170 FERC ¶ 62,081
UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

NorthWestern Energy Project No. 2188-181

ORDER APPROVING REVISED RESERVOIR DRAWDOWN PLAN
PURSUANT TO ARTICLE 403

(Issued February 7, 2020)

1. On August 29, 2019, NorthWestern Energy (licensee), filed a revised Reservoir Drawdown Plan pursuant to Article 403 of the license for Black Eagle, Rainbow, Cochrane, Ryan, and Morony reservoirs at the Missouri-Madison Hydroelectric Project.[1] The project consists of nine hydroelectric developments located on the Madison and Missouri Rivers in Gallatin, Madison, Lewis and Clark, and Cascade counties in southwestern Montana.

Background

2. In part, Article 403 specifies the normal minimum operating elevations for the five Missouri River developments (from upstream to downstream: Black Eagle, Rainbow, Cochrane, Ryan, and Morony). Water surface elevation requirements may be temporarily modified if required by operating emergencies or flow conditions beyond the control of the licensee, approved maintenance activities, or for short periods upon mutual agreement among the licensee and the resource agencies. As routine reservoir drawdowns are necessary for maintenance and inspection, Article 403 requires that prior to any scheduled drawdown, the licensee shall file a drawdown plan for Federal Energy Regulatory Commission (Commission) approval.

3. Historically, the licensee attempted to maintain a constant rate of reservoir water surface elevation decrease with minimal disruption to the bed sediments; however, this method did not minimize turbidity at all water surface elevations during the drawdown. The licensee conducted studies to identify turbidity patterns during reservoir drawdowns, and used the study results to develop drawdown schedules for the five developments. The schedules are intended 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 may compromise water quality.

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

4. In 2009, the licensee proposed a drawdown plan with optimal drawdown schedules which accounted for the specific bathymetry of each reservoir and were designed to minimize sediment mobilization and downstream sediment release during planned drawdowns for project maintenance. Commission staff approved the licensee's 2009 drawdown plan,[2] and further required the licensee to: collect turbidity data in the tailrace of the projects during reservoir drawdowns for a five-year operations period (2009-2014); monitor and verify the effectiveness of the sediment control measures; identify whether a greater than expected sediment re-suspension occurs during a drawdown; and modify, as appropriate, the drawdown schedules for each reservoir.

5. In 2014, the licensee provided its five-year drawdown monitoring report. The licensee's report summarized how it followed the drawdown schedules for each development and provided the tailrace turbidity data collected during drawdown events during the monitoring period. Though turbidity data was not consistently available during each drawdown, the licensee found no definitive correlation between the drawdown rate and turbidity. The licensee proposed to continue monitoring in the reservoirs to determine the relationship between drawdown events and turbidity for another five-year monitoring period, starting July 15, 2014 and ending July 15, 2019. The licensee proposed to continue maintaining the previously approved drawdown limits. In order to provide a more complete dataset to inform future drawdowns, the licensee also proposed to deploy improved instruments to monitor turbidity at the reservoirs and to measure both turbidity and reservoir elevation. On August 4, 2014, Commission staff approved the licensee's 2014-2019 drawdown plan.[3]

Licensee's Results and Revised Drawdown Plan

6. The licensee reports on a total of six drawdowns that occurred in the five-year monitoring period (no drawdowns occurred in the 2019 reporting year). The licensee monitored turbidity and water surface elevations during drawdowns at the Black Eagle, Rainbow, Cochrane, and Ryan dams; no drawdowns occurred at the Morony Dam during the monitoring period. In general and system wide, the licensee reports that turbidity is seasonally variable, but typically highest in May and June. When compared to the other developments, Black Eagle Reservoir generally has higher turbidity levels throughout the year and Morony Reservoir generally has lower turbidity. Based on the available data, and similar to its findings during the 2009-2014 monitoring period, the licensee concluded that there is not a strong correlation between the drawdown rates and turbidity.

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[2] Order Approving Reservoir Drawdown Plans Under Article 403 (128 FERC ¶ 62,099), issued on August 7, 2009.

[3] Order Approving Revised Reservoir Drawdown Plans under Article 403 (148 FERC ¶ 62,108).

The licensee also concluded that turbidity appears to be linked more to the reservoir water surface elevation than the drawdown rate.

7. The licensee provides a summary of how suspended sediments may affect fish health and freshwater mussels, and states that biota respond to both the concentration of suspended sediments and the duration of exposure. The licensee utilizes a Stress Index to assess potential impacts to fish in the Missouri River using the turbidity data collected during the drawdowns in the last five-year monitoring period. The licensee concludes that turbidity spikes related to reservoir operations are short in duration and within the typical seasonal variation and therefore, increases in turbidity are not likely to have a significant effect on fish health. In order to assess potential effects of a drawdown on mussel species, the licensee and Montana FWP obtained general observations of mussels in the drawdown zone of the Black Eagle development in 2016. Two species of mussels known to occur in the project area are the Grooved Fingernail clam and the Fatmucket, which are both abundant in Montana. The licensee reports that both species were observed in the drawdown zone during the drawdown at the Black Eagle development in 2016, and that some stranding occurred. Although mussels may respond to receding water during a drawdown event by moving horizontally or burrowing vertically, motility may be limited, and the licensee acknowledges that the rate and extent of a drawdown may cause mussels to be stranded.

8. The licensee states that the reservoirs are normally maintained at or near (within one foot of) full pool. Based on historical operations, intermediate drawdowns (to an elevation 1-2 feet lower than the concrete crest of the dam/spillway overflow section) are the most frequent, and are necessary to ensure worker safety during repairs. The licensee reports that turbidity values are generally attenuated as flow progresses downstream though the lower reservoirs and that releases from the Morony development are not significantly influenced by upstream development turbidity spikes.

9. Routine reservoir drawdowns are necessary for maintenance and inspection activities at the dams. Due to the operational constraints of managing a drawdown rate of less than 0.10 feet per hour (ft/hr) and based on the monitoring results, the license proposes to follow modified drawdown rates for the next five-year monitoring period. The proposed drawdown rates would provide dam operators some flexibility to maintain the drawdown rates and would simplify dam operations during a planned drawdown to stay in compliance with the drawdown plan while simultaneously remaining conservative enough to protect aquatic resources. Under this proposal, the licensee would enact a drawdown rate based on a four-hour running average. This is specified in the table below, with the water surface elevation (WSE) and drawdown rates from the previous drawdown plans for reference.

Development	**WSE (feet), 2009-2019**	**Optimal drawdown rate (ft/h), 2009-2014**	**Optimal drawdown rate (ft/h), 2014-2019**	**WSE (feet), 2019-2024**	**Average Drawdown Rate (ft/hr), 2019-2024**
Black Eagle	(1) 3,289 to 3,285	(1) 0.10	(1) 0.10	(1) below 3,289	(1) 0.10
	(2) below 3,285	(2) 0.05	(2) 0.05		
Rainbow	(1) 3,223 to 3,216	(1) 0.30	(1) 0.30	(1) 3,223 to 3,214	(1) 0.20
	(2) 3,216 to 3,214	(2) 0.10	(2) 0.10	(2) below 3,214	(2) 0.10
	(3) below 3,214	(3) 0.03	(3) 0.03		
Cochrane	(1) below 3,105	(1) 0.03	(1) 0.03	(1) below 3,110	(1) 0.10
	(2) 3,110 to 3,108.9	(2) 0.10	(2) 0.10		
	(3) below 3,108.9	(3) 0.03	(3) 0.03		
Ryan	(1) 3,036 to 3,027	(1) 0.20	(1) 0.20	(1) 3,036 (3,029)[4] to 3,024	(1) 0.20
	(2) 3,027 to 3,024	(2) 0.10	(2) 0.10	(2) below 3,024	(2) 0.10
	(3) below 3,024	(3) 0.05	(3) 0.05		
Morony	(1) 2,878 to 2,870	(1) 0.10	(1) 0.10	(1) below 2,878	(1) 0.10
	(2) below 2,870	(2) 0.05	(2) 0.05		

[4] On August 29, 2019, the licensee filed an amendment to change the normal operating level at the Ryan development, which is under review in a separate proceeding. If approved, the operator would start the drawdown rates at an elevation of 3,029 feet.

10. The proposed drawdown rates are based on a four-hour running average and are intended to reflect the actual conditions observed by operators while conducting the drawdown resulting from limited precision of operational control of drawdown rates. The running average is intended to be a check to keep drawdown rates within the target ranges since it is a continual average (of the current hour and the past 3 hours). Since the data collected to date has not conclusively correlated drawdown rate and turbidity, the licensee does not anticipate that the proposed four-hour running average would increase turbidity. As with previous drawdown plans, the licensee states it would continue to coordinate with the resource agencies to identify ways to improve or modify the drawdown schedule. The licensee proposes to maintain the proposed drawdown limits for a five-year monitoring period ending January 2024, and would report the monitoring results to the agencies by December 31, 2024. Additionally, the licensee would notify Montana Fish, Wildlife and Parks (Montana FWP) of planned drawdowns so that recreation and trout stocking efforts may be effectively managed.

Agency Consultation

11. The licensee consulted with the Montana FWP, Montana Department of Environmental Quality (Montana DEQ) and U.S. Fish and Wildlife Service (FWS) in preparing the drawdown report and proposal. Montana DEQ and FWS provided approval on July 11 and July 17, 2019, respectively.

12. Montana FWP provided comments on July 2, 2019. Montana FWP expressed concerns that the drawdown rates wouldn't protect against dramatic fluctuations and that the licensee had not sufficiently considered the effects of sediment mobility (as indicated by turbidity measurements) on fish, mussels, and aquatic habitat. Montana FWP disagreed with the licensee's conclusions that turbidity within the normal seasonal fluctuations would have no significant impacts to fish, noting that it could be stressful to aquatic organisms when increased turbidity due to project operations occurs outside of periods of seasonally high turbidity, and that mobilizing sediment during periods of low flow could impact aquatic habitat differently than when it occurs during periods of high flow. Montana FWP also stated that mobilized sediment could contain metal contaminants.

13. In response, the licensee noted that its initial 2009 drawdown plan provided methods consistent with Montana DEQ requirements to ensure that continued reservoir operations be done in the best practicable manner to minimize harmful effects, and that the 2014 and current revisions have allowed for improved turbidity monitoring as well as provided better control of drawdowns. The licensee states that the proposed running average drawdown rate would reflect actual conditions and allow operators to keep the drawdown rates in the target range. In order to address concerns about effects on aquatic species and habitat, the licensee included an assessment of potential effects to mussels which acknowledged the likelihood of stranding and that the drawdowns are scheduled between June and October in order to minimize the potential for impacts to spawning

habitat and redds. The timing of planned drawdowns is selected in order to minimize impacts to aquatic habitat and species to the extent practicable, although it may not be possible to completely eliminate all impacts. If the existing protection measures during drawdown (timing, rate of drawdown) are insufficient, the licensee notes that it can work with the stakeholders to mitigate impacts by enacting protection measures to protect, mitigate, and enhance fish populations and habitat under license Article 417.[5]

14. With regard to contaminants in the mobilized sediment, the licensee states that they have collected water quality samples for sediment metals analysis and has collected water quality samples above and below the Great Falls reservoir complex. Based on the water quality analysis, the licensee states that the sediment does not have a leaching potential to releases metals that may be bound to the sediment and that there is not a significant change in metals concentrations from upstream to downstream developments. Sediment contaminants are not expected to be a significant concern during drawdowns, and the licensee would be able to adequately monitor and protect water quality under Article 404 of the license.[6]

Discussion and Conclusion

15. The licensee's five-year monitoring report summarizes how it followed the drawdown schedule for each development and concludes that there is no definitive correlation between the drawdown rate and turbidity, which is consistent with previous findings. The revised Drawdown Plan should assist the licensee and resource agencies in ensuring improved operational control during drawdowns and minimizing impacts to aquatic habitat and species associated with drawdowns. Further, the revised Drawdown Plan provides a framework for consulting with the resource agencies regarding planned drawdowns during the next five years of monitoring, as well as coordinating with the agencies to identify ways to improve or modify the drawdown schedule at the end of the monitoring period. The licensee developed the revised Drawdown Plan in consultation with the resource agencies. The revised Drawdown Plans is consistent with Montana DEQ requirements to ensure that reservoir operations be performed in the best practicable manner to minimize harmful effects of drawdown events, and should be approved.

[5] Order Modifying and Approving Revised Five-Year Fisheries Protection, Mitigation, And Enhancement Plans Pursuant to Articles 408, 409, 412, 414, 416 and 417 (167 FERC ¶ 62,069), issued April 29, 2019.

[6] Order Approving Revised Ten-Year Water Quality Monitoring Plan Pursuant to License Article 404 (157 FERC ¶ 62,129), issued November 17, 2016.

The Director orders:

(A) NorthWestern Energy's revised Drawdown Plan, filed on August 29, 2019, for Black Eagle, Rainbow, Cochrane, Ryan, and Morony developments of the Missouri-Madison Hydroelectric Project No. 2188, is approved.

(B) This order constitutes final agency action. Any party may file a request for rehearing of this order within 30 days from the date of its issuance, as provided in section 313(a) of the Federal Power Act, 16 U.S.C. § 825*l* (2018), and the Commission's regulations at 18 C.F.R. § 385.713 (2019). The filing of a request for rehearing does not operate as a stay of the effective date of this order, or of any other date specified in this order. The licensee's failure to file a request for rehearing shall constitute acceptance of this order.

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

Document Content(s)

NorthWestern Energy
Delivering a Bright Future

2019-08-29 NWE-2188-3703

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

August 29, 2019

Re: NorthWestern Energy filing Revised Five Year (2019-2024) Drawdown Plan and Report for Black Eagle, Rainbow, Cochrane, Ryan, and Morony Reservoirs per Project 2188 License Article 403

Dear Secretary Bose:

By Order dated August 4, 2014, the Commission approved NorthWestern Energy's revised reservoir drawdown plans for Black Eagle, Rainbow, Cochrane, Ryan, and Morony Reservoirs per Article 403 of the Project 2188 License. This order instructed NorthWestern Energy to collect tailrace turbidity data during reservoir drawdowns and to verify sediment control effectiveness from July 15, 2014 through July 15, 2019.

NorthWestern Energy developed a summary report titled "Missouri-Madison Hydroelectric Project Reservoir Drawdowns 2013-2018 for Black Eagle, Rainbow, Cochrane, Ryan, and Morony Dams" which is included with this letter. Six reservoir drawdowns occurred in this period, the details of which are identified below in Table 1. There were no reservoir drawdowns from January 1, 2019 to July 15, 2019.

Table 1: Summary of the drawdown events at the Missouri River projects between January 2013 and December 2018.

Project	Drawdown	Drawdown Depth (ft.)	Max Turbidity Recorded During Drawdown
Black Eagle	August 2016	4.1	90
	July 2018 (flood)	9.9	140
Rainbow	September 2018	15.5	367[1]
Cochrane	October 2014	11.2	167[1]
Ryan	July 2017	14.9	75
	September 2018	10.9	30
Morony	None	N/A	N/A

[1]Maximum turbidity based on hydrolab sensor data, which is exposed and prone to disturbance and debris during drawdowns.

Based on turbidity data collected, it was determined that there is not a strong correlation between the drawdown rates and turbidity. Turbidity appears to be tied more to reservoir water surface elevation than drawdown rate. Furthermore, due to the operational constraints of managing a drawdown rate of less than 0.10 feet/hour, NorthWestern Energy is proposing an update to the drawdown rates for Black Eagle, Rainbow, Cochrane, Ryan, and Morony Dams (Table 2). These drawdown rates will be based on a four-hour running average. The proposed drawdown rates will simplify dam operations during a planned drawdown to help operators stay in compliance with the Drawdown Plan, while at the same time, protect the aquatic resources.

Table 2: Proposed drawdown rates for the 2019-2024 period.

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) 3,036 (3,029)[2] 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.
[2]A proposed amendment to change the normal operating level of Ryan Reservoir will start the drawdown rates at an elevation of 3,029 once approved.

The proposed drawdown rates identified in Table 2 above will be followed for the years 2019-2024. NorthWestern Energy will analyze the resulting data from drawdowns within this period, and provide a 5-year (January 2019 through January 2024) summary report to the agencies by December 31, 2024. Based on the results of the analysis, NorthWestern Energy will coordinate with agencies to identify ways to improve or modify the drawdown schedule. NorthWestern Energy will also continue to provide advanced notification to Montana Fish, Wildlife and Parks (MFWP) of planned drawdowns.

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

Sincerely,

Mary Gail Sullivan
Director, Environmental and Lands

CC: Andy Welch, NWE
Jordan Tollefson, NWE
Grant Grisak, NWE
Kristen Dawes, NWE
Jason Garber, MT DEQ
Don Skaar, MT FWP
James Boyd, USFWS

Northwestern Energy has consulted with agencies in the preparation and filing of the Missouri-Madison Hydroelectric Project Reservoir Drawdowns 2013-2018 for Black Eagle, Rainbow, Cochrane, Ryan, and Morony Dams. As signed below, the following agencies agree with the content described above and in the attached report:

By: Jason O. [signature]

Title: CWA Section 401 Coordinator
Representing Montana Department of Environmental Quality

Date: 7/11/2019

By: [signature]

Title: [signature] Supervisor
Representing U.S. Fish and Wildlife Service

Date: 7/17/19

By: ______________________________

Date: ______________________________

Title: ______________________________
Representing Montana Department of Fish, Wildlife and Parks

Attachment A – Agency Consultation Record

From:	James Boyd
To:	Tollefson, Jordan
Subject:	RE: [EXTERNAL] Great Falls Drawdown Report - Signatures Needed
Date:	Monday, July 15, 2019 11:29:29 AM

NOTICE: This message has been sent by an EXTERNAL sender outside of NorthWestern Energy. Please use caution when clicking on links, opening attachments, or replying to this email.

Jordan

I will get Jodi's signature for FWS on this and get a copy to you on Wed. I have reviewed and it looks good to me.

From: Tollefson, Jordan <Jordan.Tollefson@northwestern.com>
Sent: Monday, July 01, 2019 12:19 PM
To: 'Garber, Jason' <JGarber2@mt.gov>; 'Don Skaar (dskaar@mt.gov)' <dskaar@mt.gov>; 'James Boyd (James_Boyd@fws.gov)' <James_Boyd@fws.gov>
Cc: Sullivan, Mary Gail <MaryGail.Sullivan@northwestern.com>; Welch, Andrew <Andrew.Welch@northwestern.com>; 'jmullen@mt.gov' <jmullen@mt.gov>; 'lholmquist@mt.gov' <lholmquist@mt.gov>; Grisak, Grant <Grant.Grisak@northwestern.com>
Subject: [EXTERNAL] Great Falls Drawdown Report - Signatures Needed

Jason, James, and Don,

Attached is the filing letter for our Great Falls Drawdown Report and Plan for our Great Falls area reservoirs. If you approve this report, please sign the third page of the letter under your respective agency signature block, and return a copy to me.

After our last meeting on this plan, I added in some information regarding the effects of the drawdowns on mussels to address comments from FWP. I have attached that text addition for your information, and it is now located in the document in "Section 10 Drawdown Effects". Please let me know if you have any questions. Thank you!

Jordan

Jordan Tollefson
Hydro Compliance Professional
Jordan.Tollefson@NorthWestern.com
O (406) 443-8907
C (406) 565-3879
1315 N Last Chance Gulch
Helena, MT 59601

NorthWestern Energy
Delivering a Bright Future

Connect With Us:

From:	Garber, Jason
To:	Tollefson, Jordan
Subject:	RE: Great Falls Drawdown Report - Signatures Needed
Date:	Thursday, July 11, 2019 2:01:40 PM
Attachments:	drwdwn_sigpage_DEQ.pdf

Good afternoon Jordan,

Please find the attached signed signature page.

Jason

From: Tollefson, Jordan [mailto:Jordan.Tollefson@northwestern.com]
Sent: Monday, July 01, 2019 12:19 PM
To: Garber, Jason <JGarber2@mt.gov>; Skaar, Donald <dskaar@mt.gov>; 'James Boyd (James_Boyd@fws.gov)' <James_Boyd@fws.gov>
Cc: Sullivan, Mary Gail <MaryGail.Sullivan@northwestern.com>; Welch, Andrew <Andrew.Welch@northwestern.com>; Mullen, Jason <JMullen@mt.gov>; Holmquist, Luke <lholmquist@mt.gov>; Grisak, Grant <Grant.Grisak@northwestern.com>
Subject: Great Falls Drawdown Report - Signatures Needed

Jason, James, and Don,

Attached is the filing letter for our Great Falls Drawdown Report and Plan for our Great Falls area reservoirs. If you approve this report, please sign the third page of the letter under your respective agency signature block, and return a copy to me.

After our last meeting on this plan, I added in some information regarding the effects of the drawdowns on mussels to address comments from FWP. I have attached that text addition for your information, and it is now located in the document in “Section 10 Drawdown Effects”. Please let me know if you have any questions. Thank you!

Jordan

Jordan Tollefson
Hydro Compliance Professional
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1315 N Last Chance Gulch
Helena, MT 59601

NorthWestern Energy
Delivering a Bright Future

Connect With Us:

From:	Tollefson, Jordan
To:	"Skaar, Donald"
Cc:	Mullen, Jason
Subject:	RE: Great Falls Drawdown Mussel Information
Date:	Friday, August 02, 2019 10:23:34 AM
Attachments:	FERC Filing Letter for Great Falls Drawdowns.pdf image002.png

Don,

Sorry it took me a while to get back to you in regards to yours and Jason's questions on the Great Falls Drawdown Plan. I've been out of the office doing fieldwork for most of July and am now finally able to get caught up on some of these lingering office items. I hope that the below responses adequately address your questions and concerns. I have received approval from both DEQ and the Fish and Wildlife Service on this plan, so if this looks ok to you, I have attached the signature page for your approval. If you have any further questions, please let me know.

Jordan

Q1: We also had concern that your proposed drawdown rates won't be protective against dramatic fluctuations. Could we add a maximum hourly drawdown rate? Such that drawdown rates don't fluctuate dramatically yet still fall within the 4-hour average. Perhaps twice the 4-hour rate?

A1: The intent of the 4 hour running average is not to dramatically pulse a drawdown flow within that 4 hour window, rather the intent of that average is to reflect the actual conditions we are currently seeing resulting from limited precision of operational control of drawdown rates while conducting these drawdowns. Tables 4-4, 5-4, 6-4, 7-4, and 7-8 in the document show the challenges of attempting to maintain a constant drawdown rate with operational constraints and changing environmental conditions. The 4-hour running average is in itself a check to keep our drawdown rates within the target range since it is a continual average (current+past 3 hours). In addition, the turbidity data we have collected is not showing much of a correlation between drawdown rate and turbidity. Therefore, we should not see any increase in turbidity by using this method. A similar operational scenario is already occurring, as evidenced by our past drawdowns, so the intent is to update the language in the drawdown plan to reflect actual conditions.

Q2: This seemed a little off to me, as it seems to consider only living fish, and does not consider impacts to habitat (smothering of redds, degradation of spawning habitat, etc.). It also states that impacts to fish from increases in turbidity caused by reservoir operations are not significant because they are within seasonal fluctuations (page 63, paragraph 3). I disagree with this logic, as increases in turbidity during times of normal low turbidity would result in increases in stress over the baseline condition. I.e., these would be times when stress would normally be low and this amount of time is being decreased by reservoir operations. Mobilizing sediment during low flows may also result in sedimentation in different areas than during high flows. Stress index also doesn't account for mobilization of sediment that may be contaminated by metals from historic smelter operations.

A2: This plan was approved by FERC in 2009 as an acceptable mechanism for sediment control during maintenance drawdowns required to maintain the integrity of the hydroelectric facilities to ensure dam safety and equipment reliability. This report describes how we implemented the plan. In our 10 year Monitoring Agreement with the state, we agree that we will *"…conduct periodic evaluations of aquatic organisms and habitat… will be made in Black Eagle Reservoir during maintenance drawdowns…"* During the last maintenance drawdown at Black Eagle Reservoir in 2016, NWE consulted with FWP who did a cursory examination of the mussels in the area near Riverside Park, and made some general observations about the presence of mussels and reported that some mussels were stranded in that area. We clarified some of the recent mussel questions raised by FWP in a previous response. We also evaluated the turbidity of the reservoir water during the drawdown.

Q3: Mobilization of sediment that may contain metals contaminants.

A3: Pages 1 and 4 state "…The intent of the drawdown schedule was 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…" In previous drawdown events, we have collected samples for sediment metals analysis; in addition, we also collect quarterly water quality samples above and below the Great Falls reservoir complex, which are analyzed for both the total recoverable and dissolved fractions. The TCLP analyses on the sediment samples are showing that the sediment does not have a leaching potential to release metals that might be bound to it. Water quality samples are showing that there is not a significant change in metals concentrations from Black Eagle to Morony. DEQ is currently collecting water quality data for a re-assessment of the Missouri River from Toston to Ft. Benton.

Q4: Smothering of redds, degradation of spawning habitat, etc.

A4: We don't believe sediment mobilization associated with drawdowns, and analyzed here, contribute to smothering redds because the drawdowns occurred at times when trout eggs are not in redds incubating. As stated in on Pages 1 and 4, the intent is to minimize harmful effects from these operations, so the drawdown timing occurred between June and October.
2016 Black Eagle Reservoir – August 6-9.
2018 Rainbow Reservoir – September 10-24.
2014 Cochrane Reservoir – September 26 –November 2. No known trout spawning habitat between Cochrane Reservoir and Morony Dam.
2017 Ryan Reservoir – June 20-August 19. No known trout spawning habitat between Ryan Reservoir and Morony Dam.
2018 Ryan Reservoir September 27-October 8. No known trout spawning habitat between Ryan Reservoir and Morony Dam.

2018 Black Eagle Reservoir – June/July 2018. Although this event is listed in the 2019 report, it is important to note that stanchions were tripped at Black Eagle Dam on June 20, 2019 as an emergency provision to pass debris that was building on the face of the dam and protect the structural integrity of the dam.

Q5: Disagree with logic that timing of drawdowns. Increases in turbidity during times of normal low turbidity would result in increases in stress over the baseline condition.

A5: Although it's true that maintenance-caused turbidity is higher than the base turbidity at the time when the maintenance is conducted, there is no option to conduct this work at another time. Our timing window was selected to minimize impacts as much as practicable. It is uncertain if we can completely eliminate the impacts. As such, Article 417 of License 2188 orders a plan to protect, mitigate and enhance fish populations and habitat in the Great Falls reservoirs and tailwaters. If existing protection measures are not sufficient, and monitoring shows the need, NWE can work with our partners to mitigate impacts through this program.

From: Skaar, Donald <dskaar@mt.gov>
Sent: Tuesday, July 02, 2019 8:24 AM
To: Tollefson, Jordan <Jordan.Tollefson@northwestern.com>
Cc: Mullen, Jason <JMullen@mt.gov>
Subject: FW: Great Falls Drawdown Mussel Information

Hi Jordon: Sorry to provide these comments so late. Please see the comment below from Jason Mullen regarding the stress Index discussion. Might you be able to address his concerns with some new text? We also had concern that your proposed drawdown rates won't be protective against dramatic fluctuations. Could we add a maximum hourly drawdown rate? Such that drawdown rates don't fluctuate dramatically yet still fall within the 4-hour average. Perhaps twice the 4-hour rate?

Thanks for your consideration of these comments.

Don Skaar
Habitat and Access Bureau Chief
Fisheries Division
Montana Fish, Wildlife and Parks

1420 East 6th Avenue
Helena, MT 59620
406-444-7409 (office)
406-465-6135 (cell)

dskaar@mt.gov

THE **OUTSIDE** IS IN US ALL.

From: Mullen, Jason
Sent: Monday, June 24, 2019 2:30 PM
To: Skaar, Donald <dskaar@mt.gov>
Subject: RE: Great Falls Drawdown Mussel Information

Don, see below. I'd like to provide the following comments to NWE regarding the stress index. If you agree and think it is appropriate would you forward to Jordan? Thanks - Jason

Jordan,

Yes. Thanks for adding that.

One other section I held back on during the conference call, hoping to discuss with Don first, was the Stress Index section. I think it has some good information but it seemed to take a prominent role in the report and deemphasized impacts to aquatic life. This seemed a little off to me, as it seems to consider only living fish, and does not consider impacts to habitat (smothering of redds, degradation of spawning habitat, etc.). It also states that impacts to fish from increases in turbidity caused by reservoir operations are not significant because they are within seasonal fluctuations (page 63, paragraph 3). I disagree with this logic, as increases in turbidity during times of normal low turbidity would result in increases in stress over the baseline condition. I.e., these would be times when stress would normally be low and this amount of time is being decreased by reservoir operations. Mobilizing sediment during low flows may also result in sedimentation in different areas than during high flows. Stress index also doesn't account for mobilization of sediment that may be contaminated by metals from historic smelter operations.

Anyway, I think some minor edits, tweaking of the language, adding caveats, etc. could improve this section.

From: Tollefson, Jordan <Jordan.Tollefson@northwestern.com>
Sent: Friday, June 21, 2019 4:07 PM
To: Mullen, Jason <JMullen@mt.gov>
Cc: Grisak, Grant <Grant.Grisak@northwestern.com>; Welch, Andrew <Andrew.Welch@northwestern.com>
Subject: Great Falls Drawdown Mussel Information

Jason,

I added in some information to the Great Falls Reservoirs Drawdown Plan document regarding effects on mussels (attached). This text goes into the document right after the information about effects of turbidity on fish. Grant was able to provide this information and his first-hand knowledge from being on site during the 2016 drawdown. Does this language look ok to you as far as addressing FWP's concerns about mussels?

Jordan

Jordan Tollefson
Hydro Compliance Professional
Jordan.Tollefson@NorthWestern.com
O (406) 443-8907
C (406) 565-3879
1315 N Last Chance Gulch
Helena, MT 59601

Subject: RE: Great Falls Reservoirs Drawdown Plan update for your review

From: Tollefson, Jordan
Sent: Wednesday, May 29, 2019 2:23 PM
To: 'Jason Garber' <JGarber2@mt.gov>; 'Don Skaar (dskaar@mt.gov)' <dskaar@mt.gov>; 'James Boyd (James_Boyd@fws.gov)' <James_Boyd@fws.gov>
Cc: Sullivan, Mary Gail <MaryGail.Sullivan@northwestern.com>; Welch, Andrew <Andrew.Welch@northwestern.com>; Grisak, Grant <Grant.Grisak@northwestern.com>; ggillin@geiconsultants.com
Subject: Great Falls Reservoirs Drawdown Plan update for your review

Fellow Agency Partners,

NorthWestern Energy has been working on updating the drawdown plans for the Great Falls area reservoirs, and has developed a document summarizing the 2013-2018 data and a plan for future reservoir drawdowns through 2024. This document (attached) is available for your review and comment. Please take a few minutes to review the attached document and if you have any comments, you can send them to me and I will incorporate them into the final document and send an updated version to all of you, as well as the FERC filing letter for your signature. The deadline for the review period is Friday, June 28th, so please try to have your comments and signatures back to me before then.

I would also like to plan a webinar/conference call to go over this report, so please fill out the Doodle poll here and indicate which time(s) work best for you: https://doodle.com/poll/cf9fpd2cuvf9mkzt

Thank you for taking the time to review this report.

Jordan

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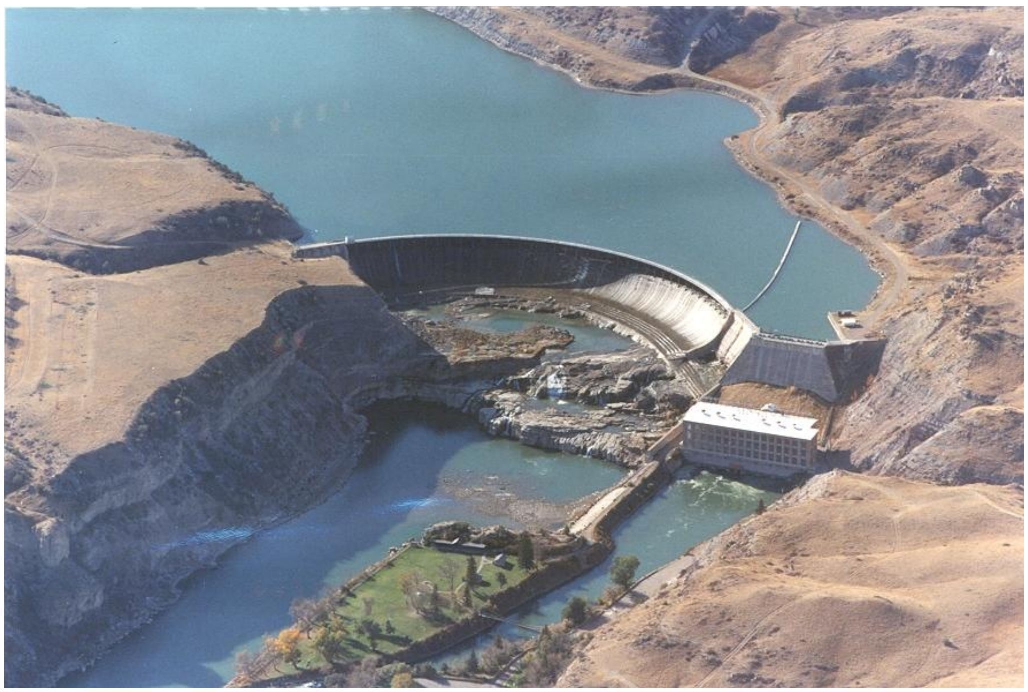
Missouri-Madison Hydroelectric Project
Reservoir Drawdowns 2013 – 2018
Black Eagle, Rainbow, Cochrane, Ryan, and Morony Dams

FERC Project 2188
May 24, 2019



Submitted by:
NorthWestern Energy Corporation
Butte, Montana

With Assistance From:
GEI Consultants, Inc.
Portland, Oregon

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Executive Summary

NorthWestern Energy 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. As a requirement of the license, NorthWestern Energy (previously MPC) 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 Missouri-Madison Hydroelectric 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 Project, including the Missouri River reservoirs (Black Eagle, Rainbow, Cochrane, Ryan, and Morony). 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 plans 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 plans 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.

The drawdown plan for the five Missouri River reservoirs was filed with the FERC on July 8, 2009. FERC approved the plan on August 7, 2009. Included in FERC approval of the Missouri River drawdown plan was a requirement for NorthWestern Energy 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 Missouri River projects from January 6, 2013 through December 1, 2019.

During the monitoring period, no drawdowns were recorded at Morony Reservoir. Turbidity was monitored during drawdowns at Black Eagle, Rainbow, Cochrane, 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 Project also indicate turbidity levels often respond to some degree to fluctuations and drops in WSE. However, the turbidity response has not always related to occasions when drawdown rates have exceeded the limits outlined in the 2009 Drawdown Plan. Turbidity increased when drawdown rates were less and, in some cases, when drawdown rates exceeded the limits specified in the 2009 Drawdown Plan. The correlation between the drawdown rate and turbidity is not definitive based on the available data.

Due to the operational constraints of managing a drawdown rate of less than 0.10 feet/hour, NorthWestern Energy is proposing an update to the drawdown rates for Black Eagle, Rainbow, Cochrane, Ryan, and Morony Dams (Table 11-2). These drawdown rates will be based on a four-hour running average, which will afford dam operators some flexibility in trying to maintain these drawdown rates. The proposed drawdown rates will simplify dam operations during a planned drawdown to help operators stay in compliance with the Drawdown Plan, while at the same time, remaining conservative enough to protect the aquatic resources of these reservoirs.

The drawdown rates identified in Table 11-2 will be followed for the years 2019-2024. NorthWestern Energy proposes to analyze the resulting data from drawdowns within this period, and provide a 5-year (January 2019 through January 2024) summary report to the agencies by December 31, 2024. NorthWestern Energy will perform a detailed review of the effectiveness of the recommended drawdown rates based on the data that was collected nearly continuously during the last 5 years. Based on the review, NorthWestern Energy 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 Energy will also provide advanced notification to 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. NorthWestern Energy subsequently purchased the project from MPC and operates the project under the terms of the Project 2188 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 Energy is required to demonstrate the use of Best Management Practices (BMPs) 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 3,036*[1] *feet (within one foot of normal full pool 3,037 feet)*
- *Morony: WSE 2,878 feet (within ten feet of normal full pool 2,888 feet)*

[1]There is currently a proposed license amendment to change the normal minimum operating elevation of Ryan Reservoir to 3,029.

As a requirement of the license, NorthWestern Energy must 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 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 Missouri-Madison Hydroelectric 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 Missouri River reservoirs (Black Eagle, Rainbow, Cochrane, Ryan, and Morony). 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.

The 2009 Drawdown Plan for the five Missouri River reservoirs was filed with the FERC on July 8, 2009. FERC approved the plan on August 7, 2009. Included in FERC approval of the Missouri River drawdown plan was a requirement for NorthWestern Energy to collect tailrace turbidity data during reservoir drawdowns on 5-year-cycles to monitor and verify the plans sediment control effectiveness.

In July 2014, the Licensee submitted a report (Missouri-Madison Hydroelectric Project Reservoir Drawdowns 2009-2014) summarizing the results of turbidity monitoring during drawdowns at the five Missouri River reservoirs from January 1, 2009 through February 27, 2014. That report noted that, to some degree, the turbidity levels respond to fluctuations and drops in water surface elevations. 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

---

[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."

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 revised reservoir drawdown plan. This report summarizes the results of turbidity monitoring during drawdowns at the five Missouri River projects from January 1, 2013 through December 1, 2018.

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 five Missouri River reservoirs in the Missouri-Madison Hydroelectric Project (FERC No. 2188).

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	Project Engineer

The Project Manager for NorthWestern Energy was Jordan Tollefson.

1.4 Elevation Datum

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

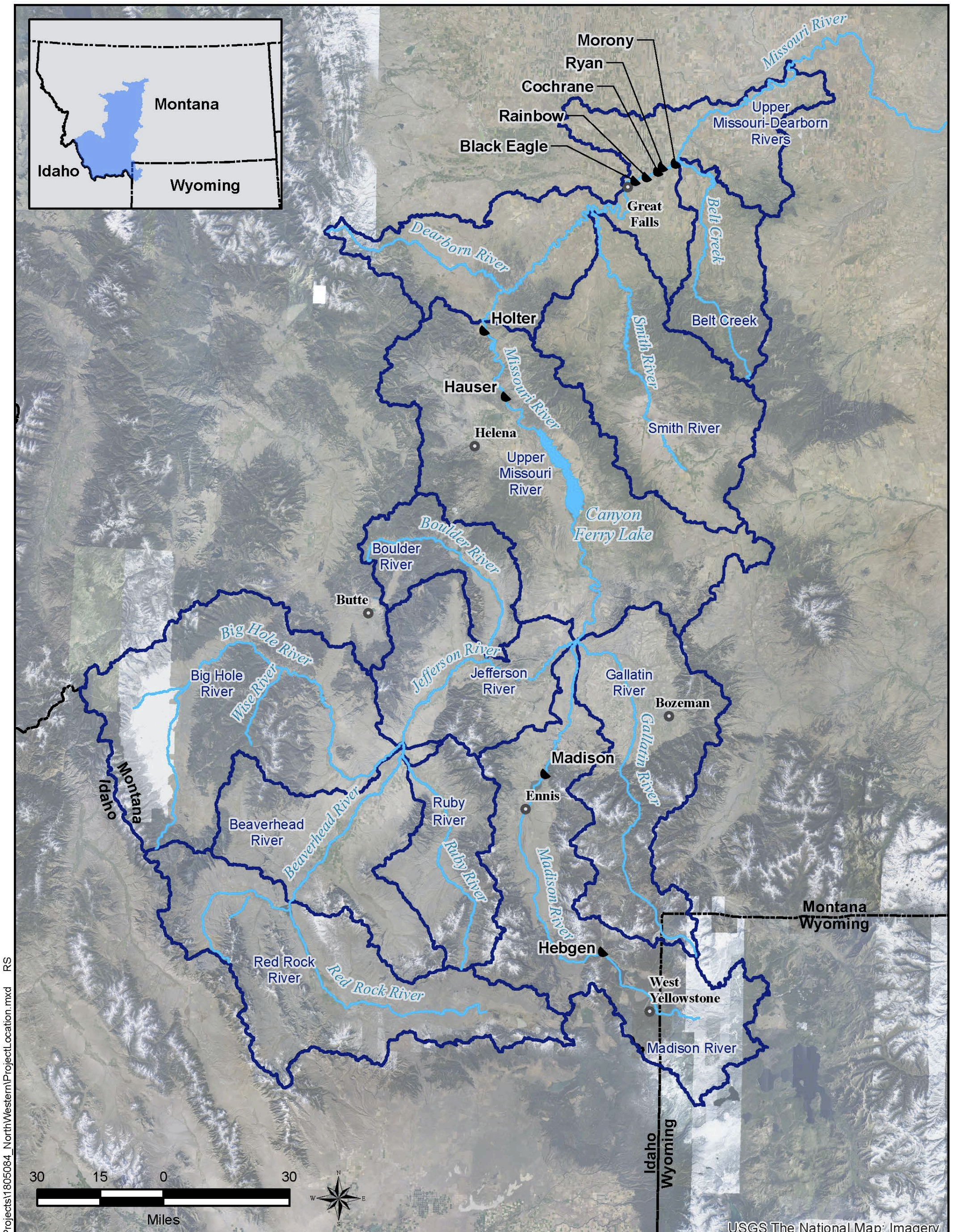
1.5 Limitation of Liability

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 Great Falls Project. 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 in the Missouri-Madison Hydroelectric Project 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 of the dams in the Missouri-Madison Hydroelectric Project.



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Missouri River Drawdown Report Montana, USA	GEI Consultants NorthWestern Energy Delivering a Bright Future	Project Location		
Northwestern Energy Corporation		APRIL 2019	DRAFT	FIGURE

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 miles 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)	3,035-3,037[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

[1]A proposed license amendment will change the normal operating elevation of Ryan Reservoir to 3,029-3,038.

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 Project, 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 Project dams are located over a distance of 13 river miles with no free-flowing river segments between the dams. 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 operation as peaking projects. Cochrane, downstream of Rainbow, is operated as a daily peaking plant, draining and recharging over an elevation range up to 10 feet. The Ryan Project[2] maintains a relatively constant full pool but serves as a daily peaking plant by passing the peaking flows from Cochrane. Morony, the downstream-most project, re-regulates flow and varies reservoir elevations over a range up to 10 feet (typical range is 3 feet) 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, the five Missouri reservoirs are normally maintained at or near (within one 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, and Ryan dams. Cochrane and Morony dams do 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.

[2] A license amendment to modify reservoir operations at Ryan is currently pending.

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 Project 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.

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 NTU (NorthWestern Energy, 2009). Data were collected during other reservoir drawdown events have also clearly shown spikes in turbidity (NorthWestern Energy, 2009). By minimizing increases in turbidity during drawdowns, water quality in the Missouri River system downstream of the Great Falls Project can be protected. To the extent that trace metals are bound to sediments, minimizing turbidity also minimizes metal concentrations in the river.

2.3 Drawdown Plan Requirements

The August 2009 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 Missouri River projects, as approved by FERC August 7, 2009.

Reservoir	Reservoir Water Elevation (feet)	Optimal Drawdown Rate (feet/hour)
Black Eagle	(1) 3,289 to 3,285 (2) below 3,285	(1) 0.10 (2) 0.05
Rainbow	(1) 3,223 to 3,216 (2) 3,216 to 3,214 (3) below 3,214	(1) 0.30 (2) 0.10 (3) 0.03
Cochrane	(1) 3,110 to 3,108.9 (2) below 3,108.9	(1) 0.10 (2) 0.03
Ryan	(1) 3,036 to 3,027 (2) 3,027 to 3,024 (3) below 3,024	(1) 0.20 (2) 0.10 (3) 0.05
Morony	(1) 2,878 to 2,870 (2) below 2,870	(1) 0.10 (2) 0.05

The 2009 FERC Order also specified that NorthWestern Energy 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 (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 feet 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, but at Ryan Dam the generators can continue running through a very deep drawdown. Overall, NorthWestern Energy 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 located 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 power house.
- 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 half way 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: Morony Dam has not been drawn down and NorthWestern Energy 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 five-year monitoring period there were two drawdown events when this occurred which include the Cochrane Dam October 2014 drawdown and the Rainbow Dam September 2018 drawdown. For these two drawdown events, the Hydrolab data is provided. However, NorthWestern Energy 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 3289 and 3290 feet. Water surface elevation data were collected at 15-minute intervals at Black Eagle Reservoir from April 5, 2013 to December 1, 2018 and converted to a daily mean as shown in Figure 4-1. There were two brief periods where the data indicate that the reservoir WSE was less than 3289 feet; one in August 2016; and the second in July 2018. Turbidity, elevation and discharge data were available for both drawdown events.

The drawdown rate at Black Eagle requires 160 hours (6.7 days) to draw the reservoir down from full pool to crest (3279 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.

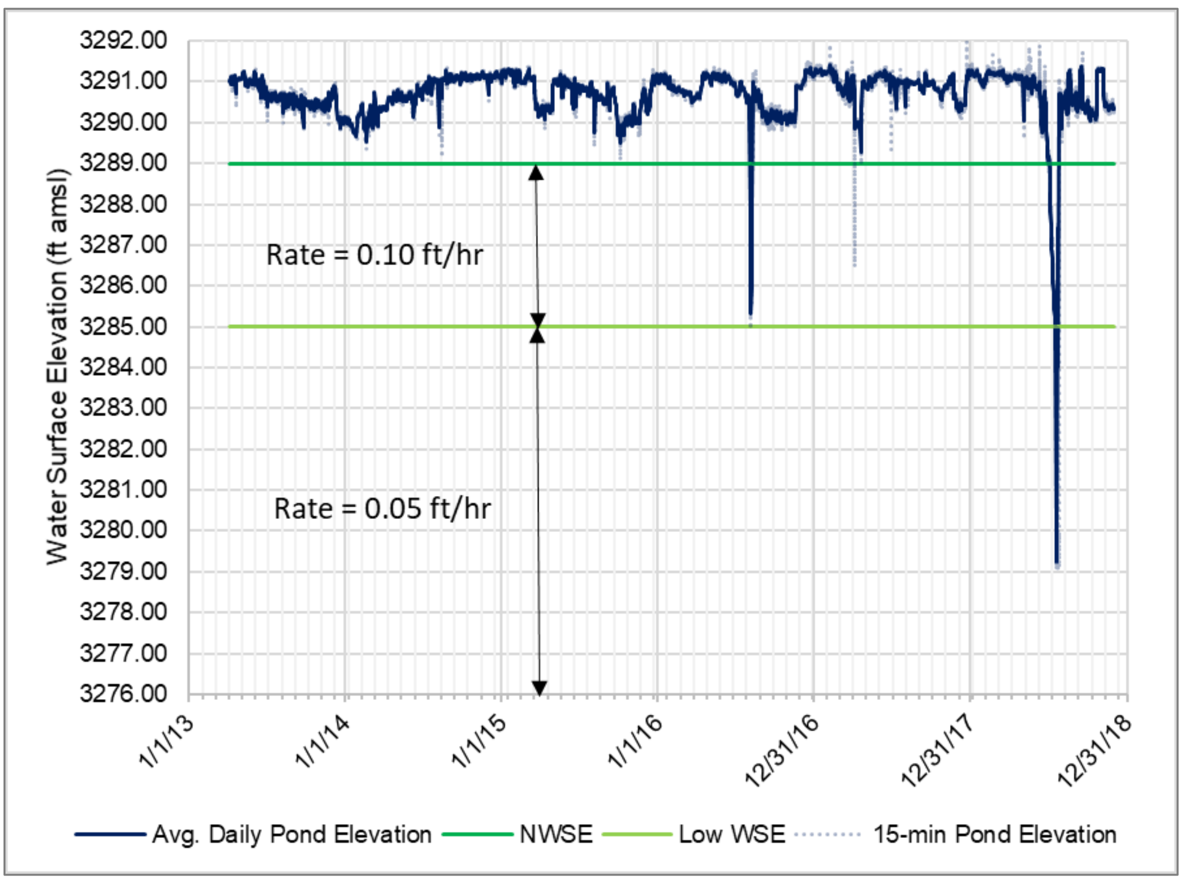

Figure 4-1: Mean daily water surface elevation (in blue), Black Eagle Reservoir, April 5, 2013 through December 1, 2018. The green lines represent the drawdown thresholds.

4.2 August 2016 Drawdown

The August 2016 drawdown generally occurred between August 2, 2016 to August 9, 2016. The drawdown was 4.1 feet, with minimum 15-minute WSE of 3284.9 feet.

4.2.1 August 2016 Drawdown Rates

During the August 2016 drawdown of Black Eagle Reservoir, the pond elevation was generally drawn down at a rate of 0.10 feet per hour, as specified in the 2009 Drawdown Plan, except for some hourly drawdown rates that exceeded the value (Figure 4-2).

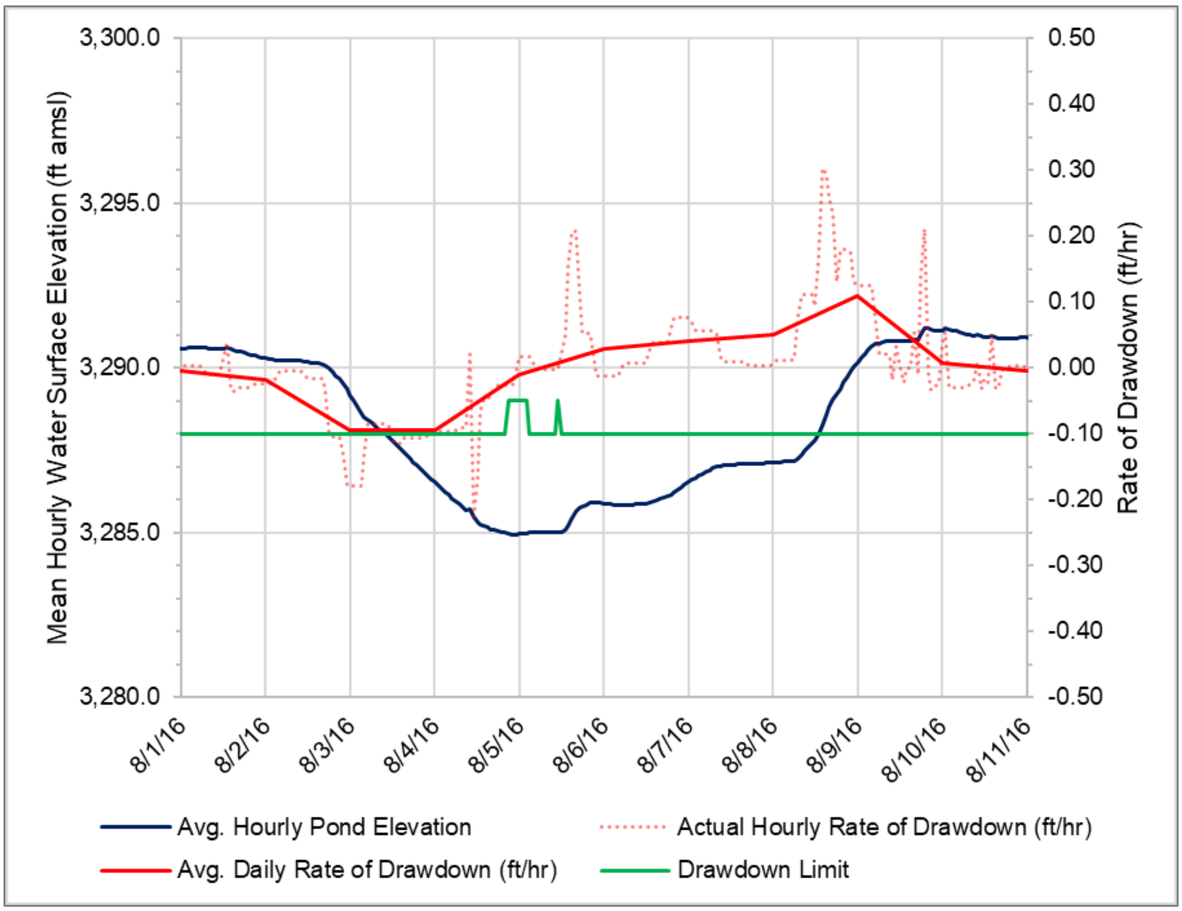

Figure 4-2. Hourly water surface elevation with daily and hourly rate of drawdown, Black Eagle Reservoir, during drawdown August 2016. The green line indicates the limits to the drawdown rate per the 2009 Drawdown Plan.

A total of 23 hourly drawdown rates exceeded the Drawdown Plan rates. During those hours the average drawdown rate was 0.13 feet per hour, with a maximum drawdown rate of 0.22 feet per hour.

4.2.2 August 2016 Turbidity

Water surface elevation and turbidity data are available for the August 2016 drawdown (Figure 4-3). During the August 2016 drawdown when the WSE declined to 3286 and 3285 feet, hourly turbidity increased briefly from approximately 30 nephelometric turbidity units (NTUs) to approximately 90 NTUs, then generally returned to the baseline level. Turbidity data compared to the August 2016 drawdown rates is shown in Figure 4-4. The turbidity increased when the drawdown rate was near the Drawdown Plan limit. Turbidity data compared to the average daily and hourly discharge rates are shown in Figure 4-5. The turbidity data showed poor correlation with the discharge rates during the August 2016 drawdown.

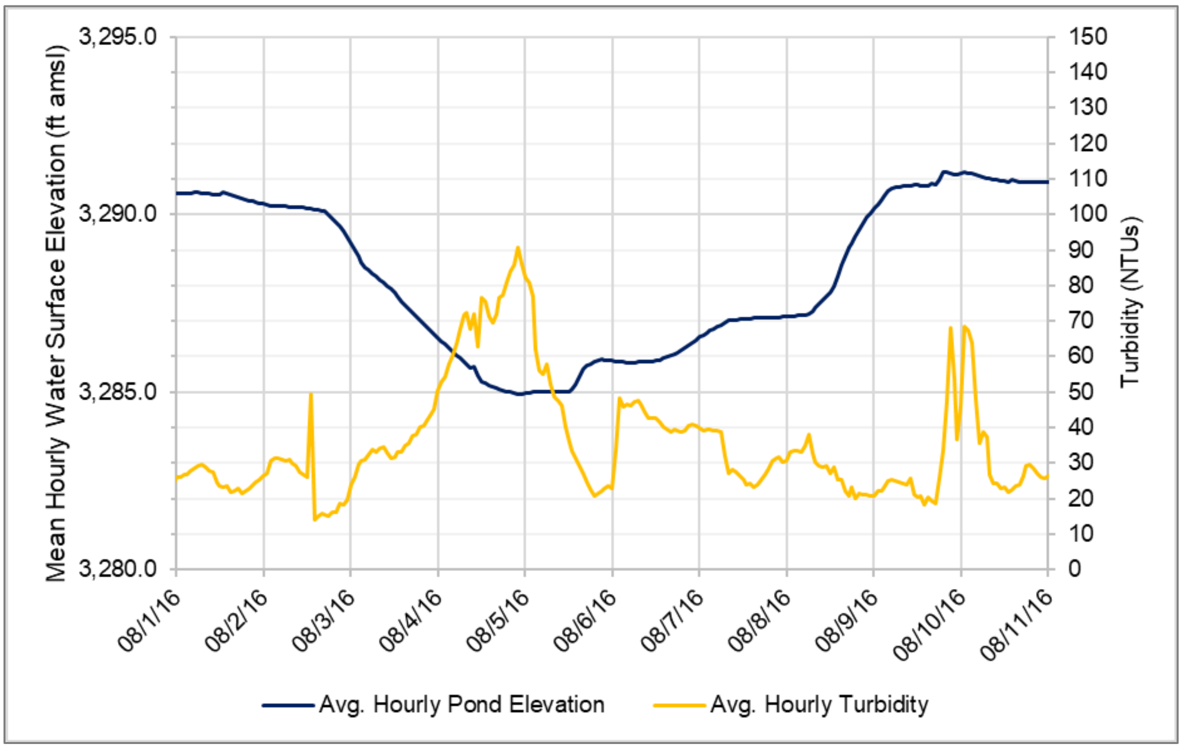

Figure 4-3: Mean hourly water surface elevation and mean hourly turbidity, Black Eagle Reservoir, August 1, 2016 through August 11, 2016.

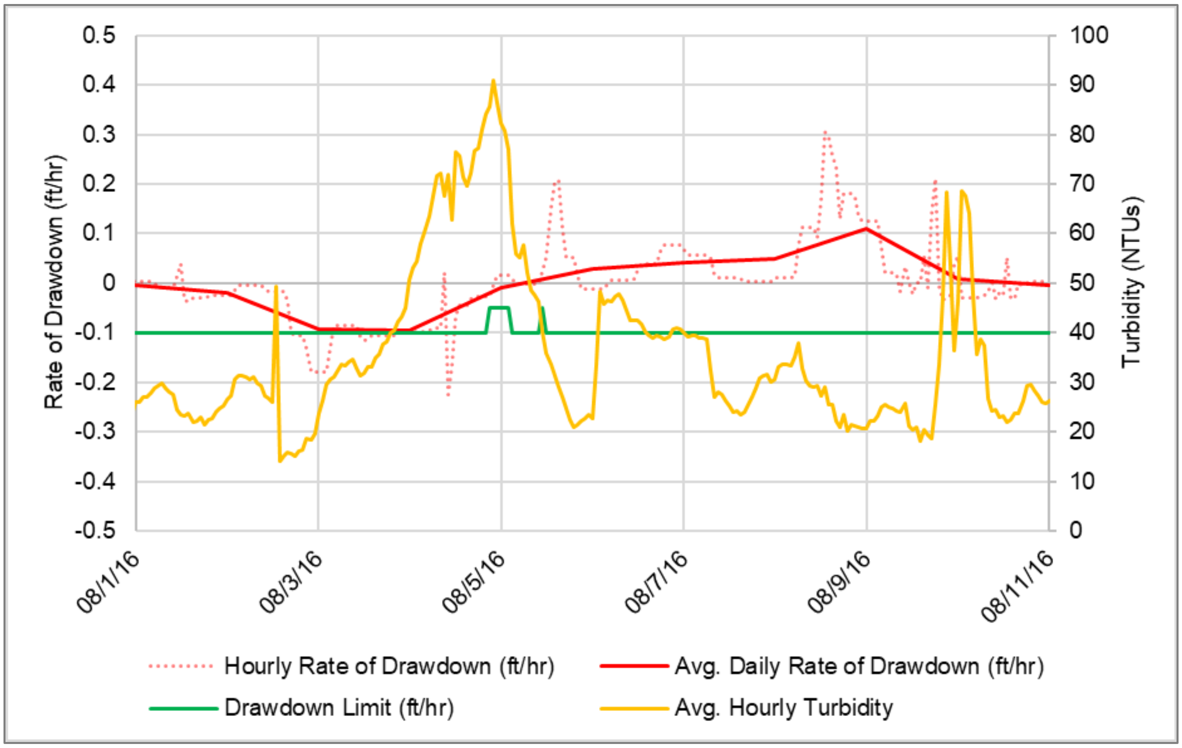

Figure 4-4. Mean daily and hourly rate of change in reservoir elevation and mean hourly turbidity, Black Eagle Reservoir, August 1, 2016 through August 11, 2016.

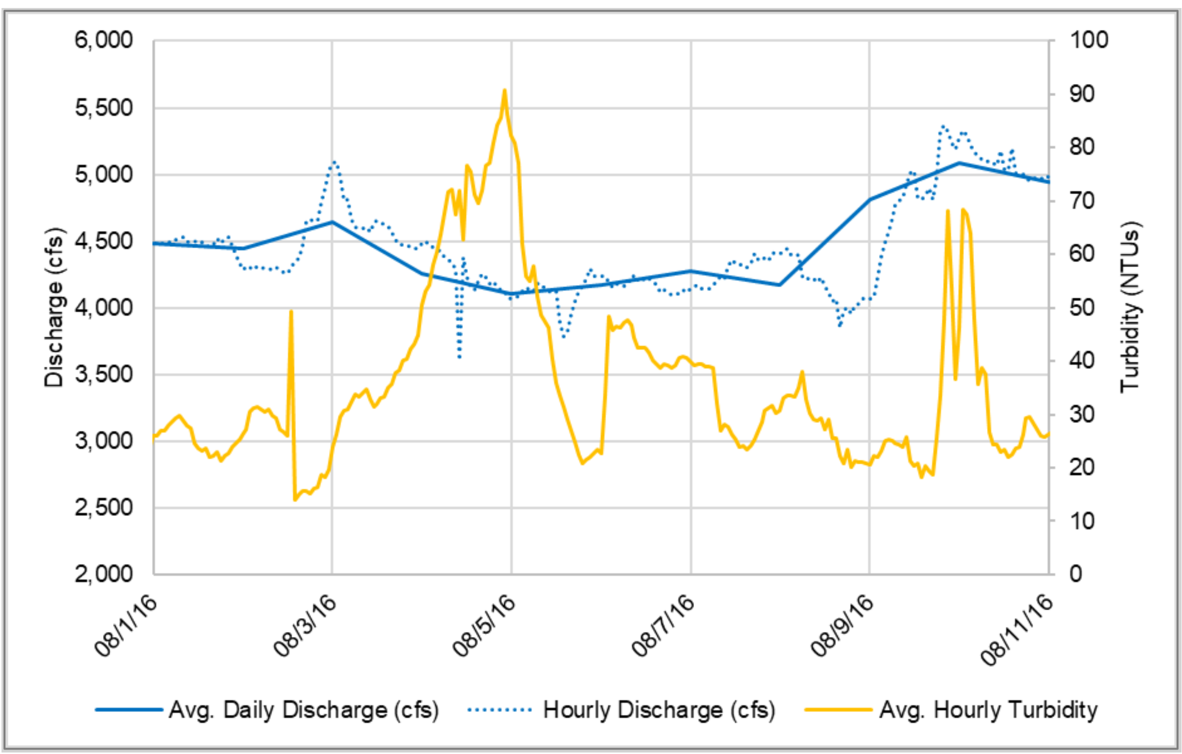

Figure 4-5. Mean daily and hourly discharge rate and mean hourly turbidity, Black Eagle Reservoir, August 1, 2016 through August 11, 2016.

4.3 July 2018 Drawdown

The July 2018 drawdown generally occurred between June 26, 2018 to July 25, 2018. The drawdown was 9.9 feet, with minimum 15-minute WSE of 3279.1 feet.

4.3.1 July 2018 Drawdown Rates

During the July 2018 drawdown of Black Eagle Reservoir, the pond elevation was generally drawn down at a rate less than 0.10 feet per hour, as specified in the 2009 Drawdown Plan, except for one daily rate and some hourly drawdown rates that exceeded the value (Figure 4-6). A large flood occurred in June 2018 that caused the spillway stanchions to be tripped on June 21, 2018, which made it difficult for the operators to control WSEs and drawdown rates.

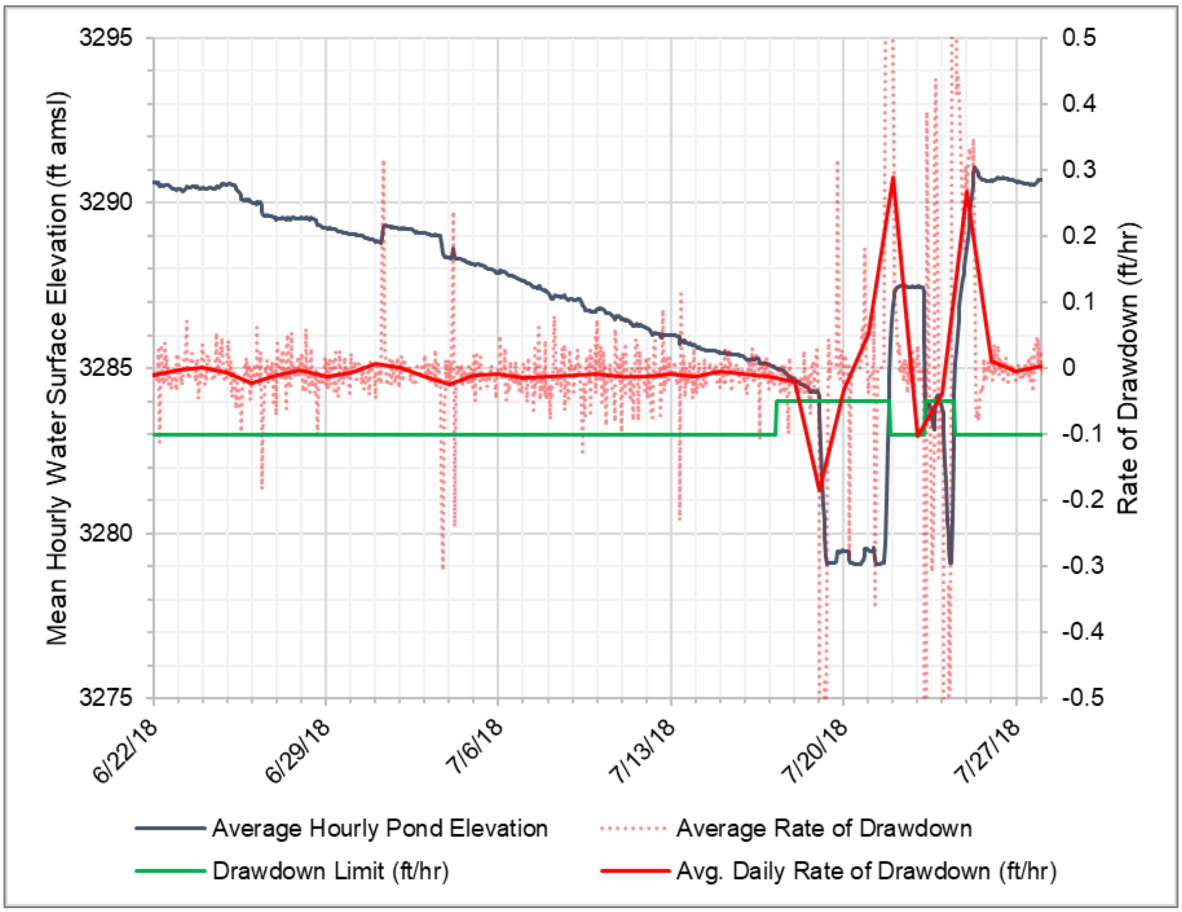

Figure 4-6. Hourly water surface elevation with daily and hourly rate of drawdown, Black Eagle Reservoir, during drawdown July 2018. The green line indicates the limits to the drawdown rate per the 2009 Drawdown Plan.

A total of 37 hourly drawdown rates exceeded the Drawdown Plan rates. During those hours the average drawdown rate was 0.45 feet per hour, with a maximum drawdown rate of 2.25 feet per hour.

4.3.2 July 2018 Turbidity

Water surface elevation and turbidity data are available for the July 2018 drawdown (Figure 4-7). During the July 2018 drawdown when the WSE declined below 3285 feet, hourly turbidity increased briefly from approximately 30 NTUs to approximately 140 NTUs, then generally returned to the baseline level. Turbidity data compared to the July 2018 drawdown rates is shown in Figure 4-8. The turbidity increased when the drawdown rate exceeded the Drawdown Plan limit. Turbidity data compared to the average daily and hourly discharge rates is shown in Figure 4-9. The turbidity data showed a noticeable correlation with the discharge during the June 2018 flood event, remaining above 100 NTUs for 10 days. As the flood receded the turbidity steadily declined. Following the flood, the reservoir was drawdown during July 2018 with limited operational control due to the spillway stanchions tripping. During the July 2018 drawdown the turbidity peaked near the level of the flood event for approximately 3 days. The turbidity data showed poor correlation with the discharge rates during the July 2018 drawdown.

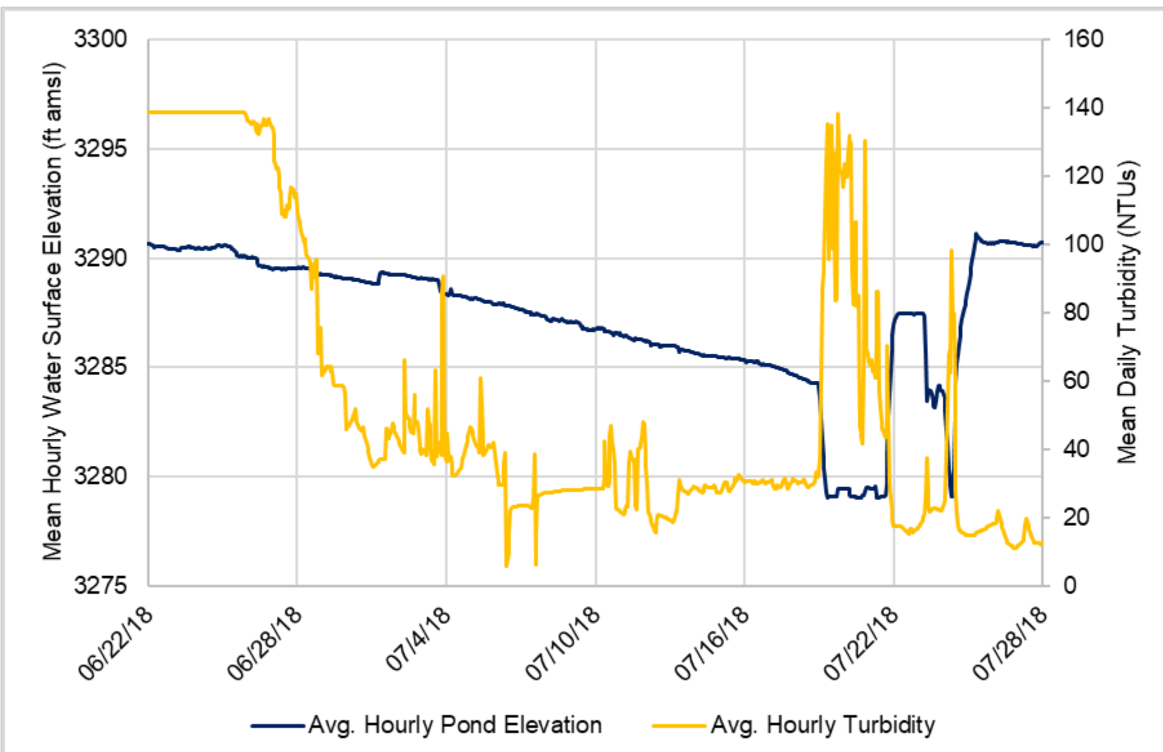

Figure 4-7: Mean hourly water surface elevation and mean hourly turbidity, Black Eagle Reservoir, June 22, 2018 through July 28, 2018.

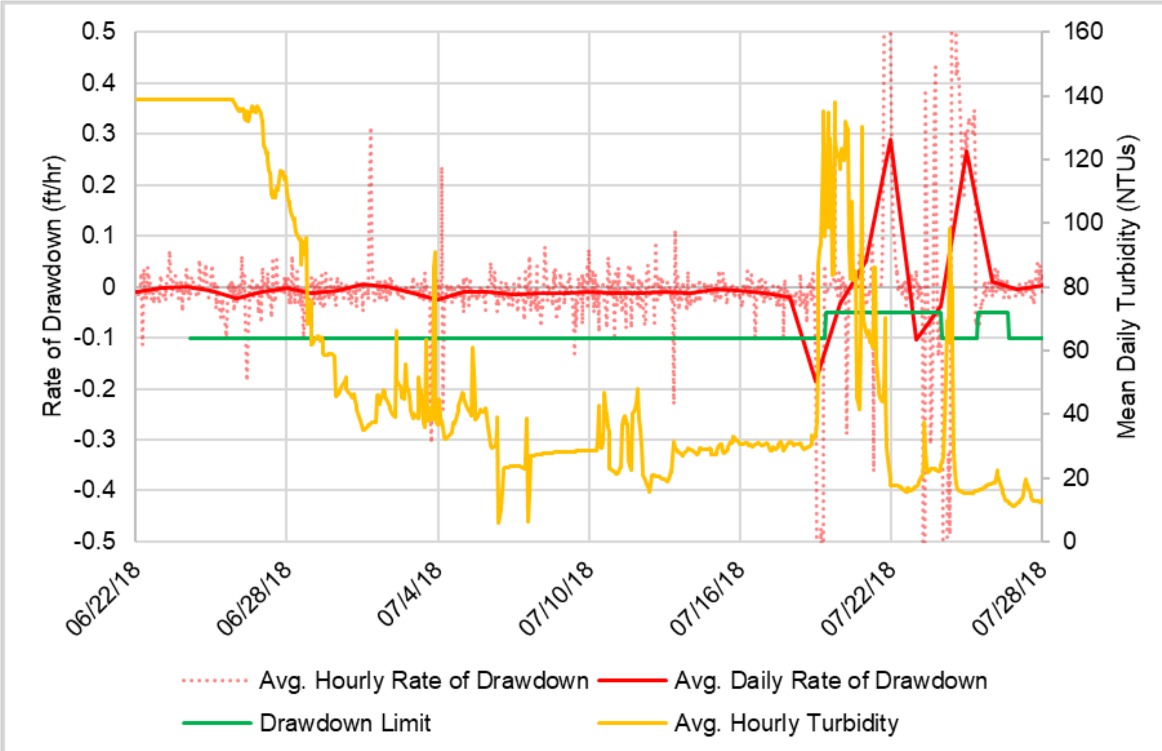

Figure 4-8. Mean daily and hourly rate of change in reservoir elevation and mean hourly turbidity, Black Eagle Reservoir, June 22, 2018 through July 28, 2018.

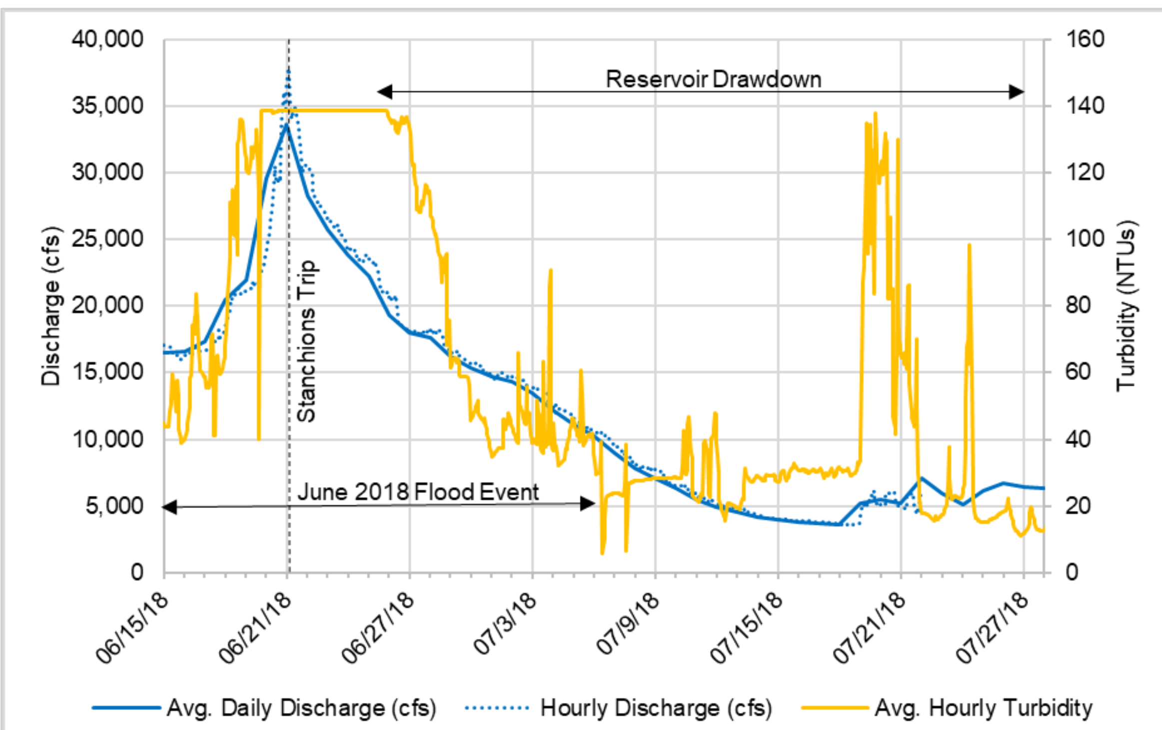

Figure 4-9. Mean daily and hourly discharge rate and mean hourly turbidity, Black Eagle Reservoir, August 1, 2016 through August 11, 2016.

4.4 Black Eagle Turbidity

Turbidity in the Missouri River varies seasonally. Figure 4-10 shows turbidity and water surface elevations measured at Black Eagle since April 2013. 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 (near 20 NTUs), which is likely a result of irrigation return flows entering the river system. This is indicated in Figure 4-11 which shows the turbidity by month in a box-and-whisker plot. Additionally, when irrigation activities end on October 1, turbidity levels continue 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 two drawdown events the increase in turbidity coincided with the drawdown activity; although other, larger, spikes in turbidity have been observed unrelated to reservoir drawdowns (Figure 4-10).

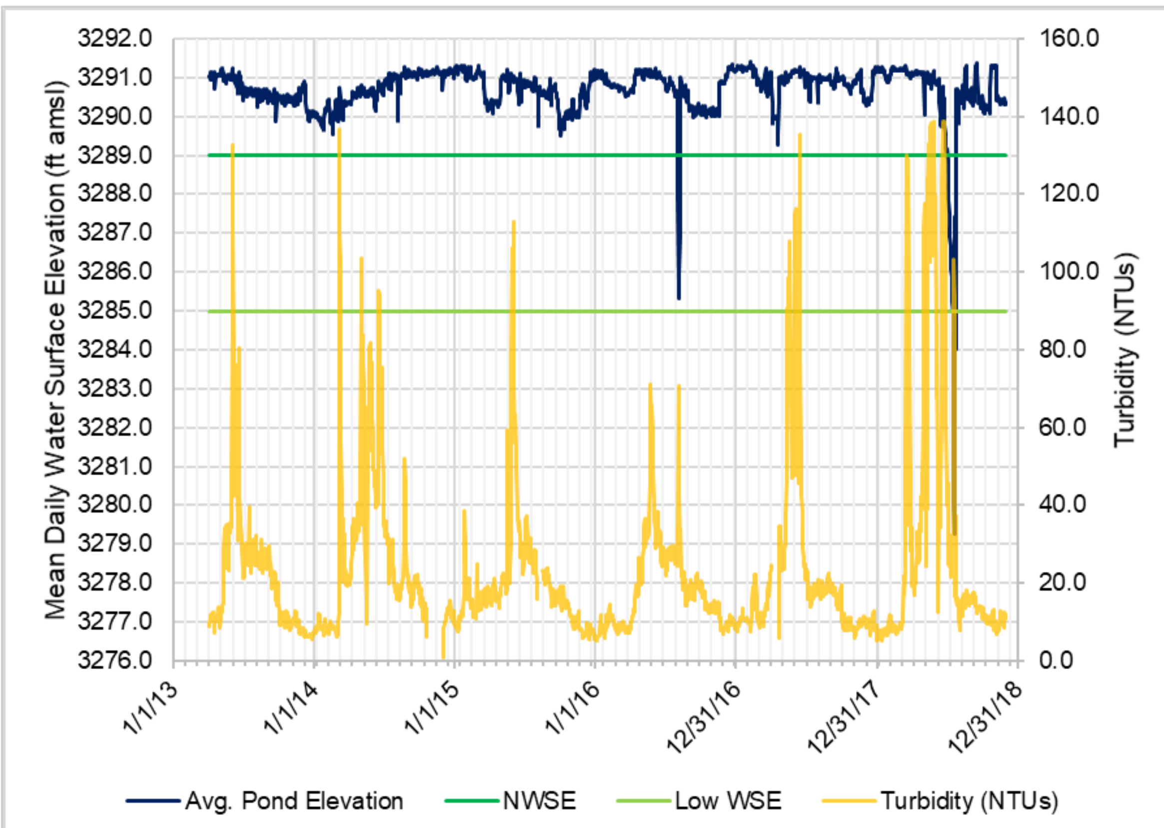

Figure 4-10: Mean daily turbidity and water surface elevation, Black Eagle Reservoir, April 5, 2013 through December 1, 2018.

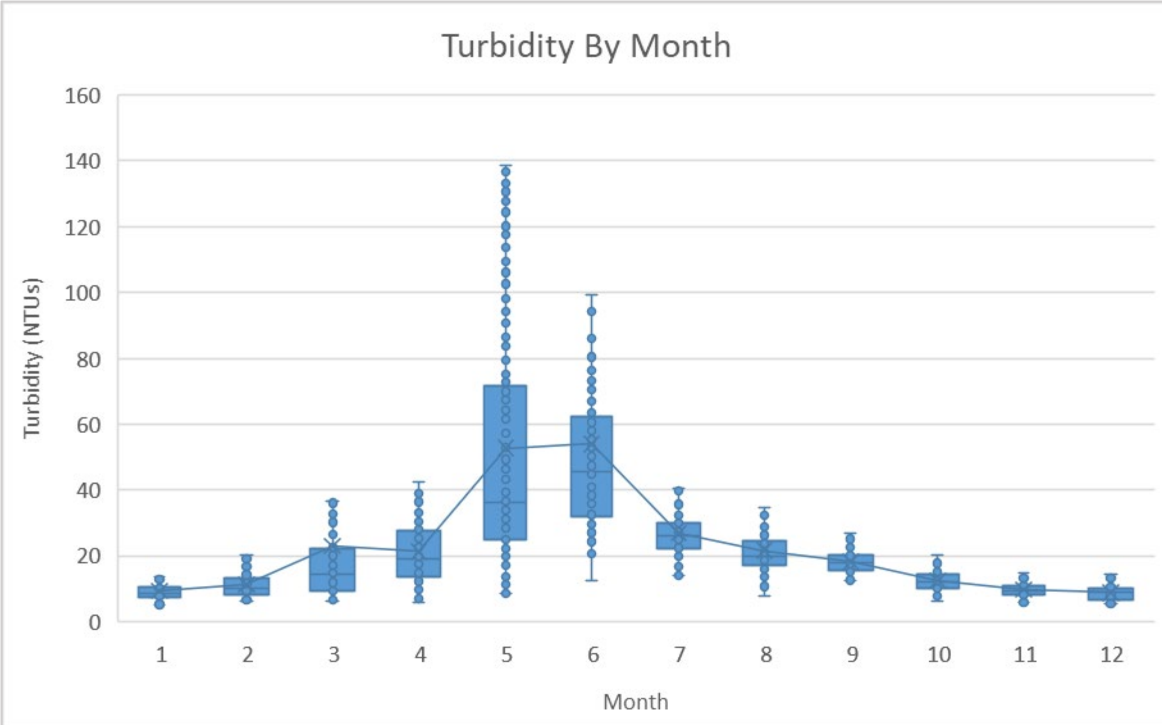

Figure 4-11: Mean daily turbidity by month, Black Eagle Reservoir, April 5, 2013 through December 1, 2018.

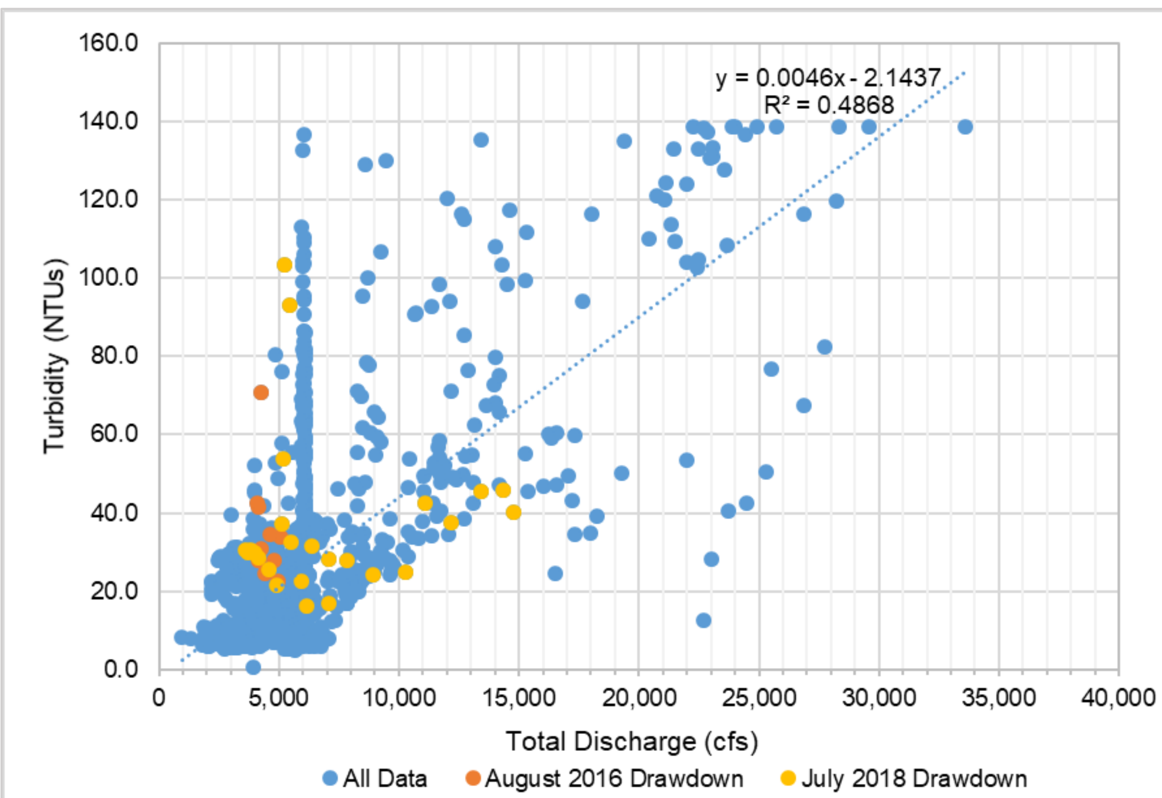

Figure 4-12: Mean daily turbidity versus mean daily flow (spill and generation), Black Eagle Reservoir, April 5, 2013 through December 1, 2018.

Figures 4-12 shows turbidity in relationship to river discharge. Overall, there is limited correlation between river discharge and turbidity, but turbidity generally increases with discharge rates.

4.5 Conclusions

In August 2016, Black Eagle Reservoir was drawn down to approximately 3284.9 feet, and the drawdown rate generally stayed at or below the specified rates in the 2009 Drawdown Plan. During the August 2016 drawdown when the WSE declined to 3286 and 3285 feet, hourly turbidity increased briefly from approximately 30 NTUs to approximately 90 NTUs, then generally returned to the baseline level.

In July 2018, Black Eagle Reservoir was drawn down to approximately 3279.1 feet, and the drawdown generally stayed at or below the rates specified in the 2009 Drawdown Plan, except for one daily rate and some hourly drawdown rates that exceeded the value. A large flood occurred in June 2018 that caused the spillway stanchions to be tripped on June 21, 2018, which made it difficult for the operators to control WSEs and drawdown rates. During the July 2018 drawdown, turbidity increased from approximately 30 NTUs to approximately 138 NTUs when the WSE declined below 3285 feet. The turbidity measurements appeared to increase in response to the drawdown but 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 above 100 NTUs during spring flows and is around 20-30 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 3224 feet. A drawdown event is defined by WSE dropping below 3223 feet as shown by the green lines in Figure 5-1. Water surface elevation data were collected at 15-minute intervals at Rainbow Reservoir from September 10, 2015 to December 1, 2018 and converted to daily means as shown in Figure 5-1. The data collected during this period indicate there were some fluctuations of WSE below 3223 feet that are not reflective of drawdown events. There was one drawdown event that occurred in September 2018. Turbidity and elevation data were available for the drawdown event. No discharge data was available for the drawdown event.

It requires 110 hours (4.5 days) to drawdown Rainbow Reservoir from full pool elevation to crest (3212 feet). Maintaining the drawdown schedule requires continuous attendance by the operators.

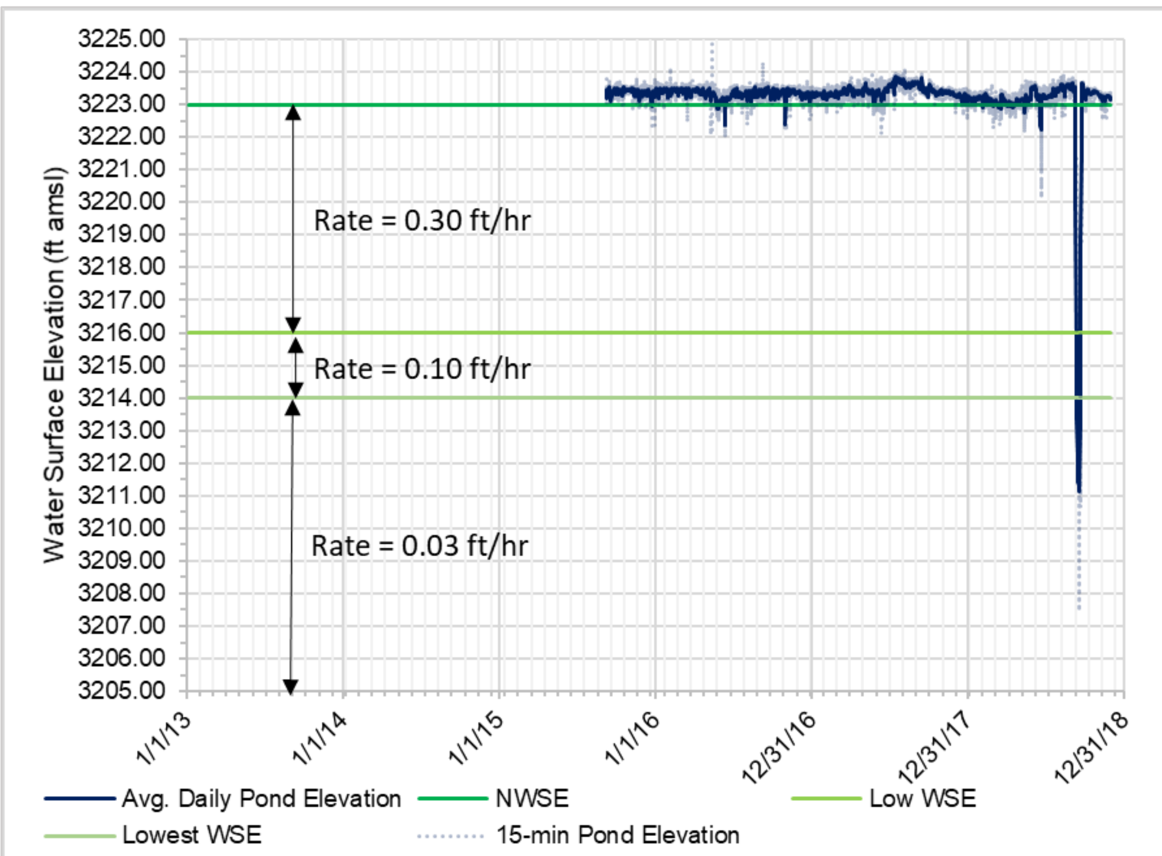

Figure 5-1: Mean daily water surface elevation, Rainbow Reservoir, September 10, 2015 through December 1, 2018. The green lines represent the drawdown thresholds.

5.2 September 2018 Drawdown

The September 2018 drawdown generally occurred between September 10, 2018 to September 24, 2018. The drawdown was 15.5 feet, with minimum 15-minute WSE of 3207.5 feet.

5.2.1 September 2018 Drawdown Rates

During the September 2018 drawdown of Rainbow Reservoir, the pond elevation was generally drawn down at the rates specified in the 2009 Drawdown Plan, except for some hourly drawdown rates that exceeded the value (Figure 5-2).

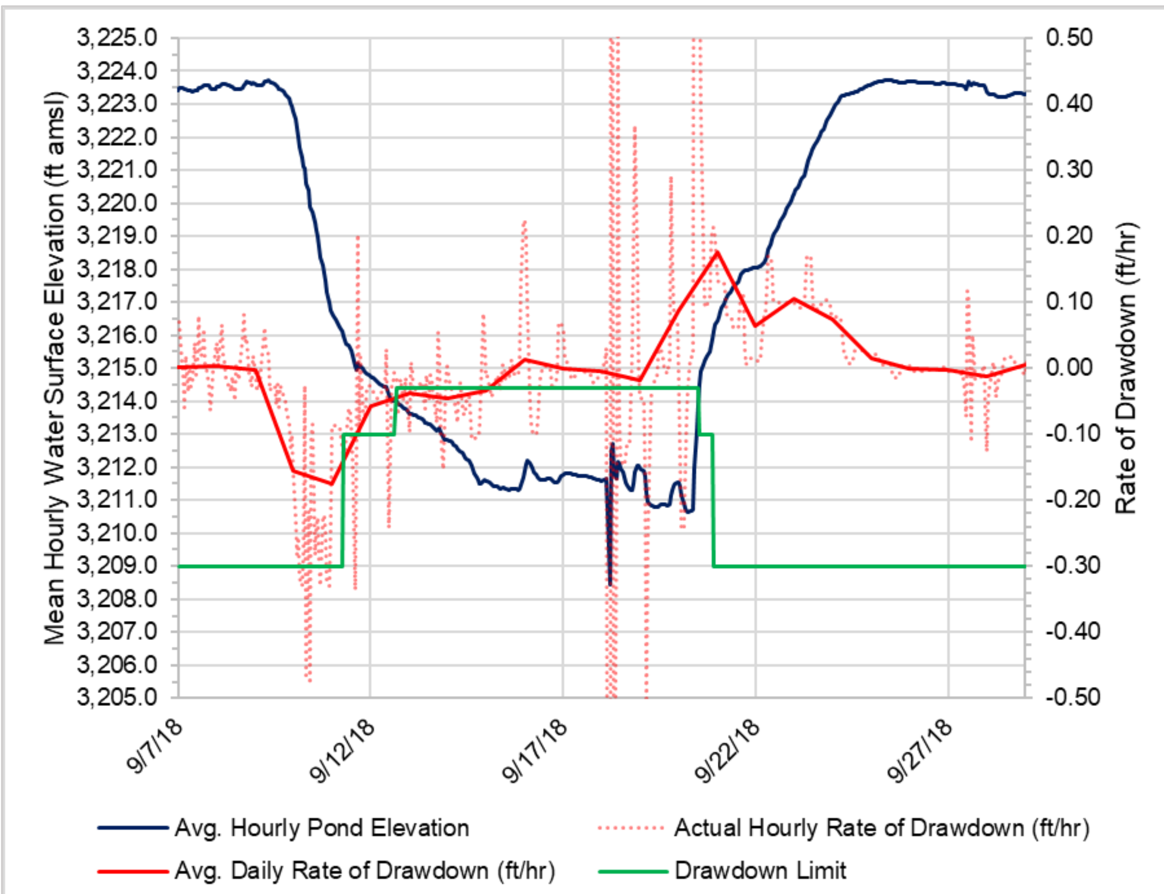

Figure 5-2. Hourly water surface elevation with daily and hourly rate of drawdown, Rainbow Reservoir, during drawdown September 2018. The green line indicates the limits to the drawdown rate per the 2009 Drawdown Plan.

A total of 87 hourly drawdown rates exceeded the Drawdown Plan rates. During those hours the average drawdown rate was 0.16 feet per hour, with a maximum drawdown rate of 2.22 feet per hour.

5.2.2 September 2018 Turbidity

Water surface elevation and turbidity data are available for the September drawdown (Figure 5-3). During the September 2018 drawdown the reservoir was low enough that the generators could not operate, therefore, the hydrolab sensor was used to supplement the turbidity data. Based on the hydrolab data, there was a noticeable spike in turbidity up to 367 NTU during the drawdown, with a significant increase when the reservoir was near WSE 3,216. Turbidity data compared to the September 2018 drawdown rates are shown in Figure 5-4. 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 Drawdown Plan on a daily basis.

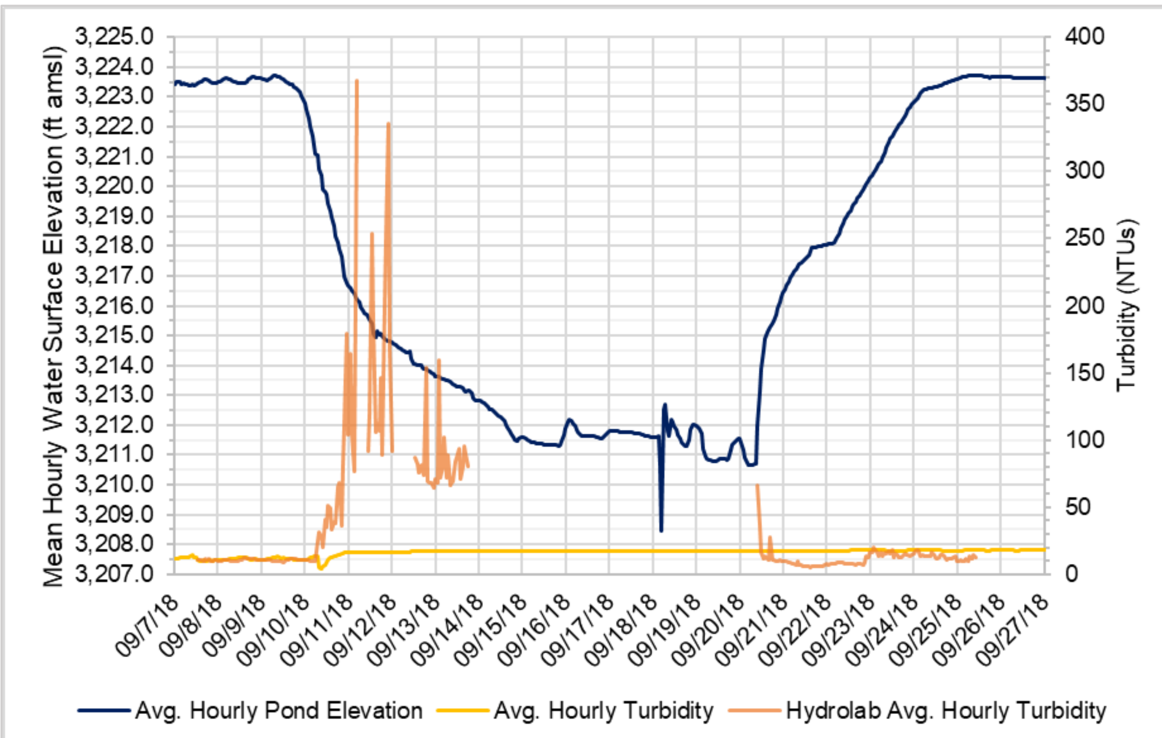

Figure 5-3: Mean hourly water surface elevation and mean hourly turbidity, Rainbow Reservoir, September 10, 2018 through September 24, 2018.

The hydrolab turbidity data was not continuously collected during the event due to the exposure of the sensor and debris disturbing the sensor, therefore the quality of the data may be limited. Also, based on NorthWestern Energy 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 power house intake on left bank, then once the powerhouse is shut down, 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 spike in turbidity when the powerhouse is shut down and then reduces once the new channel is cut through the sediments.

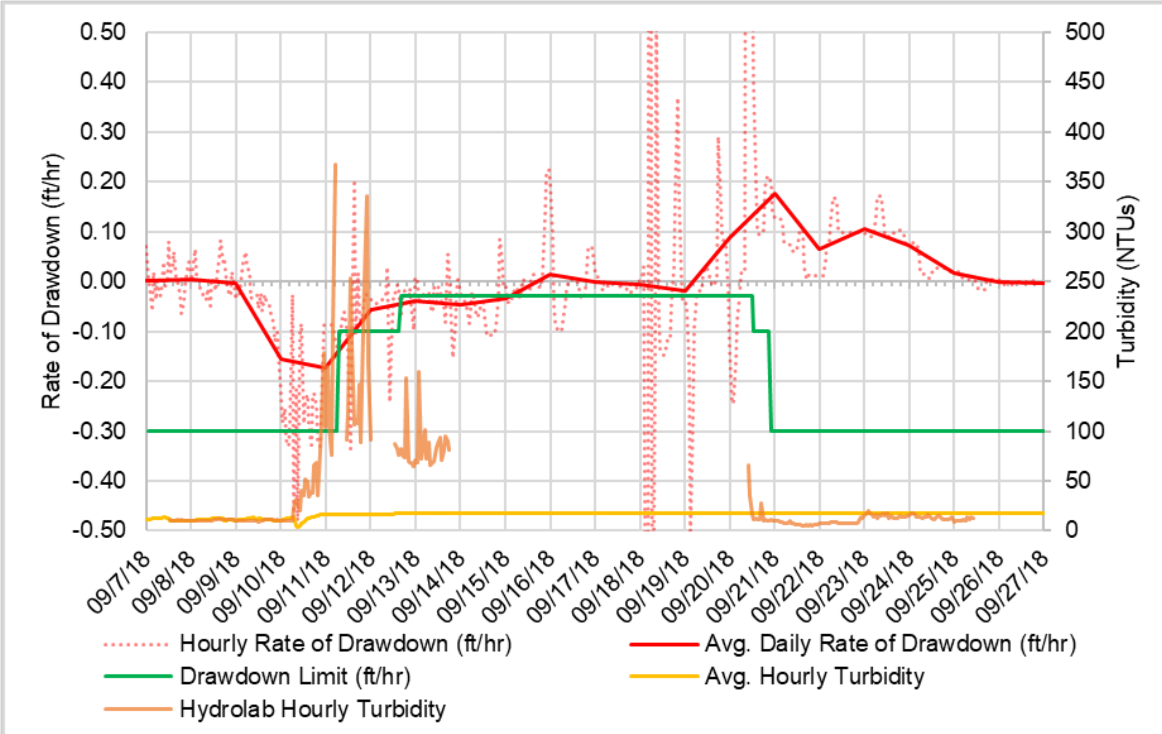

Figure 5-4. Mean daily and hourly rate of change in reservoir elevation and mean hourly turbidity, Rainbow Reservoir, September 10, 2018 through September 24, 2018.

5.3 Rainbow Turbidity

Turbidity in the Missouri River varies seasonally. Figure 5-5 shows turbidity and water surface elevations measured at Rainbow from September 2013. 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 (near 20 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 220 NTUs during the spring. These spikes in turbidity were generally unrelated to reservoir operations at Rainbow Dam. During the drawdown event there was a noticeable increase in turbidity based on the hydrolab sensor data, but otherwise the noticeable spikes in turbidity observed were unrelated to reservoir drawdowns (Figure 5-5).

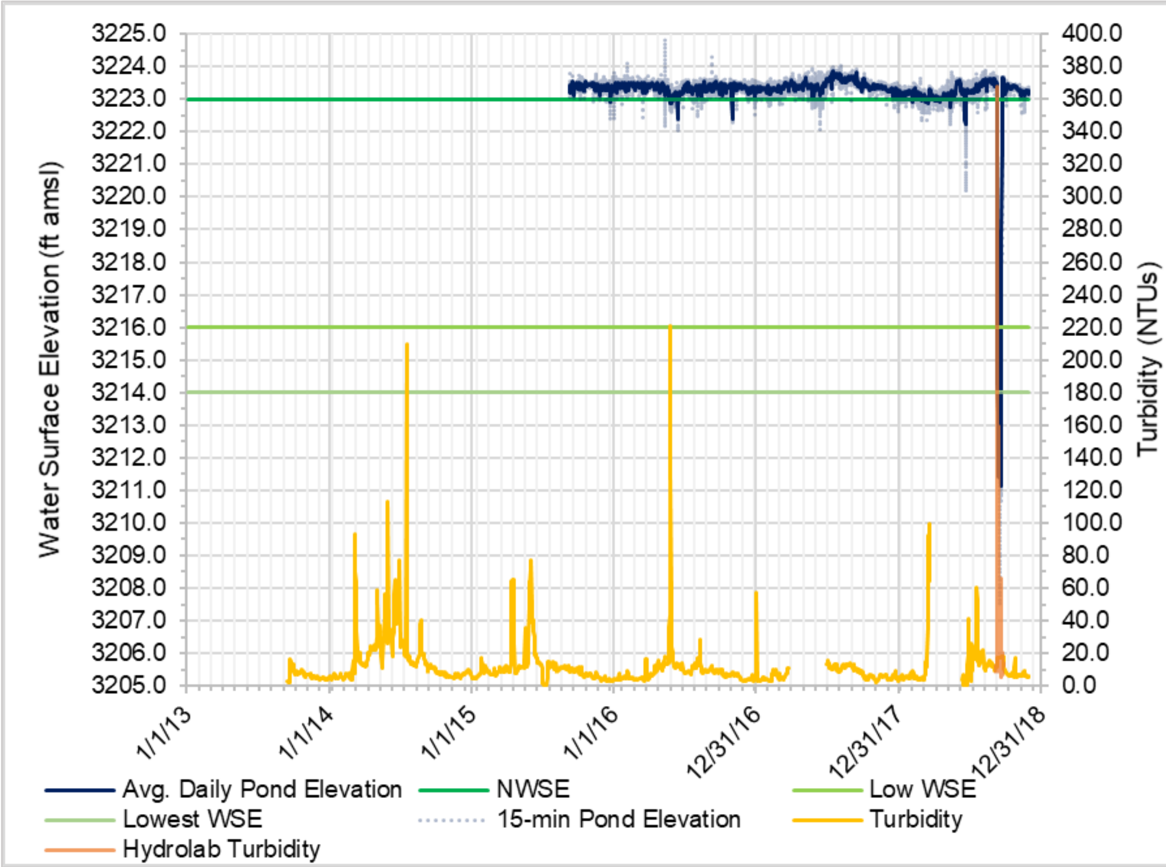

Figure 5-5: Mean daily turbidity and water surface elevation, Rainbow Reservoir, September 16, 2013 through December 1, 2018.

5.4 Conclusions

In September 2018, Rainbow Reservoir was drawn down to approximately 3207.5 feet, and the drawdown rate generally stayed at or below the specified rates in the 2009 Drawdown Plan on a daily basis but several of the hourly drawdown rates exceeded the specified rates. During the September 2018 drawdown there was a noticeable spike in the hourly turbidity based on the hydrolab data, but the quality of this data may be limited due to exposure of the sensor.

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 20-30 NTUs during the summer and early fall months.

6 Results – Cochrane

6.1 Drawdown Occurrences and Drawdown Rate Plan

The Cochrane Reservoir normal operating water surface elevations are between 3110 and 3120 feet. A drawdown event is defined by WSE dropping below 3110 feet as shown by the green lines in Figure 6-1. Following the commencement of operations of the new Rainbow powerhouse (April 22, 2013), the FERC-approved Cochrane drawdown plan specifies that the reservoir not be drawn down more than 0.10 feet per hour between WSE 3110 feet and 3108.9 feet and no more than 0.03 feet per hour below 3108.9 feet.

Water surface elevation data are available from January 6, 2013 through December 1, 2018 (Figure 6-1). Over the monitoring period, one drawdown event occurred in October 2014. Turbidity data were available for the drawdown event. Discharge data were not available for the October 2014 drawdown. Specifics regarding the WSE, turbidity, and drawdown rates (rate of change in WSE) for the drawdown event are discussed in the following sections.

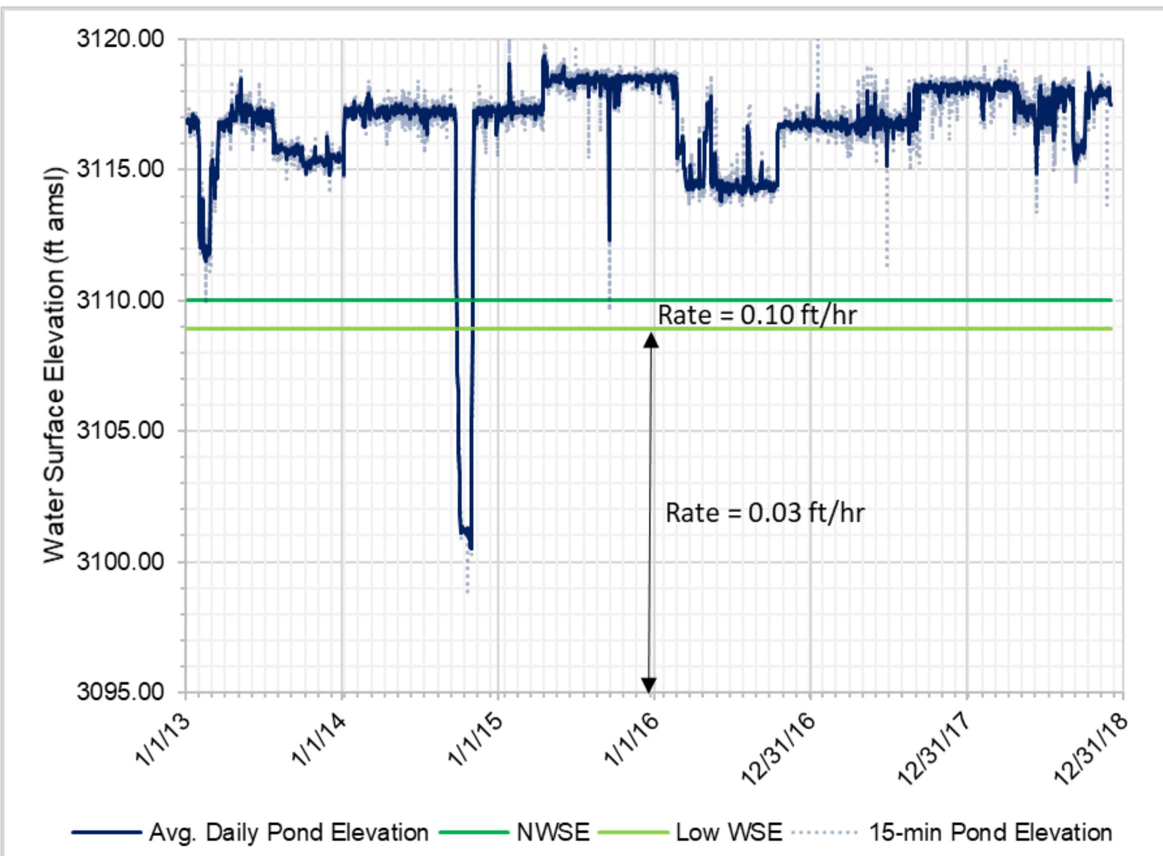

Figure 6-1: Mean daily water surface elevation, Cochrane Reservoir, January 6, 2013 through December 1, 2018. The green lines represent the drawdown thresholds.

6.2 October 2014 Drawdown

The October 2014 drawdown generally occurred between September 26, 2014 to November 2, 2014. The drawdown was 11.2 feet, with minimum 15-minute WSE of 3098.8 feet.

6.2.1 October 2014 Drawdown Rates

During the October 2014 drawdown of Cochrane Reservoir, the pond elevation was generally drawn down on a daily basis at the rates specified in the 2009 Drawdown Plan, except for some hourly drawdown rates that exceeded the value (Figure 6-2).

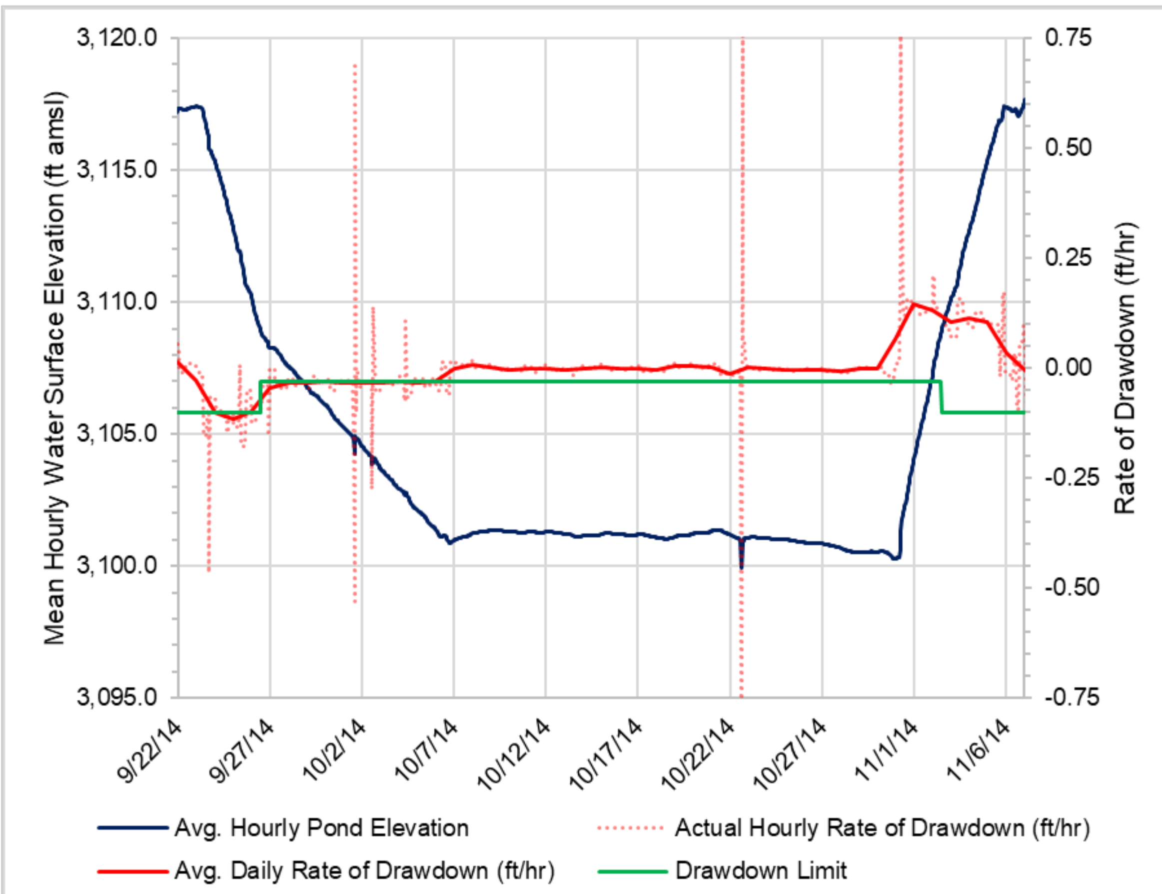

Figure 6-2. Hourly water surface elevation with daily and hourly rate of drawdown, Cochrane Reservoir, during drawdown October 2014. The green line indicates the limits to the drawdown rate per the 2009 Drawdown Plan.

A total of 173 hourly drawdown rates exceeded the Drawdown Plan rates, with 131 of those during the 0.03 feet per hour limit. During those hours, the average drawdown rate was 0.08 feet per hour, with a maximum drawdown rate of 1.09 feet per hour.

6.2.2 October 2014 Turbidity

Water surface elevation and turbidity data are available for the October 2014 drawdown (Figure 6-3). During the October 2014 drawdown the reservoir was low enough that the generators could not operate, therefore, the hydrolab sensor was used to supplement the turbidity data. During the October 2014 drawdown there was a noticeable spike in the turbidity near WSE 3108.5, which is near the WSE 3108.9, where the drawdown rate changes to 0.03 feet per hour. Turbidity also spiked near WSE 3105.0 and at the bottom of the drawdown near WSE 3101.0. When the pond was drawn down the turbidity increased from about 20 NTUs up to about 167 NTUs, but then quickly returned to the baseline level of about 20 NTUs. Turbidity data compared to the October 2014 drawdown rates are shown in Figure 6-4. The turbidity increased noticeably even though the drawdown rate was near the Drawdown Plan lower limit, and then the turbidity returned to baseline conditions.

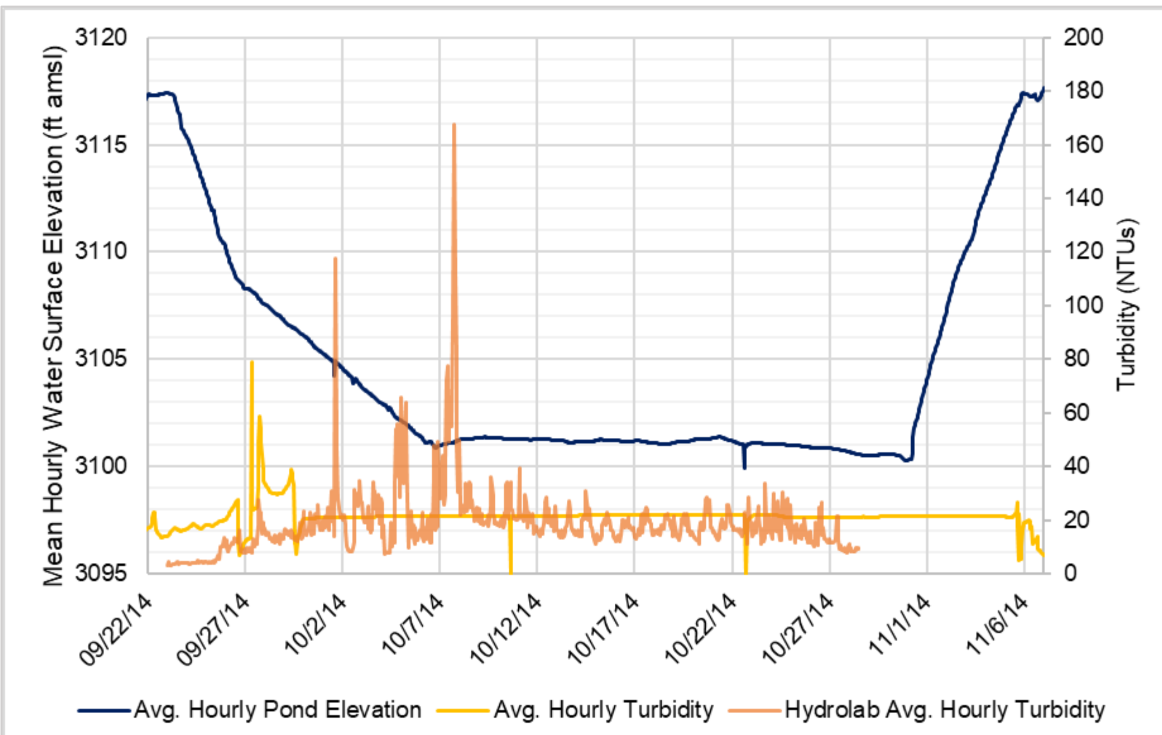

Figure 6-3: Mean hourly water surface elevation and mean hourly turbidity, Cochrane Reservoir, September 10, 2018 through September 24, 2018.

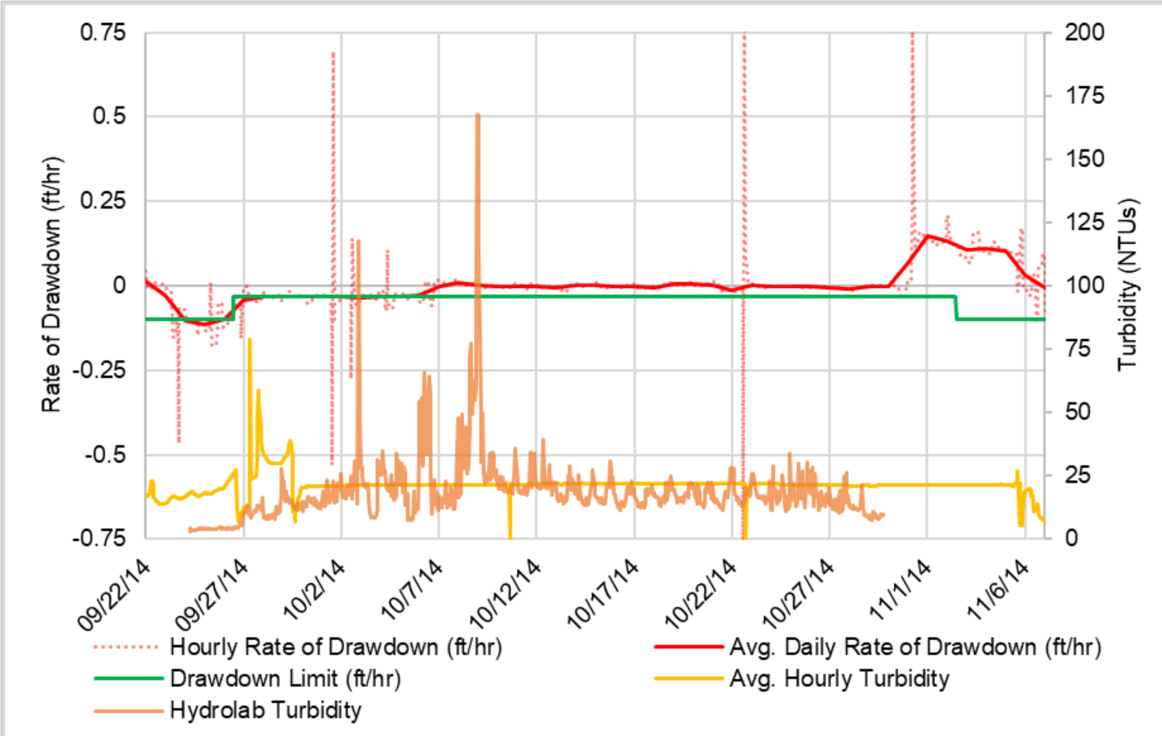

Figure 6-4. Mean daily and hourly rate of change in reservoir elevation and mean hourly turbidity, Cochrane Reservoir, September 22, 2014 through November 6, 2014.

6.3 Cochrane Turbidity

Turbidity in the Missouri River varies seasonally. Figure 6-5 shows turbidity and water surface elevations measured at Cochrane from January 2013. 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 (near 20 NTUs), which is likely a result of irrigation return flows entering the river system.

At its peak, turbidity in the Missouri River at Cochrane Dam reached approximately 240 NTUs during the summer in 2018. These spike in turbidity were generally unrelated to reservoir operations at Cochrane Dam. During the drawdown event there was an increase in turbidity and but the other noticeable spikes in turbidity observed were unrelated to reservoir drawdowns (Figure 6-5).

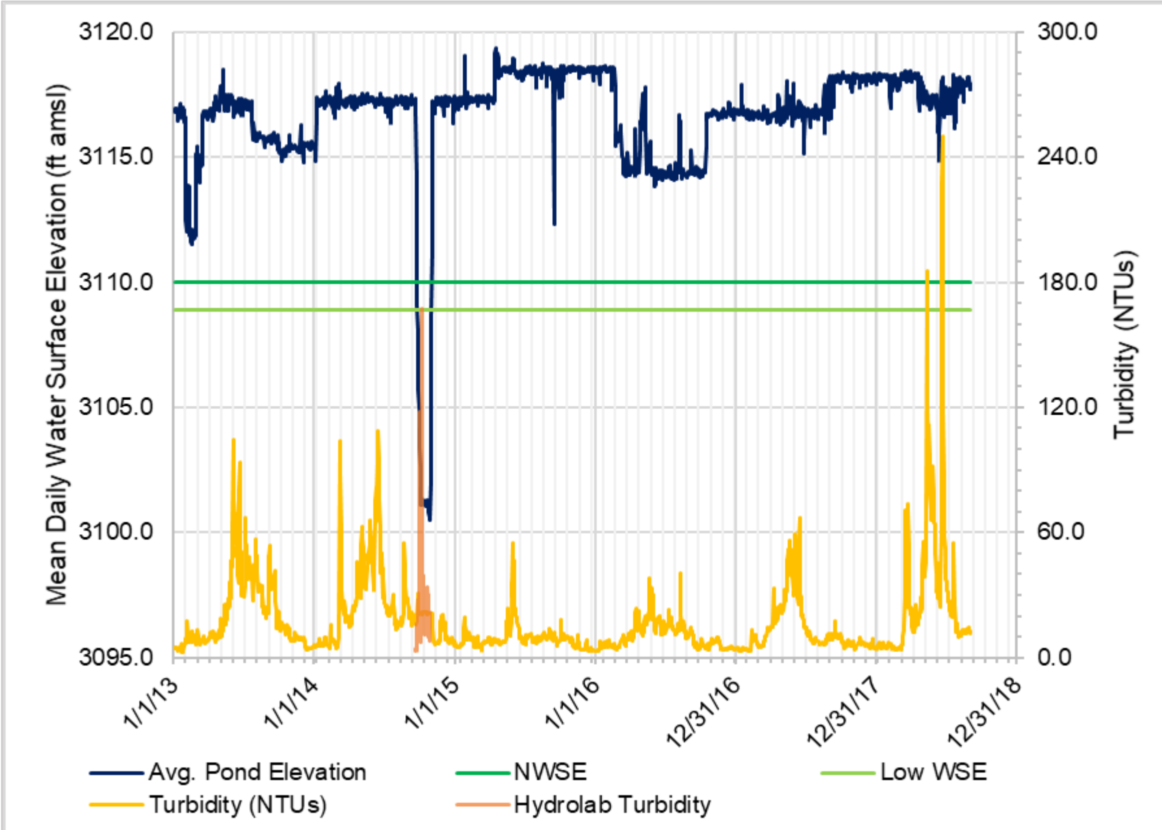

Figure 6-5: Mean daily turbidity and water surface elevation, Cochrane Reservoir, January 6, 2013 through December 1, 2018.

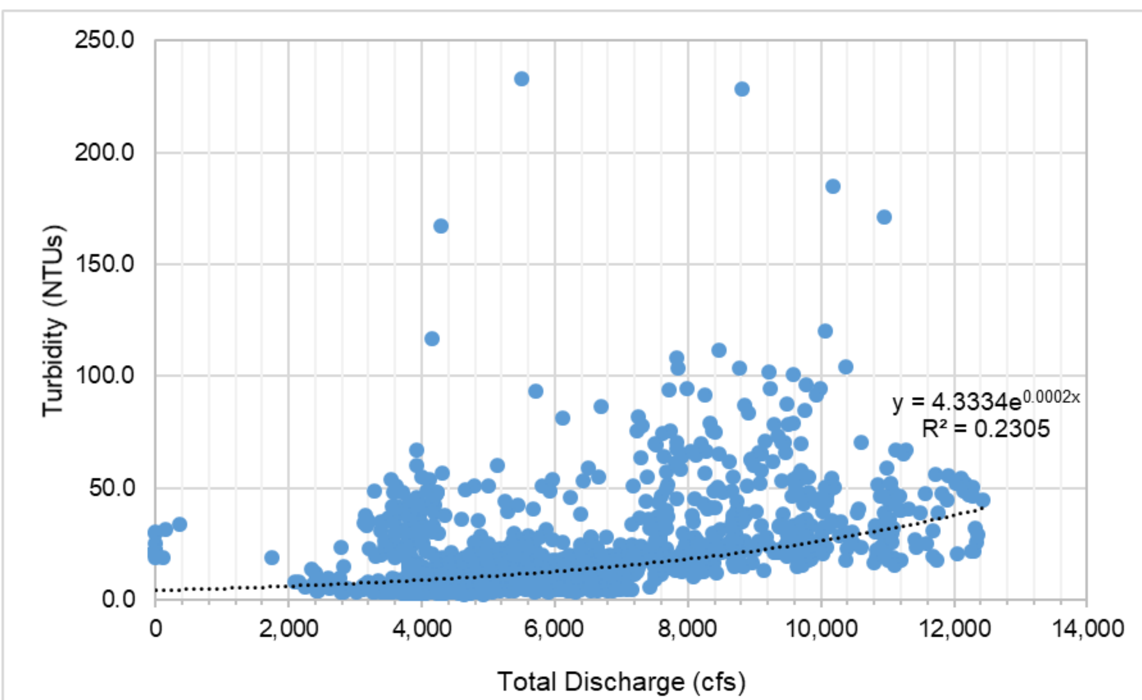

Figure 6-6: Mean daily turbidity versus mean daily flow (spill and generation), Cochrane Reservoir, January 6, 2013 through December 1, 2018.

Figures 6-6 shows turbidity in relationship to river discharge. Overall, there is limited correlation between river discharge and turbidity, but turbidity generally increases with discharge rates.

6.4 Conclusions

In October 2014, Cochrane Reservoir was drawn down to approximately 3098.8 feet. The drawdown rates during this event generally stayed at or below the specified rates in the 2009 Drawdown Plan on a daily basis, but several of the hourly drawdown rates exceeded the specified rates, particularly the lower limit of 0.03 feet per hour. The hours when the drawdown rate exceeded 0.03 reflects the difficulty of managing a drawdown rate that is so small it may not be fully controllable or measurable and may exceed the operator's ability to control flows. During the October 2014 drawdown there was a brief but noticeable spike in the hourly turbidity, but the turbidity quickly returned to baseline conditions. The turbidity spike may have been caused by the sediments that are deposited in front of the waste gates.

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 240 NTUs during spring or summer flows and then returns to around 20-30 NTUs during the early fall months.

7 Results – Ryan

7.1 Drawdown Occurrences and Drawdown Rate Plan

The Ryan Reservoir normal operating WSE is approximately 3035 - 3037 feet. Water surface elevation data were collected at 15-minute intervals at Ryan Reservoir from January 6, 2013 to December 1, 2018 and converted to a daily mean as shown in Figure 7-1. A drawdown event is defined by WSE dropping below 3035 feet as shown by the green lines in Figure 7-1. The Drawdown Plan specifies that the reservoir not be drawn down more than 0.20 feet per hour between WSE 3035 feet and 3027 feet, 0.10 feet per hour between WSE 3027 feet to WSE 3024 feet, and no more than 0.05 feet per hour below 3024 feet. The data collected during this period indicate there were some fluctuations of WSE below 3035 feet that are not reflective of drawdown events. There were two brief periods where the data indicate that the reservoir WSE was less than 3035 feet; one in July 2017; and the second in September 2018. Turbidity, elevation and discharge data were available for both drawdown events.

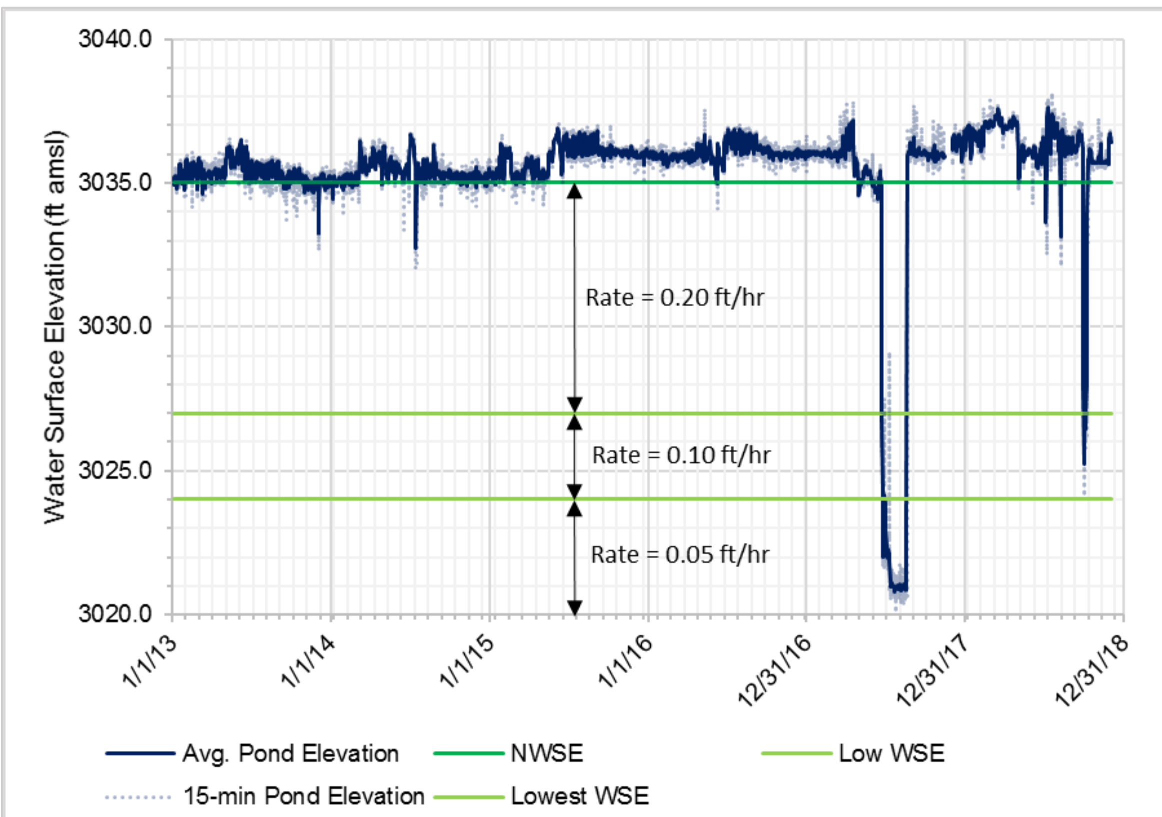

Figure 7-1: Mean daily water surface elevation (in blue), Ryan Reservoir, January 6, 2013 through December 1, 2013. The green lines represent the drawdown thresholds.

7.2 July 2017 Drawdown

The July 2017 drawdown generally occurred between June 20, 2017 to August 19, 2017. The drawdown was 14.9 feet, with minimum 15-minute WSE of 3020.1 feet.

7.2.1 July 2017 Drawdown Rates

During the July 2017 drawdown of Ryan Reservoir, the pond elevation was generally drawn down at the rates specified in the 2009 Drawdown Plan on a daily basis, however there were several hourly drawdown rates that exceeded the values (Figure 7-2).

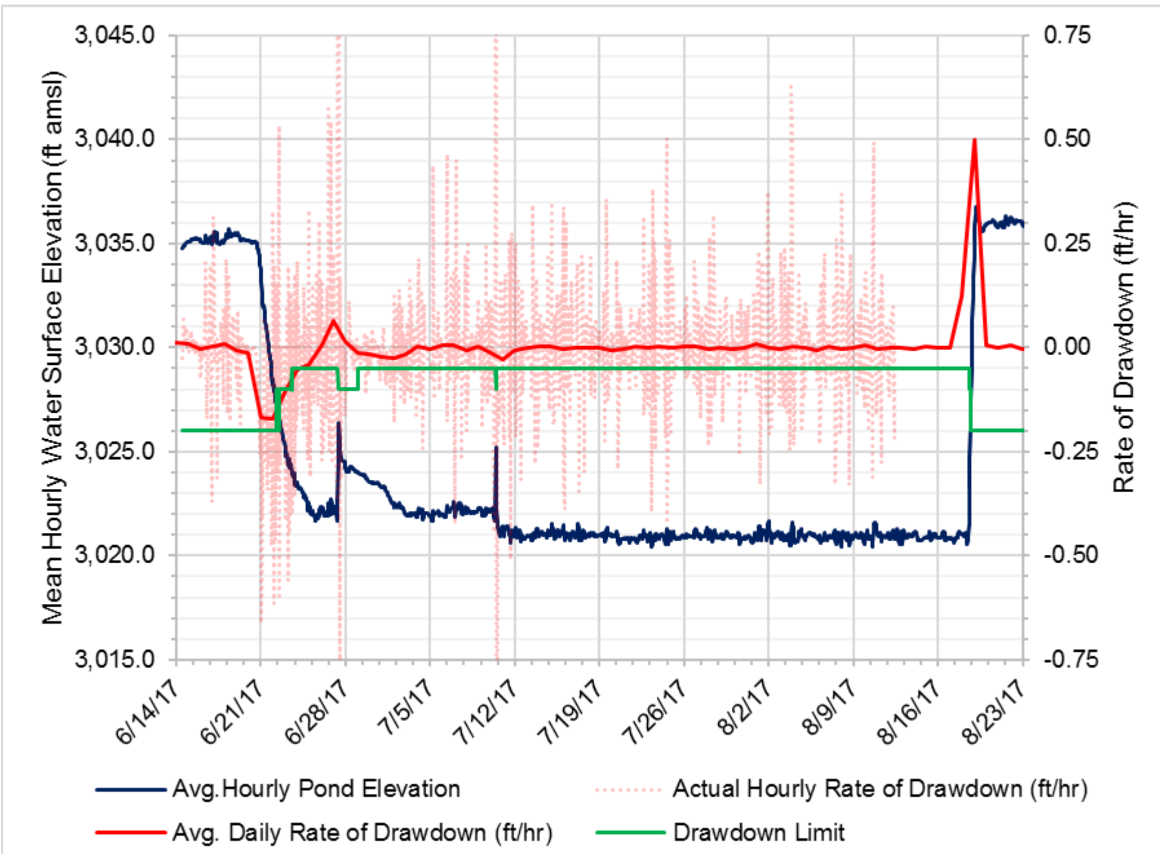

Figure 7-2. Hourly water surface elevation with daily and hourly rate of drawdown, Ryan Reservoir, during drawdown July 2017. The green line indicates the limits to the drawdown rate per the 2009 Drawdown Plan.

A total of 408 hourly drawdown rates exceeded the Drawdown Plan rates. During those hours the average drawdown rate was 0.17 feet per hour, with a maximum drawdown rate of 3.02 feet per hour.

7.2.2 July 2017 Turbidity

Water surface elevation and turbidity data are available for the July 2017 drawdown (Figure 7-3). During the July 2017 drawdown when the WSE declined to 3024 and 3022 feet, hourly turbidity increased briefly from approximately 20 NTUs to approximately 75 NTUs, then generally returned to the baseline level. Turbidity data compared to the July 2017 drawdown rates is shown in Figure 7-4. The turbidity increased when the drawdown rate was near the Drawdown Plan limit of 0.05 feet per hour below WSE 3024. Turbidity data compared to the average daily and hourly discharge rates are shown in Figure 7-5. The turbidity data showed poor correlation with the discharge rates during the July 2017 drawdown.

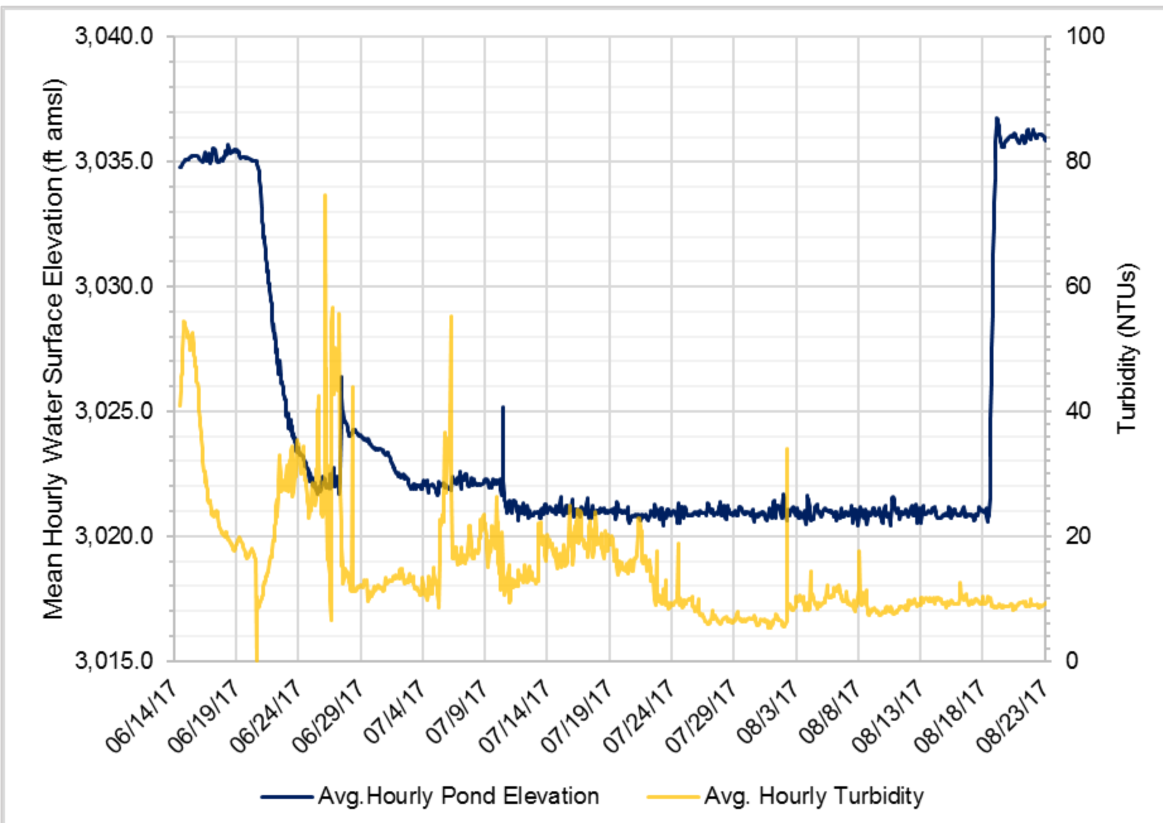

Figure 7-3: Mean hourly water surface elevation and mean hourly turbidity, Ryan Reservoir, June 14, 2017 through August 23, 2017.

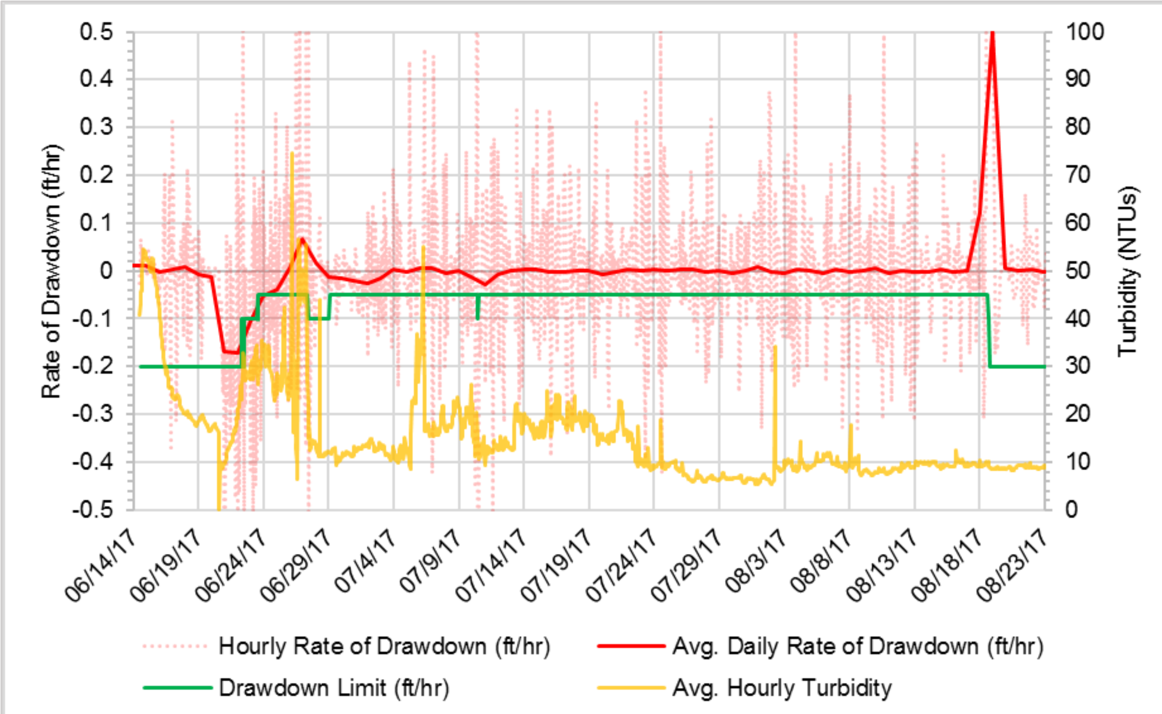

Figure 7-4. Mean daily and hourly rate of change in reservoir elevation and mean hourly turbidity, Ryan Reservoir, June 14, 2017 through August 23, 2017.

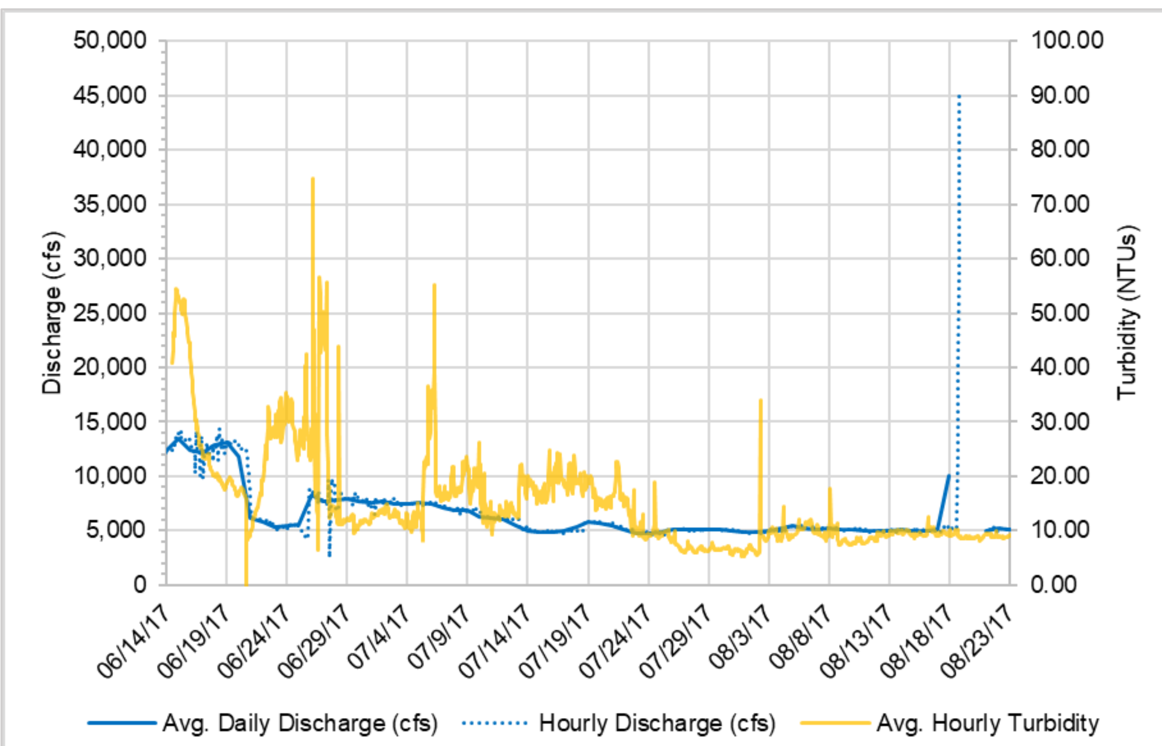

Figure 7-5. Mean daily and hourly discharge rate and mean hourly turbidity, Ryan Reservoir, June 14, 2017 through August 23, 2017.

7.3 September 2018 Drawdown

The September 2018 drawdown generally occurred between September 27, 2018 to October 8, 2018. The drawdown was 10.9 feet, with minimum 15-minute WSE of 3024.1 feet.

7.3.1 September 2018 Drawdown Rates

During the September 2018 drawdown of Ryan Reservoir, the pond elevation was generally drawn down at the rates specified in the 2009 Drawdown Plan on a daily basis, however there were several hourly drawdown rates that exceeded the values (Figure 7-6).

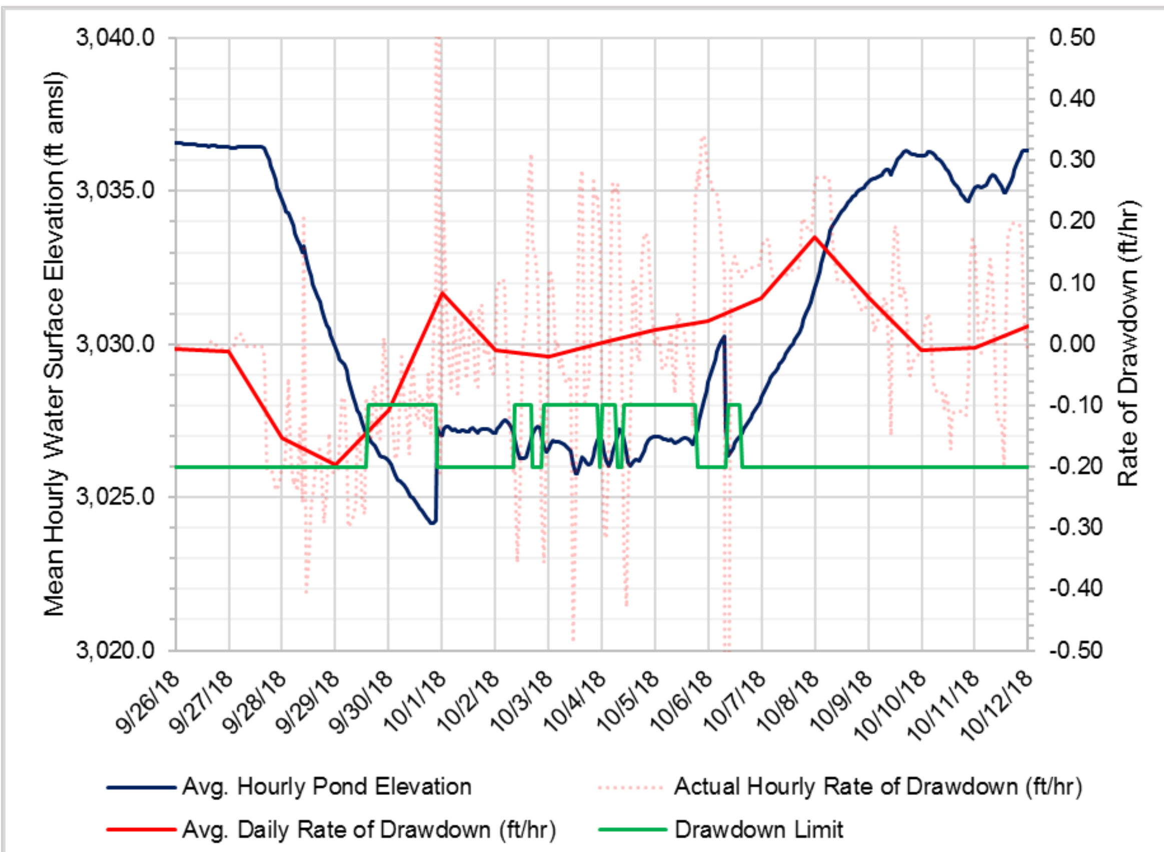

Figure 7-6. Hourly water surface elevation with daily and hourly rate of drawdown, Ryan Reservoir, during drawdown September 2018. The green line indicates the limits to the drawdown rate per the 2009 Drawdown Plan.

A total of 79 hourly drawdown rates exceeded the Drawdown Plan rates. During those hours the average drawdown rate was 0.27 feet per hour, with a maximum drawdown rate of 2.99 feet per hour.

7.3.2 September 2018 Turbidity

Water surface elevation and turbidity data are available for the September 2018 drawdown (Figure 7-7). During the September 2018 drawdown there was limited correlation with the WSE and hourly turbidity, generally staying in the baseline conditions that range from approximately 10 NTUs to approximately 30 NTUs. Turbidity data compared to the September 2018 drawdown rates is shown in Figure 7-8. The turbidity data had limited correlation with the drawdown rates during the September 2018 drawdown. Turbidity data compared to the average daily and hourly discharge rates is shown in Figure 7-9. The turbidity data showed poor correlation with the discharge rates during the September 2018 drawdown.

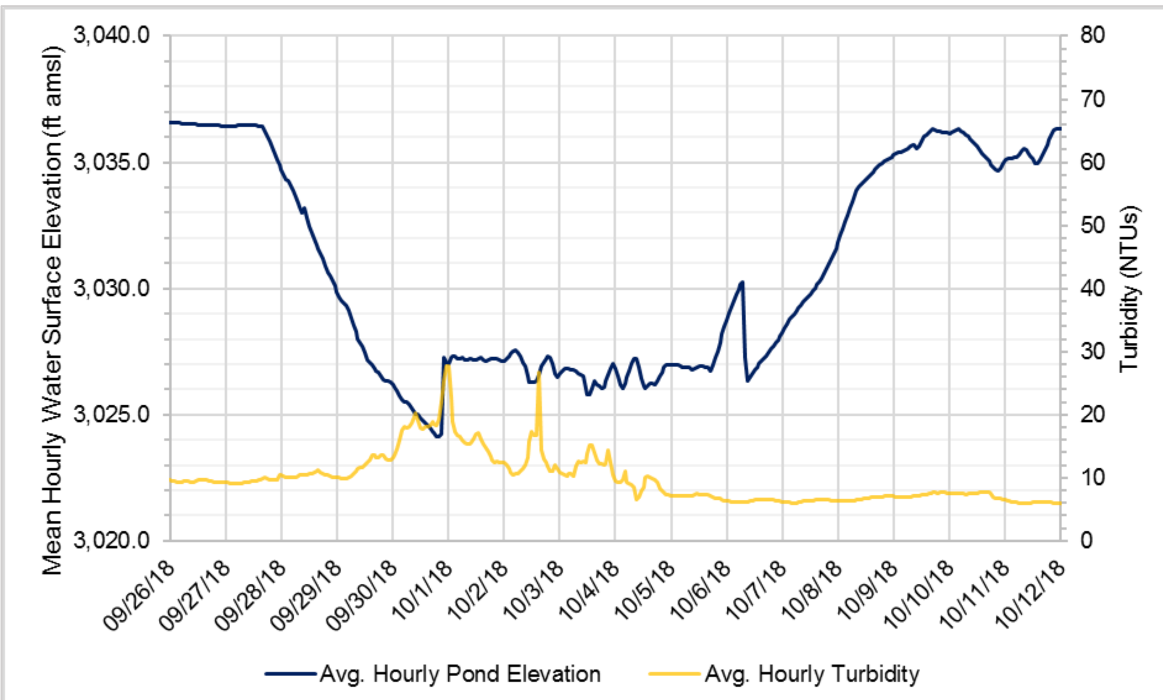

Figure 7-7: Mean hourly water surface elevation and mean hourly turbidity, Ryan Reservoir, September 26, 2018 through October 12, 2018.

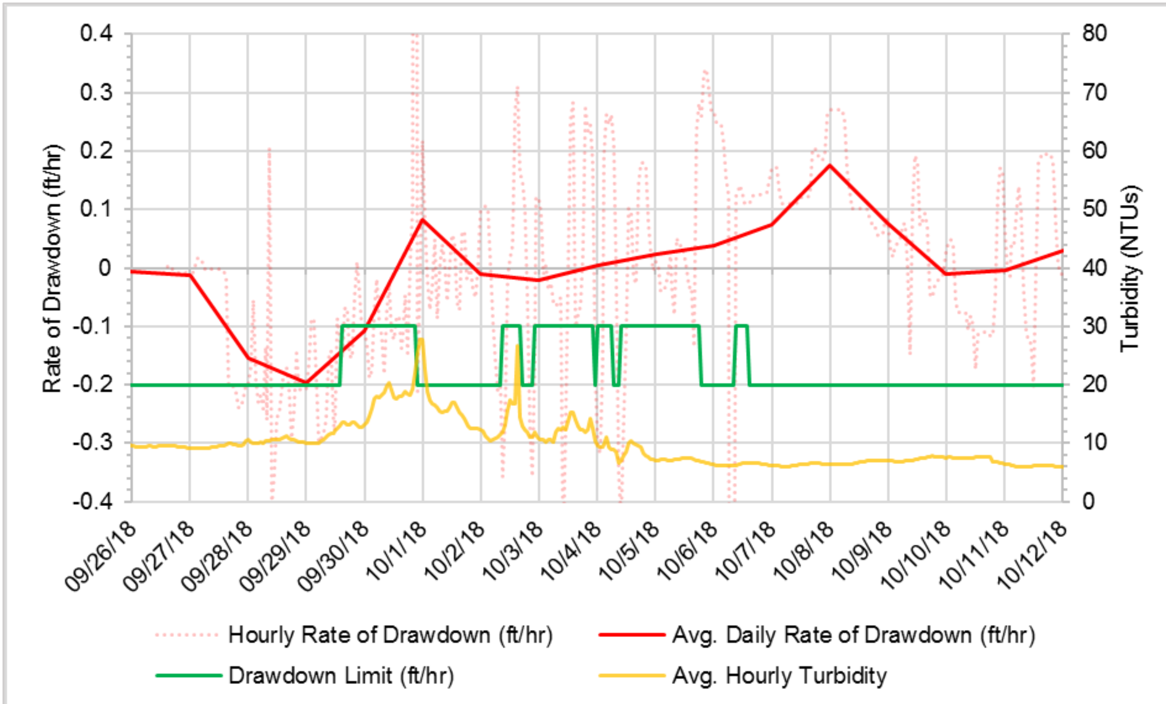

Figure 7-8. Mean daily and hourly rate of change in reservoir elevation and mean hourly turbidity, Ryan Reservoir, September 26, 2018 through October 12, 2018.

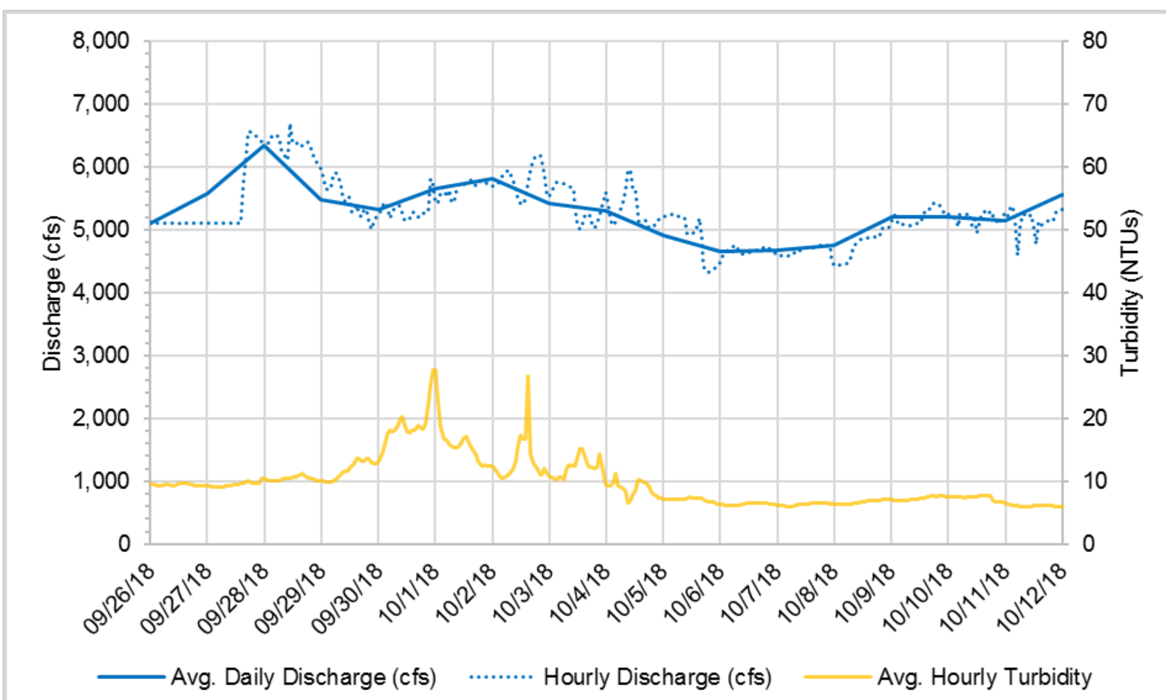

Figure 7-9. Mean daily and hourly discharge rate and mean hourly turbidity, Ryan Reservoir, September 26, 2018 through October 12, 2018.

7.4 Ryan Turbidity

Turbidity in the Missouri River varies seasonally. Figure 7-10 shows turbidity and water surface elevations measured at Ryan Reservoir since January 2013. 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 (near 20 NTUs), which is likely a result of irrigation return flows entering the river system. This is indicated in Figure 7-11 which shows the turbidity and discharge of the 5-year period.

At its peak, turbidity in the Missouri River at Ryan Dam reached approximately 400 NTUs during the June 2018 flooding when river flows peaked around 35,000 cfs. This spike in turbidity was generally unrelated to reservoir operations at Ryan Dam. During the two drawdown events there was minimal increase in turbidity during the drawdown activity; and other larger spikes in turbidity have been observed unrelated to reservoir drawdowns (Figure 7-10).

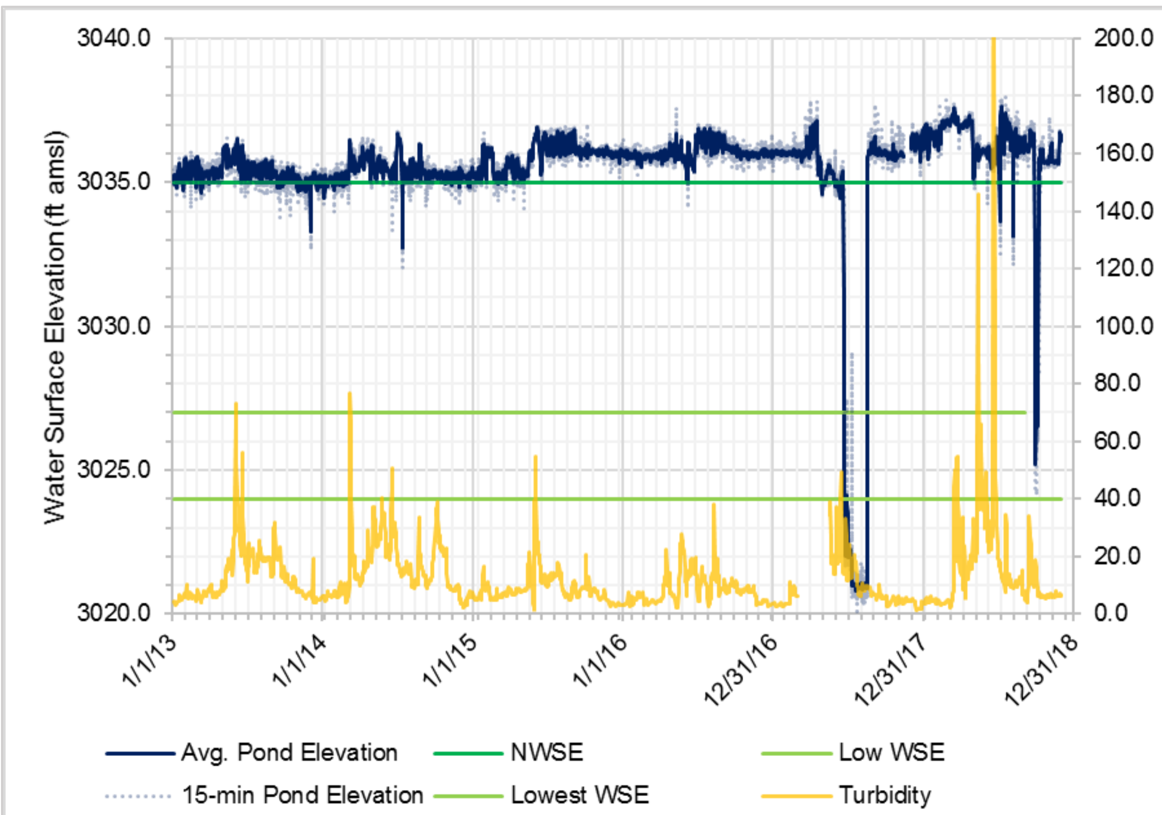

Figure 7-10: Mean daily turbidity and water surface elevation, Ryan Reservoir, January 6, 2013 through December 1, 2018.

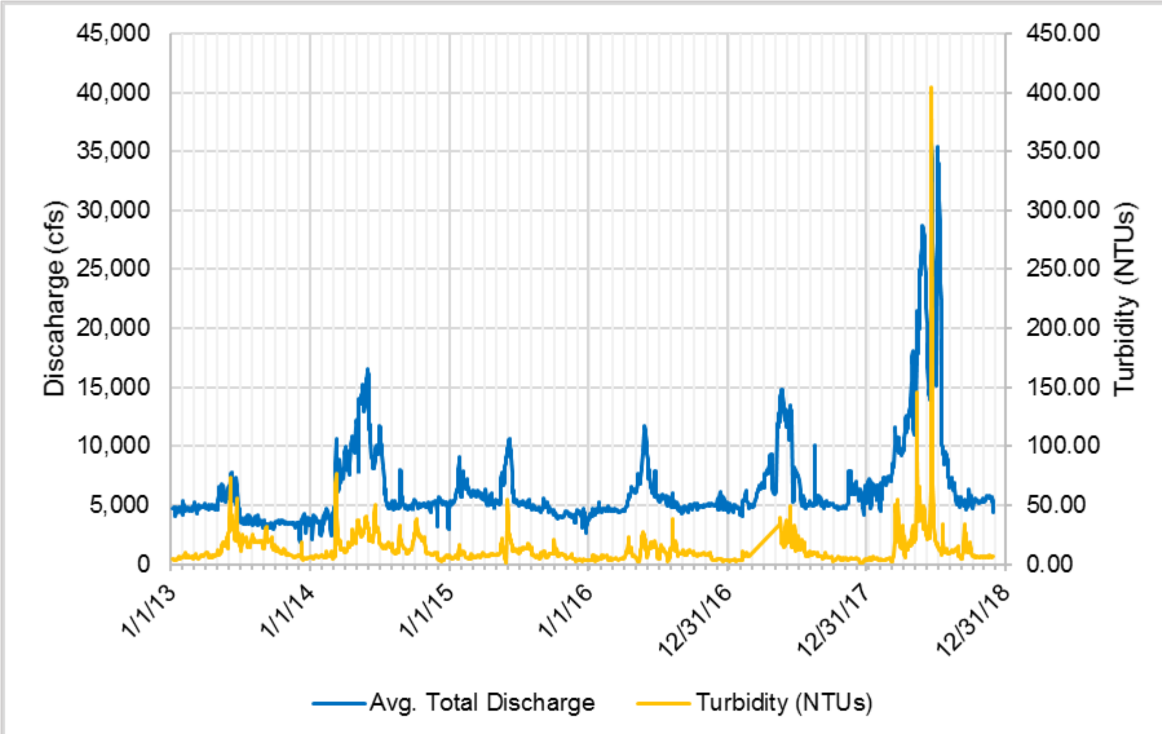

Figure 7-11: Mean daily turbidity and discharge, Ryan Reservoir, January 6, 2013 through December 1, 2018.

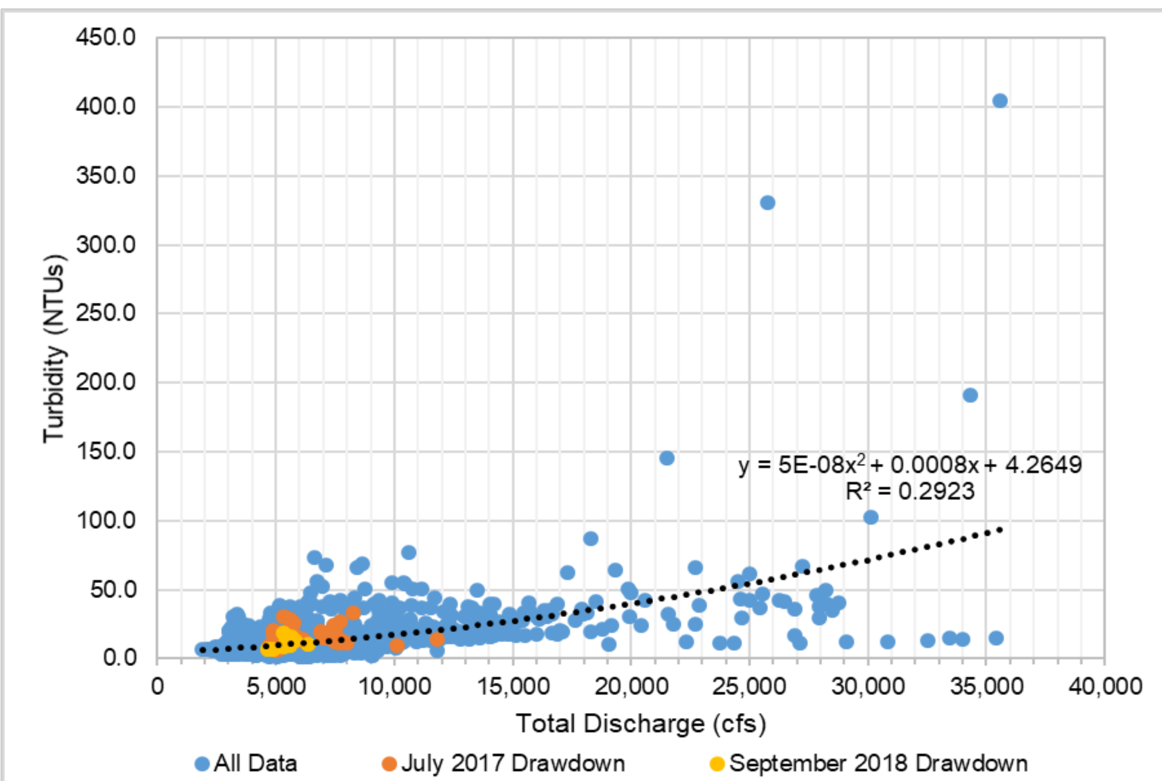

Figure 7-12: Mean daily turbidity versus mean daily flow (spill and generation), Ryan Reservoir, January 6, 2013 through December 1, 2018.

Figures 7-12 shows turbidity in relationship to river discharge. Overall, there is limited correlation between river discharge and turbidity, but turbidity generally increases with discharge rates.

7.5 Conclusions

In July 2017, Ryan Reservoir was drawn down approximately 14.9 feet to WSE 3020.1 feet to install new two new waste gates. The drawdown rates during this event generally stayed at or below the specified rates in the 2009 Drawdown Plan on a daily basis, but several of the hourly drawdown rates exceeded the specified rates. During the July 2017 drawdown when the WSE declined to 3024 and 3022 feet, hourly turbidity increased briefly from approximately 20 NTUs to approximately 75 NTUs, then generally returned to the baseline level.

In September 2018, Ryan Reservoir was drawn down approximately 10.9 feet to WSE 3027.5 feet. The drawdown rates during this event generally stayed at or below the specified rates in the 2009 Drawdown Plan on a daily basis, but several of the hourly drawdown rates exceeded the specified rates. However, the September 2018 drawdown did manage the hourly drawdown rates better than the July 2017 drawdown, likely due to the installation of the two new waste gates that provided the operators with more operational flexibility. During the September 2018 drawdown there was minimal change in the turbidity relative to the baseline conditions.

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 80 NTUs during spring flows and is around 20-30 NTUs during the summer and early fall months. The highest turbidity occurred during the flooding in June of 2018 and reached a peak of about 400 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 2886 and 2887 feet. Water surface elevation data were collected at 15-minute intervals at Morony Reservoir from January 6, 2013 to December 1, 2018 and converted to a daily mean as shown in Figure 8-1. A drawdown event is classified as when the WSE is below 2878 feet as shown by the green lines in Figure 8-1. The drawdown plan specifies the drawdown rate limit is 0.10 feet per hour for WSEs between 2878 and 2870 feet, and 0.05 feet per hour when WSEs are below 2870 feet. Water surface elevations at Morony were never below 2878 feet between 2013 and 2018; therefore, there were no drawdown occurrences in the Morony Reservoir to evaluate. Turbidity, elevation and discharge data were generally available for entire 5-year period.

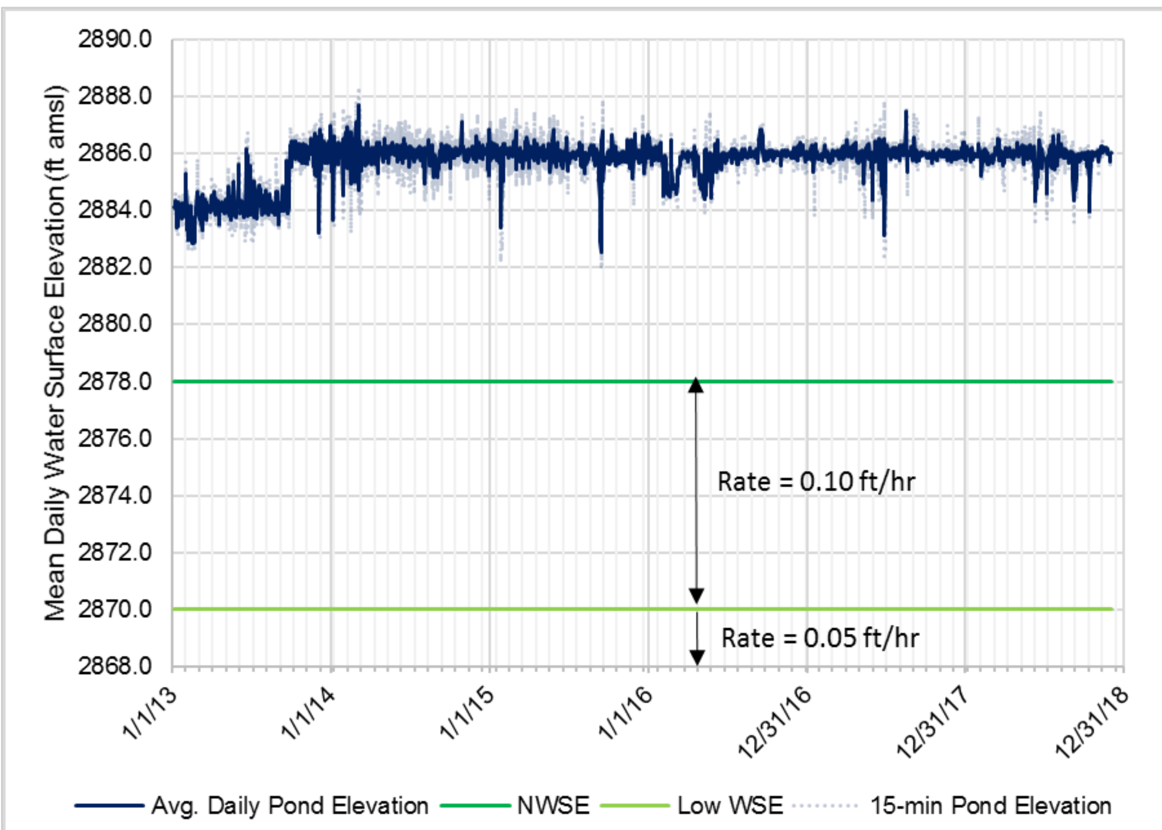

Figure 8-1: Mean daily water surface elevation (in blue), Morony Reservoir, January 6, 2013 through December 1, 2013. The green lines represent the drawdown thresholds.

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.

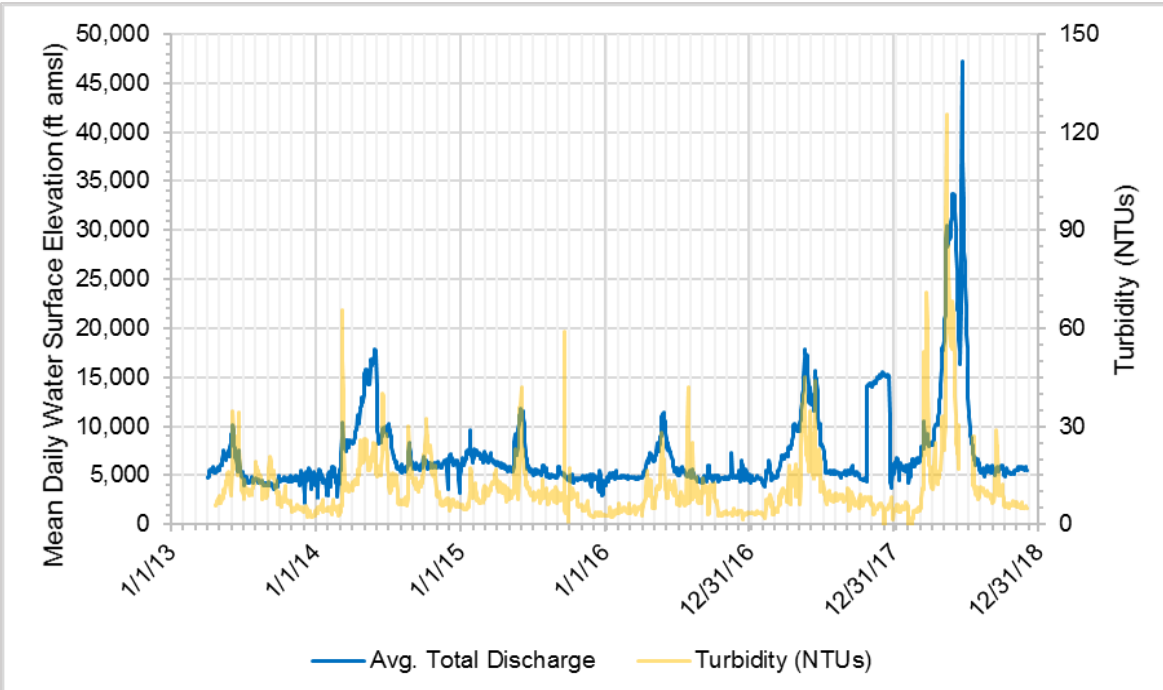

Figure 8-2: Daily flow (generation, restoration gates, and spill gates) and turbidity, Morony Reservoir, April 23, 2013 to December 1, 2018.

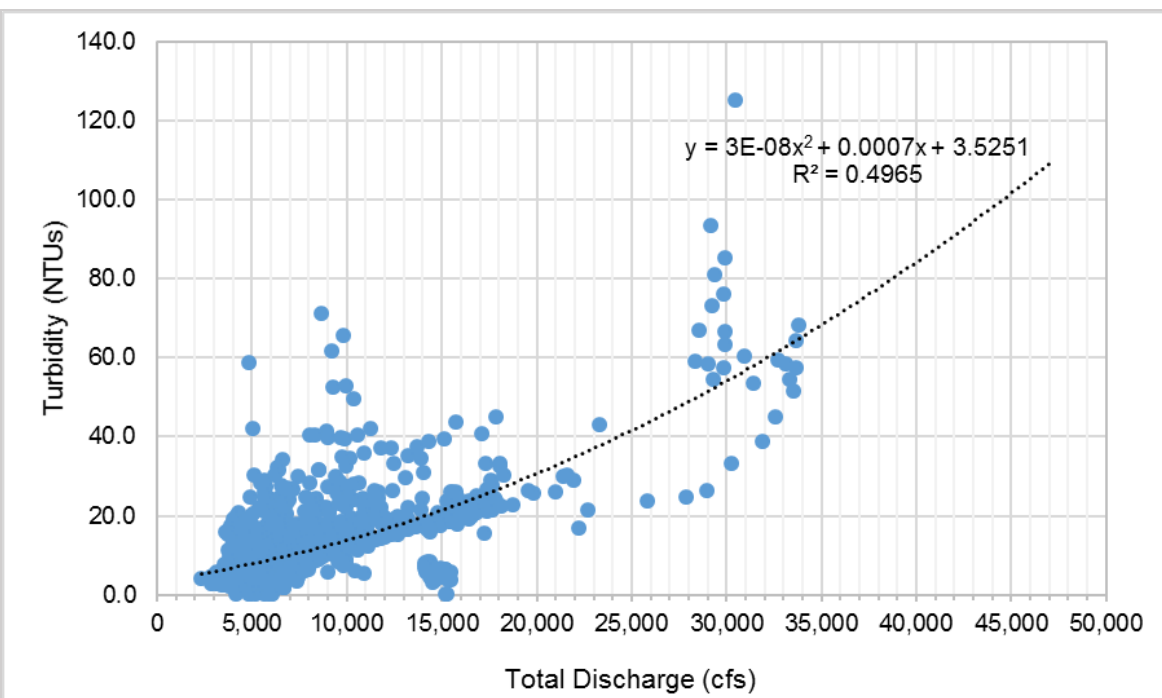

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Figure 8-3: Hourly turbidity versus hourly flow (generation, restoration, and spill), Morony Reservoir. Data taken from April 22, through November 10, 2013.

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 turbidity for each reservoir for the 5-year period from 2013 to 2018 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, Rainbow, Cochrane and Ryan reservoirs had the largest turbidity spikes of approximately 220, 250 and 405 NTUs, respectively.

Mean daily turbidity values fluctuated the most and had the highest spikes during the years of 2014, 2016 and 2018. Figures 9-2, 9-3, and 9-4 provide a closer evaluation of those years with the highest fluctuations. Figures 9-5, 9-6, and 9-7 provide a closer evaluation of the drawdown events that occurred at Black Eagle Reservoir in 2016 and 2018, and the Rainbow Reservoir and Ryan Reservoir drawdowns that occurred in September 2018. These figures demonstrate that the turbidity values in the system are generally attenuated as flow progresses downstream through the lower reservoirs and releases from Morony Reservoir are not significantly influenced by upstream reservoir turbidity spikes.

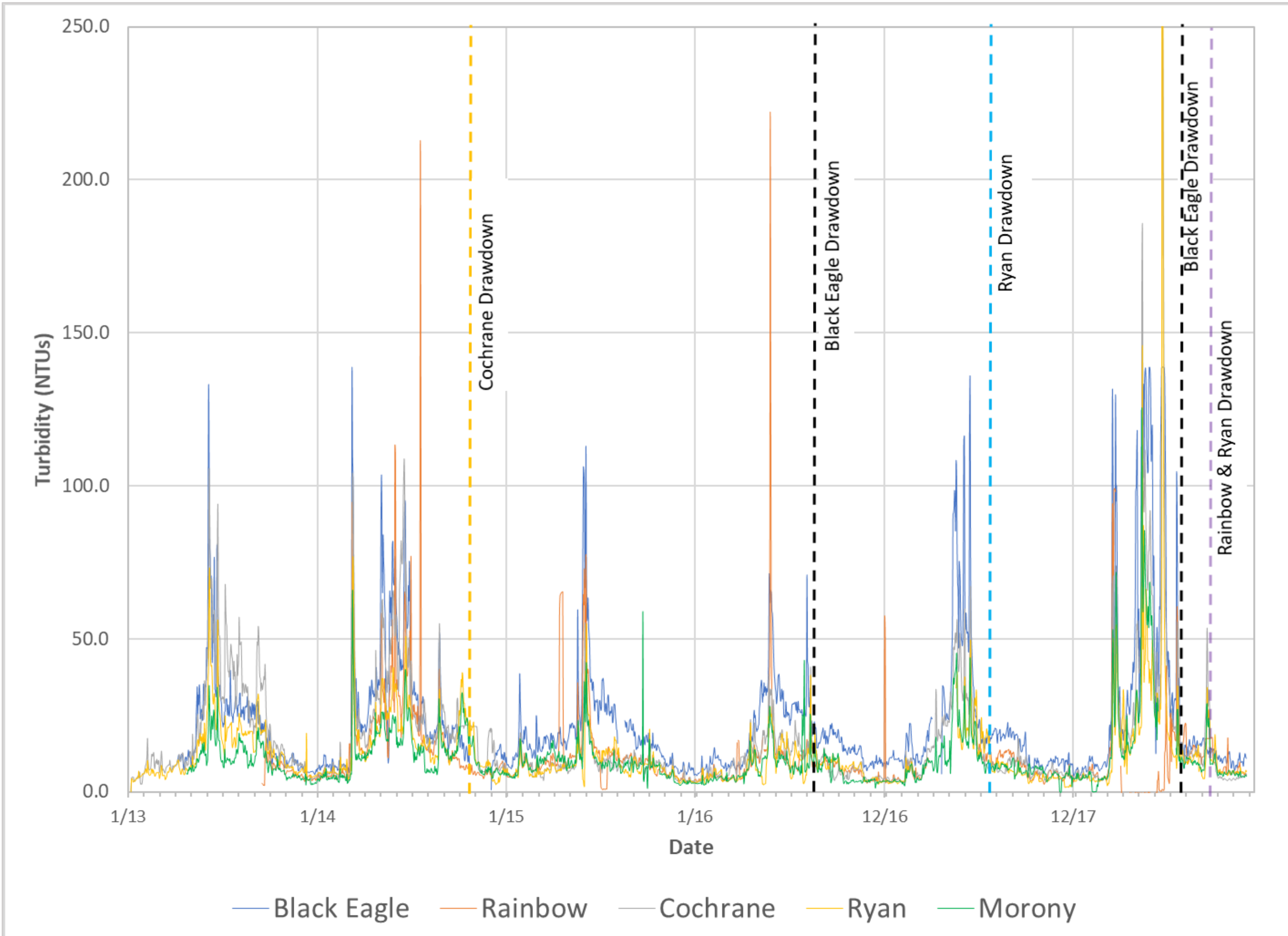

Figure 9-1: Mean daily turbidity Black Eagle, Rainbow, Cochrane, Ryan and Morony Reservoirs. January 6, 2013 through December 1, 2018.

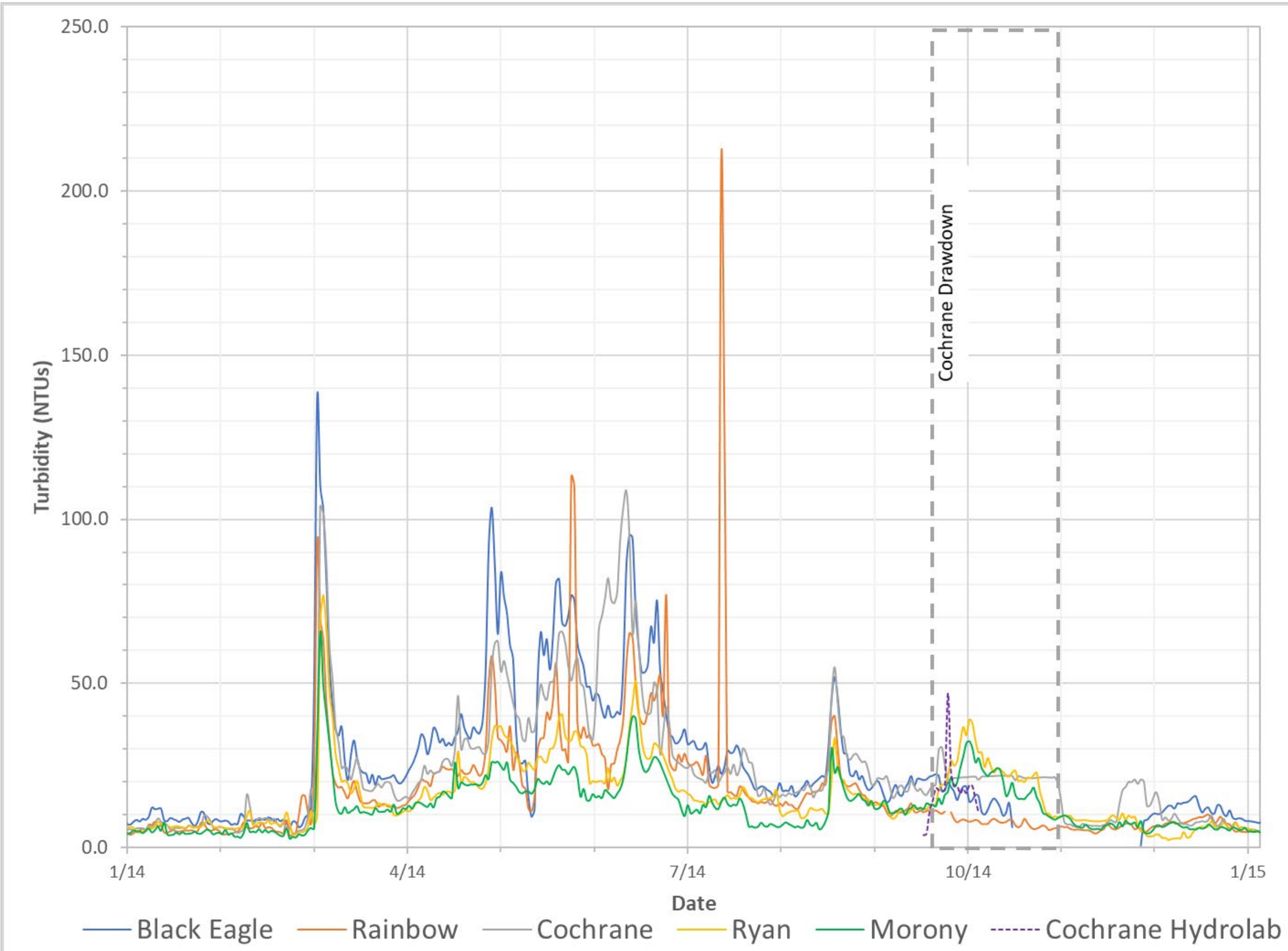

Figure 9-2: Mean daily turbidity Black Eagle, Cochrane, Ryan and Morony Reservoirs. January 1, 2014 through December 31, 2014.

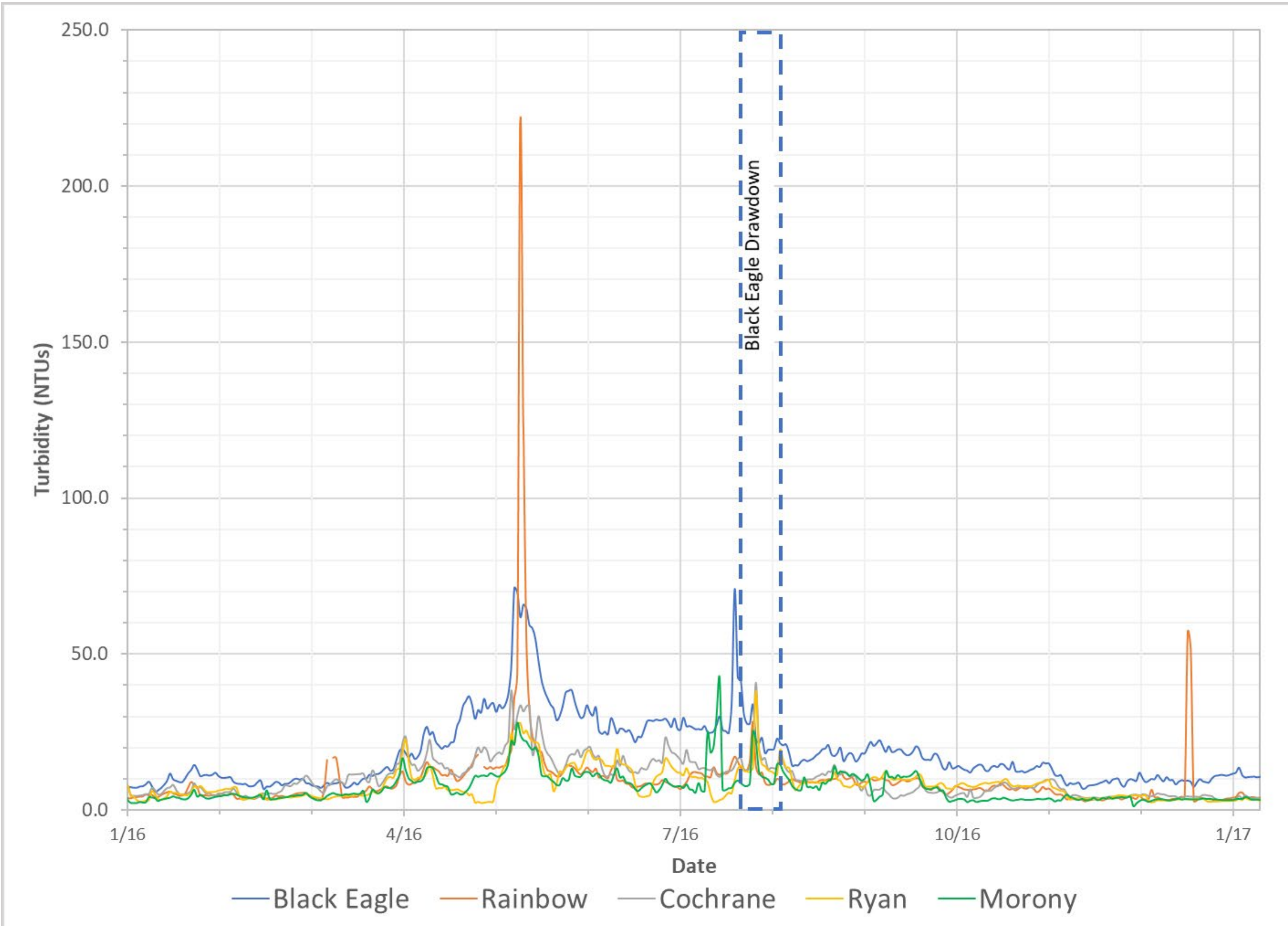

Figure 9-3: Mean daily turbidity Black Eagle, Cochrane, Ryan and Morony Reservoirs. January 1, 2016 through December 31, 2016.

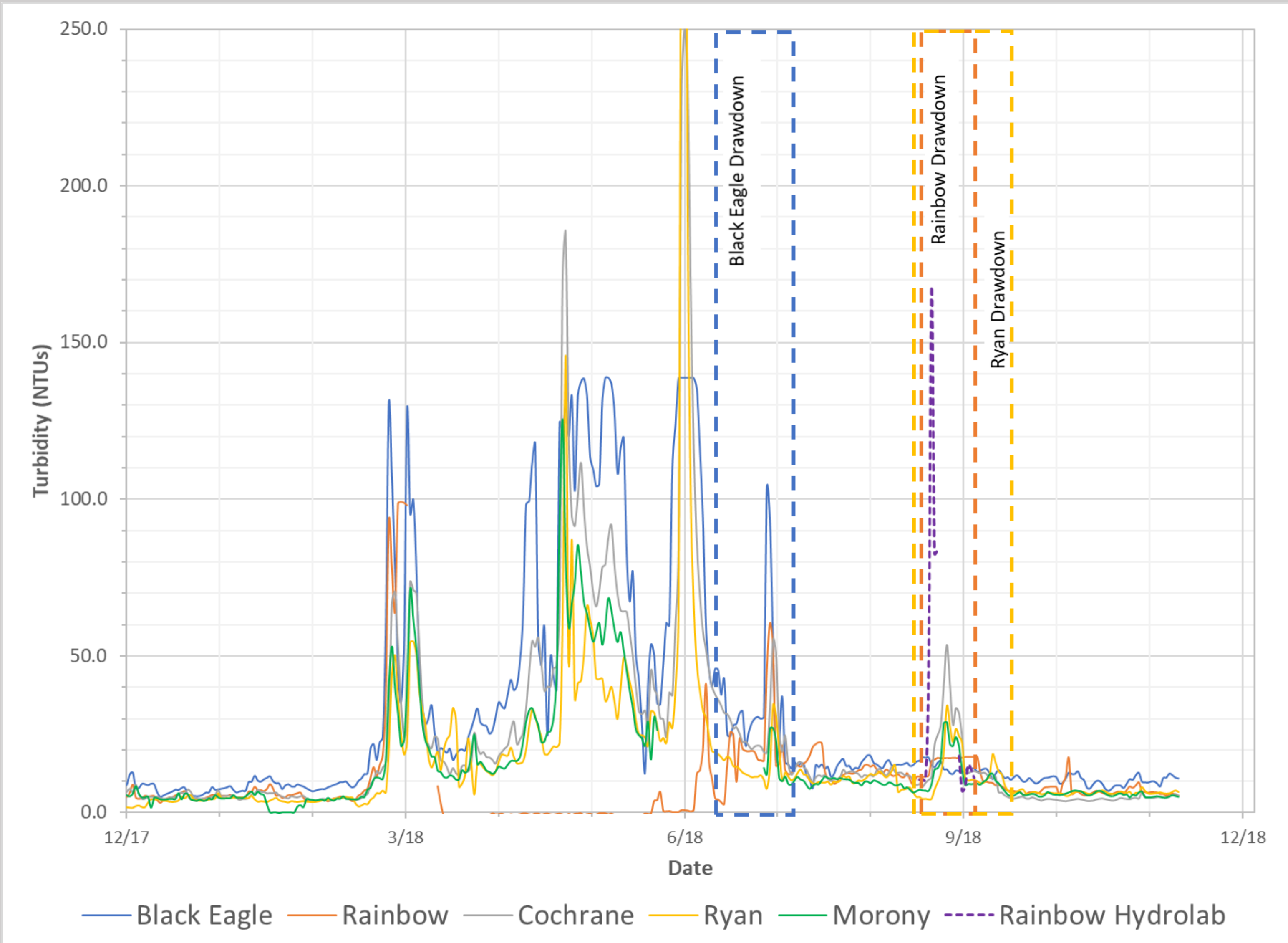

Figure 9-4: Mean daily turbidity Black Eagle, Cochrane, Ryan and Morony Reservoirs. January 1, 2018 through December 1, 2018.

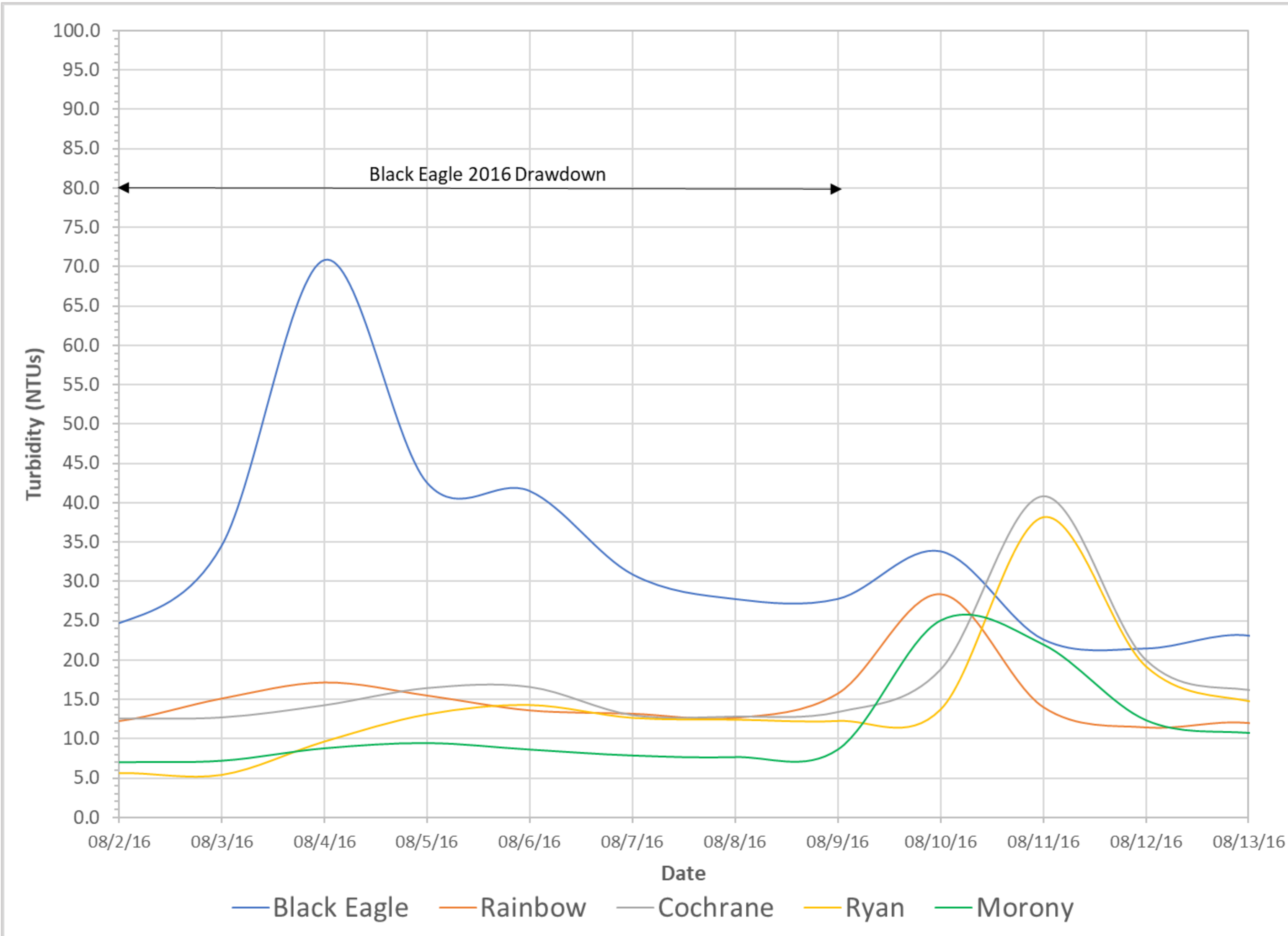

Figure 9-5: Mean daily turbidity at Black Eagle, Rainbow, Cochrane, Ryan and Morony Reservoirs during Black Eagle August 2016 drawdown.

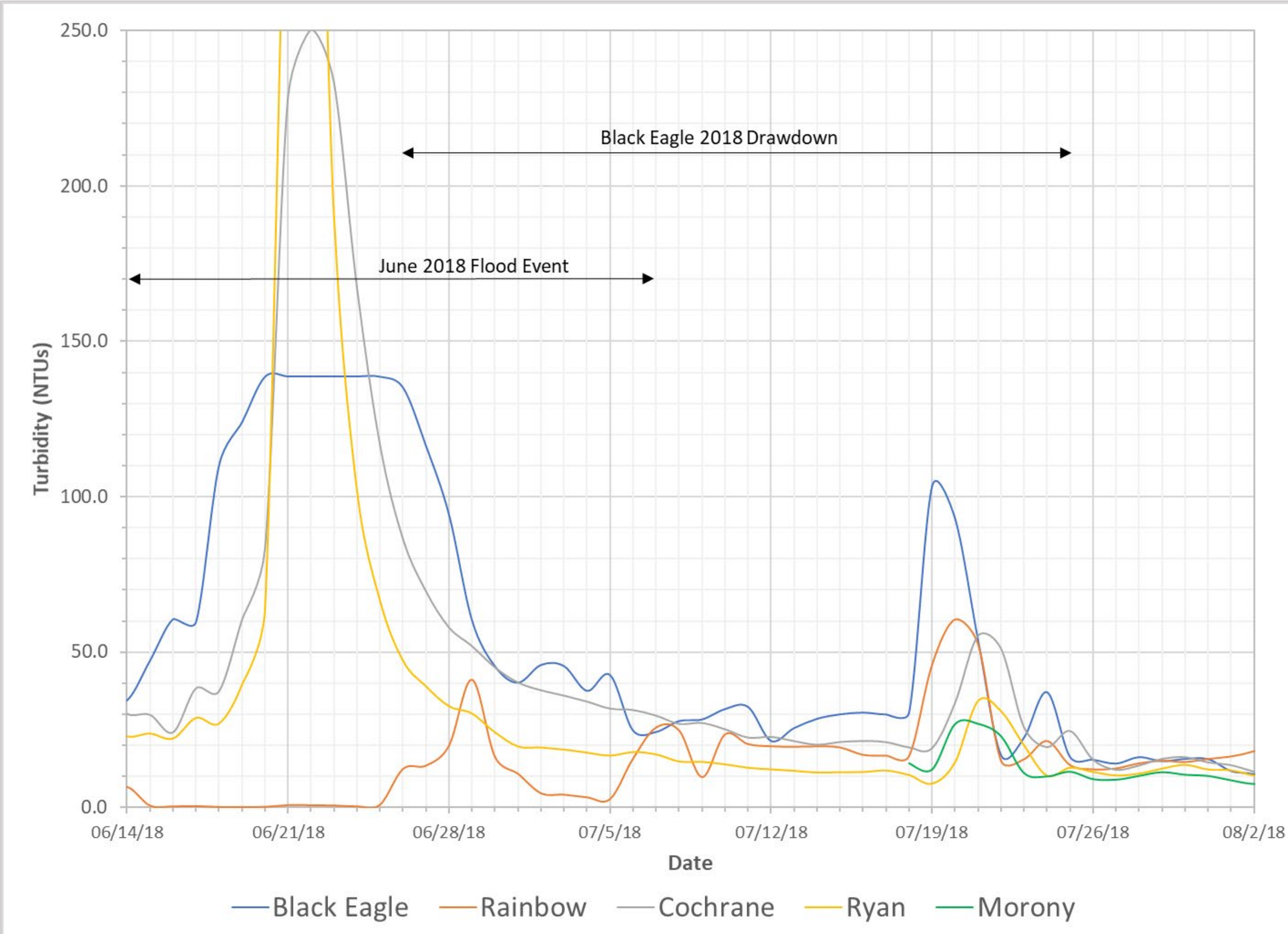

Figure 9-6: Mean daily turbidity at Black Eagle, Rainbow, Cochrane, Ryan and Morony Reservoirs during Black Eagle July 2018 drawdown.

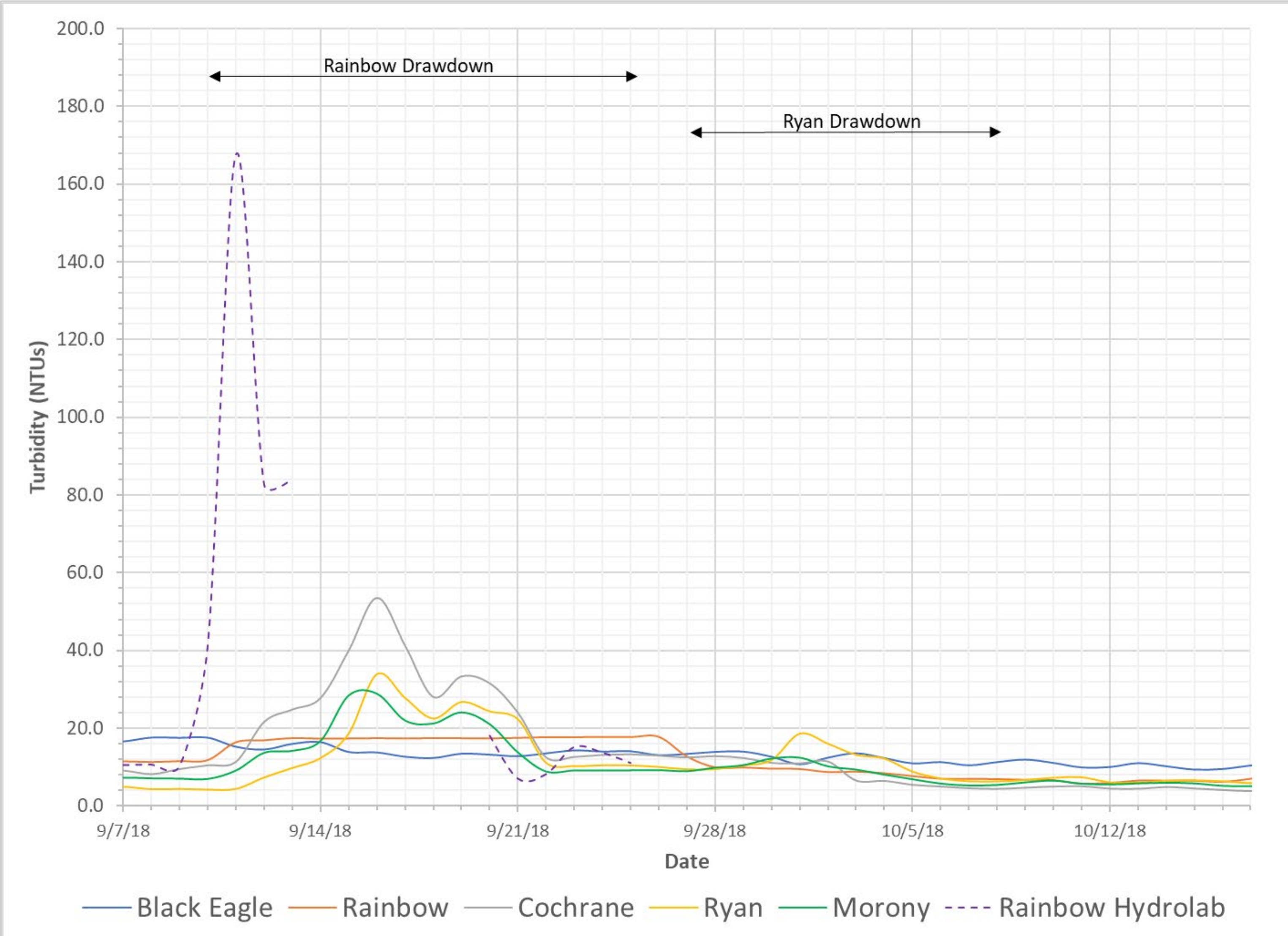

Figure 9-7: Mean daily turbidity at Black Eagle, Rainbow, Cochrane, Ryan and Morony Reservoirs during Rainbow and Ryan September 2018 drawdowns.

Figure 9-8 presents turbidity versus discharge rate for Black Eagle, Cochrane, Ryan, and Morony reservoirs. Discharge data was 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 and the downstream reservoirs require noticeable 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.

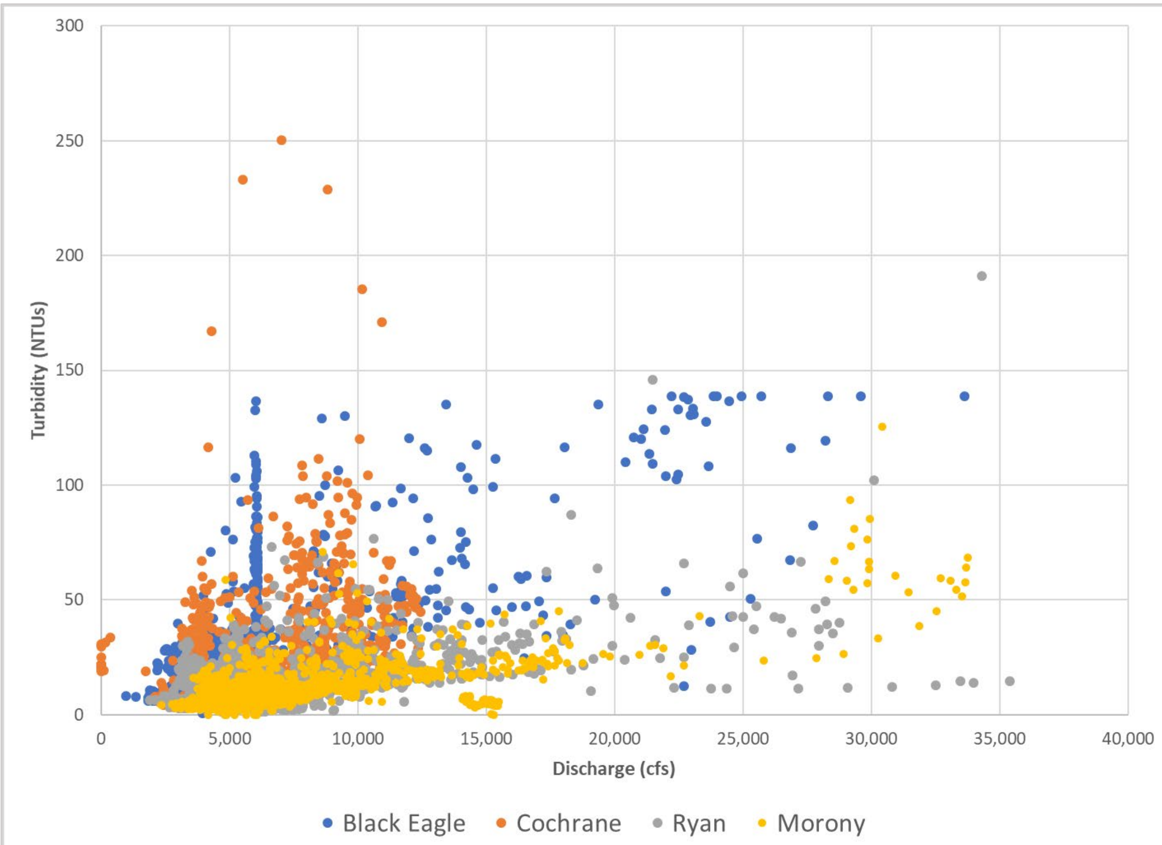

Figure 9-8: Mean daily turbidity versus discharge rate Black Eagle, Cochrane, Ryan and Morony Reservoirs. January 6, 2013 through December 1, 2018.

10 Drawdown 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. Nephelometric turbidity units (NTUs) are used as a rough index of the fine suspended sediment content of the water (Davies-Colley and Smith, 2000).

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 (Davis-Colley and Smith 2000) 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 100-200 mg/l.

At moderate levels of turbidity, cutthroat trout (Oncorhynchus clarkia) 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 (mg/1) and duration of exposure (hours). The resulting value is expressed in terms of mg.hr/1. 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 Missouri River 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 Ryan) 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 Rainbow Reservoir, Cochrane Reservoir and Ryan Reservoir are shown in Figures 10-1, 10-2 and 10-3, respectively. As shown in these figures, the average Stress Index generally ranges from about 5.0 to 6.5 throughout the years, with spikes that occasionally exceed 8.0, although the duration of these turbidity spikes are relatively short. 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.

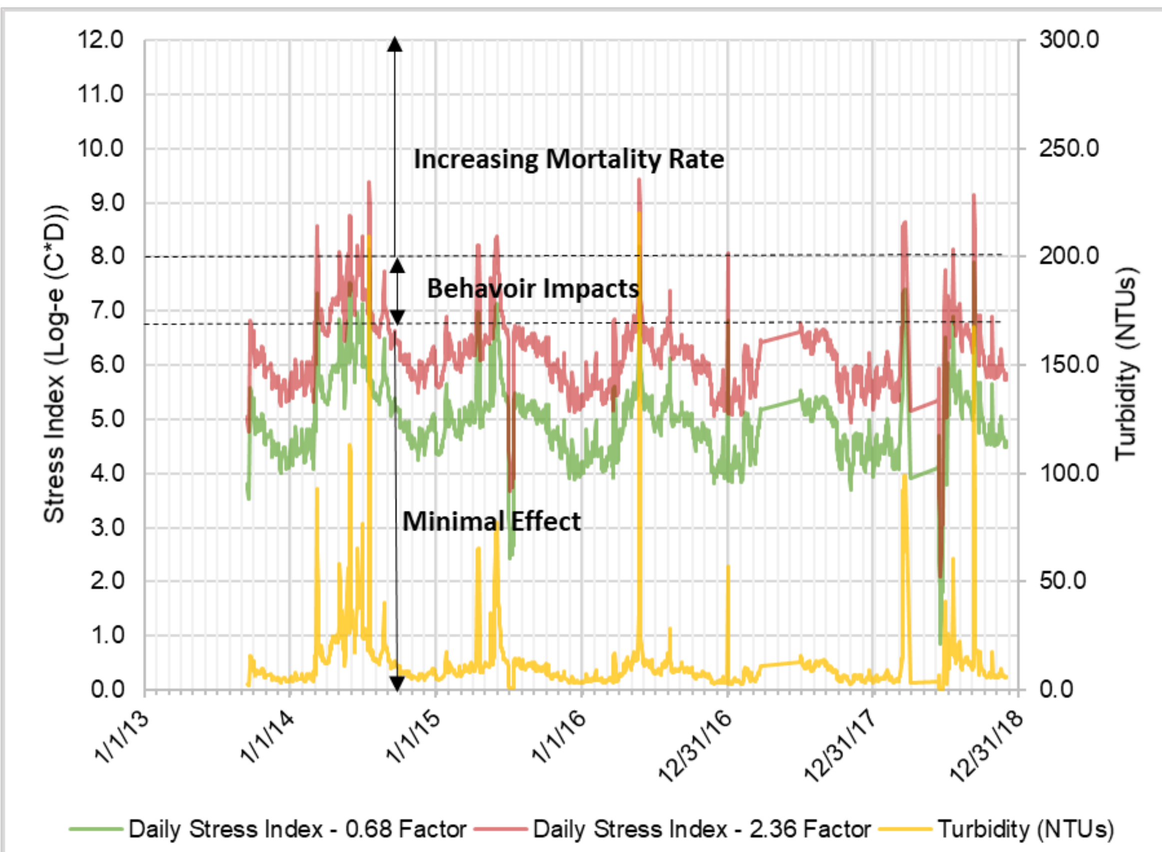

Figure 10-1: Mean daily stress index and turbidity at Rainbow Reservoir. September 17, 2013 through December 1, 2018.

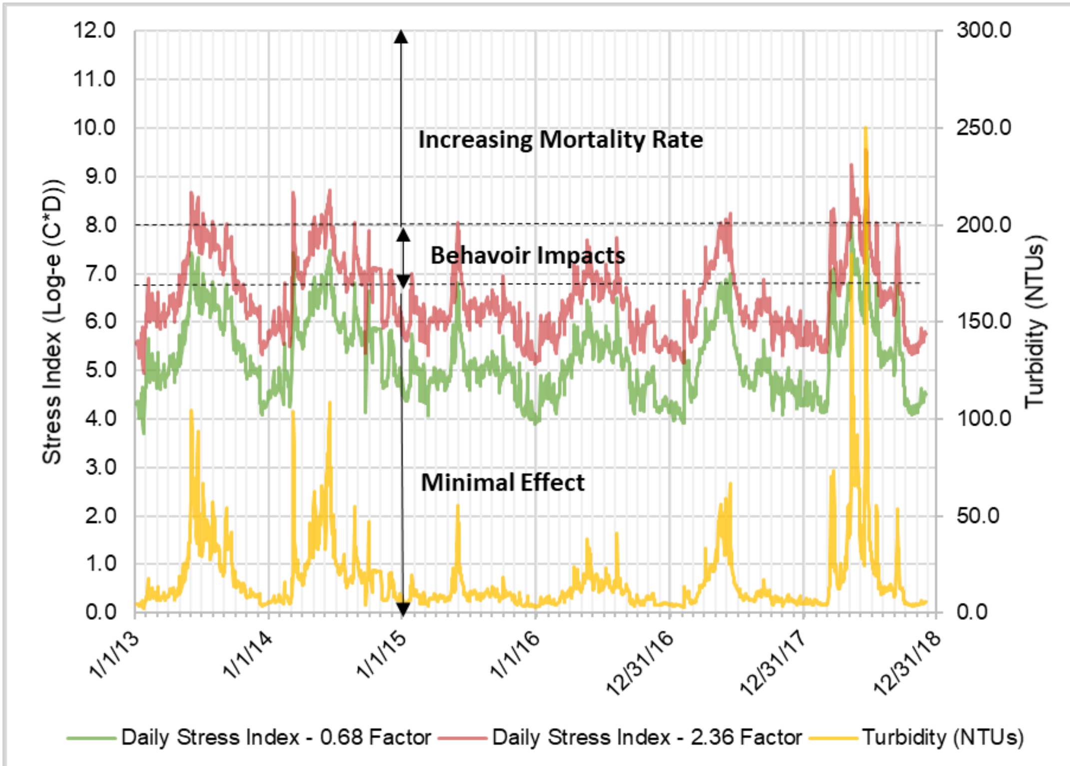

Figure 10-2: Mean daily stress index and turbidity at Cochrane Reservoir. January 6, 2013 through December 1, 2018.

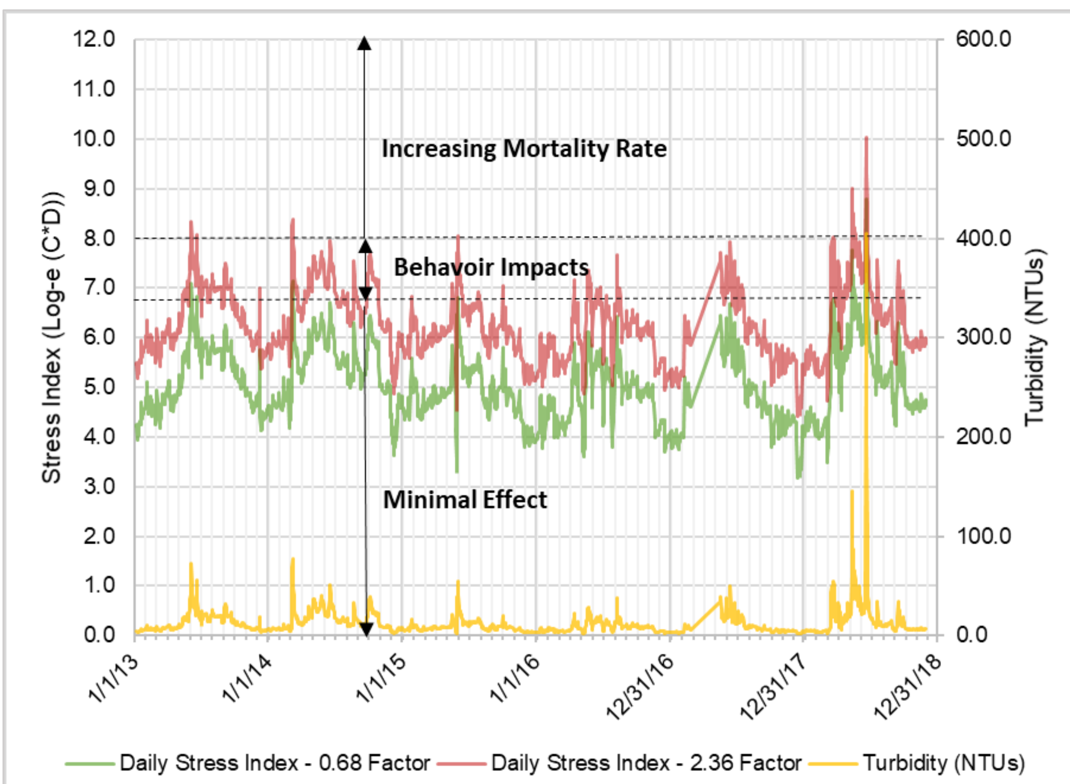

Figure 10-3: Mean daily stress index and turbidity at Ryan Reservoir. January 6, 2013 through December 1, 2018.

10.4 Drawdown Effects on Freshwater Mussels

There are two species of freshwater mussel known to occur in the project area; Grooved Fingernailclam (*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. 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.

Surveys in the Great Falls area between 2015 and 2016 showed large numbers of both species (G. Grisak personal communication, 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 (Figure 10-4).

Galbraith et al. (2014) 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 US 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 cm/d) and moderate (8 cm/d) drawdown rates and all individuals would be stranded at a fast (120 cm/d) drawdown rate. The 2016 Black Eagle drawdown rate (64 cm/d) roughly corresponded to half of the Galbraith et al. (2014) fast rate and about 8 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. 2014, Byrne and McMahon 1994).

During the 2016 Black Eagle Reservoir drawdown, Fatmucket mussels were observed in burrowed positions, exposed/sessile positions and exposed/motile positions. Evidence of motility included long paths in the sediment where the mantle foot was used to move the mussel. As such, despite the horizontal movement and burrowing behavior, we would expect some Fatmucket mussels to become stranded in some of the upper Black Eagle Reservoir littoral zones during a drawdown of 4.1 feet or greater. Given the small size of Fingernail clams, horizontal movement is not likely a suitable avoidance mechanism (G. Grisak personal communication, 2019).

Black Eagle Reservoir drawdowns for dam maintenance purposes is an uncommon practice and has occurred only once during the nine-year period the drawdown plan has been in effect. In 2018 an emergency reservoir drawdown occurred as a result of flooding in June that required the reservoir to reach base equilibrium to restore dam structures.

Figure 10-4: Approximate area in Black Eagle Reservoir occupied by freshwater mussels that is dewatered during reservoir drawdowns.

11 Conclusions and Recommendations

The data collected during the various drawdown events in the Missouri River project indicate turbidity levels often respond to some degree to fluctuations and drops in water surface elevations. 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 2009 Drawdown Plan. Turbidity increased when drawdown rates were less and, in some cases, when drawdown rates exceeded the limits specified in the 2009 Drawdown Plan. The correlation between the drawdown rate and turbidity is not definitive based on the available data.

A summary of the drawdown events and available data between January 2013 and December 2018 for the five dams comprising the Missouri River projects is provided in Table 11-1. Table 11-1 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: Summary of the drawdown events at the Missouri River projects between January 2013 and December 2018.

Project	Drawdown	Total Duration Drawdown Rate Exceeded	Average and Maximum Drawdown Rate During Exceedance	WSE Prone to Turbidity Spike	Max Turbidity Recorded During Drawdown
Black Eagle	August 2016	23 hrs	0.13 ft/hr; 0.22 ft/hr	3285-3286	90
	July 2018 (flood)	37 hrs	0.45 ft/hr; 2.25 ft/hr	3284-3285	140
Rainbow	September 2018	87 hrs	0.16 ft/hr; 2.22 ft/hr	3215-3216	367[1]
Cochrane	October 2014	173 hrs	0.08 ft/hr; 1.09 ft/hr	3108-3109	167[1]
Ryan	July 2017	408 hrs	0.17 ft/hr; 3.02 ft/hr	3022	75
	September 2018	79 hrs	0.27 ft/hr; 2.99 ft/hr	N/A	30
Morony	None	None	N/A	N/A	N/A

1. Maximum turbidity based on hydrolab sensor data, which is exposed and prone to disturbance and debris during drawdowns.

Due to the operational constraints of managing a drawdown rate of less than 0.10 feet/hour, NorthWestern Energy is proposing an update to the drawdown rates for Black Eagle, Rainbow, Cochrane, Ryan, and Morony Dams (Table 11-2). These drawdown rates will be based on a four-hour running average, which will afford dam operators some flexibility in trying to maintain these drawdown rates. The proposed drawdown rates will simplify dam operations during a planned drawdown to help operators stay in compliance with the Drawdown Plan, while at the same time, remaining conservative enough to protect the aquatic resources of these reservoirs.

Table 11-2: Proposed drawdown rates for the 2019-2024 period.

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) 3,036 (3,029)[2] 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.
[2]A proposed amendment to change the normal operating level of Ryan Reservoir will start the drawdown rates at an elevation of 3,029 once approved.

The drawdown rates identified in Table 11-2 above will be followed for the years 2019-2024. NorthWestern Energy proposes to analyze the resulting data from drawdowns within this period, and provide a 5-year (January 2019 through January 2024) summary report to the agencies by December 31, 2024. NorthWestern Energy will perform a detailed review of the effectiveness of the recommended drawdown rates based on the data that will be collected nearly continuously during the next 5 years. Based on the review, NorthWestern Energy 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 Energy will 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.

12 References

Alabaster, J. S. and R. Lloyd. 1980. Finely divided solids. p. 1-20 In Water Quality Criteria for Freshwater Fish, Food and Agriculture Organization of the United Nations, Butterworth, London. 297 p.

Archambault, J.M., W.G. Cope and T.J. Kwak. 2014. Survival and behaviour of juvenile unionid mussels exposed to thermal stress and dewatering in the presence of a sediment temperature gradient. Freshwater Biology (2014) 59, 601–613.

Bash et al. 2001. Effects of Turbidity and Suspended Solids on Salmonids.

Berg, L. 1982. The effect of exposure to short-term pulses of suspended sediment on the behavior of juvenile salmonids. P. 177-196 in G.F. Hartman et al. [eds.] Proceedings of the Carnation Creek workshop: a ten-year review. Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, Canada.

Berg, L. and T.G. Northcote. 1985. Changes in territorial, gill-flaring, and feeding behavior in juvenile coho salmon (Oncohynchus kisutch) following short-term pulses of suspended sediment. Canadian Journal of Fisheries and Aquatic Sciences 42: 1410-1417.

Berli BI, Gilbert MJ, Ralph AL, Tierney KB, Burkhardt-Holm P (2014) Acute exposure to a common suspended sediment affects the swimming performance and physiology of juvenile salmonids. Comp Biochem Phys A Mol Integr Physiol 176:1–10. doi: 10.1016/j.cbpa.2014.03.013

Bisson, P.A. and R.E. Bilby. 1982. Avoidance of suspended sediment by juvenile coho salmon. North American Journal of Fisheries Management 4: 371-374. Davies-Colley, R.J. and D.G. Smith. 2000. Suspended Sediment, Turbidity and Clarity of Water, a Review. Unpublished draft.

Byrne, R. A., and R. F. McMahon. 1994. Behavioral and physiological responses to emersion in freshwater bivalves. American Zoologist 34:194–204.

Eaton and Sloman. 2011. Subordinate brown trout exaggerate social signaling in turbid conditions.

Everest, F.H., R.L. Beschta, J.C.Scrivener, K.V. Koski, J.R. Sedell, and C.J. Cederholm. 1987. Fine sediment and salmonid production: a paradox. In E.O. Salo and T.W. Cundy [ed.] Streamside Management: Forestry and Fishery Interactions. University of Washington Institute of Forest Resources, Seattle, Washington.

Galbraith, H.S., C. J. Blakeslee and W.A. Lellis. 2014. Behavioral responses of freshwater mussels to experimental dewatering. Freshwater Science. 2015. 34(1):42–52.

Harvey ad Railsback 2009. Exploring the Persistence of Stream-Dwelling Trout Populations under Alternative Real-World Turbidity Regimes with an Individual-Based Model.

Harvey and White 2008. Use of Benthic Prey by Salmonids under Turbid Conditions in a Laboratory Stream.

Kerr 1995. Silt, Turbidity and Suspended Sediments in the Aquatic Environment: An Annotated Bibliography and Literature Review.

Lloyd 1987. Turbidity as a water quality standard for Salmonid habitats in Alaska.

Muck 2010. Biological effects of sediment on bull trout and their habitat – guidance for evaluating effects.

NorthWestern Energy. 2013. Reservoir Drawdown Plans for Missouri-Madison Hydroelectric Project. Black Eagle, Rainbow, Cochrane, Ryan and Morony Dams. FERC Project 2188. With Assistance from GEI Consultants, Inc., Lake Oswego, Oregon. Filed with FERC June 2013.

Robertson-Bryan, Inc. 2006. Suspended solids and turbidity requirements of freshwater aquatic life and example relationship between tss (mg/l) and turbidity (NTUs) for a treated municipal effluent.

Sorenson, D.L., M.M. McCarthy, E.J. Middlebrooks, and D.B. Porcella. 1977. Suspended and dissolved solids effects on freshwater biota: a review. United States Environmental Protection Agency, Report 600/3-77-042, Environmental Research Laboratory, Corvallis, Oregon, USA.

Ward et al. 2016. Effects of Turbidity on Predation Vulnerability of Juvenile Humpback Chub to Rainbow Trout and Brown Trout.