NWE-2188-4465

Debbie-Anne A. Reese
Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

November 4, 2024

Re: NorthWestern Energy filing Revised Five Year (2019-2023) Drawdown Report for Black Eagle, Rainbow, Cochrane, Ryan, and Morony Reservoirs per Project 2188 License Article 403

Dear Secretary Reese,

By Order dated February 7, 2020, the Federal Energy Regulatory Commission (Commission) approved NorthWestern Energy's (NorthWestern) Revised Reservoir Drawdown Plans for Black Eagle, Rainbow, Cochrane, Ryan, and Morony Reservoirs per Article 403 of the Project 2188 License[1]. Per the Commission approved Drawdown Plans, NorthWestern continued to collect tailrace turbidity data during reservoir drawdowns and to verify sediment control effectiveness from July 15, 2019 through January 1, 2024. Based on the data collected during this five-year period, NorthWestern developed a summary report titled "Missouri-Madison Hydroelectric Project Reservoir Drawdowns 2019-2023 for Black Eagle, Rainbow, Cochrane, Ryan, and Morony Dams" which is included with this letter.

Four reservoir drawdowns occurred in the period from July 15, 2019 through January 1, 2024, the details of which are identified below in **Table 1**.

Table 1: Summary of the drawdown events at the Great Falls Projects on the Missouri between January 15, 2019 and January 1, 2024.

Project	Drawdown	Drawdown Depth (ft.)	Max Turbidity Recorded During Drawdown
Black Eagle	July 2019	7.2	83
Rainbow	September 2021	4.1	20
	September 2022	11.7	352
Cochrane	None	N/A	N/A
Ryan	September 2023	6.3	27
Morony	None	N/A	N/A

[1] Order Approving Revised Reservoir Drawdown Plans Pursuant to Article 403 (170 FERC ¶ 62,081)

Turbidity data collected during this period demonstrates no strong correlation between the drawdown rates used and turbidity. Observed increases in turbidity are tied more closely to reservoir water surface elevation than drawdown rate. These findings are consistent with drawdown reports and evaluations conducted in 2014 and 2019 of Black Eagle, Rainbow, Cochrane, Ryan, and Morony Reservoirs.

The drawdown rates for these reservoirs (**Table 2**) were found to be protective against large increases in downstream turbidity. These drawdown rates, adopted upon Commission approval in 2020, are based on a four-hour running average which helps set an achievable compliance goal for dam operations during a planned drawdown to help operators maintain compliance with the Drawdown Plan, while also at the same time protect aquatic resources.

Table 2: Drawdown rates for Black Eagle, Rainbow, Cochrane, Ryan, and Morony Reservoirs.

Reservoir	Reservoir Water Elevation (ft)	Average Drawdown Rate (ft/hr)[1]
Black Eagle	(1) below 3,289	(1) 0.10
Rainbow	(1) 3,223 to 3,214	(1) 0.20
	(2) below 3,214	(2) 0.10
Cochrane	(1) below 3,110	(1) 0.10
Ryan	(1) 3,029 to 3,024	(1) 0.20
	(2) below 3,024	(2) 0.10
Morony	(1) below 2,878	(1) 0.10

[1]Average drawdown rate is based on a four-hour running average.

NorthWestern proposes to continue using the Commission approved drawdown rates in **Table 2** above for the remainder of the current operating License. These drawdown rates have shown to be protective of aquatic resources in Black Eagle, Rainbow, Cochrane, Ryan, and Morony Reservoirs and also the Missouri River downstream. Any increases in turbidity observed during drawdowns are related to reservoir elevation and not the rate of drawdown, are temporary in nature, and smaller in magnitude than observed springtime turbidity resulting from the natural high flow period of the hydrograph.

The notification process for future drawdown events will occur prior to the start of the drawdown in accordance to current practice and pursuant to the 2020 Order Approving Revised Reservoir Drawdown Plan Pursuant to Article 403. Under the Drawdown Plan, the notification process entails NorthWestern providing advance notification of the drawdown to the Regional Engineer of the FERC Portland Regional Office per 18 CFR § 12.4(b), as well as Montana Fish, Wildlife and Parks (FWP) for the purposes of recreation management and the coordination of reservoir fish stocking efforts.

Due to the infrequent nature of planned drawdowns, NorthWestern proposes to provide a report analyzing ten years of future reservoir drawdowns that will occur between January 1, 2024 and December 31, 2033 in order to provide a larger number of drawdown events for comparison and analysis. NorthWestern will consult with FWP, Montana Department of Environmental Quality, and the U.S. Fish and Wildlife Service for comment prior to submitting that report to the Commission by December 31, 2034.

NorthWestern consulted with FWP, Montana Department of Environmental Quality, and the U.S. Fish and Wildlife Service on the development of this drawdown report, the continued use of the approved drawdown rates, the notification procedure, and the modified schedule to submit future reports. Record of consultation is included in Attachment A.

Please contact Jordan Tollefson at 406-443-8907 or Jordan.Tollefson@NorthWestern.com with any questions.

Sincerely,

Andy Welch
Manager, Hydropower License Compliance
Andrew.Welch@NorthWestern.com
O 406-444-8115
C 406-565-7549

CC: Sady Babcock, NWE
John Tabaracci, NWE
Jeremy Clotfelter, NWE
Carrie Harris, NWE
Jordan Tollefson, NWE
Grant Grisak, NWE
Keenan Storrar, MT DEQ
Adam Strainer, MT FWP
James Boyd, USFWS

Attachment A – Agency Consultation Record

NorthWestern Energy consulted with Montana Fish, Wildlife and Parks, the Montana Department of Environmental Quality, and the U.S. Fish and Wildlife Service in the development of this plan, and a record of that consultation is included with this letter as Attachment A.

By: [signature]

Date: 10·25·24

Title: Fisheries Division Habitat Bureau Chief

Representing Montana Department of Fish, Wildlife and Parks

By: Keenan Storrar

Date: November 1, 2024

Title: 401 WQC coordinator

Representing Montana Department of Environmental Quality

By: JAMES BOYD Digitally signed by JAMES BOYD Date: 2024.11.04 07:14:11 -07'00'

Date: ______________________________

Title: ______________________________

Representing U.S. Fish and Wildlife Service

From: Tollefson, Jordan
To: Strainer, Adam; "ageik@mt.gov"; "James Boyd (James_Boyd@fws.gov)"; Keenan Storrar
Cc: Welch, Andrew; Grisak, Grant; Babcock, Sarah (Sady)
Subject: Great Falls Reservoirs Drawdown Report Available for Review and Comment
Date: Tuesday, October 1, 2024 10:08:00 AM
Attachments: FERC Filing Letter for 2024 Great Falls Drawdown Report.pdf

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Greetings,

NorthWestern Energy has recently completed a report summarizing the planned reservoir drawdown events that have occurred in the Great Falls reservoirs from 2019-2023. This report discusses the details of each drawdown, the drawdown rates used, and the turbidity data collected. To download the report, please use the following link below:

https://send.northwesternenergy.com/link/LXJoFaKcRkon2nZndYht5K

If you have any comments on the report, please provide those to me by no later than November 1st, and I can incorporate them into the final report to be submitted to FERC. We are seeking signed agency approval of this report from FWP, DEQ, and USFWS, so if you approve of this report to be filed, please sign the attached cover letter under your agency's signature block in Attachment A by November 1st. I'm planning to host a meeting to provide an overview of this report the week of October 14th, so please respond to the Doodle poll using the link below to let me know your availability and preference for a meeting time.

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

If you have any questions or are having trouble accessing the report, please let me know. We appreciate the partnership that we have with your agencies and truly value your input on these projects!

Jordan

Jordan Tollefson
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Jordan.Tollefson@NorthWestern.com
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208 N Montana Avenue, Suite 200
Helena, MT 59601

From:	Strainer, Adam
To:	Tollefson, Jordan; Geik, Adam; Mullen, Jason; Boyd, James W; Storrar, Keenan
Cc:	Grisak, Grant; Babcock, Sarah (Sady); Welch, Andrew
Subject:	[EXTERNAL] Re: Great Falls Drawdown Report Follow-Up
Date:	Friday, October 25, 2024 1:06:40 PM
Attachments:	image015.png image018.png image019.png image020.png image021.png image004.png image008.png image012.png image014.png image016.png Outlook-A picture .png Outlook-m32nukiy.png Outlook-ymmcw3ni.png Outlook-fgcguqfu.png Outlook-fgg5l0t0.png

Thanks, Jordan. I appreciate your understanding and effort on this . We are committed to getting you a signature by Nov. 1.

Adam Strainer | *Habitat Bureau Chief*
Fisheries Division
Montana Fish, Wildlife & Parks
(406) 444-2447

THE OUTSIDE IS IN US ALL.

Montana FWP | Montana Outdoors Magazine

From: Tollefson, Jordan <Jordan.Tollefson@northwestern.com>
Sent: Friday, October 25, 2024 12:08 PM
To: Strainer, Adam <astrainer@mt.gov>; Geik, Adam <ageik@mt.gov>; Mullen, Jason

<JMullen@mt.gov>; Boyd, James W <james_boyd@fws.gov>; Storrar, Keenan <Keenan.Storrar@mt.gov>
Cc: grant.grisak@northwestern.com <Grant.Grisak@northwestern.com>; Babcock, Sarah (Sady) <Sady.Babcock@northwestern.com>; Andy Welch <andrew.welch@northwestern.com>
Subject: [EXTERNAL] RE: Great Falls Drawdown Report Follow-Up

Adam,

Thank you for the response and feedback. I have updated the language in the FERC filing letter (attached) to reflect the 10-year reporting cycle instead of the previously proposed 15-year cycle. I think that 10 years should at least give us a decent dataset to analyze for the next drawdown report. I also went into the document and removed that sentence from Section 10.2 as you suggested in your comment below. Thank you all again for taking the time to provide your valuable input. We are still requesting agency approvals by November 1st, so if your agency approves of the revisions to the plan, please sign and return the updated attached FERC filing letter by November 1st. Have a nice weekend everyone!

Jordan

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From: Strainer, Adam <astrainer@mt.gov>
Sent: Thursday, October 24, 2024 11:54 AM
To: Welch, Andrew <Andrew.Welch@northwestern.com>; Tollefson, Jordan <Jordan.Tollefson@northwestern.com>; Geik, Adam <ageik@mt.gov>; Mullen, Jason <JMullen@mt.gov>; Boyd, James W <james_boyd@fws.gov>; Storrar, Keenan <Keenan.Storrar@mt.gov>
Cc: Grisak, Grant <Grant.Grisak@northwestern.com>; Babcock, Sarah (Sady) <Sady.Babcock@northwestern.com>
Subject: [EXTERNAL] Re: Great Falls Drawdown Report Follow-Up

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Andy,

Thanks for the continued discussion. Here's our response to your comment below on 10/21:

A 10-year cycle is acceptable to FWP.

Regarding #2. We agree section 10 is thorough. Section 10.2 does a good job of explaining all the different factors that could be related to the effects seen on fish. Copied below are excepts from the report that detail the different factors. The section acknowledges that the effects on fish vary depending on these factors (e.g, temperature, life stage of fish, etc.). These factors vary through the course of the year. For example, water temperature is very different during spring runoff than in July or September. Different life stages are present during spring runoff than in July or September. Flow is much different during spring runoff than during July or September. All of these factors and more (described in 10.2) could have a different effect on fish in July or September (or any other time) than during spring runoff when turbidity is highest.

Thus, we don't agree that "since concentrations are within the typical seasonal variations." the resulting stress indices are not likely to have significant effects on fish health. It is making the argument that any amount of turbidity is fine if it is within seasonal variation, which we think is contrary to the discussion provided in 10.2.

Examination of the Stress Index graphs is difficult as the drawdown periods are not identified. It appears to show spikes above the base level for that time associated with the Black Eagle July 2019 drawdown (peaks with increasing mortality rate for the 2.36 factor) and September 2021 Rainbow drawdown (peaks with behavioral Impacts).

Our recommendation would be to delete the sentence and focus on the change in Stress Index values associated with the drawdown events.

We appreciate the opportunity to comment.

Adam Strainer | *Habitat Bureau Chief*
Fisheries Division
Montana Fish, Wildlife & Parks
(406) 444-2447

Montana FWP | Montana Outdoors Magazine

From: Welch, Andrew <Andrew.Welch@northwestern.com>
Sent: Monday, October 21, 2024 4:34 PM
To: Strainer, Adam <astrainer@mt.gov>; Tollefson, Jordan <Jordan.Tollefson@northwestern.com>; Geik, Adam <ageik@mt.gov>; Mullen, Jason <JMullen@mt.gov>; Boyd, James W <james_boyd@fws.gov>; Storrar, Keenan <Keenan.Storrar@mt.gov>
Cc: grant.grisak@northwestern.com <Grant.Grisak@northwestern.com>; Babcock, Sarah (Sady) <Sady.Babcock@northwestern.com>
Subject: [EXTERNAL] RE: Great Falls Drawdown Report Follow-Up

Adam, et al.,
Thank you for taking the time and providing your agencies feedback on the drawdown report. Jordan and I conferred on your comments and have the following feedback and response that correlate to your numbering below:

1. We do not feel there is much gained from moving this to a 7or 8 year cycle as that will only slightly increase the amount of information we have to inform our drawdown operations. The issue isn't the elapsed time but rather the experience of going through drawdowns and gathering information we can use to inform and guide our operations. We have learned a lot from these infrequent operations over the last 20+ years and accordingly have made changes to how we complete monitoring and to the rates included in the drawdown plan. We will continue to have the need to complete these infrequent drawdowns but don't feel one additional event added in a 7-year cycle, compared to 5 years, is enough to inform any significant changes to our longstanding plan. We propose to move to a 10-year cycle to benefit the next analysis with more data but to also be sensitive to your concerns about duration.

2. We believe section 10 of the document is thorough and does a good job of characterizing the types of stress potentially realized from the drawdowns. We have added a lot to this analysis over the last couple iterations of this report and supplemented it with numerous references to back up our statements. Relative to your comment specifically on the stress indices and your recommendation to clarify the statement, can you please provide us some additional information to back up your perspective and also provide proposed language for the report you believe more accurately represents the stress to fish health?

Regards,
Andy

From: Strainer, Adam <astrainer@mt.gov>
Sent: Monday, October 21, 2024 3:21 PM

To: Tollefson, Jordan <Jordan.Tollefson@northwestern.com>; Geik, Adam <ageik@mt.gov>; Mullen, Jason <JMullen@mt.gov>; Boyd, James W <james_boyd@fws.gov>; Storrar, Keenan <Keenan.Storrar@mt.gov>
Cc: Welch, Andrew <Andrew.Welch@northwestern.com>; Grisak, Grant <Grant.Grisak@northwestern.com>; Babcock, Sarah (Sady) <Sady.Babcock@northwestern.com>
Subject: [EXTERNAL] Re: Great Falls Drawdown Report Follow-Up

Hey Jordan,

Thanks for sending this along and addressing some of our concerns (e.g., PFAS) in your email below. That said, we still have a few comments.

1. FWP staff conferred after the meeting last week and agreed that a 15-year reporting period is simply too long. FWP suggests, as a compromise, reporting via a drawdown report every 7 or 8 years. This will increase the amount of time to collect more data to report on but provide reporting on a reasonable timeframe compared to 15 years. If this is not suitable recommends maintaining a 5-year reporting timeframe.
2. Page 49 – Stress Index Section – "Additionally, any increases in turbidity related to reservoir operations have relatively short durations and the resulting Stress Indices are not likely to have significant effect on fish health since concentrations are within the typical seasonal variations."
   1. While significant effects on fish health may not be significant based on Stress Indices results, additional turbidity related to reservoir operations is cumulative and comes outside of typical seasonal variations, which may have different effects based on life stage, temperature, life history adaptations, timing, flows, etc. (as noted in Section 10.2). We do not believe it is accurate to say that significant effects on fish health are not likely "since concentrations are within typical seasonal variations" given that stress could be cumulative and different than what occurs under natural seasonal variation. Recommend this statement is clarified.

FWP appreciates you taking the comments above into consideration and please let us know if you have any further comments or questions.

Thanks,

Adam Strainer | *Habitat Bureau Chief*
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Montana Fish, Wildlife & Parks
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From: Tollefson, Jordan <Jordan.Tollefson@northwestern.com>
Sent: Friday, October 18, 2024 3:02 PM
To: Strainer, Adam <astrainer@mt.gov>; Geik, Adam <ageik@mt.gov>; Mullen, Jason <JMullen@mt.gov>; Boyd, James W <james_boyd@fws.gov>; Storrar, Keenan <Keenan.Storrar@mt.gov>
Cc: Andy Welch <andrew.welch@northwestern.com>; grant.grisak@northwestern.com <Grant.Grisak@northwestern.com>; Babcock, Sarah (Sady) <Sady.Babcock@northwestern.com>
Subject: [EXTERNAL] Great Falls Drawdown Report Follow-Up

Thank you all for taking the time out of your day on Wednesday to meet about the Great Falls Drawdown Report. I appreciate your valuable input. Based on our conversations, I have made a few edits to the report (updates shown in red below). If you have any more comments or questions regarding the report, please let me know by November 1st. We are also seeking agency approval from DEQ, FWP, and USFWS on this report prior to us filing it with FERC, so if your agency approves of the report, please sign and return the attached letter under your respective agency's signature box in Attachment A.

The following changes were made to the report to reflect comments received during the 10/16 meeting:

Section 2.1.6. General Facility Operations
The five Great Falls Development dams are located over a distance of 13 river miles with generally no free-flowing river segments between the dams. With the exception of a short section of river between the Black Eagle tailrace and the Rainbow Reservoir, each dam is located at the headwater of the next dam downstream.

Section 2.2 Drawdown Concerns
However, the Missouri River upstream of the Great Falls Development is characterized by naturally high levels of suspended sediment, much of which originates in Muddy Creek, a tributary of the Sun River and enters the Missouri River just upstream of Black Eagle Reservoir. High sediment loads have resulted in sediment deposition in the Great Falls reservoirs, with greatest deposition volumes in the upper two reservoirs (Black Eagle and Rainbow). During reservoir drawdowns, these sediment deposits can be disturbed, and result in a spike in turbidity. NorthWestern attempts to avoid utilizing reservoir drawdowns for maintenance and repair work on the Project facilities whenever possible to

further minimize the risk of impacting downstream turbidity, however in some cases avoidance is not possible due to the nature of the work required.

.....

By minimizing increases in turbidity during drawdowns, water quality in the Missouri River system downstream of the Great Falls Development can be protected. To the extent that trace metals or other pollutants are bound to sediments, minimizing turbidity also minimizes the resuspension of these pollutants in the river.

Section 11. Conclusions and Recommendations

NorthWestern proposes to continue to manage drawdowns using the rates approved in the 2019 Revised Reservoir Drawdown Plan, approved by FERC in 2020, for the remainder of the current operating license. NorthWestern will submit turbidity data for Black Eagle, Rainbow, Cochrane, Ryan, and Morony Reservoirs from drawdown events covered under this plan to the DEQ as requested. NorthWestern will also continue to provide advanced notification to MFWP of planned drawdowns, so that MFWP can effectively manage recreation and trout stocking efforts, particularly in the Rainbow Reservoir.

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From:	Tollefson, Jordan
To:	"Kron, Darrin"
Cc:	Storrar, Keenan
Subject:	RE: Great Falls Turbidity Data
Date:	Friday, October 18, 2024 3:15:00 PM
Attachments:	image001.jpg

Thanks for the reply Darrin. I made this change to the report (in red), and it sounds like it probably reflects what you just mentioned in that email. Let me know if the below language sounds ok with you and Keenan:

NorthWestern proposes to continue to manage drawdowns using the rates approved in the 2019 Revised Reservoir Drawdown Plan, approved by FERC in 2020, for the remainder of the current operating license. NorthWestern will submit turbidity data for Black Eagle, Rainbow, Cochrane, Ryan, and Morony Reservoirs from drawdown events covered under this plan to the DEQ as requested. NorthWestern will also continue to provide advanced notification to MFWP of planned drawdowns, so that MFWP can effectively manage recreation and trout stocking efforts, particularly in the Rainbow Reservoir.

Jordan

From: Kron, Darrin <dkron@mt.gov>
Sent: Friday, October 18, 2024 3:09 PM
To: Tollefson, Jordan <Jordan.Tollefson@northwestern.com>
Cc: Storrar, Keenan <Keenan.Storrar@mt.gov>
Subject: [EXTERNAL] RE: Great Falls Turbidity Data

Hi Jordan,

Thanks for checking in on this topic. This type of data is not very useful to represent long term assessment unit conditions and only a small timeframe of turbidity/TSS data would generally is not useful for our program. So, I don’t think we need to upload it to our database for now. We reserve the right to request it from NWE if needed. If it were to show increases above WQ standards, I would think it would be addressed through Keenan’s group.

Thanks,
Darrin

From: Tollefson, Jordan <Jordan.Tollefson@northwestern.com>
Sent: Thursday, October 17, 2024 8:25 AM
To: Kron, Darrin <dkron@mt.gov>
Cc: Storrar, Keenan <Keenan.Storrar@mt.gov>
Subject: [EXTERNAL] Great Falls Turbidity Data

Good morning Darrin,

We had a meeting yesterday talking about our Great Falls drawdown report and Keenan had asked if we currently report that data to DEQ. DEQ is a signatory approval on the report, but outside of the report itself, we have not sent over the raw turbidity data in the past. If it would be useful to you, we'd be more than happy to share it. This data is data that we collect when doing reservoir drawdowns for maintenance projects at the dams. Let me know if you would like this data and if there is a good way to get it over to you. These drawdown events typically only occur once every 5-7 years per reservoir, I guess my only concern is that you would want to make sure that it is not used for characterizing the "normal" condition of the assessment unit as these events are infrequent and not a part of our normal day to day operations. If you would like this data let me know and I can work on getting it over to you.

Jordan

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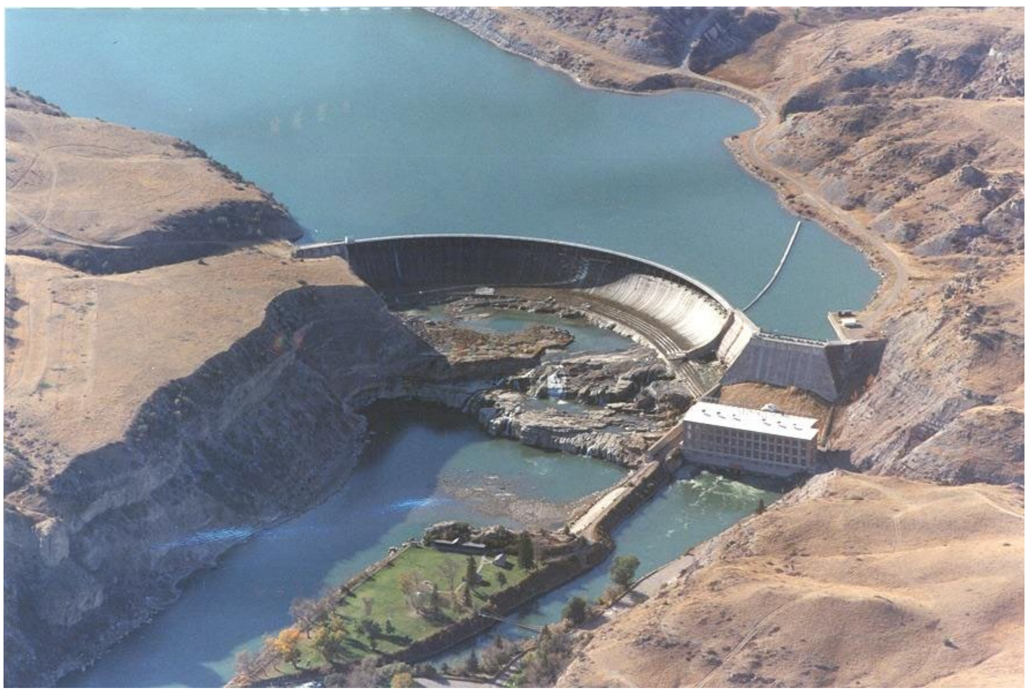
Missouri-Madison Hydroelectric Project
Reservoir Drawdowns 2019 – 2023
Black Eagle, Rainbow, Cochrane, Ryan, and Morony Dams

FERC Project #2188
August 15, 2024



Submitted by:
NorthWestern Energy
Butte, Montana

With Assistance From:
GEI Consultants, Inc.
Denver, Colorado

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Abbreviations and Acronyms

~	about, approximately, near
cm/d	centimeter per day
DEQ	Montana Department of Environmental Quality
El.	elevation
FERC	Federal Energy Regulatory Commission
GEI	GEI Consultants, Inc.
Licensee	NorthWestern Energy
Great Falls Development	Black Eagle, Rainbow, Cochrane, Ryan, and Morony reservoirs
mg/1	milligram per liter
MFWP	Montana Fish, Wildlife, and Parks
mg/l	milligrams per liter
MPC	Montana Power Company
MW	megawatt
NAVD 88	North American Vertical Datum of 1988 datum
NTU	nephelometric turbidity units
NorthWestern	NorthWestern Energy
NWSE	normal water surface elevation
plan	NorthWestern's 2019 Revised Reservoir Drawdown Plan for the five Great Falls Development reservoirs
Project	Missouri-Madison Hydroelectric Project 2188
TSS	Total Suspended Solids
vs.	versus
WSE	water surface elevation
WQS	water quality standard

Executive Summary

NorthWestern Energy (NorthWestern) received a new Federal Energy Regulatory Commission (FERC) License (No. 2188) dated September 27, 2000, to operate the nine dams that make up the Missouri-Madison Hydroelectric Project (project). As a requirement of the license, the Licensee, Montana Power Company (now NorthWestern) was required to develop a plan to minimize water quality impacts during maintenance drawdowns of its reservoirs. Initially, according to FERC License Article 3, Appendix A,

> *MPC shall within 3 months of issuance assure that continued operations will be done in the best practicable manner to minimize harmful effects. Upon approval or modification by the DHES MPC may then change its operations consistent with these drawdown plans (p. 86).*

Routine reservoir drawdowns are needed for maintenance and inspection. Historically, drawdown schedules were on a trial-and-error basis, with the goal of maintaining a constant rate of reservoir water surface elevation (WSE) decrease with minimal disruption to bed sediments. This method did not minimize turbidity at all reservoir WSEs during the drawdowns, therefore, studies were conducted throughout the project to determine the optimal drawdown rates that would allow reservoir drawdown in an efficient manner while minimizing turbidity. These studies were both theoretical and empirical in nature and were used to identify turbidity patterns during reservoir drawdowns. The results were used to create recommended drawdown schedules for the Great Falls Development, including Black Eagle, Rainbow, Cochrane, Ryan, and Morony reservoirs. The intent of the drawdown schedules is to achieve routine reservoir drawdowns "in the best practicable manner to minimize harmful effects" caused by mobilizing reservoir sediments that may contain heavy metals or other constituents that can compromise water quality (Administrative Rules of Montana 17.30.636).

The drawdown schedules were developed specific to the bathymetry of each reservoir and were designed to minimize sediment mobilization and downstream sediment release during planned (non-emergency) drawdowns to various elevations where temporary bulkheads or other methods to limit or avoid reservoir drawdown are not possible. These drawdown schedules are consistent with Montana Department of Environmental Quality requirements to assure that continued reservoir operations be done in the best practicable manner to minimize harmful effects.

On August 29, 2019, NorthWestern filed with FERC, a 2019 Revised Reservoir Drawdown Plan (plan) for the five Great Falls Development reservoirs (NorthWestern 2020). On February 7, 2020, FERC approved the plan, which includes a requirement for NorthWestern to collect tailrace turbidity data during reservoir drawdowns for a 5-year-period, to monitor and verify the plan's sediment control effectiveness.

This report summarizes the results of turbidity monitoring during drawdowns at the five Great Falls Developments from January 1, 2019, through December 31, 2023.

During the monitoring period, no drawdowns were recorded at Morony or Cochrane reservoirs. Turbidity was monitored during drawdowns at Black Eagle, Rainbow, and Ryan reservoirs.

Turbidity displays a natural fluctuation in the Missouri River that coincides with spring flows and significant rain events. The data collected during the various drawdown events in the Great Falls Development also indicate turbidity levels often respond to some degree to fluctuations and drops in WSE. However, the turbidity response did not always relate to occasions when drawdown rates have exceeded the limits outlined in the 2019 Revised Reservoir Drawdown Plan. Turbidity increased when drawdown rates were less and, in some cases, when drawdown rates exceeded the limits specified in the 2019 Revised Reservoir Drawdown Plan. The correlation between the drawdown rate and turbidity is not definitive based on the available data.

The drawdown rates identified in Table 11-2 were followed for the years 2019 to 2023. Drawdown rates are based on a 4-hour running average, which allows dam operators some flexibility in trying to maintain the approved drawdown rate. NorthWestern analyzed the resulting data from drawdowns within this period and has developed a 5-year (January 2019 – December 2023) summary, which is included in this report. In addition, NorthWestern performed a detailed review of the effectiveness of the recommended drawdown rates based on the data that were collected nearly continuously during the last 5 years. NorthWestern will continue to coordinate with agencies to identify ways to improve or modify the drawdown schedule, as appropriate based on the results from the 5-year summary report.

NorthWestern will also provide advanced notification to Montana Fish, Wildlife, and Parks (MFWP) of planned drawdowns, so that MFWP can effectively manage recreation and trout stocking efforts, particularly in the Rainbow Reservoir.

1. Introduction

1.1. Background

The Montana Power Company (MPC) received a new Federal Energy Regulatory Commission (FERC) License (No. 2188) dated September 27, 2000, to operate the nine-dam Missouri-Madison Hydroelectric Project (project, Project 2188). NorthWestern Energy (NorthWestern) subsequently purchased the project from MPC and operates under the terms of the project's FERC license. The FERC license includes a Water Quality Certification issued by the Montana Department of Environmental Quality (DEQ). In addition, according to the Administrative Rules of Montana 17.30.636:

> *Owners and operators of water impoundments that cause conditions harmful to prescribed beneficial uses of state water shall demonstrate to the satisfaction of the department that continued operations will be done in the best practicable manner to minimize harmful effects.*

The Montana DEQ has issued water quality standards (WQSs) and regulations that apply to the Missouri River and its impoundments. Some WQSs are violated by the natural background condition of the Missouri River, which receives contributions from constituent-rich sources such as Yellowstone National Park. Nevertheless, NorthWestern is required to demonstrate the use of Best Management Practices to minimize water quality impacts. Article 403 of the Project 2188 License specifies the normal minimum operating elevations for each reservoir as:

- *Black Eagle: water surface elevation (WSE) 3,289 feet (within one foot of normal full pool WSE 3,290 feet)*
- *Rainbow: WSE 3,223 feet (within one foot of normal full pool WSE 3,224 feet)*
- *Cochrane: WSE 3,110 feet (within ten foot of normal full pool WSE 3,120 feet)*
- *Ryan: WSE 3,029 feet (within one foot above and 8 feet below of normal full pool 3,037 feet)*
- *Morony: WSE 2,878 feet (within ten feet of normal full pool 2,888 feet)*

As a requirement of the license, NorthWestern must develop a plan to minimize water quality impacts during maintenance drawdowns of its reservoirs. Initially, according to FERC Project 2188 License Article 3, Appendix A,

> *MPC shall within 3 months of issuance assure that continued operations will be done in the best practicable manner to minimize harmful effects. Upon approval or modification by the DHES, MPC may then change its operations consistent with these drawdown plans (p. 86).*

Routine reservoir drawdowns are needed for maintenance and inspection. Historically, drawdown schedules have been on a trial-and-error basis, with the goal of maintaining a constant rate of reservoir WSE decrease with minimal disruption to bed sediments. This method did not minimize turbidity at all reservoir WSEs during the drawdowns, therefore, studies have been conducted throughout the project since the early 1990s to determine the optimal drawdown rates that would allow reservoir drawdown in an efficient manner while minimizing turbidity. These studies were both theoretical and empirical in nature and were used to identify turbidity patterns during reservoir drawdowns. The results of these studies were used to create the drawdown schedules for the Great Falls Developments (Black Eagle, Rainbow, Cochrane, Ryan, and Morony reservoirs). The intent of the drawdown schedules was to achieve routine reservoir drawdowns “in the best practicable manner to minimize harmful effects” [1] caused by mobilizing reservoir sediments that may contain heavy metals or other constituents that can compromise water quality.

In July 2014, the Licensee submitted a report summarizing the results of turbidity monitoring during drawdowns at the Great Falls Development from January 1, 2009, through February 27, 2014 (NorthWestern 2009). That report noted that, to some degree, the turbidity levels respond to fluctuations and drops in WSEs. During reservoir drawdowns, the report noted that sediment deposits can be disturbed and result in a spike in turbidity, though generally such spikes are of short duration over a time frame of hours and were generally lower than the naturally occurring turbidity recorded during high flow periods. The report emphasized that turbidity response was not always related to occasions when drawdown rates exceeded the specified limits. Based on the data collected from 2009 through 2014, the Licensee concluded that there is no definitive correlation between the drawdown rate and turbidity. However, the review of the effectiveness of the recommended drawdown rates was hindered by gaps in data collection during some of the drawdowns. On August 4, 2014, FERC issued an Order approving the 2014 Drawdown Plan.

On August 29, 2019, NorthWestern filed with FERC, a 2019 Revised Reservoir Drawdown Plan (plan) for the five Great Falls Development reservoirs (NorthWestern 2020). On February 7, 2020, FERC approved the plan, which includes a requirement for NorthWestern to collect turbidity data during reservoir drawdowns on 5-year-cycles to monitor and verify the plans sediment control effectiveness.

This report summarizes the results of turbidity monitoring during drawdowns at the five Great Falls Developments from January 1, 2019, through December 31, 2023.

1.2. Scope of Work

GEI Consultants, Inc. (GEI) performed the following scope of work in support of this report:

- Reviewed and summarized existing turbidity, discharge and WSE data.
- Summarized conclusions and recommendations.
- Prepared this report for 5 Great Falls Development reservoirs in the Missouri-Madison Hydroelectric Project (FERC No. 2188).

[1] Administrative Rules of Montana 17.30.636 states, “Owners and operators of water impoundments that cause conditions harmful to prescribed beneficial uses of state water shall demonstrate to the satisfaction of the department that continued operations will be done in the best practicable manner to minimize harmful effects.”

1.3. Project Personnel

The scope of work for this task order was completed by the following personnel from GEI:

Ginger Gillin, CFP	Project Manager
Nick Miller, PE, PH	Senior Project Engineer
Bobby Lanzilotta, EIT	Project Engineer

The Project Manager for NorthWestern was Jordan Tollefson.

1.4. Elevation Datum

Elevations in this report are in feet and are referenced with respect to the North American Vertical Datum of 1988 (NAVD 88) datum.

1.5. Limitation of Liability

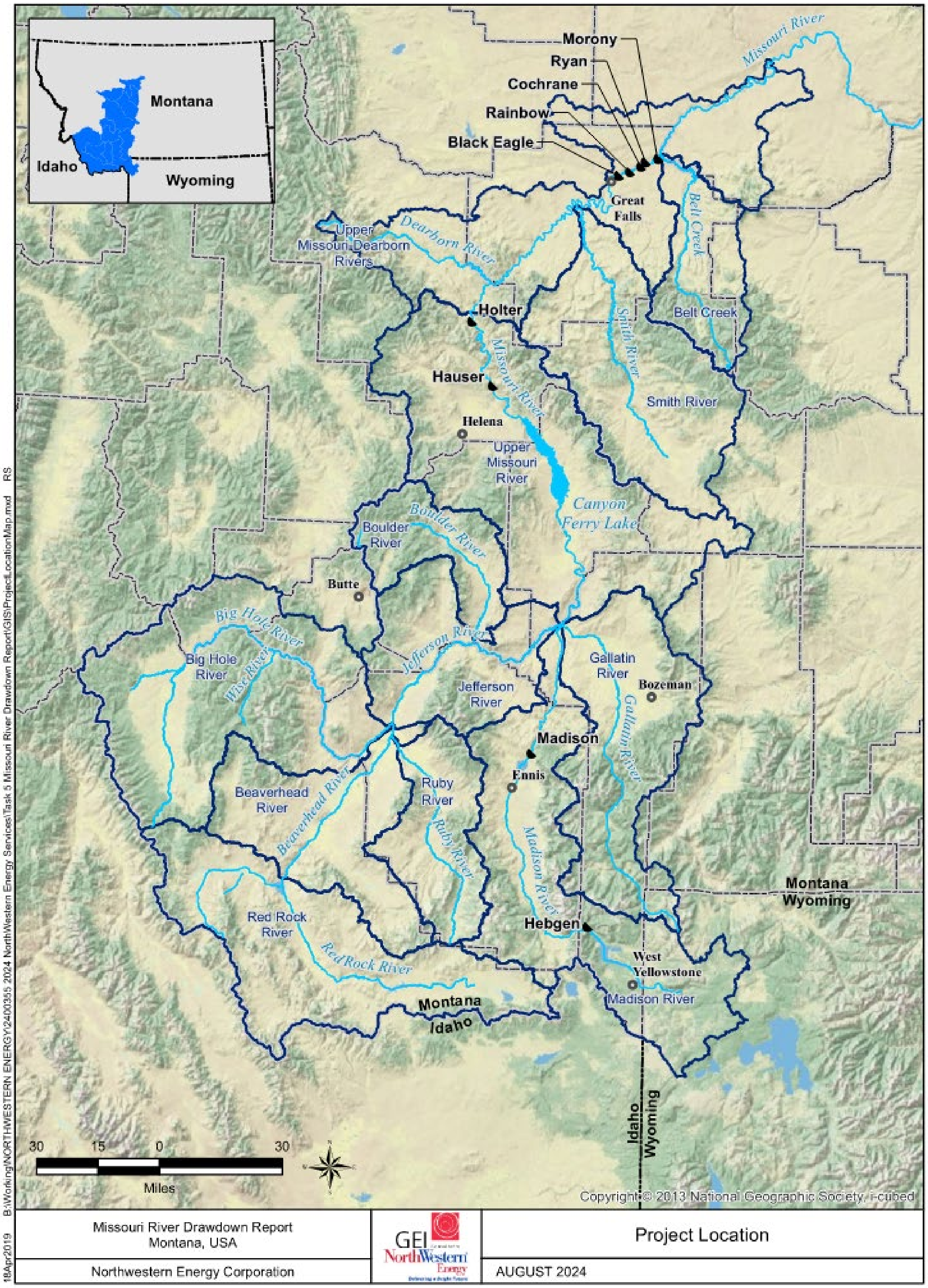
This report summarizes data from a number of studies and historical records, and provides summaries and recommendations based on specified procedures and engineering judgment. GEI used a professional standard of practice to review, analyze, and apply pertinent data. No warrantees are implied or expressed by GEI. Reuse of this report for any other purpose, in part or in whole, is at the sole risk of the user.

2. Project Overview and Background

2.1. Facility Overview

Five Missouri River dams form the portions of Project 2188 known as the Great Falls Development. Black Eagle Dam is the furthest upstream. It is located approximately 2 miles downstream of Great Falls, Montana. Rainbow, Cochrane, Ryan, and Morony dams are located 3, 6, 8, and 12 river miles downstream of Black Eagle Dam, respectively. The four remaining dams the comprise the Great Falls Development are located upstream of Black Eagle Dam: in sequence moving upstream, Holter and Hauser dams are located on the Missouri River; and Madison and Hebgen dams are located on the Madison River. Figure 2-1 shows the general location of each dam in the project.

Figure 2-1. Map of the Missouri-Madison Hydroelectric Project (FERC No. 2188)



2.1.1. Facility Location and Description – Black Eagle Dam

Black Eagle Dam is a concrete gravity dam that was constructed in 1891 (Figure 2-2). A 21-megawatt (MW) powerhouse is located on the downstream apron of the left abutment. Basic dam and reservoir characteristics are summarized in Table 2-1.

Table 2-1. Black Eagle Dam and Reservoir Characteristics

Characteristic	Value
Dam Height (feet)	13
Dam Length (feet)	753
Spillway Length (feet)	627
Normal Operating Elevation (feet)	3,289-3,290
Normal Reservoir Surface Area (acre)	388
Normal Reservoir Capacity (acre-feet)	1,860
Reservoir Length (approximate mileage)	3
Spillway Controls	Flashboards, 11’ high
Low Level Outlet Works	8-10.25’ x 9’ waste gates
Crest Elevation (feet)	3,279

Figure 2-2. Photograph of Black Eagle Dam

2.1.2. Facility Location and Description – Rainbow Dam

Rainbow Dam is a concrete gravity dam that was constructed in 1910 (Figure 2-3). The original 38-MW powerhouse is located 0.5 mile downstream of the dam at the end of a bypass reach. Construction of a new powerhouse was completed and in commercial operation on April 22, 2013. The new powerhouse has one unit (Unit 9) and has a nameplate capacity of 60-MW. The new powerhouse sits about 2,500 feet downstream from the dam and 200 feet from the old powerhouse. As of April 2013, the old powerhouse is no longer in operation. Basic dam and reservoir characteristics are summarized in Table 2-2.

Table 2-2. Rainbow Dam and Reservoir Characteristics

Characteristic	Value
Dam Height (feet)	29
Dam Length (feet)	1,146
Spillway Length (feet)	1,065
Normal Operating Elevation (feet)	3,224
Normal Reservoir Surface Area (acres)	126
Normal Reservoir Capacity (acre-feet)	1,237
Reservoir Length (approximate mileage)	3
Spillway Controls	Rubber dams and flashboards
Low Level Outlet Works	5-8’ x 10’ waste gates
Crest Elevation (feet)	3,212

Figure 2-3. Photograph of Rainbow Dam

2.1.3. Facility Location and Description – Cochrane Dam

Cochrane Dam is located on the Missouri River about 8 miles downstream of Great Falls, Montana. Cochrane Dam is a concrete gravity dam that was constructed in 1958 (Figure 2-4). Each radial gate is 40 feet wide and can be raised 22.4 feet high. A 60-MW powerhouse is located on the downstream apron of the left abutment. Basic dam and reservoir characteristics are summarized in Table 2-3

Table 2-3. Cochrane Dam and Reservoir Characteristics

Characteristic	Value
Dam Height (feet)	59
Dam Length (feet)	753
Spillway Length (feet)	334
Normal Operating Elevation (feet)	3,110-3,120
Normal Reservoir Surface Area (acres)	216
Normal Reservoir Capacity (acre-feet)	3,077
Reservoir Length (approximate mileage)	3
Spillway Controls	7 radial gates
Low Level Outlet Works	none
Crest Elevation (feet)	3,094.74

Figure 2-4. Photograph of Cochrane Dam

2.1.4. Facility Location and Description – Ryan Dam

Ryan Dam is a concrete gravity dam that was constructed in 1915 (Figure 2-5). A 62-MW powerhouse is located on the downstream apron of the left abutment. Basic dam and reservoir characteristics are summarized in Table 2-4.

Table 2-4. Ryan Dam and Reservoir Characteristics

Characteristic	Value
Dam Height (feet)	61
Dam Length (feet)	1,366
Spillway Length (feet)	1,001
Normal Operating Elevation (feet)	3,029-3,038[1]
Normal Reservoir Surface Area (acre)	165
Normal Reservoir Capacity (acre-feet)	2,477
Reservoir Length (approximate mileage)	2
Spillway Controls	Flashboards 14’ high
Low Level Outlet Works	6-6.0’ x 6.0’ waste gates
Crest Elevation (feet)	3,023

Figure 2-5. Aerial Photograph of Ryan Dam

2.1.5. Facility Location and Description – Morony Dam

Morony Dam is the last dam in downstream series at the Great Falls Development, located on the Missouri River approximately 14 miles downstream of Great Falls, Montana. Morony Dam is a concrete gravity dam that was constructed in 1930 (Figure 2-6). A 48 MW powerhouse is located on the downstream apron of the left abutment. Basic dam and reservoir characteristics are summarized in Table 2-5.

Table 2-5. Morony Dam and Reservoir Characteristics

Characteristic	Value
Dam Height (feet)	59
Dam Length (feet)	883
Spillway Length (feet)	390
Normal Operating Elevation (feet)	2,886-2,888
Normal Reservoir Surface Area (acre)	333
Normal Reservoir Capacity (acre-feet)	6,081
Reservoir Length (approximate mileage)	5
Spillway Controls	9 tainter gates
Low Level Outlet Works	none
Crest Elevation (feet)	2,864

Figure 2-6. Photograph of Morony Dam

2.1.6. General Facility Operations

The five Great Falls Development dams are located over a distance of 13 river miles with generally no free-flowing river segments between the dams, with the exception of a short section of river between the Black Eagle tailrace and the Rainbow Reservoir. Each dam is located at the headwater of the next dam downstream. The upper two reservoirs (Black Eagle and Rainbow) are operated in run-of-the-river mode, such that their outflow approximately equals their inflow to maintain a constant reservoir pool elevation. Cochrane, Ryan, and Morony are licensed for peaking operations. Cochrane, downstream of Rainbow, is operated as a daily peaking plant, draining and recharging over an elevation range up to 10 feet. Ryan maintains a relatively constant full pool but can vary up to 9 feet to serve as a daily peaking plant by passing the peaking flows from Cochrane. Morony, the downstream-most development, re-regulates flow and varies reservoir elevations over a range up to 10 feet (3 feet is typical) to level peaking operations, such that downstream discharges match average daily inflow at Black Eagle Reservoir. Except for peaking drawdowns up to 10 feet at Cochrane and Morony, and drawdowns up to 8 feet at Ryan, the five Missouri reservoirs are normally maintained at or near (within 1 foot of) full pool.

2.1.7. Drawdown Operations

Drawdowns outside of normal operations can occur to three depth ranges:

1. Shallow - (a few feet below normal maximum pool) to perform repairs at boat ramps or other high-elevation facilities.
2. Intermediate - (to an elevation 1 or 2 feet lower than the concrete crest of the dam/spillway overflow section) to allow for spillway repairs or maintenance.
3. Deep - (more than 2 feet below the elevation of the concrete crest of the dam or spillway up to maximum drawdown depth) to allow for repairs or maintenance of trash racks, intakes, power tunnels and gate structures; to perform safety inspections; or to facilitate reservoir sediment management.

Based on historical operations, intermediate drawdowns occur most often. To ensure that workers remain safe from a rising pool, intermediate and deep drawdowns are not undertaken unless inflows can be safely passed for the duration of repair work without encroaching on the dam, spillway crest, or work areas. Therefore, inflow must not exceed the hydraulic capacity of the waste gates at Black Eagle, Rainbow, Ryan, and Morony dams. Cochrane dam does not have waste gates; therefore, inflow must be passed through turbine flow and requires the intakes to be fully submerged. Under these conditions, the lowest drawdown elevation depends in part on the inflow rate in conjunction with operational requirements.

Historical drawdown planning has included consideration of several factors, including the following:

- Keep drawdown rate slow to protect dam equipment and structures from the sloughing of sediment banks, and to limit sediment mobilization.
- Keep drawdown rate fast enough to complete drawdown and reservoir refill within a reasonable time period. Typically, drawdowns have been completed in 7 days.

- Verify sufficiently high inflow rates to expeditiously refill the reservoir.
- Forecast sufficiently low inflow rates to maintain drawdown elevations while work continues.
- Avoid drawing down more than one reservoir at a time to isolate turbidity impacts and improve the ability to meaningfully interpret water quality data being collected.

2.2. Drawdown Concerns

Flows in the Missouri River near Great Falls derive mostly from snowmelt. Major potential sediment sources include sediment in natural runoff and sediment from irrigation return flows. Canyon Ferry, which is a large reservoir located upstream of Helena, Montana, traps the majority of sediment from the upper Missouri River before it reaches the Great Falls area.

However, the Missouri River upstream of the Great Falls Development is characterized by naturally high levels of suspended sediment, much of which originates in Muddy Creek, a tributary of the Sun River and enters the Missouri River just upstream of Black Eagle Reservoir. High sediment loads have resulted in sediment deposition in the Great Falls reservoirs, with greatest deposition volumes in the upper two reservoirs (Black Eagle and Rainbow). During reservoir drawdowns, these sediment deposits can be disturbed, and result in a spike in turbidity. NorthWestern attempts to avoid utilizing reservoir drawdowns for maintenance and repair work on the Project facilities whenever possible to further minimize the risk of impacting downstream turbidity, however in some cases avoidance is not possible due to the nature of the work required.

The greater the amounts of Total Suspended Solids (TSS) in water, the murkier it appears and the higher the measured turbidity. TSS can have a variety of detrimental effects on aquatic biota, such as clogged fish gills, reduced growth rates of fish, decreased resistance to disease, suffocation of fish eggs and larvae and aquatic insects. TSS may be caused by localized sediment mobilization within a project reach.

During drawdown events, spikes in turbidity have been recorded. During a drawdown at Black Eagle Reservoir in August 1994, turbidity was recorded at 690 nephelometric turbidity units (NTU) (NorthWestern 2009). Data was collected during other reservoir drawdown events have also clearly shown spikes in turbidity (NorthWestern 2009). By minimizing increases in turbidity during drawdowns, water quality in the Missouri River system downstream of the Great Falls Development can be protected. To the extent that trace metals or other pollutants are bound to sediments, minimizing turbidity also minimizes the resuspension of these pollutants in the river.

2.3. 2019 Revised Reservoir Drawdown Plan Requirements

The February 2020 FERC Order approved implementation of drawdown protocols that would utilize the specified drawdown rates as described in Table 2-6.

Table 2-6. Drawdown Schedule for the Great Falls Developments, as Approved by FERC February 7, 2020

Reservoir	Reservoir Water Elevation (ft)	Average Drawdown Rate (ft/hr)[1]
Black Eagle	(1) below 3,289	(1) 0.10
Rainbow	(1) 3,223 to 3,214	(1) 0.20
	(2) below 3,214	(2) 0.10
Cochrane	(1) below 3,110	(1) 0.10
Ryan	(1) 3,029 to 3,024	(1) 0.20
	(2) below 3,024	(2) 0.10
Morony	(1) below 2,878	(1) 0.10

Note:
1. Average drawdown rate is based on a 4-hour running average.

The 2020 FERC Order also specified that NorthWestern shall implement the following:

- Collect tailrace turbidity data during reservoir drawdowns on 5-year-cycles.
- Monitor and verify the plans sediment control effectiveness and identify whether greater than expected sediment re-suspension occurs during a drawdown.
- Modify, as appropriate, the FERC approved drawdown schedule and rates (refer to Table 2-6) in consultation with resource agencies.

3. Methods

3.1. Drawdown Monitoring

Surface water elevations are monitored in all Great Falls reservoirs. Submersible hydrostatic level transducers are permanently installed in the forebay of each reservoir. The water level sensors are manufactured by Measurement Specialties, model KPSI 705.

The level transducers are hardwired into the Great Falls control system and are used for all reservoir operations. The level transducers measure continuously and record values every 0.05 foot of change and/or every 15 minutes.

3.2. Turbidity Data Collection

Automatic turbidity meters are permanently installed at all Great Falls facilities. The meters are plumbed with a continuous feed of 15 to 30 liters per minute of water sourced from the cooling water system. The water travels through the intake, into the penstocks, through the cooling lines and turbidity meters before being discharged into the tailrace at each facility.

The turbidity units are manufactured by Hach, model Surface Scatter 7 with sc100 or sc200 controls. The have an accuracy of ±5% of the turbidity reading or ±0.1 NTU, whichever is greater. The sc100 or sc200 controls are hardwired by 4-20mA outputs to offload that data into the Great Falls control system. The turbidity meter takes a reading every 0.1 seconds and reports to the control system when a change of 1.5 NTU is measured. The turbidity data is reported in 15-minute intervals.

3.3. Hydrolab Turbidity Data Collection

Hydrolab turbidity data is collected to supplement the data set when reservoir elevations are below the level which operations can use the generators and cooling water lines that supply the plant turbidity meters. The threshold elevations for the generators are different for each dam. For example, at Rainbow Dam, the powerplant shuts down at a relatively high elevation during a drawdown, while at Ryan Dam, the generators can continue running through a very deep drawdown. Overall, NorthWestern considers the turbidity sensors on the Hydrolabs sondes to be less reliable and less accurate than the plant turbidity meters.

In addition to the different type of sensors, the Hydrolab sondes are in different locations than the plant turbidity sensors. The Hydrolab deployment locations are summarized as follows:

- Rainbow Dam: The Hydrolab sensor is located on the far-right bank near the waste gates, which is the opposite side of the river from the intake to the powerhouse.
- Black Eagle Dam: The Hydrolab sensor is located in a galvanized pipe at the entrance to the intake canal.

- Cochrane Dam: The Hydrolab sensor is located in a stilling case on the upstream face of the dam about halfway between the waste gates on the right bank and the powerhouse intakes on the left bank.
- Ryan Dam: The Hydrolab sensor is located in a stilling well case directly above the intake at the dam.
- Morony Dam: This dam has not been drawn down and NorthWestern has not been able to determine a location for a Hydrolab sensor.

As indicated above, Hydrolab turbidity data is collected to supplement the data set when reservoir elevations are below the level which operations can use the generators and cooling water lines that supply the plant turbidity meters. During the 5-year monitoring period there were four drawdown events when this occurred:

- Black Eagle July 2019
- Rainbow Dam September 2021 and September 2022
- Ryan Dam September 2023

For the two Rainbow Dam drawdown events and one Ryan Dam, the Hydrolab data is provided. However, NorthWestern is concerned about data quality at Rainbow Dam because the location of the sensor is exposed on the right bank and the sensor was disturbed by debris during the drawdown event.

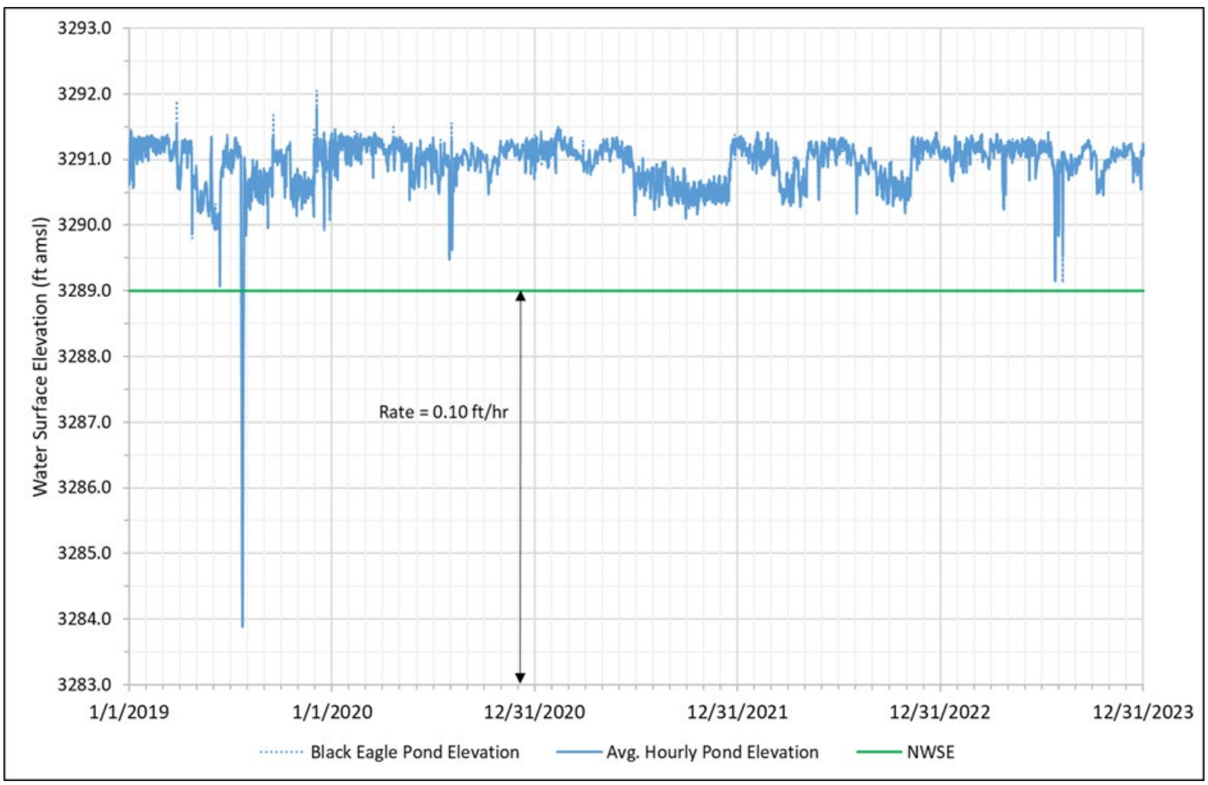
4. Results – Black Eagle

4.1. Drawdown Occurrences and Drawdown Rate Plan

The normal WSE at Black Eagle is between 3,289 and 3,290 feet. WSE data were collected at 30-minute intervals at Black Eagle Reservoir from January 1, 2019, to December 31, 2023, and converted to an hourly mean as shown in Figure 4-1. There was one period where the data indicate that the reservoir WSE was less than 3,289 feet in July 2019. Turbidity, elevation and discharge data were available for the July 2019 drawdown event.

The drawdown rate at Black Eagle requires 160 hours (6.7 days) to draw the reservoir down from full pool to crest (3,279 feet). In order to stay within the scheduled limits, the plant has to be manned continuously and water has to be released exclusively through the waste gates.

Figure 4-1. Black Eagle Reservoir – Mean Daily Water Surface Elevation (in blue) and Drawdown Threshold (green line): January 1, 2019 – December 31, 2023



4.2. July 2019 Drawdown

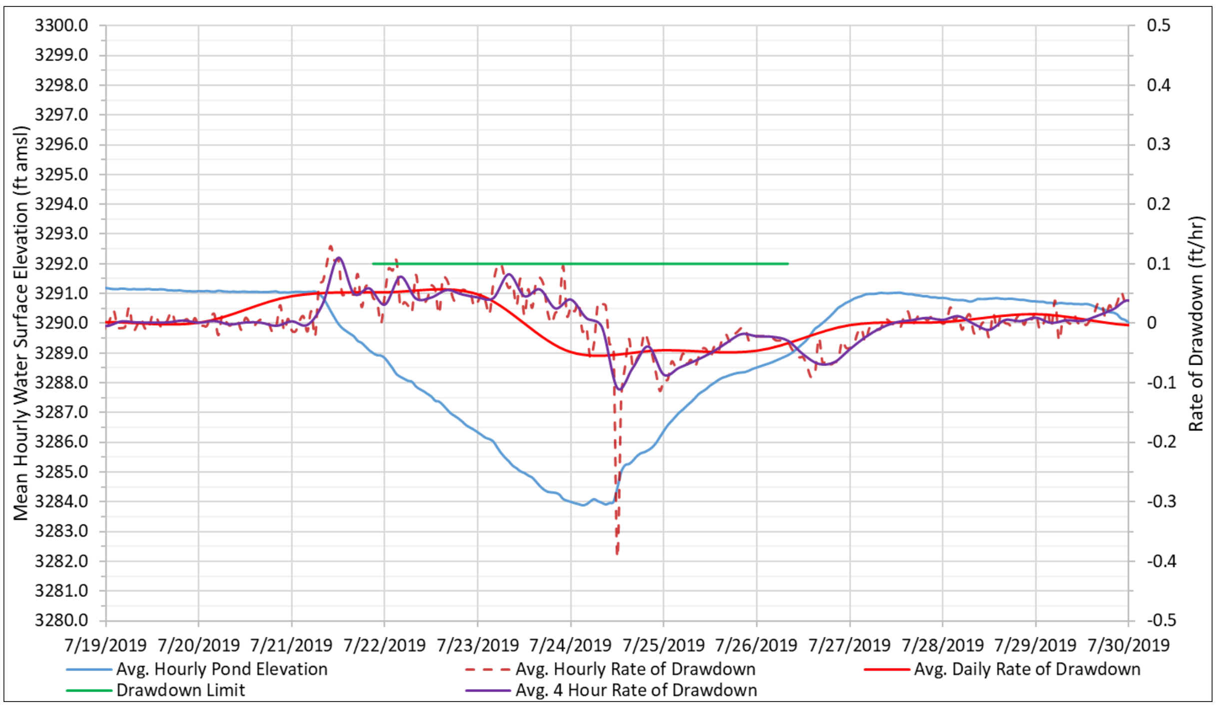
The July 2019 drawdown generally occurred between July 21, 2019, to July 30, 2019. The drawdown was 7.2 feet, with minimum 30-minute WSE of 3,283.9 feet.

4.2.1. July 2019 Drawdown Rates

During the July 2019 drawdown of Black Eagle Reservoir, the pond elevation (blue line) was generally drawn down at a rate of 0.1 foot per hour, as specified in the 2019 Revised Reservoir Drawdown Plan (Figure 4-2).

As shown in Figure 4-2, none of the 4-hour average drawdown rates exceeded the rates specified in the plan.

Figure 4-2. Black Eagle Reservoir, Drawdown July 2019 – Hourly Water Surface Elevation (blue line), Daily and Hourly Rate of Drawdown (red lines), and Limit to the Drawdown Rate (green line) per the 2019 Revised Reservoir Drawdown Plan



4.2.2. July 2019 Turbidity

During the July 2019 drawdown (Figure 4-3) when the WSE declined to 3,283.9 feet, hourly turbidity increased briefly from approximately 30 to approximately 80 NTUs, then generally returned to the baseline level. The turbidity generally increased when the reservoir was drawn down below WSE 3,289.0 feet and returned to baseline levels as the reservoir returned to the normal pool. The turbidity increased when the drawdown rate was near the rate specified in the plan (Figure 4-4). The turbidity data showed poor correlation with the discharge rates during the July 2019 drawdown (Figure 4-5).

Figure 4-3. Black Eagle Reservoir – Mean Hourly Water Surface Elevation and Mean Hourly Turbidity: July 21-30, 2019

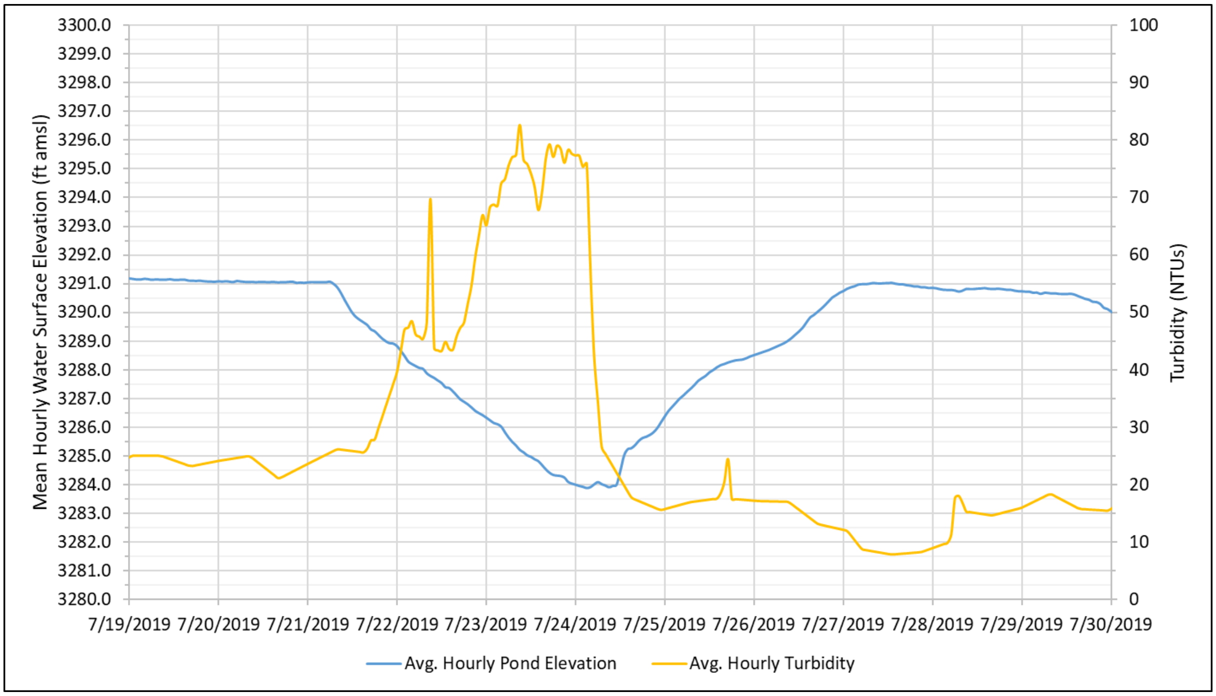


Figure 4-4. Black Eagle Reservoir – Mean Daily and Hourly Rate of Change in Reservoir Elevation and Mean Hourly Turbidity: July 21-30, 2019

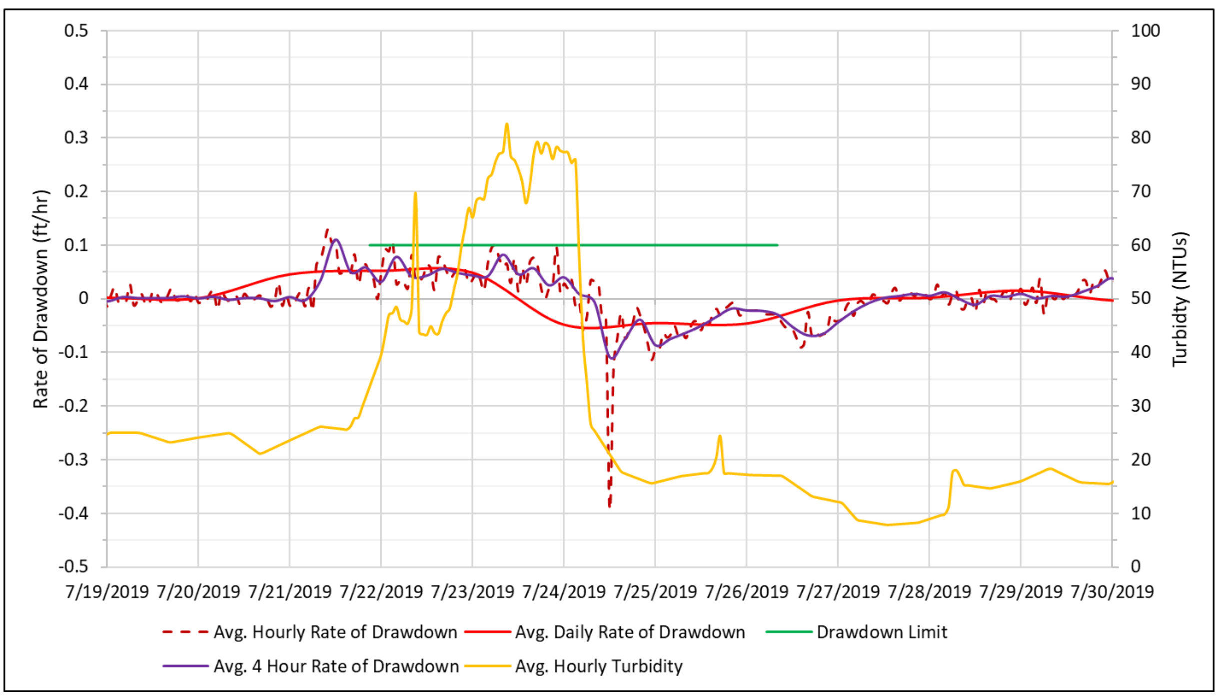
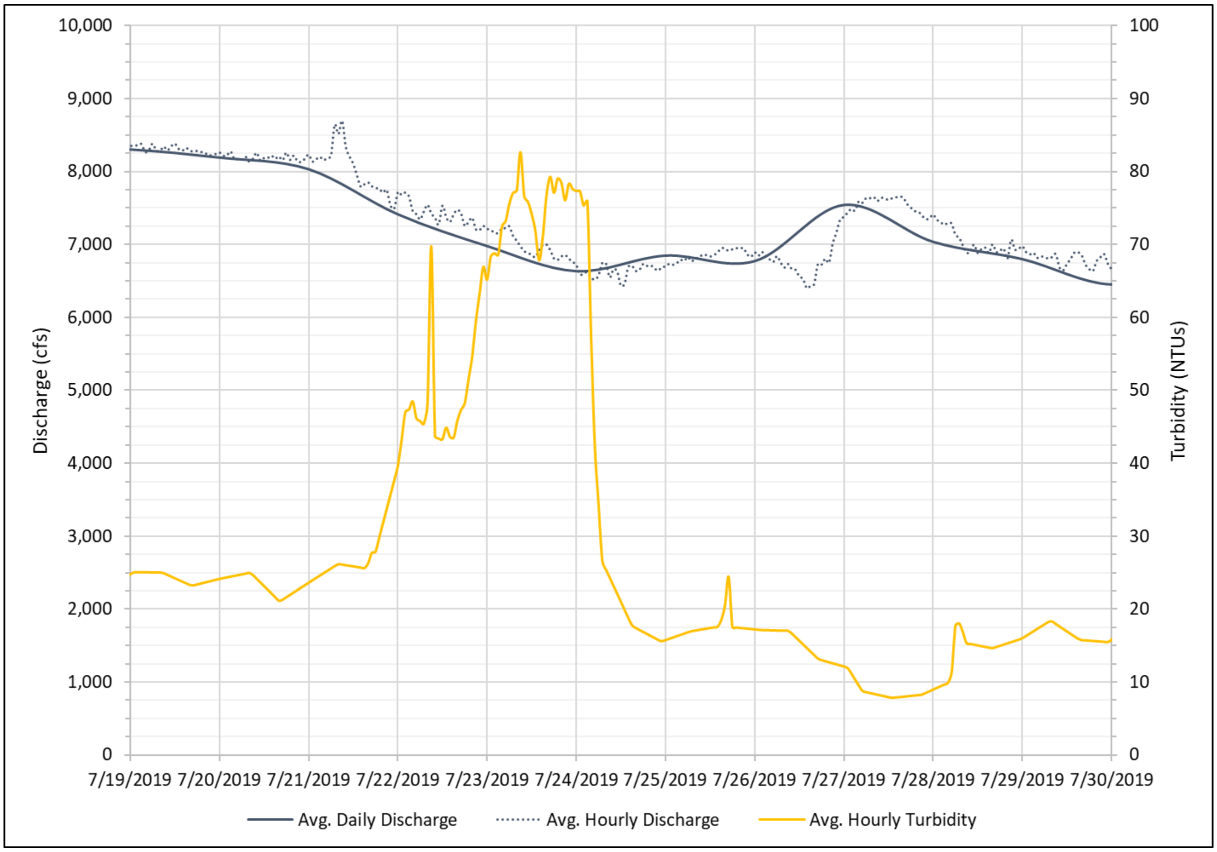


Figure 4-5. Black Eagle Reservoir – Mean Daily and Hourly Discharge Rate and Mean Hourly Turbidity: July 21-30, 2019



4.3. Black Eagle Turbidity

Turbidity in the Missouri River varies seasonally. Figure 4-6 shows turbidity and WSEs measured at Black Eagle since January 2019. These data indicate that turbidity was lowest in winter (typically at approximately 10 NTUs) and peaks in the spring during the period of high spring flow. Turbidity levels naturally increase in the spring with spring flows and remain slightly above baseline levels during the summer (~30 NTUs), which is likely a result of irrigation return flows entering the river system. This is indicated in Figure 4-7 which shows the turbidity by month in a box-and-whisker plot. Additionally, when irrigation activities end on October 1, turbidity levels continued to decline.

At its peak, turbidity in the Missouri River at Black Eagle Dam reached approximately 140 NTUs during the spring. These spikes in turbidity were generally unrelated to reservoir operations at Black Eagle Dam. During the drawdown event the increase in turbidity coincided with the drawdown activity; although other, larger, spikes in turbidity have been observed unrelated to reservoir drawdowns (Figure 4-6).

Figure 4-6. Black Eagle Reservoir – Mean Daily Turbidity (in yellow) and Water Surface Elevation (in blue): January 1, 2019 – December 31, 2023

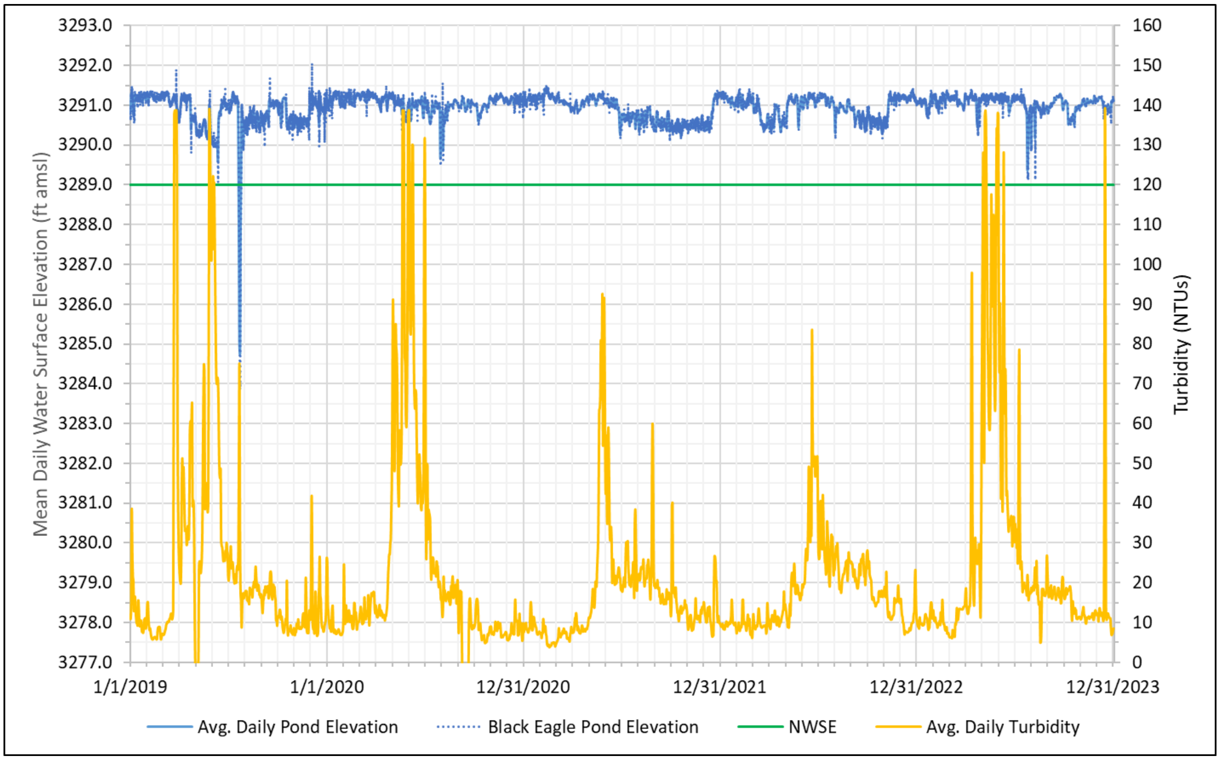


Figure 4-7. Black Eagle Reservoir – Mean Daily Turbidity by Month: January 1, 2019 – December 31, 2023

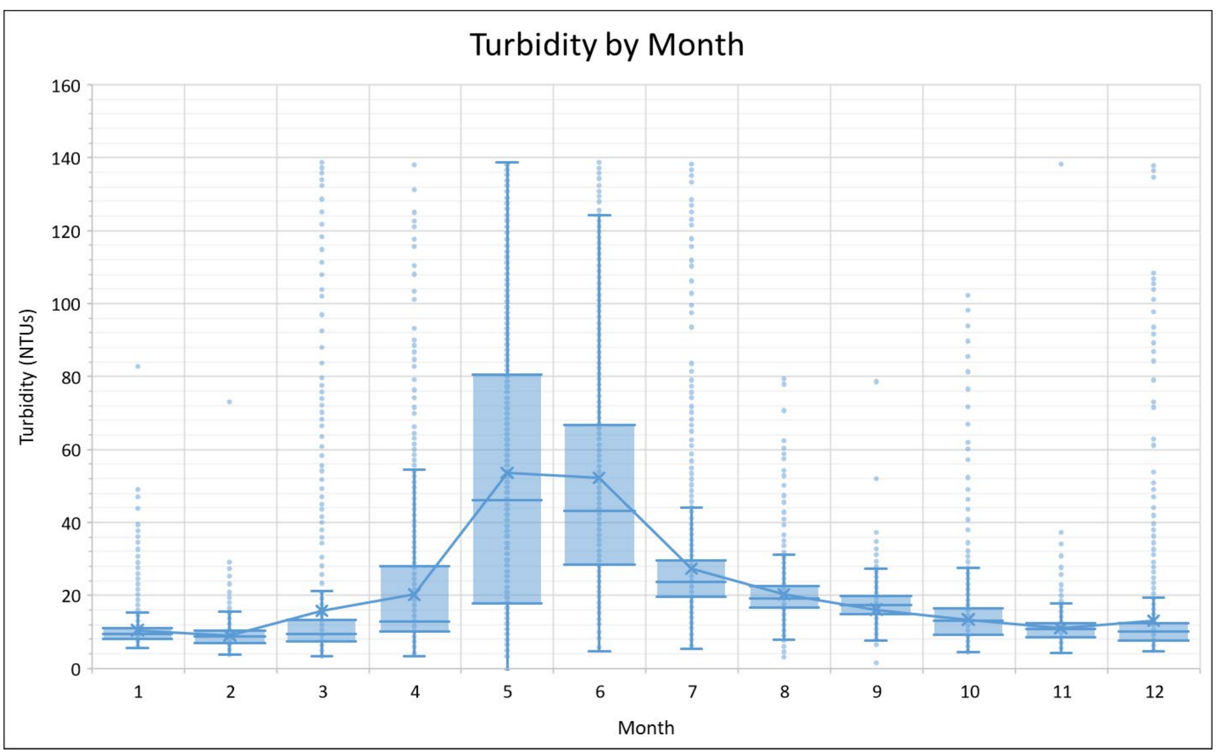
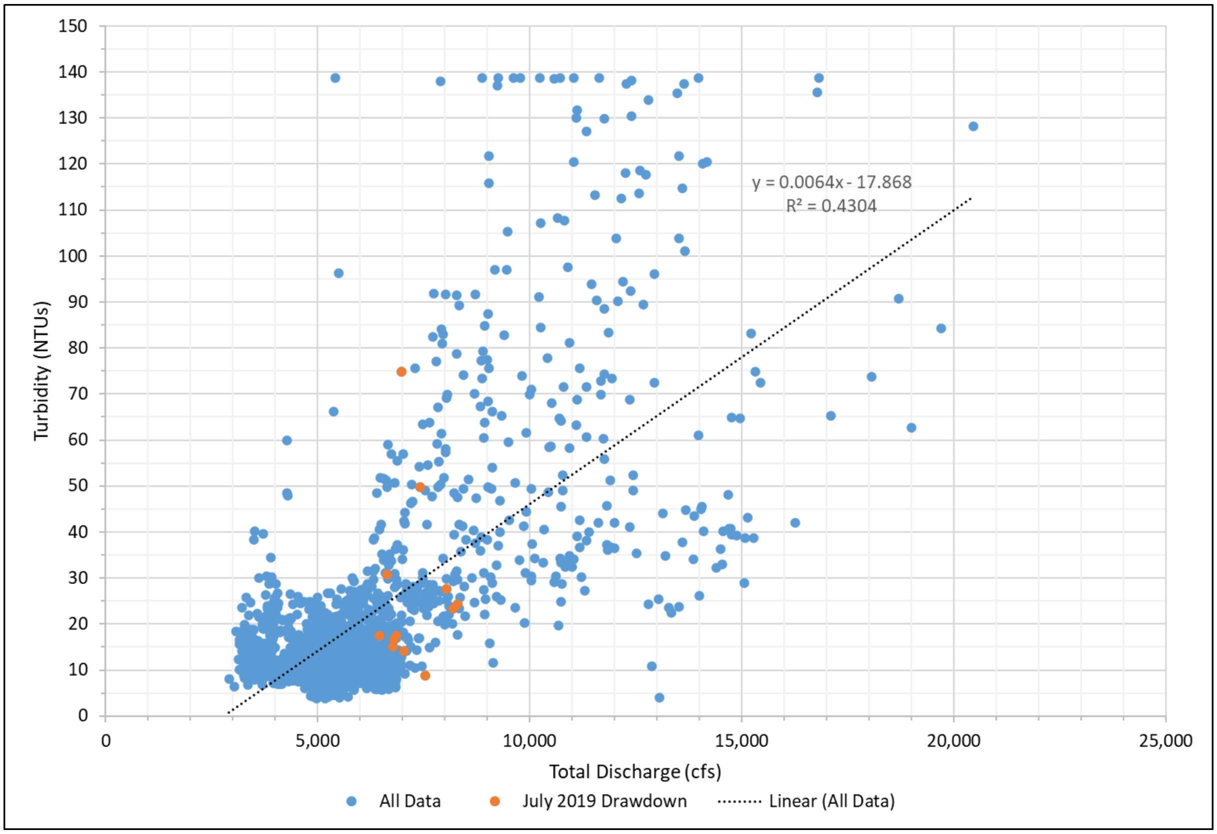


Figure 4-8 shows turbidity in relationship to river discharge. Overall, there is limited correlation between river discharge and turbidity, but turbidity generally increases with discharge rates.

Figure 4-8. Black Eagle Reservoir – Mean Daily Turbidity vs. Mean Daily Flow (spill and generation): January 1, 2019 – December 31, 2023



4.4. Conclusions

In July 2019, Black Eagle Reservoir was drawn down to approximately 3,283.9 feet, and the drawdown rate generally stayed at or below the specified rates in the 2019 Revised Reservoir Drawdown Plan. During the July 2019 drawdown when the WSE declined to 3283.9 feet, hourly turbidity increased briefly from approximately 30 NTUs to approximately 80 NTUs, then generally returned to the baseline level.

Overall, the turbidity data collected during the 5-year period indicates that turbidity is around 10 to 20 NTUs during low-flow periods but increases to above 100 NTUs during spring flows and is around 20 to 30 NTUs during the summer and early fall months.

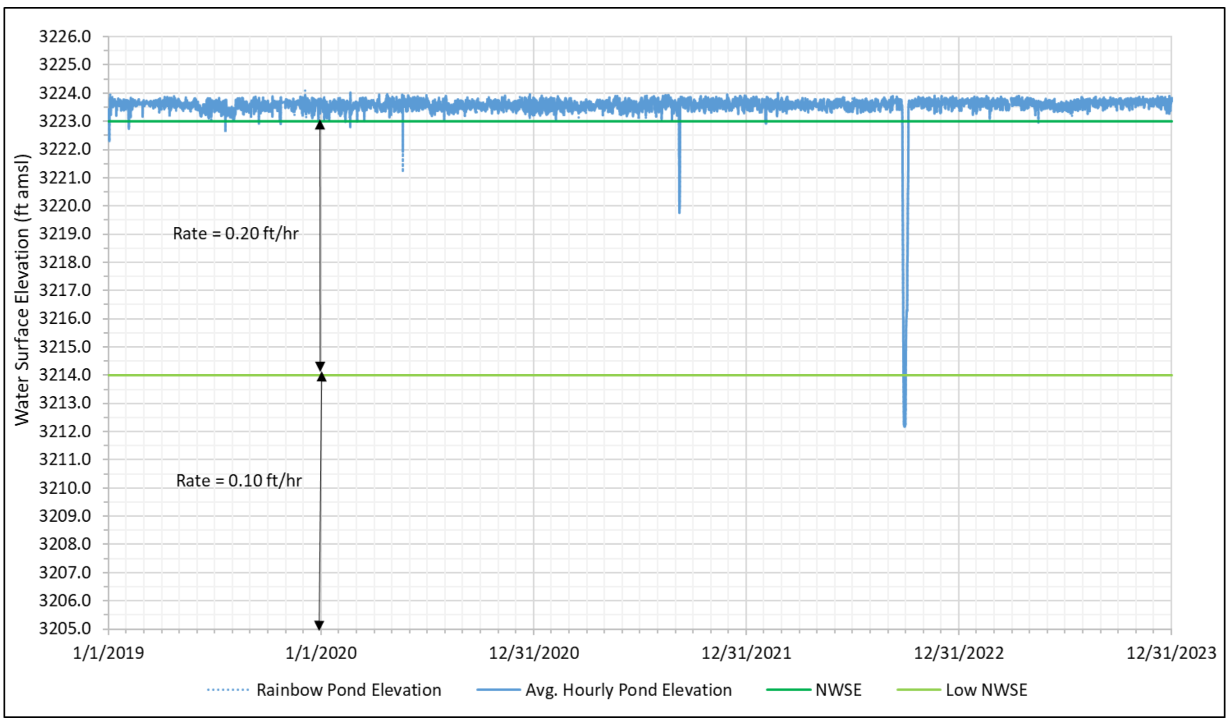
5. Results – Rainbow

5.1. Drawdown Occurrences and Drawdown Rate Plan

The Rainbow Reservoir normal operating WSE is approximately 3,224 feet. A drawdown event is defined by WSE dropping below 3,223 feet as shown by the green lines in Figure 5-1. WSE data were collected at 30-minute intervals at Rainbow Reservoir from January 1, 2019, to December 31, 2023, and converted to an hourly mean as shown in Figure 5-1. The data collected during this period indicate there were some fluctuations of WSE below 3,223 feet that are not reflective of drawdown events. These small fluctuations are caused by cleaning and calibration of the pond level transducer. There was one event where the water level dropped below 3,223 feet in May of 2020 that was reported and discussed with FERC. There were two drawdown events: one in September 2021 and one in September 2022. Turbidity and elevation data were available for the drawdown events. No discharge data were available for the drawdown events.

It requires 110 hours (4.5 days) to drawdown Rainbow Reservoir from full pool elevation to crest (3,212 feet). Maintaining the drawdown schedule requires continuous attendance by the operators.

Figure 5-1. Rainbow Reservoir – Mean Daily Water Surface Elevation (in blue) and Drawdown Thresholds (green lines): January 1, 2019 – December 31, 2023



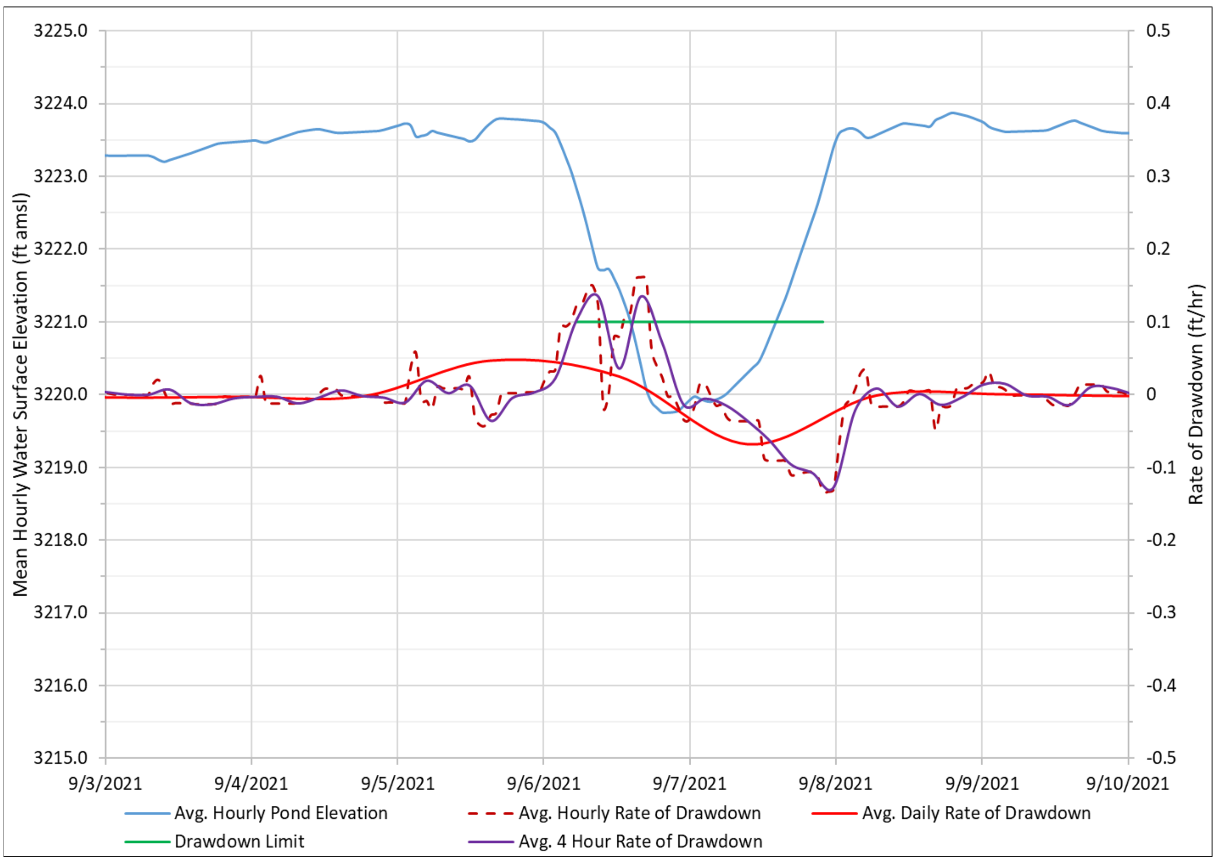
5.2. September 2021 Drawdown

The September 2021 drawdown generally occurred between September 3, 2021, to September 9, 2021. The drawdown was 4.1 feet, with a minimum 30-minute WSE of 3,219.8 feet. This drawdown was requested by MFWP.

5.2.1. September 2021 Drawdown Rates

During the September 2021 drawdown of Rainbow Reservoir, the pond elevation was generally drawn down at the rates specified in the plan (Figure 5-2). A total of 3- of the 4-hour average drawdown rates exceeded the rate specified in the plan. During those hours the average drawdown rate was 0.124 foot per hour, with a maximum drawdown rate of 0.135 foot per hour.

Figure 5-2. Rainbow Reservoir, Drawdown September 2021 – Hourly Water Surface Elevation (blue line), Daily and Hourly Rate of Drawdown (red lines), and Limits to the Drawdown Rate (green line) per the 2019 Revised Reservoir Drawdown Plan



5.2.2. September 2021 Turbidity

During the September 2021 drawdown there was minimal change in turbidity when the WSE declined (Figure 5-3). Hydrolab sensor data were used to supplement the turbidity data during the September 2021 drawdown. The Hydrolab data were generally consistent with the plant turbidity data. The turbidity increased slightly when the drawdown rate was near the rate specified in the plan but generally remained at the baseline turbidity levels (Figure 5-4).

Figure 5-3. Rainbow Reservoir – Mean Hourly Water Surface Elevation and Mean Hourly Turbidity: September 3-10, 2021

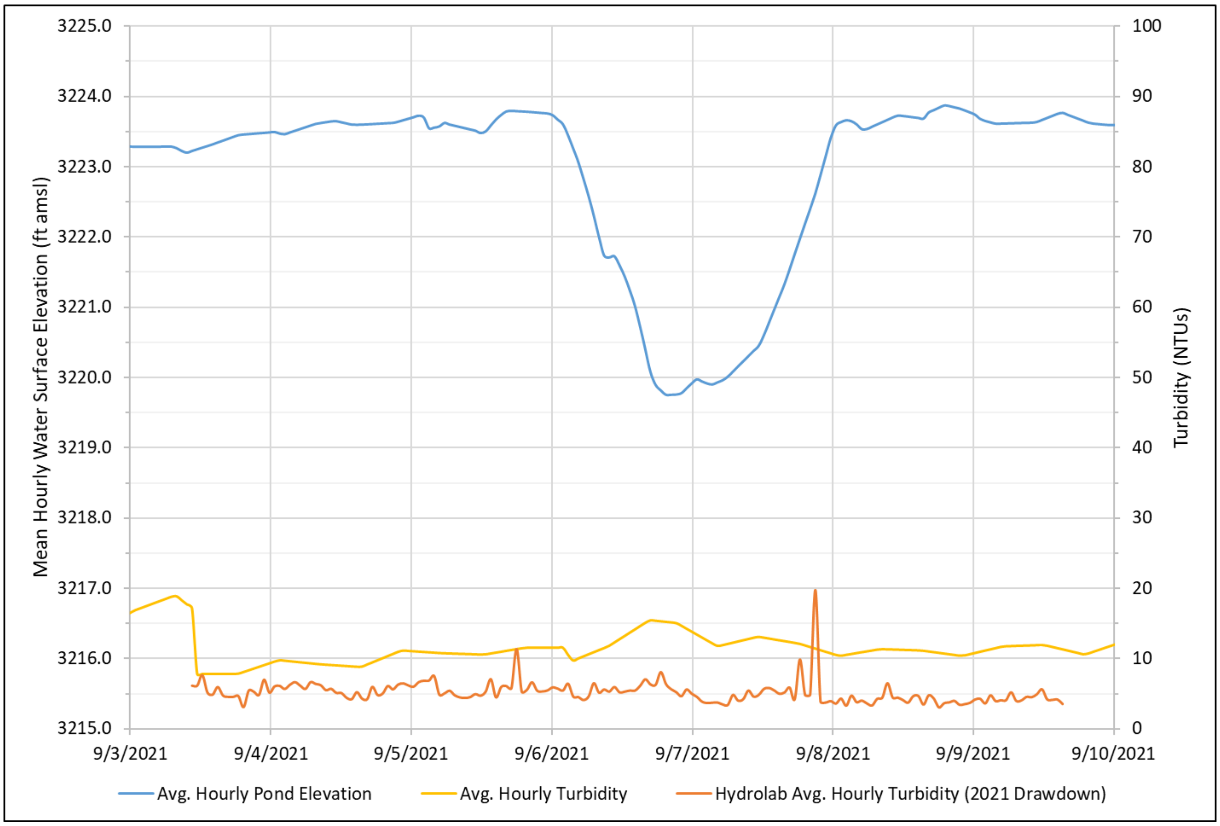
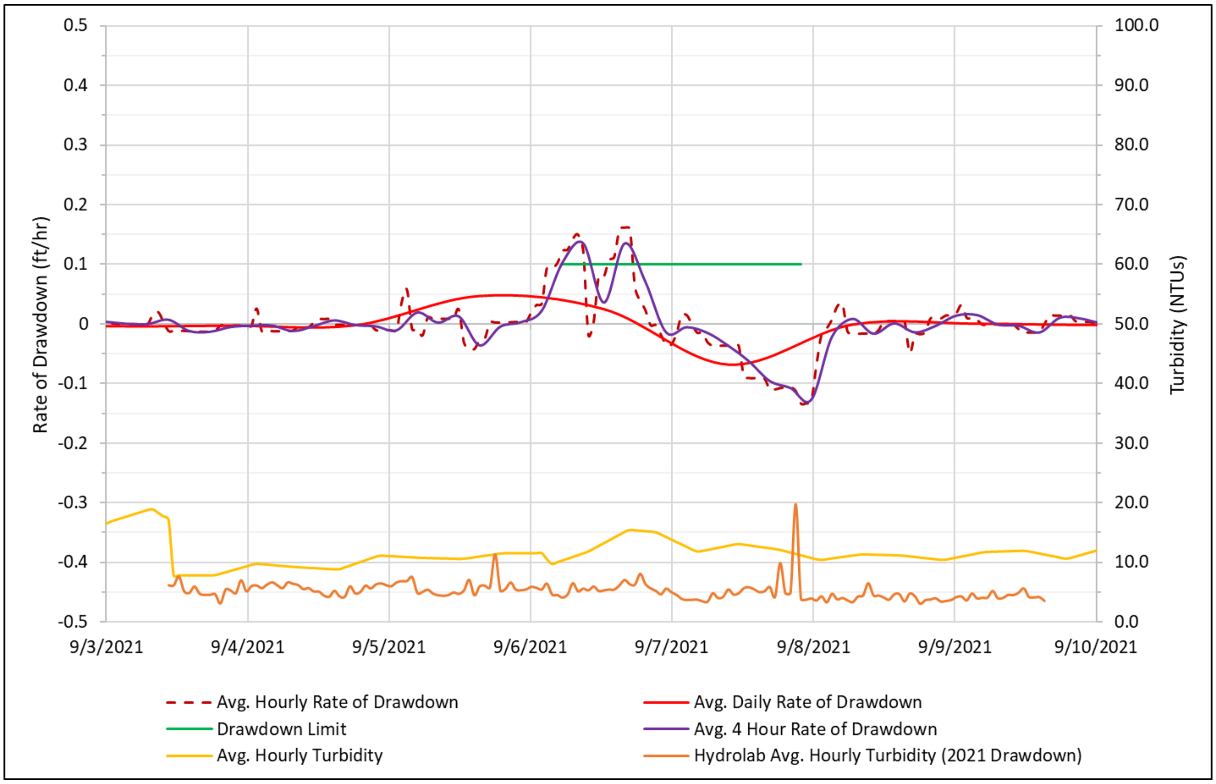


Figure 5-4. Rainbow Reservoir – Mean Daily and Hourly Rate of Change in Reservoir Elevation and Mean Hourly Turbidity: September 3-10, 2021



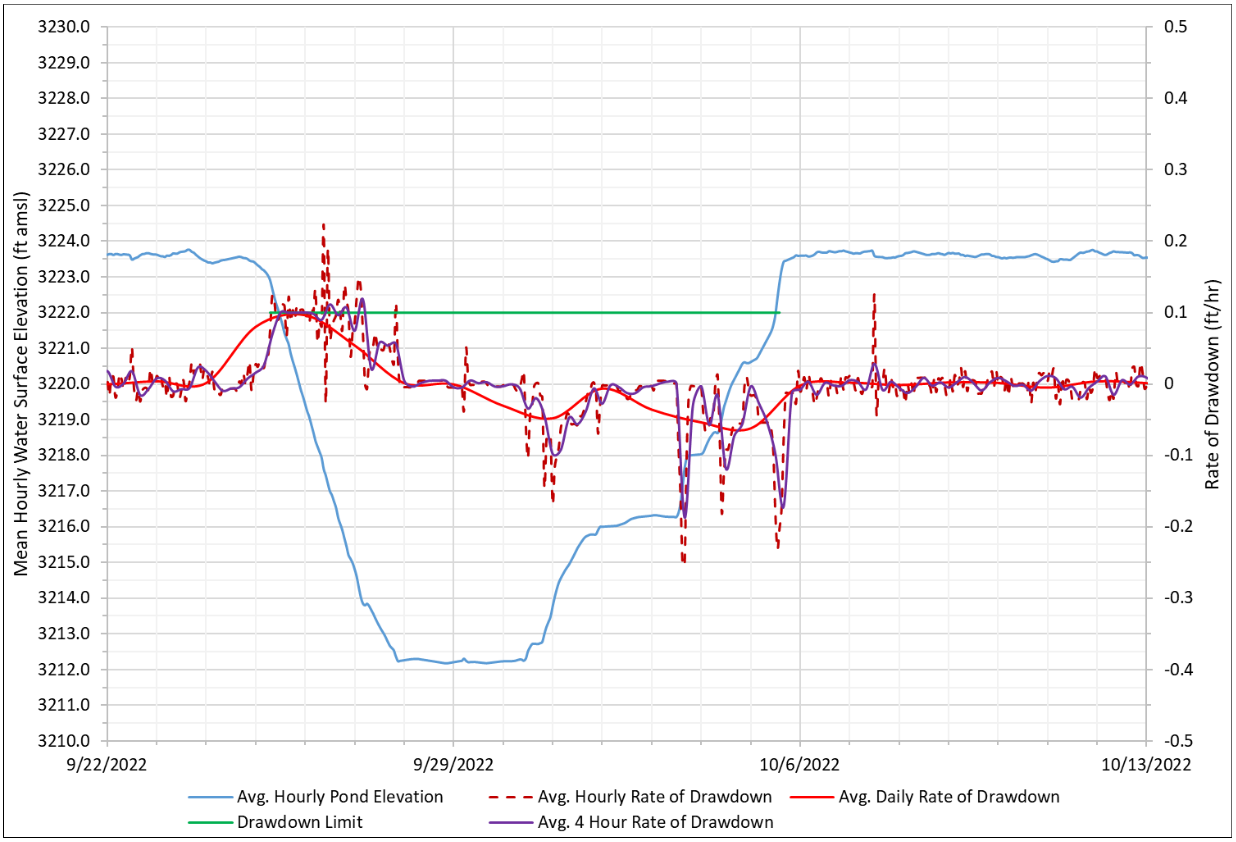
5.3. September 2022 Drawdown

The September 2022 drawdown generally occurred between September 22, 2022, to November 3, 2022. The drawdown was 11.7 feet, with a minimum 30-minute WSE of 3,212.2 feet.

5.3.1. September 2022 Drawdown Rates

During the September 2022 drawdown of Rainbow Reservoir, the pond elevation was generally drawn down at the rates specified in the plan, except for some hourly drawdown rates that exceeded the value (Figure 5-5). A total of four of the 4-hour average drawdown rates exceeded the rates specified in the plan. During those hours the average drawdown rate was 0.109 foot per hour, with a maximum drawdown rate of 0.119 foot per hour.

Figure 5-5. Rainbow Reservoir – Mean Daily and Hourly Rate of Change in Reservoir Elevation and Mean Hourly Turbidity: September 22 – October 13, 2022



5.3.2. September 2022 Turbidity

WSE and turbidity data were available for the September 2022 drawdown (Figure 5-6). Hydrolab sensor data were used to supplement the turbidity data during the September 2022 drawdown. The Hydrolab data showed elevated turbidity when the WSE declined below El. 3,214.0 feet, with three noticeable, short-term spikes above 140 NTUs. The plant turbidity data showed an increase to 40 NTU, not nearly as high as the Hydrolab data. Turbidity data compared to the September 2022 drawdown rates are shown in Figure 5-7. Based on the Hydrolab sensor data, the turbidity showed a noticeable increase even though the operators were generally able meet the drawdown rates in the plan on a 4-hour and daily basis.

The Hydrolab turbidity data were not continuously collected during the event due to the exposure of the sensor and debris disturbing the sensor causing sensor drift, therefore the quality of the data may be limited. Also, based on NorthWestern observations, there is essentially a river channel that forms when drawing down Rainbow Dam. This channel cuts through sediments as reservoir elevations are reduced, first near the powerhouse intake on left bank, then once the powerhouse is shut down and the flow transitions to the right bank and through the waste gates. This transition in discharge locations cuts another channel upstream and parallel to the dam through the deposited sediments until a new flow route is scoured through the sediments. This process likely causes the observed spikes in turbidity when the powerhouse is shut down, and then reduces once a new channel is cut through the sediments.

Figure 5-6. Rainbow Reservoir – Mean Hourly Water Surface Elevation and Mean Hourly Turbidity: September 22 – October 13, 2022

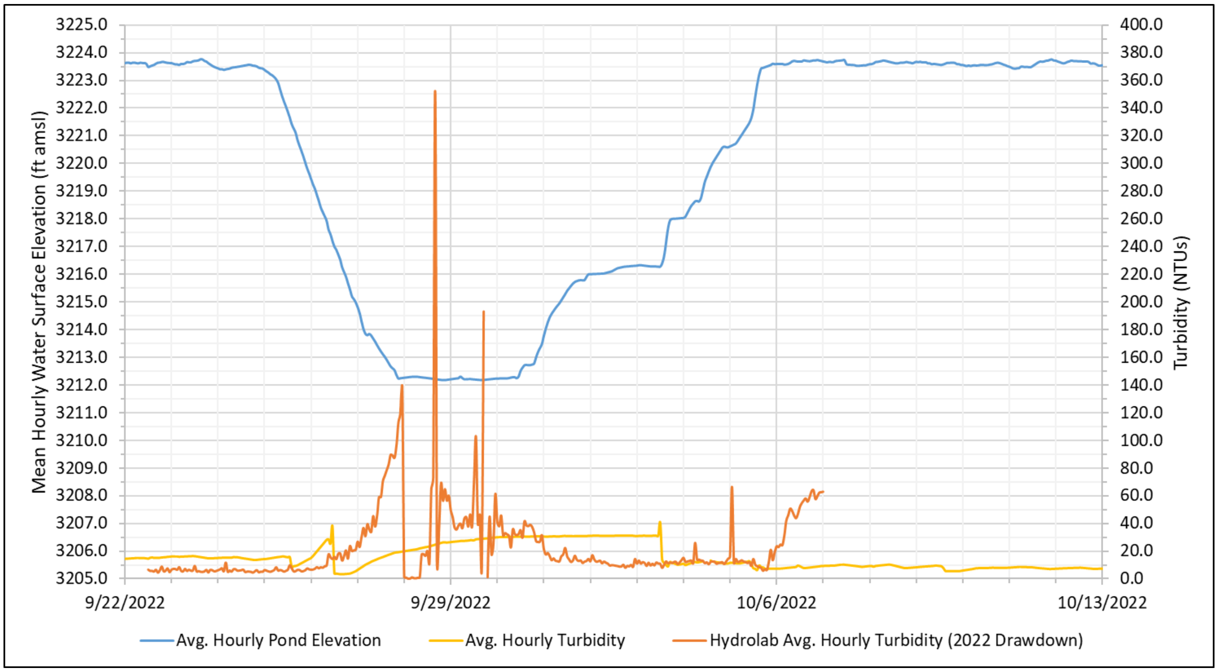
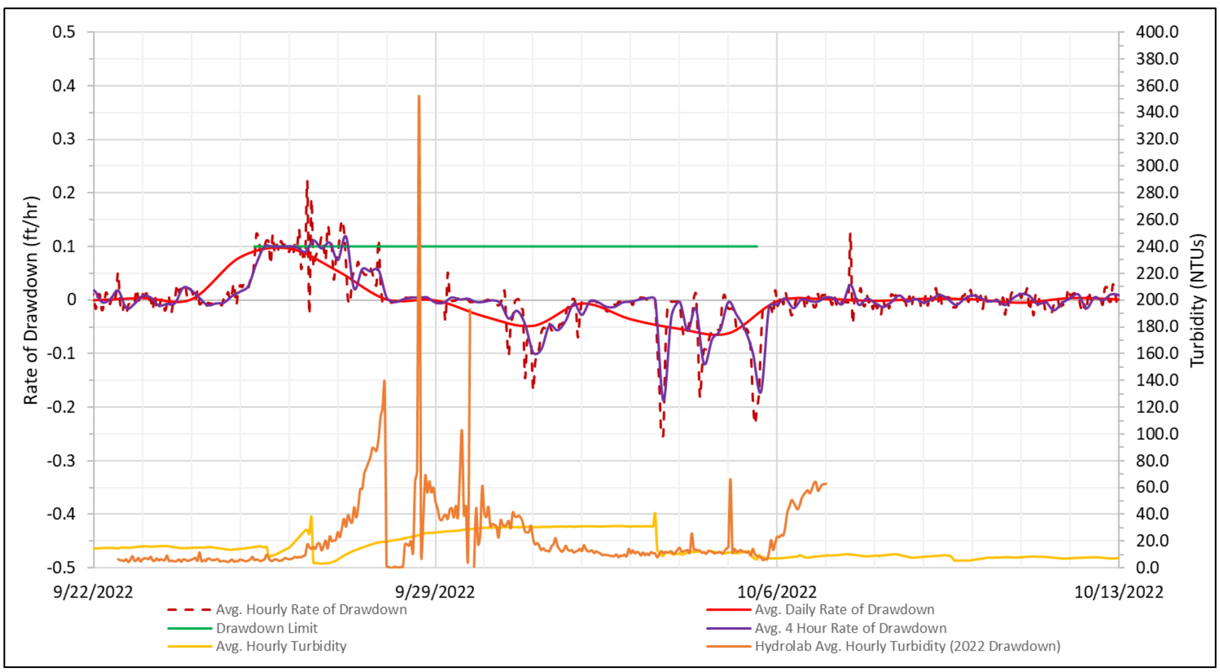


Figure 5-7. Rainbow Reservoir – Mean Daily and Hourly Rate of Change in Reservoir Elevation and Mean Hourly Turbidity: September 22 – October 13, 2022

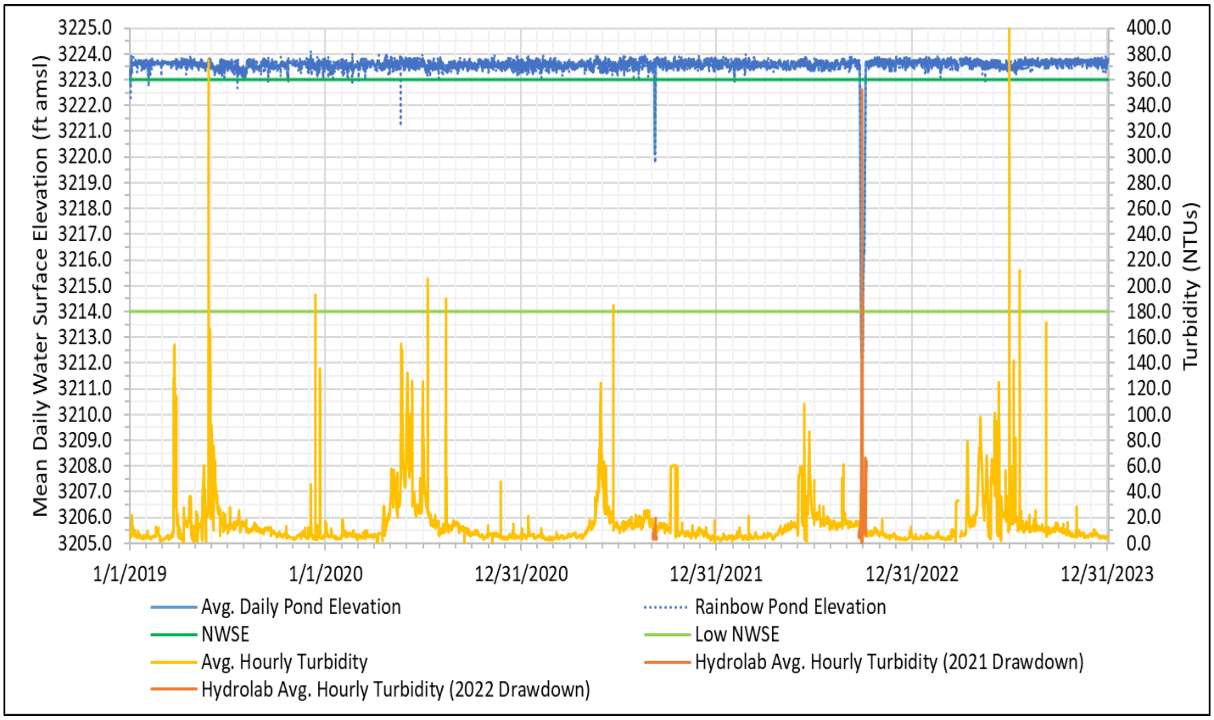


5.4. Rainbow Turbidity

Turbidity in the Missouri River varies seasonally. Figure 5-8 shows turbidity and WSEs measured at Rainbow Dam from January 2019. These data indicate that turbidity was lowest in winter (typically at ~10 NTUs) and peaks in the spring during the period of high spring flow. Turbidity levels naturally increase in the spring with spring flows and remain slightly above baseline levels during the summer (~30 NTUs), which is likely a result of irrigation return flows entering the river system.

At its peak, turbidity in the Missouri River at Rainbow Dam reached approximately 352 NTUs during the September 2022 drawdown event based on the Hydrolab data. The spikes in turbidity were generally unrelated to the drawdown rate and were likely the result of the river channel migrating through the sediments deposited near Rainbow Dam.

Figure 5-8 Rainbow Reservoir – Mean Hourly Turbidity (in yellow) and Water Surface Elevation (blue line): January 1, 2019 – December 31, 2023



5.5. Conclusions

In September 2021, Rainbow Reservoir was drawn down to approximately 3,219.8 feet, and the drawdown rate generally stayed at or below the specified rates in the 2019 Revised Reservoir Drawdown Plan on a daily basis, but a few of the 4-hour average drawdown rates exceeded the rates specified in the plan. During the September 2022 drawdown, Rainbow Reservoir was drawn down to approximately 3,212.2 feet, and the drawdown rates generally stayed at or below the drawdown limits on a daily and 4-hour average basis. During the September 2022 drawdown there was an increase in the hourly turbidity, with a few short-term spikes when the reservoir WSE was below 3,214.0 feet, but the drawdown rate was below the specified limit. This indicates that the increase in turbidity could potentially be more related to the reservoir WSE rather than the rate at which the reservoir is drawn down.

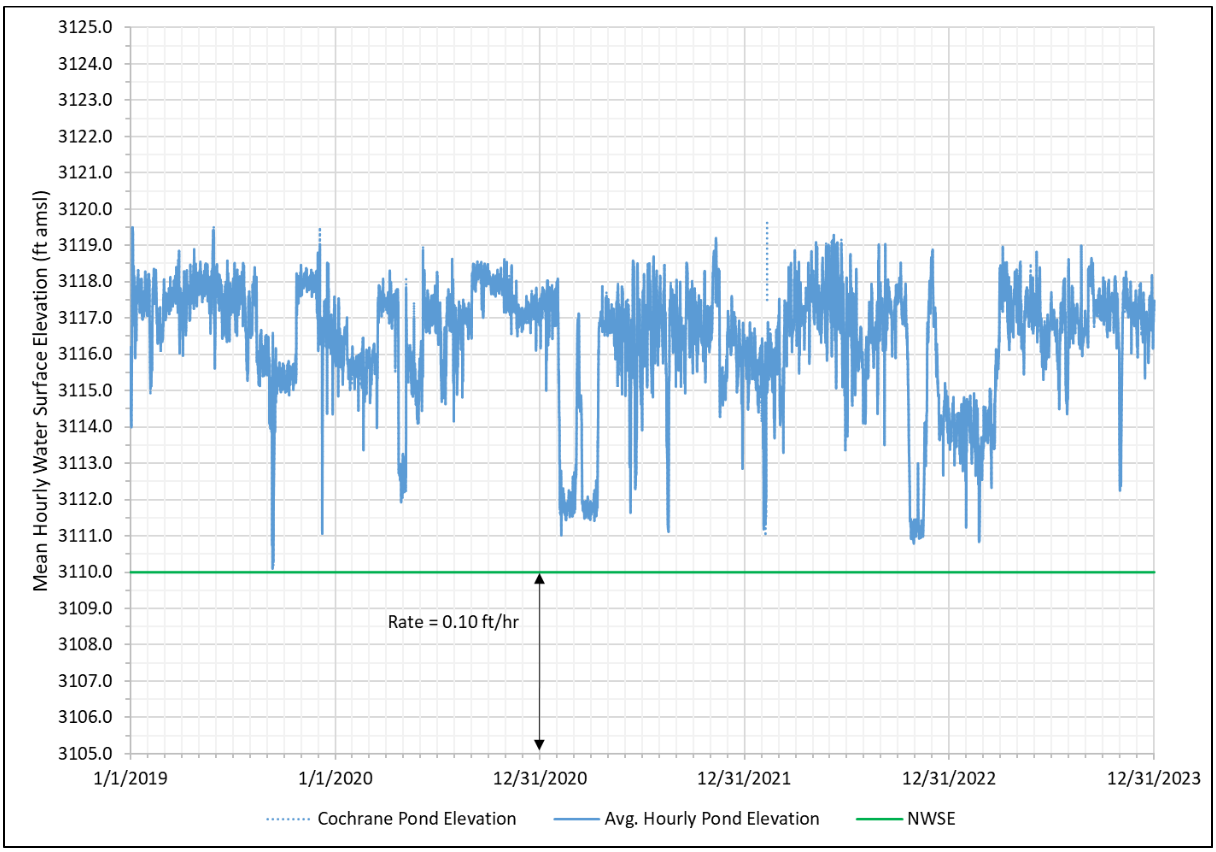
Overall, the turbidity data collected during the 5-year period indicates that turbidity is around 10 NTUs during low-flow periods but can increase to above 200 NTUs during spring flows and then returns to around 20 to 30 NTUs during the summer and early fall months.

6. Results – Cochrane

6.1. Surface Water Elevation and Turbidity

The Cochrane Reservoir normal operating WSEs are between 3,110 and 3,120 feet. WSE data were collected at 30-minute intervals at Cochrane Reservoir from January 1, 2019, through December 31, 2023, and converted to an hourly mean (Figure 6-1). A drawdown event is defined by WSE dropping below 3,110 feet (green line). WSEs at Cochrane Reservoir were never below El. 3,110 feet between 2019 and 2023; therefore, there were no drawdown occurrences in the Cochrane Reservoir to evaluate. The plan specifies the drawdown rate limit is 0.1 foot per hour for WSEs below 3,110 feet. Turbidity, elevation, and discharge data were generally available for entire 5-year period.

Figure 6-1. Cochrane Reservoir – Mean Daily Water Surface Elevation (in blue) and Drawdown Thresholds (green line): January 1, 2019 – December 31, 2023



As at the other Great Falls Development reservoirs, turbidity generally increases with discharge, especially when stream flows are in excess of 7,000 cfs (Figure 6-2). Figure 6-3 shows turbidity in relationship to river discharge.

Figure 6-2. Cochrane Reservoir – Daily Discharge (spill and generation) and Turbidity: January 1, 2019 – December 31, 2023

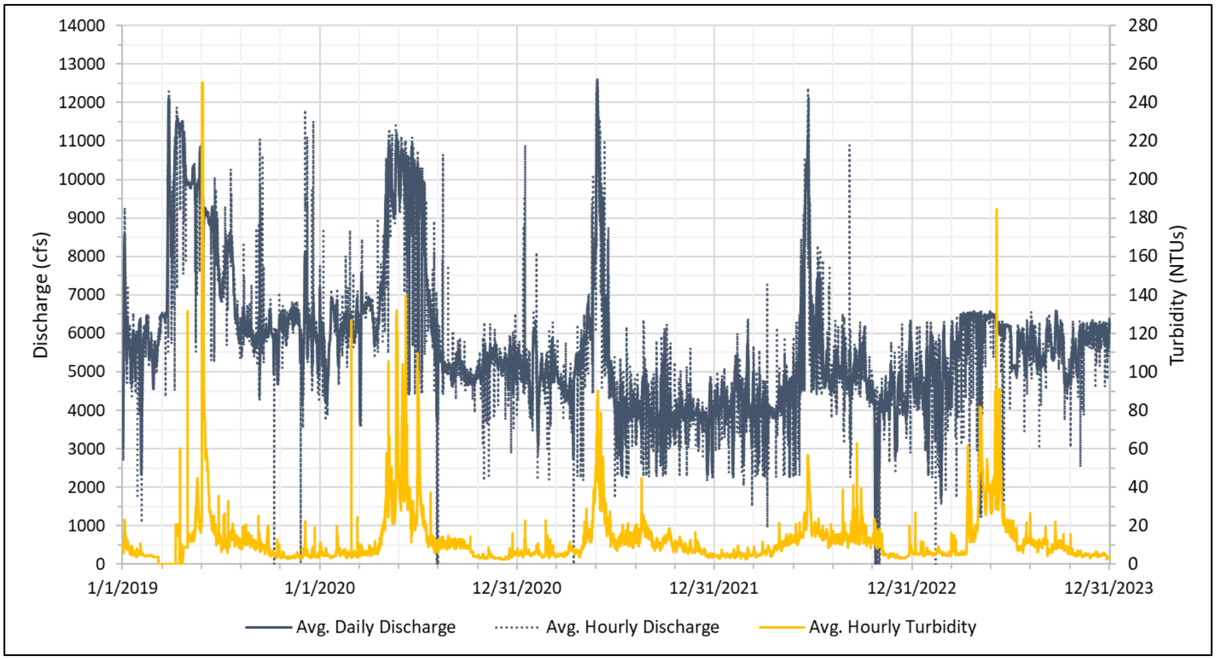
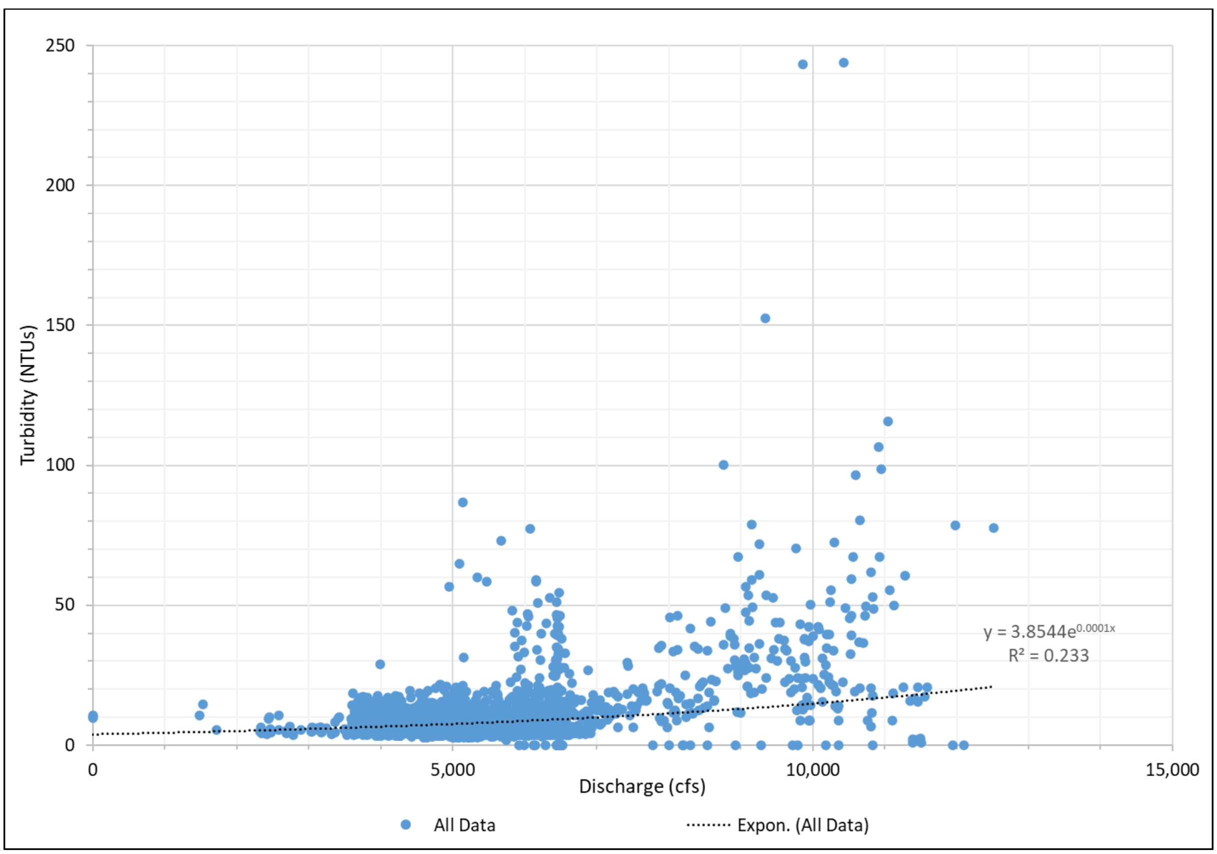


Figure 6-3. Cochrane Reservoir – Mean Daily Turbidity vs. Mean Daily Discharge (spill and generation): January 1, 2019 – December 31, 2023

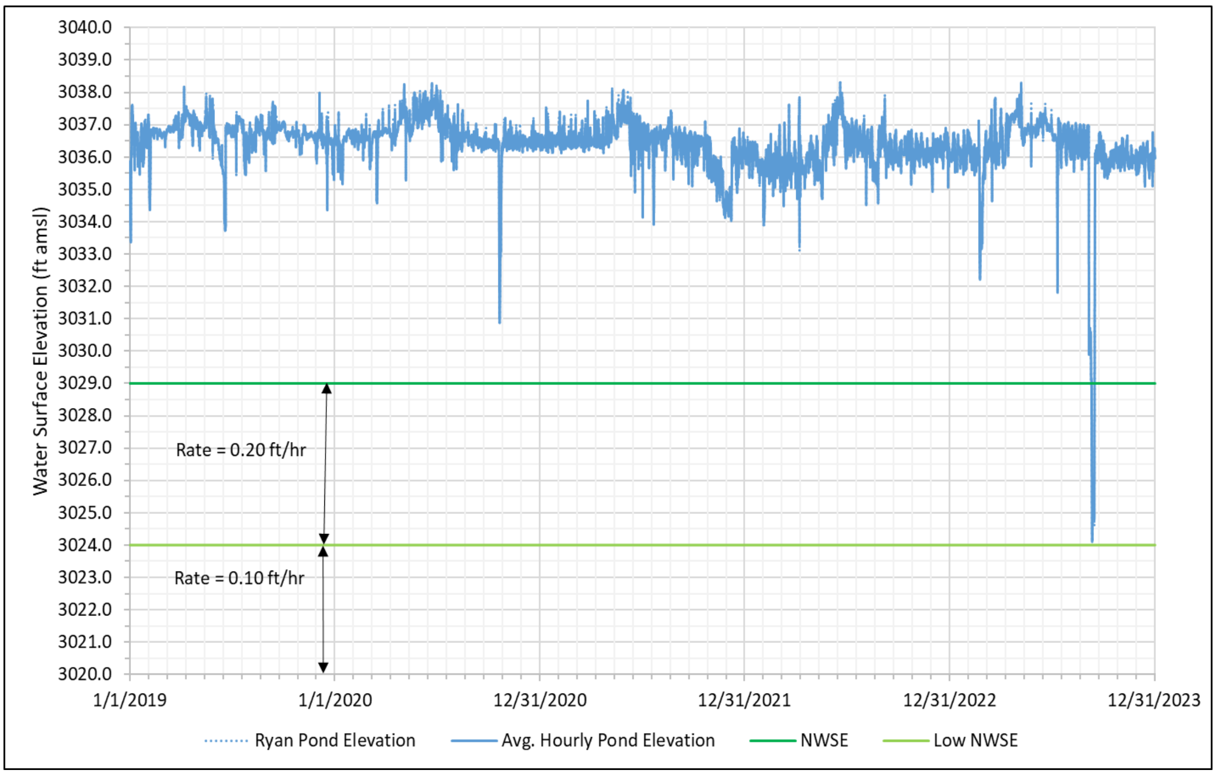


7. Results – Ryan

7.1. Drawdown Occurrences and Drawdown Rate Plan

The Ryan Reservoir normal operating WSE is approximately 3,035 to 3,037 feet. WSE data were collected at 30-minute intervals at Ryan Reservoir from January 1, 2019, to December 31, 2023, and converted to an hourly mean as shown in Figure 7-1. A drawdown event (green lines) is defined by WSE dropping below 3,029 feet. The plan specifies that the reservoir shall not be drawn down more than 0.20 foot per hour between WSE 3,029 and 3,024 feet, and no more than 0.10 foot per hour below WSE 3,024 feet. There was one period in September 2023 where the data indicated that the reservoir WSE was near or less than 3,029 feet. Turbidity, elevation, and discharge data were available for the drawdown event.

Figure 7-1. Ryan Reservoir – Mean Daily Water Surface Elevation (in blue) and Drawdown Thresholds (green lines): January 1, 2019 – December 31, 2023



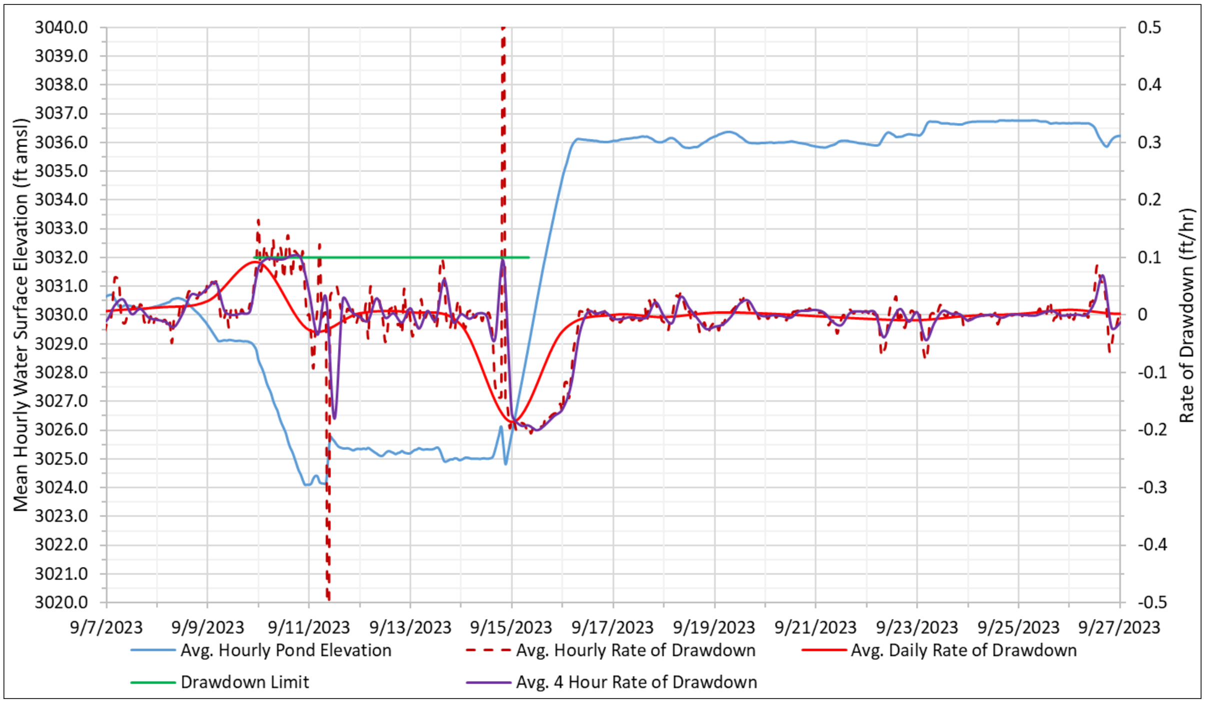
7.2. September 2023 Drawdown

The September 2023 drawdown generally occurred between September 7, 2023, to September 27, 2023. The drawdown was 6.3 feet, with minimum 30-minute WSE of 3,024.1 feet.

7.2.1. September 2023 Drawdown Rates

During the September 2023 drawdown of Ryan Reservoir, the pond elevation was generally drawn down at the rates specified in the plan on a daily basis (Figure 7-2). A total of one, 4-hour average drawdown rates exceeded the rates specified in the plan. During this time, the rate of drawdown rate was 0.103 foot per hour.

Figure 7-2. Ryan Reservoir Drawdown, September 2023 – Hourly Water Surface Elevation (blue line), Daily and Hourly Rate of Drawdown (red lines), and Limits to the Drawdown Rate (green line) per the 2019 Revised Reservoir Drawdown Plan



7.2.2. September 2023 Turbidity

WSE and turbidity data were available for the September 2023 drawdown (Figure 7-3). Hydrolab sensor data were used to supplement the plant turbidity data during the drawdown. During the September 2023 drawdown there was some correlation with the WSE and hourly turbidity, generally increasing from the baseline conditions at approximately 10 NTUs up to approximately 30 NTUs below WSE 3,026.0 feet (Figure 7-3). The turbidity data showed some correlation with the drawdown rates, generally peaking at the highest drawdown rate during the September 2023 drawdown (Figure 7-4). The turbidity data showed poor correlation with the discharge rates during the September 2023 drawdown (Figure 7-5).

Figure 7-3. Ryan Reservoir – Mean Hourly Water Surface Elevation and Mean Hourly Turbidity: September 7-27, 2023

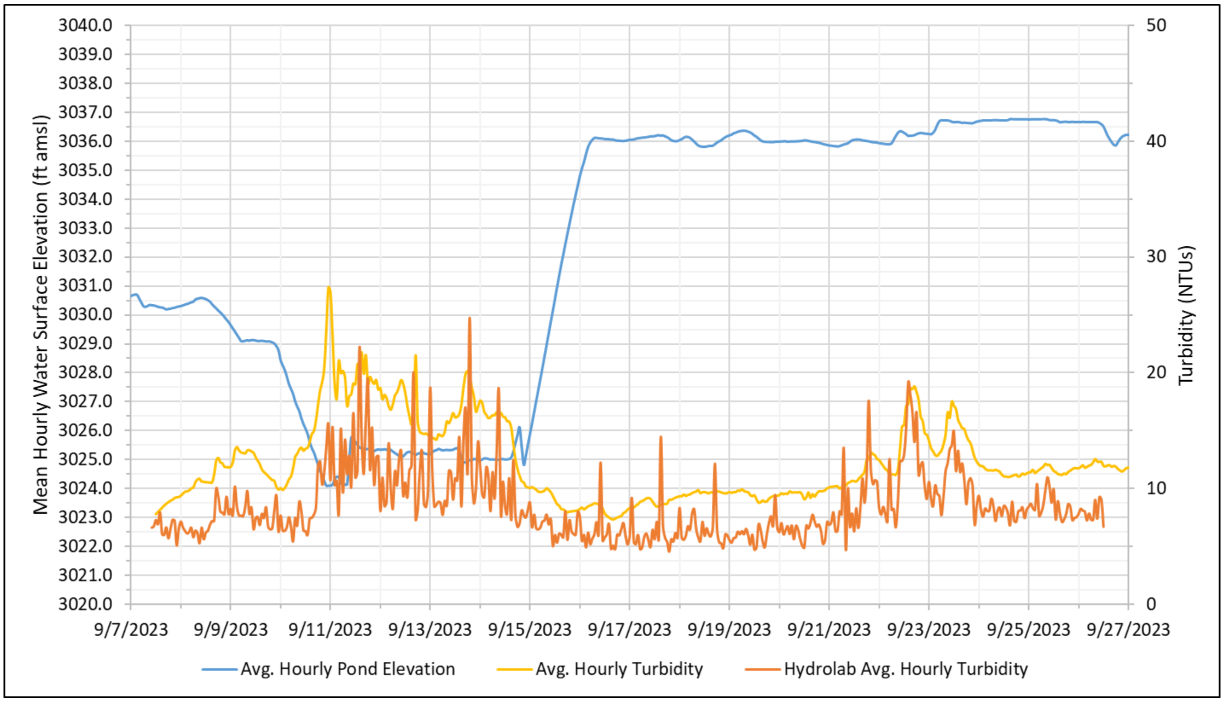


Figure 7-4. Ryan Reservoir – Mean Daily and Hourly Rate of Change in Reservoir Elevation and Mean Hourly Turbidity: September 7-27, 2023

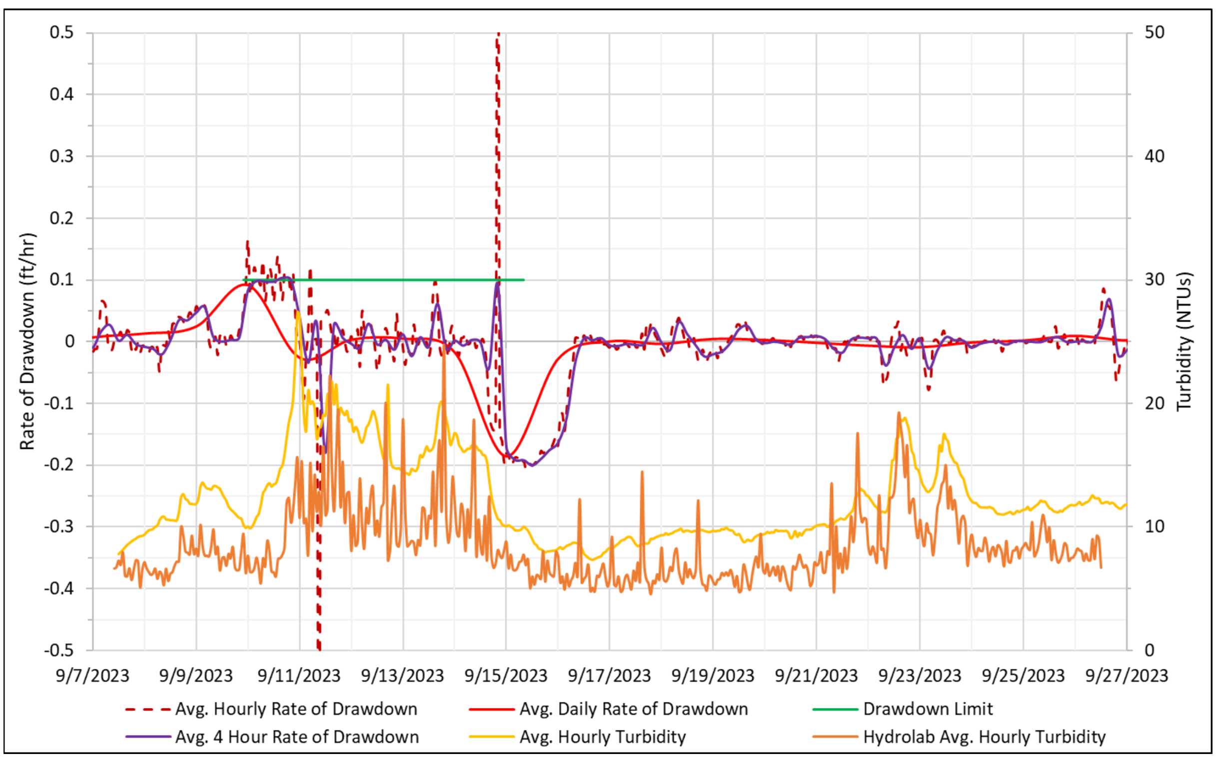
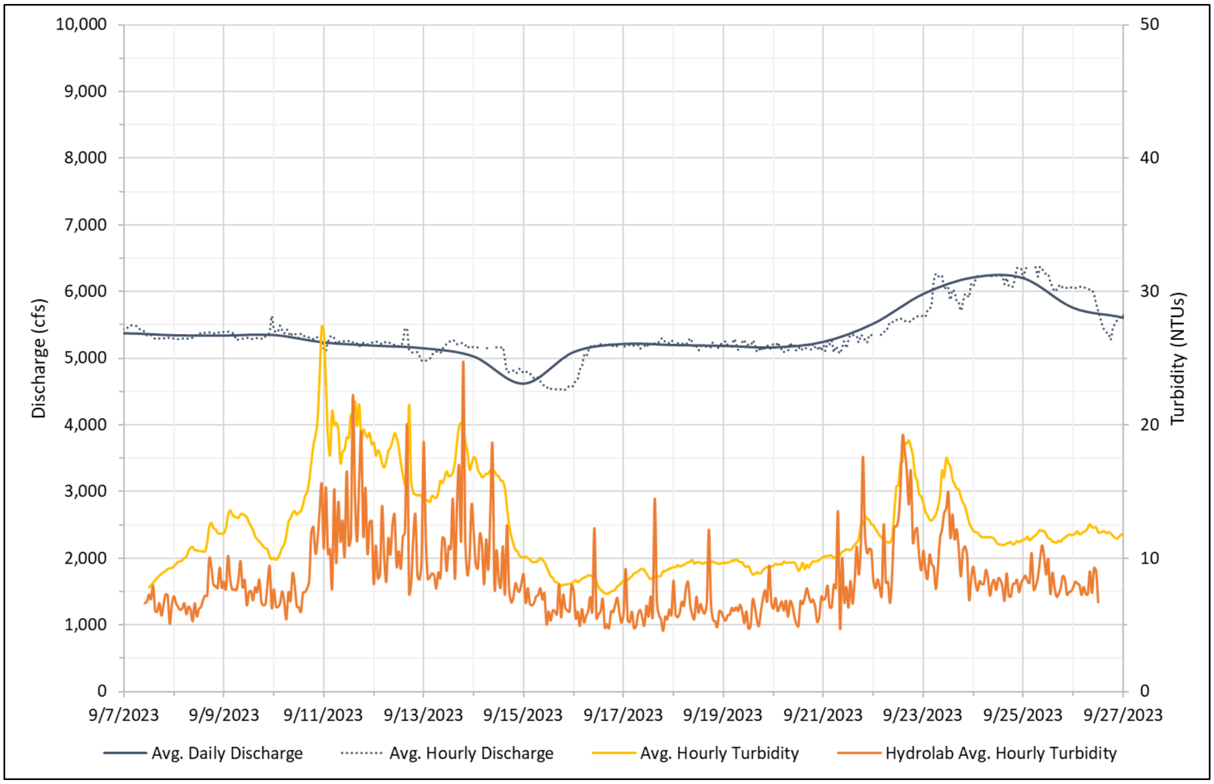


Figure 7-5. Ryan Reservoir – Mean Daily and Hourly Discharge Rate and Mean Hourly Turbidity: September 7-27, 2023



7.3. Ryan Turbidity

Turbidity in the Missouri River varies seasonally. Figure 7-6 shows turbidity and WSEs measured at Ryan Reservoir since January 2019. These data indicate that turbidity was lowest in winter (typically at ~10 NTUs) and peaks in the spring during the period of high spring flow. Turbidity levels naturally increase in the spring with spring flows and remain slightly above baseline levels during the summer (~20 NTUs), which is likely a result of irrigation return flows entering the river system. This is indicated in Figure 7-7 which shows the turbidity and discharge of the 5-year period.

At its peak, turbidity in the Missouri River at Ryan Dam reached approximately 100 NTUs during the spring flows. This spike in turbidity was generally unrelated to reservoir operations at Ryan Dam. During the drawdown event there was minimal increase in turbidity during the drawdown activity; and other larger spikes in turbidity have been observed unrelated to reservoir drawdowns (Figure 7-6).

Figure 7-8 shows turbidity in relationship to river discharge. Overall, there is limited correlation between river discharge and turbidity, but turbidity generally increases with discharge rates.

Figure 7-6. Ryan Reservoir – Mean Daily Turbidity and Water Surface Elevation: January 1, 2019 – December 31, 2023

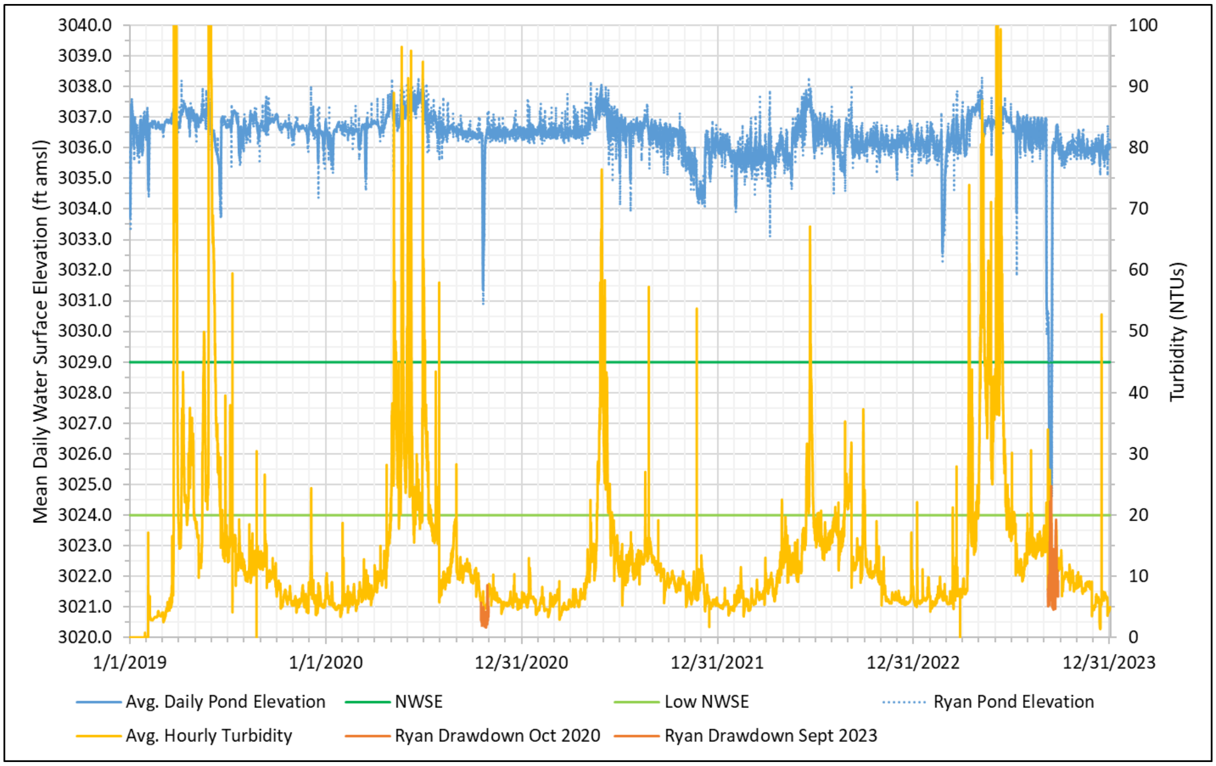


Figure 7-7. Ryan Reservoir – Mean Hourly Turbidity and Mean Hourly and Daily Discharge: January 1, 2019 – December 31, 2023

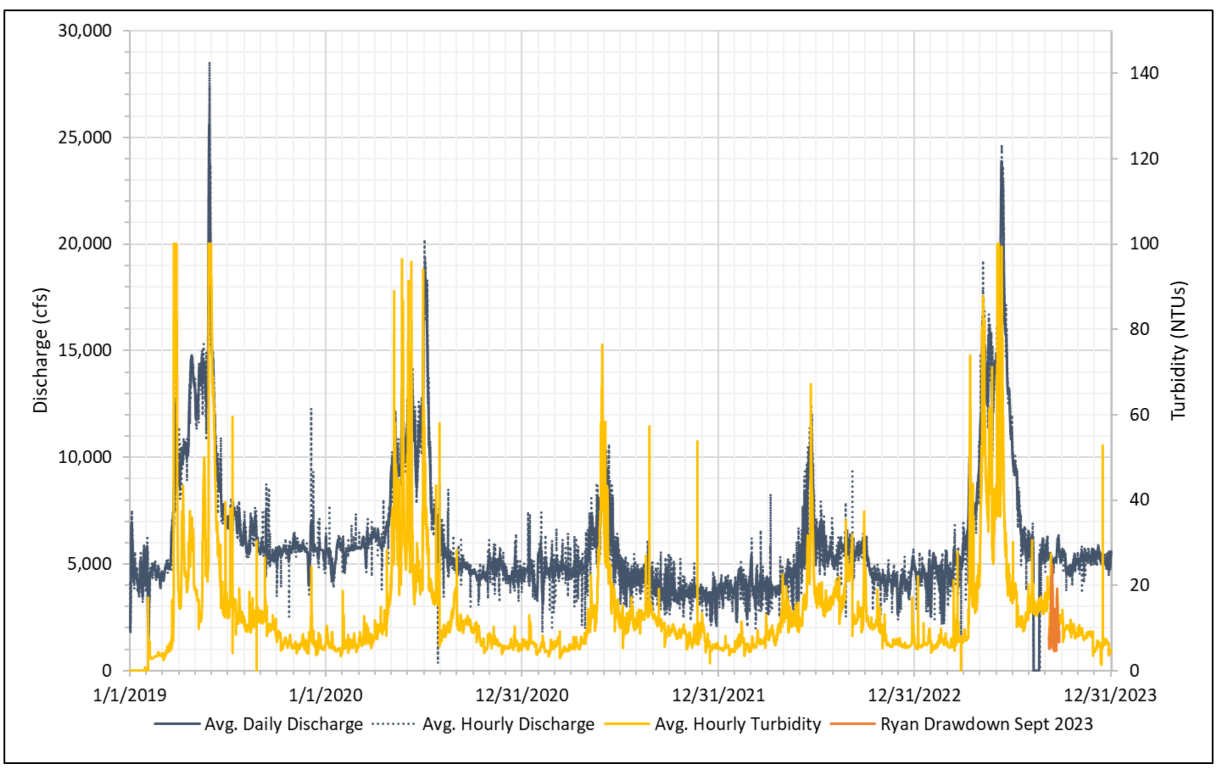
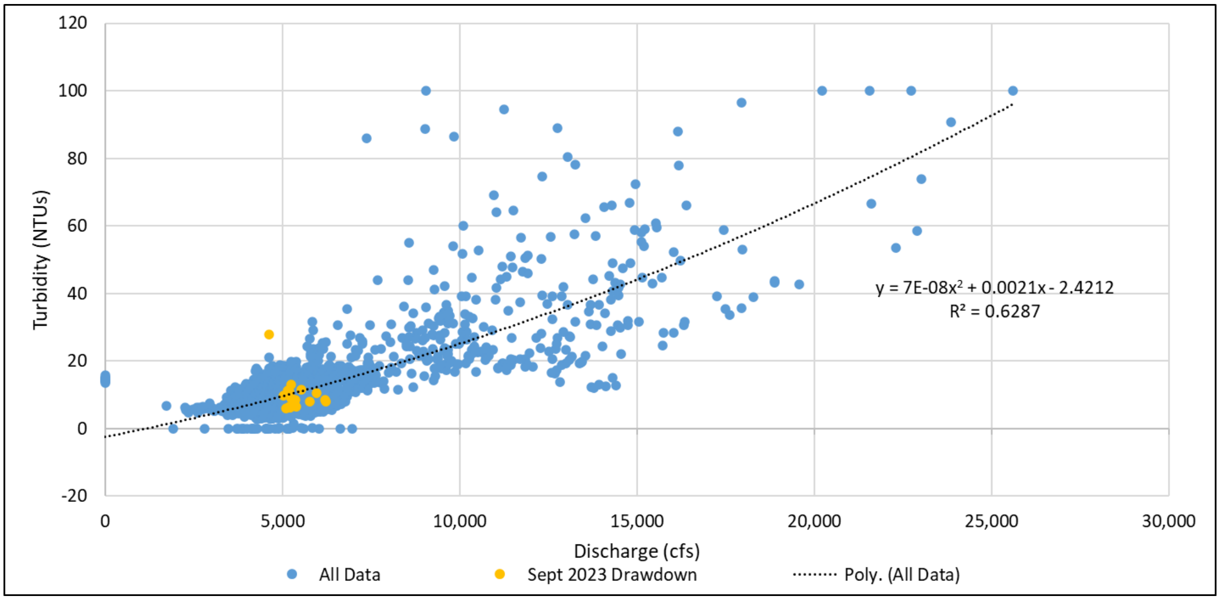


Figure 7-8. Ryan Reservoir – Mean Daily Turbidity vs. Mean Daily Flow (spill and generation): January 1, 2019 – December 31, 2023



7.4. Conclusions

In September 2023, Ryan Reservoir was drawn down approximately 6.3 feet to WSE 3,024.1 feet. The drawdown rates during this event generally stayed at or below the specified rates in the 2019 Drawdown Plan on a daily basis, but one of the 4-hour and several of the hourly drawdown rates exceeded the specified rates. During the September 2023 drawdown, hourly turbidity increased briefly from approximately 10 NTUs to approximately 100 NTUs, then generally returned to the baseline level.

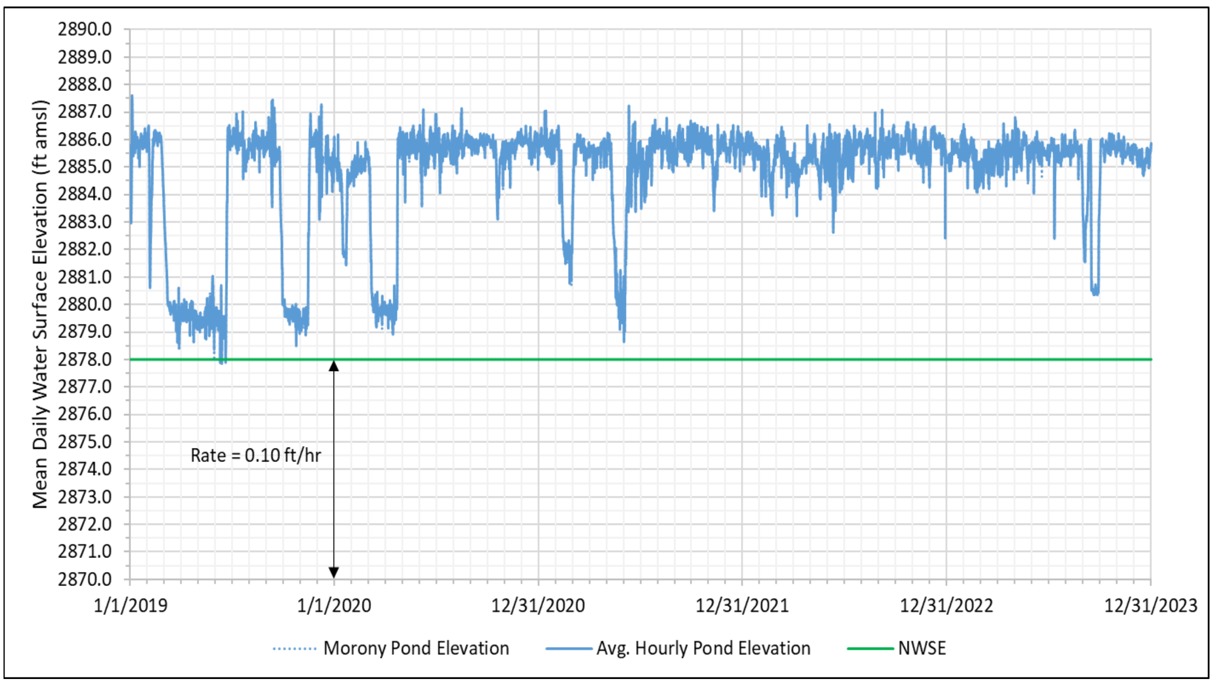
Overall, the turbidity data collected during the 5-year period indicates that turbidity is around 10 NTUs during low-flow periods but increases to about 100 NTUs during spring flows and is around 20 to 30 NTUs during the summer and early fall months. The highest turbidity occurred during June of 2023 and reached a peak of about 100 NTUs. Overall, turbidity appeared to have a minimal response to any of the drawdown events.

8. Results – Morony

8.1. Surface Water Elevation and Turbidity

Morony normal WSEs fluctuates between 2,886 and 2,887 feet. WSE data were collected at 30-minute intervals at Morony Reservoir from January 1, 2019, to December 31, 2023, and converted to an hourly mean as shown in Figure 8-1. A drawdown event is classified as when the WSE is below 2,878 feet as shown by the green lines in Figure 8-1. The plan specifies the drawdown rate limit is 0.10 foot per hour for WSEs below 2,878 feet. WSEs at Morony were never below El. 2,878 feet between 2019 and 2023; therefore, there were no drawdown occurrences in the Morony Reservoir to evaluate. There was a brief period in June 2019 where the reservoir was near El. 2,878.0 feet and varied within a tenth of a foot for a few hours but then returned to normal pool elevations. Turbidity, elevation, and discharge data were generally available for entire 5-year period.

Figure 8-1. Morony Reservoir – Mean Daily Water Surface Elevation (in blue) and Drawdown Threshold (green line): January 1, 2019 – December 31, 2023



As at the other Great Falls reservoirs, turbidity generally increases with discharge, especially when stream flows are in excess of 7,000 cfs (Figure 8-2). Figure 8-3 shows turbidity in relationship to river discharge.

Figure 8-2. Morony Reservoir – Daily Discharge (generation, restoration gates, and spill gates) and Turbidity: January 1, 2019 – December 31, 2023

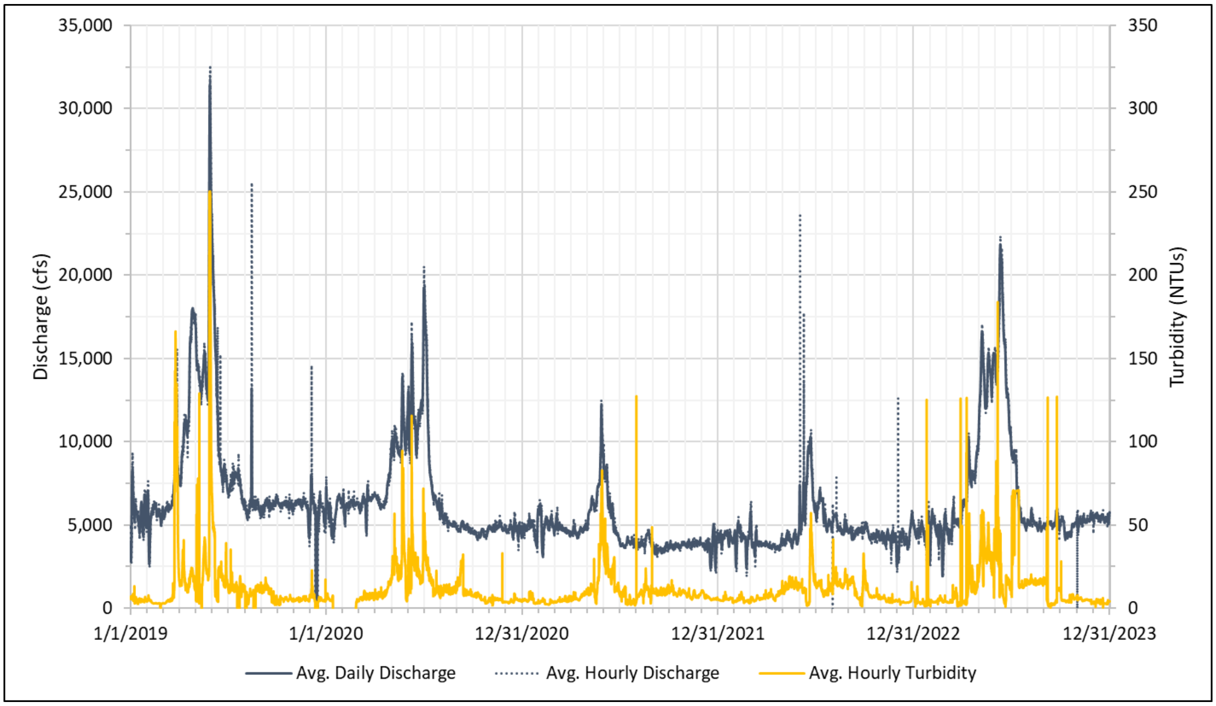
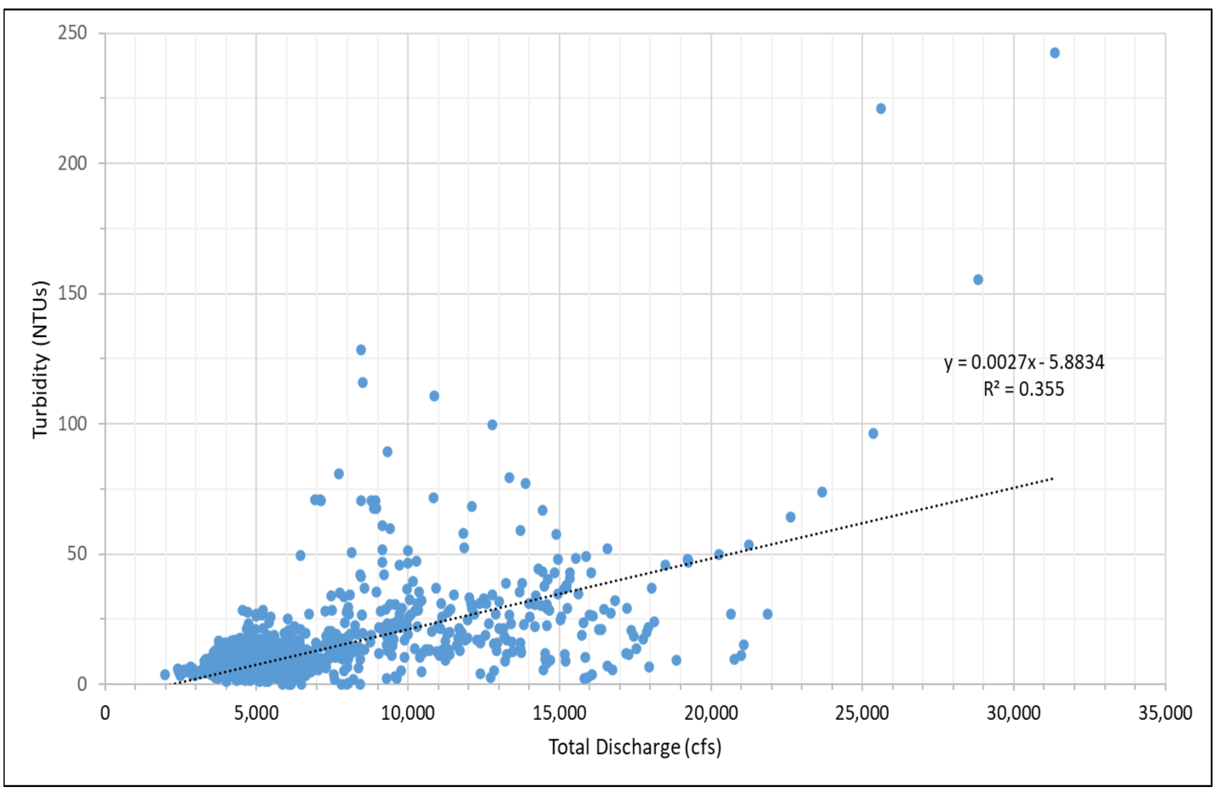


Figure 8-3. Morony Reservoir – Mean Daily Turbidity vs. Mean Daily Flow (generation, restoration gates, and spill gates): January 1, 2019 – December 31, 2023



9. Results – Entire System

9.1. Overall System

Turbidity varies depending on the time of year and from reservoir to reservoir. Figure 9-1 shows the mean daily turbidity for each reservoir for the 5-year period from 2019 to 2023 and the major drawdown events that occurred. Figure 9-1 indicates how the entire reservoir system works together and responds to turbidity changes. In general, turbidity varies seasonally and is typically highest in the months of May and June. As shown in Figure 9-1, Black Eagle Reservoir generally has higher turbidity values through the year relative to the other reservoirs and Morony Reservoir generally has lower turbidity values. However, during the 5-year period, Cochrane, Morony and Rainbow reservoirs had the largest mean daily turbidity spikes of approximately 244, 243 and 142 NTUs, respectively.

Mean daily turbidity values fluctuated the most and had the highest spikes during the years of 2019, 2020 and 2023. Figures 9-2 through 9-6 provide a closer evaluation of the 5 years of turbidity data. These figures demonstrate that the turbidity values in the system are generally attenuated as flow progresses downstream through the lower reservoirs. The data also show that releases from Morony Reservoir are not significantly influenced by upstream reservoir turbidity spikes.

Figure 9-1. Mean Daily Turbidity Black Eagle, Rainbow, Cochrane, Ryan, and Morony Reservoirs: January 1, 2019 – December 31, 2023

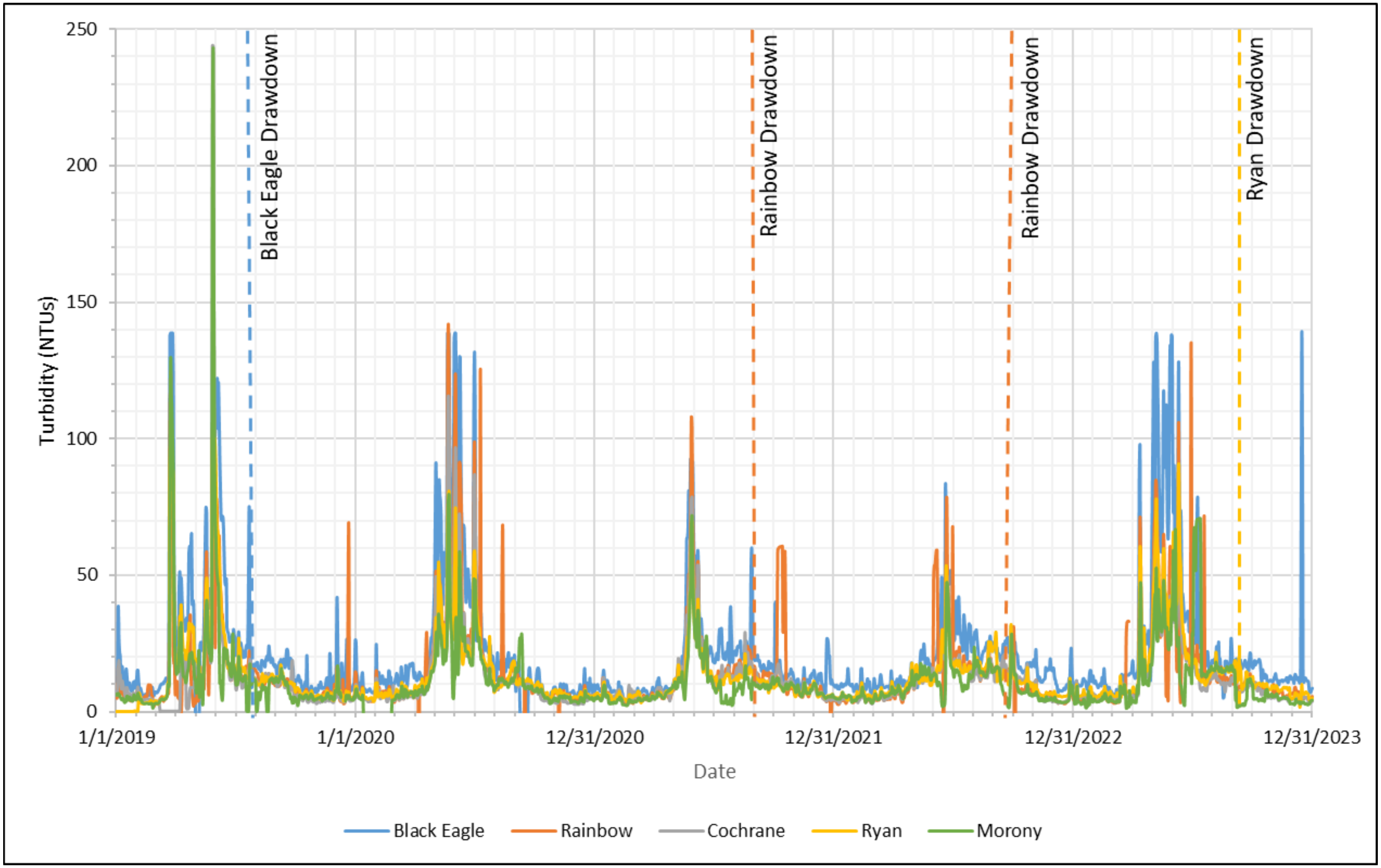


Figure 9-2. Mean Daily Turbidity Black Eagle, Rainbow, Cochrane, Ryan and Morony Reservoirs: January 1, 2019 – January 1, 2020

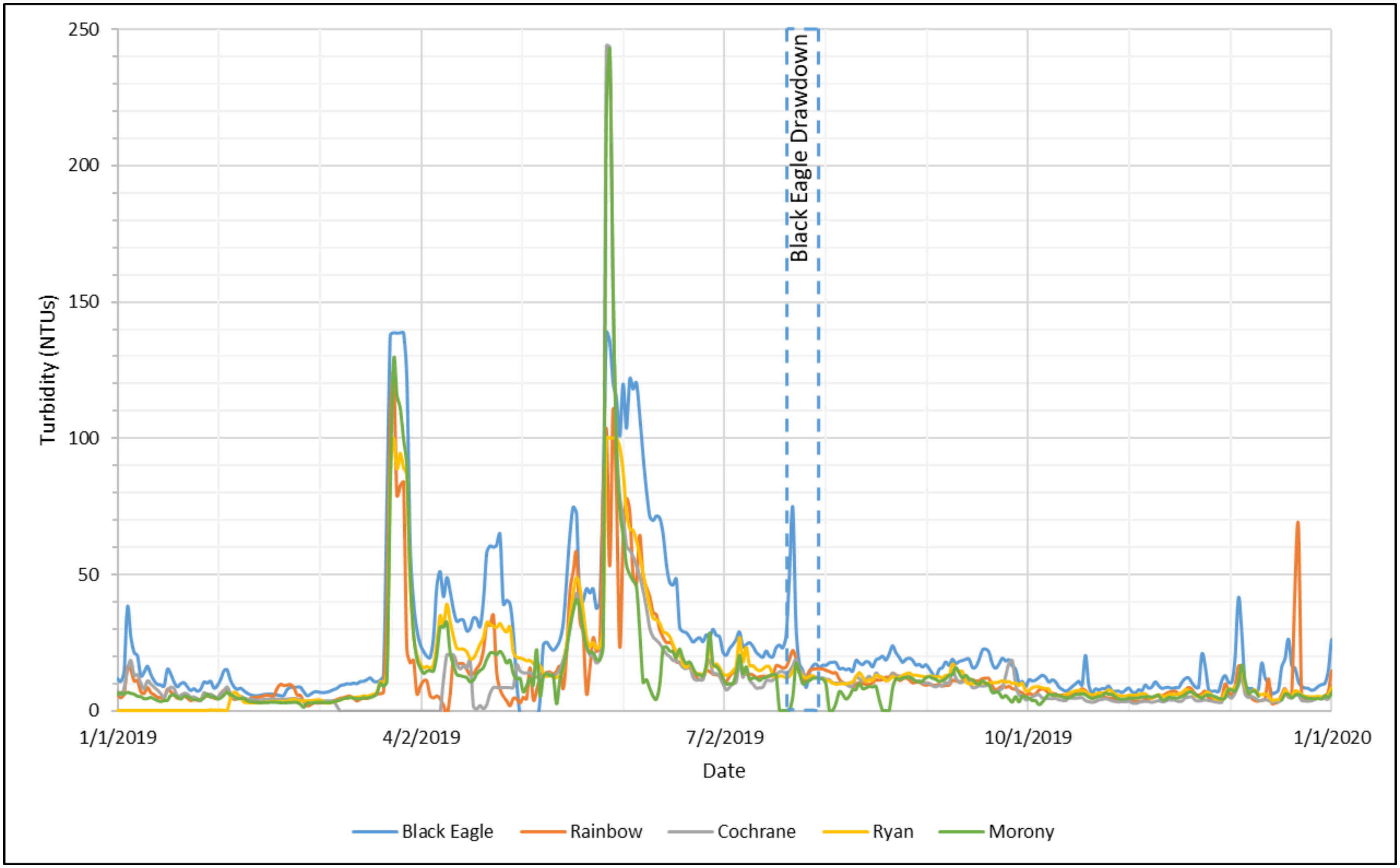


Figure 9-3. Mean Daily Turbidity Black Eagle, Rainbow, Cochrane, Ryan, and Morony Reservoirs: January 1, 2020 – January 1, 2021

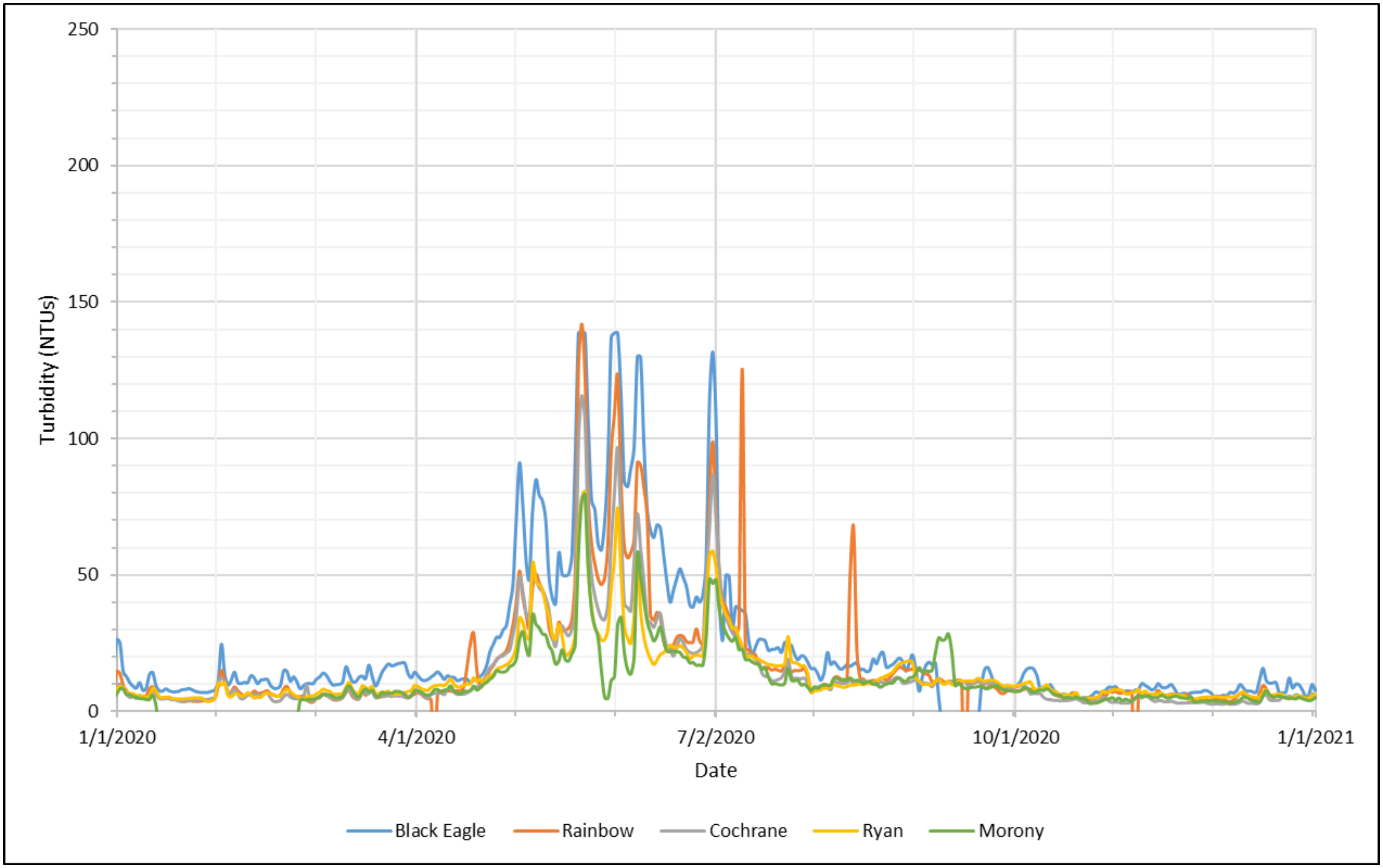


Figure 9-4. Mean Daily Turbidity Black Eagle, Rainbow, Cochrane, Ryan, and Morony Reservoirs: January 1, 2021 – January 1, 2022

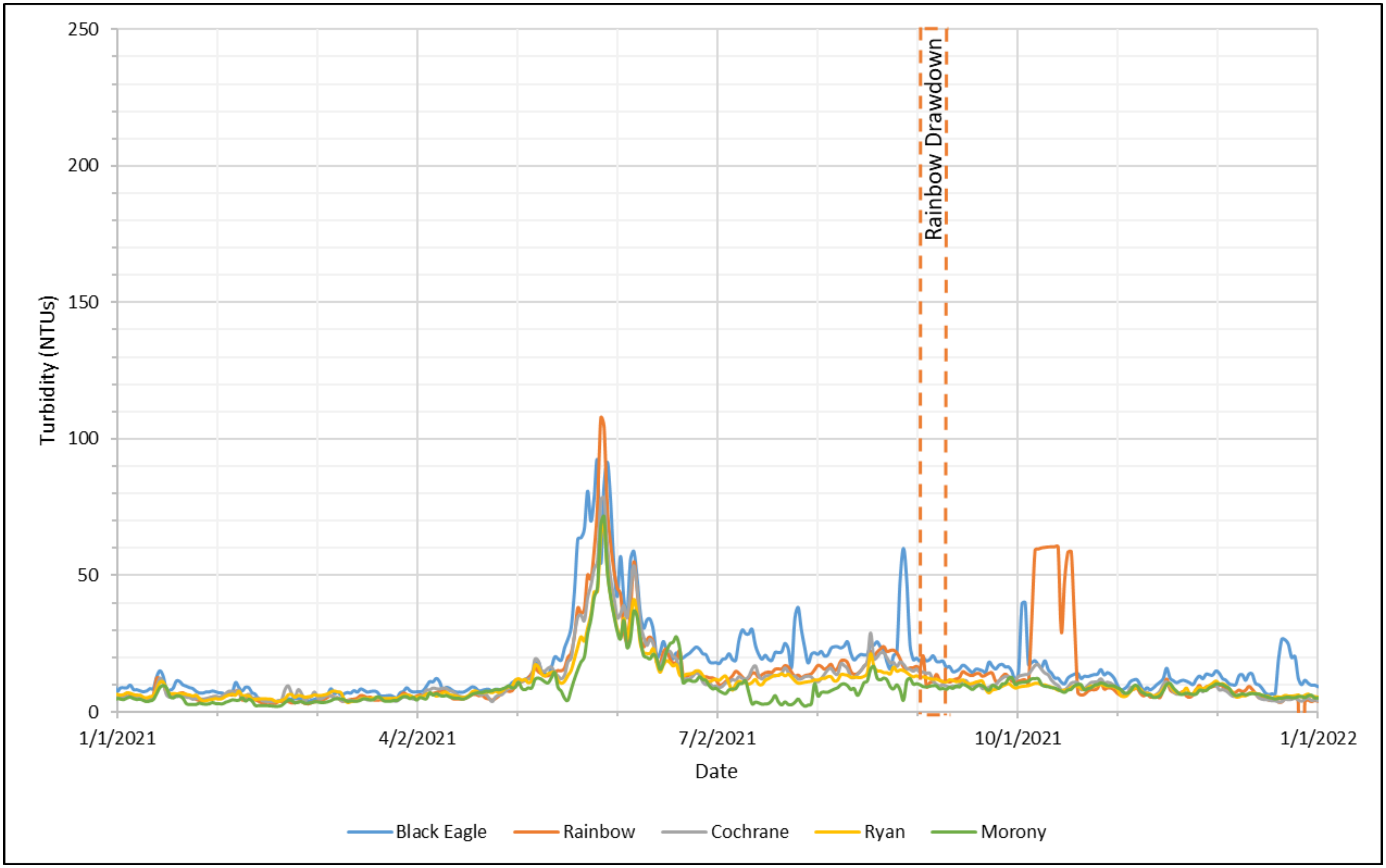


Figure 9-5. Mean Daily Turbidity Black Eagle, Rainbow, Cochrane, Ryan, and Morony Reservoirs: January 1, 2022 – January 1, 2023

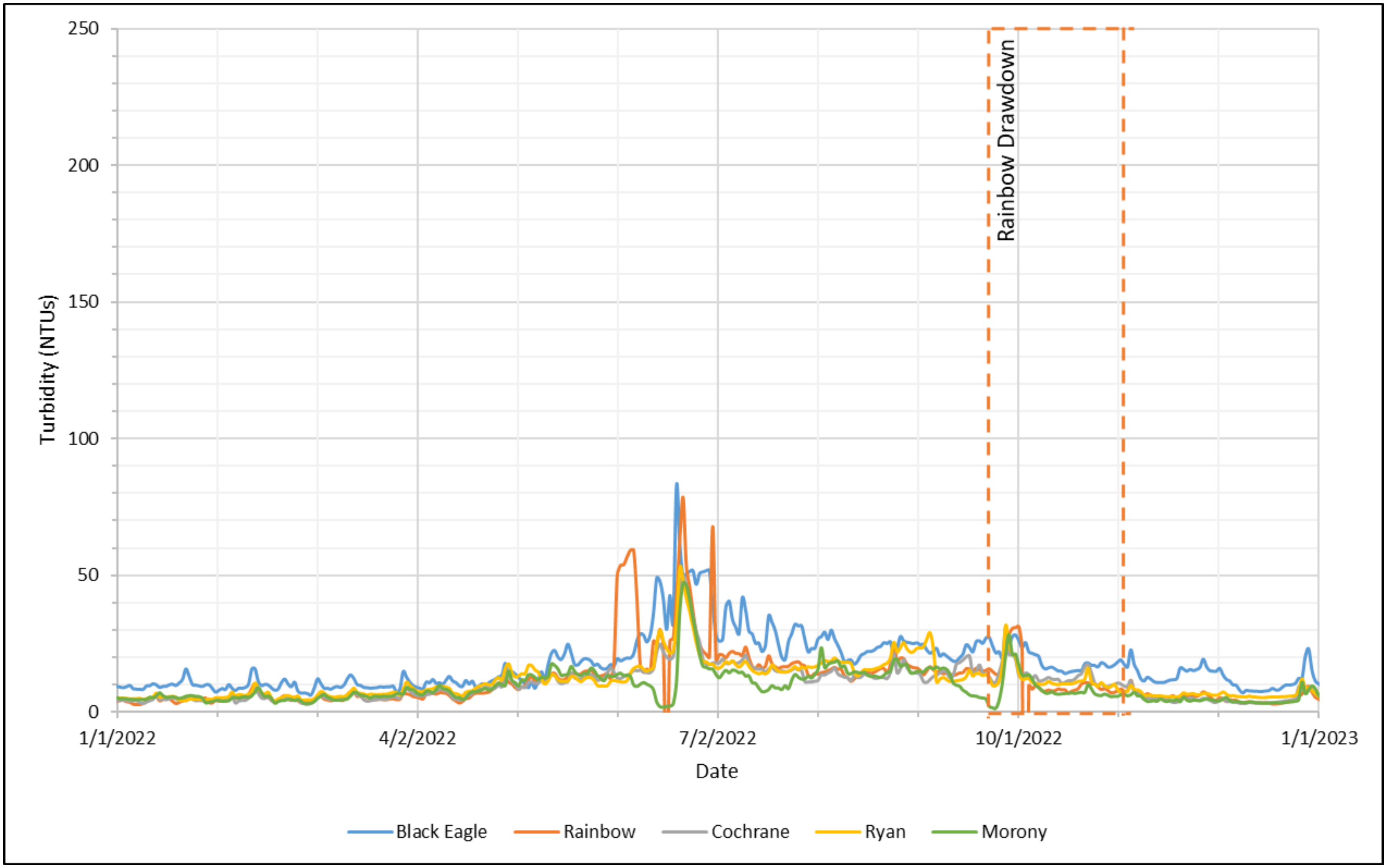


Figure 9-6. Mean Daily Turbidity at Black Eagle, Rainbow, Cochrane, Ryan, and Morony Reservoirs: January 1, 2023 – January 1, 2024

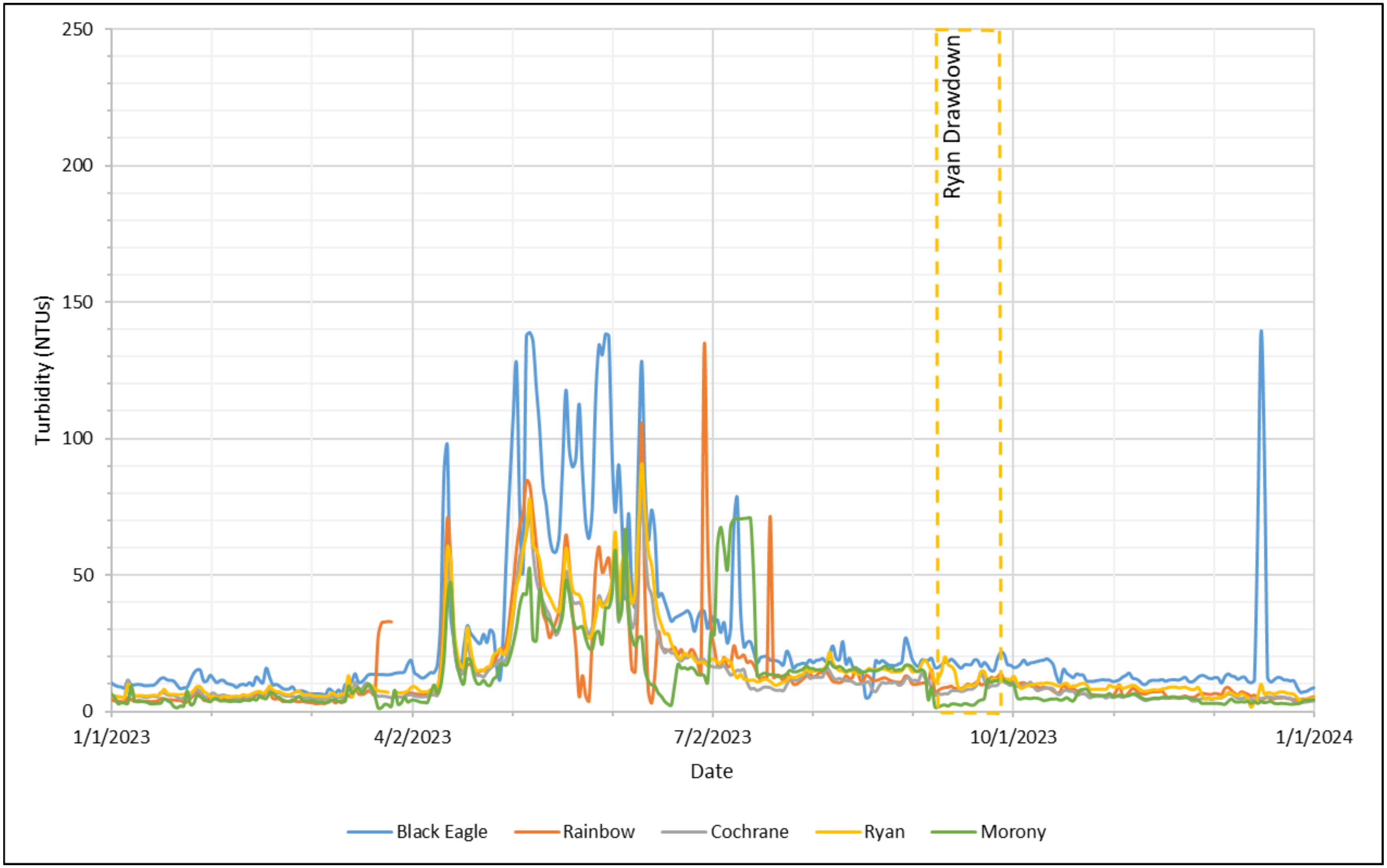
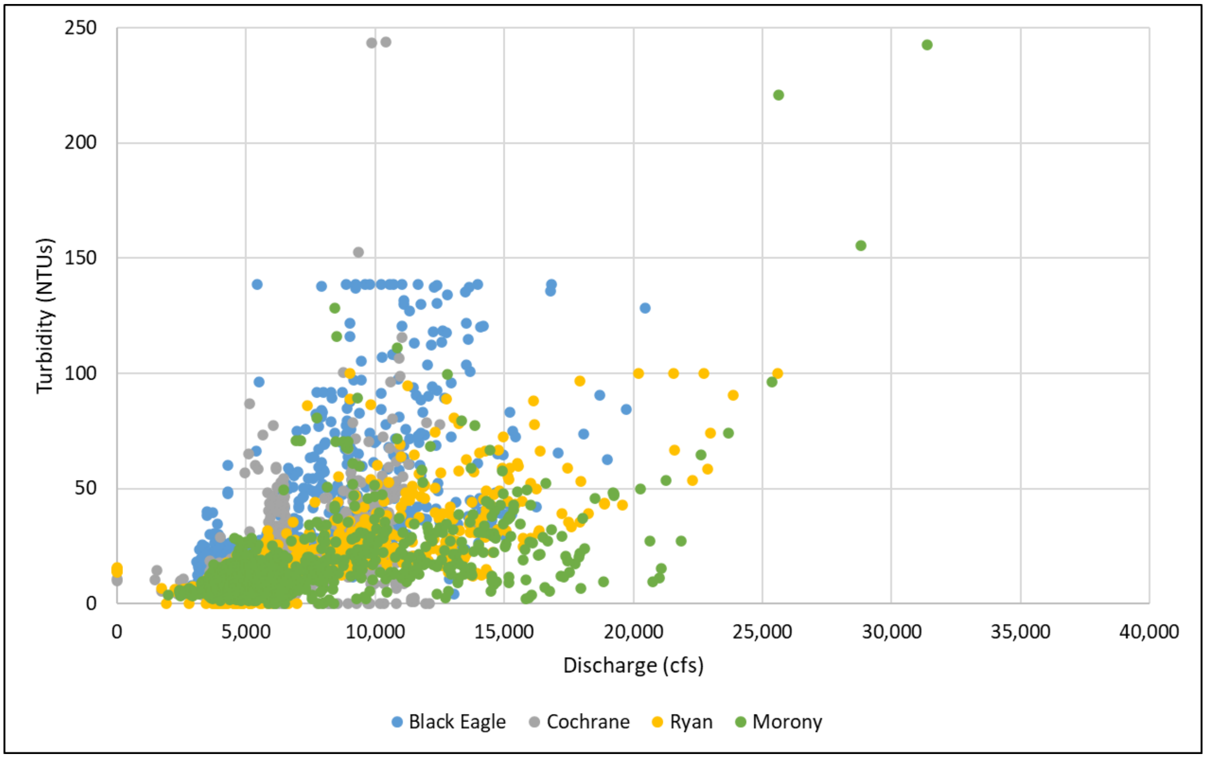


Figure 9-7 presents turbidity versus discharge rate for Black Eagle, Cochrane, Ryan, and Morony reservoirs. Discharge data were not available for Rainbow Reservoir. In general, the turbidity increases with increasing discharge rate. The upstream reservoirs (Black Eagle and Cochrane) generally have higher turbidity values at lower discharge rates. The downstream reservoirs require noticeably higher discharges to substantially increase turbidity values. Additionally, the upstream reservoirs typically have more scatter in the data set and the downstream reservoirs have better correlation with discharge rate.

Figure 9-7. Mean Daily Turbidity vs. Discharge Rate Black Eagle, Cochrane, Ryan, and Morony Reservoirs: January 1, 2019 – December 31, 2023



10. Turbidity Effects

10.1. Turbidity Overview

Generally, there are three primary ways in which sediment in the water column is measured: turbidity, total suspended solids, and water clarity. These three metrics measure different aspects of suspended sediments in the water column. These measures are frequently correlated with one another, but the strength of correlation can vary widely between samples from different sites and watersheds. Factors that can affect the correlation include parent material in a basin, weathering rate, texture of sediment and soils produced through weathering and erodibility all have a great influence on the amount, texture, and behavior of fine sediments in streams (Everest et al. 1987).

Turbidity is an optical property of water where suspended and dissolved materials such as silt, clay, finely divided organic and inorganic matter, chemicals, plankton, and other microscopic organisms cause light to be scattered. Measurements of turbidity have been developed to quickly estimate the amount of sediment within a sample of water and to describe the effect of suspended solids blocking the transmission of light through a body of water (Lloyd, 1987). Turbidity is usually measured by nephelometers that detect light scattered by a water sample. NTUs are used as a rough index of the fine suspended sediment content of the water (Davies-Colley and Smith 2007).

The widespread use of turbidity as a water quality standard and indicator of suspended solid concentration is likely attributed to the ease and cost of using a nephelometric turbidity meter in the field (Davies-Colley and Smith 2007) in comparison to the direct measurement of suspended solids. Direct measurement of settleable solids is generally more difficult and time consuming. Turbidity cannot always be correlated with suspended solid concentrations due to the effects of size, shape, and refractive index of particles (Sorenson et al. 1977). The disadvantage of turbidity is that it is only an indicator of suspended sediment effects, rather than a direct measure, and may not accurately reflect the effects suspended sediment have on fish.

10.2. Turbidity Impacts to Fish Health

Suspended sediment has been associated with negative effects on the spawning, growth, and reproduction of fish. Effects on fish vary from site to site, by species, and the developmental stage of the fish. Suspended sediments can affect fish by altering their physiology, behavior, and habitat, all of which can lead to physiological stress and reduced overall survival rates. Several studies have been performed using both laboratory and field-based relationships between turbidity, total suspended sediments, and fish health. The relationship between turbidity measurements, suspended sediments, and their effects on fish at various life stages provide an understanding of the potential impacts of activities that increase sedimentation.

As indicated above, turbidity measurements are typically used to evaluate suspended sediments, but turbidity is only an indicator of suspended sediment effects, rather than a direct measure, and may not accurately reflect the effect on fish. The inconsistent correlation between turbidity measurements and mass of suspended solids indicates turbidity may not be a consistent and reliable tool for determining the effects of suspended solids on fish. Other factors, such as life stage, time of year, size and angularity of sediment, availability of off-channel and tributary habitat, and composition of sediment may be more telling in determining the effect of sediment on fish. Additionally, short-term pulses of suspended solids likely have different effects on fish, rather than long-term chronic exposure to high levels.

A summary of the physiological, behavioral, and habitat effects and environmental factors that affect fish is provided in Table 10-1.

Table 10-1. Summary of Effects on Fish from Total Suspended Solids and Turbidity

Physiological	Behavioral	Habitat	Environmental Factors Affecting the Effect of Sediment
• Gill trauma • Osmoregulation • Blood chemistry • Reproduction and Growth	• Avoidance • Territoriality • Foraging and predation • Homing and migration	• Reduction in spawning habitat • Effect of hyporheic upwelling • Reduction in benthic invertebrate habitat • Damage to redds	• Duration of exposure • Frequency of exposure • Toxicity • Temperature • Life stage of fish • Angularity of particle • Size of particle • Type of particle • Severity/magnitude of pulse • Natural background turbidity of area (e.g., watershed position, legacy) • Time of occurrence • Other stressors and general condition of biota • Availability of and access to refugia

Studies have suggested that high levels of suspended solids may be fatal to fish, while lower levels of suspended solids and turbidity may cause chronic sublethal effects such as loss or reduction of foraging capability, reduced growth, resistance to disease, increased stress, and interference with orientation in homing and migration. Additionally, fish gills are delicate and easily damaged by abrasive silt particles. As sediment begins to accumulate in the filaments, fish excessively open and close their gills to expunge the silt. If irritation continues, mucus is produced to protect the gill surface, which may impede the circulation of water over gills and interfere with fish respiration (Berg 1982).

The effects of suspended sediment on swimming ability on juvenile Brown Trout (*Salmo trutta*) and Rainbow Trout (*Oncorhynchus mykiss*) were explored by Berli et al. (2014). Both species experienced a decrease in swimming performance as turbidity increased, but Rainbow Trout were impaired to a greater extent. In laboratory experiments, it has been shown that fish will move to less turbid waters, if available, after a short-term pulse (Berg and Northcote 1985). Bisson and Bilby (1982) illustrated the displacement of fish in water with turbidities greater than 70 NTU. These results suggest that fish in a river system might seek out turbidity refugia when subjected to short-term pulses of sediment. Alabaster and Lloyd (1980) cited several studies that reported the loss of fish communities in rivers downstream from the discharge of large quantities of suspended solids. However, the affected fish reappeared downstream of where suspended solids levels were reduced to 100 to 200 milligrams per liter (mg/l).

At moderate levels of turbidity, Cutthroat Trout (*Oncorhynchus clarki*) feeding on live oligochaetes in a laboratory stream consumed virtually all available prey in clear water, but as turbidity increased consumption decreased: minimal feeding was observed at 200 NTUs and no feeding was observed at 400 NTUs (Harvey and White 2008). In the second experiment, benthic feeding success of Cutthroat Trout at 150 NTU was about 35 percent of their performance in clear water but dropped to near 0 percent at 200 NTU; and again, no feeding was observed at 400 NTU.

Overall, there are many environmental factors and influences that affect fish physiology, behavior, and habitat, and turbidity is one that has been used historically to correlate the effects on fish, but to provide a comprehensive understanding other factors must also be considered.

10.3. Stress Index

Turbidity and suspended solids measurement values provide one aspect of the environmental factors that potentially impact fish, but the other aspect that must be considered is the duration of exposure to increased suspended solids. Aquatic biota respond to both the concentration of suspended sediments and duration of exposure, much as they do for other environmental contaminants. The Stress Index provides a convenient method for assessing the potential effects of a pollution episode of know intensity. The Stress Index is based on the natural logarithm of the product of suspended solid concentration (milligram per liter (mg/l)) and duration of exposure (hours). It is important to realize that average severity of effects differ among fish species as well as life history stage.

Turbidity measurements are provided in NTUs. Conversion of NTUs to mg/l is required since NTU is used as a surrogate for total suspended solids. Once a relationship is established between NTUs and mg/l, the Stress Index can be computed for the Great Falls Development reservoirs. The conversion factors can vary considerably depending on various site conditions, soil particle size, measurement device and flow characteristics. In general, the conversion factor can range from about 0.68 mg/l per NTU up to 2.36 mg/l per NTU, although higher values have been observed. Using this range of conversions factor, the Stress Index were computed on a daily basis (24-hour exposure duration) for the three reservoirs (Rainbow, Cochrane, and Morony) that had the highest turbidity spikes during the 5-year cycle.

The Stress Index values can be used to assess the impacts to the fish in the Missouri River system. Research data (Bash et al., 2001) indicate that impacts to fish are generally minimal at a Stress Index of 6.8 or lower, behavioral impacts occur between Stress Indices of 6.8 and about 8.0, and mortality rates begin to increase above a Stress Index of about 8.0. However, these values can vary depending on fish species and life cycle stage.

The calculated range of daily Stress Index during the 5-year cycle for Black Eagle, Rainbow, Cochrane, Ryan and Morony reservoirs are shown in Figures 10-1, through 10-5, respectively. As shown in these figures, the average Stress Index generally ranges from about 5.0 to 6.0 throughout the years, with spikes that occasionally exceed 8.0, although the duration of these turbidity spikes is relatively short.

Figure 10-1. Black Eagle Reservoir – Mean Daily Stress Index and Turbidity: January 1, 2019 – December 31, 2023

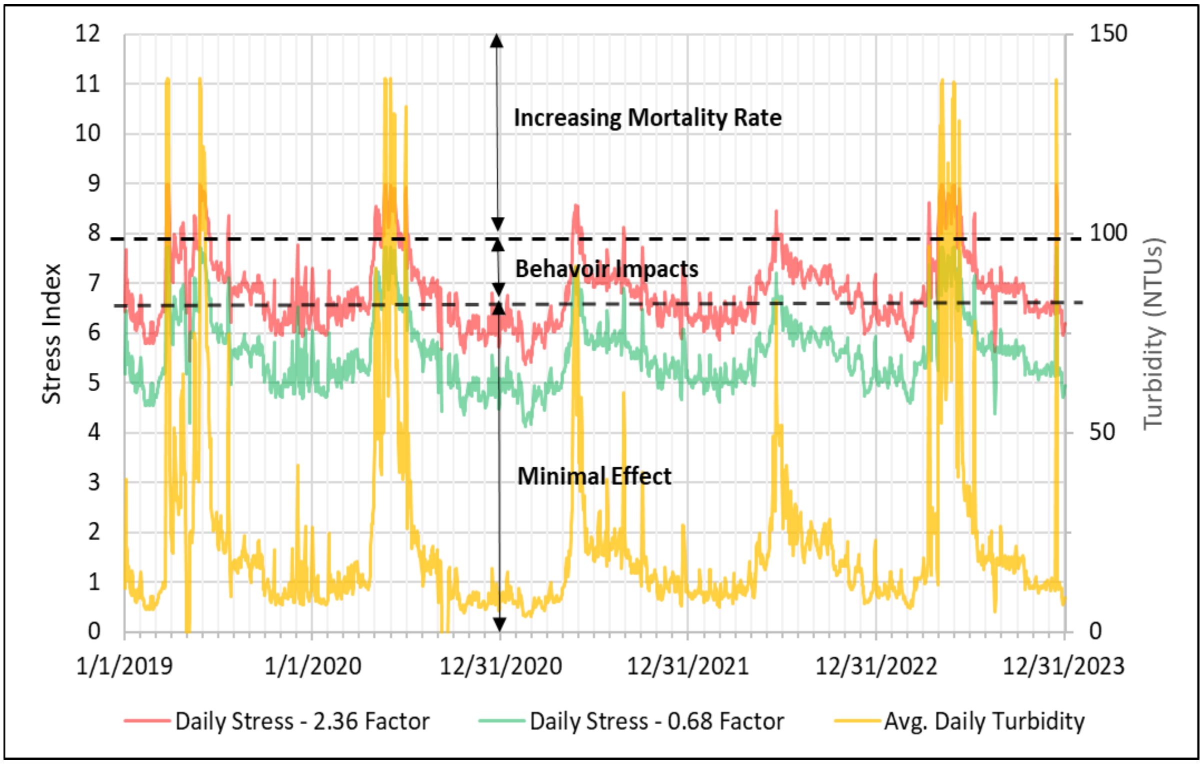


Figure 10-2. Rainbow Reservoir – Mean Daily Stress Index and Turbidity: January 1, 2019 – December 31, 2023

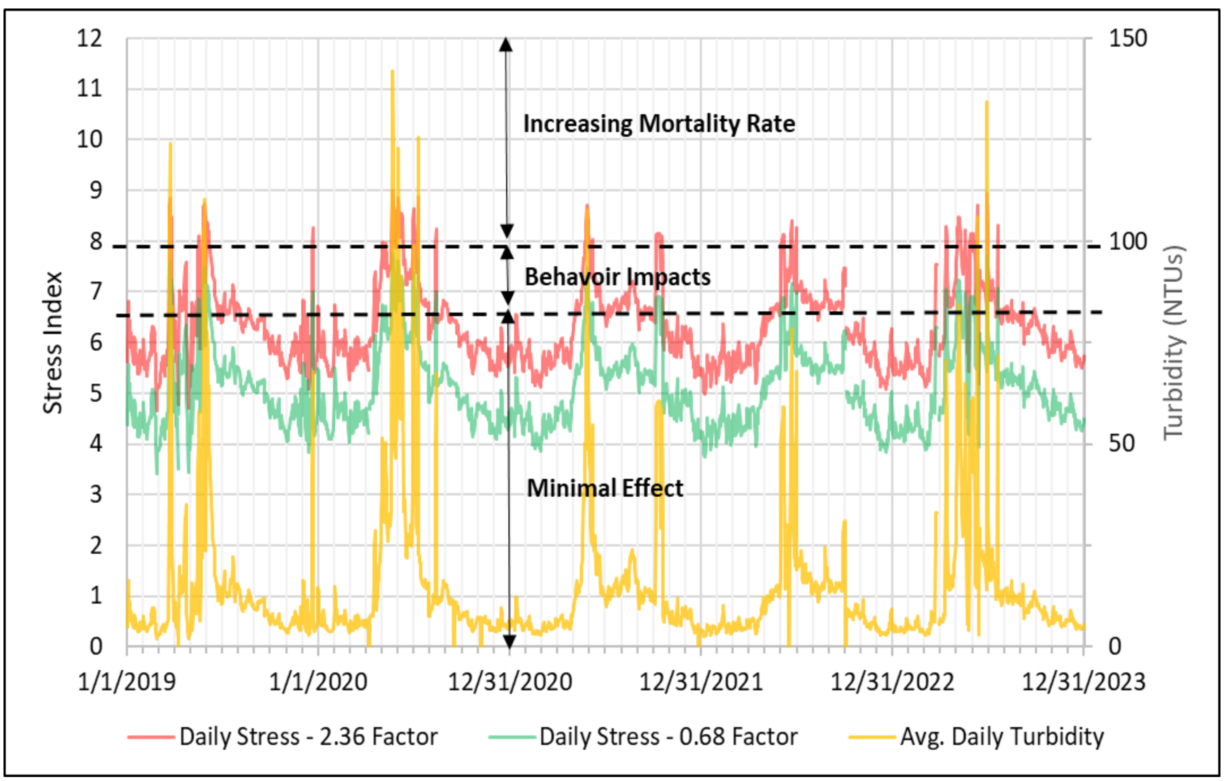


Figure 10-3. Cochrane Reservoir – Mean Daily Stress Index and Turbidity: January 1, 2019 – December 31, 2023

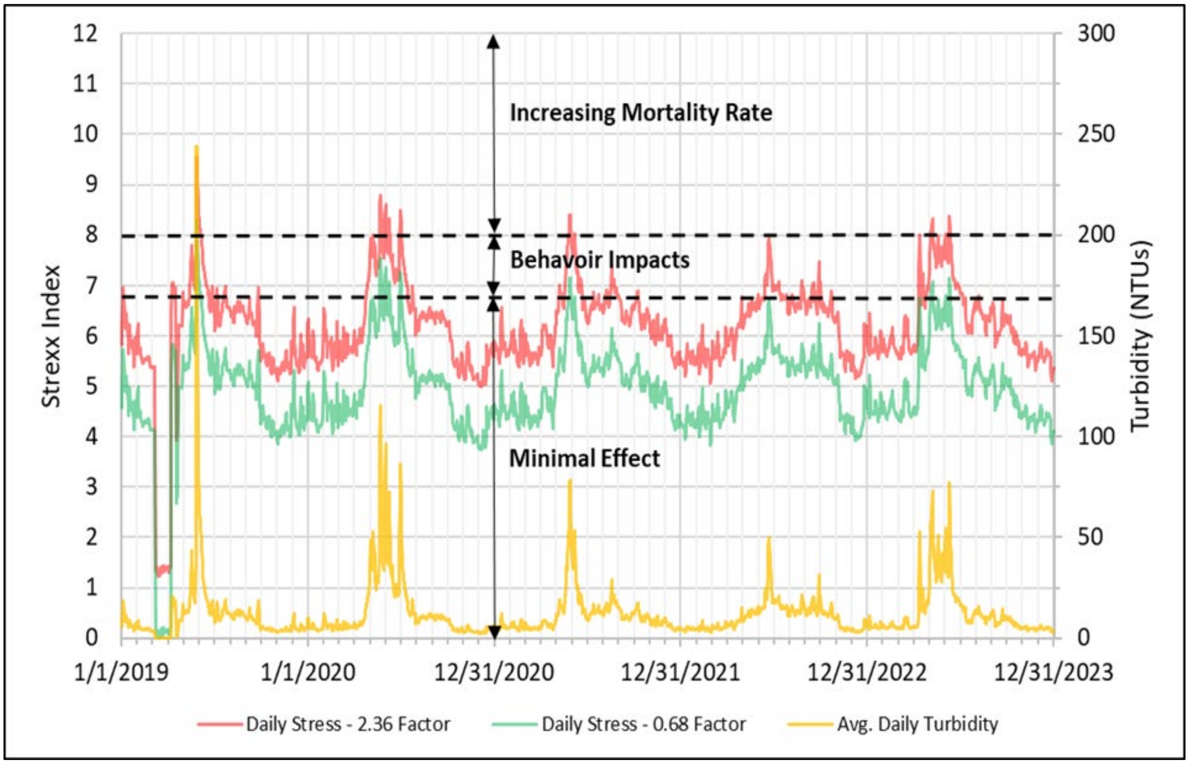


Figure 10-4. Ryan Reservoir – Mean Daily Stress Index and Turbidity: January 1, 2019 – December 31, 2023

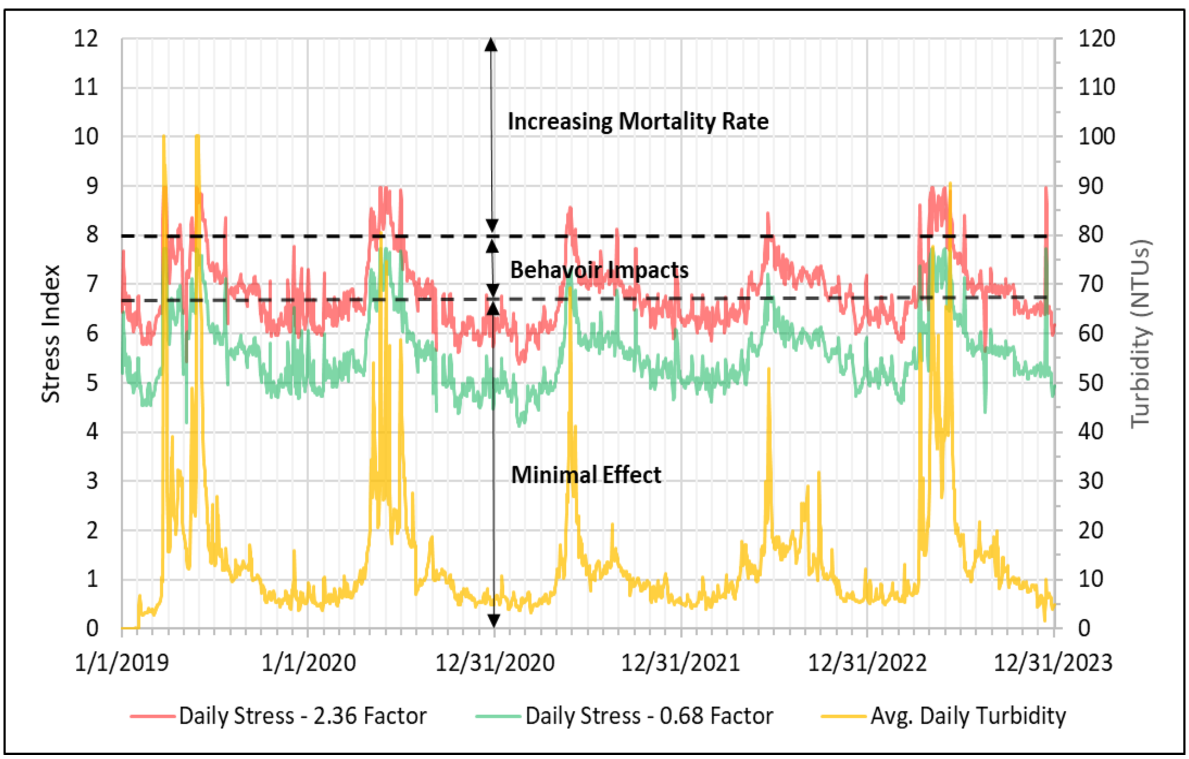
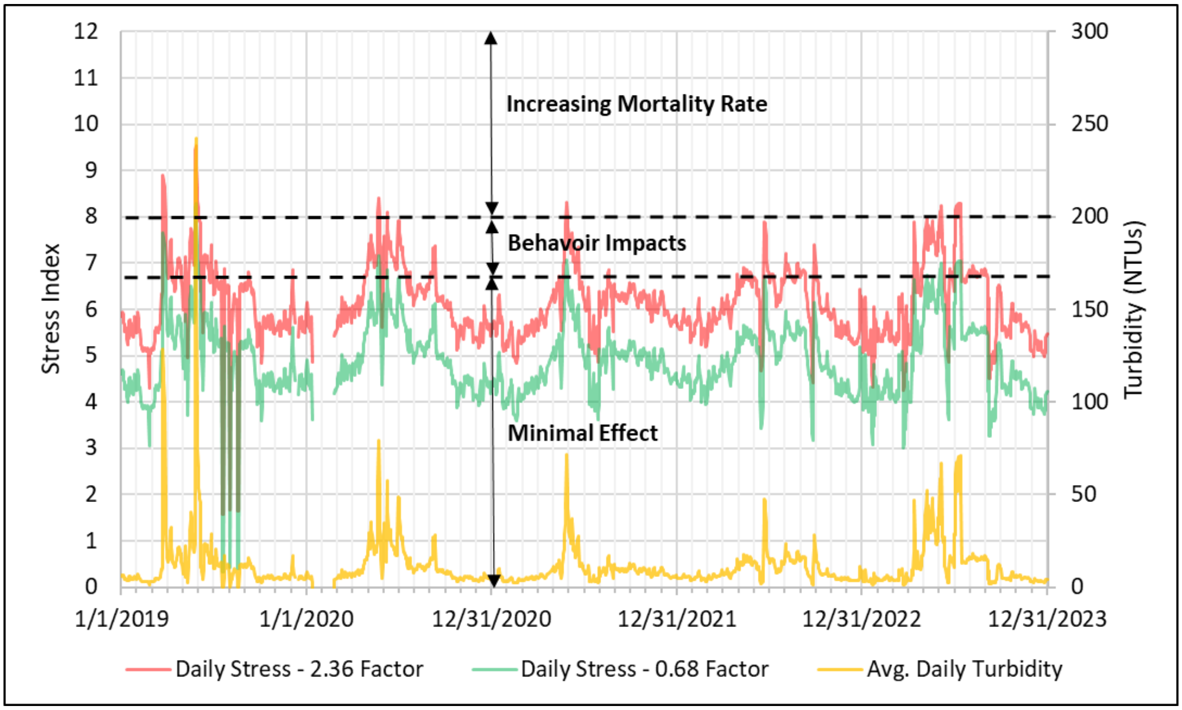


Figure 10-5. Morony Reservoir – Mean Daily Stress Index and Turbidity: January 1, 2019 – December 31, 2023



10.4. Drawdown Effects on Freshwater Mussels

Two species of freshwater mussel known to occur in the project area: Grooved Fingernail clam (*Sphaerium simile*) and the Fatmucket (*Lampsilis siliquoidea*). General information provided by the Montana Natural Heritage Program states Fingernail clams are a small bottom-dwelling, filter-feeding native mussel found throughout Montana and can be quite abundant (Stagliano, n.d.). They provide food for a variety of animals and produce large accumulations of empty shells. The Fatmucket is Montana's most widespread and abundant mussel and is believed to be the most widely distributed mussel in North America (Stagliano, n.d.).

Surveys in the Great Falls area between 2015 and 2016 showed large numbers of both species (G. Grisak, NorthWestern, pers. comm. 2019). During the Black Eagle Reservoir drawdown in 2016 both species were observed in the upper most portion of the drawdown zone. The dewatered portion of the reservoir, which was occupied by mussels, generally consisted of an approximately 16-acre area on the river right bank from the Burlington Northern Santa Fe rail bridge downstream to the upper portion of Elks Riverside Park.

Galbraith et al. (2015) studied the response of six mussel species at three drawdown rates (slow, moderate, fast) under laboratory conditions and applied mussel movement results to drawdown rates of 21 eastern United States rivers to determine likely stranding rates. Although the vast majority of six freshwater mussel species appeared to move short distances horizontally in response to receding water levels, that study concluded most mussels would likely be stranded at a slow (4 centimeter/day (cm/d)) and moderate (8 cm/d) drawdown rates and all individuals would be stranded at a fast (120 cm/d) drawdown rate. The 2019 Black Eagle drawdown rate (73 cm/d) corresponded to over half of the

Galbraith et al. (2015) fast rate and about 9 times the moderate drawdown rate. Vertical burrowing is another dewatering stress avoidance mechanism in mussels. Although vertical burrowing is a common behavior during normal conditions, in many species and live stages, burrowing has been observed in mussels as an environmental avoidance mechanism during high stress periods (Archambault et al. 2013, Byrne and McMahon 1994).

The 2019 Black Eagle Reservoir drawdown event was brief, lasting July 21, 2019, to July 30, 2019. The drawdown limit was only in effect July 22, 2019, to July 26, 2019. This was considered to be a relatively quick drawdown period so the mussels experienced limited dewatering, however some mussels may become stranded in the upper Black Eagle Reservoir littoral zones during the drawdown. Given the small size of Fingernail clams, horizontal movement is not likely a suitable avoidance mechanism (G. Grisak, NorthWestern, pers. comm. 2019).

Black Eagle Reservoir drawdowns for dam maintenance purposes is an uncommon practice and has occurred only once during the 5-year period the plan has been in effect.

11. Conclusions and Recommendations

The data collected during the various drawdown events in the Great Falls Developments indicate turbidity levels often respond to some degree to fluctuations and drops in WSEs. Turbidity spikes during drawdowns were noted during some drawdowns in the system. These spikes were of short duration (generally over a time frame of hours).

Turbidity displays a natural fluctuation in the Missouri River that coincides with spring flows, significant rain events, and irrigation season. The turbidity spikes noted during drawdowns were generally lower than the naturally occurring turbidity during high flow periods.

Turbidity response has not always related to occasions when drawdown rates have exceeded the limits outlined in the 2019 Drawdown Plan. Turbidity increased when drawdown rates were less and, in some cases, when drawdown rates exceeded the limits specified in the 2019 Drawdown Plan. The correlation between the drawdown rate and turbidity is not definitive based on the available data.

Table 11 provides a summary of the drawdown events and available data between January 2019 and December 2023 for the five dams that comprise the Great Falls Developments. Table 11-1 also identifies the timing of the drawdown at each dam, the total duration of time (not consecutive) that the drawdown rate limit was exceeded, the average and maximum drawdown rates during exceedance, the WSE that is prone to turbidity spikes, and the maximum turbidity recorded during the drawdown event.

Table 11-1. Great Falls Developments Summary of Drawdown Events: January 2019 – January 2024

Development	Drawdown	Number of 4-Hour Average Drawdown Rates Exceeded	Average and Maximum Drawdown Rate During Exceedance	WSE Prone to Turbidity Spike	Max Turbidity Recorded During Drawdown
Black Eagle	July 2019	0	N/A	3284-3288	83
Rainbow	September 2021	3	0.12 ft/hr; 0.14 ft/hr	NA	20
	September 2022	4	0.11 ft/hr; 0.12 ft/hr	3213	352
Cochrane	October 2022	None	N/A	N/A	N/A
Ryan	September 2023	1	0.103 ft/hr; 0.103 ft/hr	3025	27
Morony	None	None	N/A	N/A	N/A

NorthWestern proposes to continue to manage drawdowns using the rates approved in the 2019 Revised Reservoir Drawdown Plan, approved by FERC in 2020, for the remainder of the current operating license. NorthWestern will provide a summary of turbidity data for Black Eagle, Rainbow, Cochrane, Ryan, and Morony Reservoirs from drawdown events covered under this plan to the DEQ as requested. NorthWestern will also continue to provide advanced notification to MFWP of planned drawdowns, so that MFWP can effectively manage recreation and trout stocking efforts, particularly in the Rainbow Reservoir.

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