White Paper

Proposal for improving Sheyenne River connectivity and aquatic habitat for mitigation of aquatic impacts associated with the Fargo-Moorhead Metropolitan Area Flood Risk Management Project.

June 2021

Background

The Red River basin in eastern North Dakota and western Minnesota has a long history of flooding due to the unique hydrology and topography of the area. The US Army Corps of Engineers (USACE) completed the Final Feasibility Report and Environmental Impact Statement (FEIS) for the Fargo-Moorhead Metropolitan Area Flood Risk Management Project (FMM Project) in July 2011. The Project was later authorized by Congress in the Water Resources Reform and Development Act of 2014.

Detailed engineering and design conducted since the completion of the FEIS have resulted in modifications to the FMM Project. This resulted in a Supplemental Environmental Assessment (SEA) in 2013, with the most current designs and associated impacts outlined in SEA #2 in 2019.

The FMM Project will include various environmental effects, some substantial enough to warrant mitigation. This document outlines a proposal to fulfill mitigation needs for specific impacts to lost aquatic habitat resulting from the project in the State of North Dakota. Other mitigation needs (e.g., wetlands and forest habitat) are outlined in the project's Adaptive Monitoring and Management Plan.

Aquatic Habitat Impacts

Construction of FMM Project will result in adverse impacts to riverine aquatic habitat. In many cases, major features must be built "in the dry," in areas disconnected from river flows. Once construction of the features is substantially completed, the rivers would be re-routed through the newly constructed channel and features. Existing river channel that is filled, excavated, or abandoned was considered in the calculation of aquatic habitat impact. Aquatic habitat impacts requiring mitigation are primarily associated with the gated control structures on the Red and Wild Rice Rivers (the Red River Structure and the Wild Rice River Structure), and the aqueducts (river bridges) that allow the Sheyenne and Maple rivers to cross the FMM Project's diversion channel.

Table 1. Location and amount of lost riverine aquatic habitat associated with the FMM Project that will be mitigated.

Riverine Aquatic Impact Location	Acres Lost
Red River Structure (MN/ND)	12.9
Wild Rice River Structure (ND)	7.8
Sheyenne River Aqueduct (ND)	8.0
Maple River Aqueduct (ND)	10.0
Total	**38.7**

Mitigation Strategy

Minnesota

Mitigation needs for aquatic habitat impacts associated with waters of Minnesota caused by the FMM Project are outlined in the Minnesota DNR Dam Safety & Public Waters Work Permit (Permit # 2018-0819). Specifically, Condition 27 of that permit outlines how mitigation will be handled for Minnesota waters.

Condition 27 includes USACE/sponsorship coordination with the DNR to set the mitigation needs to address impacts, including both amounts and location of mitigation. About 6.5 acres of lost aquatic habitat occur within Minnesota (half of the impacts on the Red River). USACE is working with Minnesota DNR to implement mitigation projects, likely on the Lower Otter Tail River, to offset these losses.

North Dakota

USACE had lengthy discussions with agency partners searching for potential mitigation actions in North Dakota. This included restoration of habitat on the Bois de Sioux, as well as other rivers. However, candidate sites are nearly non-existent, primarily due to the lack of available real estate. Land owners, particularly near the project area, are hesitant or unwilling to provide real estate to implement mitigation projects. This has made it extremely difficult to mitigate lost aquatic habitat in North Dakota.

Previous discussions with North Dakota resource agencies identified a desire to improve habitat connectivity (e.g., fish passage) and whether projects that improve connectivity could serve as mitigation. While the comparison of direct habitat loss is difficult to make compared to a functional improvement like connectivity, the improved habitat quality is something that could be used to mitigate for habitat losses resulting from the FMM Project.

Several potential fish passage/connectivity projects were discussed with North Dakota resource agencies. One with substantial interest focused on the lower Sheyenne River. Connectivity in this area has been substantially reduced due to several features constructed previously, many of which were built as part of the Sheyenne River Flood Control Project (SRFCP) in the 1990s. This river reach is extremely attractive from a mitigation standpoint because:

- The river reach is located near the project impacts, and within the FMM Project area
- The Sheyenne River is the largest tributary to the Red River in North Dakota, and provides valuable habitat to many species
- The real estate necessary to implement mitigation is owned by local government
- The connectivity impairments are immediately adjacent to the Red River; resolving these impairments improves connectivity for fish migration between the two rivers.

In addition to connectivity improvements, there is also a disconnected oxbow on the Sheyenne River adjacent to County Road 17 between West Fargo and Horace. Accessibility and real estate don't appear to be a problem, and the site would provide roughly three acres (1,750 lineal feet) of restored habitat.

Overview of Existing Connectivity Impairments on the Sheyenne

The SRFCP is a federal project authorized in the 1986 Water Resources Development Act. The SRFCP was designed and constructed by USACE, becoming operational in 1993. The project is owned and operated by the Southeast Cass Water Resource District. The pertinent features associated with the SRFCP and the proposed FMM Project are in Figure 1. The SRFCP consists of the following key features:

- Weir structure across the river at upstream end of the Horace to West Fargo Diversion Channel (HWFDC)
- Culvert and baffle structure adjacent to the weir structure at the upstream end of the HWFDC
- Sheet pile weir structure across the river at upstream end of the West Fargo Diversion Channel
- Gated structure on the river just upstream of I-94
- Gated structure and pumping station on the river near 12th Ave

Figure 1. Overview of the Sheyenne River Flood Control Project (SRFCP) and associated features of the Sheyenne mitigation project.

At the upstream end of the HWFDC, flow is split when flow in the natural channel reaches approximately 1,100 cfs. Flow that continues along the natural channel must pass through the culvert and baffle structure. The percent of flow entering the HWFDC via the HWFDC inlet structure fixed-crest weir increases as the total river flow increases. Under current conditions there is very little freeboard provided by the natural channel banks for the 1/100 Annual Excedence Probability (AEP) event.

At the upstream end of the WFDC, flow is split when the flow in the natural channel reaches approximately 700 to 750 cfs. Flow that continues along the natural channel must pass through a gated culvert structure just upstream of I-94. The existing SRFCP operation & maintenance plan calls for this gated culvert structure to be closed if either the local water surface elevation reaches 898.93 feet (which corresponds to a flow of approximately 900 cfs) or the water surface elevation at the downstream end of the SRFCP near the 12th Avenue North gated culvert structure and pump station reaches 890.94 feet. Soon after the gated structure just upstream of I-94 is closed, the downstream gated structure near 12th Avenue North is closed. These gated structures have been closed a high percentage of the time, especially in recent wetter years. It was estimated that from 2012 to 2019, the gates for this project were closed around 900 days. This is about 32% of the all days during that period. Further review suggests the gates may have been closed about 42% of days from March through November; and about 48% of days March through June. A flow analysis has been attached to this document to demonstrate the frequency of flow exceedance for the project area, including an analysis of how Devils Lake pumping influences those flows. This provides context in understanding flow frequency and distribution for the existing Sheyenne project, as well as conditions with the mitigation project proposed below.

Fish passage and other biologic connectivity are impacted by the SRFCP. Six miles of natural channel are hydraulically severed when the gated culvert structures near I-94 and 12th Avenue North are closed. Bank instabilities resulting from the relatively quick drop in water elevations immediately after closure of these gates and the poor water quality that develops with an extended closure degrade the habitat value and function in this six mile reach of natural channel. Connectivity along the natural channel is also hindered at the culvert and baffle structure adjacent to the HFWDC inlet structure since the baffle slot is subject to blockage by debris and high velocities occur through the submerged box culverts. The culvert structures, even when those with gates have their gates open, produce adverse light and velocity conditions for fish passage. Fish that are drawn up the diversion channels are faced with challenges getting back into the natural channel. The WFDC inlet structure likely passes some fish, but the flow conditions are not what they should be to pass fish over a wide range of flow conditions. Sedimentation has made the fish passage structure at the HWFDC inlet structure inaccessible at low to moderate flows in the HWFDC.

Outside of SRFCP, other barriers also exist on the lower Sheyenne River. Review of aerial imagery identifies a low-head dam immediately north of the railroad bridge crossing on the Sheyenne River in West Fargo (between Main Street and 12th Avenue). This dam is often inundated, but would be a barrier to fish during periods when not flooded out. It is not immediately known who the owner of the dam is, or its historical purpose.

Another issue is a number of existing bridges and box culverts on the Sheyenne in the project area. Some of these could be a partial barrier to fish, particularly at higher discharges. While these do not appear to be as significant of a barrier as the items outlined above, they could further restrict fish movement.

Collectively, fish in the lower Sheyenne and Red Rivers cannot reliably access the Sheyenne River above Horace, ND, particular during periods of higher river flow which often coincides with important migration periods.

Proposed Connectivity Improvements

To achieve habitat improvements and meet mitigation needs for lost aquatic habitat in North Dakota due to the FMM Project, USACE is proposing modifications to the SRFCP to improve connectivity. The Southeast Cass Water Resource District and the cities of West Fargo and Horace are in support of this proposed mitigation project, provided they continue to receive flood protection as provided by the SRFCP. To accomplish this requires a delicate balance of hydraulic design in concert with the broader FMM Project.

The required modifications to the SRFCP are provided here:

- Modifications to the HWFDC Reach (see Figure 2)
  - Remove the Sheyenne River culvert and baffle structure adjacent to the HWFDC inlet structure
  - Maintain the HWFDC inlet structure fixed-crest weir elevation and width, and retrofit with rock rapids to allow fish passage out of the HWFDC back into the Sheyenne River
  - The resulting slight decrease in water surface elevation at the split location due to removal of existing culvert and baffle structure will slightly increase the flow at which the flow split first occurs.
- Modifications to the WFDC Reach (see Figure 3 and Figure 4)
  - Remove the Sheyenne River gated structure just south of I-94
  - Remove the Sheyenne River gated structure and pump station just north of 12th Ave North
  - Lower the WFDC inlet weir invert to limit flow in the Sheyenne River between I-94 and 12th Ave North to 700 cfs up through the Sheyenne River Standard Project Flood (SPF) event
  - Lowering of the WFDC inlet structure weir will increase the frequency of flow being diverted into the WFDC, but removal of the gated structures assures that there will always be flow along the natural channel
  - Design/update the rock rapids below the crest of lowered WFDC inlet structure to allow fish passage out of the WFDC back into the Sheyenne River
  - The increase in frequency of flow into the WFDC will be determined by first getting a USGS flow measurement at the existing-condition threshold point (confirm/revise the estimated 650 cfs threshold) and then performing detailed modeling and design of the lowered WFDC inlet structure to determine the new threshold flow.
  - Design of the lowered WFDC inlet structure will be an iterative effort that considers the benefits of no longer closing off the natural channel through West Fargo, the increase in the frequency of flow into the WFDC, and the cost of the WFDC inlet structure modifications.
- The design of the rock rapids will likely employ similar designs to recent rock rapids projects (e.g, 3% overall slope; localized water surface elevation drops between stone arch weirs of about 0.5' or less).
- **Modifications to the SRFCP cannot be constructed until the broader FMM FRM Project construction is complete and operational and levee certification is achieved; flood protection currently provided by the SRFCP must be maintained at all times**

The following would also be completed with the broader FMM Project to facilitate the modifications outlined above:

- Modifications to the SRFCP will not be completed by the P3 Developer. This will be a USACE and/or Local Sponsor project.
- The FMM Project's Sheyenne River aqueduct structure will begin diverting water into the Diversion Channel at 1,200 cfs, with a maximum flow through the aqueduct of 1,500 cfs. It is not anticipated that this limit will significantly affect habitat or geomorphic function.
- The FMM Project's Maple River aqueduct structure will begin diverting water into the Diversion Channel at 1,700 cfs, with a maximum flow through the aqueduct of 3,500 cfs. It is not anticipated that this limit will significantly affect habitat or geomorphic function.
- Emergency positive closure will be added to the downstream side of both Sheyenne and Maple aqueduct structures to prevent exceeding the maximum flows. The positive closures would only operate in events in excess of 500-year annual exceedance flows or in an emergency situation.

Outside of the SRFCP modifications, two other items will be considered for connectivity improvements on the Sheyenne River. First, the low-head dam immediately north of the railroad bridge in West Fargo will be investigated (Figure 5). If at all feasible, the dam will be removed or retrofitted with a rock rapids fishway similar to design as other recent fishways in the region.

The second item is future consideration for improvements to bridges and box culverts on the Sheyenne River between the Sheyenne River aqueduct and the mouth of the river. Some of these bridges and culverts could be a partial barrier to fish, particularly at higher discharges. While re-designing or retrofitting several such crossings would be difficult, local officials will consider fish friendly crossings with future road/bridge improvements when these needs arise.

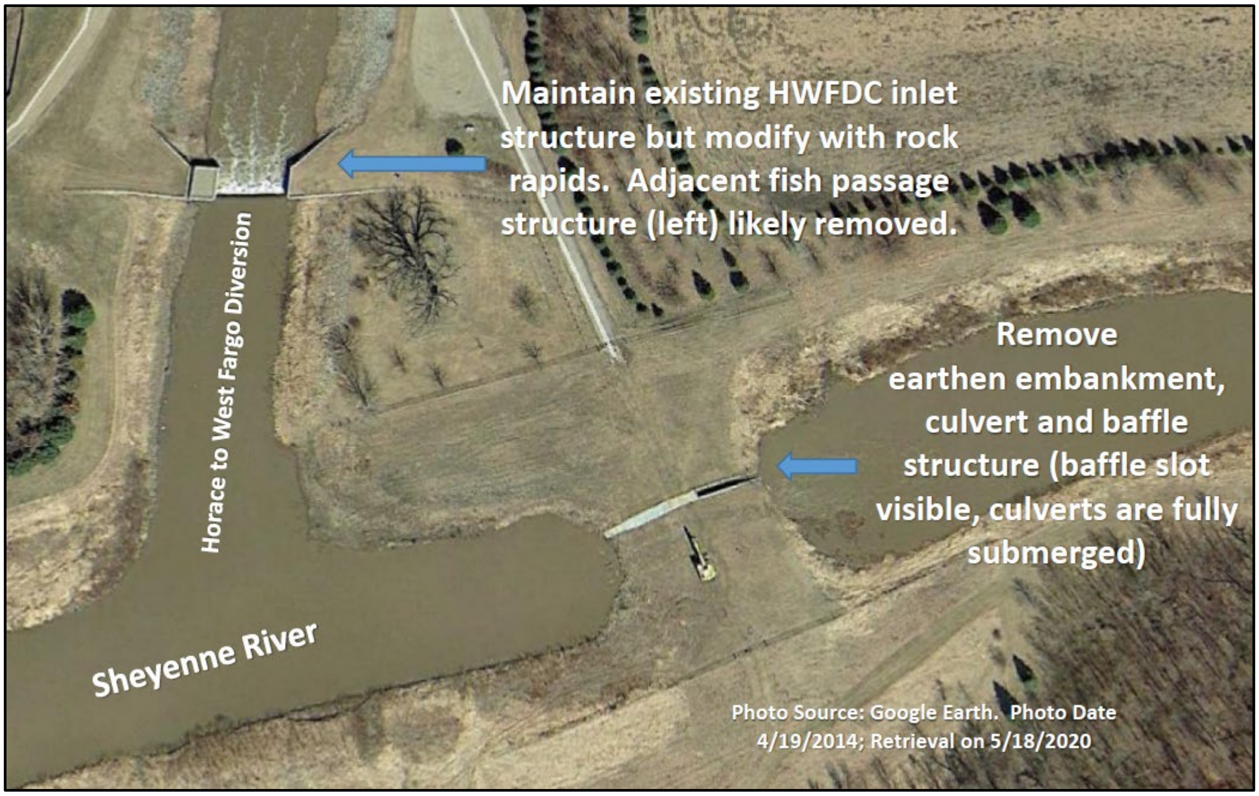

Figure 2. Overview of Sheyenne River connectivity improvements near Horace, ND.

Figure 3. Overview of Sheyenne River connectivity improvements near I-94 in West Fargo, ND.

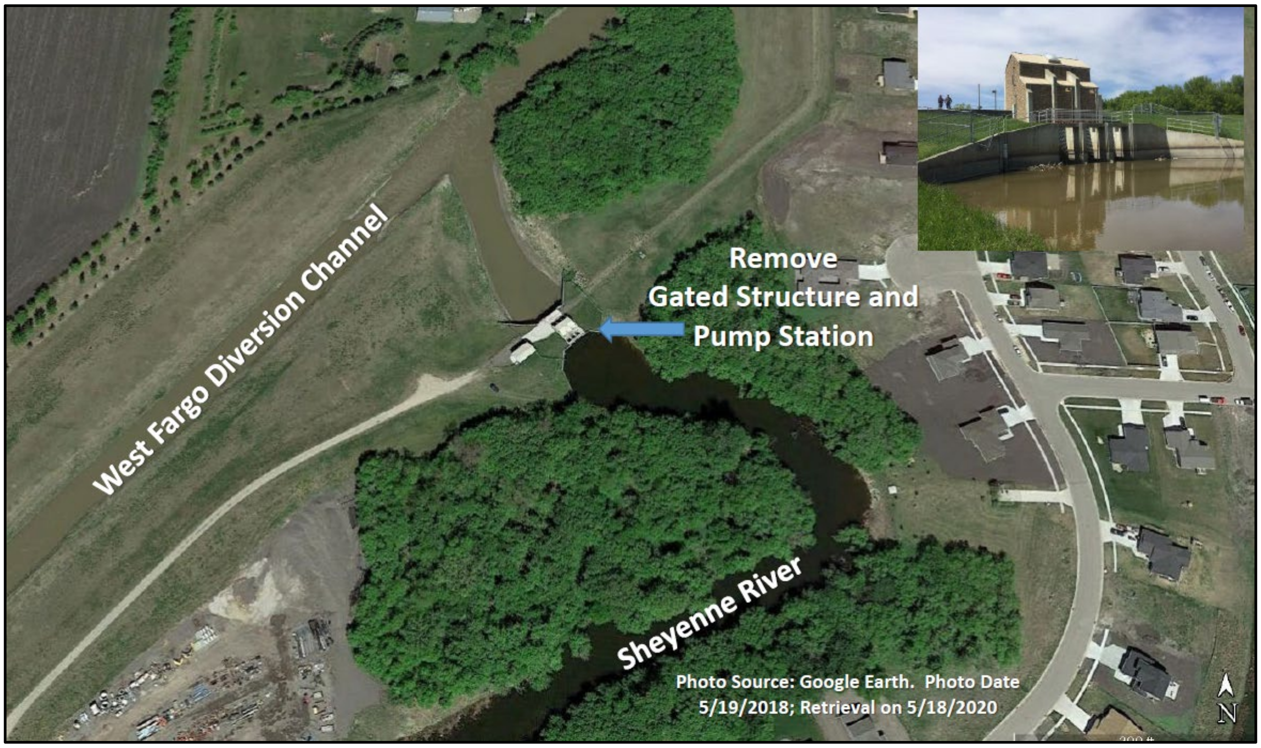

Figure 4. Overview of Sheyenne River connectivity improvements near 12th Avenue in West Fargo, ND.

Figure 5. Location of low head dam for fish passage considerations on the Sheyenne River in West Fargo, ND.

Overview and Proposed Action for Sheyenne Oxbow Restoration

The Sheyenne River oxbow in question is adjacent to County Road 17 between West Fargo and Horace, North Dakota (Figure 6). The proposed restoration would be to excavate both oxbow ends to reconnect the oxbow, and potentially excavate oxbow depth to maintain needed conveyance. Consideration would be given to whether erosion or stability protection is needed for the adjacent County Road 17, or adjacent properties. The Sheyenne River would be "plugged" with an overflow weir to direct flow into the oxbow. The plug may be at a low enough elevation where flood flows may also move through the reach to be abandoned.

Figure 6. Overview of propose oxbow restoration on the Sheyenne River near Horace, ND. Photo source: GoogleEarth May 14, 2020 (Imagery Date 5/19/2018).

Project Benefits

"The Sheyenne River is one of the most biologically diverse rivers in North Dakota and is the 4th longest river in the state, meandering approximately 600 miles. Fifty-three fish species and 12 mussel species occur within the Sheyenne River watershed (DeLorme 2011; Delorme et al. 2019; Peterka 1978; as cited in USFWS 2018). Many of these fish species are known to be migratory, including walleye, sauger, channel catfish, and several redhorse species. The Sheyenne River is listed as a Class 1 River, meaning it is classified as a highest-valued fishery resource in North Dakota (USGS 1978, as cited in USFWS 2018). Currently the lower Sheyenne River is almost impassable. The reconnection efforts described above would reconnect over 100 miles of Sheyenne River habitat (USFWS 2018). This would extend from the Red River to the next most upstream low-head dam, which is the upstream of Horace, ND. The Sheyenne River is the largest Red River tributary in North Dakota, so this reconnection would provide a substantial improvement for fishery resources in the Sheyenne River, as well as Red River fishes that use the Sheyenne River for seasonal needs.

Connectivity would be achieved through fish movement both in the Sheyenne River Channel, as well as potential fish movement through the required, adjacent HWFDC and WFDC. The attached flow analysis provides context to how frequently river discharge will meet thresholds where flows would be passed down through the HWFDC and WFDC. Regardless of river discharge, the mitigation will strive to promote connectivity across almost all river flows.

The oxbow restoration would restore about three acres (1,750 lineal feet) of Sheyenne River previously abandoned. This would provide some habitat of the same type lost due to the project.

Mitigation Credit

Use of fish passage/connectivity as a mitigation strategy for direct loss of aquatic habitat presents a unique challenge of accounting. It's difficult to gage how the level of functional improvement directly compares to lost physical habitat space. While some ecological models and other tools are beginning to explore these possibilities, the reality is that it remains difficult to directly compare how much functional improvement offsets a loss of river habitat.

Note that USACE policy directs the Corps to offset significant habitat losses to the fullest extent practicable, while trying to avoid or minimize both over- and under-mitigating for a significant effect. Corps policy recommends the use of habitat models for such quantification, with adaptive management and monitoring to help ensure mitigation is working. Such quantification would be difficult in this case. Yet the need remains for the Corps to be able to document when mitigation has been fulfilled.

This issue has been discussed with the State of North Dakota, including the Department of Game and Fish, Department of Environmental Quality, as well as the State Water Commission. This group mutually agreed that implementation of the project features outlined above (both fish passage and oxbow restoration), in concert with other benefits that will be obtained from the Drayton Dam Fish Passage Project (which will also be implemented as a part of project mitigation activities) would adequately offset the loss of aquatic habitat within the State of North Dakota. This include the loss of habitat associated with the Red River Structure, Wild Rice River Structure, Sheyenne River aqueduct, and Maple

River aqueduct. This loss is approximately 32 to 33 acres, but could vary slightly as the design efforts progress.

Documentation Process

USACE policy requires measurements to demonstrate, to the extent practical, that habitat losses have been fully mitigated. That cannot be realistically done in this instance at this time. In lieu of this, USACE proposes an agreement with the natural resource agencies in North Dakota that the proposed Sheyenne River mitigation project adequately offsets the losses of aquatic habitat.

USACE will transmit to the Department of Game and Fish, and Department of Environmental Quality, a letter with this white paper outlining the Sheyenne River mitigation efforts, and request concurrence from each agency that the project fulfills the mitigation need for lost aquatic habitat in the State of North Dakota. This coordination is not a legally binding agreement, but an agreement of understanding that this specific mitigation need in North Dakota has been fulfilled. USACE can then use this coordination to document completion of this mitigation need, and provide for vertical reporting within our agency should concerns arise over adequate levels of mitigation for this impact.

Environmental Compliance

The proposed mitigation actions discussed herein would undergo its own environmental compliance review. This would include public review pursuant to the National Environmental Policy Act, as well as considerations for Clean Water Act, Endangered Species Act, National Historic Preservation Act and other statutes. The action would consider needs for CWA 404 and 401 Water Quality Certification, and necessary permits from the North Dakota State Water Commission.

Sheyenne River above the Sheyenne Diversion near Horace, ND

Flow Duration Curve Update

September 2020

Addendum No. 1

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1 Monthly Flow Duration

This addendum was added to the *Sheyenne River above the Sheyenne Diversion near Horace, ND Flow Duration Curve Update* report in response to a request from the FMM project team for monthly flow duration information at the Sheyenne River above the Sheyenne Diversion near Horace, ND gage. Specifically, the project team requested the approximate percent time of exceedance for two discharges, 1,100 cfs and 650 cfs, for each month of the year. These two discharges correspond to the threshold at which flow begins to enter the Horace to West Fargo Diversion Channel and the West Fargo Diversion Channel, respectively. This information is presented in Table 1 for 1992-2020 and 1952-2020, the two time periods analyzed for the flow duration curve update.

Table 1. Monthly percent time of exceedance for 1,100 cfs and 650 cfs, Sheyenne River above the Sheyenne Diversion Channel near Horace, ND

Month	Approximate % Time of Exceedance			
	1992-2020		1952-2020	
	1,100 cfs	650 cfs	1,100 cfs	650 cfs
January	< 0.1	< 0.1	< 0.1	< 0.1
February	0.5	1.6	0.3	0.8
March	12	23	8	15
April	50	66	33	45
May	39	64	20	35
June	25	55	11	25
July	17	45	8	22
August	7	26	3	11
September	3	23	1	8
October	4	24	2	10
November	2	14	1	6
December	< 0.1	1	< 0.1	0.5

Figure 1 through Figure 12 display the flow duration curve for each month for the periods 1992-2020 and 1952-2020. For all plots, the y-axis was limited to a maximum of 1,500 cfs to highlight the range of discharges of greatest concern to the project team. For all months, the curve computed for the period 1992-2020 plots above the curve computed for the period 1952-2020. This is due to a relatively wet period occurring over the last 30 years as well as the effects of pumping from Devils Lake, which has been occurring since 2005.

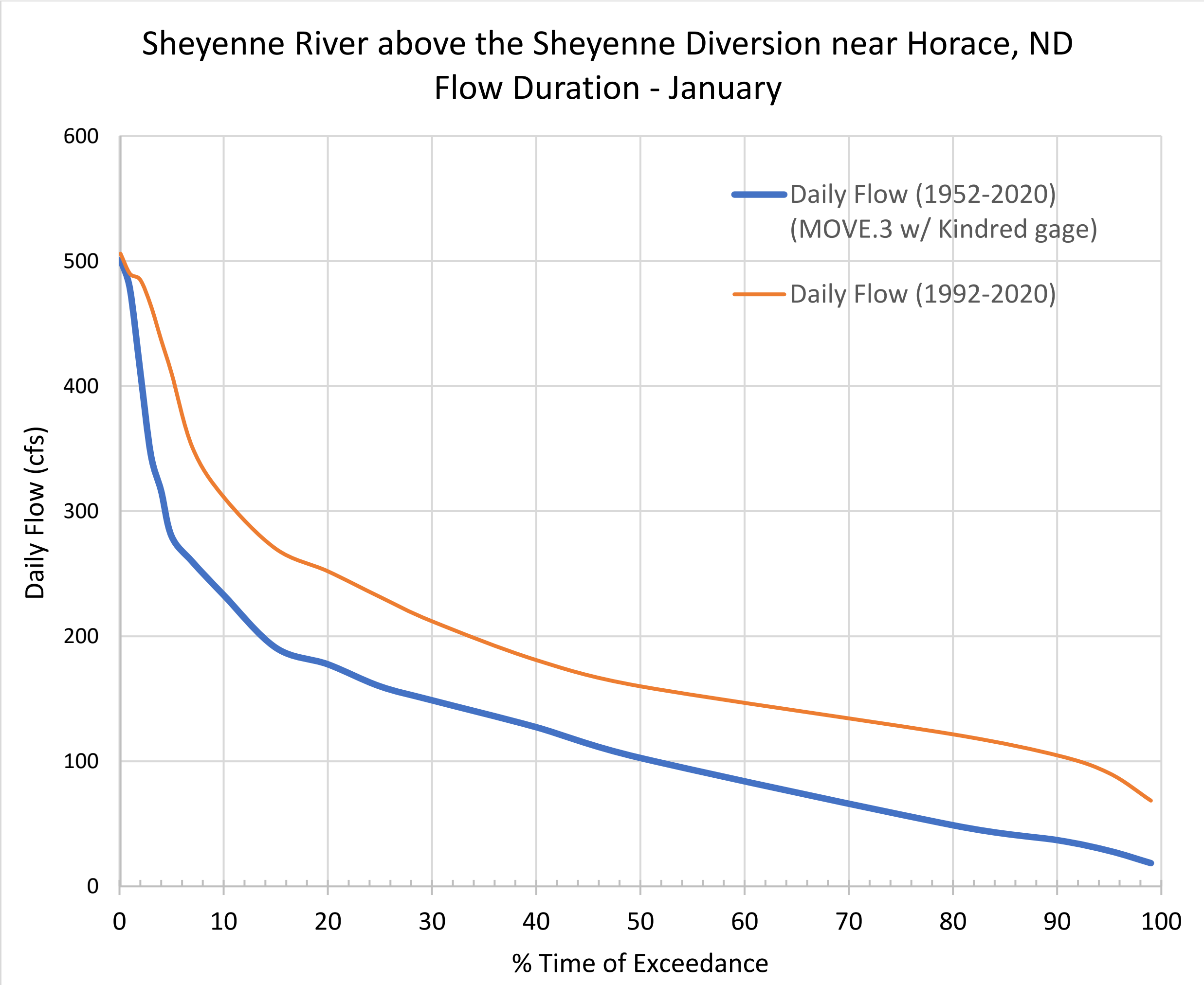


Figure 1. January flow duration curve, Sheyenne River above the Sheyenne Diversion near Horace, ND

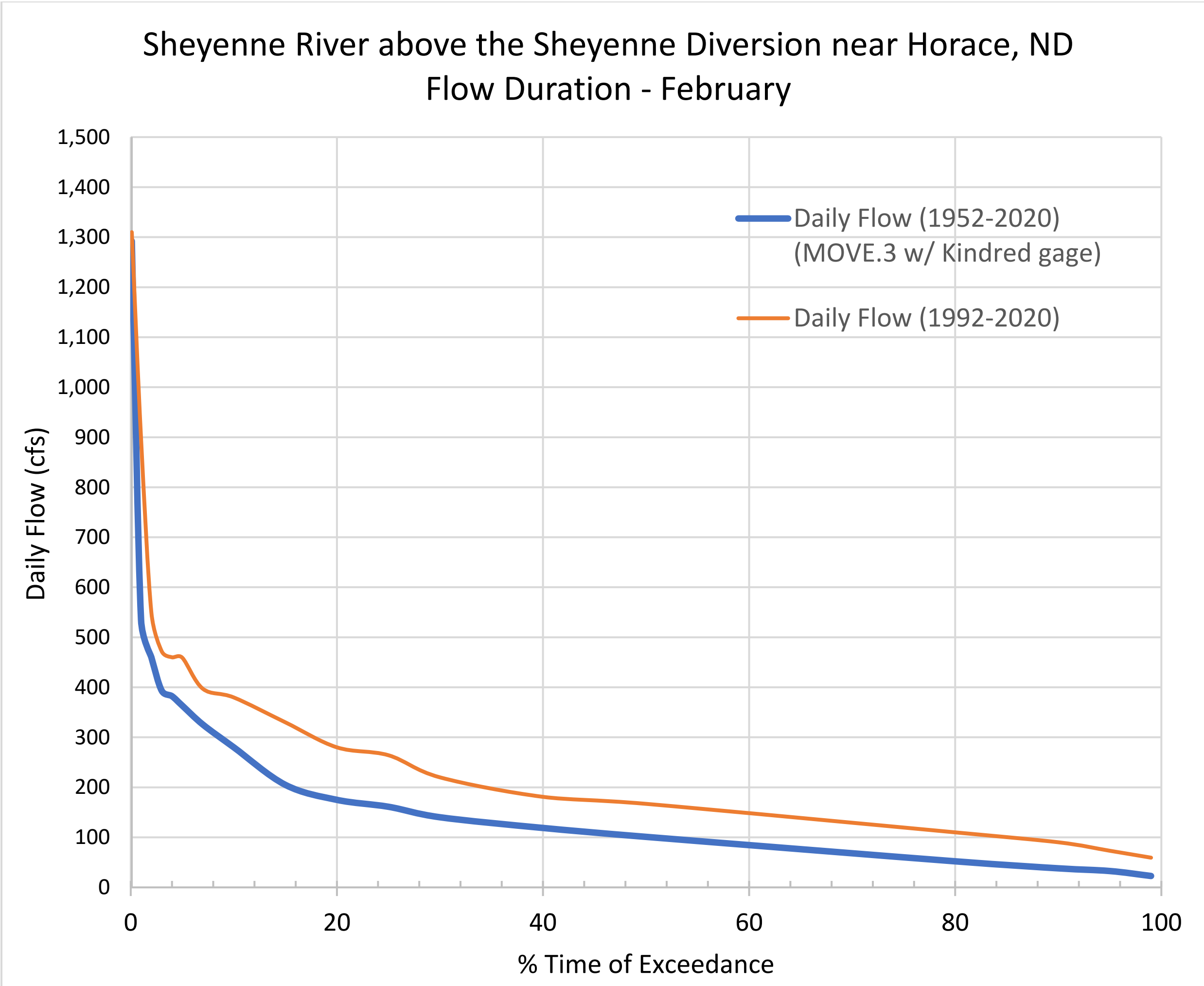


Figure 2. February flow duration curve, Sheyenne River above the Sheyenne Diversion near Horace, ND

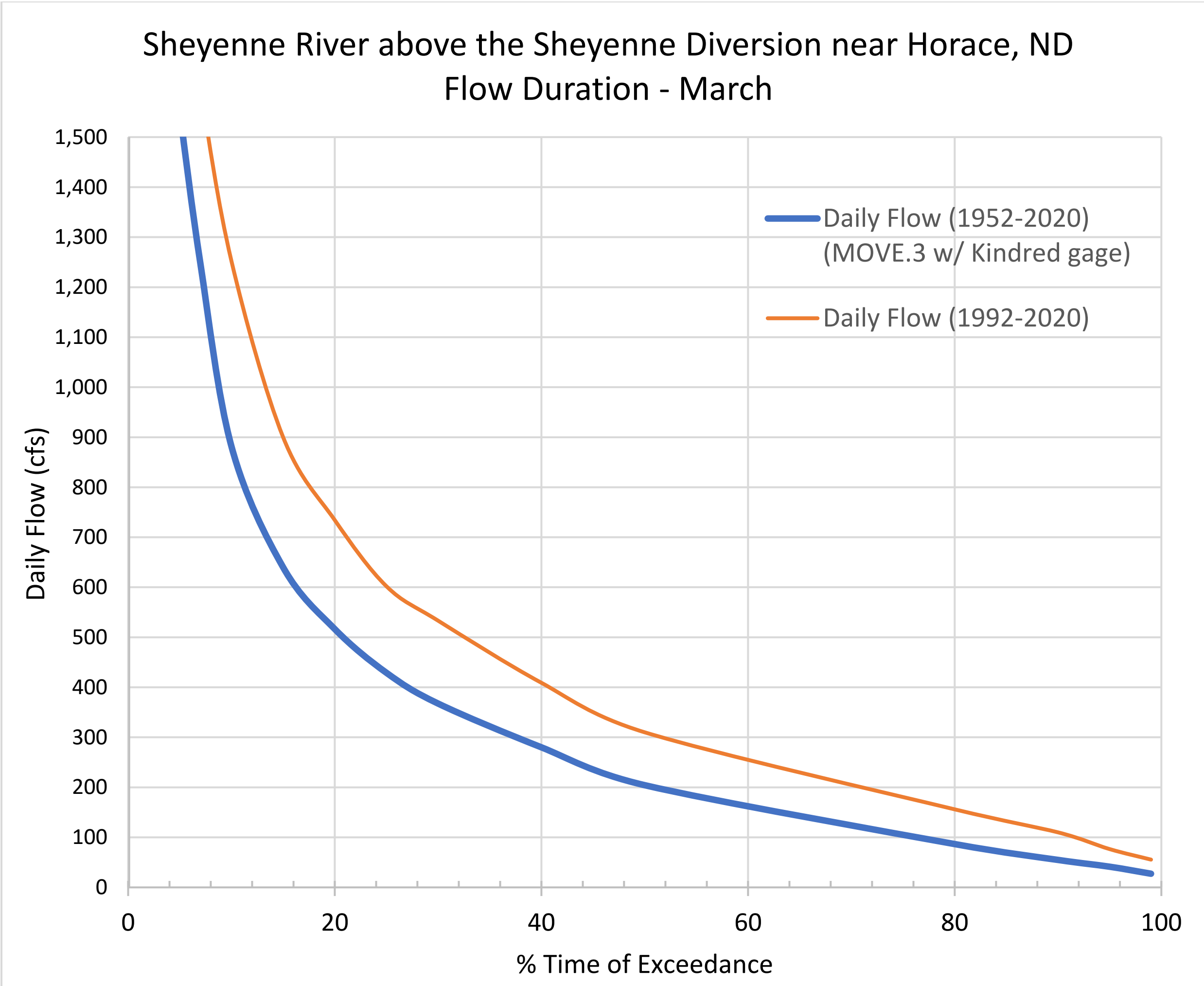


Figure 3. March flow duration curve, Sheyenne River above the Sheyenne Diversion near Horace, ND

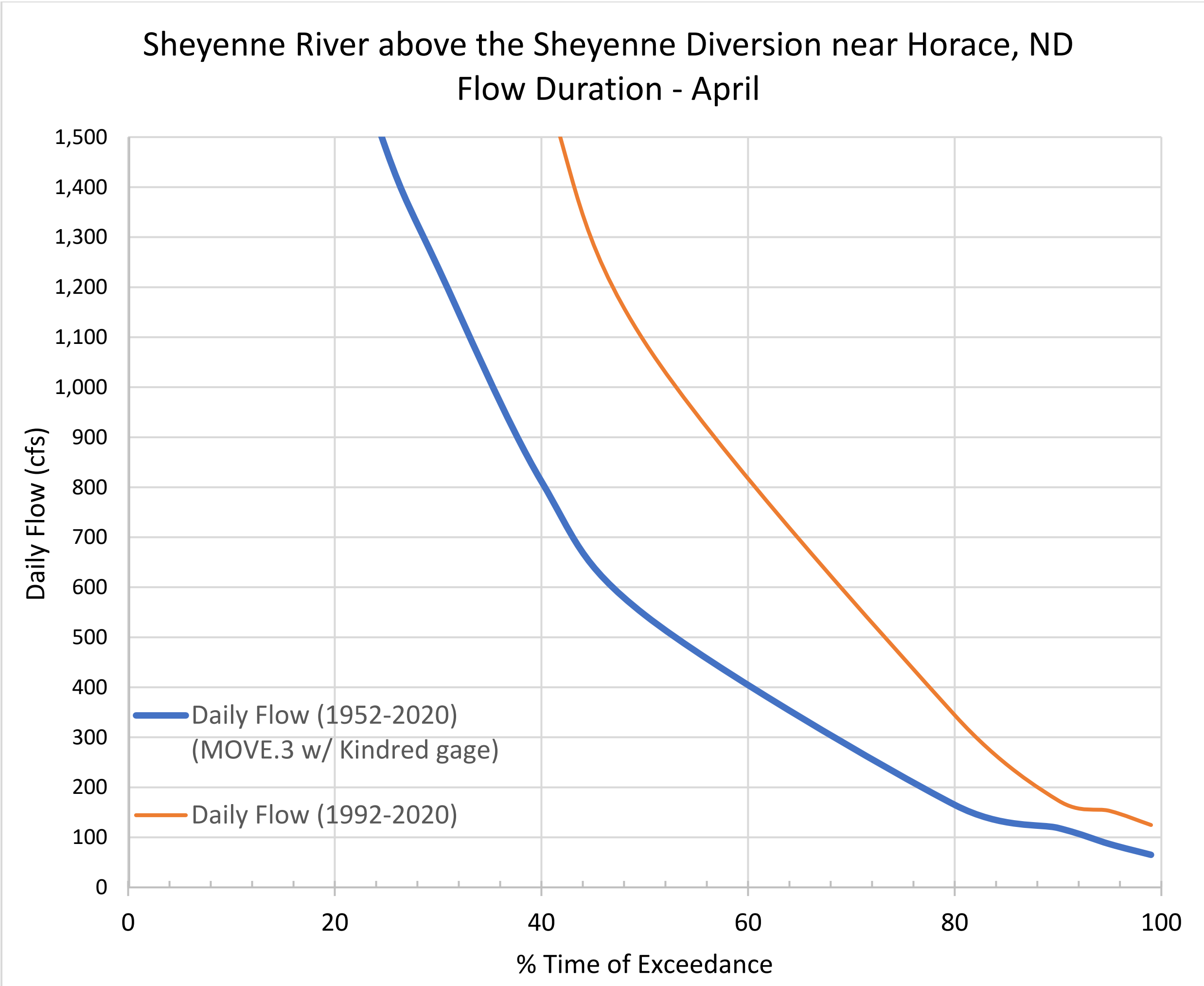


Figure 4. April flow duration curve, Sheyenne River above the Sheyenne Diversion near Horace, ND

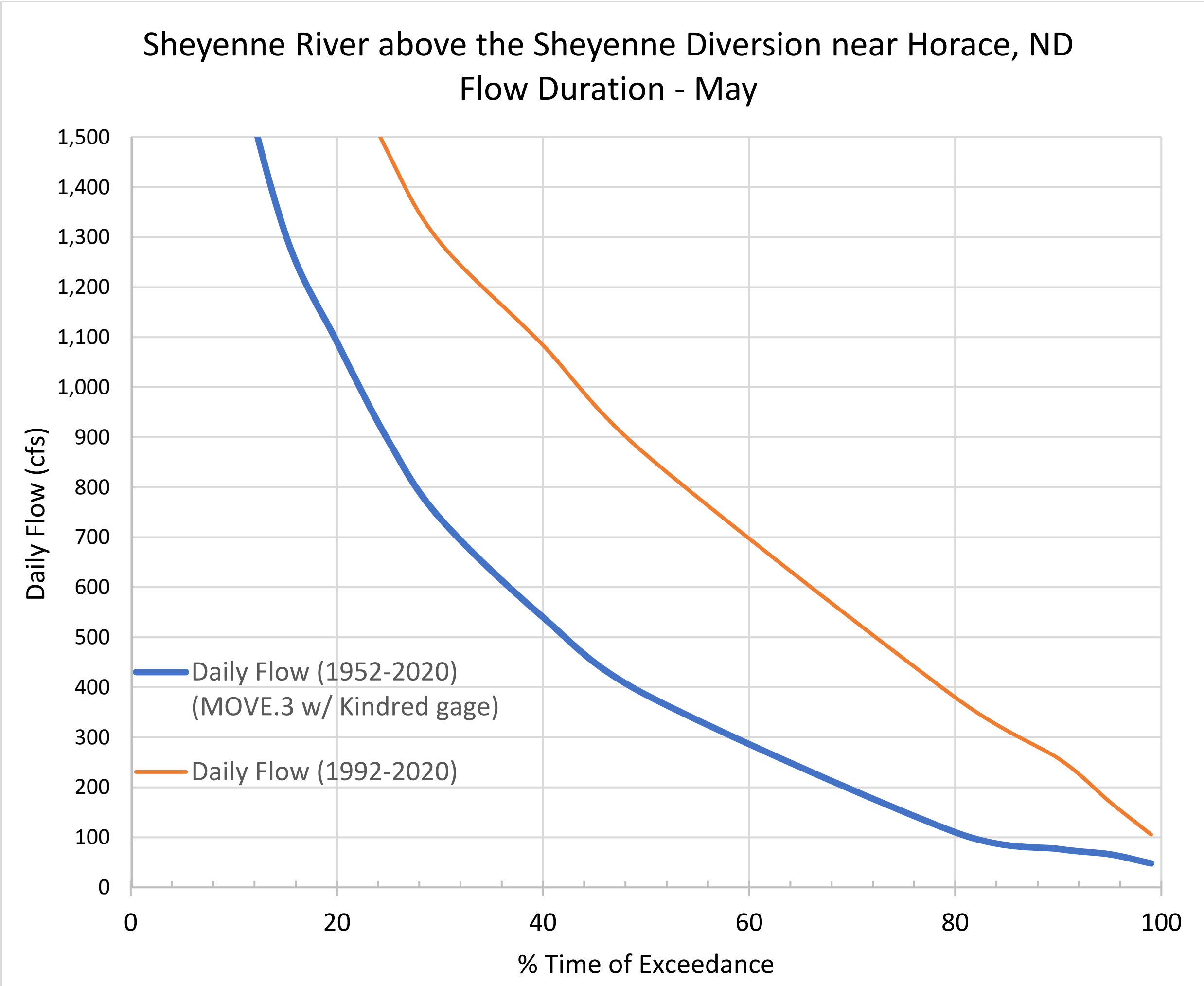


Figure 5. May flow duration curve, Sheyenne River above the Sheyenne Diversion near Horace, ND

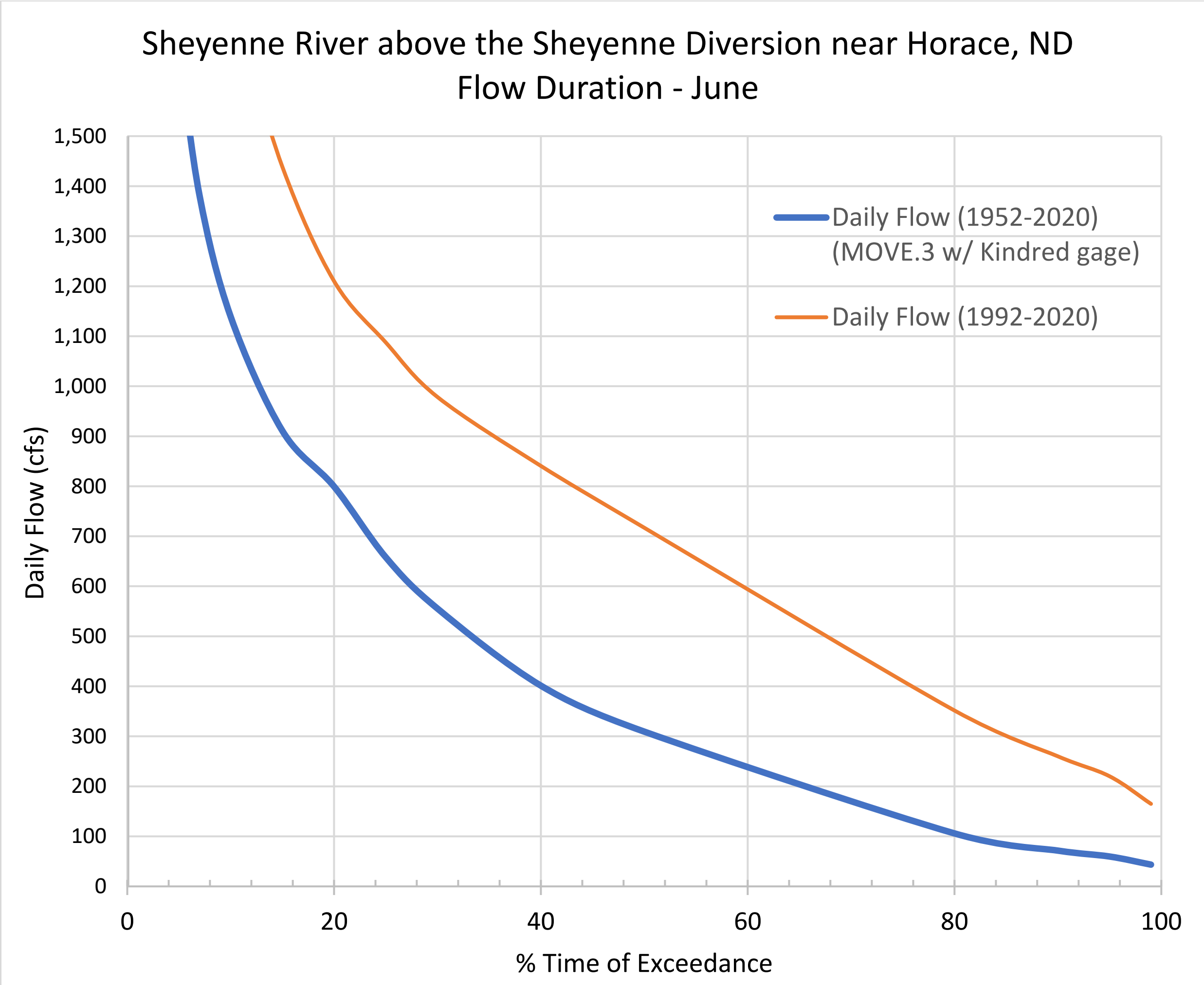


Figure 6. June flow duration curve, Sheyenne River above the Sheyenne Diversion near Horace, ND

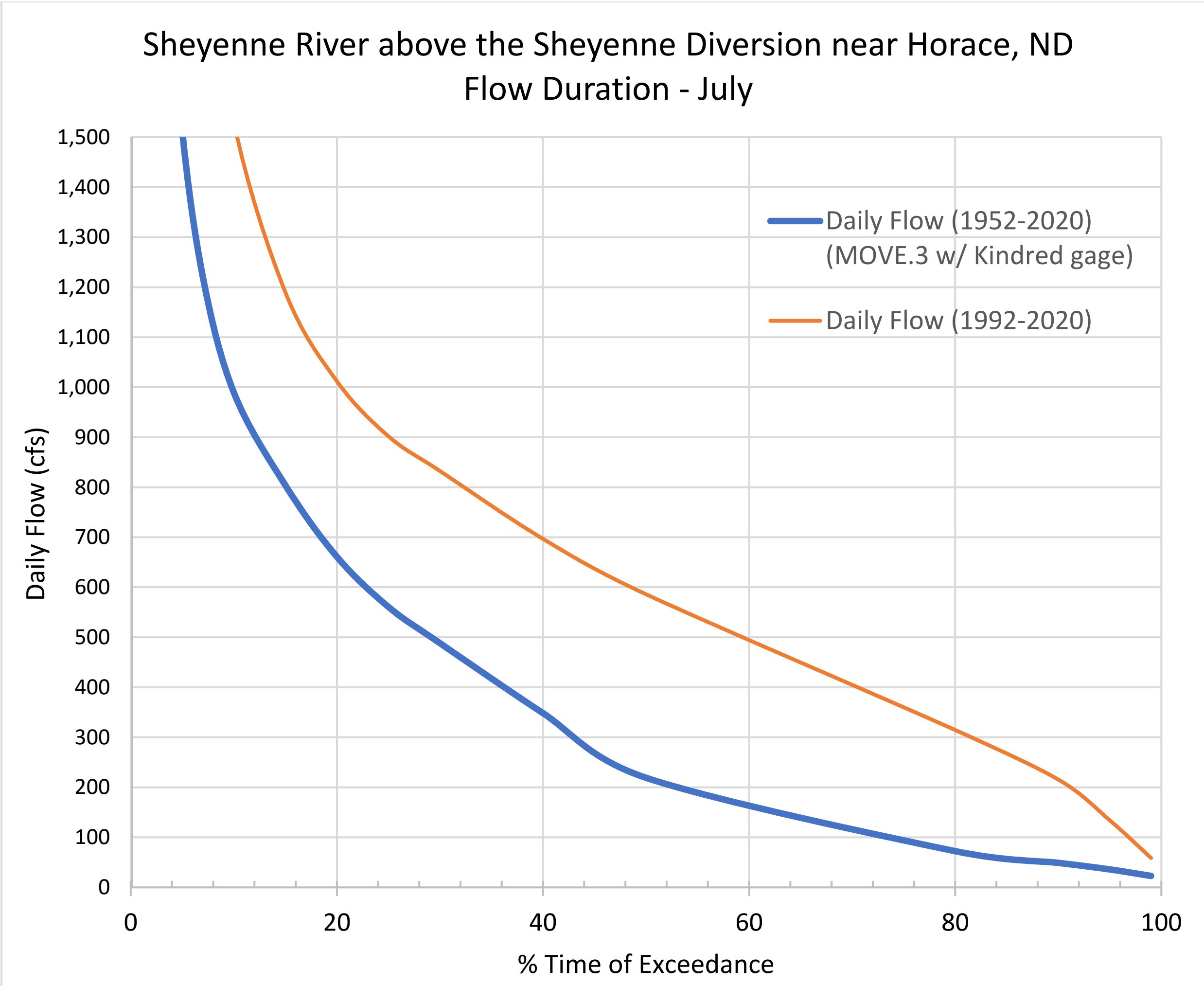


Figure 7. July flow duration curve, Sheyenne River above the Sheyenne Diversion near Horace, ND

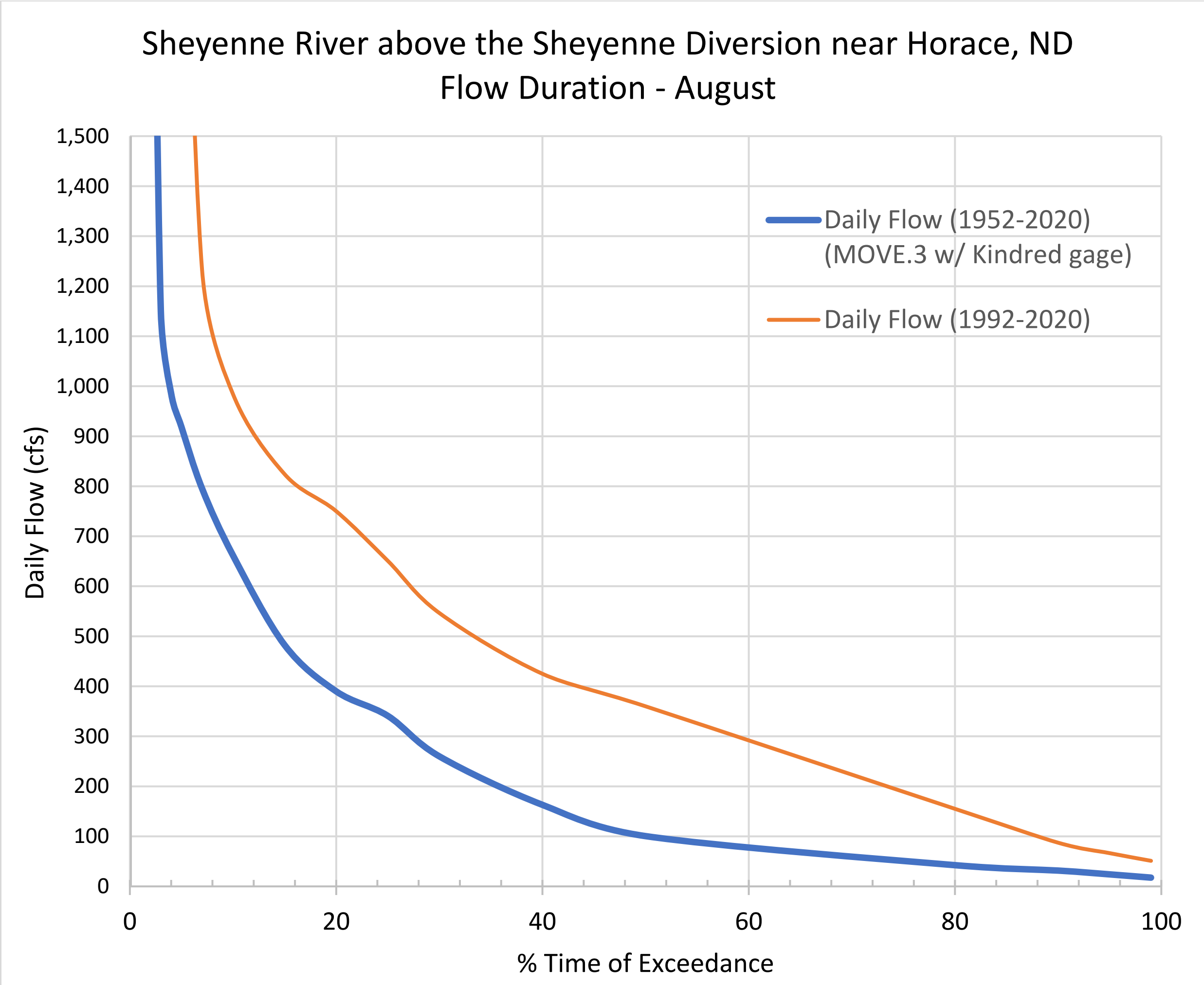


Figure 8. August flow duration curve, Sheyenne River above the Sheyenne Diversion near Horace, ND

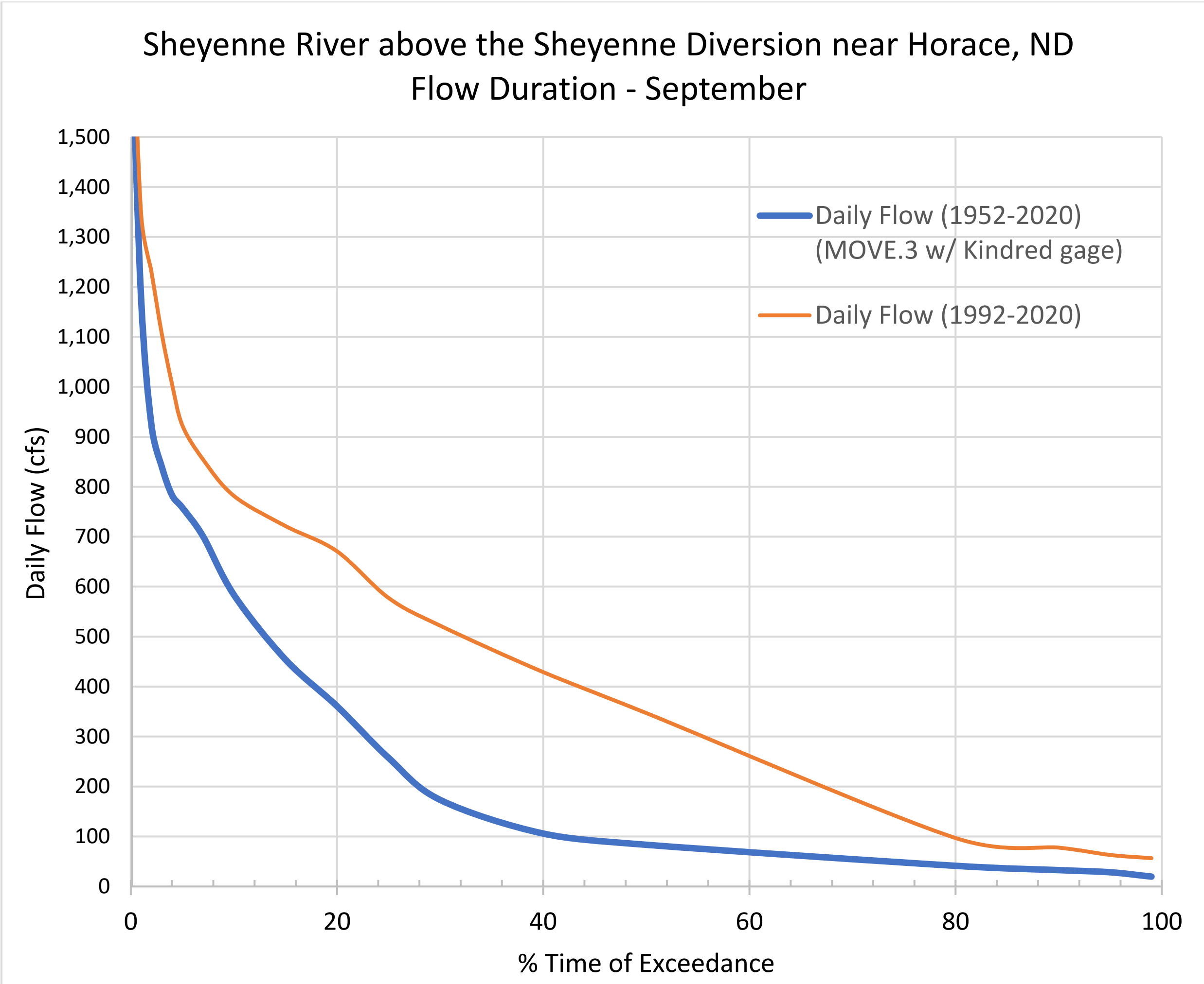


Figure 9. September flow duration curve, Sheyenne River above the Sheyenne Diversion near Horace, ND

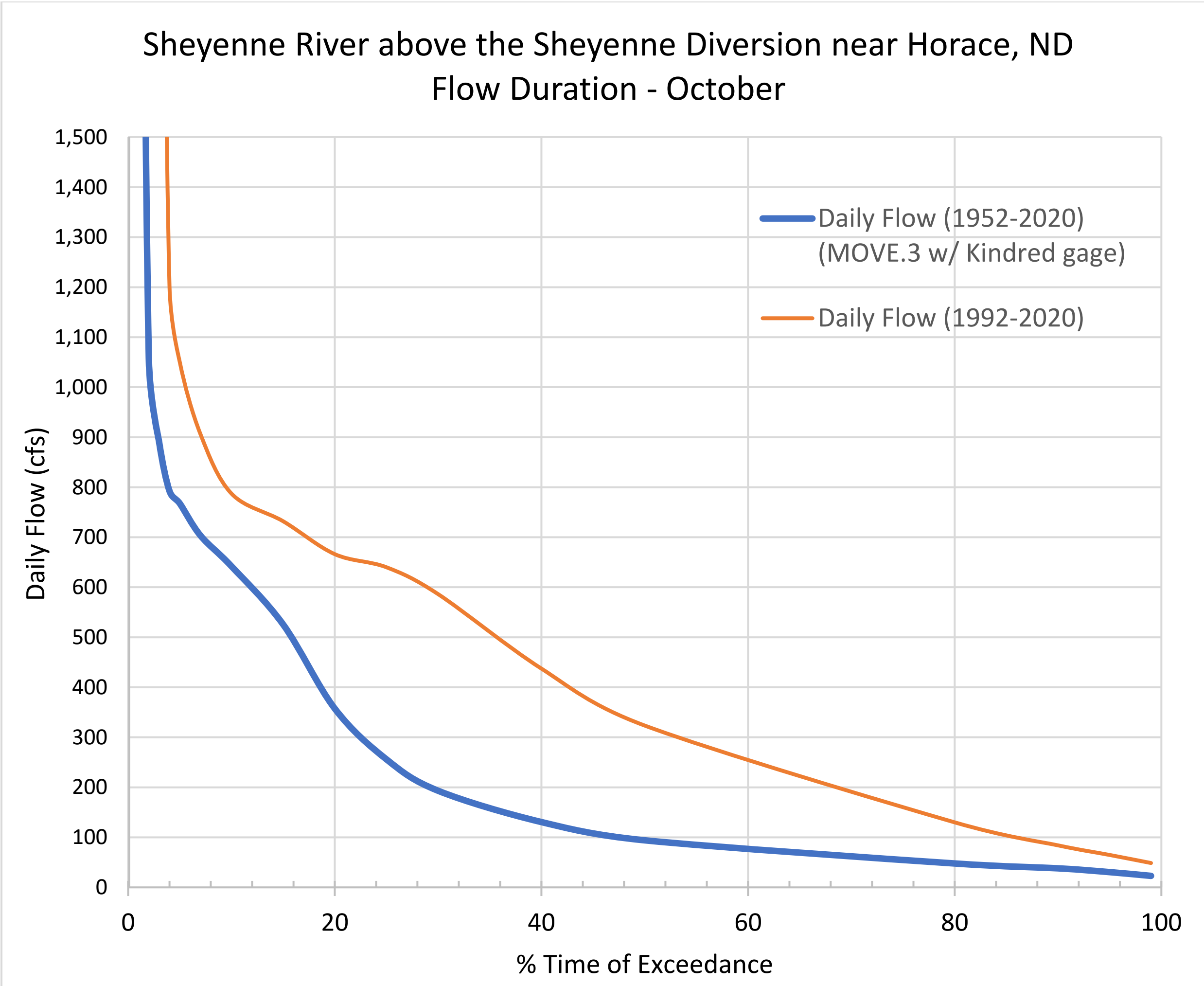


Figure 10. October flow duration curve, Sheyenne River above the Sheyenne Diversion near Horace, ND

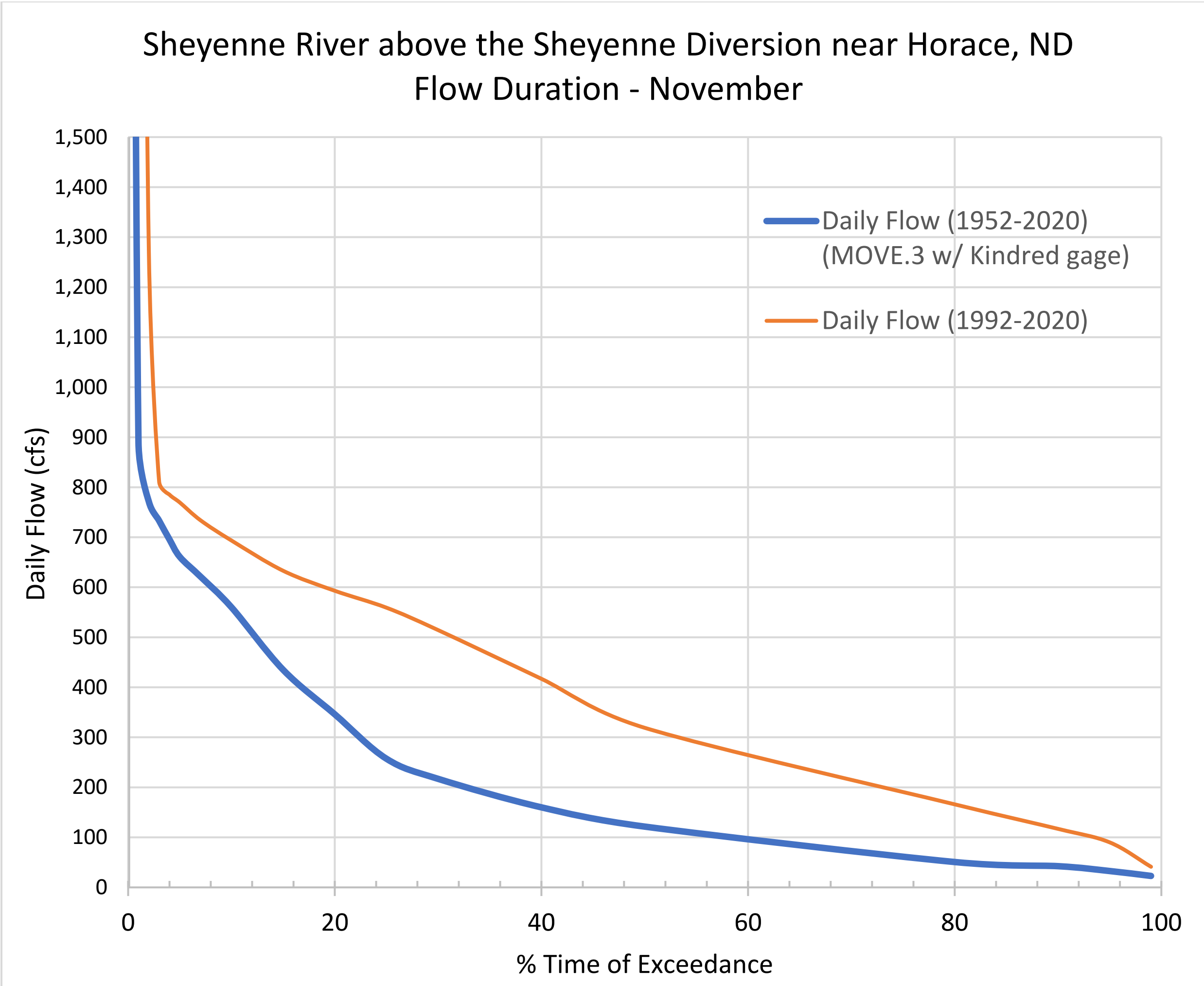


Figure 11. November flow duration curve, Sheyenne River above the Sheyenne Diversion near Horace, ND

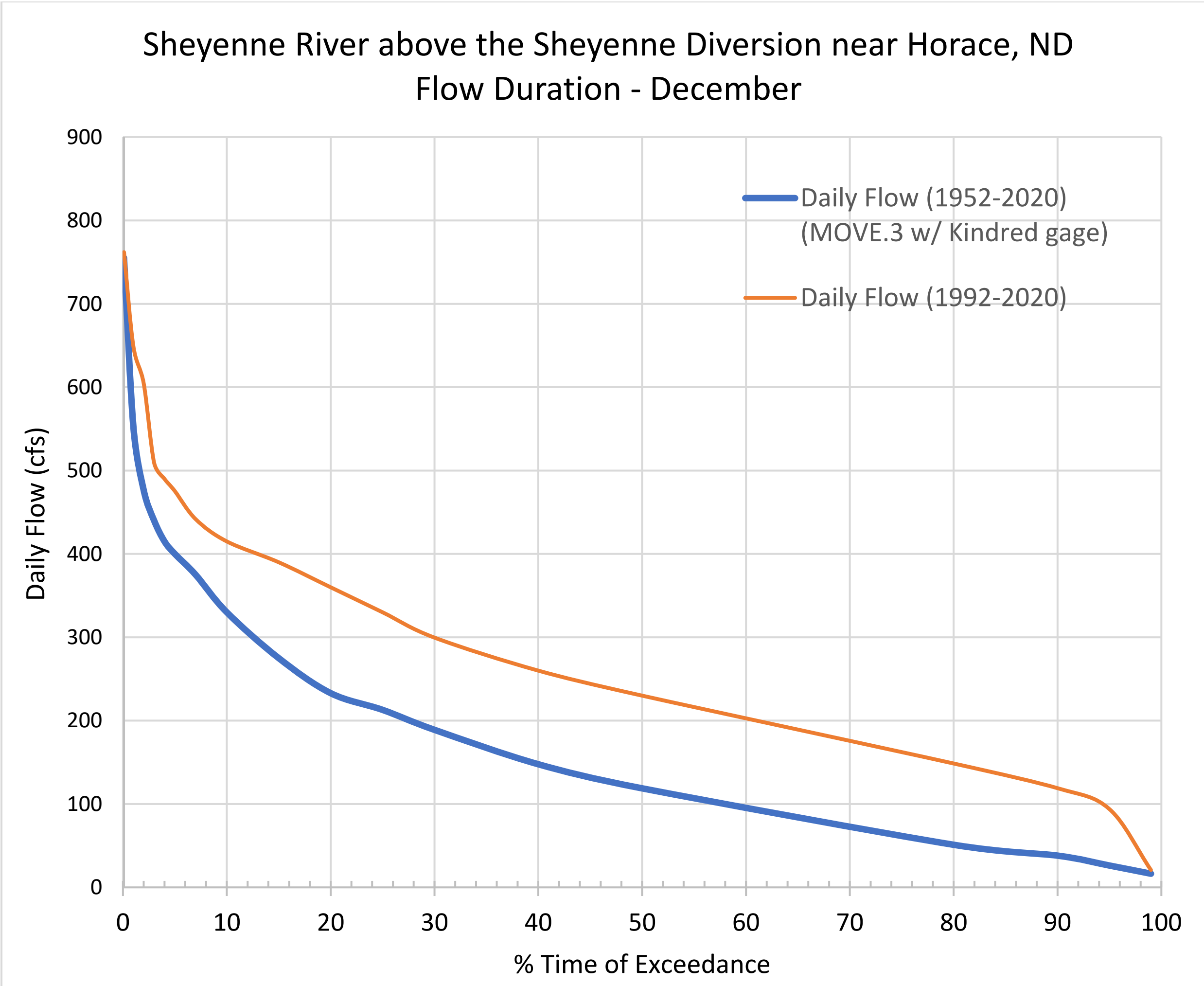


Figure 12. December flow duration curve, Sheyenne River above the Sheyenne Diversion near Horace, ND

Devils Lake Pumping

Purpose

The Sheyenne River mitigation project is one of the primary mitigation measures used to offset environmental impacts resulting from the construction of the Fargo-Moorhead Metropolitan Area Flood Risk Management Project. Understanding Sheyenne River flows is important for understanding how frequently different components of the Sheyenne River mitigation project convey water. It is hypothesized that Devils Lake pumping has increased Sheyenne River flows. Therefore, an investigation was conducted to better understand Devils Lake pumping and determine if the pumping increased flows along the Sheyenne River in the vicinity of the Sheyenne River mitigation project. Findings from the investigation are summarized in this document in response to specific questions. Findings from the investigation should not be used to associate Devils Lake pumping more broadly with any other changes in the Sheyenne River basin without further assessment.

Questions

1. When did pumping from Devils Lake begin?
2. How are the pump stations operated?
3. Is pumping from Devils Lake currently happening?
4. How much water is pumped from Devils Lake?
5. When is pumping from Devils Lake likely to end?
6. Does pumping from Devils Lake significantly impact flows on the Sheyenne River above the Sheyenne Diversion near Horace, ND?

Answers

1. There are two pump stations pumping water from Devils Lake to the Sheyenne River, the West End Outlet and the East End Outlet. The West End Outlet began operating in 2005, and the East End Outlet began operating in 2012. Initially, the maximum discharge capacity of the West End Outlet was 100 cfs, and the pump station was operated intermittently. However, in 2010, the discharge capacity was increased to 250 cfs. The East End Outlet has a discharge capacity of 350 cfs. A map displaying the location of each outlet and other important locations along the Sheyenne River is shown in Figure 1.

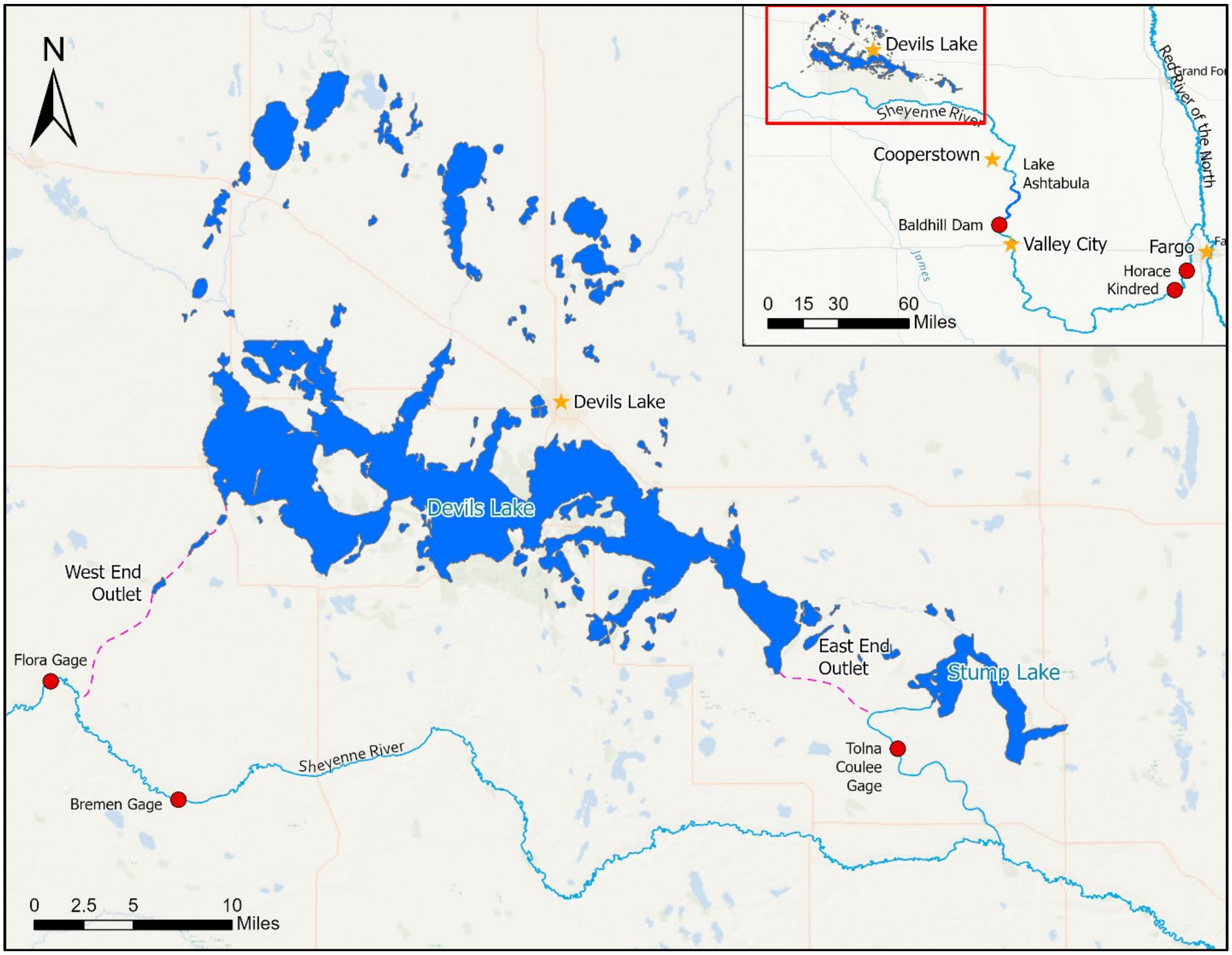


Figure 1. Map of Devils Lake outlets and Sheyenne River

2. Both pump stations are operated to limit flood damages and maintain water quality standards. According to the *Devils Lake Outlet Operational Guide* (North Dakota State Water Commission, 2020), the pumps do not operate when downstream flood gages are above flood stage. USGS gages in the Devils Lake and Sheyenne River basins are monitored and outlet discharge is adjusted to prevent flooding to the greatest extent possible. Based on past operation it has been determined that flooding begins to occur along the Sheyenne River near Cooperstown at flow above approximately 800 cfs. Twenty sites ranging from above the West End Outlet insertion point to the Red River at Pembina are regularly sampled and outlet discharge is adjusted to prevent exceedances of the water quality standards.

   Decisions regarding how the pumps are operated are made by the Governor of North Dakota and the North Dakota State Water Commission (SWC). To inform the operational decisions, the Devils Lake Outlet Management Advisory Committee was formed. Each spring, the 17-member committee meets to review the lake rise probability forecast and develop a recommendation that dictates how the pump stations will be managed for the rest of the year. Day-to-day operations are managed by the NDSWC.

The two pumps are operated simultaneously to balance downstream water quality and quantity. The pumps only operate after spring runoff has passed so as not to contribute to spring flooding. The outlets are typically operated continuously throughout the warm weather months unless large rainfall events occur, or they need to be shut down for maintenance. In the fall, the pumps are winterized after ambient air temperatures fall below 32 degrees F for an extended period. The West End Outlet was designed to operate for a minimum Devils Lake Level of 1445 feet and the East End Outlet was designed for a minimum lake elevation of 1446 feet. Since 2016, the target lake elevation for Devils Lake has been 1448 feet.

3. Pumping from Devils Lake is ongoing. Discharge records indicate the pumps are typically operated April through November, and pumping has occurred every year the structures have been in operation. Actual operation start and end dates are dictated based on spring runoff conditions and fall freeze-up. Pumping has only occurred consistently since 2010, and the current, maximum discharge capacity (600 cfs) was not achieved until the East End Outlet began operating in 2012. Releases from the outlets peaked in 2015 and have been decreasing since that point. The duration of pumping in 2019 was shorter than in preceding years because of high water on the Sheyenne River in late spring and early summer. Figure 2 is a plot from the *Devils Lake Outlet Operational Guide* (North Dakota State Water Commission, 2020) that shows annual pump discharge through 2019.

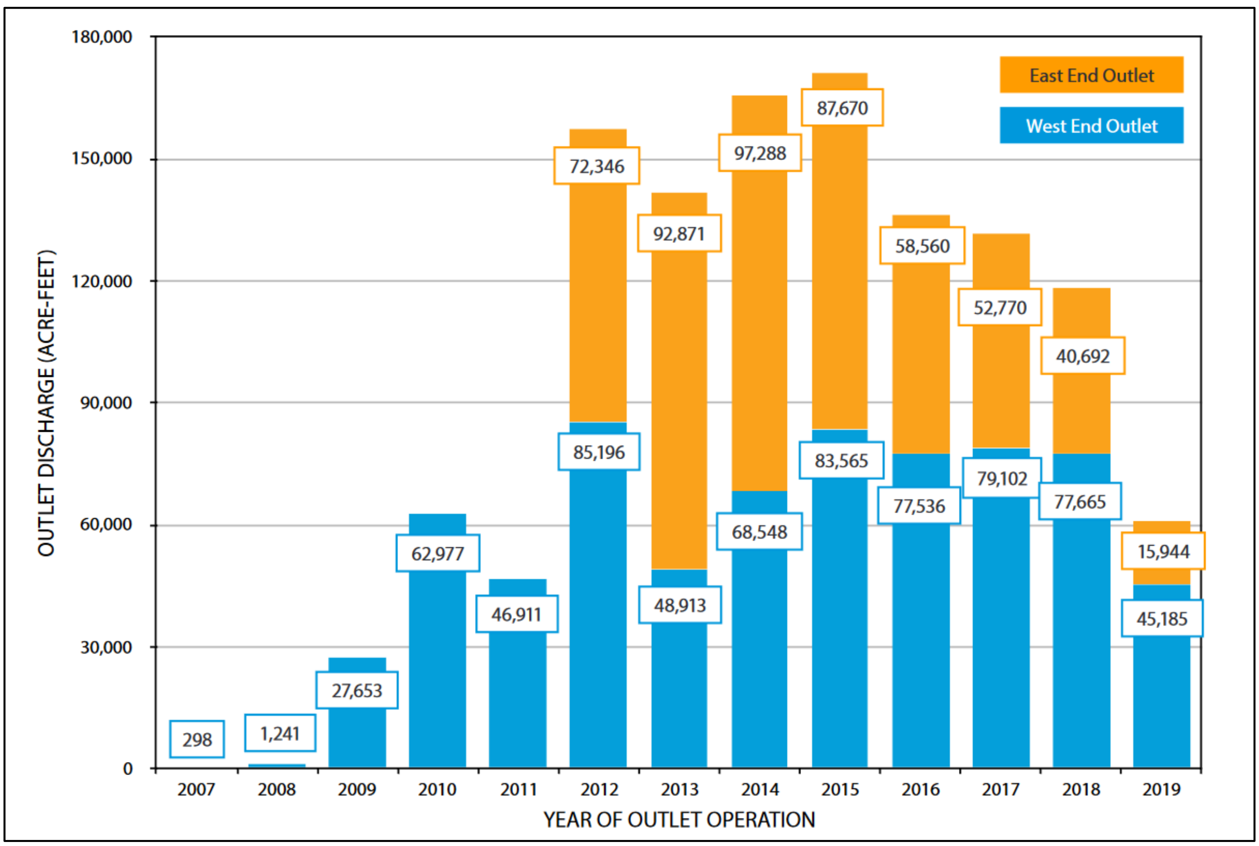


Figure 2. Annual Outlet Discharge from 2007-2019 (source: https://www.swc.nd.gov/pdfs/outlets_operations_plan.pdf)

4. Currently, the combined, maximum capacity of the West End and East End outlets is 600 cfs. Since 2012, the combined pumping rate has typically ranged from 200 cfs to 600 cfs. The discharge from both structures can be estimated using the *Estimating Outlet Discharges* fact sheet (North Dakota State Water Commission, 2017). To estimate the discharge at the West End Outlet, the discharge at the Sheyenne River above Devils Lake State Outlet near Flora, ND gage (USGS 05055300) is subtracted from the Sheyenne River below Devils Lake State Outlet near Bremen, ND gage (USGS 05055400). Negative flows, which occasionally result from this computation due to daily average flows at Flora exceeding daily average flows at Bremen, were removed in order to conduct the analysis described below. The discharge at the Tolna Coulee near Tolna, ND gage (USGS 05056678) is approximately equal to the outflows from the East End Outlet. The combined discharge from both pumping stations was estimated by advancing the West End Outlet discharges by 2 days to account for travel time to the Sheyenne River-Tolna Coulee confluence and combing the resulting flows with the East End Outlet discharges. These computation steps are shown in Figure 3. The computed discharge for each outlet, as well as the resulting, combined pumping discharge, is shown in Figure 4 for the period 2012-2020. Refer to Figure 1 for the location of each gage. Note the combined discharge occasionally exceeds the maximum pumping capacity of 600 cfs. This is due to the intervening drainage area between the gaged locations used to estimate pumped discharge, as well as small variations in routing and travel time between each gaged location.

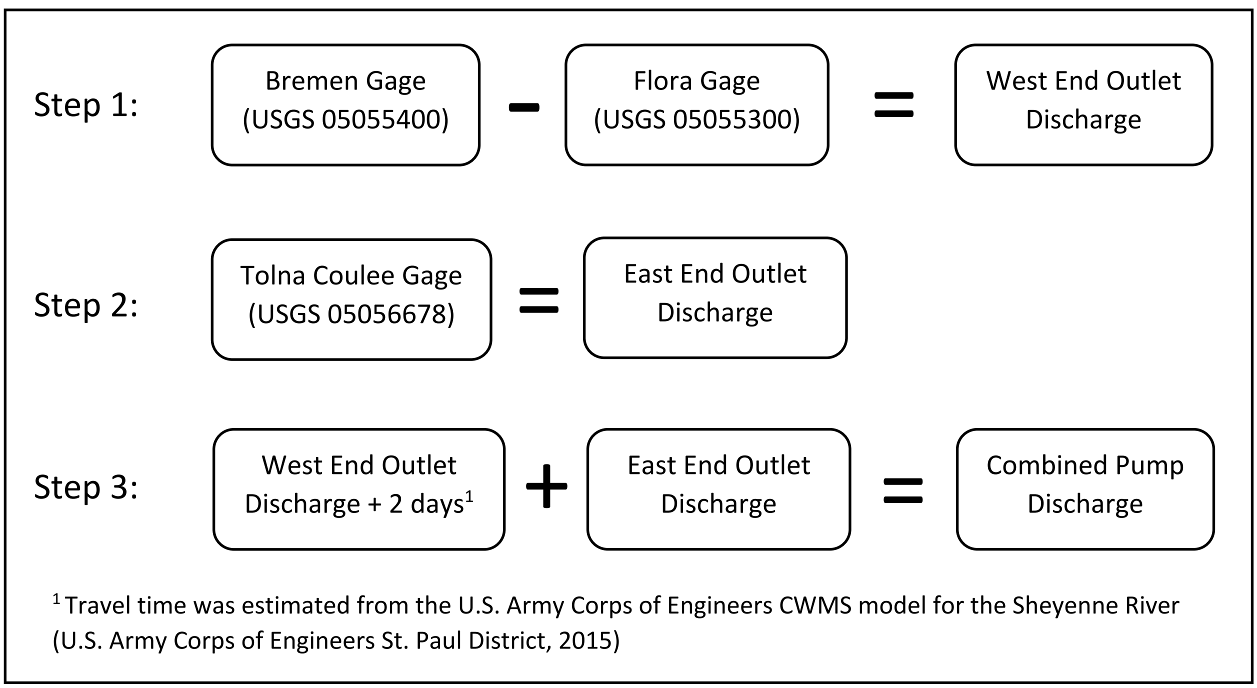
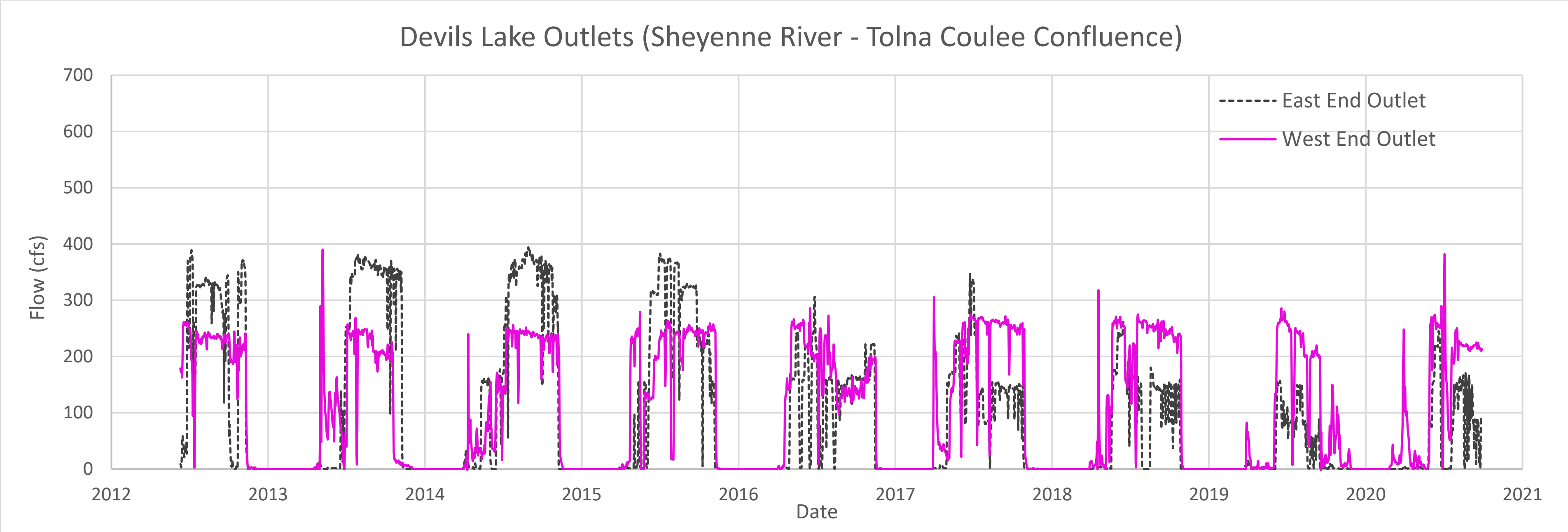


Figure 3. Computation steps to estimate combined pumping discharge from Devils Lake



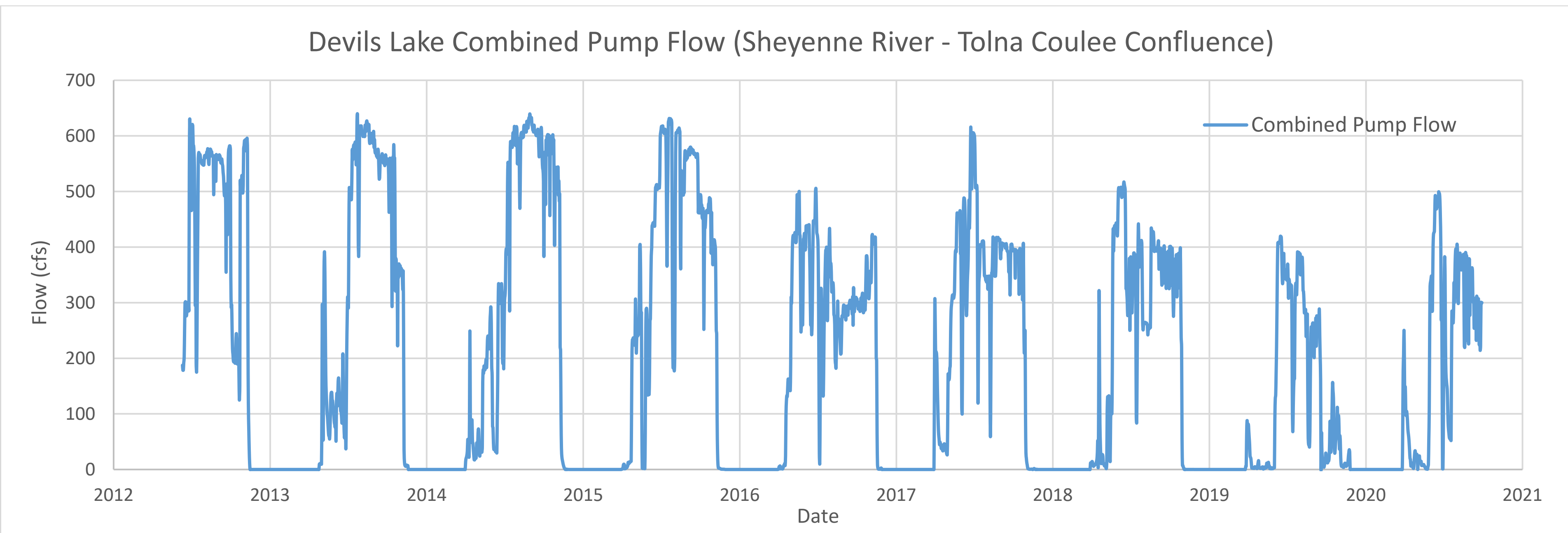


Figure 4. Discharge from the West End and East End outlets at Devils Lake, 2012-2020

5. It is not clear how long the pumping stations will operate in the future. Devils Lake reached its peak elevation of 1,454.3 ft (NGVD 29) in 2011 and has been falling since. If the lake level continues to decline, the outlets will eventually be forced to cease operation. According to the *Devils Lake Outlet Operational Guide* (North Dakota State Water Commission, 2020), there has been ongoing discussion regarding at what lake elevation pumping should cease. Higher lake elevations offer recreational benefits so some argue that pumping should be discontinued before the lake elevation falls too much further from where it is at presently. While others feel that the lake should be drawn down further to recover currently inundated agricultural land and to offer flood protection. During a full season of operation, the outlets are capable of reducing the Devils Lake water surface elevation by up to one foot. Within the past decade there have been several instances where spring runoff alone has caused the lake to rise over two feet.

   Both pump stations are designed to continue operating as necessary until the lake elevation falls below the pump station inverts (North Dakota State Water Commission, 2020). If the lake elevation continues to fall at the rate it has been falling since its peak in 2011, the pump stations will be rendered inoperable within the next 2-5 years (Figure 5). However, there is no guarantee the lake elevation will continue its downward trajectory.

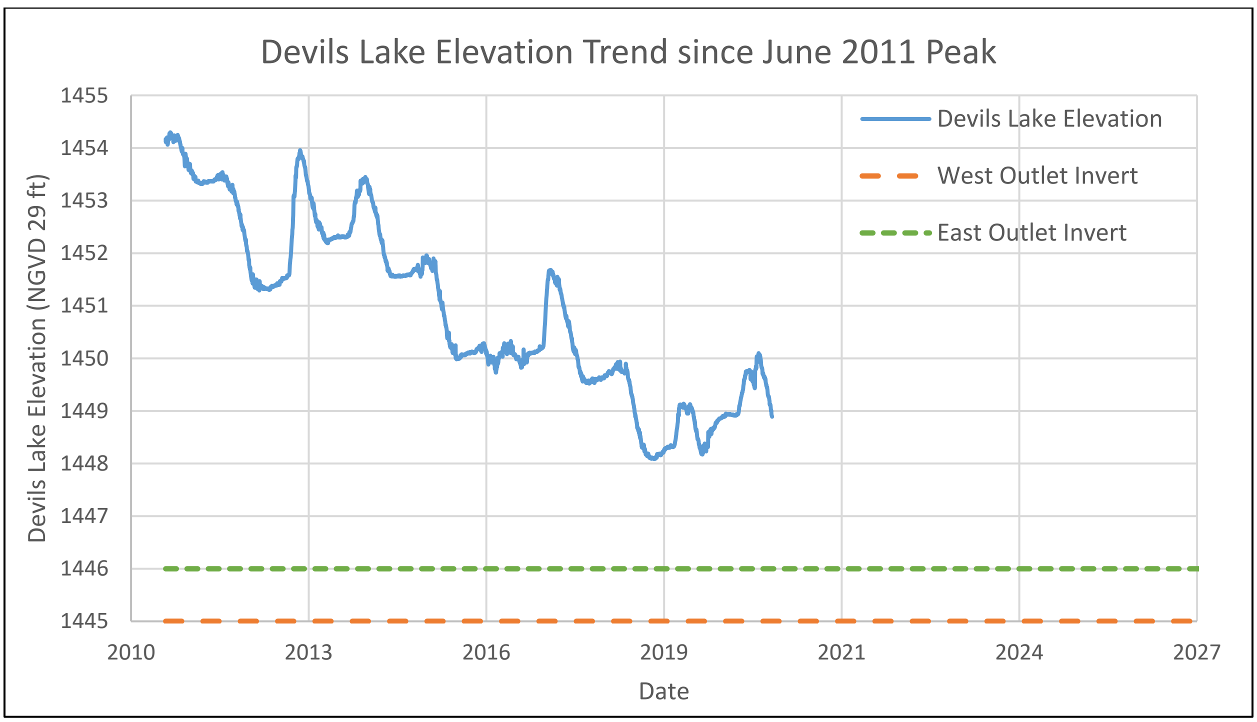


Figure 5. Devils Lake water surface elevation since peak in June 2011

6. To evaluate how discharge from the Devils Lake outlets affects flow on the Sheyenne River above the Sheyenne Diversion near Horace, ND, the approximated, daily combined pump discharge record from Devils Lake was translated downstream to Horace, ND and compared to the total daily flow record observed at Horace between 2012 and 2020 (as approximated based on the gaged record at Kindred, ND).

To assess how much attenuation and lag occurs to the pumped outflow between the pumps and Horace a routing model was used. This was accomplished by routing a 600 cfs pulse of flow (equivalent to the maximum combined pump capacity) from the West End and East End outlets downstream to Kindred, ND using the U.S. Army Corps of Engineers 2020 Corps Water Management System (CWMS) model for the Sheyenne River (U.S. Army Corps of Engineers St. Paul District, 2015). The Sheyenne River CWMS model contains Baldhill Dam which forms the impoundment of Lake Ashtabula. Observed flows at Kindred and Horace were compared to assess the lag time between the two locations.

The CWMS model is a comprehensive forecasting model that simulates a precipitation-runoff response in conjunction with reservoir operation by linking three separate models together. First, precipitation runoff throughout the Sheyenne River basin along with streamflow routing above Lake Ashtabula is modeled using the hydrologic model, HEC-HMS (version 4.2.1). Then, the pool elevation of Lake Ashtabula and releases from Baldhill Dam are modeled in the HEC-ResSim (version 3.4) reservoir model according to the physical characteristics of the dam and its water control manual. Finally, releases from Baldhill Dam are routed downstream to Kindred, ND using an HEC-RAS hydraulic model (version 5.0.7). The CWMS interface and a schematic of each associated model is shown in Figure 6.

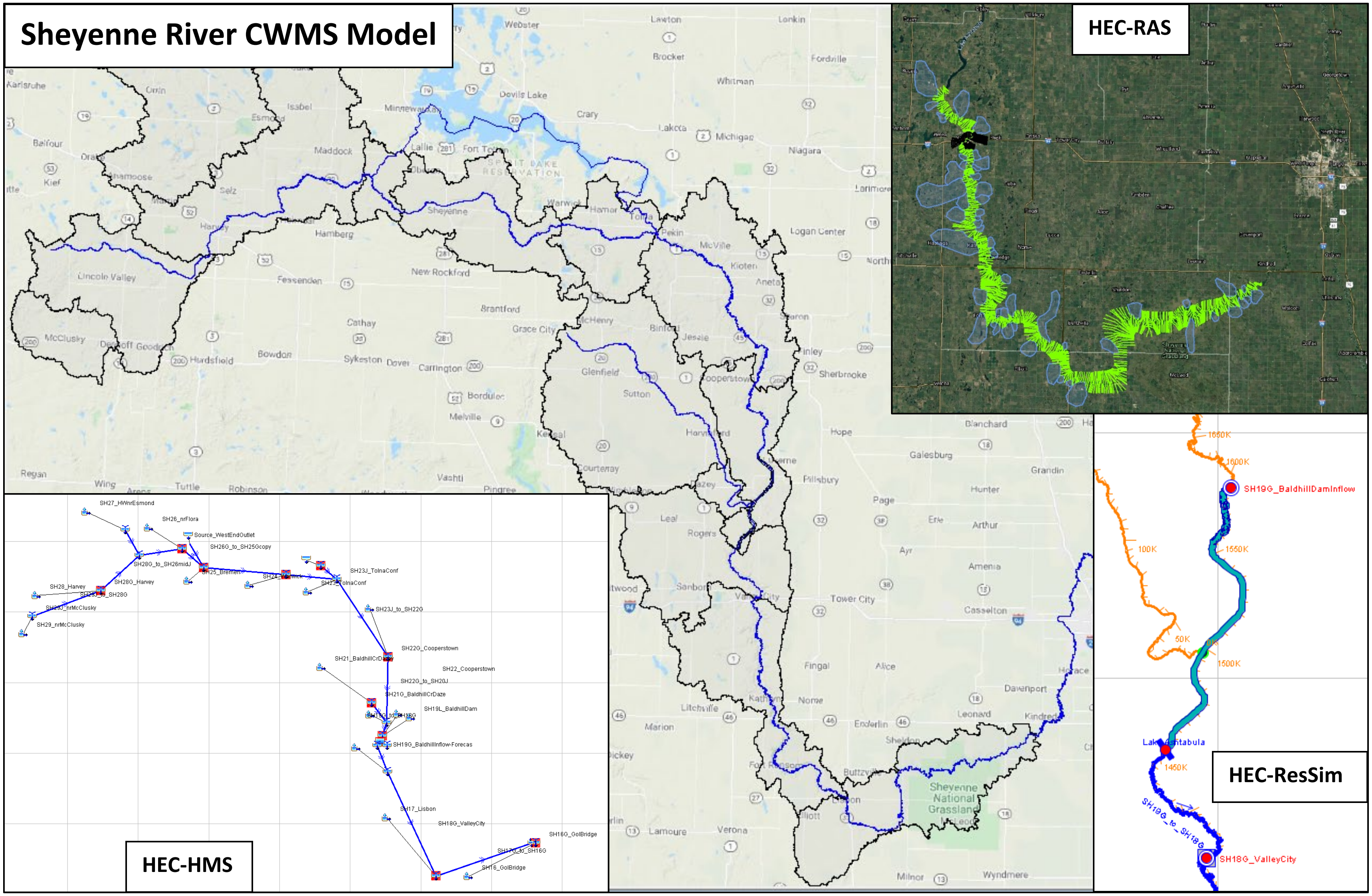


Figure 6. CWMS model interface and associated rainfall-runoff (HEC-HMS), reservoir operation (HEC-ResSim) and hydraulic models (HEC-RAS)

According to the Baldhill Dam Water Control Manual (U.S. Army Corps of Engineers St. Paul District, 2013), Lake Ashtabula is drawn down over the winter months (beginning on the first of October) to provide flood storage for spring snowmelt runoff. The normal drawdown schedule for Lake Ashtabula is displayed in Table 1. The pool must be drawn down to elevation 1262.5 feet by March 1st. If conditions in the basin indicate there is more than 1.0 inch of snow-water-equivalent (SWE) additional drawdown may be required during the month of March. During the summer months, Baldhill Dam is operated to maintain a constant pool elevation of 1266 feet +/- 0.2 feet (NGVD 29).

Table 1. Normal Drawdown Schedule (Table 7-9 From the Water Control Manual)

Normal Pool Drawdown Schedule		
Month	**Storage Volume (acre-feet)**	**Pool Elevation (feet NGVD 29)**
1 October	70,600	1266.0
1 November	66,680	1265.3
1 December	62,800	1264.6
1 January	59,000	1263.9
1 February	55,500	1263.2
1 March	52,250	1262.5

Although the water control manual specifies that drawdown prior to spring runoff should be maintained until 31 March, the water control manual does not indicate when operators should allow the pool to climb back to the normal conservation elevation of 1266 +/- 0.2 feet (NGVD29). Based on an assessment of historic water surface elevation records it was determined that on average Lake Ashtabula reaches its summer conservation pool by mid-April (Valley City Feasibility Study 2012). Since normal pool is maintained at Lake Ashtabula between April and October, it is reasonable to assume that inflow is equivalent to outflow during these months unless flood operations have been initiated. As noted previously (see 3), the Devils Lake pumps are typically operated from April (post spring snowmelt) through November unless flooding occurs.

To route the 600 cfs pulse from the pumps downstream using the CWMS model, all discharge from Devils Lake via the pumps was assumed to pass through Lake Ashtabula (600 cfs inflow to the reservoir = 600 cfs outflow from the reservoir). This is consistent with how both the pumps and Baldhill Dam have been operated historically during non-flood conditions in the summer months (mid-April through September). According to the simulation results, the combined pumped discharge from Devils Lake (as measured at the Sheyenne River-Tolna Coulee confluence) reaches Kindred, ND in approximately 14 days, and attenuation reduces the magnitude of flow by approximately 25%. A plot of the simulation results is shown in Figure 7. Note the outflow from Lake Ashtabula is slightly lower than the inflow to the reservoir due to evaporation on the pool.

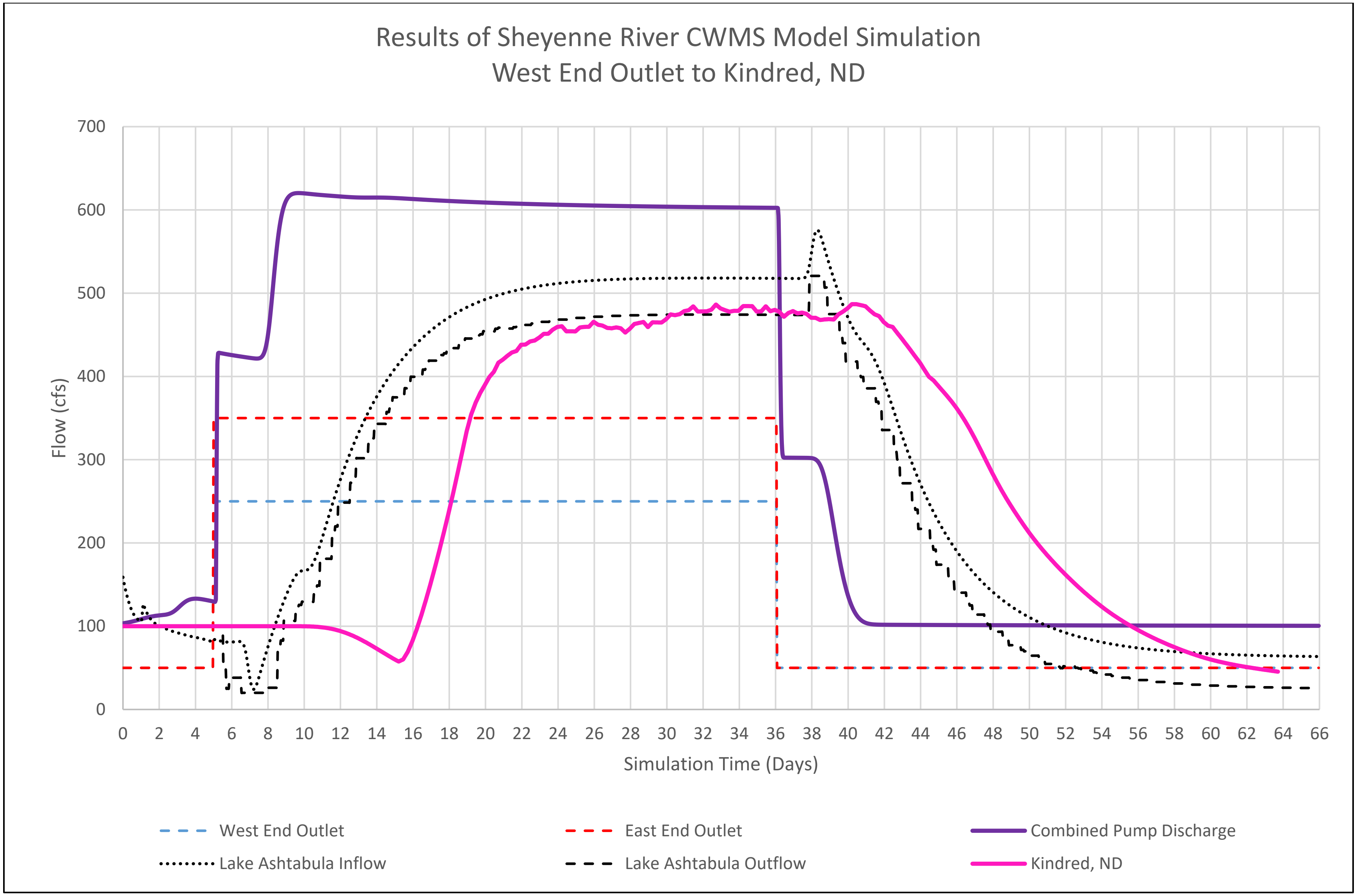
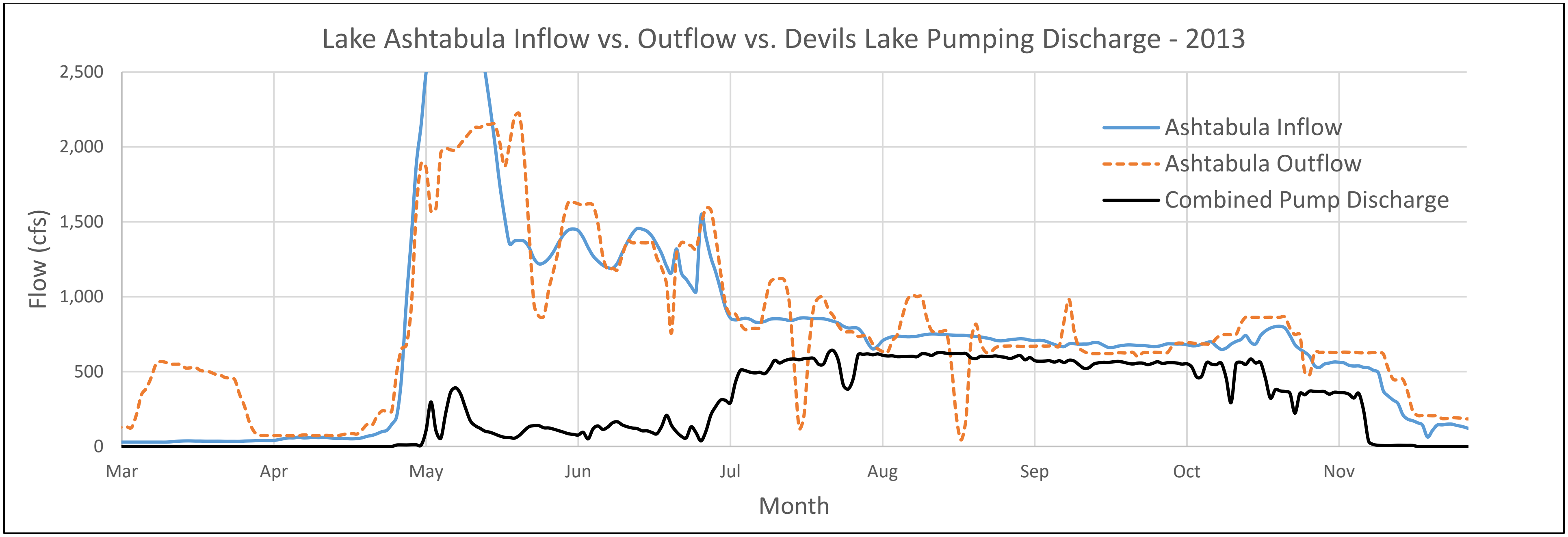


Figure 7. Results of CWMS routing model simulation

A comparison of discharge records at Kindred, ND and Horace, ND indicated the travel time from Kindred to Horace is approximately one day, and there is limited attenuation. Therefore, the combined pumping discharge from Devils Lake translated downstream to Horace, ND was approximated by advancing the flows approximated at Kindred by one additional day (total travel time 15 days).

To evaluate the impacts of the pumped flows between 2012 and 2020 the approximated, daily flow record representative of total pumped outflow from Devils Lake was lagged by 15 days and reduced by 25 percent to produce a representation of the pumped flows translated downstream to Horace. Since this approach does not account for any intervening local flow between Devils Lake and Kindred and assumes a constant pool elevation at Lake Ashtabula, the approximation of travel time and attenuation of pumped flows from Devils Lake is only applicable during scenarios in which pumped flows make up a significant percentage of inflow to Lake Ashtabula, the reservoir is releasing its inflow, and there is limited local flow inputs between the dam and Horace.

During the years 2012-2020, Lake Ashtabula maintained a consistent pool elevation of approximately 1266 feet (NGVD29) during the months of May through September. During years in which the reservoir was used for flood storage during a late spring, summer or fall flood event, such as 2013 (spring) and 2019 (fall), the Devils Lake pumps were either inactive or making limited releases. This is consistent with the operating objectives described in the *Devils Lake Outlet Operational Guide* (North Dakota State Water Commission, 2020), which states the pump discharge is adjusted to prevent flooding to the greatest extent possible. To illustrate how the pumps are operated in conjunction with flood events, as well as the operation of Baldhill Dam during the warm weather months, hydrographs for the years 2013 and 2017 are shown in Figure 8. These plots display Lake Ashtabula's inflow and outflow, as well as the combined pumping discharge from Devils Lake. As can be seen, the pumps make limited releases when inflow to the reservoir is high during the spring flood event and then ramp up releases when local inflows to the reservoir decrease. When the pumps are operating at capacity, their discharge makes up the majority of inflow into the reservoir, and the reservoir is approximately releasing the inflow it receives. Note the combined pump discharge shown in Figure 8 is computed at the Sheyenne River-Tolna Coulee confluence, and there are several days of travel time from that location to the reservoir.



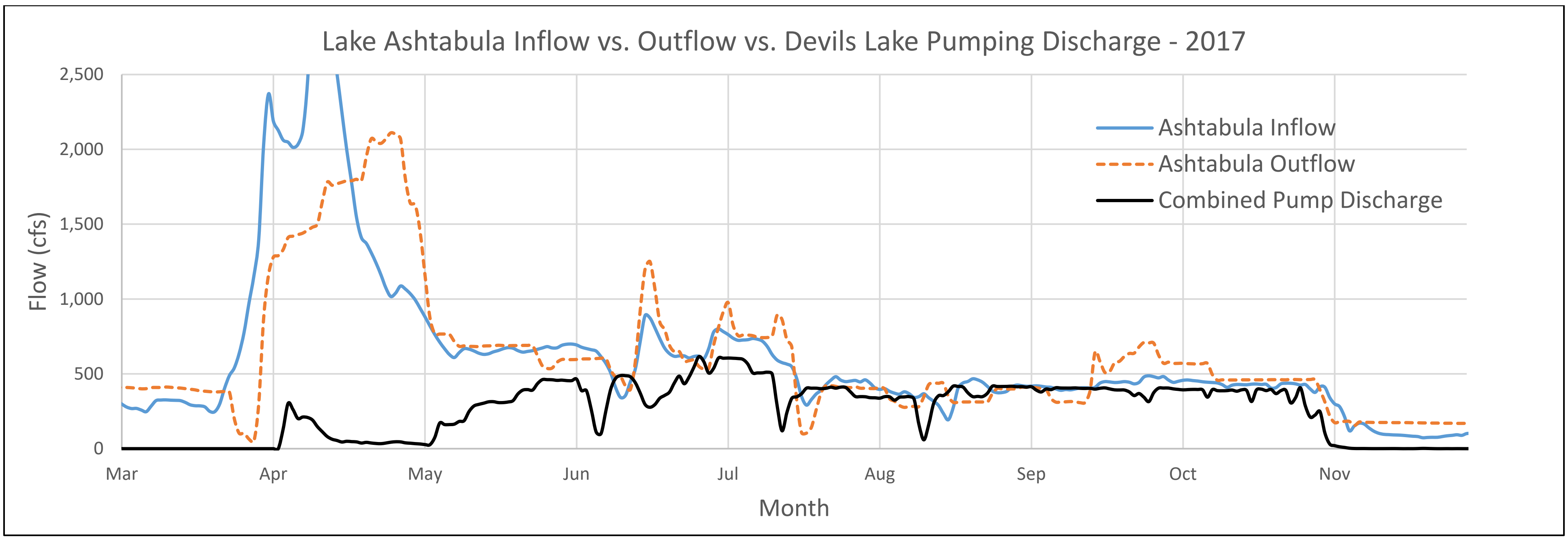


Figure 8. Combined pumping discharge compared to inflow and outflow of Lake Ashtabula

During October and November, the pool is drawn down by approximately 1.4 feet. As Lake Ashtabula is drawn down, releases slightly higher than inflow are made. Consequently, the reservoir at a minimum releases any water pumped from Devils Lake. Although breakout flows have been known to occur between Baldhill Dam and Horace, these breakout flows only occur when the discharge is above approximately 3,500 cfs at Kindred. Pumping from Devils Lake has not occurred when this threshold has been exceeded.

For these reasons, it is reasonable to assume that the vast majority of the inflow to Lake Ashtabula during non-flood conditions between April (post melt) and November (until freeze up) comes from Devils Lake and that outflow can reasonably be assumed to be equivalent to inflow. Therefore, for the purposes of this analysis, the simplified approach described above gives a reasonable approximation of the effects of pumping from Devils Lake during the period 2012-2017. The estimated, combined pumping discharge from Devils Lake translated to Horace, ND is shown in Figure 9.

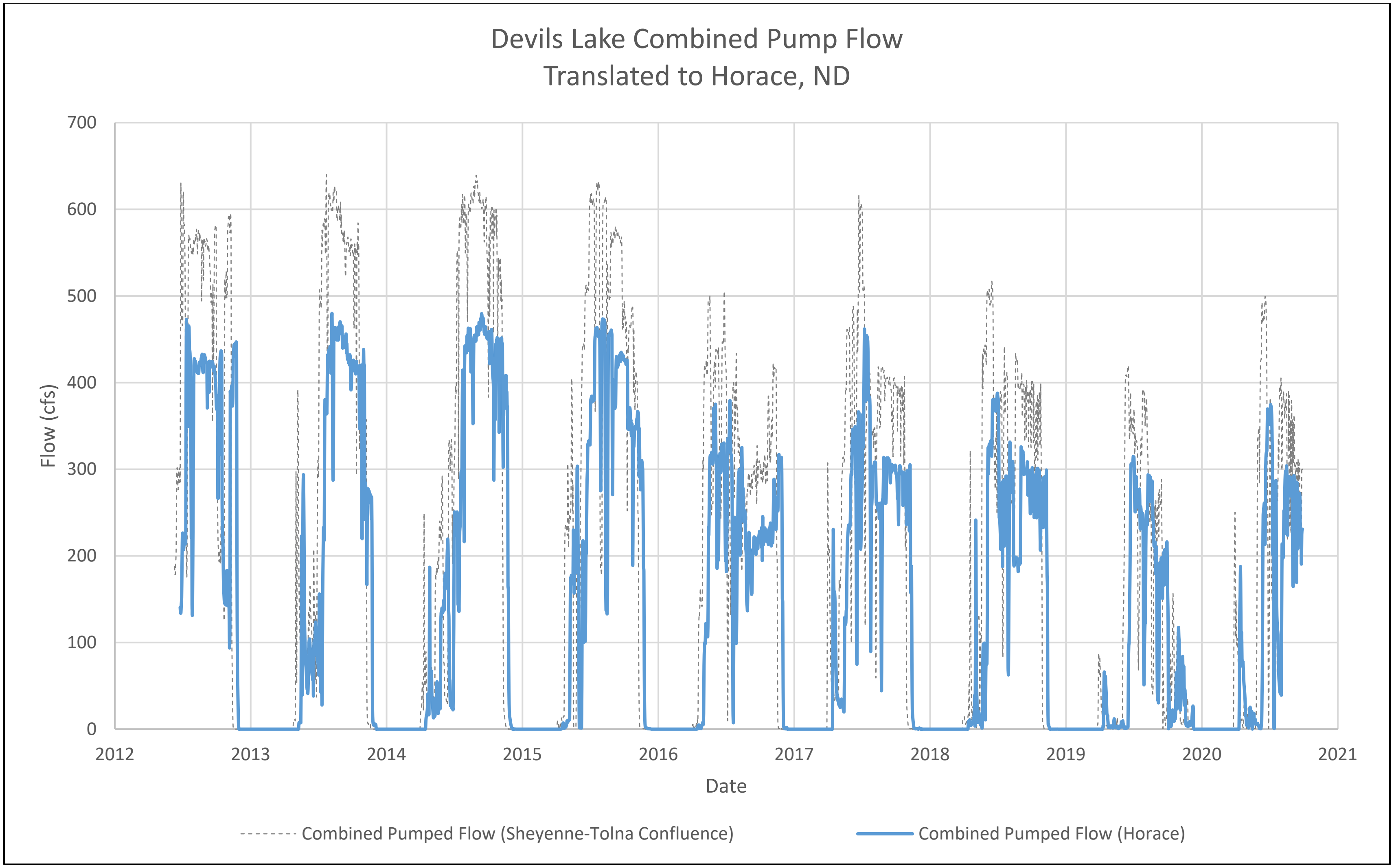


Figure 9. Devils Lake pumping discharge routed to Horace, ND

After estimating the contribution from pumped flows at Horace, ND, the average monthly volume of the translated pumped flows at Horace was compared to the average monthly volume of the observed flows at Horace (pumped flow contribution versus total flow). As shown in Figure 10, the pumped flows from Devils Lake made up at least 30% of the total flow volume at Horace during the months of July through November. During the months of August and September, the pumped flows accounted for approximately 50% of the flow volume at Horace. Note during October, November, and December, Lake Ashtabula is drawn down in accordance with its operating plan, so it is required to release flows in excess of inflow. During the month of December, the pumps have not historically operated, although some flow at Horace is attributed to pumping from Devils Lake due to the travel time from Devils Lake to Horace.

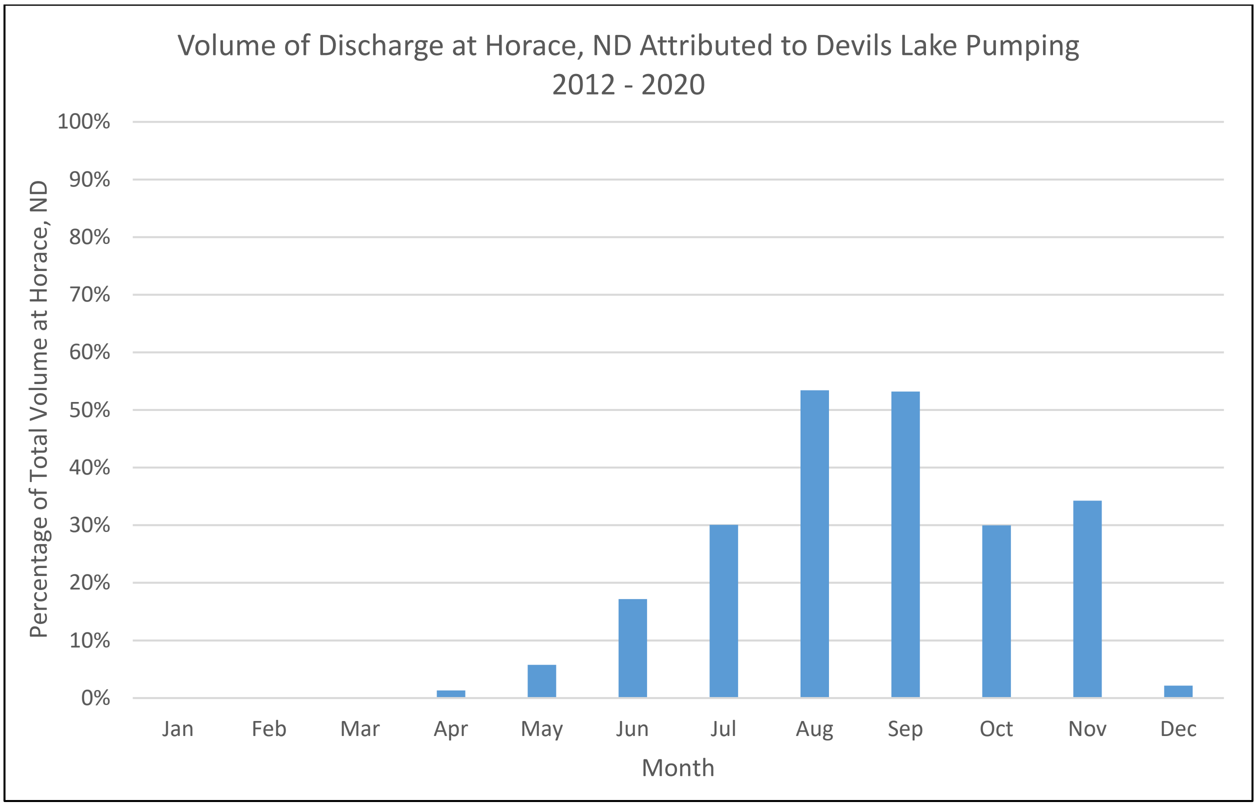


Figure 10. Monthly volume at Horace, ND attributed to pumping from Devils Lake, 2012-2020

The observed discharge record at Horace was modified to represent what the flows at that location would have been if the Devils Lake pumps were not in operation during the period 2012-2020. To do this, the translated, pumped flows displayed in Figure 9 (blue line) were subtracted from the flows recorded on the Sheyenne River above the Sheyenne Diversion near Horace, ND. Negative values were removed. The resulting hydrograph is shown in Figure 11.

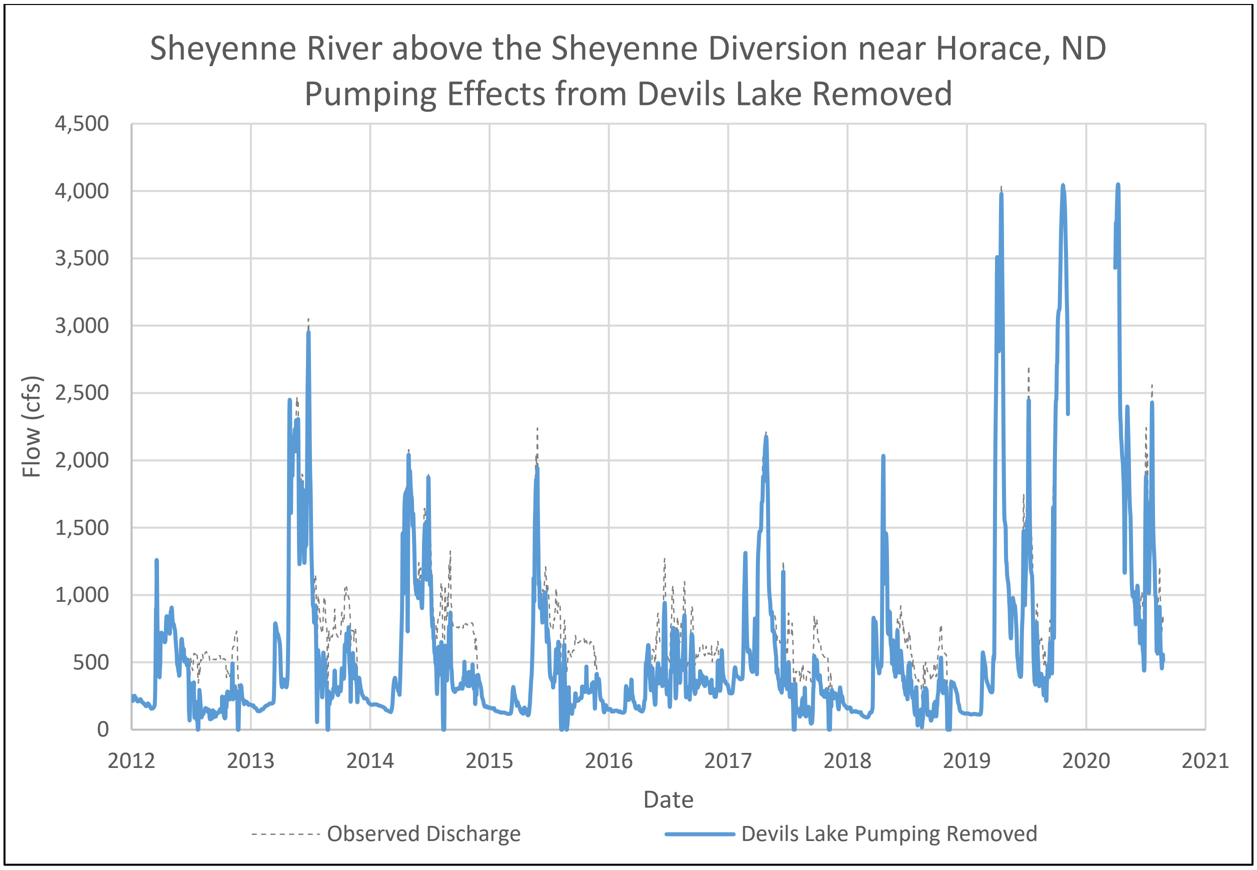


Figure 11. Sheyenne River above the Sheyenne Diversion near Horace, ND - observed vs. estimated without Devils Lake pumping

Annual flow duration curves at Horace for the period 2012-2020 were computed using both the observed flow record (with pumped flows) and the estimated flow record without the pumping effects from Devils Lake. Duration curves are shown in Figure 12. The pumps have had a significant impact on the low flow regime. The percentage time at which flows are maintained between 200 cfs to 1,000 cfs has increased. Note since pumping from Devils Lake does not impact the exceedance probability of large flood events, the y-axes of all flow duration curves shown in this document are limited to 1,500 cfs.

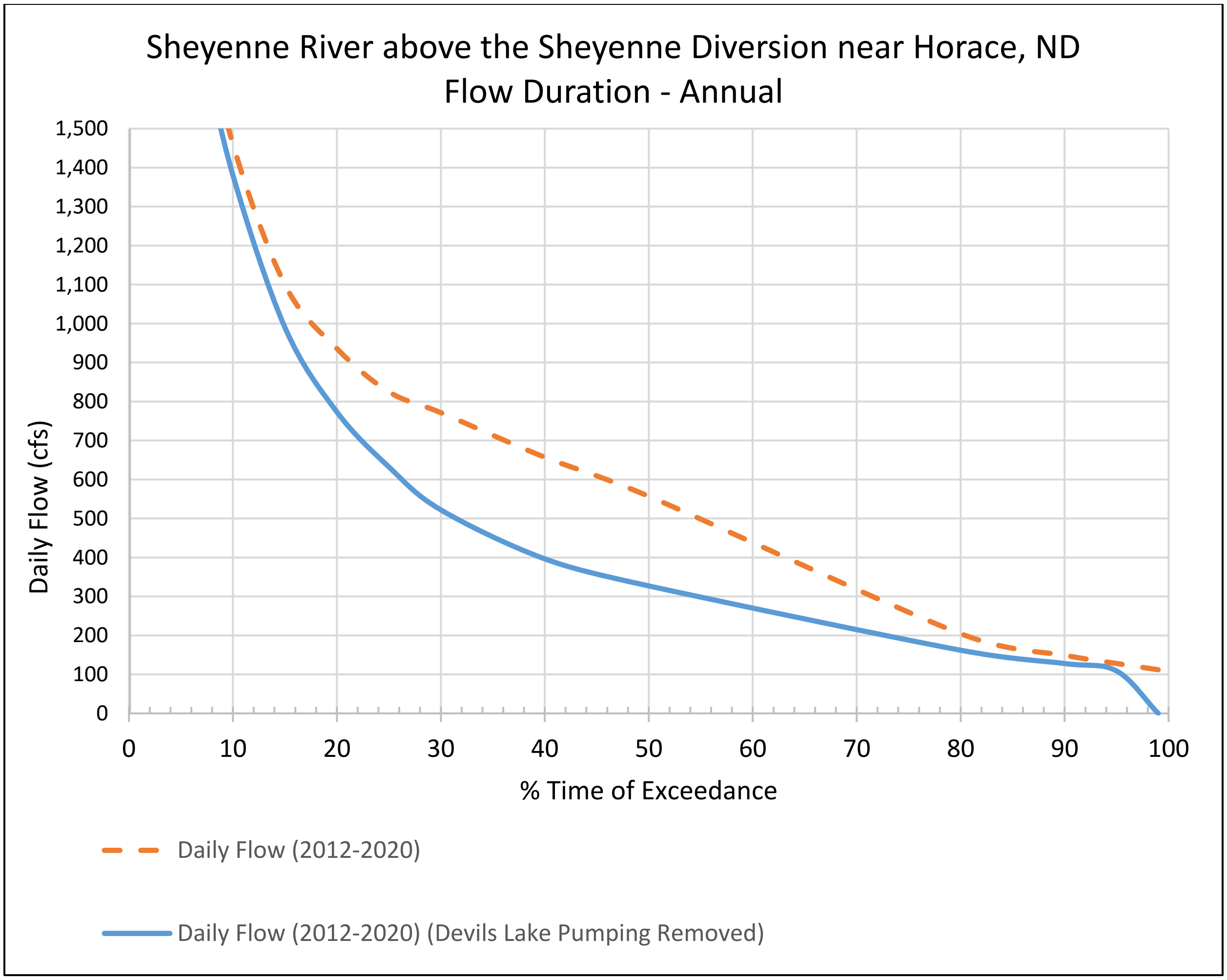


Figure 12. Flow duration curve comparison after removing Devils Lake pumping flows - annual

Monthly flow duration curves were also computed for the period 2012-2020, both with and without the effects of pumping from Devils Lake. These curves are shown in Figure 13 through Figure 21. As suggested by the monthly volume distribution shown in Figure 10, pumping from Devils Lake significantly increases the frequency at which flows exceed between 200 cfs and 1,000 cfs during the months of June through November. Pumping does not significantly affect the flow duration curves for the months of December through May.

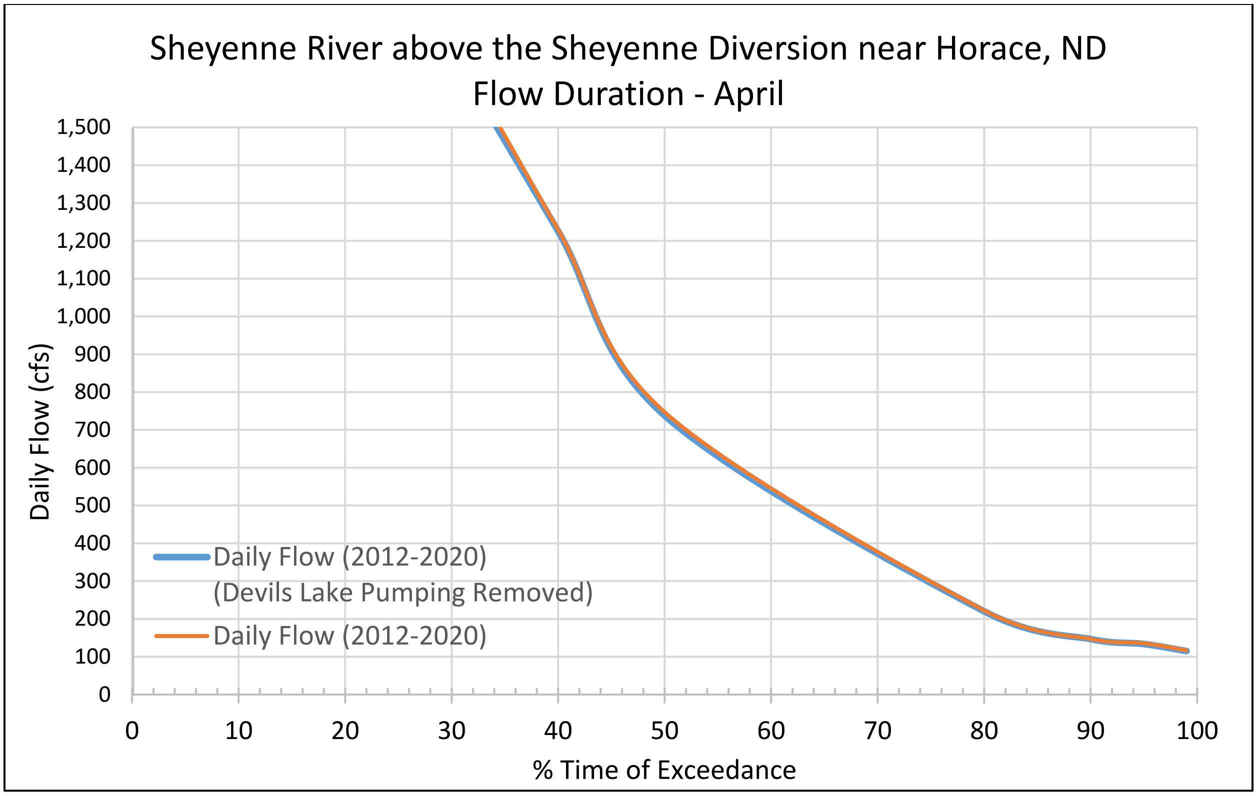


Figure 13. Flow duration curve comparison after removing Devils Lake pumping flows – April

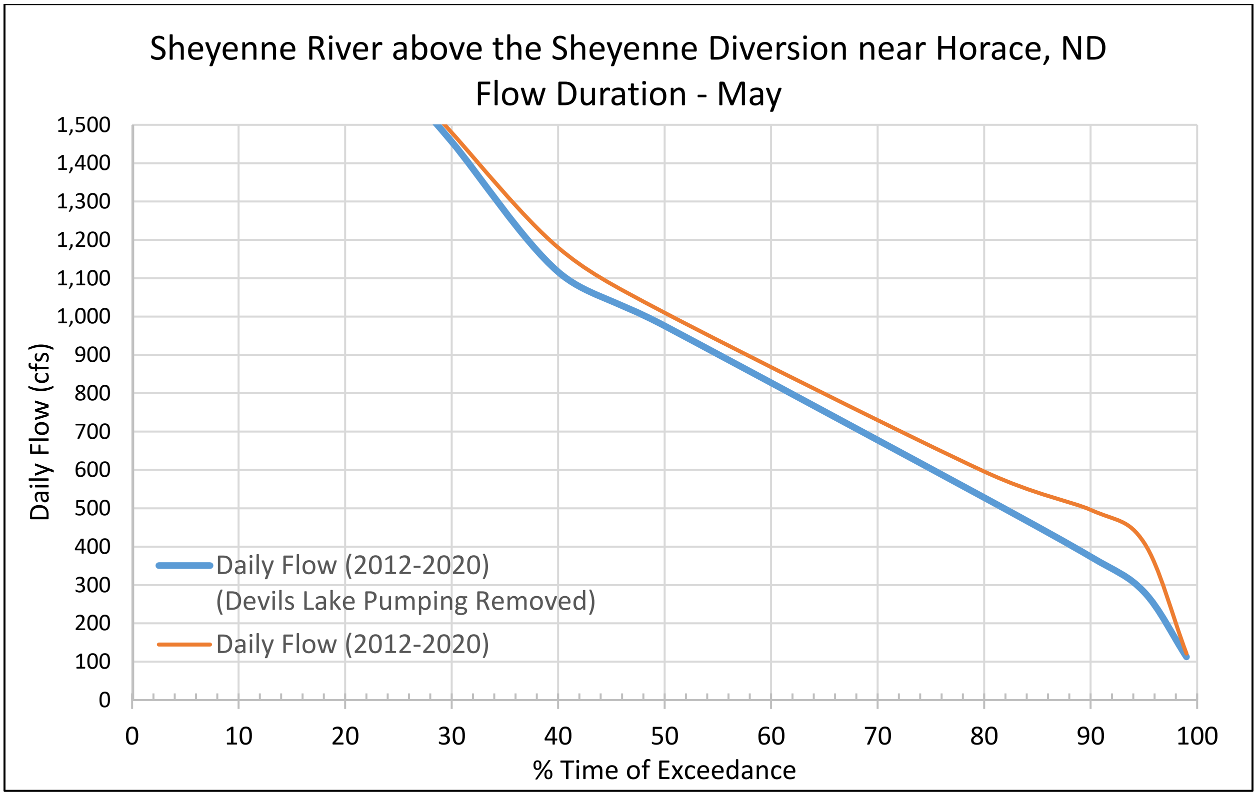


Figure 14. Flow duration curve comparison after removing Devils Lake pumping flows – May

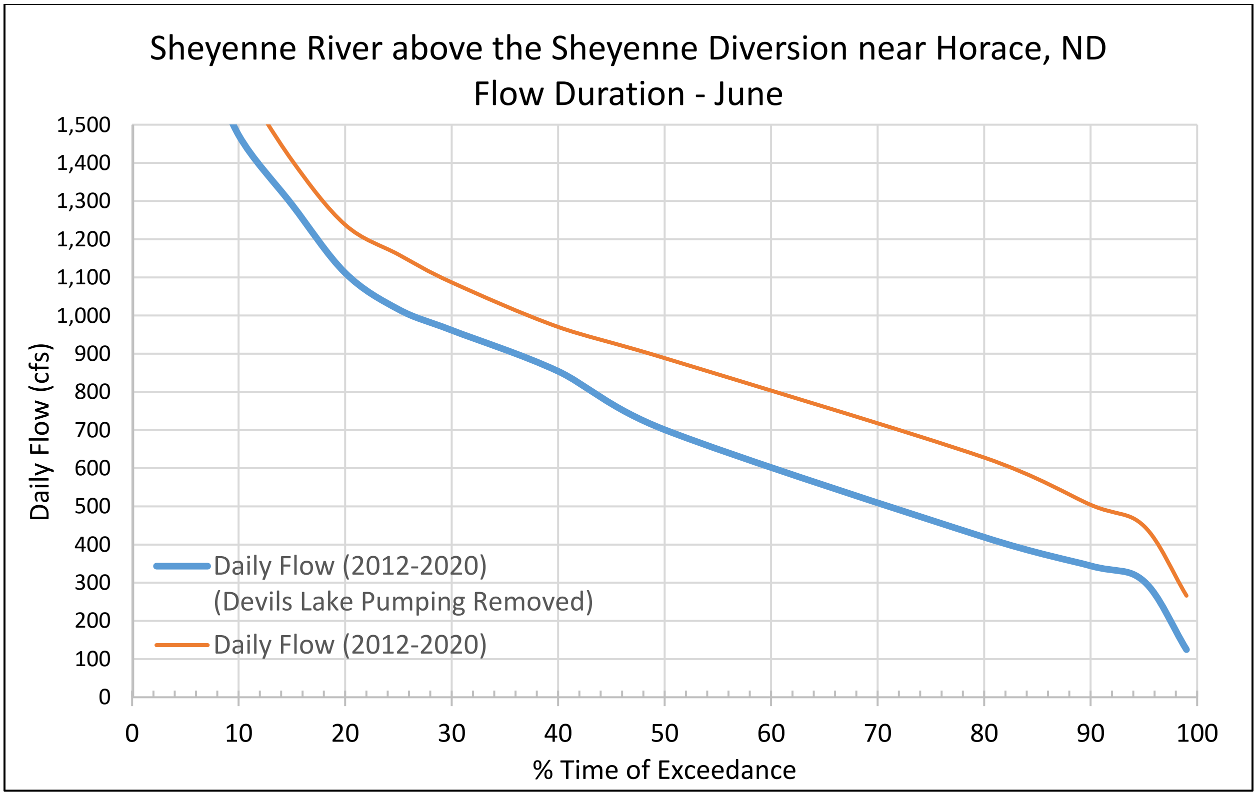


Figure 15. Flow duration curve comparison after removing Devils Lake pumping flows – June

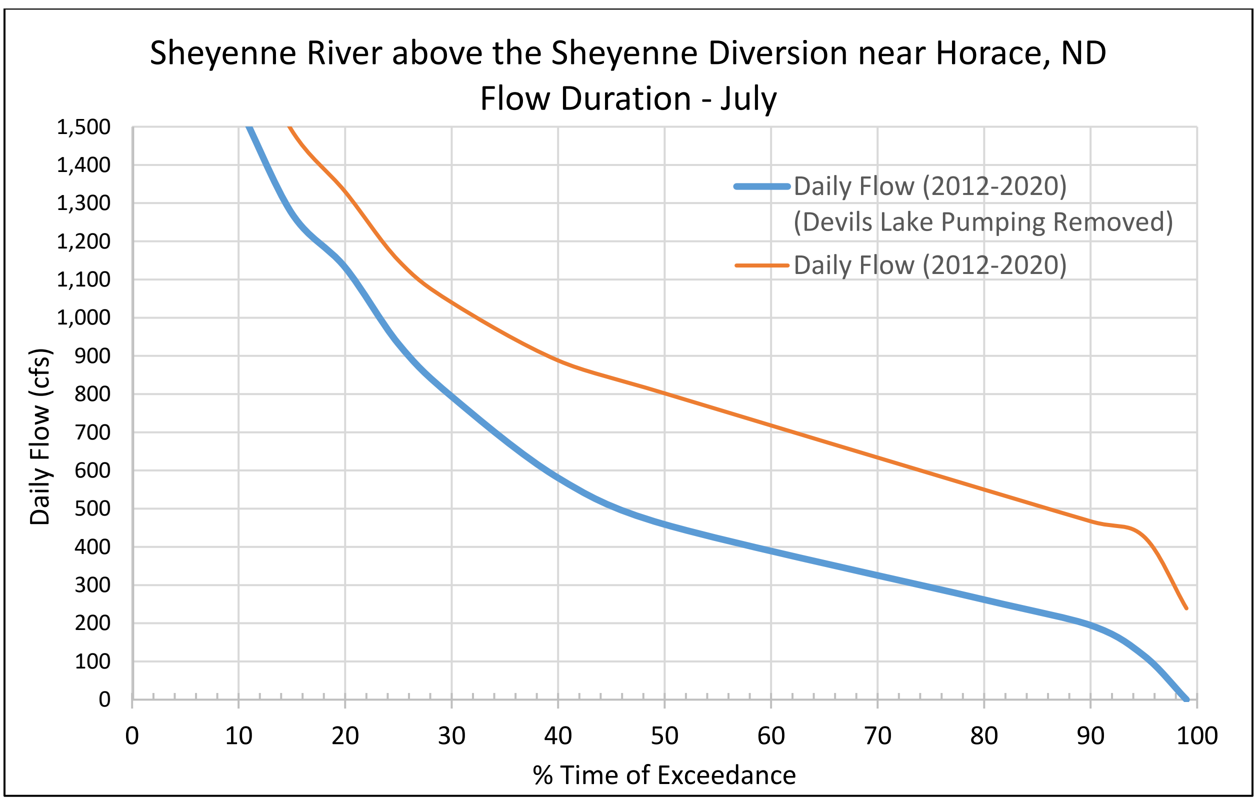


Figure 16. Flow duration curve comparison after removing Devils Lake pumping flows – July

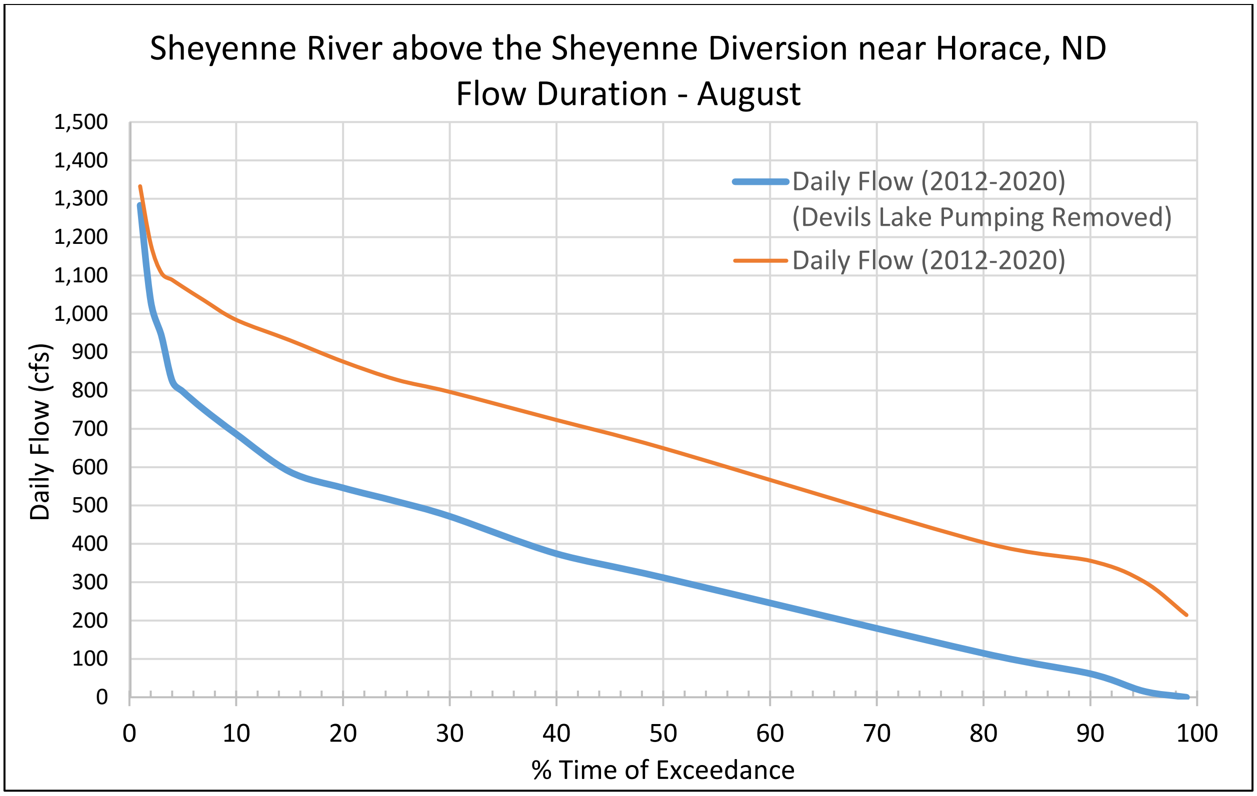


Figure 17. Flow duration curve comparison after removing Devils Lake pumping flows – August

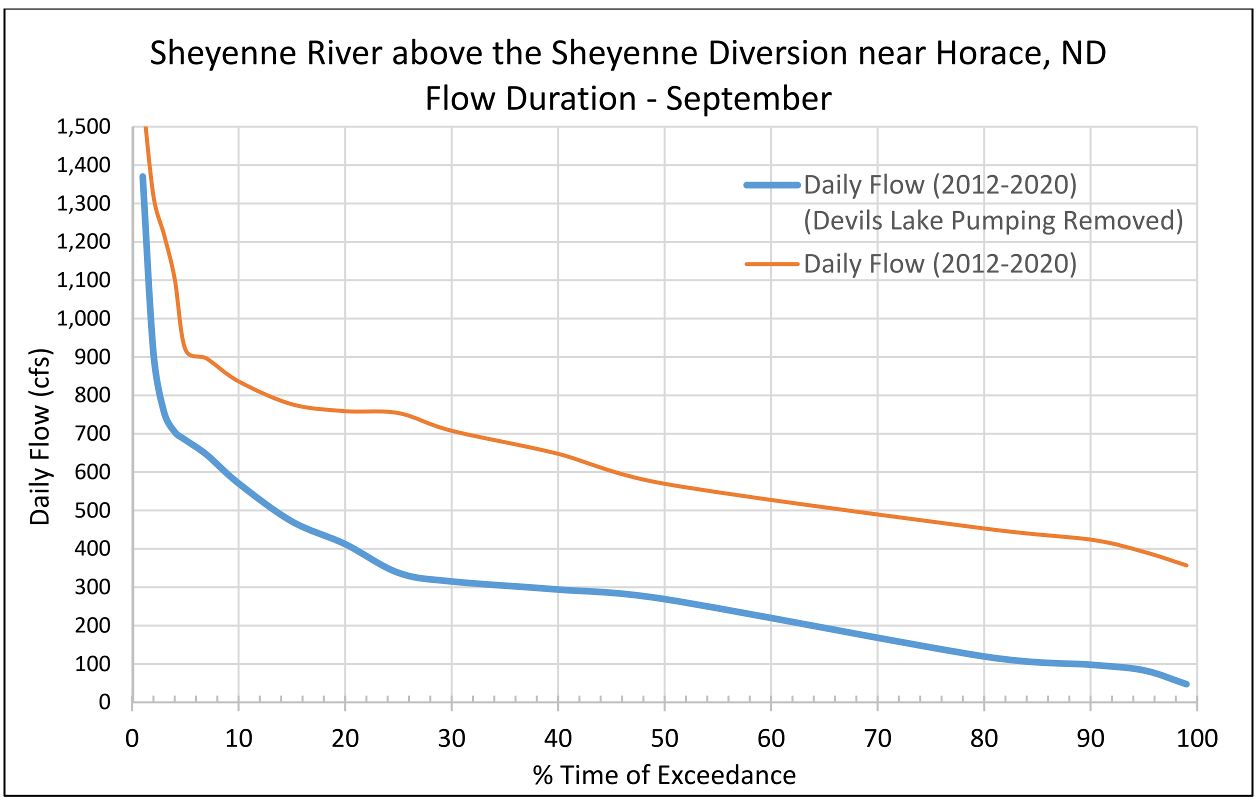


Figure 18. Flow duration curve comparison after removing Devils Lake pumping flows – September

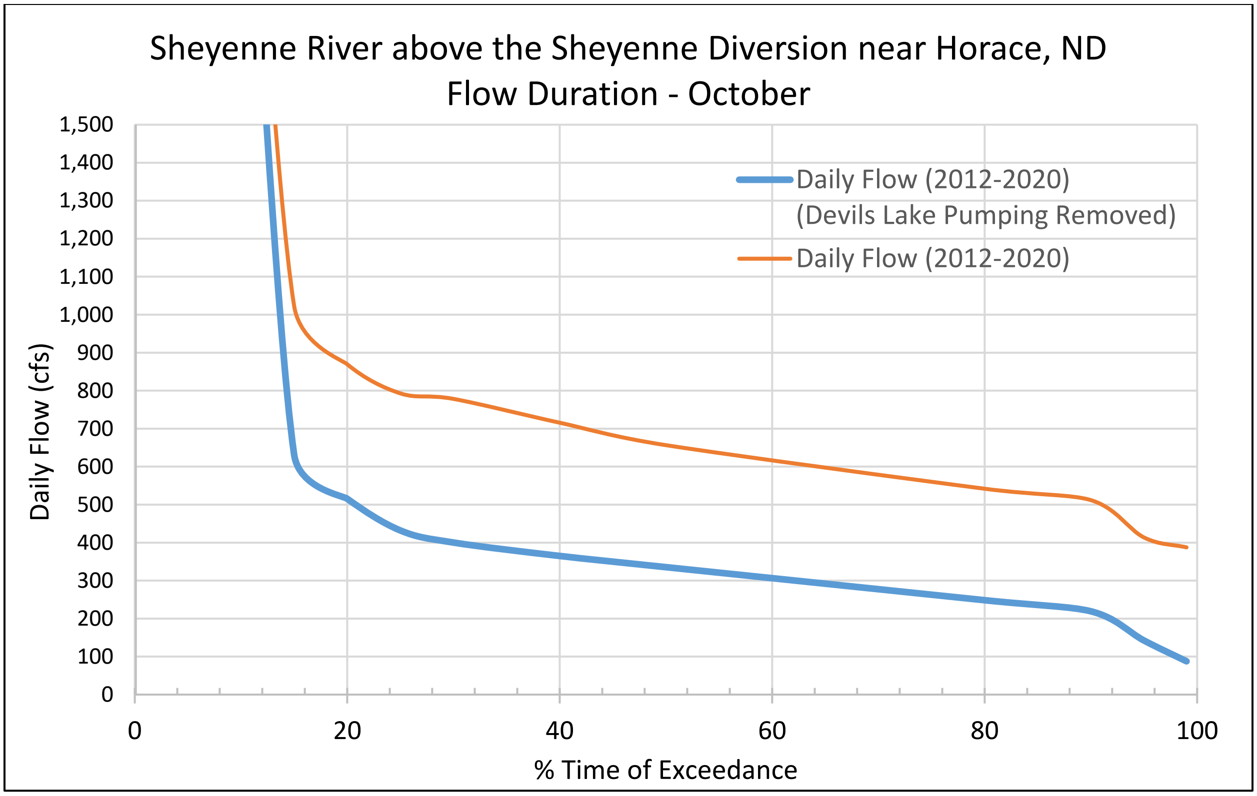


Figure 19. Flow duration curve comparison after removing Devils Lake pumping flows – October

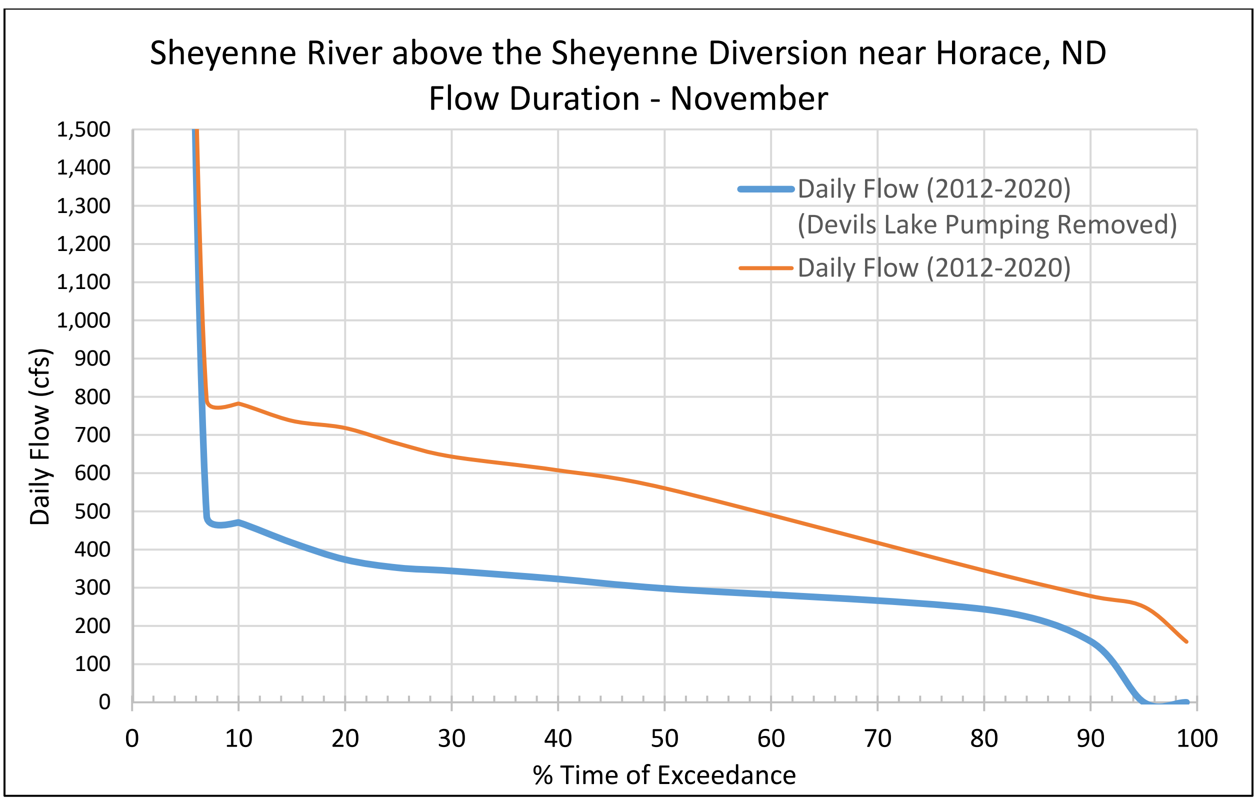


Figure 20. Flow duration curve comparison after removing Devils Lake pumping flows – November

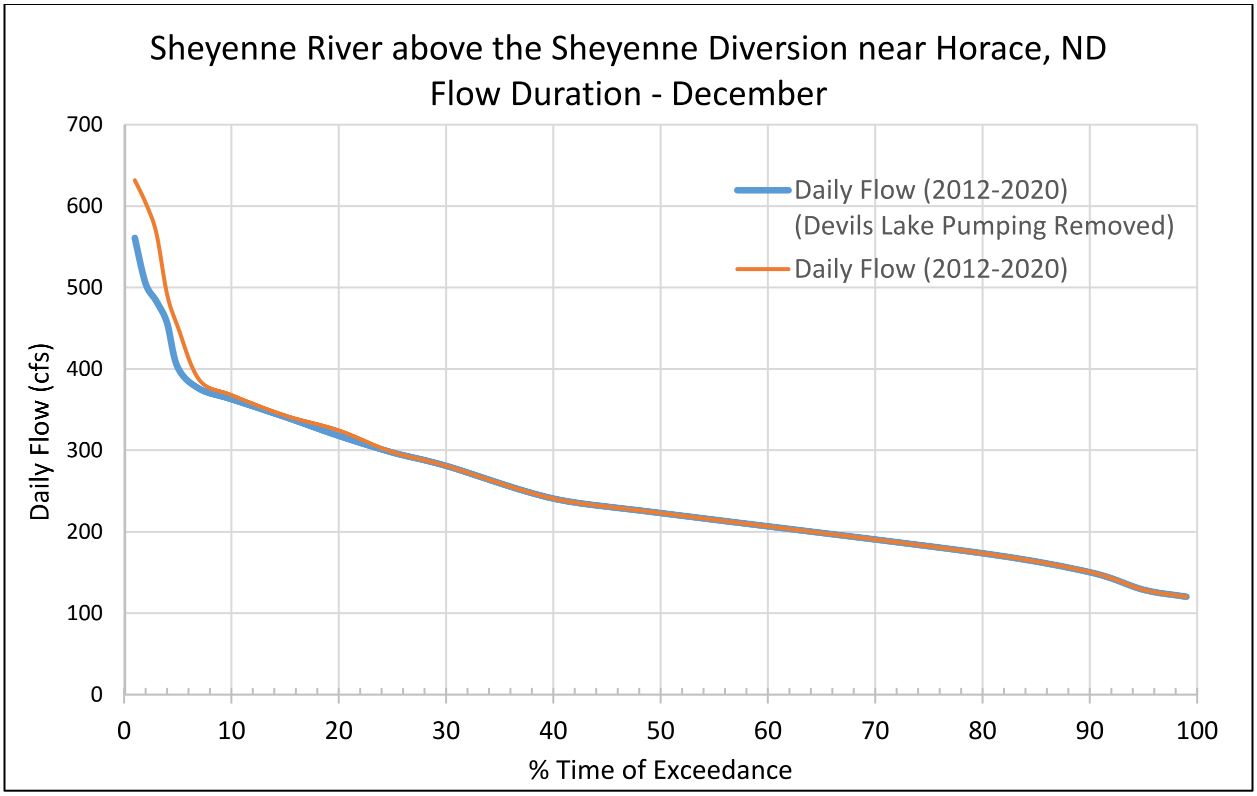


Figure 21. Flow duration curve comparison after removing Devils Lake pumping flows – December

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