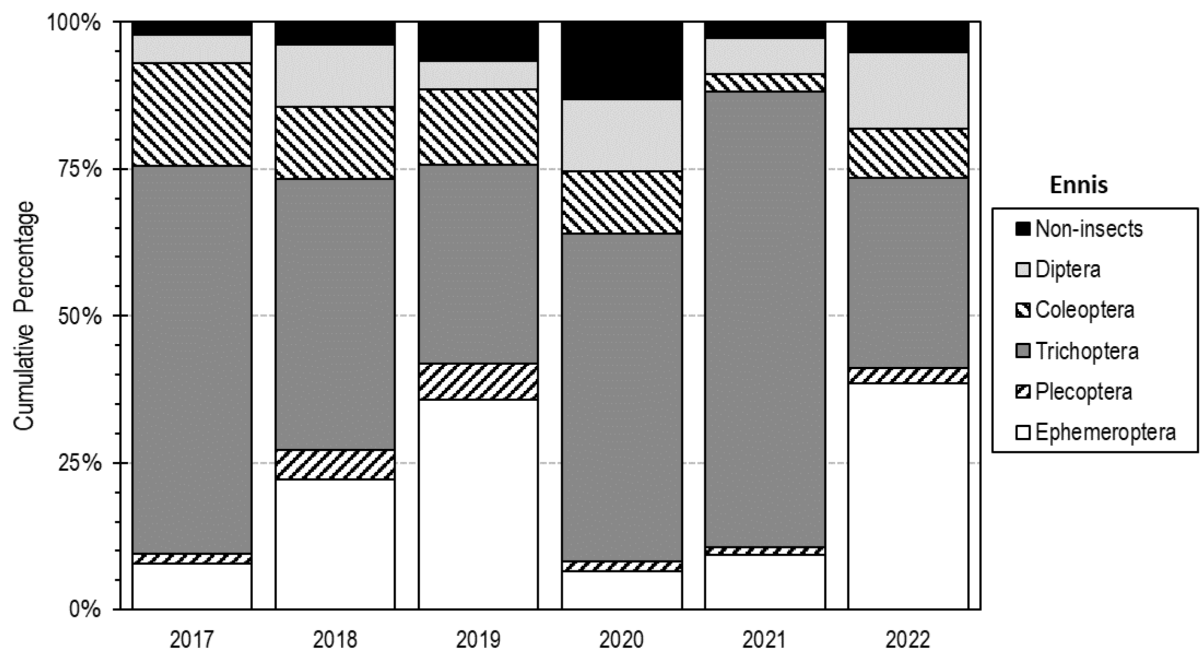


Figure 3-9 Community Compositions by Ordinal Relative Abundances of Six Major Taxonomic Groups at the Ennis Station on The Madison River, Montana for August Surveys 2017-2022.

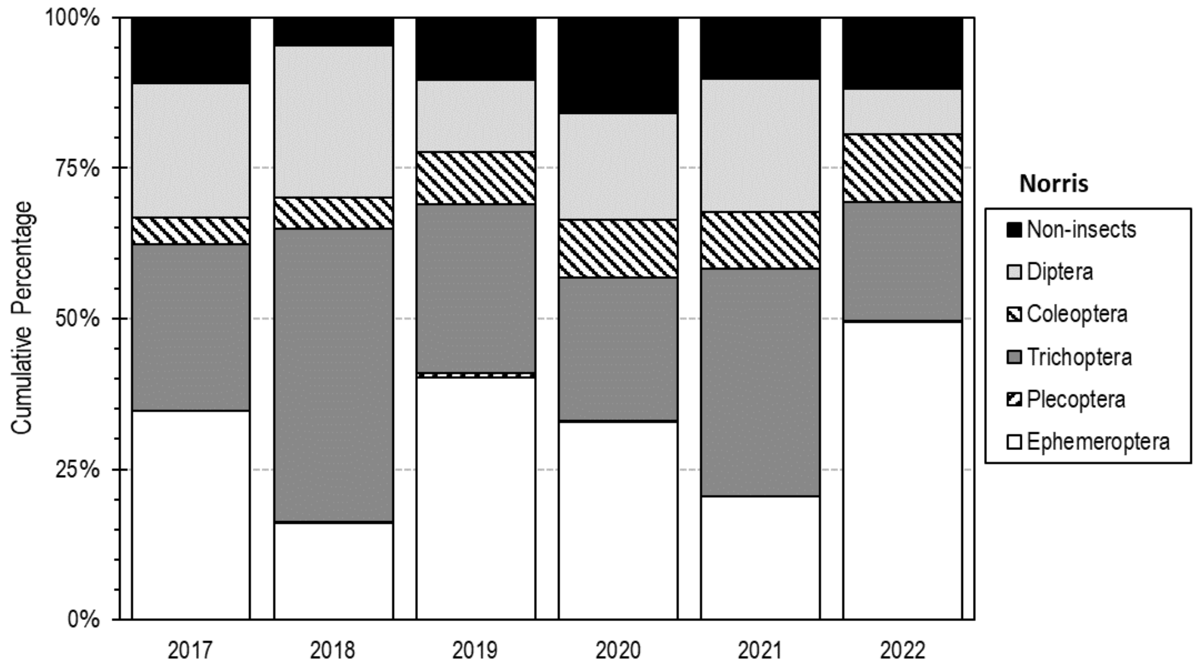


Figure 3-10 Community Compositions by Ordinal Relative Abundances of Six Major Taxonomic Groups at the Norris Station on the Madison River, Montana for August Surveys 2017-2022.

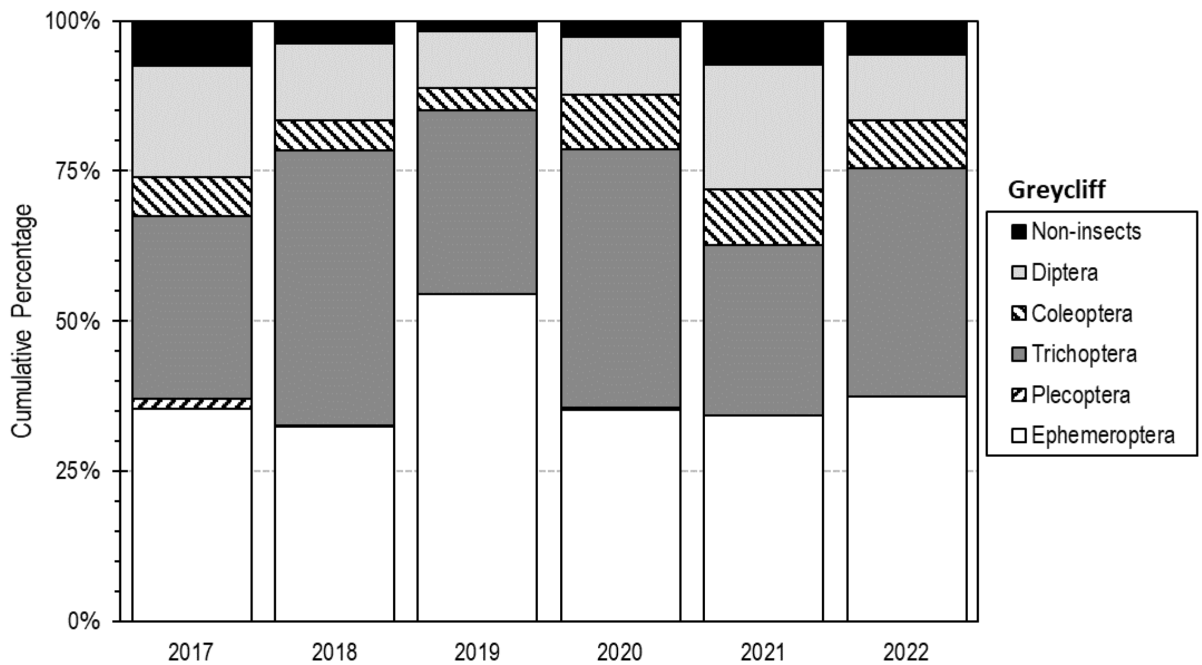


Figure 3-11 Community Compositions by Ordinal Relative Abundances of Six Major Taxonomic Groups at the Greycliff Station on the Madison River, Montana for August Surveys 2017-2022.

The Ennis site appears to be mostly dominated by Trichoptera but fluctuates with the resurgence of Ephemeroptera every 2 to 3 years. Trichoptera abundance was 65.6% in 2017, gradually declined to 33% relative abundance by 2019, increased again to 76.4% by 2021, only to be reduced again to 32% in 2022. Caddisfly abundances appear to be replaced with Ephemeroptera, rising from 7.7% in 2017 to 35.7% abundance in 2019 (Figure 3-9). This fluctuation was followed with another three-year cycle, with low abundances in 2020 and 2021 (<10%) and peaking again in 2022 at 38.3%. Plecoptera show a similar, but much smaller trend. Coleoptera, Diptera, and Non-insect contributions generally contribute around 25% of the total relative abundance in a given year, with 2020 and 2021 being two exceptions (Figure 3-9).

The Norris site has shown minor fluctuations in Ephemeroptera composition over the past six years, falling to a low of 16% in 2018, rising to 40% in 2019, declining to 20% by 2021, and then increasing to 49% in 2022 (Figure 3-10). Increases and decreases in Ephemeroptera are offset by Trichoptera, maintaining the total EPT relative abundance around 60-65% over the past 6 years. The Diptera community composition is generally stable, ranging from 17% to 25%, with declines to 12% in 2019, and to 7% in 2022, largely due to increases in mayflies and non-insect taxa in those years.

The Greycliff site had relatively consistent community structure during this time period, with Ephemeroptera relative abundances generally maintained around 35% in most years, with the exception of 2019, when it increased to 54% (Figure 3-11). Trichoptera abundances generally fluctuated around 30-45%. As a result, EPT abundances are consistently above 60% in all years (Figure 3-11).

In addition to changes over time, the macroinvertebrate community compositions at the four Madison River sites also show distinct and consistent spatial differences. In review of the previous 10 years of monitoring data, the Kirby and Ennis sites have generally lower relative abundances of Ephemeroptera than Norris and Greycliff (Figure 3-12). In contrast, Kirby and Ennis show consistently higher relative abundances of Plecoptera than Norris and Greycliff (Figure 3-13).

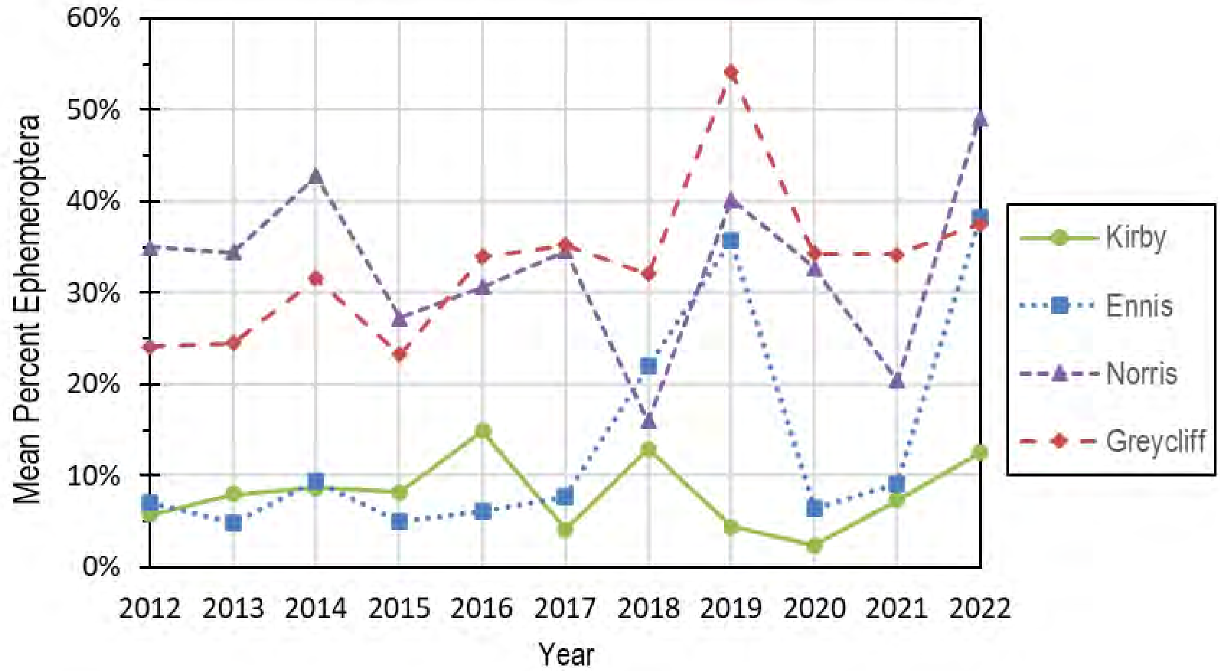


Figure 3-12 Mean Relative Abundances of Ephemeroptera (Mayflies) at Four Sites on The Madison River, Montana for August Surveys from 2012-2022.

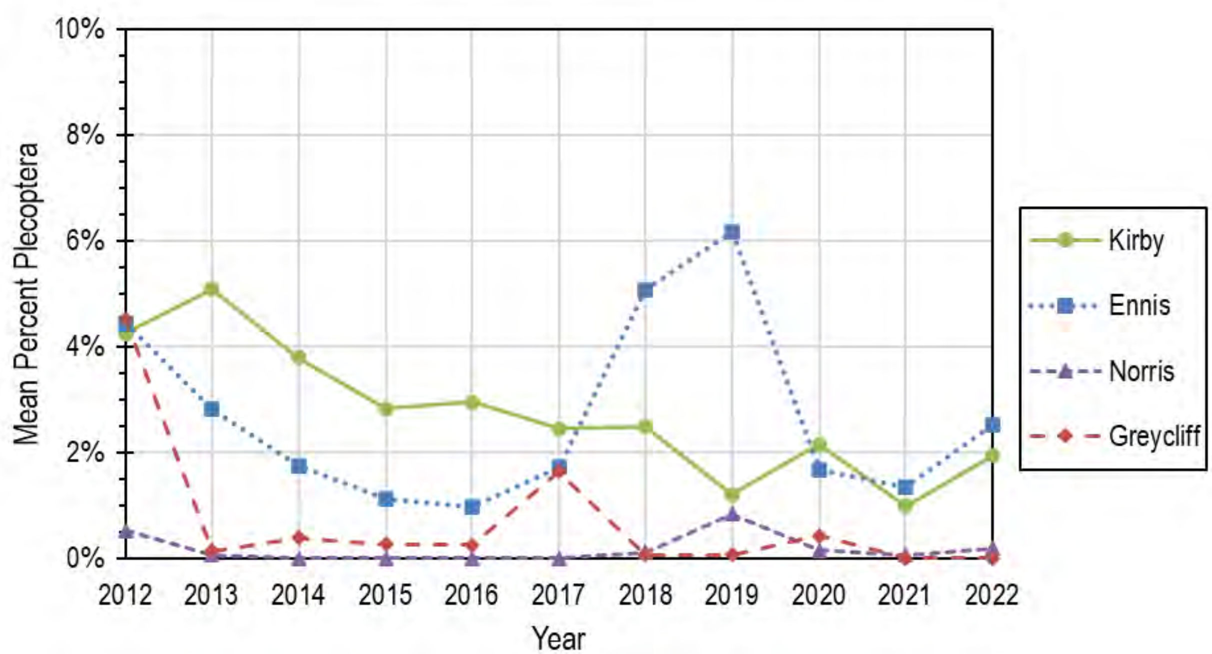


Figure 3-13 Mean Relative Abundances of Plecoptera at Four Sites on the Madison River, Montana for August Surveys from 2012-2022.

Taxa Richness

Taxa richness values were generally indicative of healthy to slightly impaired benthic communities in the Madison River. Mean taxa richness was at least 28 at each site for the majority of sampling dates as shown in Figure 3-14. The four sites experienced similar levels of variability in the richness indicator, and no temporal patterns are evident. Mean taxa richness was highest at Norris in 2019 with 42.8 taxa, and lowest at Kirby in 2013 with 25.8. The site averages in the most recent 5-year period (2018-2022) ranged from 31.6 at Kirby to 40.6 at Norris. For all sites combined, taxa richness averaged 37 taxa in 2018, 34.5 in 2019, 35.8 in 2020, 33.8 in 2021, and 35.7 in 2022.

EPT Taxa Richness and Relative Abundance

Mayflies, stoneflies and caddisflies were fairly abundant and diverse at the Madison River sites. Mean EPT richness across all sites over the past 10 years was 16.8 taxa per subsample and ranged from 11.4 at Norris in 2015 to 21.6 at Norris in 2019 as shown in Figure 3-15. No temporal trends in EPT richness are evident. With the exception of 2015, 2016, and most recently 2022, EPT richness has generally been lowest at Kirby. In the recent 5-year period, Norris has shown the highest EPT richness. The site averages in the most recent 5-year period (2018-2022) ranged from 14.8 at Kirby to 20 at Norris. For all sites combined, EPT richness averaged 20 in 2018, 18 in 2019, 16.8 in 2020, 15.9 in 2021, and 17.2 in 2022.

The combined relative percentage of mayflies, stoneflies and caddisflies in Madison River samples is generally above 50% at three sites, but relatively lower than 50% at the Kirby site as shown in Figure 3-16. The Norris site appears to be increasing from 2015 to 2019 and has been generally holding in a plateau around 63%. The site averages in the most recent 5-year period (2018-2022) ranged from 28.2% at Kirby to 75.2% at Greycliff. For all sites combined, relative abundance of EPT taxa averaged 65.6% in 2018, 61.8% in 2019, 54.3% in 2020, 58.6% in 2021, and 61.2% in 2022.

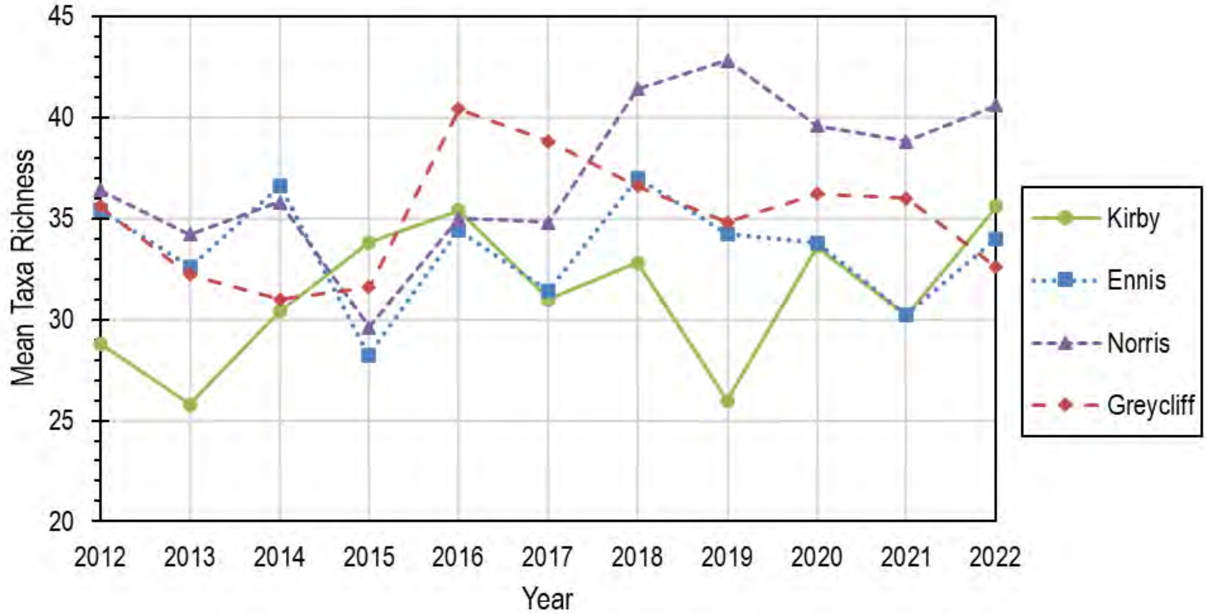


Figure 3-14 Mean Taxa Richness at Four Sites on the Madison River, Montana during August 2012-2022.

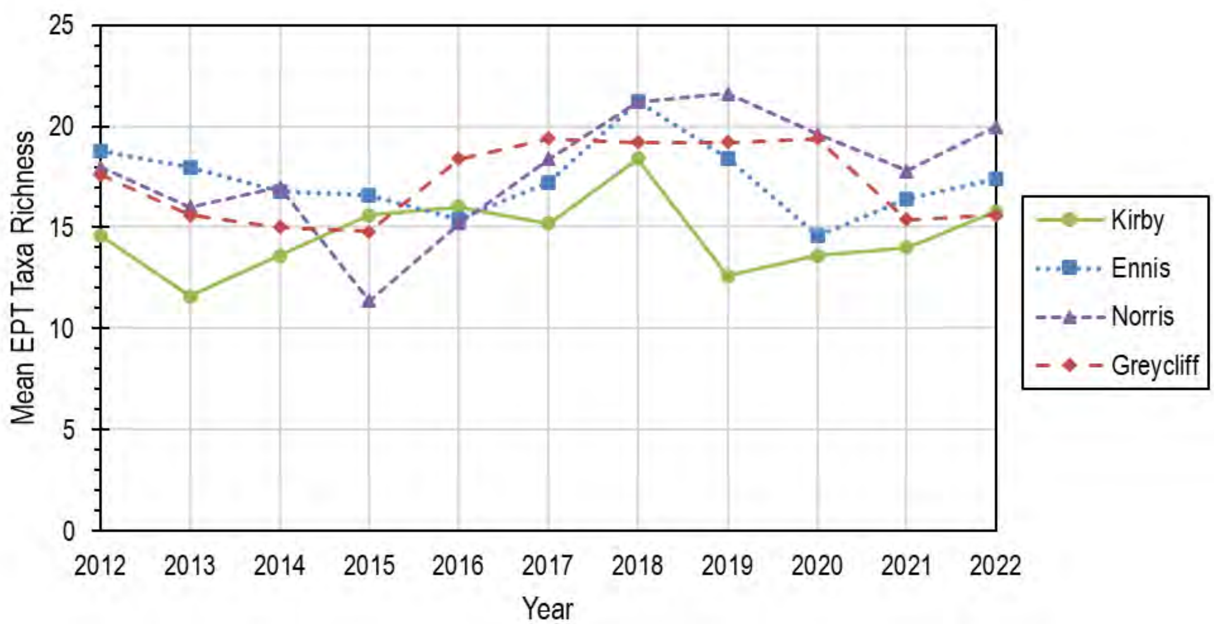


Figure 3-15 Mean EPT Taxa Richness at Four Sites on the Madison River, Montana during August 2012-2022.

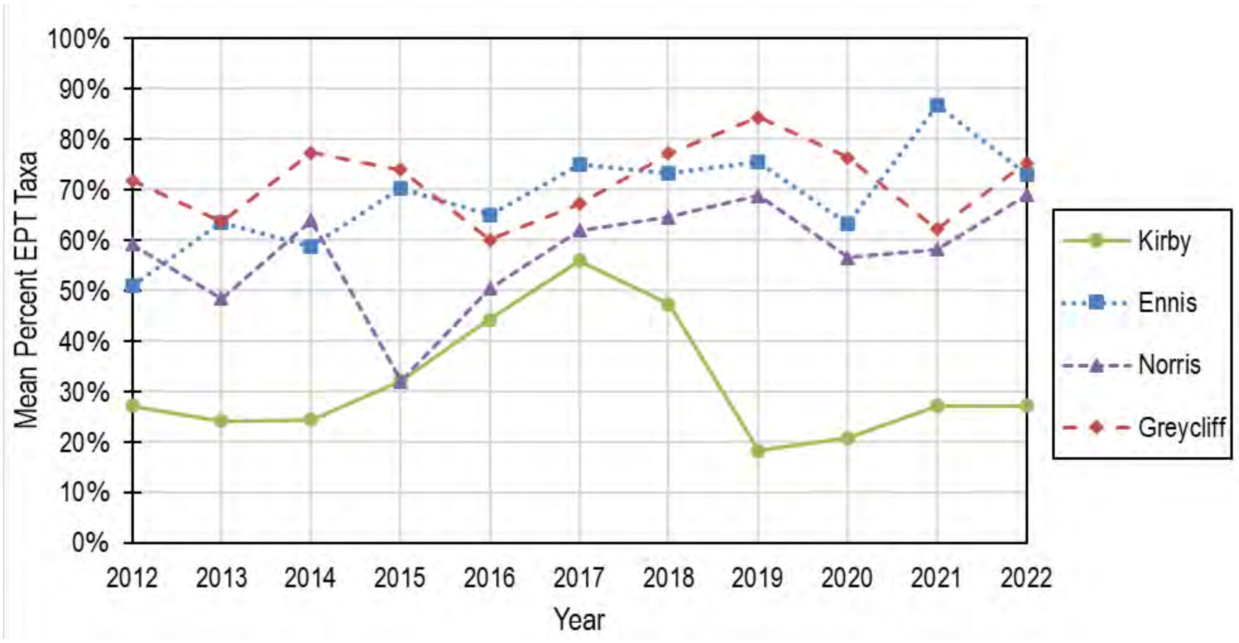


Figure 3-16 Mean Percent Abundance of EPT Taxa at Four Sites on the Madison River, Montana during August 2012-2022.

Biotic Index

The modified HBI is primarily a measure of organic pollution and trophic status (Hilsenhoff 1987). Montana Foothill and Valley streams free of significant nutrient or organic pollution are characterized by values less than 4.0 (Bukantis 1998). Bollman (1998) found the Montana BI to be correlated with water temperature, substrate embeddedness, and the percentage of fine sediments in small streams. Over the previous 10 years of monitoring, biotic index values at Kirby indicate some fairly significant pollution between 2012 and 2014 (average of 5.49), and significant pollution between 2019 and 2022 (average of 6.00) as shown in Figure 3-17. Conditions at the lower Madison sites, Norris and Greycliff, appear to be trending slightly downward to under 5.00, and currently indicating "very good" conditions (scores of 4.07 and 3.89, respectively) in 2022. Ennis has consistently shown "very good" conditions, averaging 3.51 over the entire 11 years as shown in Figure 3-17. The site averages in the most recent 5-year period (2018-2022) were 5.75 at Kirby, 3.37 at Ennis, 4.26 at Norris, and 4.04 at Greycliff. For all sites combined, the biotic index averaged 4.04 in 2018, 4.33 in 2019, 4.43 in 2020, 4.49 in 2021, and 4.49 in 2022.

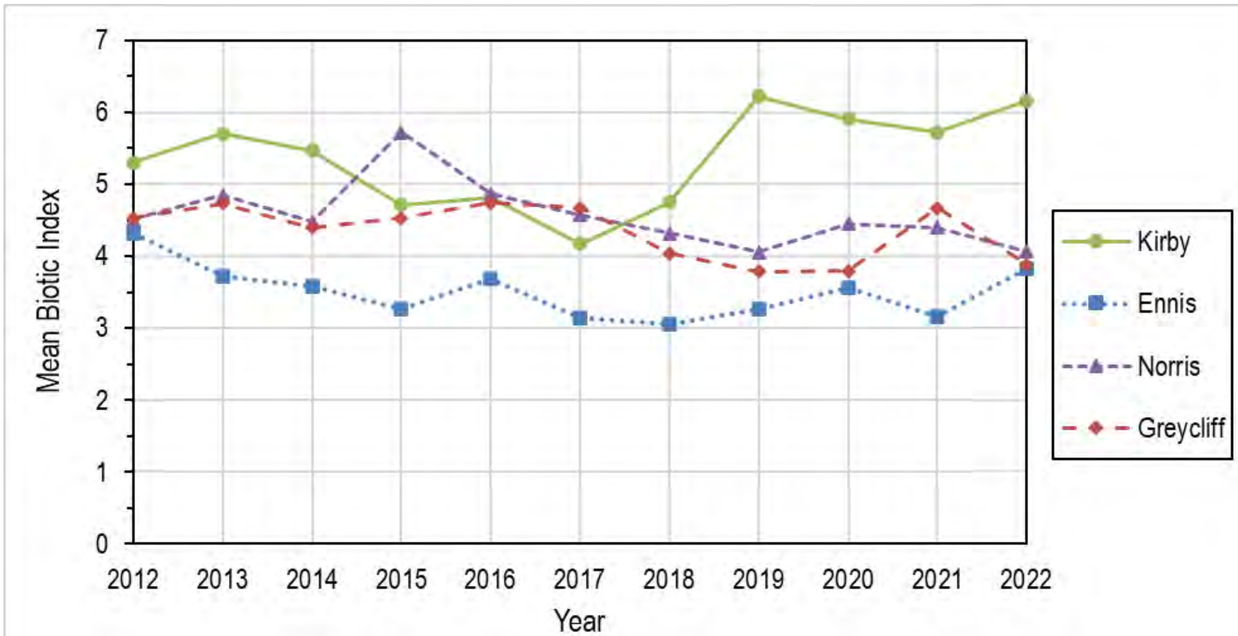


Figure 3-17 Mean Modified HBI Scores at Four Sites on the Madison River, Montana during August 2012-2022.

Sediment Tolerance Metrics

Trends in the sediment tolerance at the four Madison River sites show variability over the past ten years in the different metrics, but no consistent changes. The total number of sediment tolerant taxa at the four sites on the Madison River, Montana from 2012-2022 is shown in Figure 3-18. Results show that the two upstream sites, Kirby and Ennis, had fewer tolerant taxa than Norris and Greycliff downstream, with the exception of the last three years at Kirby, which show taxa numbers comparable with the downstream sites. Within each site, numbers of sediment tolerant taxa were variable, but overall showed no trending increase or decrease over the 2012 to 2022 period. At Greycliff, the number of sediment tolerant taxa was generally around 12-16 taxa, but briefly increased to 23 in 2016 and 19 in 2017, before returning to 13-15 taxa for the last five years (Figure 3-18).

The total number of sediment intolerant taxa at the four sites on the Madison River, Montana from 2012 to 2022 is shown in Figure 3-19. Sediment intolerant taxa are very rare at the downstream sites, typically 4 taxa or less. Kirby and Ennis consistently register higher numbers of intolerant taxa, generally in the range of 6 to 10 taxa.

Looking at relative abundances of sediment-tolerant taxa at four sites on the Madison River over the 2012 to 2022 period in Figure 3-20, Kirby shows a trend of much higher percentages of sediment tolerance taxa starting in 2015, likely due to the increased numbers of snails in recent years. Relative abundances of sediment tolerant taxa at Ennis have fluctuated less than at other sites, generally ranging from 8% to 12%, although dropping as low as 2.8% in 2021. Sediment tolerance abundances at Norris have fluctuated as high as 36% in 2015, and as low as 10% in 2018, but have averaged around 20% in recent years (Figure 3-20). Greycliff abundances for sediment tolerant taxa have fluctuated around 30%, plus or minus 10% during the 2012 to 2022 period.

Relative abundances of sediment-intolerant taxa at four sites on the Madison River over the 2012 to 2022 period are shown in Figure 3-21. Sediment intolerant taxa contribute very little to abundances at Norris and Greycliff, rarely exceeding 2.5%. Slight increases can be seen in 2018, 2019, and 2020, during years with above average flows. Those same higher flow years also increased the relative abundances of sediment intolerant taxa at Ennis, peaking at 33.3% in 2018, 26.3% in 2019, and 27.3% in 2020 before declining in 2021 and 2022 (Figure 3-21).

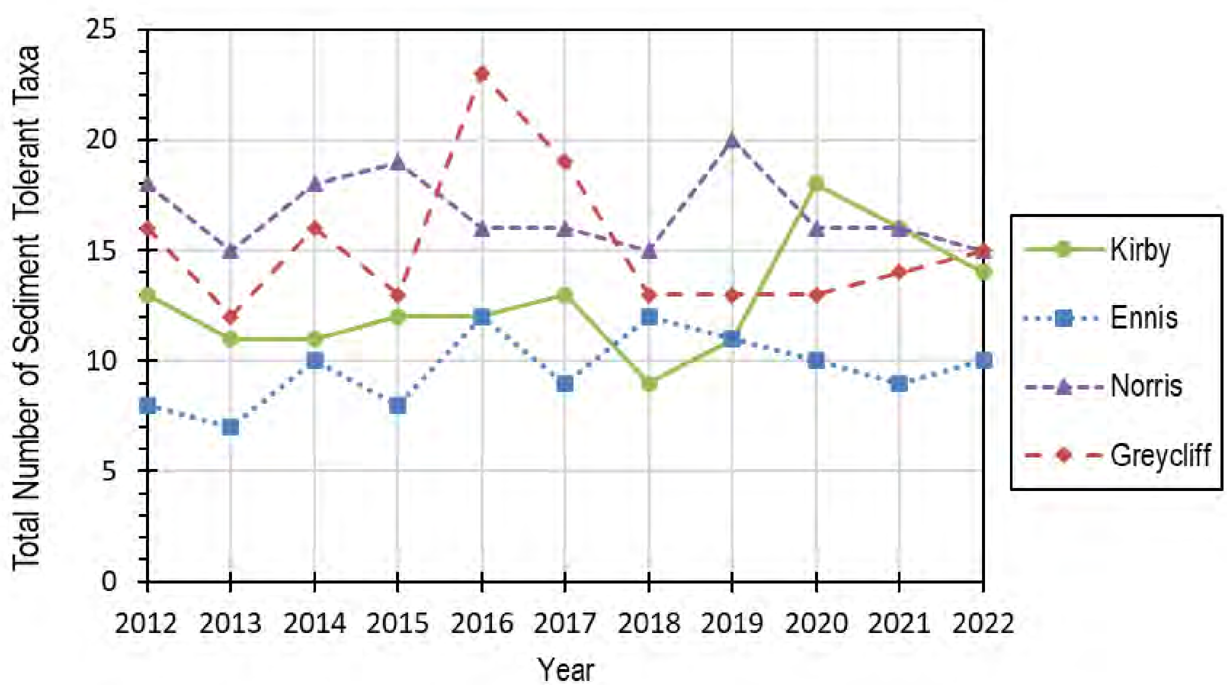


Figure 3-18 Total Number of Sediment-Tolerant Taxa at Four Sites on the Madison River, Montana during August 2012-2022.

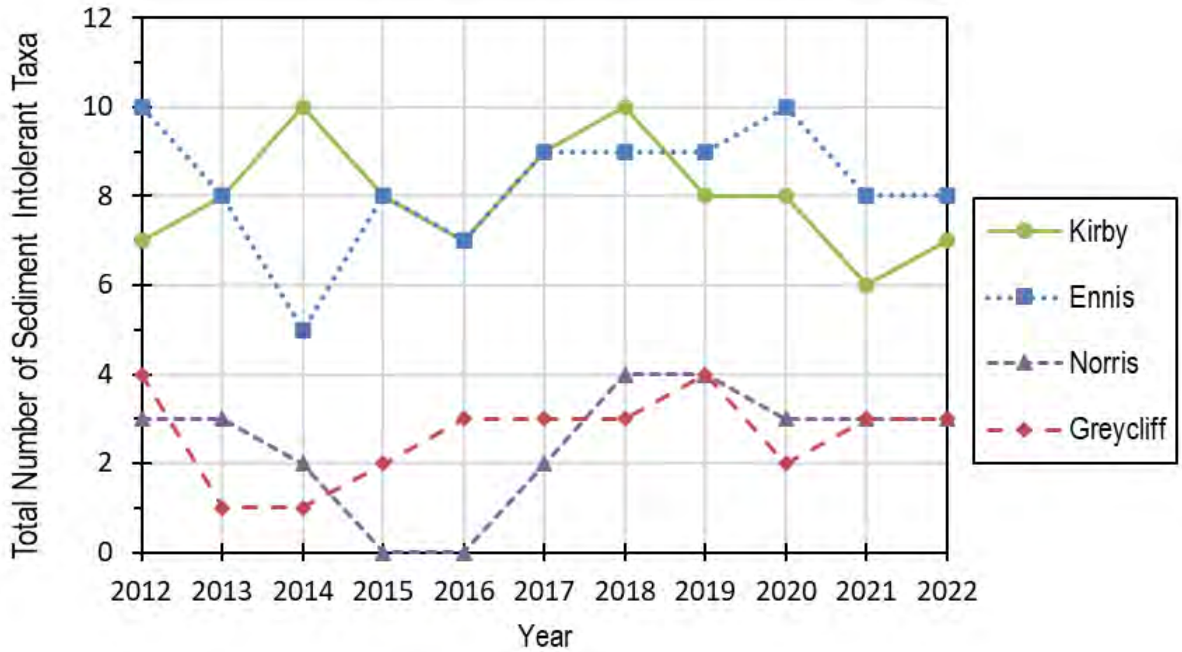


Figure 3-19 Total Number of Sediment-Intolerant Taxa at Four Sites on the Madison River, Montana during August 2012-2022.

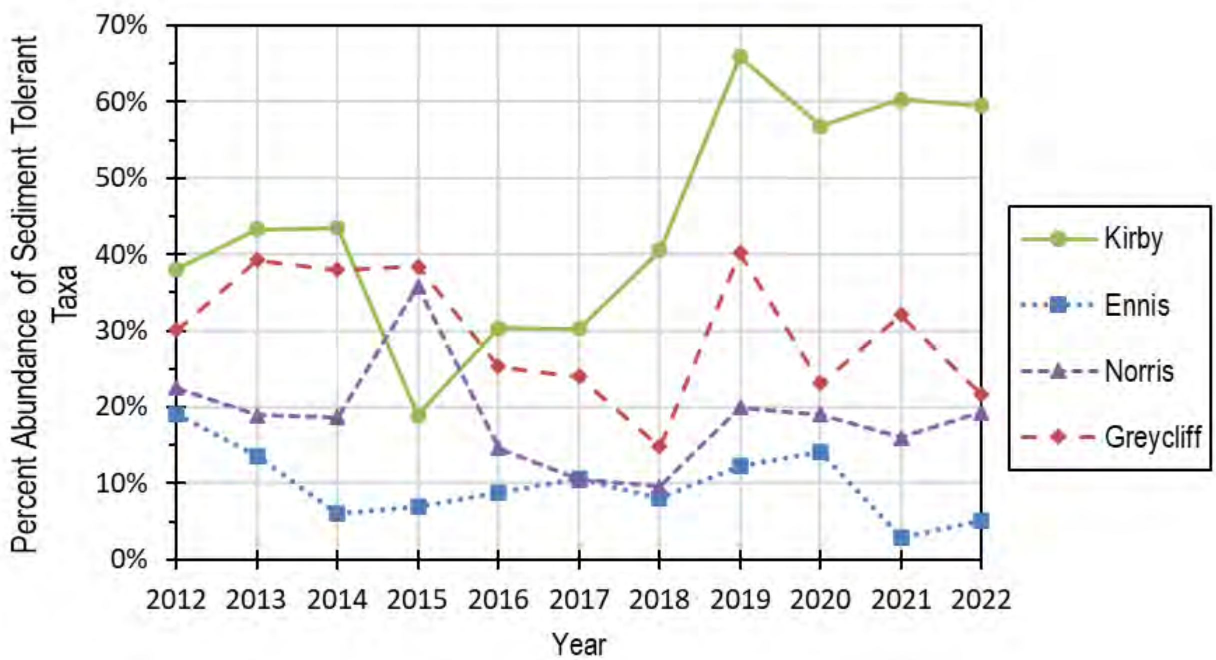


Figure 3-20 Relative Abundance of Sediment-Tolerant Taxa at Four Sites on the Madison River, Montana during August 2012-2022.

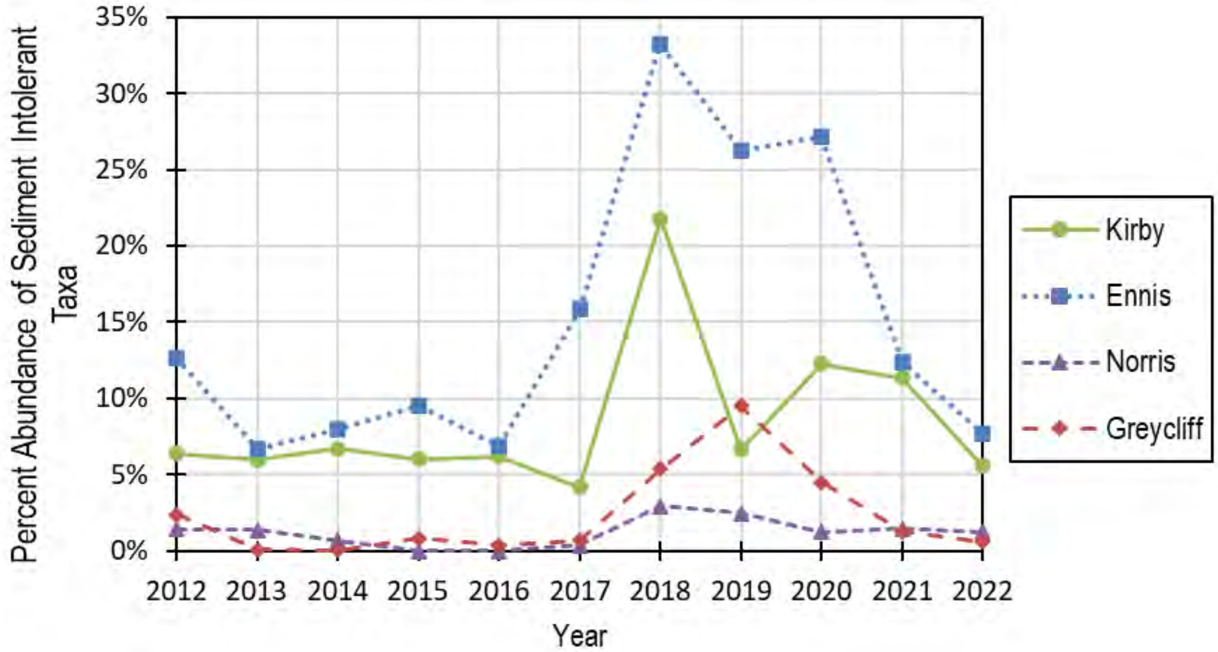


Figure 3-21 Relative Abundance of Sediment-Intolerant Taxa at Four Sites on the Madison River, Montana during August 2012-2022.

3.2.1.2 Water Temperature Metrics

Temperature directly affects macroinvertebrates by regulating their metabolic rates, influencing growth and development from egg to adult. Most importantly, temperature is involved in the timing of life cycles, synchronizing critical stages with important environmental events, as well as the frequency of those life cycles, or voltinism (Ward 1992; Williams and Feltmate 1992). Therefore, with the apparent significance of temperature on the development and growth of macroinvertebrates, it is important to note the thermal regime can have an influence on the macroinvertebrate community.

Water temperatures measured in the Madison River below Ennis Lake (USGS Gage 06041000) were analyzed to characterize the long-term thermal regime of the river. Daily average water temperatures were obtained for Water Years 1978 through 2022. For each day of the year, the maximum, median, and minimum daily average water temperatures were determined from the 45-year period of record. The seasonal pattern of daily average water temperatures is shown in Figure 3-22. Warmest temperatures generally occur in July and August around the time of macroinvertebrate sampling.

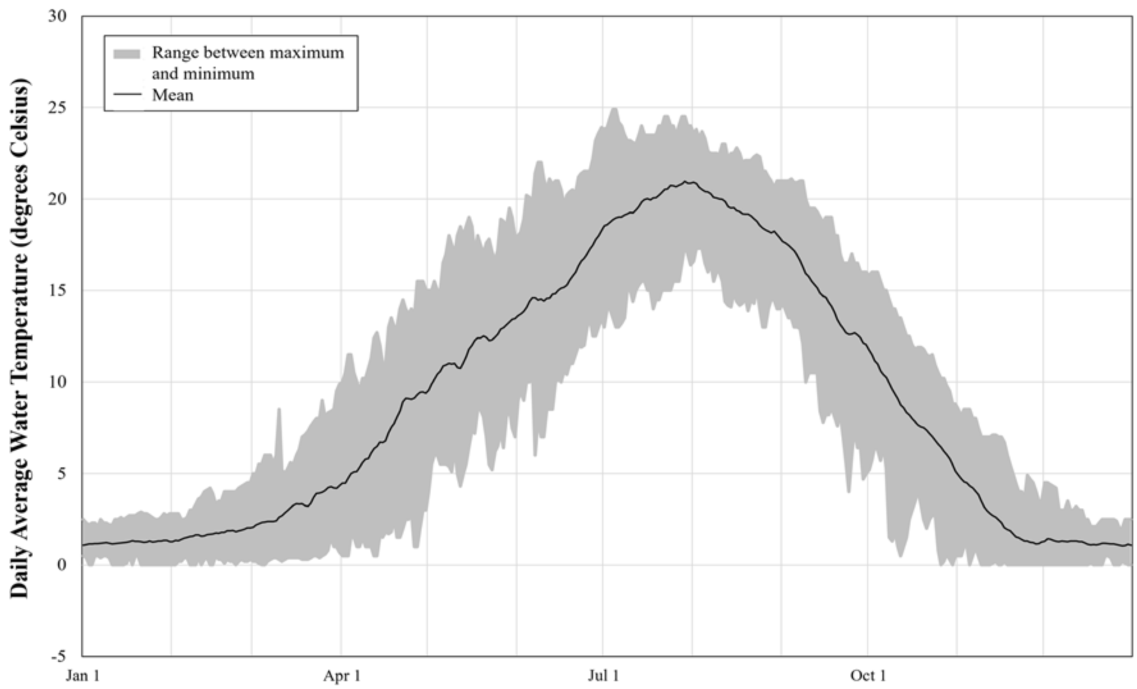


Figure 3-22 Seasonal Pattern of Daily Average Water Temperatures Measured in the Madison River below Ennis Lake, Derived from 40 Years of Record from Water Year 1978 through 2022.

From the daily average water temperatures measured in the Madison River below Ennis Lake, the average temperature during the warmest part of the year (July and August) was calculated for each to the 45 water years from 1978 through 2022. Results of these calculations are shown in Figure 3-23. The average July/August water temperature was relatively cool during the first 23 years (19.0 degrees Celsius), and relatively warm during the last 22 years (20.2 degrees Celsius).

Macroinvertebrate data collected annually in the Madison River appears to confirm this warming trend. Temperature tolerance metrics are being developed for the Madison River (McGuire 2017; McGuire and Stagliano 2018; Stagliano 2019, 2020, 2021, 2022, 2023). The temperature tolerances and thresholds for macroinvertebrate taxa have been derived from the published literature and professional opinion (see for an explanation of the calculation method). These thermal tolerances have been categorized as cold-water taxa (thermal tolerance less than or equal to ~18° C) and warm-water taxa (thermal tolerance greater than ~22° C).

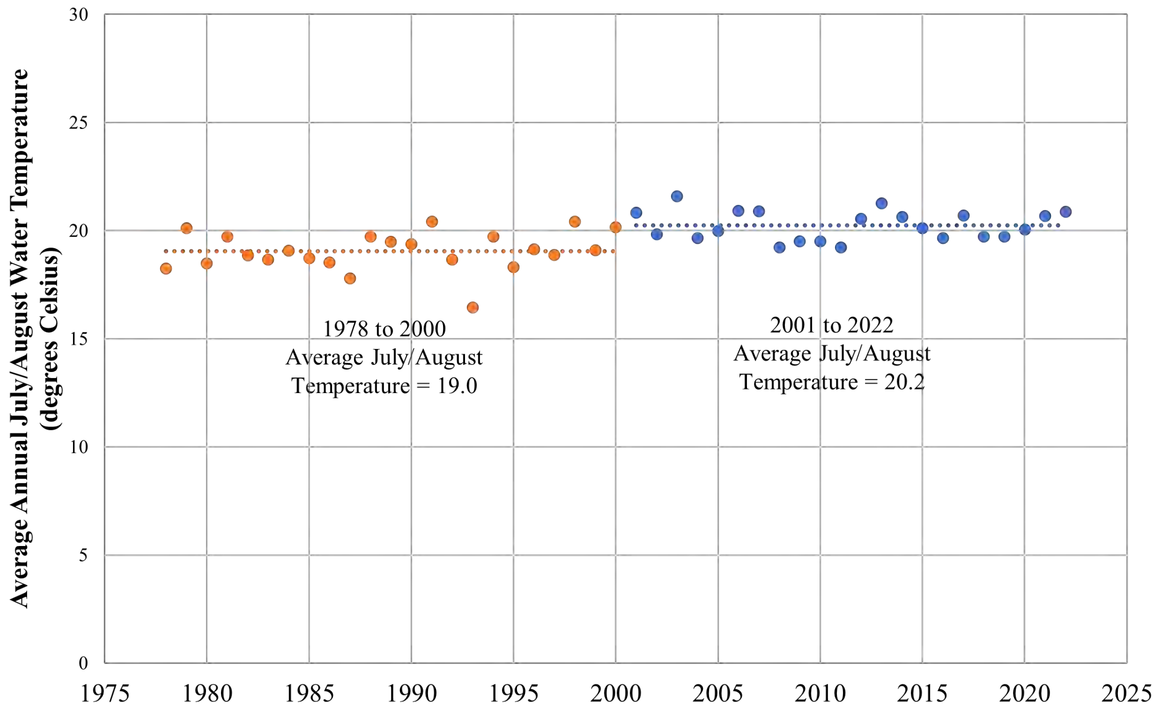


Figure 3-23 Average Annual July/August Water Temperatures in the Madison River Below Ennis Lake, 1978 through 2022.

Recent trends have been thoroughly assessed by Stagliano (2019, 2020, 2021, 2022), revealing a clear dichotomy between the upper and lower reaches of the Madison River; CW taxa were more common in the upper river (Hebgen, Kirby, and Ennis) while warm-water taxa dominated in the lower river below the Madison Powerhouse (Norris, Greycliff). However, warmer water temperatures and drought-related stream flows in 2021 have exacerbated these differences. Stagliano (2022) noted that the Hebgen, Kirby, Ennis, Norris, and Greycliff sites continued to exhibit the effects of warming water temperatures in the period from 2008-2021 with an upward trend in the number and relative abundance of warm-water taxa (with associated declines in cold-water taxa) in the BMI community.

3.2.1.3 Multimetric Bioassessments

MMRMA bioassessments for 2018 to 2022 are presented in Table 3-2 through Table 3-10 and Figure 3-24, and a longer-term view of the scores at each site is presented in Figure 3-25 through Figure 3-28. For 2018 to 2022, assessment scores averaged 68% at Kirby, 93% at Ennis, 91% at Norris, and 95% at Greycliff. These values indicate healthy macroinvertebrate communities at all sites except Kirby. Kirby has recently declined from a healthy score (80% in 2018) to relatively poor (57% in 2019) in recent years (Figure 3-24).

The multimetric assessment developed for Missouri and Madison River kick samples (Table 2-2) indicated environmental stress at Kirby during 2022, with a score of 67% (Table 3-10). Ennis, Norris, and Greycliff all had a relatively high score of 93%, scoring 28 of the maximum 30 points, indicating healthy macroinvertebrate communities. The primary indicators of environmental stress at Kirby were a relatively low relative abundance of EPT taxa, and a relatively high HBI score, both attributed to the high abundance of snails present.

The Kirby site maintained a score of 80% from 2016 to 2018, the highest level observed since 1997. Based on visual review of the trend in Figure 3-25, biointegrity was high in the 1990s at the Kirby site but has fluctuated in the impaired range since 2002. Ennis routinely had the highest bioassessment scores of the Madison River sampling sites, and it had been consistently over 90% since 2008 (Figure 3-26) until recently dropping to 83% in 2021 before rising back to 93% in 2022. Norris has had the most variability in biointegrity through time, ranging from 50% in 2001 and 2003 to 100% in 2011 (Figure 3-26). The score steadily declined until 2015, when it hit 60%, the most impaired score since 2003, but scores have rebounded and have been maintained around 90% since 2017. Greycliff has been over 80% in every year sampled and still shows no signs of impairment (Figure 3-28).

Table 3-6 Mean Metric Values and Bioassessment Scores* at Four Sites on the Madison River, Montana in August 2018.

2018	**Site**					
METRICS	**Kirby**	**Ennis**	**Norris**	**Greycliff**	**Mean**	**St. Dev.**
Taxa richness	32.8	37.0	41.4	36.6	37.0	3.5
EPT richness	18.4	21.2	21.2	19.2	20.0	1.4
Shannon diversity	3.7	4.1	4.0	4.0	3.9	0.2
Biotic index	4.7	3.1	4.3	4.0	4.0	0.7
% EPT	47.0	73.0	65.0	77.0	65.5	13.3
% Chironomidae	11.0	8.0	24.0	12.0	13.8	7.0
METRIC SCORE						
Taxa richness	4	5	5	5	4.8	0.5
EPT richness	5	5	5	5	5.0	0.0
Shannon diversity	5	5	5	5	5.0	0.0
Biotic index	3	5	4	5	4.3	1.0
% EPT	2	5	4	5	4.0	1.4
% Chironomidae	5	5	4	5	4.8	0.5
Total Score	24	30	27	30	27.8	2.9
Percentage of Possible	**80%**	**100%**	**90%**	**100%**	93%	9.6%

* Scores based on Madison-Missouri River criteria (Table 2-2) using 5 replicates per site, with ≈300 organism subsamples from 0.25 m^2 kick samples.

Table 3-7 Mean Metric Values and Bioassessment Scores* at Four Sites on the Madison River, Montana in August 2019.

2019	Site					
METRICS	**Kirby**	**Ennis**	**Norris**	**Greycliff**	**Mean**	**St. Dev.**
Taxa richness	26.0	34.2	42.8	34.8	34.5	6.9
EPT richness	12.6	18.4	21.6	19.2	18.0	3.8
Shannon diversity	2.6	3.9	4.5	3.8	3.7	0.8
Biotic index	6.2	3.3	4.1	3.8	4.3	1.3
% EPT	18.0	76.0	69.0	84.0	61.8	29.8
% Chironomidae	8.0	4.0	11.0	9.0	8.0	2.9
METRIC SCORE						
Taxa richness	3	5	5	5	4.5	1.0
EPT richness	4	5	5	5	4.8	0.5
Shannon diversity	3	5	5	5	4.5	1.0
Biotic index	2	5	4	5	4.0	1.4
% EPT	0	5	4	5	3.5	2.4
% Chironomidae	5	5	5	5	5.0	0.0
Total Score	17	30	28	30	26.3	6.2
Percentage of Possible	**57%**	**100%**	**93%**	**100%**	88%	21%

* Scores based on Madison-Missouri River criteria (Table 2-2) using 5 replicates per site, with ≈300 organism subsamples from 0.25 m^2 kick samples.

Table 3-8 Mean Metric Values and Bioassessment Scores at Four Sites on the Madison River, Montana in August 2020.

2020	Site					
METRICS	**Kirby**	**Ennis**	**Norris**	**Greycliff**	**Mean**	**St. Dev.**
Taxa richness	33.6	33.8	39.6	36.2	35.8	2.8
EPT richness	13.6	14.6	19.6	19.4	16.8	3.1
Shannon diversity	3.3	3.4	4.3	4.0	3.7	0.5
Biotic index	5.9	3.6	4.5	3.8	4.4	1.1
% EPT	21.0	63.0	57.0	76.0	54.3	23.5
% Chironomidae	14.0	9.0	17.0	9.0	12.3	3.9
METRIC SCORE						
Taxa richness	5	5	5	5	5.0	0.0
EPT richness	4	4	5	5	4.5	0.6
Shannon diversity	4	4	5	5	4.5	0.6
Biotic index	3	5	4	5	4.3	1.0
% EPT	0	4	3	5	3.0	2.2
% Chironomidae	5	5	5	5	5.0	0.0
Total Score	21	27	27	30	26.3	3.8
Percentage of Possible	**70%**	**90%**	**90%**	**100%**	88%	13%

* Scores based on Madison-Missouri River criteria (Table 2-2) using 5 replicates per site, with ≈300 organism subsamples from 0.25 m2 kick samples.

Table 3-9 Mean Metric Values and Bioassessment Scores at Four Sites on the Madison River, Montana in August 2021.

2021	**Site**					
METRICS	**Kirby**	**Ennis**	**Norris**	**Greycliff**	**Mean**	**St. Dev.**
Taxa richness	30.2	30.2	38.8	36.0	33.8	4.3
EPT richness	14.0	16.4	17.8	15.4	15.9	1.6
Shannon diversity	3.2	2.5	4.0	4.1	3.5	0.8
Biotic index	5.7	3.2	4.4	4.7	4.5	1.0
% EPT	27.0	87.0	58.0	62.0	58.5	24.6
% Chironomidae	5.0	3.0	22.0	19.0	12.3	9.6
METRIC SCORE						
Taxa richness	4	4	5	5	4.5	0.6
EPT richness	4	4	5	4	4.3	0.5
Shannon diversity	4	2	5	4	3.8	1.3
Biotic index	3	5	4	3	3.8	1.0
% EPT	0	5	3	4	3.0	2.2
% Chironomidae	5	5	4	5	4.8	0.5
Total Score	20	25	26	25	24.0	2.7
Percentage of Possible	**67%**	**83%**	**87%**	**83%**	80%	9%

* Scores based on Madison-Missouri River criteria (Table 2-2) using 5 replicates per site, with ≈300 organism subsamples from 0.25 m2 kick samples.

Table 3-10 Mean Metric Values and Bioassessment Scores at Four Sites on the Madison River, Montana in August 2022.

2022	**Site**					
METRICS	**Kirby**	**Ennis**	**Norris**	**Greycliff**	**Mean**	**St. Dev.**
Taxa richness	35.6	34.0	40.6	32.6	35.7	3.5
EPT richness	15.8	17.4	20.0	15.6	17.2	2.0
Shannon diversity	3.1	3.3	3.9	3.4	3.4	0.3
Biotic index	6.2	3.8	4.1	3.9	4.5	1.1
% EPT	28.0	73.0	69.0	75.0	61.3	22.3
% Chironomidae	6.0	5.0	6.8	6.0	6.0	0.7
METRIC SCORE						
Taxa richness	5	5	5	4	4.8	0.5
EPT richness	4	5	5	4	4.5	0.6
Shannon diversity	4	3	5	5	4.3	1.0
Biotic index	2	5	4	5	4.0	1.4
% EPT	0	5	4	5	3.5	2.4
% Chironomidae	5	5	5	5	5.0	0.0
Total Score	20	28	28	28	26.0	4.0
Percentage of possible	**67%**	**93%**	**93%**	**93%**	87%	13%

* Scores based on Madison-Missouri River criteria (Table 2-2) using 5 replicates per site, with ≈300 organism subsamples from 0.25 m2 kick samples.

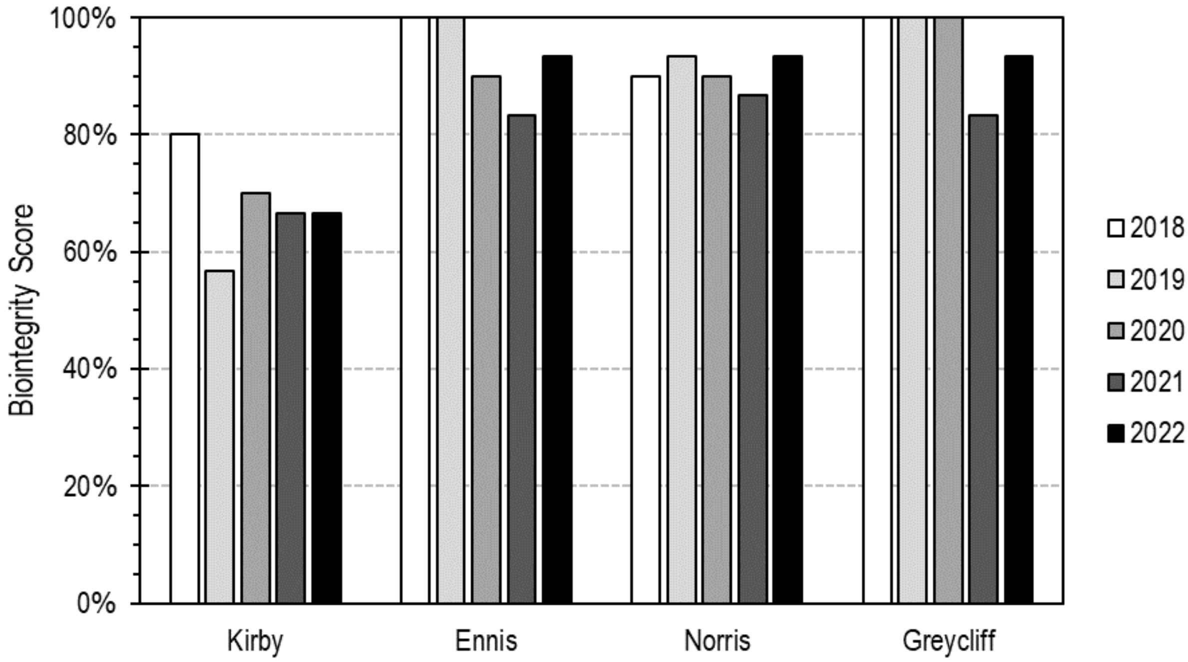


Figure 3-24 MMRMA Bioassessment Scores Collected in August for 2018 through 2022 at Four Sites on the Madison River, Montana.

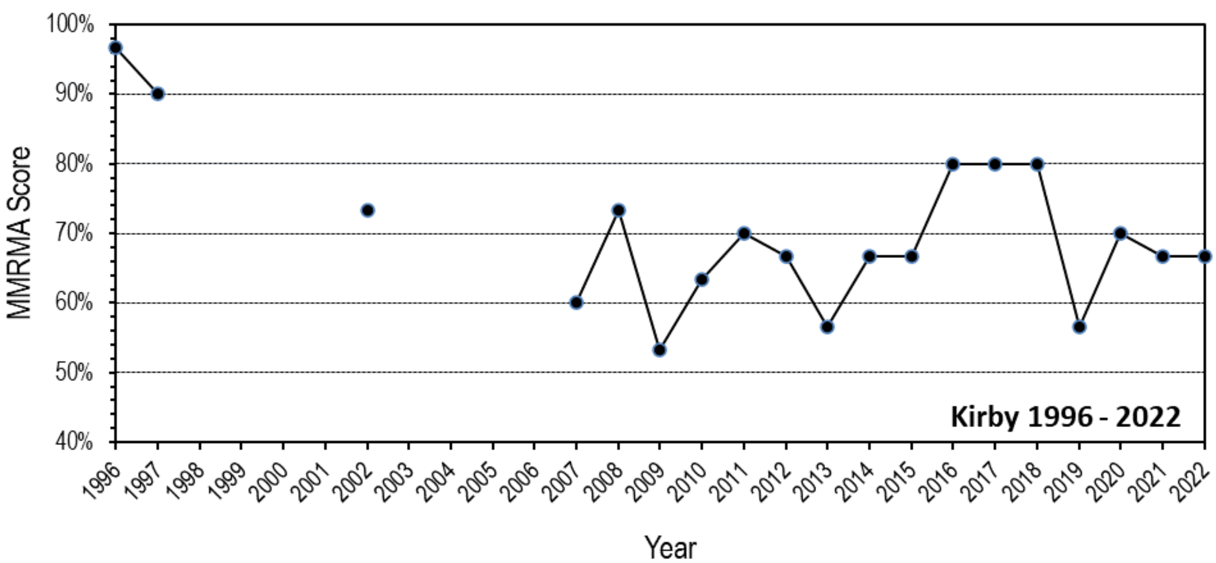


Figure 3-25 MMRMA Bioassessment Scores for NWE 2188 Annual Biomonitoring Efforts at Kirby over a Period from 1996-2022

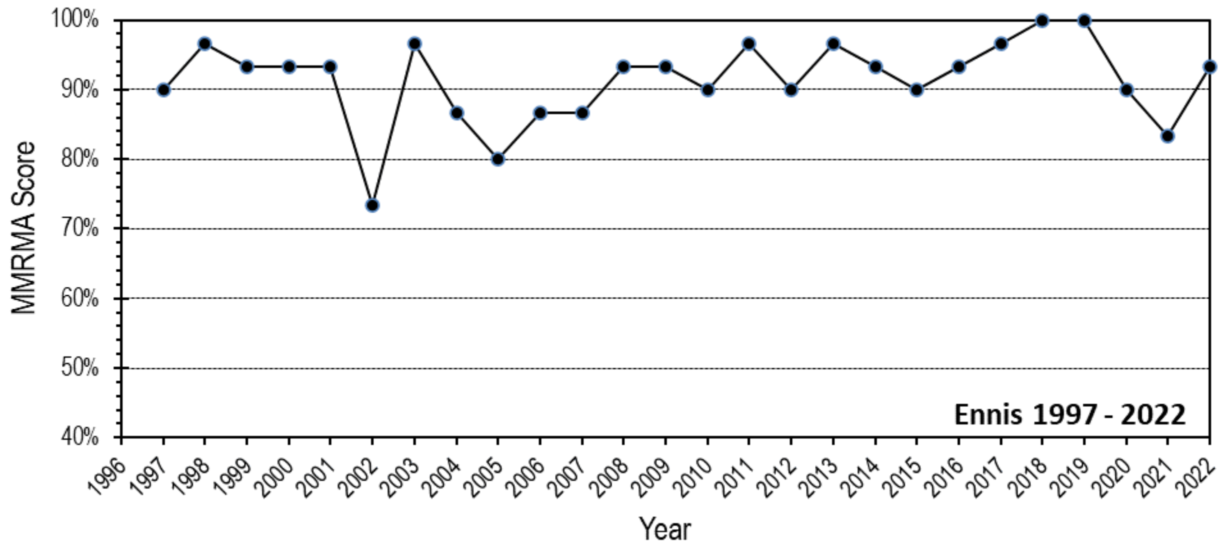


Figure 3-26 MMRMA Bioassessment Scores for NWE 2188 Annual Biomonitoring Efforts at Ennis over a Period from 1997-2022.

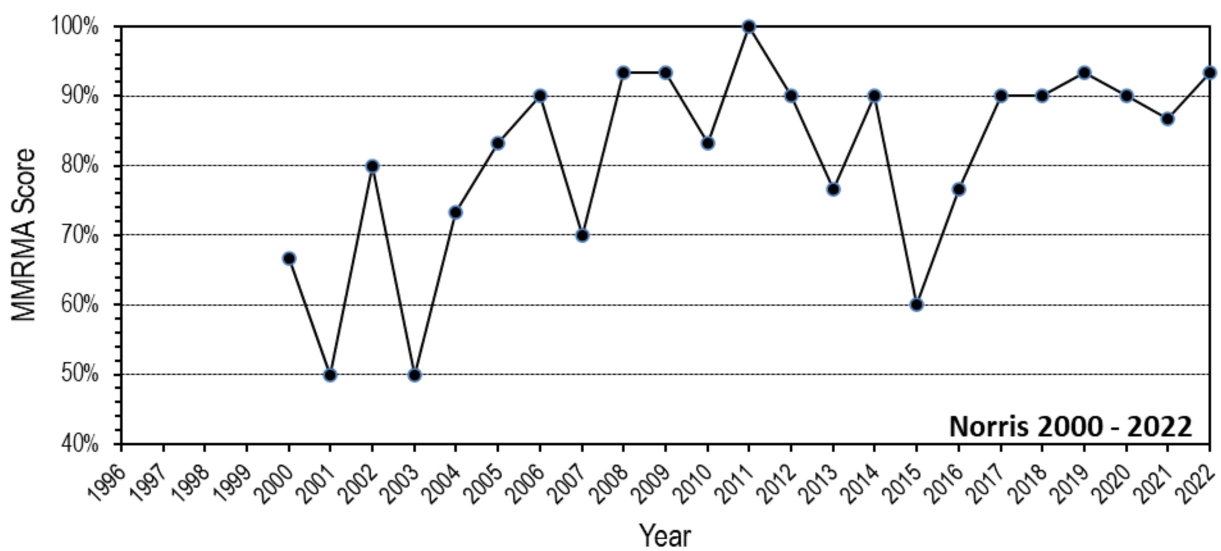


Figure 3-27 MMRMA Bioassessment Scores for NWE 2188 Annual Biomonitoring Efforts at Norris over a Period from 2000-2022.

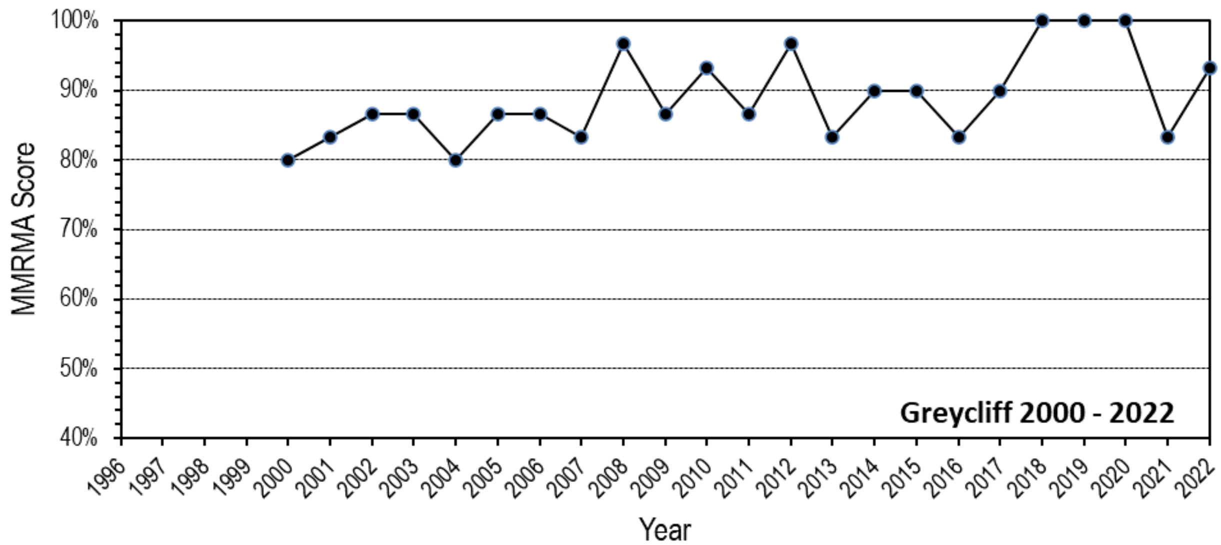


Figure 3-28 MMRMA Bioassessment Scores for NWE 2188 Annual Biomonitoring Efforts at Greycliff over a Period from 2000-2022.

3.2.2 Current Conditions (2022 Survey Results)

A total of 104 macroinvertebrate taxa were identified from the 2022 samples. Dipterans were the most diverse insect order with 31 taxa including 24 chironomid genera. Mayflies were represented by 18 species, and caddisflies included 24 taxa. Five stonefly taxa and 4 riffle beetle (Elmidae) genera were found. A single species of dragonfly, and one aquatic moth taxon were also collected. Non-insects were represented by 19 taxa including 4 snail genera, 3 worm taxa, 3 leech taxa, 2 genera of fingernail clams, 2 amphipod taxa, and single taxon of sowbug, crayfish, flatworm, and water mite. Mean metric scores calculated for macroinvertebrate samples collected in 2022 at the four Madison River sites are provided in Table 3-11. Community compositions by ordinal relative abundances of six major taxonomic groups at four sites on the Madison River in August 2022 are provided in Figure 3-29.

The Kirby and Greycliff sites had the richest fauna with 62 total taxa each, and the Ennis site had the fewest total taxa with 56 (Table 3-11). In August 2022, macroinvertebrate mean density estimates ranged from an estimated 5,959 individuals/m^2 at Norris to 9,465 individuals/m^2 at Kirby (Table 3-11). Insects dominated the Madison River macroinvertebrate fauna at three of the four sites (Figure 3-29 and Table 3-11), accounting for 88% of the macroinvertebrates collected at Norris, and more than 90% of the fauna at the Ennis and Greycliff sites. Kirby, however, was dominated by non-insects, comprising 57% of the individuals collected there.

The relative abundance of EPT taxa was lowest at Kirby (27.3%), compared with the other three sites which revealed relative abundances of 69% to 75.5% for EPT taxa (Table 3-11). Nearly half of individuals collected at Norris were Ephemeroptera (49%), with only 19.7% Trichoptera. However, at Ennis and Greycliff, Ephemeroptera and Trichoptera were nearly equally abundant (Figure 3-28 and Table 3-11).

Ephemeroptera were represented prominently by the minnow-tailed mayfly *Baetis tricaudatus* at all sites. *Baetis tricaudatus* accounted for 9.5% of the total 12% relative abundance of mayflies at Kirby, and 26% of the total 38% relative abundance of mayflies at Ennis. Norris was largely comprised of *B. tricaudatus* (19.6%) and the prong-gilled mayfly *Choroterpes* (14%). The relative abundance for Ephemeroptera at Greycliff was 37%, primarily the little stout crawler mayfly *Trichorythodes* (15.4%) and *B. tricaudatus* (14.3%).

Plecoptera contributions to relative abundances were small at the Madison River sites, but somewhat more prevalent at the upper two sites, Kirby (1.9%) and Ennis (2.5%), than at Norris (0.2%) (Figure 3-28 and Table 3-11). Three stonefly taxa were collected at Kirby, mostly the golden stonefly *Hesperoperla pacifica*. Five stonefly taxa were collected at Ennis, predominantly the perlodid *Skwala sp*., and the short-winged stonefly, *Claassenia sabulosa*. Norris had the single *Skwala* sp., present in low numbers in only two of the five samples collected. No stoneflies were counted in the Greycliff samples in 2022.

For Trichoptera, taxonomic composition varied among the four sites. At Kirby, where the total relative abundance was only 13% for Trichoptera (Figure 3-28 and Table 3-11), the long-horned caddisfly *Oecetis* (4.9%) and the little brown sedge caddisfly *Lepidostoma* (2.9%) were the most prevalent taxa. At Ennis, Trichoptera were mostly comprised of the snail-case caddisfly *Helicopysche borealis* (22.8%). Trichoptera at Norris were a mixture of 13 taxa, with none registering more than 6% relative abundance. Top genera for Norris caddisflies included the net-spinning caddisfly *Cheumatopysche* (5.4%), purse-case caddis *Leucotrichia pictipes* (3.7%), the humpless casemaker caddisfly *Brachycentrus occidentalis* (3.3%), and *H. borealis* (3.2%). The relative abundance for Trichoptera at Greycliff was 38%, dominated by *B. occidentalis* (26.2%), and *H. borealis* (6.2%).

Table 3-11 Mean Metric Scores Calculated for Macroinvertebrate Samples Collected at Four Sites on The Madison River, Montana, August 2022.

	Kirby	Ennis	Norris	Greycliff
Community Structure Metrics:				
Mean Density (Indiv./m^2)	9,465	7,780	5,959	6,364
Mean Taxa Richness	35.6	34.0	40.6	32.6
Total Taxa Richness	62	56	61	62
Shannon-Weaver Index (log e)	2.14	2.26	2.86	2.35
% Dominant Taxa	44.5%	45.4%	22.1%	33.5%
Community Composition Metrics:				
Mean EPT Richness	15.8	17.4	20.0	15.6
Total EPT Richness	27	27	28	30
% EPT	27.3%	73.0%	69.0%	75.5%
% Chironomidae	5.4%	5.0%	6.8%	6.2%
Baetidae/Ephemeroptera	0.60	0.77	0.55	0.43
Hydropsychinae/Trichoptera	0.17	0.15	0.30	0.06
Ordinal Relative Abundances (Mean %):				
Ephemeroptera	12.6%	38.3%	49.2%	37.5%
Plecoptera	1.9%	2.5%	0.2%	0.0%
Trichoptera	12.8%	32.2%	19.7%	38.0%
Coleoptera	9.1%	8.2%	11.1%	7.9%
Diptera	6.6%	13.0%	7.5%	11.0%
Non-insect	57.0%	5.1%	11.9%	5.6%
Functional Feeding Groups (Mean %):				
Scrapers/Grazers	51.8%	26.0%	11.9%	7.7%
Shredders	3.9%	5.4%	2.1%	1.8%
Filter-feeders	7.4%	11.1%	11.7%	34.0%
Collector-Gatherers	27.0%	51.2%	71.2%	53.6%
Predators	9.6%	5.8%	6.5%	3.0%
Tolerance Indices:				
Mean Modified HBI	6.16	3.83	4.07	3.89
Mean Metals Tolerance Index (MTI)	3.29	3.87	3.51	3.72
Total Sediment Tolerant Taxa	14	10	15	15
Total Sediment Intolerant Taxa	7	8	3	3
% Sediment Tolerant	59.4%	5.0%	19.3%	21.6%
% Sediment Intolerant	5.6%	7.7%	1.2%	0.6%
Macroinvertebrate-Based Estimate of Sediment:				
% Surface Fines (<0.06 mm)	14.3%	7.0%	11.2%	7.0%
% Sands (<2 mm)	25%	27.7%	32.3%	29.8%

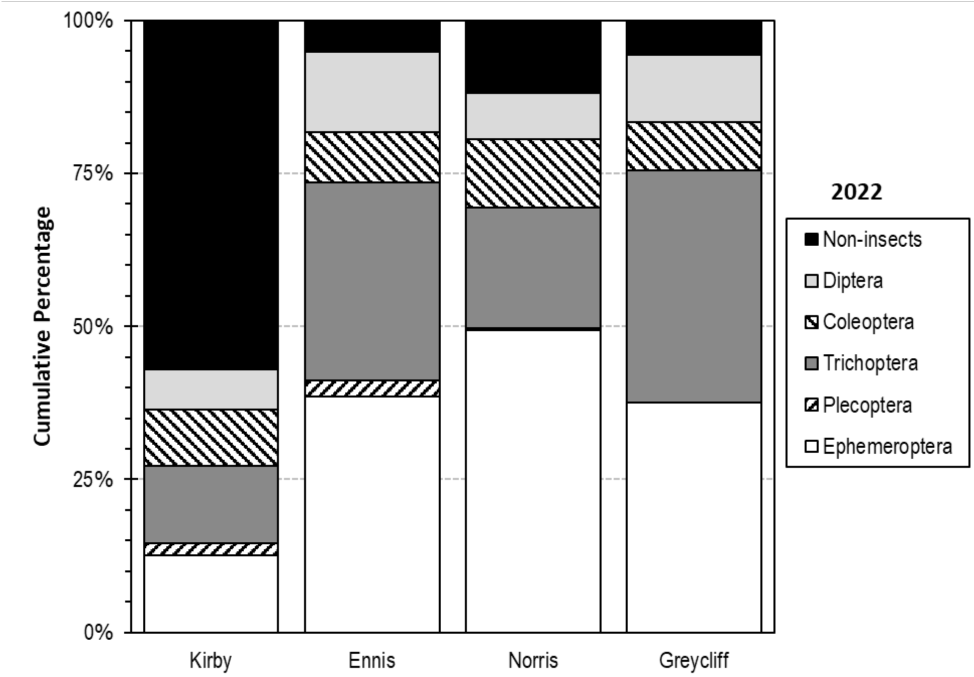


Figure 3-29 Community Compositions by Ordinal Relative Abundances of Six Major Taxonomic Groups at Four Sites on the Madison River, Montana (August 2022).

Non-insect taxa were a combination of worms, crustaceans, and molluscs. At Kirby, the samples were dominated by the physid "bladder snail" *Physella* sp. (39.1%) and the lymnaeid *Fossaria* sp. (11.7%), and these were found in all sample habitat locations except the Fast and Deep habitat. At the other three sites, these snail taxa accumulated no more than 0.5% of relative abundance. The next highest relative abundance for non-insect taxa was 11.9% at Norris (Figure 3-8 and Table 3-11), mostly comprised of the flatworm *Dugesia* (5%), the limpet snail *Ferrissia* (1.6%), and amphipods *Hyalella azteca* (1.3%) and *Gammarus* (1.1%).

Functional feeding groups by relative abundances at the four sites on the Madison River in August 2022 are provided in Figure 3-30. The functional feeding groups of the Madison River sites are generally dominated by collector-gatherer taxa (Figure 3-30 and Table 3-11), although the upper site of Kirby instead shows higher relative abundance of scrapers/grazers, due to the dominance of snail taxa at that site. The relative abundance of filter-feeders is highest at Greycliff, likely due to the increased number of *B. occidentalis*. The composition of collector-gatherers and filter-feeders increases in a downstream direction, whereas scraper and predator contributions decrease (Figure 3-30 and Table 3-11).

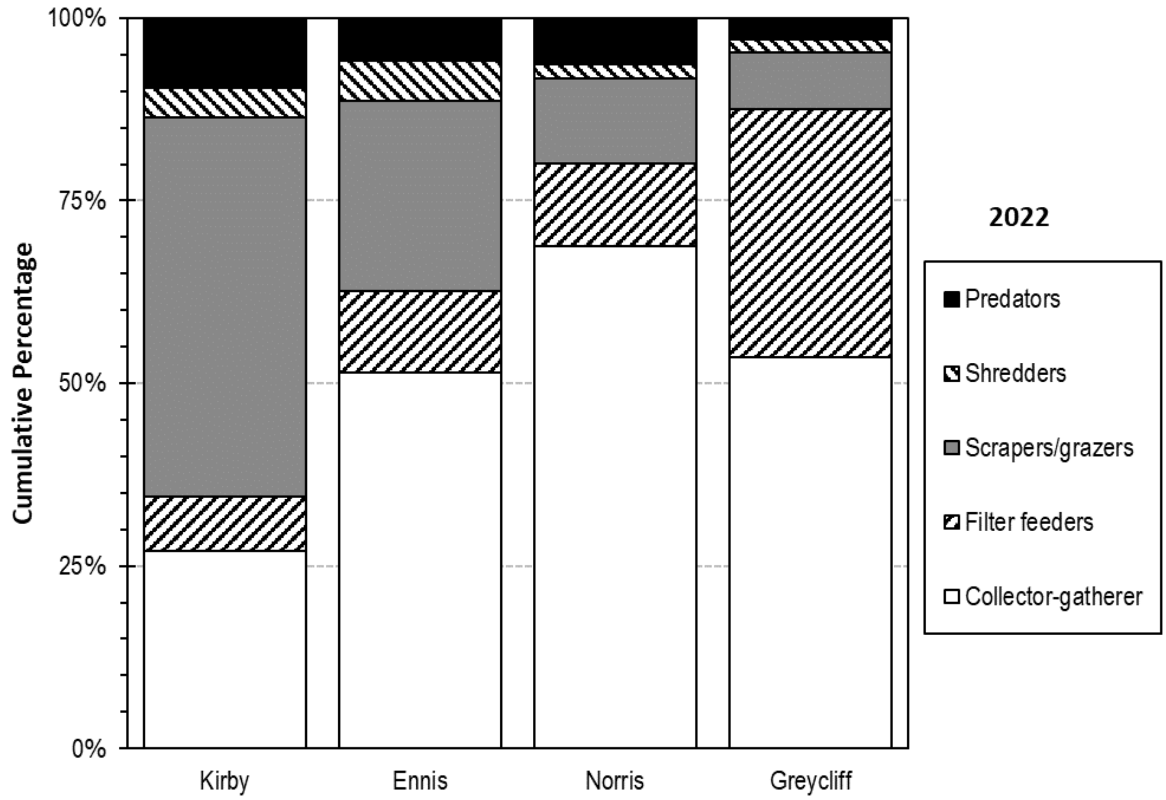


Figure 3-30 Functional Feeding Groups by Ordinal Relative Abundances at Four Sites on the Madison River, Montana (August 2022).

Total sediment tolerant and intolerant taxa and their relative abundances at the four sites on the Madison River in August 2022 are provided in Figure 3-30 and Figure 3-31, respectively. Sediment tolerance indices calculated for 2022 show a higher number of sediment tolerant taxa, at 14 and 15, with a slight decrease to 10 taxa at Ennis. Results from 2022 also show a decrease in intolerant taxa from Kirby and Ennis to Norris and Greycliff, with sediment intolerant taxa being very rare at the downstream sites (Table 3-11; Figure 3-30). Looking at relative abundances, Kirby shows a substantially higher percentage of sediment tolerance taxa, likely due to the increased numbers of snails (Table 3-10; Figure 3-31). There is notable increase in the relative abundance of sediment tolerant taxa from Ennis (5%) to Norris (19.3%) and Greycliff (21.6%). Sediment intolerant taxa were very rare at Norris and Greycliff. The experimental approach of estimating the amount of finer sediments using benthic macroinvertebrate optima is shown in Figure 3-33 and suggests that the amount of surface fines (<0.06 mm) are much higher at Kirby (14.25%), but lower at the other three sites (fines about 7 to 11%; Table 3-11and Figure 3-32). Sands (<2 mm) were similar at all four sites, ranging from about 25 to 32%.

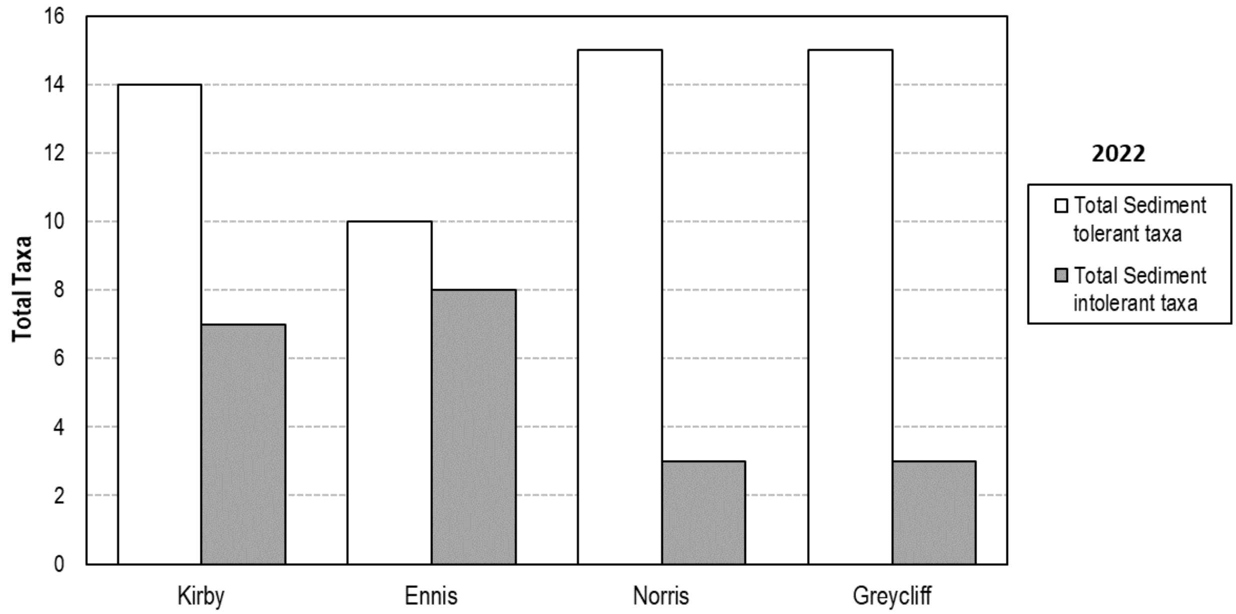


Figure 3-31 Total Sediment Tolerant and Intolerant Taxa at Four Sites on the Madison River, Montana (August 2022).

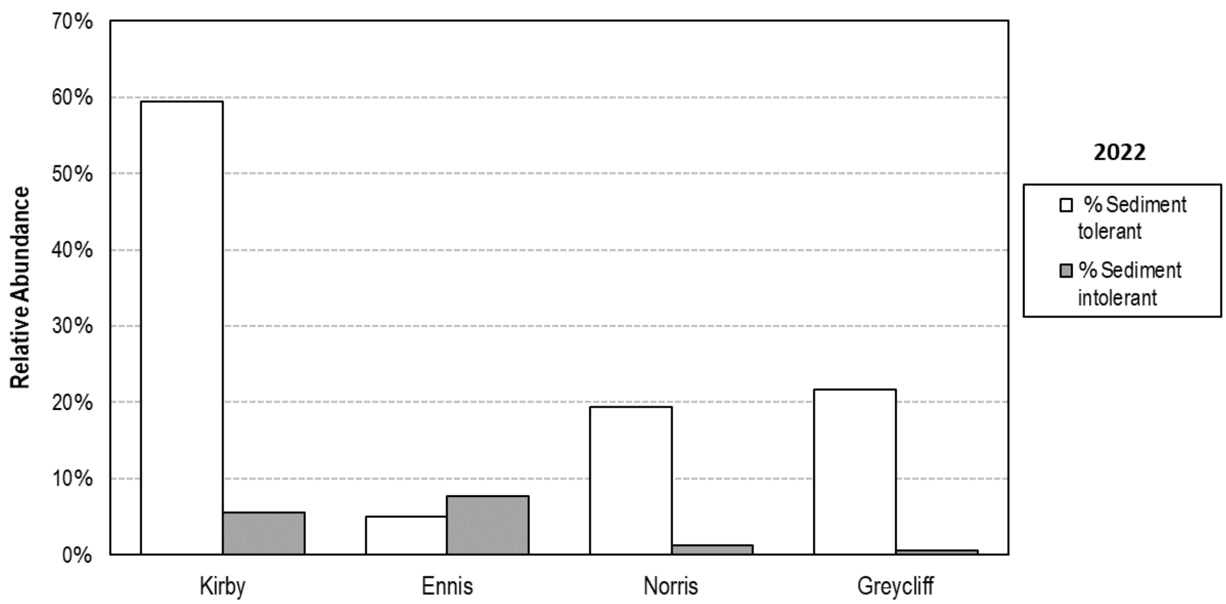


Figure 3-32 The Relative Abundances of Sediment Tolerant and Sediment Intolerant Organisms at Four Sites on the Madison River, Montana (August 2022).

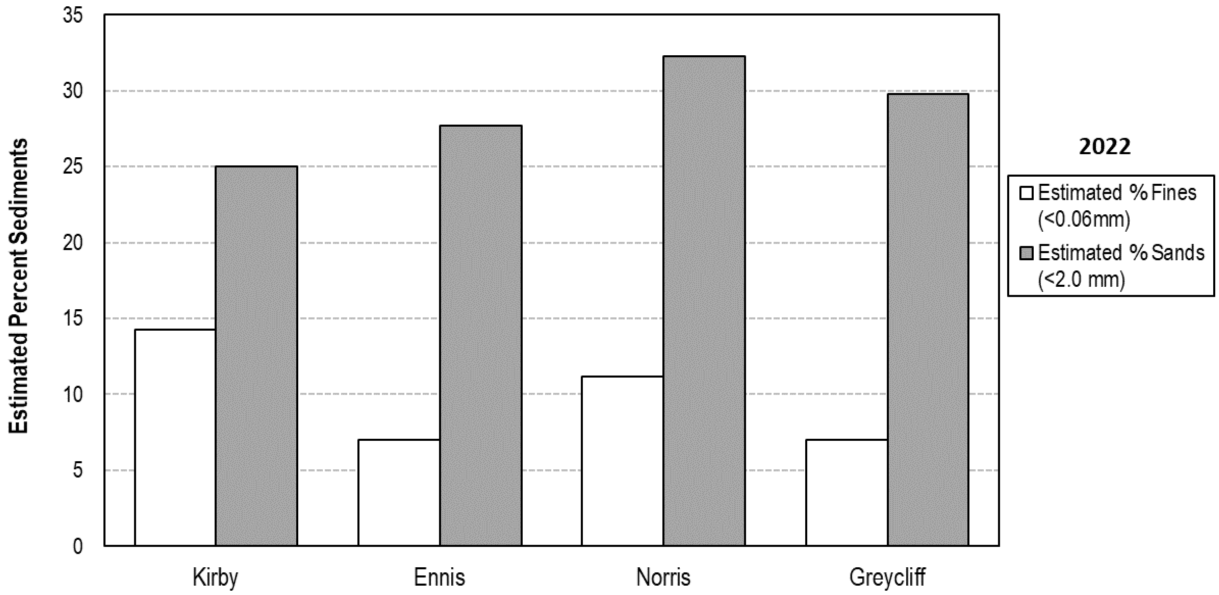


Figure 3-33 Macroinvertebrate-Based Estimates of Fine Sediments and Sands at Four Sites on the Madison River, Montana (August 2022).

3.3 Streamflow Analysis

The average annual flow in the Madison River below Ennis Lake is 1,717 cfs based on 84 years of record from Water Year 1939 through 2022. Average annual flows at this location were analyzed to determine multi-year periods when the average flow during each period was either above or below the long-term average, i.e., sustained wet and dry periods. Results of these evaluations are summarized in Table 3-12. The 8-year period from Water Year 1993 through 2000 was a sustained wet period with an average flow of 2,050 cfs, while the 16-year period from Water Year 2001 through 2016 was a sustained dry period with an average flow of 1,570 cfs. From 2017 through 2022 the flow has been close to the average for the entire 84 period of record.

Table 3-12 Sustained Wet and Dry Periods in the Madison River below Ennis Lake Derived from 84 Years of Records from Water Year 1939 through 2022.

Period	Duration (years)	Average Flow (cfs)	Hydrologic Regime
1939 to 1963	25	1,610	Sustained dry period
1964 to 1976	13	2,080	Sustained wet period
1977 to 1981	5	1,650	Sustained dry period
1982 to 1986	5	2,040	Sustained wet period
1987 to 1992	6	1,470	Sustained dry period
1993 to 2000	8	2,050	Sustained wet period
2001 to 2016	16	1,570	Sustained dry period
2017-2022	6	1,729	Average flow

Streamflow records of the Madison River below Hebgen Lake, at Kirby Ranch, and below Ennis Lake are shown in Figure 3-33 for the period covered by Water Years 1993 to 2022. Annual maximum three-day, daily, and instantaneous flows are summarized in Table 3-13.

During this 30-year period, the maximum flow release from Hebgen Dam occurred in Water Year 1993. During the same period, maximum flows in the Madison River below Ennis Lake occurred in 1996 and 1997. A higher instantaneous peak occurred in this reach in 1996, while a higher three-day flow occurred in 1997. An instantaneous peak of 3,970 cfs at the Madison River at Kirby Ranch (Gage No. 06038800) occurred in 2022 as shown in Figure 3-34 as a result of emergency operations.

The highest flows in the Madison River below Hebgen Dam did not coincide with the highest flows in the Madison River below Ennis Lake. The reason for this difference is that the Madison River receives additional unregulated flow downstream from Hebgen Dam. The timing of these natural inflows does not always coincide with the timing of flow releases from Hebgen Dam.

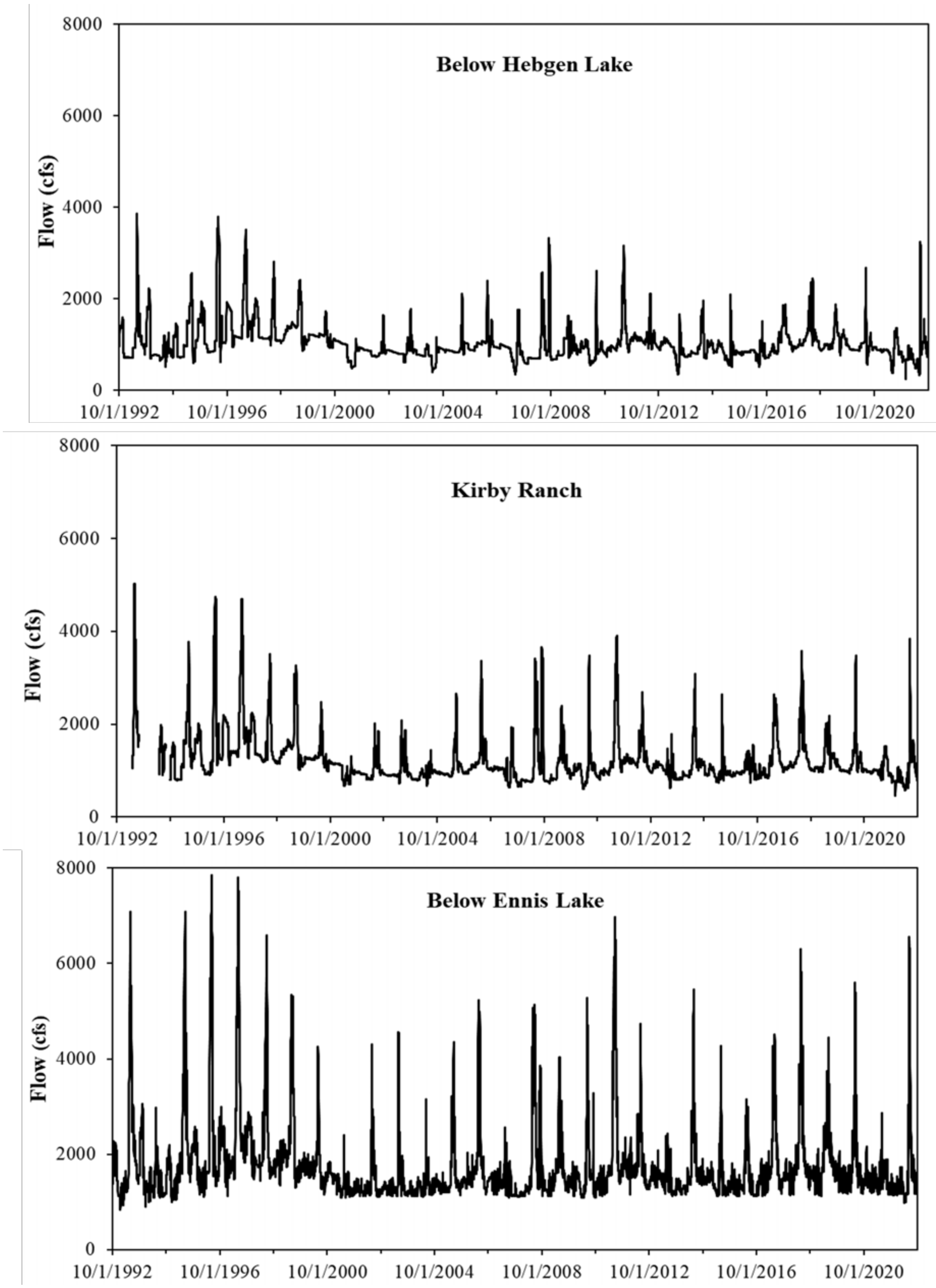


Figure 3-34 Streamflow Records of the Madison River below Hebgen Lake, at Kirby Ranch, and below Ennis Lake, Water Years 1993 To 2022.

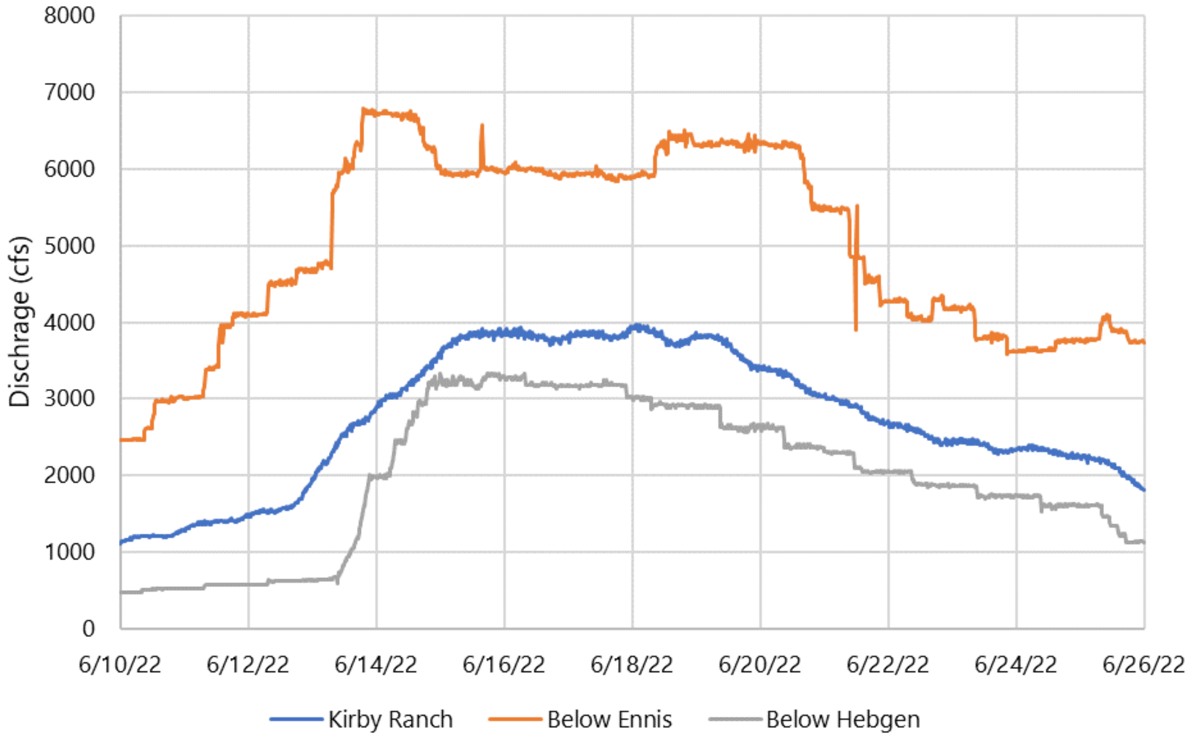


Figure 3-35 Observed Streamflows at USGS Gage Sites Madison on the River below Hebgen Lake (Gage No. 06038500), at Kirby Ranch (Gage No. 06038800), and below Ennis Lake (Gage No. 06041000) during the 2022 Emergency Operations.

Table 3-13 Annual Maximum Three-Day, Daily, and Instantaneous Flows for the Madison River below Hebgen Lake, at Kirby Ranch, and below Ennis Lake, Water Years 1993 to 2022.

	Maximum Three-Day Flow (cfs)			Maximum Daily Flow (cfs)			Maximum Instantaneous Flow (cfs)		
Water Year	Below Hebgen Dam	Kirby Ranch	Below Ennis Lake	Below Hebgen Dam	Kirby Ranch	Below Ennis Lake	Below Hebgen Dam	Kirby Ranch	Below Ennis Lake
1993	3,860	n/a	7,030	3,870	n/a	7,090	3,970	5,030	7,300
1994	2,240	n/a	3,030	2,240	n/a	3,060	2,260	1,980	3,140
1995	2,560	3,690	6,830	2,560	3,770	7,080	2,600	3,950	7,360
1996	3,750	4,700	7,620	3,800	4,750	7,850	3,880	4,840	7,980
1997	3,510	4,700	7,750	3,520	4,700	7,800	3,570	4,700	7,910
1998	2,760	3,500	6,200	2,820	3,520	6,590	2,860	3,560	6,820
1999	2,410	3,220	5,290	2,410	3,260	5,350	2,430	3,340	5,500
2000	1,730	2,440	4,030	1,740	2,470	4,260	1,750	2,520	4,450
2001	1,140	1,300	2,310	1,140	1,310	2,410	1,140	1,330	2,460
2002	1,650	1,910	4,070	1,650	2,020	4,310	1,670	2,050	5,180
2003	1,760	2,040	4,480	1,780	2,090	4,560	1,890	2,170	4,670
2004	1,120	1,350	2,480	1,170	1,440	3,160	1,270	1,490	3,440
2005	2,110	2,650	4,260	2,120	2,660	4,350	2,180	2,720	4,470
2006	2,330	3,300	5,130	2,400	3,360	5,230	2,410	3,450	5,390
2007	1,710	1,870	2,350	1,770	1,940	2,560	1,880	1,960	3,400
2008	3,290	3,610	5,080	3,330	3,660	5,130	3,710	3,680	5,390
2009	1,630	2,350	4,040	1,640	2,390	4,040	1,640	2,460	4,050
2010	2,500	3,350	5,110	2,610	3,480	5,280	2,670	3,510	5,540
2011	3,060	3,800	6,780	3,170	3,910	6,970	3,230	4,050	7,100
2012	2,110	2,640	4,400	2,120	2,690	4,730	2,160	2,760	4,810

	Maximum Three-Day Flow (cfs)			Maximum Daily Flow (cfs)			Maximum Instantaneous Flow (cfs)		
Water Year	Below Hebgen Dam	Kirby Ranch	Below Ennis Lake	Below Hebgen Dam	Kirby Ranch	Below Ennis Lake	Below Hebgen Dam	Kirby Ranch	Below Ennis Lake
2013	1,630	1,730	2,360	1,670	1,790	2,440	1,750	1,840	2,850
2014	1,940	3,020	5,280	1,970	3,090	5,460	1,990	3,200	5,560
2015	2,020	2,490	4,050	2,100	2,640	4,270	2,260	2,740	4,490
2016	1,470	1,510	3,010	1,510	1,550	3,160	1,530	1,590	3,190
2017	1,860	2,550	4,390	1,880	2,640	4,520	2,040	2,740	4,660
2018	2,350	3,540	6,020	2,453	3,584	6,301	2,510	3,680	6,510
2019	1,880	2,160	4,400	1,891	2,185	4,451	1,910	2,230	4,670
2020	2,610	3,410	5,400	2,682	3,481	5,606	2,740	3,600	6,180
2021	1,370	1,520	2,770	1,371	1,529	2,865	1,380	1,150	3,290
2022	3,210	3,830	6,200	3,243	3,841	6,563	3,330	3,970	6,790

3.4 Redd Surveys

Annual redd surveys are reviewed to help determine where to collect sediment data and are summarized in this section. The locations of redds that were surveyed at the Kirby Ranch Site are shown in Figure 3-36. Spawning activity was focused on the left bank (looking downstream). Most of the redds were located upstream from the monitoring site. The locations of redds that were surveyed at the Ennis Campground Site are shown in Figure 3-37. Most of the redds were located upstream from the monitoring site. The locations of redds that were surveyed at the Norris Bridge Site are shown in Figure 3-38. Most of the redds were located within and downstream from the monitoring site. The locations of redds that were surveyed at the Greycliff Fishing Access Site are shown in Figure 3-39. Most of the redds were located downstream from the monitoring site. The locations of redds that were surveyed at the Burnt Tree Site are shown in Figure 3-40. Most of the redds were located downstream from the monitoring site. The locations of redds that were surveyed at the Channels Ranch Site are shown in Figure 3-41. Most of the redds were located downstream from the monitoring site.

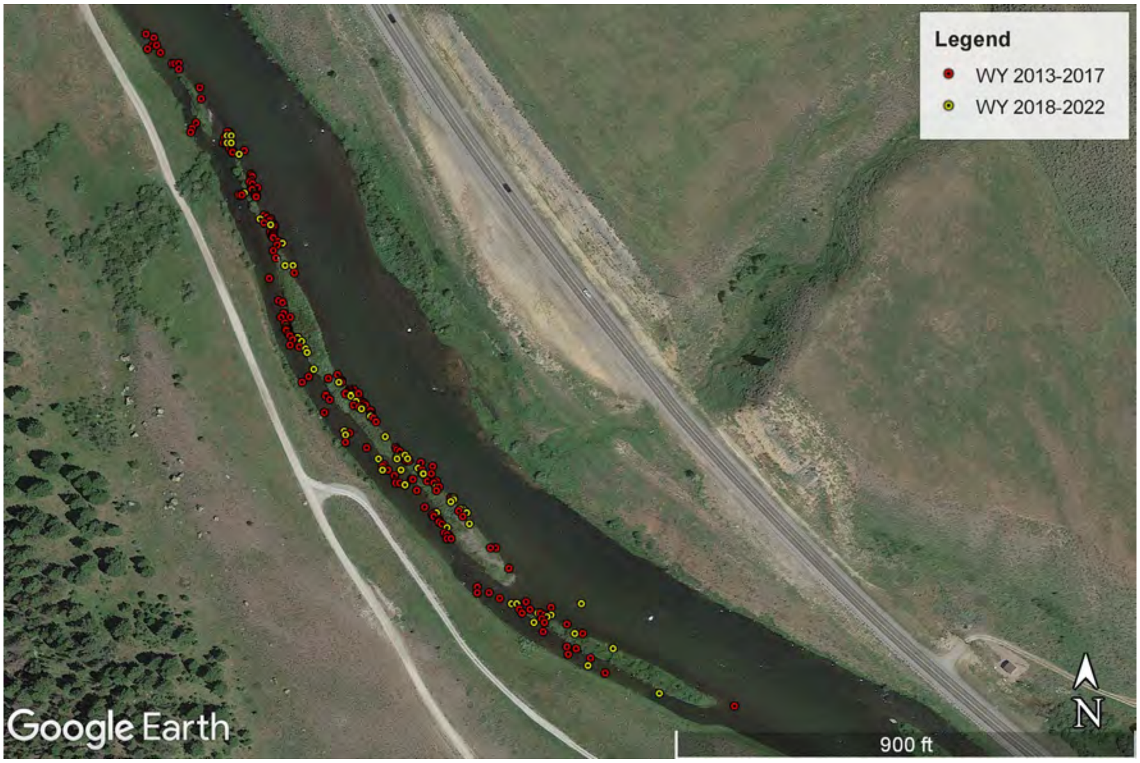


Figure 3-36 The Locations of redds Surveyed at the Kirby Ranch Site from Spring, 2013 through Spring, 2022.

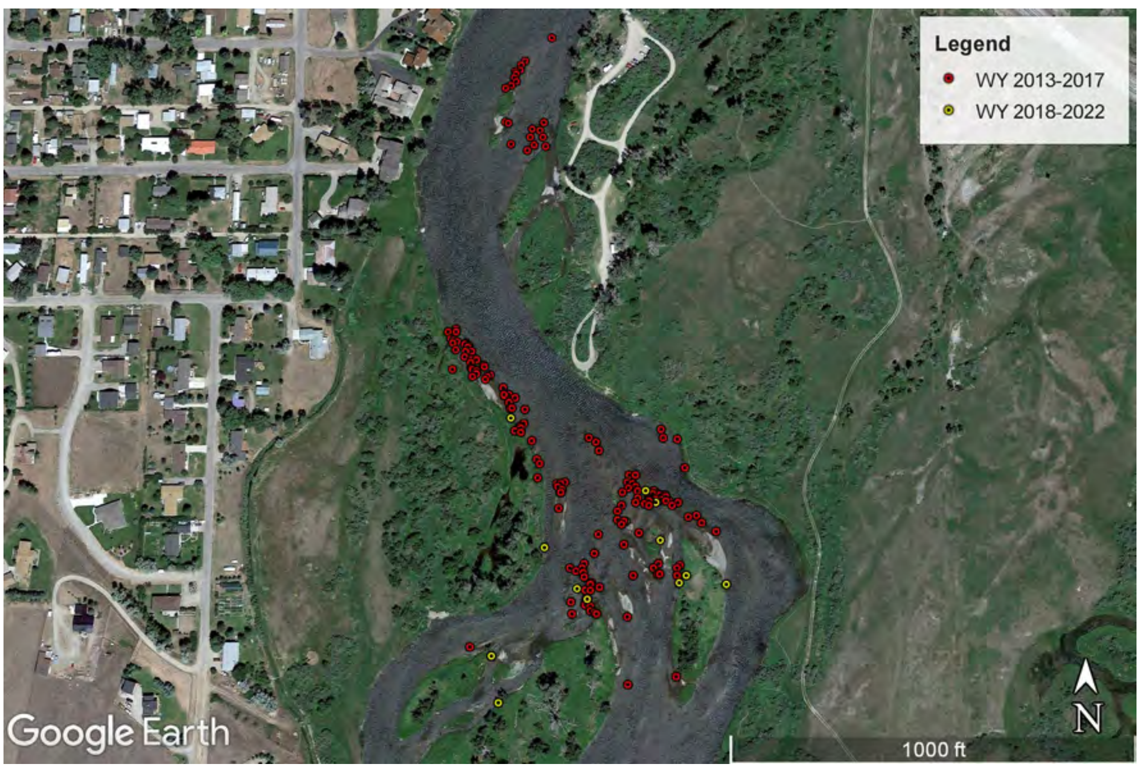


Figure 3-37 The Locations of redds Surveyed at the Ennis Campground Site from Spring, 2013 through Spring, 2022.

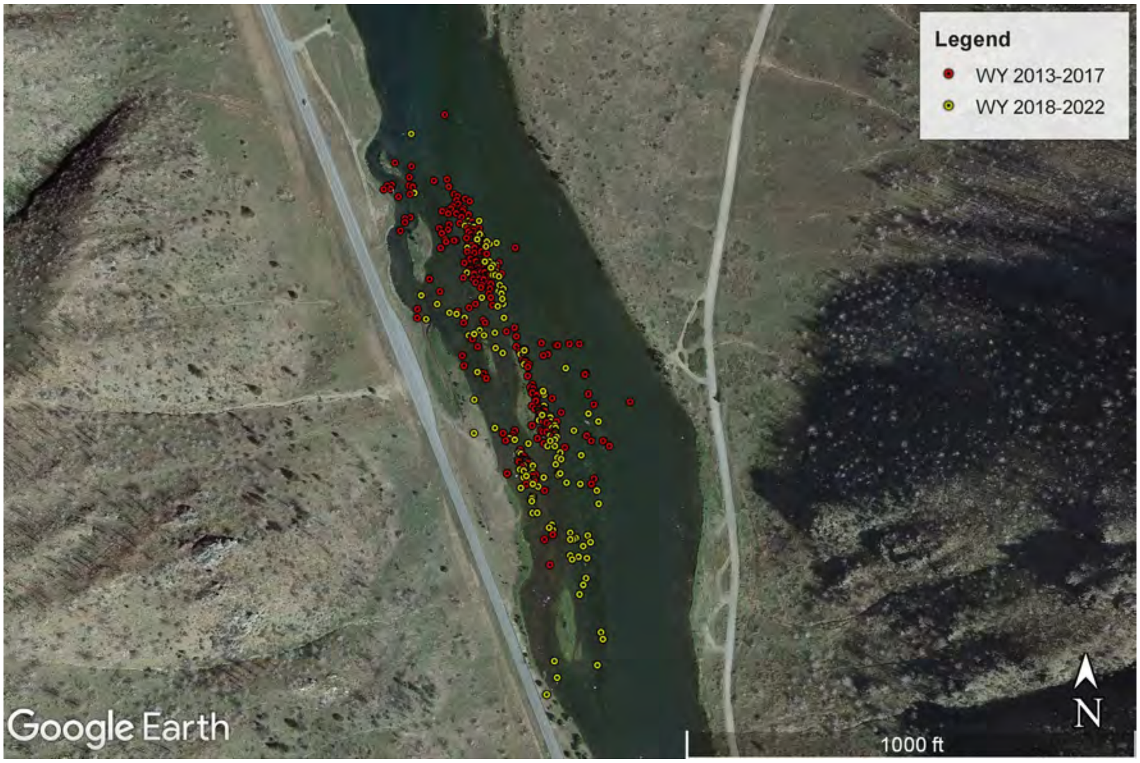


Figure 3-38 The Locations of redds Surveyed at the Norris Bridge Site from Spring, 2013 through Spring, 2022.

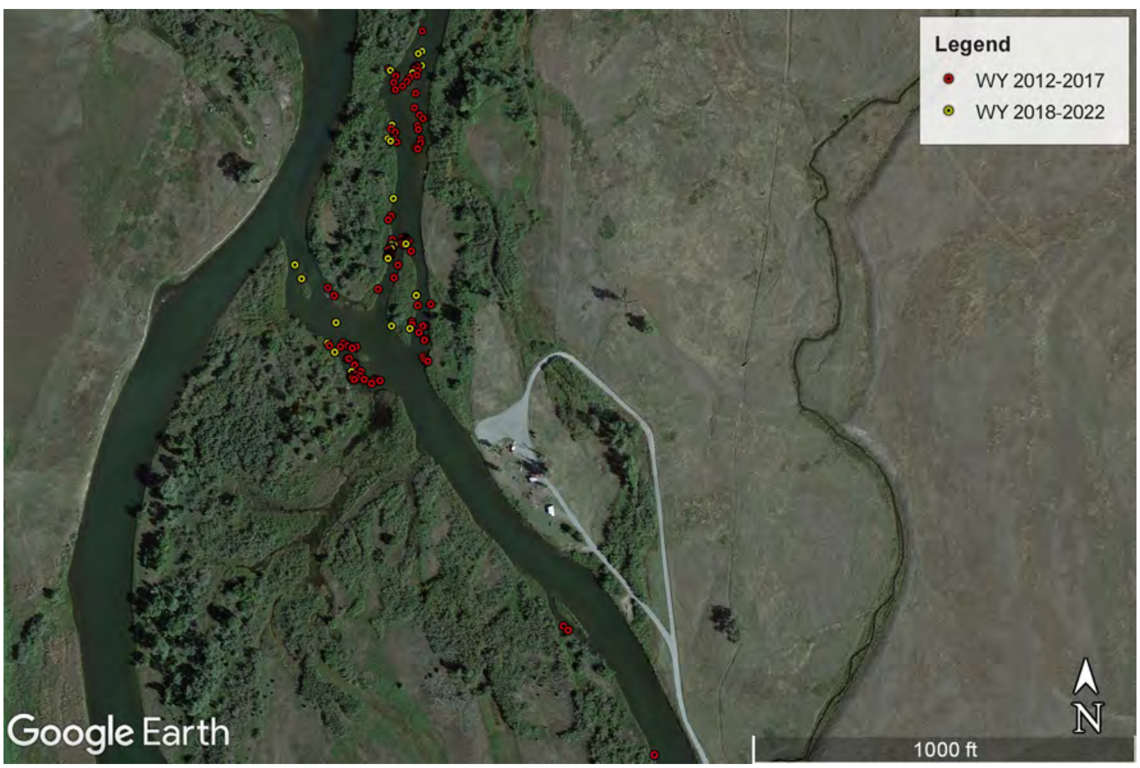


Figure 3-39 The Locations of redds Surveyed at the Greycliff Fishing Access Site from Spring, 2013 through Spring, 2022.

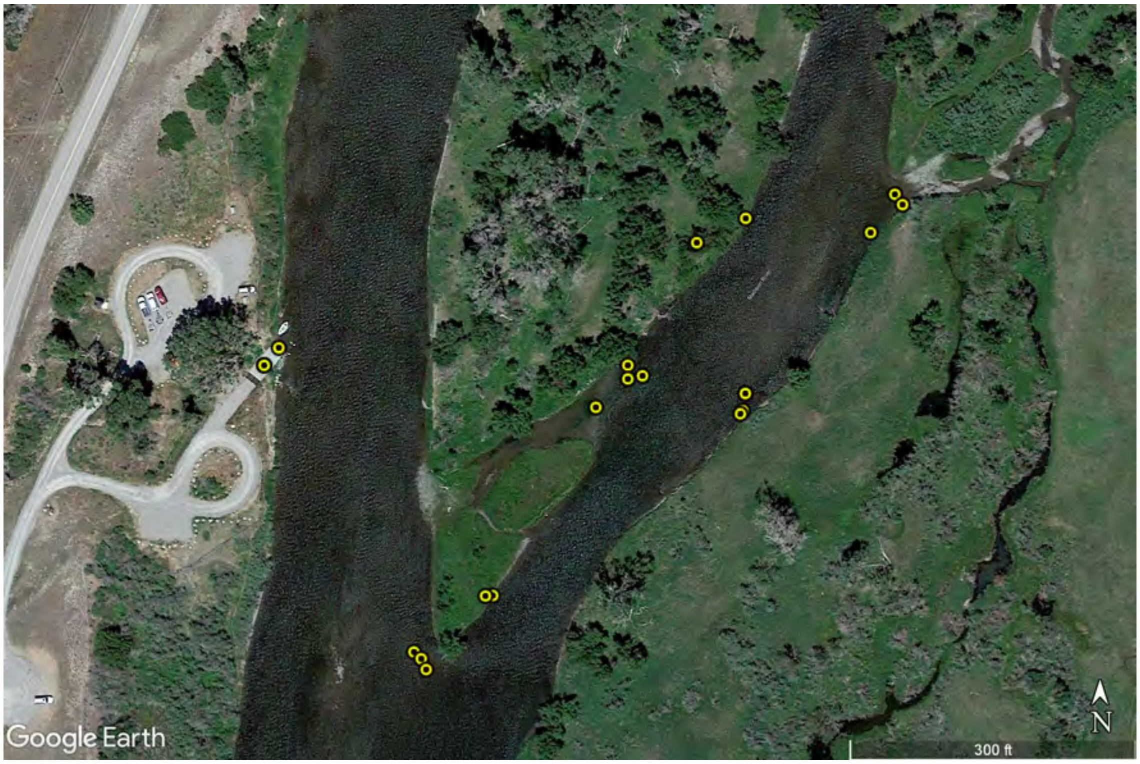


Figure 3-40 The Locations of redds Surveyed at the Burnt Tree Site from Fall, 2020 through Spring, 2022.

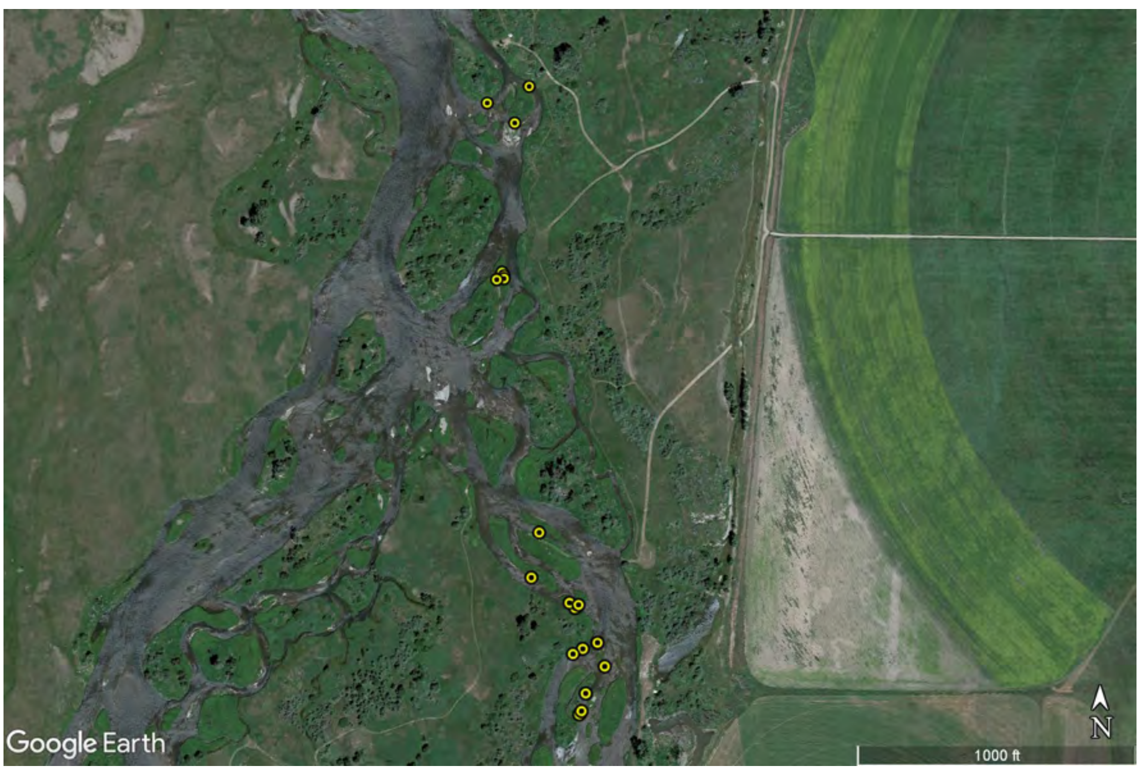


Figure 3-41 The Locations of redds Surveyed at the Channels Ranch Site from Fall, 2020 through Spring, 2022.

4.0 DISCUSSION

Channel morphology and sediment characteristics, aquatic macroinvertebrates, hydrology, and water temperature have all been monitored in the Madison River since 1994. Two distinct reaches of the Madison River have been identified: the upper Madison River extending from Hebgen Dam to Ennis Lake; and the lower Madison River extending from Madison Dam to the confluence with the Jefferson and Gallatin rivers.

Monitoring results from two sites on the upper Madison River (Kirby Ranch and Ennis) suggest that sediment characteristics are relatively good (low concentration of fine sediments in gravel substrates), and that temperature conditions are not stressful for fish. Monitoring results from two sites on the Lower Madison River (Norris Bridge and Greycliff Fishing Access) suggest that sediment characteristics are not as good as in the upper Madison River (higher concentration of fine sediments in the gravel substrates) and temperature conditions are more stressful to fish than in the upper Madison River.

These results are supported by aquatic macroinvertebrate data. Sediment-intolerant taxa were most diverse in the upper Madison River. Macroinvertebrates considered intolerant of fine sediments were rare in the lower Madison River. Coldwater taxa were more diverse, and abundant, in the upper river while warm water taxa predominated in the lower river.

To maintain channel morphology, and potentially manage the concentrations of fine sediments in the gravel substrates in the lower Madison River, flushing flow releases from Hebgen Dam were initiated with the beginning of the program in 2002 and the first flushing flow released in 2006. To provide temperature relief in the lower Madison River during the warm summer months, pulse flows are released from Madison Dam to maintain lower Madison River temperatures below 80°F. The protocol for releasing these pulse flows is described by FERC (2004).

Initial monitoring results from 1994 and 1995 indicated relatively high concentrations of fine sediment in the lower Madison River. In 1996, flows in the Madison River downstream from Madison Powerhouse peaked with a three-day average flow of 7,600 cfs. Gravel monitoring following these high flows indicated a reduction in the percentage of fine sediments. Peak flows with a similar magnitude and duration also occurred in the lower Madison River in 1997. However, there was no further reduction in the concentrations of fine sediment.

Reservoir operation modeling was conducted by R2 (2003a) to determine the feasibility of releasing flushing flows from Hebgen Dam given the operational constraints discussed in Section 1.1. It was determined that while it may not be very feasible to provide flushing flows with a magnitude of 7,600 cfs for a duration of three days in the lower Madison River, it would be more feasible to provide flushing flows with a magnitude of 5,400 cfs for a duration of three days. It was thought that flows with this magnitude would help to maintain channel morphology, and potentially maintain spawning gravel quality.

With this in mind, flushing flows were released in 2006, 2008 and 2011. The peak three-day average flows in the lower Madison River were 5,100 cfs in 2006 and 2008, and 6,800 cfs in 2011. Gravel monitoring results suggest that these flows were not effective in maintaining low concentrations of fine sediments.

The median percent fines less than 0.84 mm in the Upper Madison River were plotted against the maximum 3-day flow near Kirby Ranch in Figure 4-1. There were two years when the 3-day maximum flow was 4,700 cfs. These occurred in 1996 and 1997 before the 3,500 cfs maximum limit was adopted for the Madison River at Kirby Ranch.

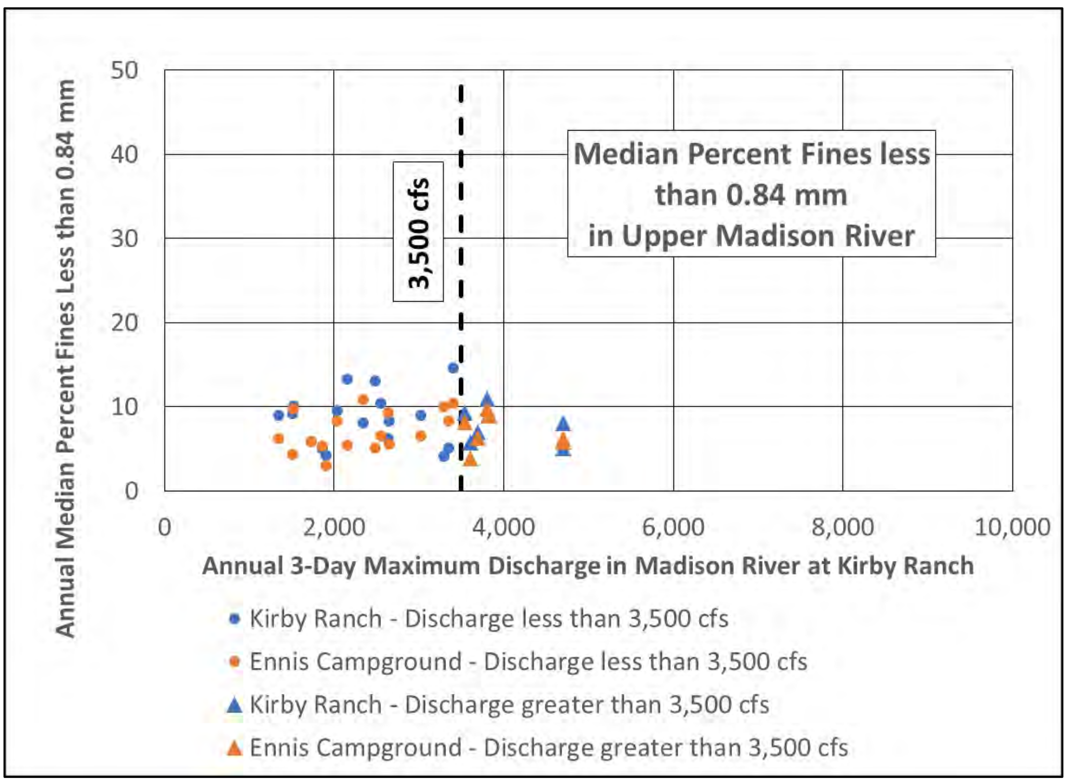


Figure 4-1 Median Annual Percent Fines less than 0.84 mm in the Upper Madison River versus Annual 3-Day Maximum Flow in Madison River near Kirby Ranch.

The median percent fines less than 0.84 mm in the Lower Madison River were plotted against the maximum 3-day flow below Ennis Lake in Figure 4-2. When the 3-day maximum flows were less than 6,800 cfs, there was much variability in percent fines and there did not appear to be a correlation between percent fines and the 3-day maximum flow. When the 3-day maximum flow was greater than 7,600 cfs, then the percent fines was relatively small. This comparison suggests that the flow needed to mobilize the stream bed ranges from 6,800 cfs to 7,600 cfs in the Lower Madison River.

The two years when the 3-day maximum flow in the Madison River below Ennis Lake was 7,600 cfs or greater occurred in 1996 and 1997. The corresponding flow in the Madison River near Kirby Ranch was 4,700 cfs for both of those years. Discharge hydrographs for the 1996 flood are shown in Figure 4-3. In the Madison River at Kirby Ranch, the discharge reached a peak of 4,700 cfs and the discharge exceeded 3,500 cfs for 34 days. In the Madison River below Ennis Lake, the discharge reached a peak of 7,600 cfs and the discharge exceeded 6,800 cfs for 11 days.

With the current maximum limit of 3,500 cfs at Kirby Ranch, the 7,600 cfs target in the Madison River below Ennis Lake may not be achievable, except for unusual occasions. A discharge of 7,600 cfs in the Madison River below Ennis Lake corresponds with a recurrence interval ranging from 10 to 25 years (Pioneer Technical Services 2022).

Annual time series of percent fines in the Lower Madison River are shown in Figure 3-1. These results suggest that there was less variability in percent fines prior to 2007, and more variability in percent fines after 2007. In the more recent sediment samples (after 2007), there were many high outliers. In 2013, one of the samples had about 70 percent fines less than 0.84 mm. This sample was primarily sand. Applied Geomorphology (Pioneer Technical Services 2022) suggested that Hot Springs Creek might be a potential source of fine sediment delivered to the Lower Madison River. However, photographs of the sediment in Hot Springs Creek consist of silts. When silt is delivered from Hot Springs Creek to the Madison River, it would likely be transported in suspension as wash load and it may not interact with sediments in the stream bed.

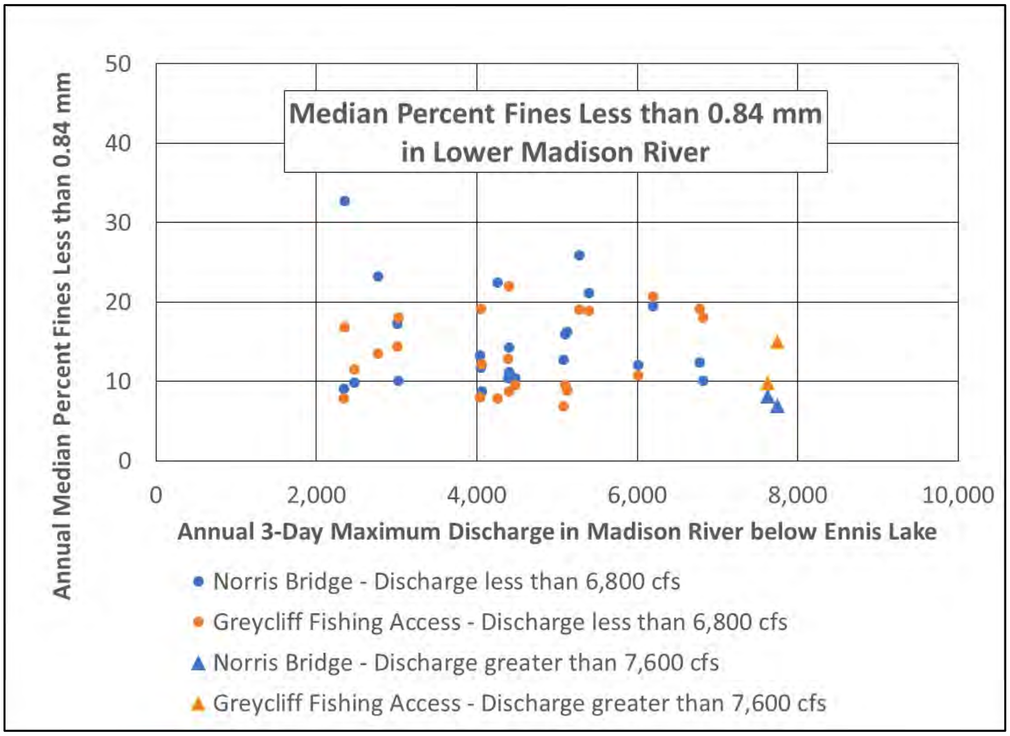


Figure 4-2 Median Annual Percent Fines less than 0.84 mm in the Lower Madison River versus Annual 3-Day Maximum Flow in Madison River Below Ennis Lake.

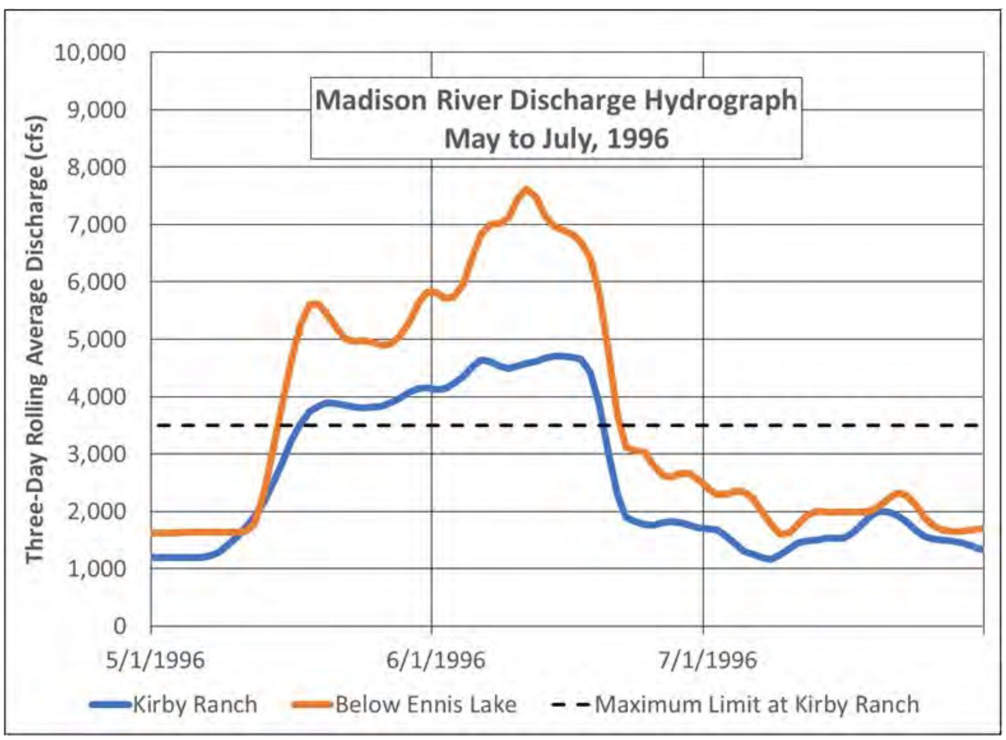


Figure 4-3 Madison River Discharge Hydrographs May 1, 1996 to July 31, 1996, at Kirby Ranch and below Ennis Lake.

A statistical comparison of the four Upper Madison River sites sampled 2020-2022 showed weak evidence of differences among sites for these years. The differences were lower percent fines (0.84 mm) at Channels Ranch than the Ennis and Kirby Sites, and lower percent fines (6.4 mm) at Channels Ranch and Kirby than the Ennis Site. This result indicates that the Kirby and Ennis Sites tend to have finer sediments than Channels Ranch and similar percent fines to Burnt Tree.

Linear model results showed evidence of a consistent monotonic increase in percent fines from 2002 to 2022 at all sites. The trend and overall level of percent fines did not differ between years with and without flushing flows. There were differences among sites in the overall mean percent fines (i.e., model intercept differed among sites), which included differences between the upper and lower Madison River sites for both the 0.84 mm and 6.4 mm size, and higher percent fines at Ennis compared to Kirby for the 6.4mm size only.

An investigation of relationships between peak flow in the Madison River at Kirby Ranch and percent fines in the upper river sites showed weak evidence of higher percent fines less than 0.84 mm at Ennis in years with peak flows over 3,000 cfs and weak evidence for a small reduction (roughly 2%) in percent fines less than 6.4 mm at Kirby in these years. An investigation of relationships between peak flow at McAllister and percent fines in the lower river sites showed no evidence of a relationship between peak flow at McAllister and percent fines observed in the Lower Madison River.

Operational constraints on flow releases from Hebgen Dam are summarized in Section 1.4. One of the constraints requires the flow in the Madison River near Kirby Ranch must be kept below 3,500 cfs to limit erosion from the outlet of Quake Lake. This constraint provides the following benefits:

- Reduces the risk of erosion at the outlet of Quake Lake, thereby preventing excessive turbidity levels in the river, preserving the geomorphic integrity of the stream, and reducing the risk of downstream flooding.
- Reduces the magnitude and frequency of floods, thereby reducing the risk of flood damage in downstream communities such as Ennis, and reducing the risk of bridge failure at downstream highway crossings.

This constraint makes it challenging to provide flushing flows, especially in the Lower Madison River where it appears that flushing flows in excess of 6,800 to 7,600 cfs may be needed.

Another operational constraint requires that flow releases from Hebgen Dam cannot be changed by more than 10% per day. This constraint helps to reduce the risk of trapping and stranding fish by limiting ramping rates when flow releases from Hebgen are decreasing. Another way to reduce the risk of trapping and stranding is to limit the down-ramping rates to be less than one inch per hour (Washington Department of Fisheries 1992). To illustrate downramping, a flushing flow hydrograph from June, 2020 is shown in Figure 4-4. (orange line). With the one inch per hour constraint, the flows could be ramped down in approximately one day. In addition, a five percent increase in flow per hour is illustrated in Figure 4-4 for upramping (green line). A FERC license amendment or approved variance would be required in order for NorthWestern to perform these operations (deviate from 10% daily flow change) from Hebgen Dam.

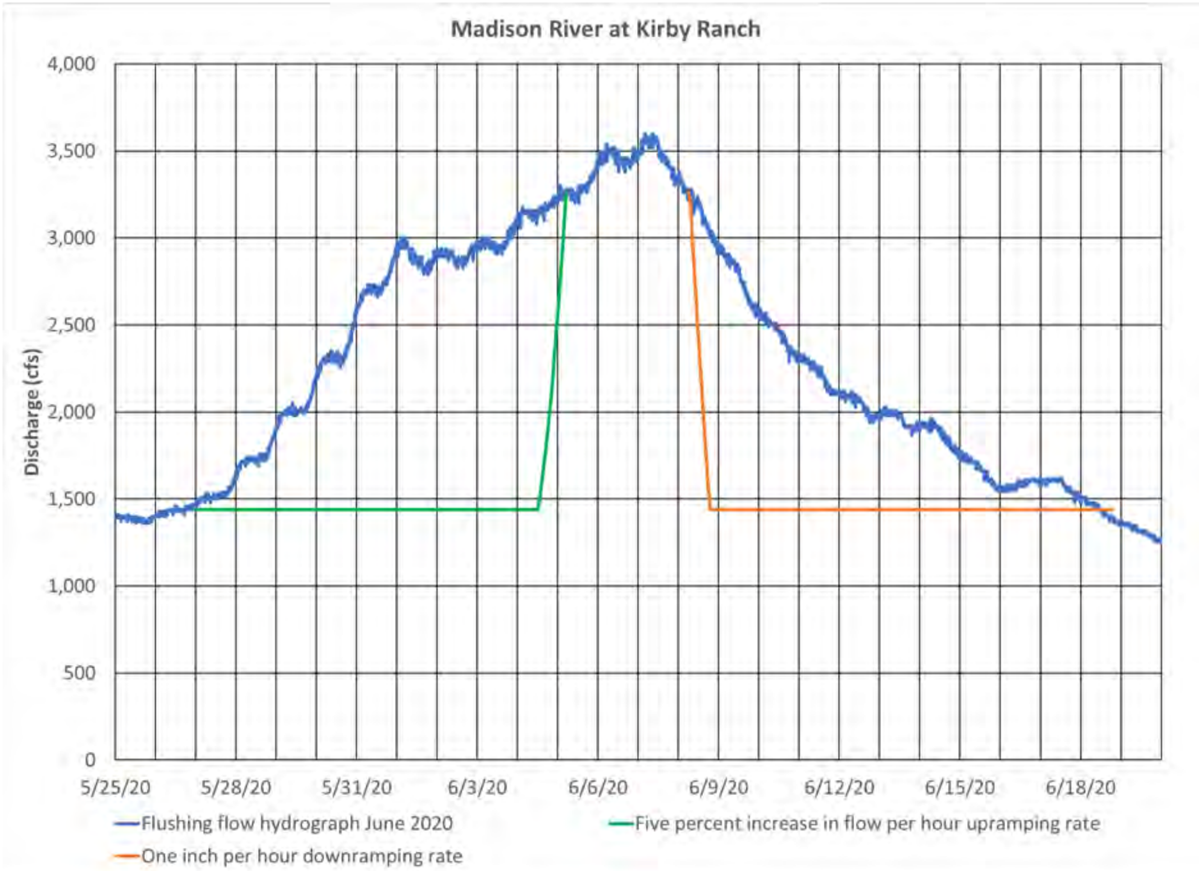


Figure 4-4 Flushing Flow Hydrograph in Madison River at Kirby Ranch in June, 2020. Comparison of Actual Hydrograph (Blue Line) with Five Percent Increase in Flow per Hour Up Ramping Rate (Green Line) and with One Inch per Hour Down-Ramping Rate (Orange Line).

When monitoring began in the mid-1990s, the Madison River supported a healthy macroinvertebrate community. Although taxonomic composition changed along the thermal and sediment gradients in the river, benthic macroinvertebrate assemblages were diverse and typically dominated by caddisflies and mayflies. Macroinvertebrate community composition has changed at most monitoring sites since 1995 (R2 2008). In general, the multimetric assessment developed for Missouri and Madison River kick samples indicates increased environmental stress at the Kirby site, with much lower MMRMA scores during 2007-2022 in comparison to the initial sampling in 1996-1997 (Figure 3-25). In contrast, NWE 2188 annual biomonitoring data indicated an overall increase in biological integrity at Norris from 2000 to 2011 followed by a decrease from 2011 to 2016. Since 2016, biological integrity has stabilized to MMRMA scores around 90% (Figure 3-27). Multimetric scores for Ennis, spanning the 1997-2011 period, show relatively stable and healthy conditions, with MMRMA scores averaging 90%, as well

(Figure 3-26). Likewise, conditions at Greycliff have been relatively stable since monitoring began in 2000, with MMRMA scores ranging from 80% in 2000 to 100% in 2018-2020 (Figure 3-28).

Results of analyses completed for the 2018-2022 period have indicated that increased environmental stresses were most evident at Kirby, with lower contributions of EPT taxa, specifically mayflies and caddisflies than the other three sites and an increased contribution of non-insect taxa, almost entirely due to two snail taxa, *Physella* and *Fossaria*. The other three sites downstream have these snail taxa present, but not at the high abundances seen at Kirby. These two snail taxa are classified as sediment tolerant, and also have higher tolerance values to organic pollution. Therefore, many of the metrics indicating environmental stress or disturbance at Kirby likely stems from the dominance of snails, and the environmental conditions that are favoring their presence.

Despite the requirements that the flow in the Madison River near Kirby Ranch must be kept below 3,500 cfs to limit erosion from the outlet of Quake Lake, some fine sediments do appear to find their way to the Kirby Ranch site, accumulating along the margins and shallow areas with lower velocities than in the thalweg. Much of the macroinvertebrate sampling is conducted in shallow margin areas, due to the safety of the sampling crew and limitations of the sampling gear. Examination of the individual replicate samples taken at Kirby revealed that snails were highly abundant in all habitat combinations except fast and deep, where numbers were significantly lower. This suggests that snails preferred shallower depths and slower velocities, which would generally be warmer and allow for more sediment deposition.

Benthic macroinvertebrate abundance and community structure are determined by numerous environmental factors. However, flow, water temperature, and substrate are considered the most important controlling factors of benthic communities (Ward and Stanford 1979; Armitage 1984; Saltveit et al. 1987; Hart and Finelli 1999). Despite the dominance of such tolerant taxa at Kirby, both upstream sites had a higher number of sediment intolerant taxa, and generally a lower number of sediment tolerant taxa (except for the recent period of 2018-2022 at Kirby). These results indicate a distinct contrast in sediment tolerances in the macroinvertebrate community between sites above and below Madison Dam. Recent reporting by Stagliano (2022) also notes a clear dichotomy between the upper and lower reaches of the Madison River in terms of the macroinvertebrate communities' thermal preferences; cold-water taxa were more common in the upper river while warm-water taxa dominated in the lower river below the Madison Powerhouse.

The experimental approach of estimating the amount of finer sediments using benthic macroinvertebrate optima suggests that Kirby has a higher amount of surface fines (<0.06 mm) than the other three sites (14.3% vs. 7 to 11%; Table 3-11 and Figure 3-25). Estimates of sands (<2 mm) based on macroinvertebrate optima were similar at all four sites, ranging from about 25 to 32%. These macroinvertebrate optima estimates are lower than fines estimates from actual sediment samples taken from the Madison River sites (Figure 3-1 and Figure 3-2), but they are generally still within the margins of error of the actual sediment samples, especially considering that the sediment samples include larger particle sizes (up to 0.84 mm for fines and up to 6.4 mm for sands).

5.0 RECOMMENDATIONS

The need for flushing flows in the Madison River is driven by the presence of fine sediment in the streambed of the Lower Madison River. Monitoring results from the last 28 years suggest that the magnitude of the flushing flows in the Lower Madison River should be in excess of 6,800 to 7,600 cfs. Under regulated conditions, 7,600 cfs in the Lower Madison has a recurrence interval ranging from 10 to 25 years.

Flow releases from Hebgen are limited to a maximum flow of 3,500 cfs at Kirby Ranch. Between the USGS Gage at Kirby Ranch and the USGS Gage below Ennis Lake, the Madison River gains an additional drainage from an area of 1,058 square miles. Runoff from this area is unregulated. Given the constraint of 3,500 cfs, the magnitude of the discharge from this unregulated area would need to be in excess of 3,300 to 4,100 cfs to achieve the 6,800 to 7,600 cfs needed for a successful flushing flow in the Lower Madison River.

Given these constraints, we recommend monitoring the discharge at the following gages from May through July each year:

1. Madison River below Ennis Lake (USGS Gage 06041000)
2. Madison River at Kirby Ranch (USGS Gage 06038800)

If the difference in flow between these two gages exceeds 3,300 cfs, then a flushing flow should be released from Hebgen. The magnitude of the flushing flow should not exceed 3,500 cfs (as measured at Kirby Ranch). To react quickly when the opportunity presents itself, a quick ramp up to 3,500 cfs is recommended. More specifically, the ramp up should not exceed a discharge increase of 5 percent per hour, as illustrated in Figure 4-4. To protect fish from stranding the ramp down should not exceed one inch per hour. A comparison of the Ennis Lake and Kirby Ranch gages since the Flushing Program was established shows a difference of 3,300 cfs only occurred twice in the 20-year record, once in 2011 and once in 2022. Both instances were a result of extreme flood conditions and in both cases, 3,500 cfs was exceeded at the Kirby Range gage. Given these data, it appears a flushing flow of necessary magnitude may only achievable when the 3,500 cfs limit is exceeded at Kirby.

In addition, the following changes are recommended for the Madison River Flushing Flow Program:

- **Channel Morphology and Sediment Characteristics**
    - The spawning gravel quality in the Upper Madison River at Kirby Ranch and Ennis Campground has been consistently good over the years. Recent core samples collected at Burnt Tree and Channels Ranch confirm the good quality of spawning gravels at Kirby Ranch and Ennis Campground. No further monitoring of core samples is recommended at Burnt Tree and Channels Ranch. In addition, the frequency of core sampling should be reduced from every year to once every two years.
    - The spawning gravel quality in the Lower Madison River (Norris Bridge and Greycliff Fishing Access) is relatively low and continued annual core sampling is recommended.
    - Spring and fall spawning surveys are currently conducted to identify locations for collection of core samples in late summer. Spawning surveys from the last 10 years have consistently shown that the location of current sediment core samples are being collected within active spawning areas. As such, no further spawning surveys are recommended.
    - Hot Springs Creek has been identified as a potential source of fine sediment input to the Madison River. Photographs of the sediment in Hot Springs Creek illustrate the presence of silt. The presence of sand would be of concern because the sand would have the potential to interact with the substrate of the Madison River. The stream bed in Hot Springs Creek should be visually inspected to see it is a source of sand. The presence of sand can be easily detected with an Imhoff Cone.
- **Aquatic Macroinvertebrates**
    - Aquatic macroinvertebrates are currently monitored in August each year at numerous sites in the upper and lower Madison River as part of the water quality monitoring program. These results should continue to be obtained and evaluated in the context of the flushing flow program.
    - Water temperature records from USGS gaging stations should be obtained and reviewed
- **Streamflow**
    - Streamflow records from USGS gages on the Madison River should continue to be obtained and reviewed.

6.0 REFERENCES

Armitage, P.D. 1984. Environmental changes induced by stream regulation and their effect on lotic macroinvertebrate communities. Pages 139-164 in A. Lillehammer and S.J. Saltveit, editors. Regulated Rivers. Universitetsforlaget AS, Norway.Barbour, M. T., and J. Gerritsen. 1996. Subsampling of benthic samples: A defense of the fixed-count method. J. North American Benthological Society 15: 386-391.

Barbour, M. T., J. B. Stribling, and J. R. Karr. 1995. The multimetric approach for establishing biocriteria and measuring biological condition. Pages 63-76 in W. S. Davis and T. P. Simon, editors. Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Ann Arbor, Michigan.

Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates and fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington D.C. 326 p.

Bollman, W. 1998. Improving stream bioassessment methods for the Montana Valleys and Foothills Ecoregion. Master's Thesis. University of Montana. Missoula, Montana.

Bukantis, R. 1998. Rapid Bioassessment Macroinvertebrate Protocols: sampling and sample analysis SOP's. 1998. Montana Department of Environmental Quality, Helena.

Burnham, K.P. and D.R. Anderson. 2002. Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach. Second Edition. Springer. New York.

Carling, P. 1995. Implications of sediment transport in instream flow modeling of aquatic habitat. In: Harper, D. M.; Ferguson, A. J. D., eds. The ecological basis for river management. Chichester, England: John Wiley & Sons: 17–32.

EA Engineering, Science, and Technology (EA). 1992. Task 1 – Report, Determination of flushing flow needs, prepared for Montana Power Company, July.

Federal Energy Regulatory Commission (FERC). 2004. Order modifying and approving final pulse flow protocol. Project No. 2188-097. December 21.

Federal Energy Regulatory Commission (FERC). 2013. Order approving Madison River flushing flow plan under Article 419. Project No. 2188-097. January 13.

Harris, T. L. and T. M. Lawrence. 1978. Environmental requirements and pollution tolerance of Trichoptera. EPA-600/4-78-061. United States Protection Agency.

Hart, D.D. and C.M. Finelli. 1999. Physical-biological coupling in streams: the pervasive effects of flow on benthic organisms. Annual Review of Ecology and Systematics 30: 363-95.

Hauer, F. R., J. A. Stanford and J. T. Gangemi. 1991. Effects of stream regulation in the upper Missouri River. Montana Power Company, Butte, Montana.

Hellawell, J. M. 1978. Biological surveillance of rivers. Water Research Centre, Stevenage, England.

Hilsenhoff, W. L. 1987. An improved biotic index of organic stream pollution. Great Lakes Entomologist 20: 31-39.

Hubbard, M. D. and W. P. Peters. 1978. Environmental requirements and pollution tolerance of Ephemeroptera. EPA- 600/4-78-061. United States Environmental Protection Agency.

Huff, D. D., S. H. Hubler, Y. Pan, and D. L. Drake. 2006. Detecting shifts in macroinvertebrate assemblage requirements: implicating causes of impairment in streams. Oregon Dept. Environmental Quality. DEQ06-LAB-0068-TR.

Jackson, W. L. 1981. Bed material routing and streambed composition in alluvial channels. Corvallis: Oregon State University, Department of Forest Engineering (Hydrology). 160 p. Ph.D. Thesis.

Karr, J. R., K. D. Fausch, P. L. Angermeier, P. R. Yant, and I. J. Schlosser. 1986. Assessment of biological integrity in running waters: A method and its rationale. Illinois Natural History Survey, Champaign, Illinois. Special Publication 5.

Kondolf, G. M. 2000. Assessing salmonid spawning gravel quality. Trans. Am. Fish Soc. Vol. 129, January, pp 262-281.

Lenat, D. R. 1983. Chironomid taxa richness: natural variation and use in pollution assessment. Freshwater Invertebrate Biol. 2: 192-198.

Lotspeich, F. B. and P. H. Everest. 1981. A new method for reporting and interpreting textural composition of spawning gravel. USDA Forest Service Research Note PNW-369. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

McGuire D.L. 2017. Madison and Missouri River Macroinvertebrate Biomonitoring: 2016 Data Summary. Prepared for Northwestern Energy, Butte, MT.

McGuire D.L. and Stagliano, D.M. 2018. Madison and Missouri River Macroinvertebrate Biomonitoring: 2017 Data Summary. Prepared for Northwestern Energy, Butte, MT.

McGuire, D. L. 1993. Clark Fork River macroinvertebrate community biointegrity: 1986 through 1992. Montana Department of Health and Environmental Sciences, Helena, Montana.

McGuire, D. L. 1999. Aquatic macroinvertebrate biomonitoring – Madison and Missouri Rivers, Montana. Summary Report: 1995-1998. Montana Power Company, Butte, Montana.

McGuire, D.L. 2012. Aquatic macroinvertebrate biomonitoring data summary 2008-2011. PPL – Montana, Butte, Montana.

McNeil, W. J., and W. H. Ahnell. 1964. Success of pink salmon spawning relative to size of spawning bed materials. U.S. Fish and Wildlife Service, Spec. Publ. Fish. No. 469. 15 p.

Montana Department of Environmental Quality (MDEQ). 1998. Rapid Bioassessment Macroinvertebrate Protocols: sampling and sampling analysis SOPs, Helena, Montana.

Montana Power Company. 1976. Memorandum of Understanding with U.S. Forest Service.

Northwestern. 2021. Missouri-Madison Project no. 2188 Water Quality and Biological Monitoring Plan For the years 2022-2040.

Petts, G. E. and I. Maddock. 1996. Flow allocation for in-river needs. In: Petts, G.; Calow, P., eds. River restoration. Oxford, England: Blackwell Science, Ltd: 60–79.

Phillips, R. W., R. L. Lantz, E. W. Claire, and J. R. Moring. 1975. Some effects of gravel mixtures on emergence of coho salmon and steelhead trout fry. Trans. Am. Fish Soc. 104(3):461 466.

Pielou, E. C. 1966. An introduction to mathematical ecology. Wiley, New York.

Pioneer Technical Services. 2022. Madison River sediment mobility assessment, prepared for NorthWestern Energy, May 5.

Pinheiro J, Bates D, R Core Team (2022). _nlme: Linear and Nonlinear Mixed Effects Models_. R package version 3.1-157, https://CRAN.R-project.org/package=nlme.

Pitlick, J. 1994. Coarse sediment transport and the maintenance of fish habitat in the Upper Colorado River. In: Cotroneo, G. V.; Rumer, R. R., eds. Proceedings of the 1994 conference hydraulic engineering '94, Vol. 2; August 1–5; ASCE Hydraulic Division, Buffalo, NY: 855–859.

Plafkin, J. L., M. T. Barbour, K. D. Porter, S. K. Gross, and R. M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers: Benthic macroinvertebrates and fish. U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington, D.C. EPA 440-4-89-001.

R Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

R2 Resource Consultants, Inc. (R2). 1994a. Determination of flushing flow needs, Madison and upper Missouri rivers, Supplemental Report, Montana Power Company, Butte, Montana.

R2 Resource Consultants, Inc. (R2). 1994b. Flushing flow investigations for the lower Madison River. Final Report. Montana Power Company, Butte, Montana.

R2 Resource Consultants, Inc. (R2). 1994c. Assessment of macroinvertebrate communities in the lower Madison River, Montana. Montana Power Company, Butte, Montana.

R2 Resource Consultants, Inc. (R2). 1996. Flushing flow needs in the Madison River, Montana: 1995 sediment and aquatic invertebrate monitoring results and comparison with 1994 results. Montana Power Company, Butte, Montana.

R2 Resource Consultants, Inc. (R2). 1997. Flushing flow needs in the Madison River, Montana: 1996 sediment and aquatic invertebrate monitoring results and comparison with 1994 and 1995 results. Montana Power Company, Butte, Montana.

R2 Resource Consultants, Inc. (R2). 2000. Flushing flow needs in the Madison River, Montana: 1997 streambed and aquatic invertebrate results; comparison with 1994, 1995, and 1996 results; and recommendations for future monitoring. PPLM, Butte, Montana.

R2 Resource Consultants, Inc. (R2). 2003a. Revised Plan to monitor and coordinate flushing flows in the Madison River below Hebgen Dam, FERC Project 2188, in response to Article 419 of New License Order, PPLM, Butte, Montana.

R2 Resource Consultants, Inc. (R2). 2003b. Flushing flow needs in the Madison River Montana: 2002 streambed and aquatic invertebrate results; and comparison with 1994, 1995, 1996, and 1997 results. PPLM, Butte, Montana.

R2 Resource Consultants, Inc. (R2). 2008. Flushing flow needs in the Madison River, Montana: 2007 streambed and aquatic invertebrate monitoring results; and comparison with 1994, 1995, 1996, 1997 and 2002 results. PPLM, Butte, Montana.

R2 Resource Consultants, Inc. (R2). 2013. Flushing flow needs in the Madison River, Montana 2008, 2009, 2010, 2011, and 2012 streambed and aquatic Invertebrate monitoring results and comparison with 1994, 1995, 1996, 1997, 2002, and 2007 results. PPLM, Butte, Montana.

R2 Resource Consultants, Inc. (R2). 2018. Flushing flow needs in the Madison River, Montana 2013 through 2017 Streambed and Aquatic Invertebrate Monitoring Results and Comparison with Results from 1994 through 2012. NorthWestern Energy, Helena, Montana.

Relyea, C. D., G. W. Minshall, and R. J. Danely. 2001. Stream insects as bioindicators of fine sediment. Stream Ecology Center, Idaho State University, Pocatello, Idaho

Ricklefs, R. E. 1979. Ecology. Chiron Press, New York. 966 p.

Ryan, S. E. and C. A. Troendle. 1996. Bedload transport patterns in coarse-grained channels under varying conditions of flow. In: Proceedings of the 6th inter-agency sedimentation 32 USDA Forest Service RMRS-GTR-128. 2004. conference; 1996 March 10–14; Las Vegas, NV. VI-22 to VI-27b.

Ryan, S. E.; L. S. Porth, and C. A. Troendle. 2002. Phases of bedload transport defined using piecewise regression. Earth Surface Processes. 27: 971–990.

Ryan, S. E.; L. S. Porth, and C. A. Troendle. 2005. Coarse sediment transport in mountain streams in Colorado and Wyoming, USA. Earth Surface Processes and Landforms.

Saltveit, S.J., J.E. Brittain, and A. Lillehammer. 1987. Stoneflies and river regulation – a review. Pages 117-129, in J.F. Craig and J.B. Kemper, editors. Regulated Streams: Advances in Ecology. Plenum Press, New York.

Shirazi, M. A. and W. K. Seim. 1979. A stream systems evaluation – An evaluation of spawning habitat for salmonids, U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, Oregon.

Stagliano, D.M. 2019. Madison and Missouri River Macroinvertebrate Biomonitoring: 2018 Data Summary. Prepared for Northwestern Energy, Butte, MT.

Stagliano, D.M. 2020. Madison and Missouri River Macroinvertebrate Biomonitoring: 2019 Data Summary. Prepared for Northwestern Energy, Butte, MT.

Stagliano, D.M. 2021. Madison and Missouri River Macroinvertebrate Biomonitoring: 2020 Data Summary and 25 Year Assessment. Prepared for Northwestern Energy, Butte, MT.

Stagliano, D.M. 2022. Macroinvertebrate Biomonitoring on the Missouri River below Holter Dam: 2021 Data Summary. Prepared for Northwestern Energy, Butte, MT.

Stagliano, D.M. 2023. Macroinvertebrate Biomonitoring on the Missouri River below Holter Dam: 2022 Data Summary. Prepared for Northwestern Energy, Butte, MT. (in preparation).

Trush, W. J.; S. M. McBain, and L. B. Leopold. 2000. Attributes of an alluvial river and their relation to water policy and management. Proceedings of the National Academy of Science. 97(22): 11858–11863.

U.S. Forest Service. 2004. Quantifying Channel Maintenance Instream Flows: An Approach for Gravel-Bed Streams in the Western United States, General Technical Report RMRS-GTR-128, prepared by Larry J. Schmidt and John P. Potyondy, May.

U.S. Geological Survey (USGS) 1975. The channels and waters of the upper Salmon River area, Idaho. Professional Pap. 870-A. prepared by W.W. Emmett. 116 p.

U.S. Geological Survey (USGS). 1964. The Hebgen Lake, Montana earthquake of August 17, 1959, Professional Paper 435.

U.S. Geological Survey (USGS). 2012. Lateral and vertical channel movement and potential for bed-material movement on the Madison River downstream from Earthquake Lake, Montana, Scientific Investigations Report 2012-5024.

Ward, J.V. and J.A. Stanford. 1979. Ecological factors controlling stream zoobenthos with emphasis on thermal modification of regulated streams. Pages 215-236 in J. V. Ward, and J. A. Stanford, editors. The Ecology of Regulated Streams. Plenum Press, New York, NY.Ward, J.V. 1992. Aquatic insect ecology: 1. biology and habitat. John Wiley and Sons, New York.

Washington Department of Fisheries (WDF) 1992. Hydropower flow fluctuations and salmonids: review of the biological effects, mechanical causes, and options for mitigation, prepared by Mark Hunter, September.

Weber, C. I. (editor). 1973. Biological field and laboratory methods for measuring the quality of surface waters and effluents. U.S. EPA. Cincinnati, Ohio. (670/4-73-001).

Whitaker, A. C. 1997. The initiation of coarse bed load transport in gravel bed streams. Bozeman: University of Montana. Ph.D. Dissertation. 148 p.

Williams, D.D. and B.W. Feltmate. 1992. Aquatic insects. CAB International, Wallingford, UK.

Yuan, L. L. 2006. Estimation and application of macroinvertebrate tolerance values. National Center for Environmental Assessment. U.S. EPA. EPA/600/P-04/116F.

APPENDIX A

ARTICLE 419

FERC PROJECT 2188

143 FERC ¶ 62,165
UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

PPL Montana, LLC   Project No. 2188-154

ORDER APPROVING MADISON RIVER FIVE-YEAR FLUSHING FLOW PLAN UNDER ARTICLE 419

(Issued June 3, 2013)

1. On March 22, 2013, PPL Montana, LLC (licensee) filed a revised Five-Year Flushing Flow Plan with the Federal Energy Regulatory Commission (Commission), pursuant to Article 419 of the license[1] for the Missouri-Madison Project No. 2188. The project consists of nine developments, and is located on the Madison and Missouri Rivers in Gallatin, Madison, Lewis and Clark, and Cascade Counties, in southwestern Montana.

BACKGROUND AND LICENSE REQUIREMENTS

2. License Article 419 requires that the licensee file for Commission approval, a plan to coordinate and monitor flushing flows in the upper Madison River, downstream of Hebgen Dam. The plan should include, but not be limited to, a provision for monitoring flushing flow needs in the upper Madison River near Kirby Ranch in 2002 and every five years thereafter, and a provision to coordinate flushing flows in the lower Madison River below Madison Dam with flushing flow requirements in the upper Madison River. The licensee filed an interim flushing flow plan with the Commission on March 27, 2002, which was approved by an ensuing Commission order on July 23, 2002.[2] Subsequent flushing flow plans were filed with the Commission on March 3, 2003 and April 11, 2008, and approved by Commission orders dated January 23, 2004[3] and September 18, 2008,[4] respectively.

3. Among the elements of the most recent plan approved on September 18, 2008, the licensee is to conduct geomorphic and macroinvertebrate studies to assess the impacts of

[1] *See* 92 FERC ¶ 61,261. Order Issuing New License (issued September 27, 2000).

[2] *See* 100 FERC ¶ 62, 054. Order Modifying and Approving Interim Madison River Flushing Flow Plan, Article 419.

[3] *See* 106 FERC ¶ 62,054. Order Modifying and Approving Madison River Flushing Flow Plan, Article 419.

[4] *See* 124 FERC ¶ 62,207. Order Approving Madison River Flushing Flow Plan.

the license-required flow regime. The required monitoring is to include core sediment samples, scour chain monitoring, macroinvertebrate sampling, cross-sectional surveys, and particle size distribution surveys. The licensee is also to compile daily streamflow data, peak-flow data, and water temperature data from the USGS. Additionally, ordering paragraph (B) of the January 23, 2004 order requires in part, that the licensee file for Commission approval, revised Madison River Flushing Flow Plans every five years, beginning March 1, 2008. The plans are to be prepared in consultation with the U.S. Forest Service (FS), U.S. Fish and Wildlife Service (FWS), Montana Department of Fish, Wildlife and Parks (MFWP), Montana Department of Environmental Quality (MDEQ), and other interested parties. The revised plans should contain documentation of agency consultation and the licensee's response to any agency comments.

LICENSEE'S PROPOSAL

4. The licensee's filing included the results of monitoring for the 2008-2012 period and a proposal to continue its monitoring studies. The licensee conducted channel morphology surveys, sediment sampling, aquatic macroinvertebrate sampling, sediment/macroinvertebrate correlation analyses, streamflow assessment, and water temperature evaluations. The studies indicated that the percent of fine sediments in the upper Madison River were generally below the upper threshold limit of 10 percent, while the managed flushing flows in the spring have generally not been successful in reducing fine sediment in the lower Madison River. The licensee's macroinvertebrate studies also indicated that sediment-intolerant and coldwater taxa were most diverse in the upper Madison River, while warmwater taxa were more prevalent in the lower Madison River. Finally, the licensee states that the flushing flow program to date, does not appear to have had a positive effect on spawning gravels or in fine sediment reduction.

5. The licensee proposes to continue implementing its approved monitoring program. However, the licensee proposes three changes to the program. Specifically, the licensee proposes to implement visual trout spawning surveys to better locate flushing flow data collection sites and more accurately correlate flushing flows with trout spawning efficiency and success. The licensee would also eliminate embeddedness surveys from the flushing flow plan. Finally, the licensee would implement scour chain monitoring at the Ennis, Norris, and Greycliff monitoring sites in years of moderate or high flow.

AGENCY CONSULTATION

6. The licensee developed its revised plan in consultation with the FS, U.S. Bureau of Land Management (BLM), FWS, MFWP, and MDEQ. During development of the plan, the licensee received formal comments from the MFWP. The MFWP's comments consisted of correction of grammatical and formatting errors, and requests to clarify several elements of the plan, to which the licensee provided the requested information.

The FS, BLM, FWS, MFWP, and MDEQ all provided signed concurrence on the revised plan.

DISCUSSION AND CONCLUSIONS

7. The licensee is proposing to continue implementing its flushing flow plan, by continuing its geomorphic and macroinvertebrate studies as they relate to flushing flows. Based on the results of prior monitoring, the licensee is also proposing a few minor changes to its monitoring protocols, which would improve the overall effectiveness of its plan. The licensee's revised plan should continue to assess the impacts of the project and the required flushing flows on aquatic habitat at the project, and should be approved.

The Director orders:

(A) PPL Montana, LLC's (licensee) Five-Year Flushing Flow Monitoring Plan, filed with the Federal Energy Regulatory Commission (Commission) on March 22, 2013, pursuant to article 419 of the license for the Missouri-Madison Project No. 2188, is approved.

(B) This order constitutes final agency action. Any party may file a request for rehearing of this order within 30 days from the date of its issuance, as provided in section 313(a) of the Federal Power Act, 16 U.S.C. § 8251 (2006), and the Commission's regulations at 18 C.F.R. § 385.713 (2013). The filing of a request for rehearing does not operate as a stay of the effective date of this order, or of any other date specified in this order. The licensee's failure to file a request for rehearing shall constitute acceptance of this order.

(for) Thomas J. LoVullo
Chief, Aquatic Resources Branch
Division of Hydropower Administration
and Compliance