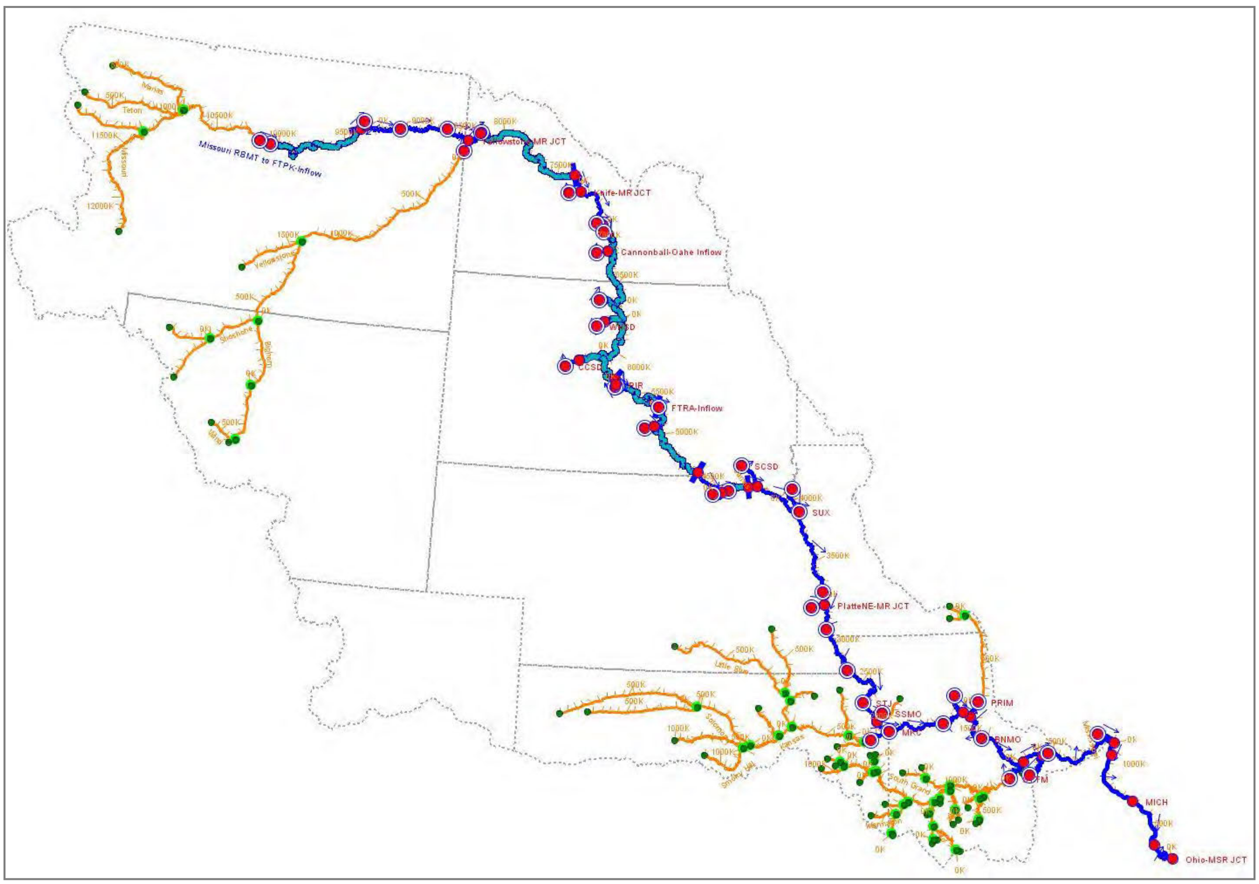
APPENDIX D

HYDROLOGY AND HYDRAULICS TECHNICAL REPORTS

US Army Corps of Engineers ®

Missouri River Mainstem HEC-ResSim Modeling for the Fort Peck EIS: DRAFT

Mainstem Missouri River Reservoir Simulation Alternatives Technical Report



HYDROLOGIC ENGINEERING BRANCH

ENGINEERING DIVISION

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DRAFT

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1 INTRODUCTION

The Missouri River Mainstem ResSim model was developed to assist in the assessment of various proposed operational changes to the mainstem reservoir system (System), shown in Figure 1-1. The operational changes for the Fort Peck EIS were concentrated at the Fort Peck project but changes were assessed at each of the six mainstem projects. Each operational change was simulated for an eighty three year period-of-record (01Mar1930-31Dec2012) and compared to a No Action simulation to estimate the changes that would occur to the System if an alternative were implemented. ResSim results such as reservoir elevations and releases, were used as direct input into other models, to quantify impacts on a variety of interests within the Missouri River Basin. ResSim simulations began on March 1, which is roughly the start of the operational season for the System, but changes associated with the proxies that were used to assess changes in the basin were calculated for a calendar year. Therefore, results discussed in this report reflect an eighty-two year period-of-record (1931-2012) to be consistent with results discussed in the draft Fort Peck Flow Test Environmental Impact Statement (EIS) (U.S. Army Corps of Engineers, 2020).

In this document, operations for each alternative assessed for the EIS are described for four seasons: spring (March – April), summer (May – August), fall (September – November), and winter (December – February). Plots of release and pool elevation changes relative to the No Action are included to show how the System is impacted by each alternative. Refer to *Mainstem Missouri River Reservoir Simulation Report* (U.S. Army Corps of Engineers, 2018) for detailed documentation of the Missouri River ResSim model.

Inflows for the model were modified from historic conditions to a present condition by utilizing U.S. Bureau of Reclamation (USBR) depletions. This means all inflows into the System are representative of the current basin condition for the entire period-of-record and care should be taken when making comparisons to actual historic data.

Figure 1-1: Missouri River Mainstem System.

1.1 Alternative Descriptions

1.1.1 No Action

Under No Action (NA), the Missouri River Mainstem Projects would continue to operate as they are currently. Operations within the ResSim model were set up to closely follow the Master Manual (U.S. Army Corps of Engineers, 2018) that is used during real-time operations of the System; however, the model does have limitations and cannot capture all real-time decisions that occur. For a more complete description of the No Action, refer to Chapter 2 of the Fort Peck Flow Test EIS (U.S. Army Corps of Engineers, 2020).

1.1.2 Alternative 1 – Fort Peck Flow Test Scaled to Fort Peck Spring Release

Alternative 1 (Alt 1) does not change System water supply, navigation, and flood target operations compared to No Action during March and April.

Alt 1 represents an operational change at Fort Peck that includes a flow regime for the pallid sturgeon based on target flows at Wolf Point, MT. The flow regime begins on April 16 with an attraction flow. Flows at Wolf Point are increased by 1.7 1,000 cubic feet per second (kcfs) per day until the peak attraction flow of 2 times the Fort Peck spring release is reached. The spring release from Fort Peck is determined by a long-term reservoir forecast and varies from year to year. If forecasted runoff is higher than average, the spring release will be higher than average to ensure storage is balanced among Fort Peck, Garrison, and Oahe. Conversely, if the forecasted runoff is low, the spring release will be lower. The peak flow is maintained for three days and then decreased by 1.3 kcfs per day for a maximum of 12 days. After 12 days, the flow is reduced by 3.0 kcfs per day until the retention flow is reached. If the retention flow is reached within the first 12 days of flow reduction, the retention flow is maintained. The retention flow is 1.5 times the Fort Peck spring release and is held until the spawning cue begins on May 28. For the spawning cue, flow is increased by 1.1 kcfs per day until the peak spawning cue flow is reached, which is 3.5 times the Fort Peck spring release. The peak spawning cue flow is held for 3 days and reduced by 1.0 kcfs for a maximum of 12 days. After 12 days, the flow is reduced by 3.0 kcfs per day until a flow of 8.0 kcfs is reached at Wolf Point, MT. The 8.0 kcfs flow at Wolf Point, MT is maintained until September 1. If the flow regime is cancelled prior to initiating the spawning cue, the 8.0 kcfs flow target is not utilized and releases are made to balance storage among the 3 upper reservoirs: Fort Peck, Garrison, and Oahe. However, if the spawning cue is initiated, the 8.0 kcfs flow target at Wolf Point, MT will be met through August. Due to travel time from Fort Peck to Wolf Point, MT, releases from Fort Peck are increased approximately 2 days prior to the dates listed previously to ensure the flow at Wolf Point, MT follows the dates and pattern described. Spillway releases are only made after the powerhouse has reached its maximum capacity.

Several criteria were developed to minimize impacts during the flow regime. If Fort Peck pool elevation is currently below or forecasted to fall below 2227.0 feet (NGVD 29), the flow regime will not be started or will be stopped due to inadequate head for spillway releases. The flow regime will not begin if the May – June Fort Peck to Garrison forecasted monthly runoff exceeds an upper quartile year. If the flow at Wolf Point, MT or Culbertson, MT is forecasted to exceed 35.0 kcfs, the flow regime will be stopped. If forecasted stages at Williston, ND exceed flood stage (22.0 feet) the flow regime will be stopped. The flow regime will be eliminated if water surface elevations exceed 1853.5 feet (NGVD 29) at the downstream portion of the Williston Levee, which is approximately 6.4 feet of freeboard. The last criterion that will eliminate the flow regime is based on the forecasted pool elevation at Lake Sakakawea. If the forecasted pool elevation exceeds 1850.0 feet (NGVD29) (bottom of exclusive flood control zone), the flow regime will be stopped. For a more complete description of Alt 1, refer to Chapter 2 of the Fort Peck Flow Test EIS (U.S. Army Corps of Engineers, 2020).

1.1.3 Alternative 1a – Fort Peck Flow Test Scaled to Fort Peck Spring Release One Week Earlier than Alternative 1

Alternative 1a (Alt 1a) is not a separate alternative in the Fort Peck Flow Test EIS. It is a sensitivity analysis for Alt 1. The same flow regime and elimination criteria described for Alt 1 are used, but the flow regime begins 1 week earlier. The attraction flow begins on April 9 and the spawning cue begins on May 21. For a more complete description of Alt 1a, refer to Chapter 2 of the Fort Peck Flow Test EIS (U.S. Army Corps of Engineers, 2020).

1.1.4 Alternative 1b – Fort Peck Flow Test Scaled to Fort Peck Spring Release One Week Later than Alternative 1

Alternative 1b (Alt 1b) is similar to Alt 1a in that it is not a separate alternative in the Fort Peck Flow Test EIS. It is a sensitivity analysis for Alt 1. The same flow regime and elimination criteria described for Alt 1 are used, but the flow regime begins 1 week later. The attraction flow begins on April 23 and the spawning cue begins on June 4. For a more complete description of Alt 1b, refer to Chapter 2 of the Fort Peck Flow Test EIS (U.S. Army Corps of Engineers, 2020).

1.1.5 Alternative 2 – Fort Peck Flow Test Scaled to Fort Peck Powerhouse Capacity

Alternative 2 (Alt 2) represents an operational change at Fort Peck that includes a flow regime for the pallid sturgeon based on target flows at Wolf Point, MT. Unlike Alt 1, the peak target flows for the attraction and spawning cue is based on the powerhouse capacity. For purposes of this study, the powerhouse capacity was estimated at 14.0 kcfs. Under current restrictions for the hydropower units at Fort Peck, the maximum powerhouse capacity is closer to 13.0 kcfs. The flow regime begins on April 16 with an attraction flow. Flows at Wolf Point are increased by 1.7 kcfs per day until the peak attraction flow is equal to the maximum powerhouse flow of 14.0 kcfs. The peak attraction flow is equal to the retention flow, 14.0 kcfs, so no reduction in flow occurs following the peak attraction flow. The retention flow is held until the spawning cue begins on May 28. For the spawning cue, flow is increased by 1.1 kcfs per day until the peak spawning cue flow is reached, which is 2 times the maximum powerhouse capacity, or 28.0 kcfs. The peak spawning cue flow is held for 3 days and reduced by 1.0 kcfs for a maximum of 12 days. After 12 days, the flow is reduced by 3.0 kcfs per day until a flow of 8.0 kcfs is reached at Wolf Point, MT. The 8.0 kcfs flow at Wolf Point, MT is maintained until September 1. If the flow regime is cancelled prior to initiating the spawning cue, the 8.0 kcfs flow target is not utilized and releases are made to balance storage among the 3 upper reservoirs: Fort Peck, Garrison, and Oahe. However, if the spawning cue is initiated, the 8.0 kcfs flow target at Wolf Point, MT will be met through August. Due to travel time from Fort Peck to Wolf Point, MT, releases from Fort Peck are increased approximately 2 days prior to the dates listed previously to ensure the flow at Wolf Point, MT follows the dates and pattern described. Spillway releases are only made after the powerhouse has reached its maximum capacity.

The same criteria developed to minimize impacts during the flow regime that are described in Alt 1 are utilized for Alt 2. For a more complete description of Alt 2, refer to Chapter 2 of the Fort Peck Flow Test EIS (U.S. Army Corps of Engineers, 2020).

1.1.6 Alternative 2a – Fort Peck Flow Test Scaled to Fort Peck Powerhouse Capacity One Week Earlier than Alternative 2

Alternative 2a (Alt 2a) is not a separate alternative in the Fort Peck Flow Test EIS. It is a sensitivity analysis for Alt 2. The same flow regime and elimination criteria described for Alt 2 are used, but the flow regime begins 1 week earlier. The attraction flow begins on April 9 and the spawning cue begins on May 21. For a more complete description of Alt 2a, refer to Chapter 2 of the Fort Peck Flow Test EIS (U.S. Army Corps of Engineers, 2020).

1.1.7 Alternative 2b – Fort Peck Flow Test Scaled to Fort Peck Powerhouse Capacity One Later Earlier than Alternative 2

Alternative 2b (Alt 2b) is not a separate alternative in the Fort Peck Flow Test EIS. It is a sensitivity analysis for Alt 2. The same flow regime and elimination criteria described for Alt 2 are used, but the flow regime begins 1 week later. The attraction flow begins on April 23 and the spawning cue begins on June 4. For a more complete description of Alt 2b, refer to Chapter 2 of the Fort Peck Flow Test EIS (U.S. Army Corps of Engineers, 2020).

2 SPRING: MARCH – APRIL

2.1 DOWNSTREAM OF GAVINS POINT

2.1.1 No Action

March 1 begins the operational year for the System within the ResSim model. Any excess flood storage from the previous year has been evacuated and the System is assessed for the upcoming year's runoff. Between March 1 and the start of the navigation season, a minimum release of 9.0 kcfs is specified to support water supply downstream of Gavins Point. In addition to the minimum release requirements, the ResSim model treats the minimum release from Gavins Point as a minimum flow requirement at three locations downstream of Gavins Point: Sioux City, Omaha, and Kansas City. If the flow at one of those three locations is forecasted to drop below 9.0 kcfs while Gavins Point is releasing 9.0 kcfs for water supply, Gavins Point releases will be increased until the forecasted flow at all three locations exceeds 9.0 kcfs. This can occur if there are depletions that remove water from the river causing flows to be less than what is released from Gavins Point. Figure 2-1 shows the minimum release for water supply during the spring highlighted by a dashed red box.

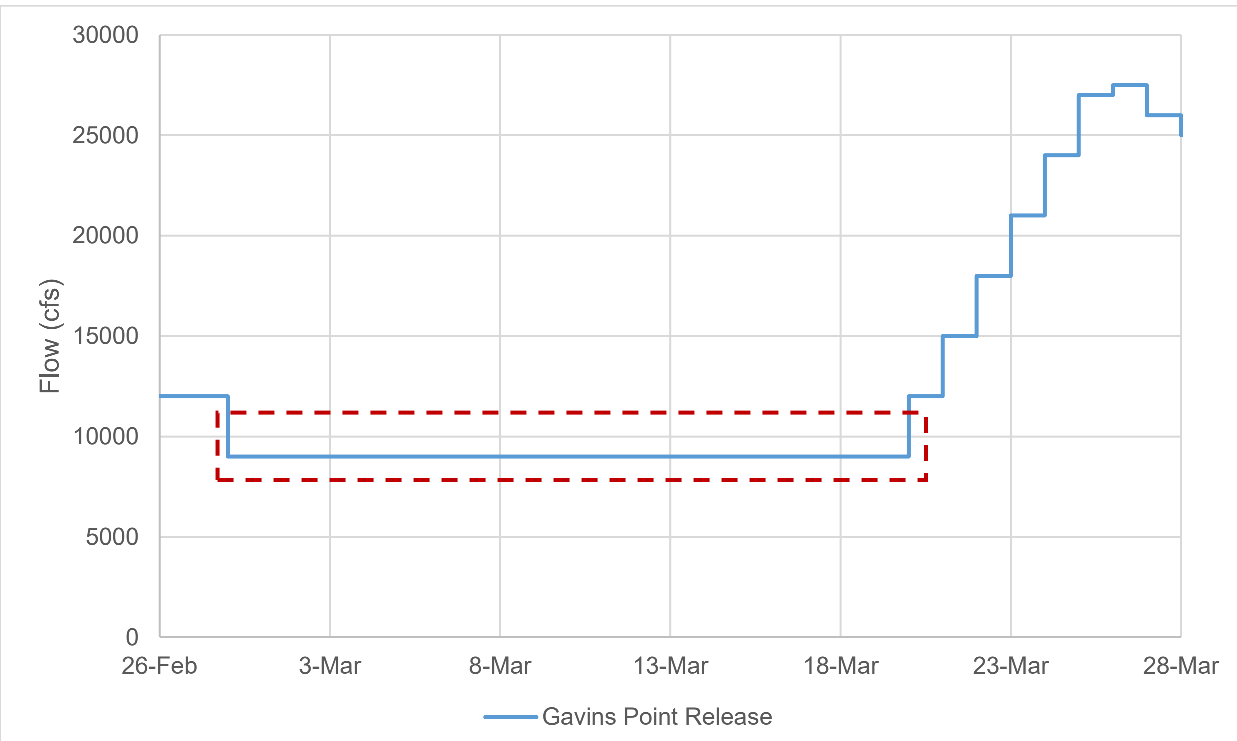

Figure 2-1: Spring water supply release from Gavins Point.

System storage is assessed again on March 15 to determine if operations will begin supporting navigation. A minimum of 31.0 million acre-feet (MAF) of System storage is required for a navigation season. If System storage is greater than 31.0 MAF on March 15, a service level is computed, which represents the level of navigation flow support. Table 2-1 summarizes the

System storage and service level relationship. Minimum service is specified if System storage is between 31.0 MAF and 49.0 MAF. An intermediate service level is specified if System storage is between 49.0 MAF and 54.5 MAF by linear interpolation. Full service is specified if the System storage is at least 54.5 MAF. Figure 2-2 shows an example of the System storage check and resulting service level. In this example, System storage was 51.4 MAF on March 15, which was between the full-service and minimum-service thresholds. The service level was linearly interpolated resulting in a service level of 31.7 kcfs for the first half of the navigation season.

Table 2-1: Service level requirements. Summarized from Table VII-2 in the Master Manual (U.S. Army Corps of Engineers, 2018).

Date	Service Level (kcfs)	Water in System Storage (MAF)
March 15	35.0 (full-service)	54.5 or more
March 15	29.0 (minimum-service)	31.0 – 49.0
March 15	No service	31.0 or less
July 1	35.0 (full-service)	57.0 or more
July 1	29.0 (minimum-service)	50.5 or less

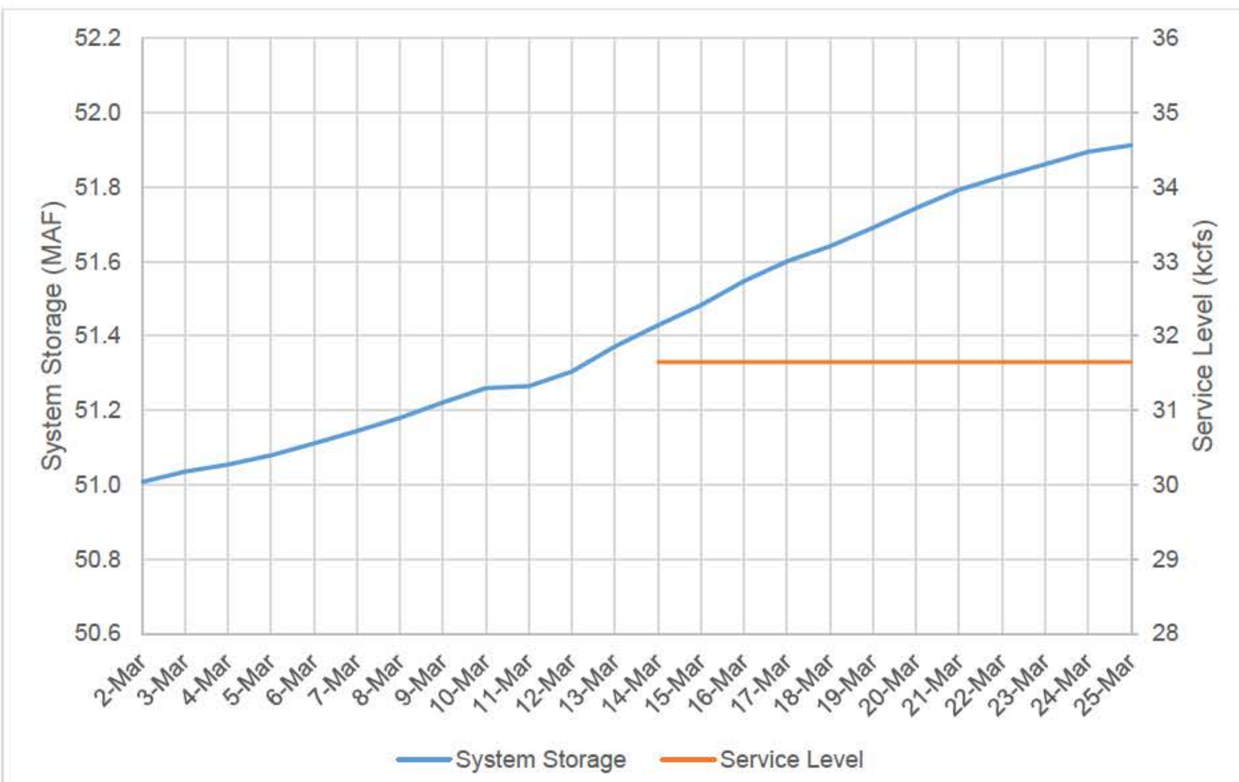

Figure 2-2: March 15 System storage assessment and resulting service level.

Based on the service level, navigation target flows are calculated for four locations: Sioux City, Omaha, Nebraska City, and Kansas City using the criteria summarized in Table 2-2. These navigation target flows represent the minimum flow that will be provided to support navigation between Sioux City and Kansas City. ResSim forecasts flows at the four target locations and adjusts Gavins Point releases to ensure that each location's target flow is met throughout the navigation season, which varies by location. This method of adjusting Gavins Point releases daily to meet the navigation target flows is called flow-to-target (FTT). Table 2-3 summarizes the navigation start and end dates for an 8-month navigation season; the calculated navigation end date is for the mouth of the river and all other location-specific end dates are based on travel time from the mouth. Figure 2-3 shows the four target locations with their respective navigation targets and flows during a representative navigation season.

Table 2-2: Navigation target flows related to service level. Summarized from Table VII-1 in the Master Manual (U.S. Army Corps of Engineers, 2018).

Target Location	Target Flow Deviation from Service Level
Sioux City	- 4.0 kcfs
Omaha	- 4.0 kcfs
Nebraska City	+ 2.0kcfs
Kansas City	+ 6.0 kcfs

Table 2-3: Navigation season at each target location. Summarized from Table VII-4 in the Master Manual (U.S. Army Corps of Engineers, 2018).

Target Location	Opening Date	Closing Date
Sioux City	March 23	November 22** (Nav End Date – 9 days)
Omaha	March 25	November 24** (Nav End Date – 7 days)
Nebraska City*	March 26	November 25** (Nav End Date – 6 days)
Kansas City	March 28	November 27** (Nav End Date – 4 days)
Mouth	April 1	December 1** (Nav End Date)

*There is no navigation start or end dates specified in the Master Manual for Nebraska City. For modeling purposes, they were assumed to be 1 day after Omaha's start and end dates.

**Example dates listed are for a normal 8-month navigation season.

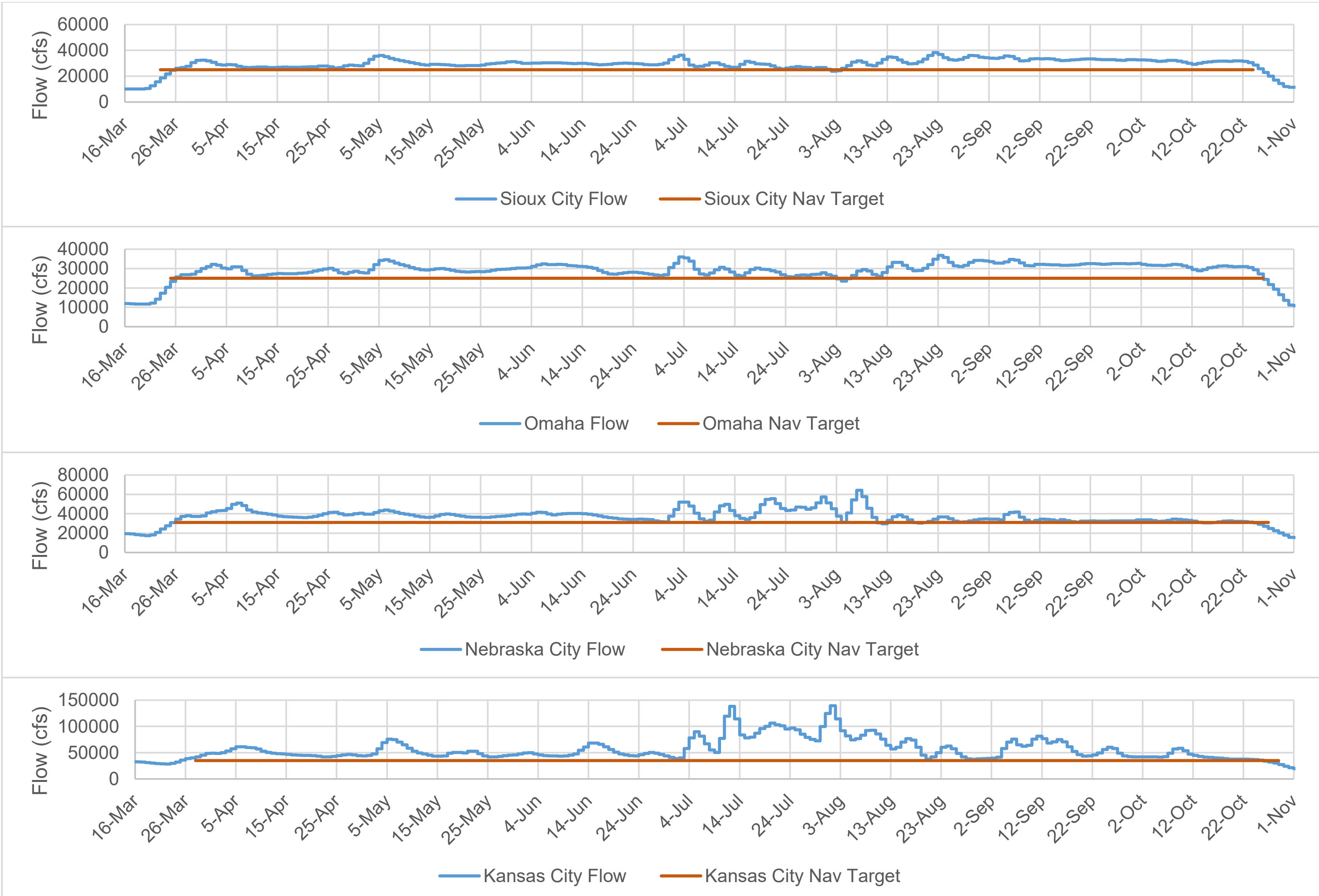

Figure 2-3: Navigation target locations with target and simulated flows.

While the System is supporting downstream navigation, Gavins Point releases can be reduced if flows at Omaha, Nebraska City, and Kansas City are forecasted to exceed flood target flows, which are summarized in Table 2-4. There are two tiers of flood targets that vary with the service level. The first tier is triggered when flow at Omaha or Nebraska City is forecasted to exceed their respective navigation target flow plus 10.0 kcfs or when flow at Kansas City is forecasted to exceed its navigation target flow plus 30.0 kcfs. When this occurs, Gavins Point releases are reduced to a level that minimizes downstream flooding and still supports full-service navigation flows at Sioux City, Omaha, Nebraska City, and Kansas City. The first tier only applies when the service level is greater than full service. If the service level is less than or equal to full service, the first tier flood targets are not utilized because the System is already operating for full service or less. The second tier is triggered when flow at Omaha is forecasted to exceed its navigation target flow plus 15.0 kcfs, when flow at Nebraska City is forecasted to exceed its navigation target flow plus 20.0 kcfs, or when flow at Kansas City is forecasted to exceed it navigation target flow plus 60.0 kcfs. When this occurs, Gavins Point releases are reduced to a level that minimizes downstream flooding and still supports minimum-service at Sioux City, Omaha, Nebraska City, and Kansas City.

Table 2-4: Downstream flood targets. Summarized from Tables VII-8 and VII-9 in the Master Manual (U.S. Army Corps of Engineers, 2018).

	Flood Targets	
	Full-Service (1st Level)	Minimum-Service (2nd Level)
Omaha	Target Flow + 10.0 kcfs	Target Flow + 15.0 kcfs
Nebraska City	Target Flow + 10.0 kcfs	Target Flow + 20.0 kcfs
Kansas City	Target Flow + 30.0 kcfs	Target Flow + 60.0 kcfs

Figure 2-4 shows an example of how ResSim reduces Gavins Point releases when flows at a target location were forecasted to exceed its flood targets. Sioux City and Nebraska City are shown in this example, but all four navigation target locations and all three flood target locations are considered. The service level is 29.0 kcfs for the first half of the navigation season, which sets Sioux City's and Nebraska City's target flows to 25.0 and 31.0 kcfs, respectively. Nebraska City's minimum-service flood target flows are 51.0 kcfs; the full-service flood target is not used because the service level is less than full service. Nebraska City's flow is forecasted to exceed its minimum-service flood target on April 9. Since the service level was already set at a minimum service, Gavins Point releases are reduced while still supporting minimum-service navigation flows. The reduction of Gavins Point releases is highlighted by the dashed red box in the top plot of Figure 2-4. By April 14, flows at Nebraska City are forecasted to fall below its minimum-service flood target flow, but Gavins Point releases continue to decrease. This occurs because there is still enough tributary flow above each target location to meet minimum-service navigation targets with lower Gavins Point releases.

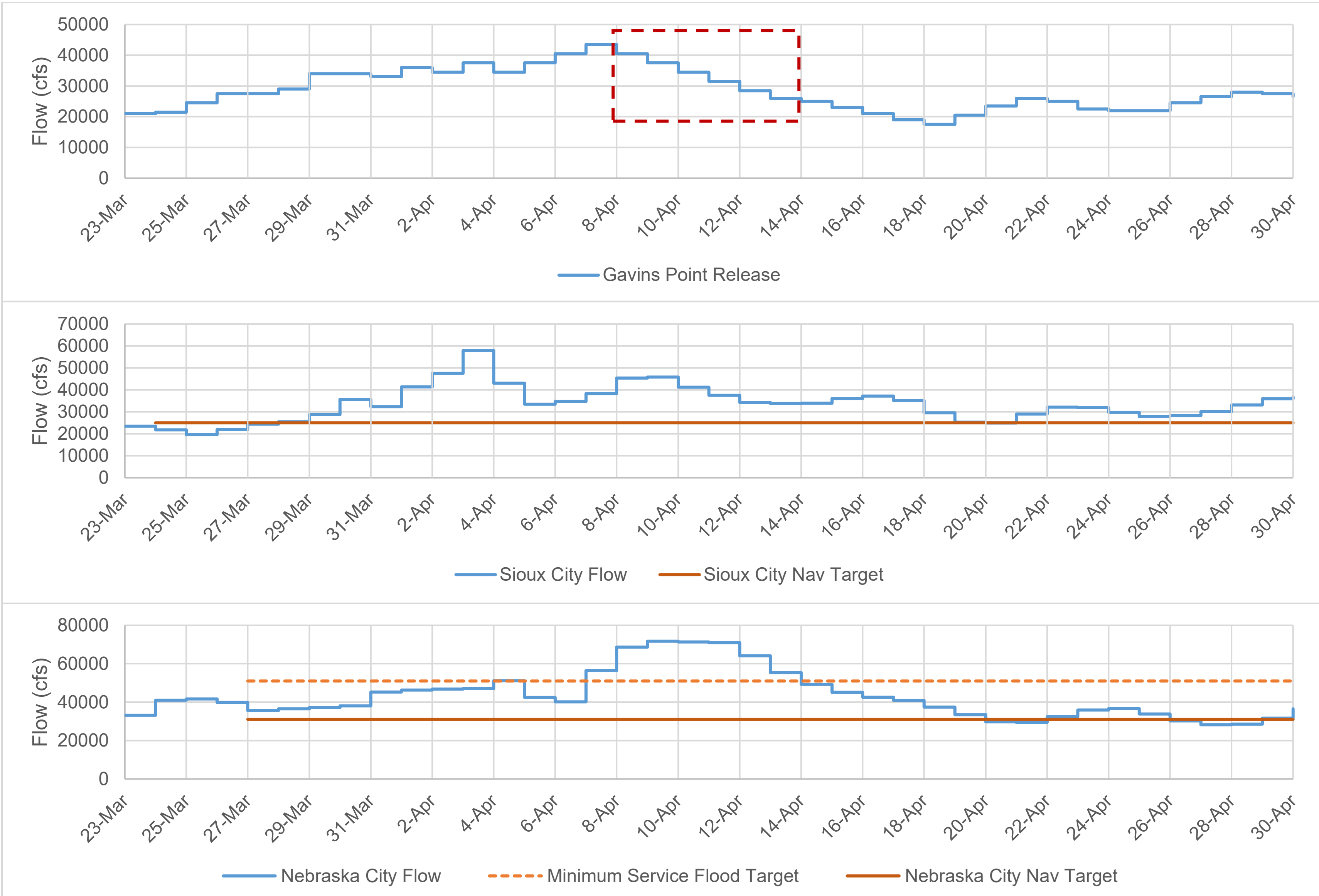

Figure 2-4: Example of reducing Gavins Point due to exceeding flood targets at Nebraska City.

If System storage was less than 31.0 MAF on March 15 and the navigation season is cancelled, System operations continue to support water supply by releasing a spring time minimum of 9.0 kcfs from Gavins Point and ensuring that a minimum flow of 9.0 kcfs is observed at the three target locations.

2.1.2 Alternatives 1, 1a, 1b, 2, 2a, and 2b

System operations downstream of Gavins Point in all alternatives do not change compared to No Action March – April with the same water supply, navigation, and flood control requirements used in the alternatives.

The operational changes that occur upstream of Gavins Point in the alternatives do not have an impact on Gavins Point pool elevation and releases. The minor changes in spring pool elevation as compared to No Action, shown in Figure 2-5, are a result of ResSim modeling and are not due to operational changes in the alternatives. Guide curve elevations are seasonally varying target elevations for a reservoir.

The changes in Gavins Point releases that occur in the alternatives, shown in Figure 2-6, are a result of the many simulation rules in ResSim reacting to minor changes in reservoir conditions. During real-time operations, these changes in conditions are too small to alter release decisions. This is especially apparent in high runoff years such as 2011 when a difference of approximately 10,000 acre-feet in System storage, which is approximately 3 days of evaporation on Lake Sakakawea, results in a 10.0 kcfs difference in Gavins Point releases. A storage difference of 10,000 acre-feet would not result in an increase of 10.0 kcfs from Gavins Point during real-time operations, but because the System model has utilized available storage, it overreacts and increases Gavins Point releases.

2.1.3 Elevation and Release Changes at Gavins Point during Spring Months for All Alternatives

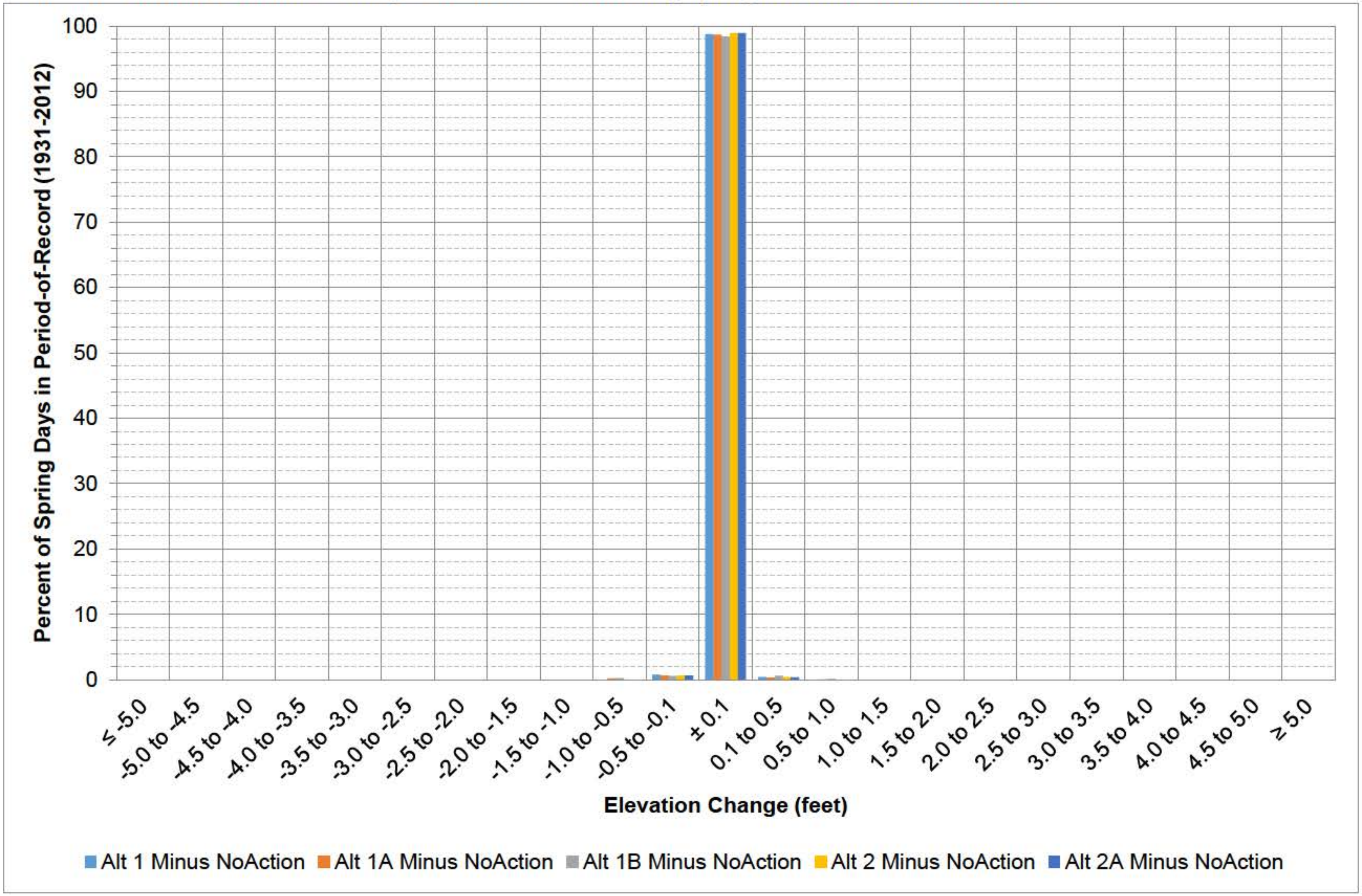

Figure 2-5: Gavins Point elevation change between each alternative and No Action during March – April.

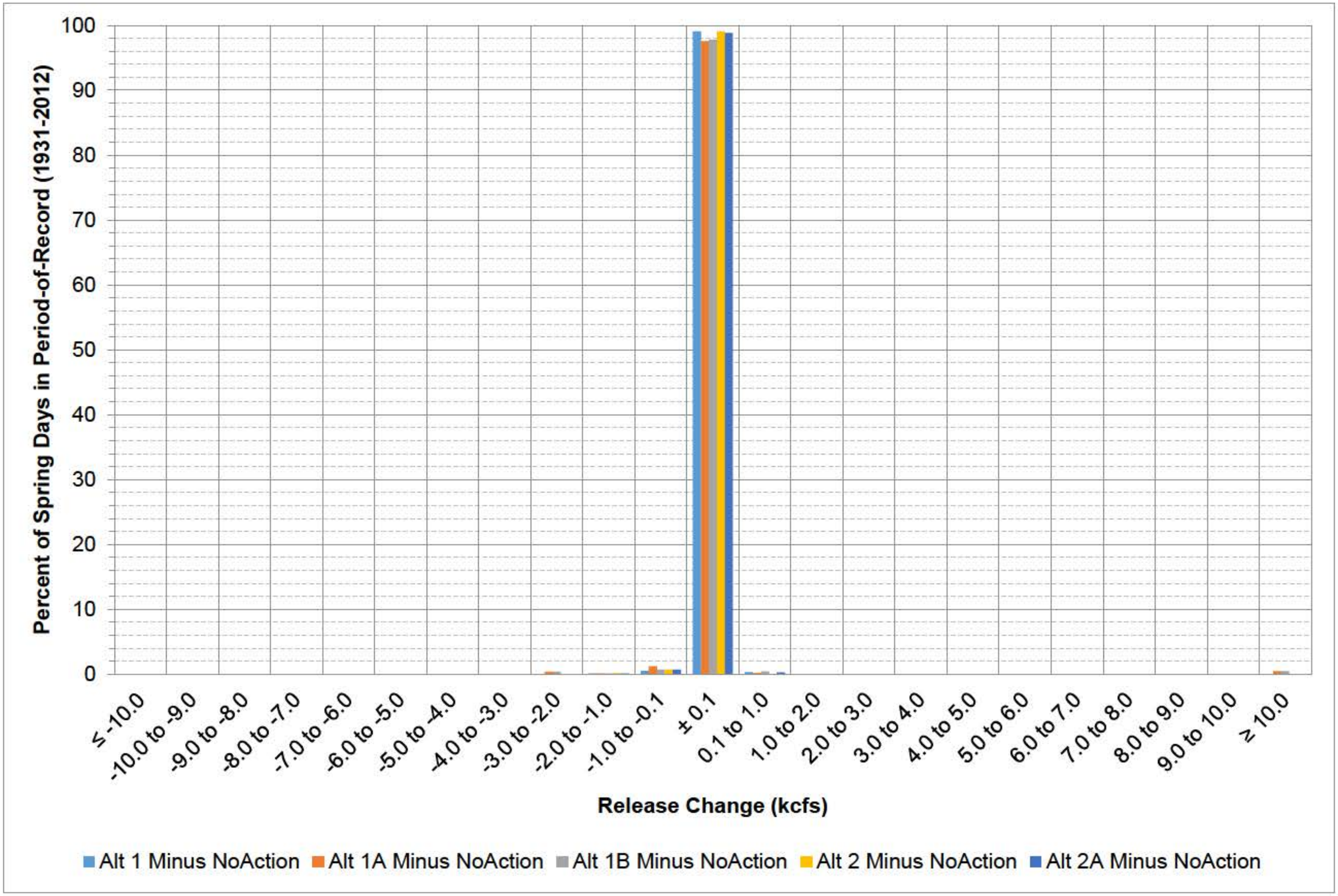

Figure 2-6: Gavins Point release change between each alternative and No Action during March – April.

2.2 UPSTREAM OF GAVINS POINT

2.2.1 No Action

After setting the System or Gavins Point releases, the model focuses on setting releases for storage balancing at Fort Peck, Garrison, and Oahe, water supply flows at Wolf Point, Culbertson, and Bismarck, and guide curve operations at Big Bend, Fort Randall, and Gavins Point.

Over ninety percent of the total System storage resides in Fort Peck, Garrison, and Oahe. Storage balancing focuses on balancing the amount of water occupying the Carryover Multiple Use Zones in these projects. During an ideal runoff year, Fort Peck, Garrison, and Oahe would begin the year at the bottom of their respective Annual Flood Control & Multiple Use Zone (top of the Carryover Multiple Use Zone). Annual runoff would be captured and released to meet the eight authorized purposes such that Fort Peck, Garrison, and Oahe all reach the bottom of their respective Annual Flood Control & Multiple Use Zone prior to the start of next year's runoff season. At that point, System storage is balanced as Fort Peck, Garrison, and Oahe all have zero percent of their respective Annual Flood Control & Multiple Use Zone or one hundred percent of their Carryover Multiple Use Zone occupied. During an extended drought, System operations cause Fort Peck, Garrison, and Oahe to draft into their Carryover Multiple Use Zone, which was designed to provide water for the System to operate for all eight authorized purposes during extended droughts. In this case, storage balancing operations use monthly runoff and release forecasts to set releases at Fort Peck and Garrison so Fort Peck, Garrison, and Oahe all have an equal percentage of occupied Carryover Multiple Use Zones by the start of next year's runoff season. Figure 2-7 shows an example of how Fort Peck, Garrison, and Oahe are balanced throughout the runoff year. The percentage of occupied carryover storage in each reservoir fluctuates throughout the runoff year but as the year progresses towards the next runoff season, the percentages of occupied carryover storage begin to converge towards each reservoir's target storage, resulting in balanced reservoir storage.

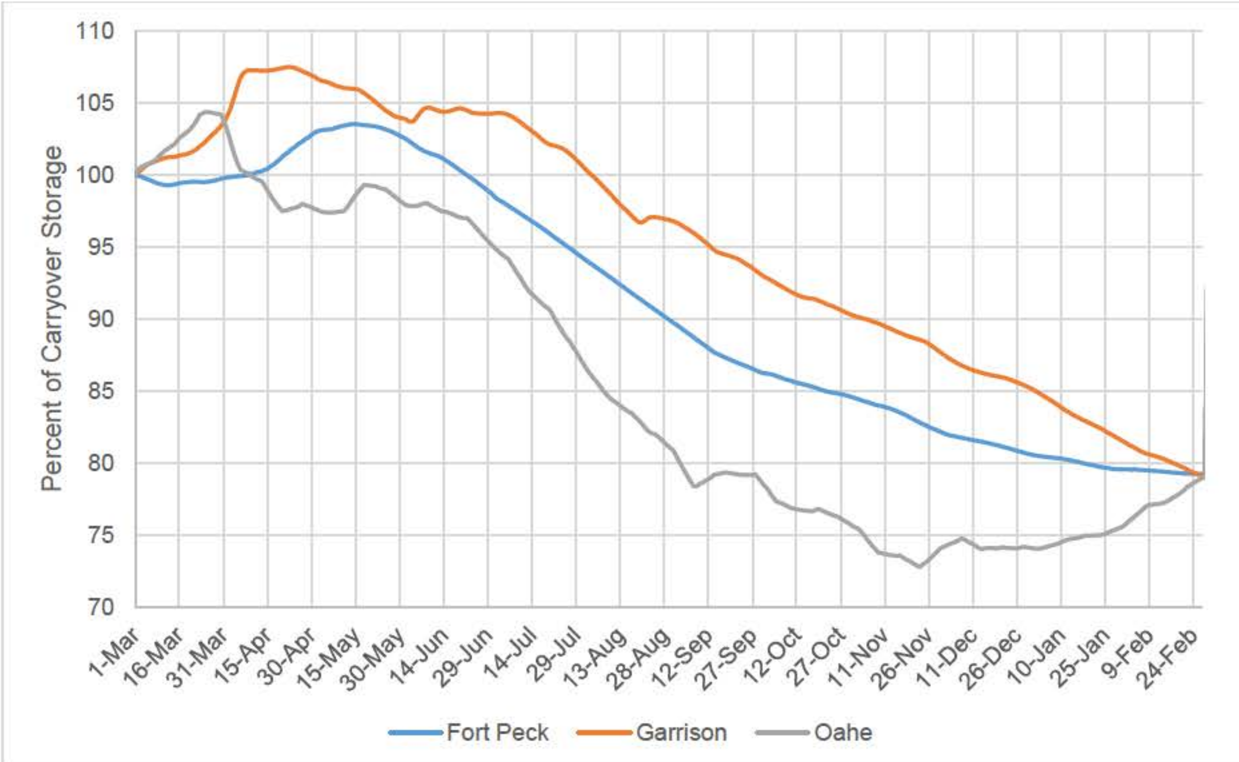

Figure 2-7: Storage balancing at Fort Peck, Garrison, and Oahe.

After setting releases at Fort Peck and Garrison, minimum flows at Wolf Point, Culbertson, and Bismarck are checked. Releases from Fort Peck are increased to ensure a minimum flow of 3.0 kcfs is forecasted at Wolf Point and Culbertson during March and April. Releases from Garrison are increased to ensure a minimum flow of 10.0 kcfs is forecasted at Bismarck during March and April.

While storage balancing and water supply operations are responsible for setting releases from Fort Peck and Garrison, guide curve operations govern releases from Oahe, Big Bend, and Fort Randall. Big Bend is a run-of-river project mainly operated for hydropower, which keeps the normal operating pool between 1420.0 feet (NGVD 29) and 1421.0 feet (NGVD 29) throughout the year. Fort Randall's pool elevation begins March near 1350.0 feet (NGVD 29) and rises to 1355.0 feet (NGVD 29) by April 1. Once Fort Randall's pool elevation reaches 1355.0 (NGVD 29), it is held constant for the remainder of April, with the exception of high runoff years. This is accomplished by adjusting releases from Oahe and Big Bend together. Gavins Point's pool elevation is kept within a narrow operational range near 1206.0 feet (NGVD 29) during March and April by adjusting releases from Fort Randall.

2.2.2 Alternative 1, 1a, and 1b

Upstream operations in Alt 1, 1a, and 1b utilize all of the operations described in the No Action during March – April. Fort Peck and Garrison still operate to balance the storage among Fort Peck, Garrison, and Oahe by the start of next year's runoff season while also ensuring water supply requirements are met at Wolf Point, Culbertson, and Bismarck. Oahe, Big Bend, and Fort Randall operate to keep their reservoirs at their respective guide curve elevations.

In addition to the operations in the No Action, another operation is incorporated into Alt 1, 1a, and 1b. The operation change is the addition of a flow regime for the pallid sturgeon. For Alt 1, the flow regime begins on April 16 with an attraction flow. Fort Peck releases are increased to ensure flows at Wolf Point are increased by 1.7 kcfs per day until the peak attraction flow of 2 times the Fort Peck spring release is reached. The peak flow is maintained for three days and then decreased by 1.3 kcfs per day for a maximum of 12 days. After 12 days, the flow is reduced by 3.0 kcfs per day until the retention flow is reached. If the retention flow is reached within the first 12 days of flow reduction, the retention flow is maintained until the spawning cue begins on May 28. The retention flow is 1.5 times the Fort Peck spring release. Alt 1a and 1b follow the same criteria for the flow regime but begin it one week earlier and later, respectively. The flow regime under Alt 1a begins April 9 and the attraction flow is held until the spawning cue begins on May 21. The flow regime under Alt 1b begins on April 23 and the attraction flow is held until the spawning cue begins on June 4.

Figure 2-8 shows the attraction flow at Wolf Point, MT for Alt 1, 1a, and 1b. Fort Peck spring release in Alt 1 and 1b was 7.0 kcfs, which resulted in a peak target flow at Wolf Point of 14.0 kcfs. The spring release in Alt 1a was 6.8 kcfs, which resulted in a peak target flow at Wolf Point of 13.6 kcfs. Due to the tributary flow forecasts not perfectly matching observed data, the peak flow in Alt 1a and 1b exceed the target peak flow. Matching the peak target flow during the spring will be more difficult than during the summer due to the higher tributary flows during the spring.

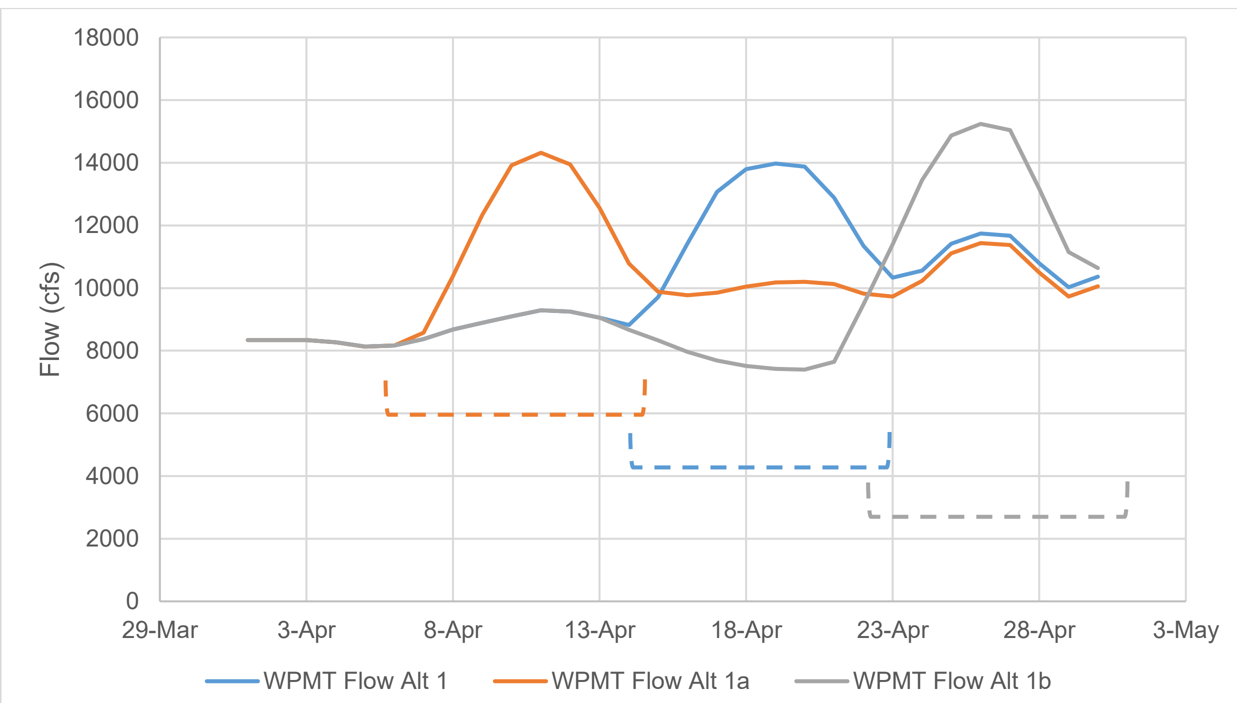

Figure 2-8: Attraction flow for Alt 1, 1a, and 1b. Dashed lines bracket the attraction flow for each alternative.

Several drought and flood criteria were developed to minimize impacts during the flow regime. The only drought conservation measure is based on Fort Peck pool elevation. In order to complete the spawning cue, the spillway must be utilized, but sufficient flow through the spillway is limited by the head on the spillway crest. A conservative estimate was 2 feet of head on the spillway would be needed to provide adequate flow over the spillway; two feet of head equates to pool elevation 2227.0 feet (NGVD 29). On the day that Fort Peck releases will be increased to meet the attraction target flow at Wolf Point, a long-term forecast is completed for Fort Peck. Using the monthly forecasted runoff and the flow regime through the spawning cue, a daily forecast of pool elevation is completed. If the pool elevation is forecasted to fall below 2227.0 feet (NGVD 29), the flow regime will not start. A 14-day forecast is also completed every day of the flow regime. If the pool elevation is forecasted to fall below 2227.0 feet (NGVD 29) during the flow regime, the flow regime will be terminated to conserve water to possibly run the flow regime the following year.

There are several flood criteria used to determine if the flow regime should not begin or discontinued. The first deals with forecasted reach runoff between Fort Peck and Garrison. The peak runoff in the Fort Peck to Garrison reach occurs when the mountain snowpack melts, late May through June, which would reduce the likelihood that the spawning cue would be completed due to other flood constraints; therefore, in order to maximize the possibility that the flow regime will be completed, the flow regime will not be started during years with a high forecasted May – June forecasted runoff in the Fort Peck to Garrison reach. If the May – June forecasted runoff in the Fort Peck to Garrison reach exceeds an upper quartile year, the flow regime will not begin. The second criterion deals with downstream flows. As stated before, a 14-day forecast will be conducted each day during the flow regime. Part of this forecast is to check river flows at 2 locations: Wolf Point, MT and Culbertson, MT. Based on estimates in the Master Manual, flood damages begin at approximately 35.0 kcfs at both locations. If forecasted flows at either location exceed 35.0 kcfs, the flow regime will be discontinued for the remainder of the year. Further downstream at Williston, ND, stages are affected by Lake Sakakawea. Therefore, relationships were developed based on flow and pool elevation to forecast stages near Williston, ND. If the forecasted stage at Williston, ND exceeds flood stage, 22.0 feet, the flow regime is cancelled. There are seepage concerns at the Williston Levee when water surface elevations exceed 1853.5 feet (NGVD 29) at the downstream portion of the levee, which is approximately 6.4 feet of freeboard. If the forecasted freeboard is less than 6.4 feet, the flow regime will be stopped. The final flood criterion during the flow regime is based on a forecasted pool elevation for Lake Sakakawea. In order to minimize the impacts associated with moving water from Fort Peck to Garrison and raising Lake Sakakawea, the flow regime will be cancelled if the forecasted pool elevation exceeds the top of Garrison's Flood Control and Annual Use Zone, 1850.0 feet (NGVD 29).

The observed changes at Fort Peck downstream to Fort Randall are shown in Figure 2-10 through Figure 2-19. In general, the majority of change from No Action occurs at Fort Peck and decreases as the location moves farther downstream from Fort Peck. Figure 2-10 shows a higher percentage of the spring months with lower elevations at Fort Peck for all alternatives compared to the No Action, which is caused by the attraction flow in April. As Fort Peck is releasing more water for the flow regime, Garrison tends to have a slightly higher pool elevation in the spring, as shown in Figure 2-12. No significant trends occur at Oahe with over 90 percent of the pool elevations changes being evenly distributed between ±0.5 feet. Big Bend and Fort Randall show little elevation change relative to No Action with approximately 98 percent of the changes falling between ±0.5 feet, which are attributed to their guide curve operations. Figure 2-16 and Figure 2-18 show Big Bend's and Fort Randall's full range of elevation changes, respectively.

Figure 2-11 shows a trend of higher releases at Fort Peck compared to the No Action. This increase in releases is also attributed to the attraction flow during April. The extra water released from Fort Peck is mostly stored in Garrison so changes in releases from Garrison are all within ±1 kcfs, as shown in Figure 2-13. Releases from Oahe are highly variable regardless of flow regimes at Fort Peck as water is released to keep Big Bend, Fort Randall, and Gavins Point at their respective guide curves. Even with the variable releases, over 90 percent of the release differences are within ±1 kcfs. Figure 2-15, Figure 2-17, and Figure 2-19 show the release differences relative to the No Action for Oahe, Big Bend, and Fort Randall, respectively.

2.2.3 Alternative 2, 2a, and 2b

Similar to Alt 1, upstream operations in Alt 2, 2a, and 2b utilize the all of the operations described in the No Action during March – April. Fort Peck and Garrison still operate to balance the storage among Fort Peck, Garrison, and Oahe by the start of next year's runoff season while also ensuring water supply requirements are met at Wolf Point, Culbertson, and Bismarck. Oahe, Big Bend, and Fort Randall operate to keep their reservoirs at their respective guide curve elevations.

In addition to the operations in the No Action, another operation is incorporated into Alt 2, 2a, and 2b. The operation change is the addition of a flow regime for the pallid sturgeon, but with a different shape and magnitude than Alt 1. For Alt 2, the flow regime begins on April 16 with an attraction flow. Fort Peck releases are increased to ensure flows at Wolf Point are increased by 1.7 kcfs per day until the peak attraction flow is equal to the maximum powerhouse release of 14.0 kcfs. The peak flow is also equal to the retention flow that occurs between the attraction and spawning cue so there is no reduction after the peak. Alt 2a and 2b follow the same criteria for the flow regime but begin one week earlier and later, respectively. The flow regime under Alt 2a begins April 9 and the attraction flow is held until the spawning cue begins on May 21. The flow regime under Alt 2b begins on April 23 and the attraction flow is held until the spawning cue begins on June 4.

Figure 2-9 shows the attraction flow at Wolf Point, MT for Alt 2, 2a, and 2b. Due to the tributary flow forecasts not perfectly matching observed data, the peak flow in Alt 2a and 2b exceed the target peak flow. Matching the peak target flow during the spring will be more difficult than during the summer due to the higher tributary flows experienced in the spring.

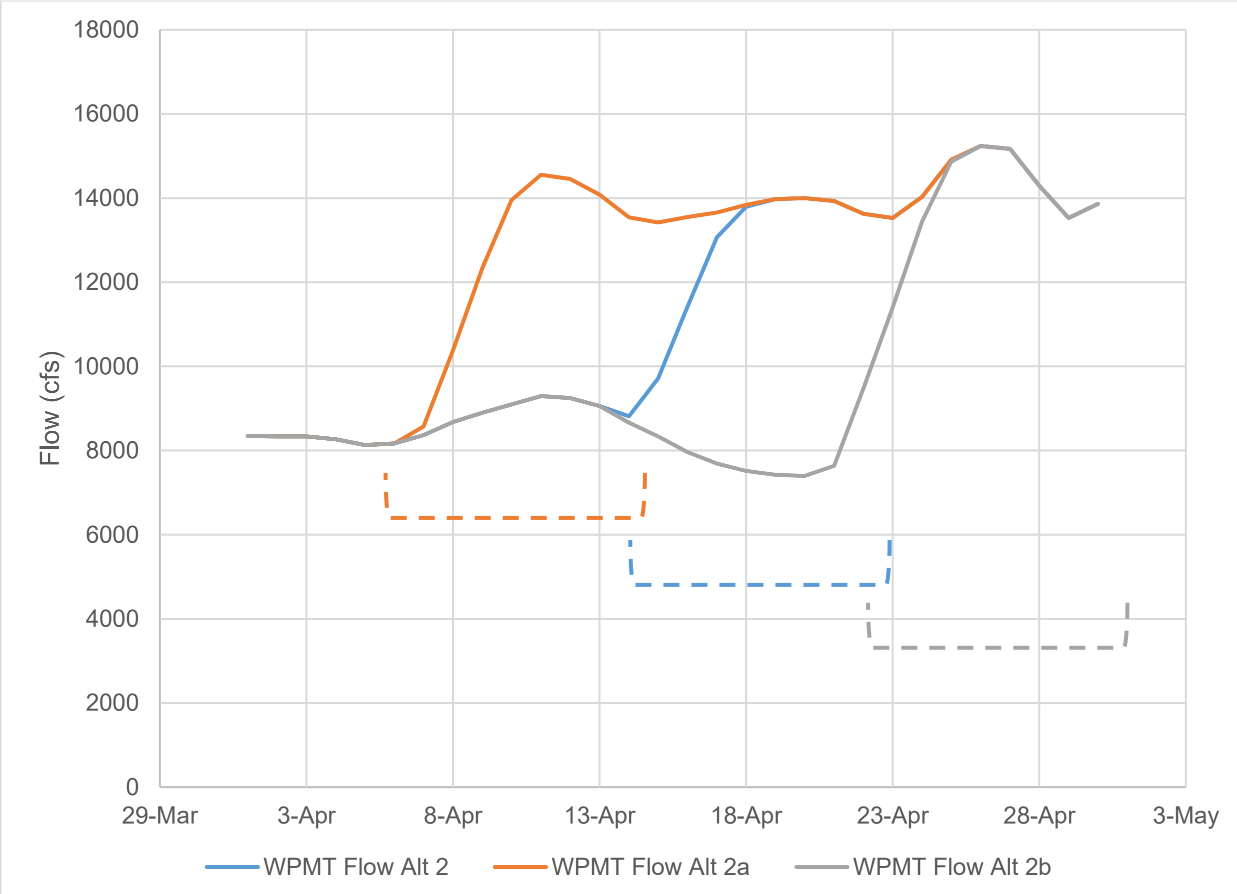

Figure 2-9: Attraction flow for Alt 2, 2a, and 2b.

The same drought and flood criteria developed for Alt 1, 1a, and 1b and described in Section 2.2.2 were used for Alt 2, 2a, and 2b.

The observed changes at Fort Peck downstream to Fort Randall are shown in Figure 2-10 through Figure 2-19 and follow the same trends as Alt 1. In general, the majority of change from No Action occurs at Fort Peck and decreases as the location moves farther downstream. Figure 2-10 shows a higher percentage of the spring months with lower elevations at Fort Peck for all alternatives compared to the No Action, which is caused by the attraction flow in April. As Fort Peck is releasing more water for the flow regime, Garrison tends to have a slightly higher pool elevation in the spring, as shown in Figure 2-12. No significant trends occur at Oahe with over 90 percent of the pool elevation changes being evenly distributed between ±0.5 feet. Big Bend and Fort Randall show little elevation change relative to No Action with approximately 98 percent of the changes falling between ±0.5 feet, which are attributed to their guide curve operations. Figure 2-16 and Figure 2-18 show Big Bend's and Fort Randall's full range of elevation changes, respectively.

Figure 2-11 shows a trend of higher releases at Fort Peck compared to the No Action. This increase in releases is also attributed to the attraction flow during April. The extra water released from Fort Peck is mostly stored in Garrison so changes in releases from Garrison are all within

±1 kcfs, as shown in Figure 2-13. Releases from Oahe are highly variable regardless of flow regimes at Fort Peck as water is released to keep Big Bend, Fort Randall, and Gavins Point at their respective guide curves. Even with the variable releases, over 90 percent of the release differences are within ±1 kcfs. Figure 2-15, Figure 2-17, and Figure 2-19 show the release differences relative to the No Action for Oahe, Big Bend, and Fort Randall, respectively.

2.2.4 Elevation and Release Changes Upstream of Gavins Point during Spring Months for All Alternatives

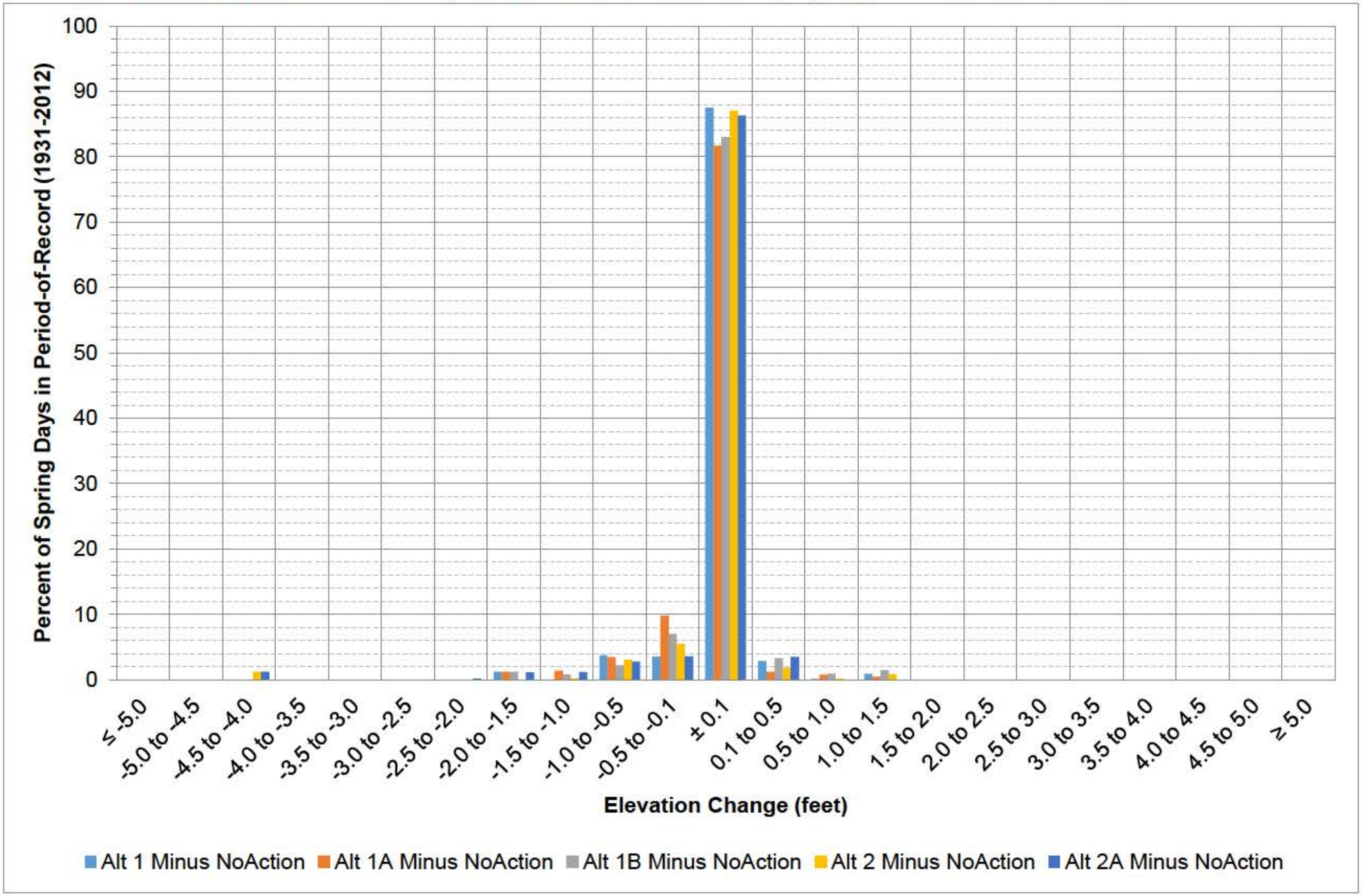

Figure 2-10: Fort Peck elevation change between each alternative and No Action during March – April.

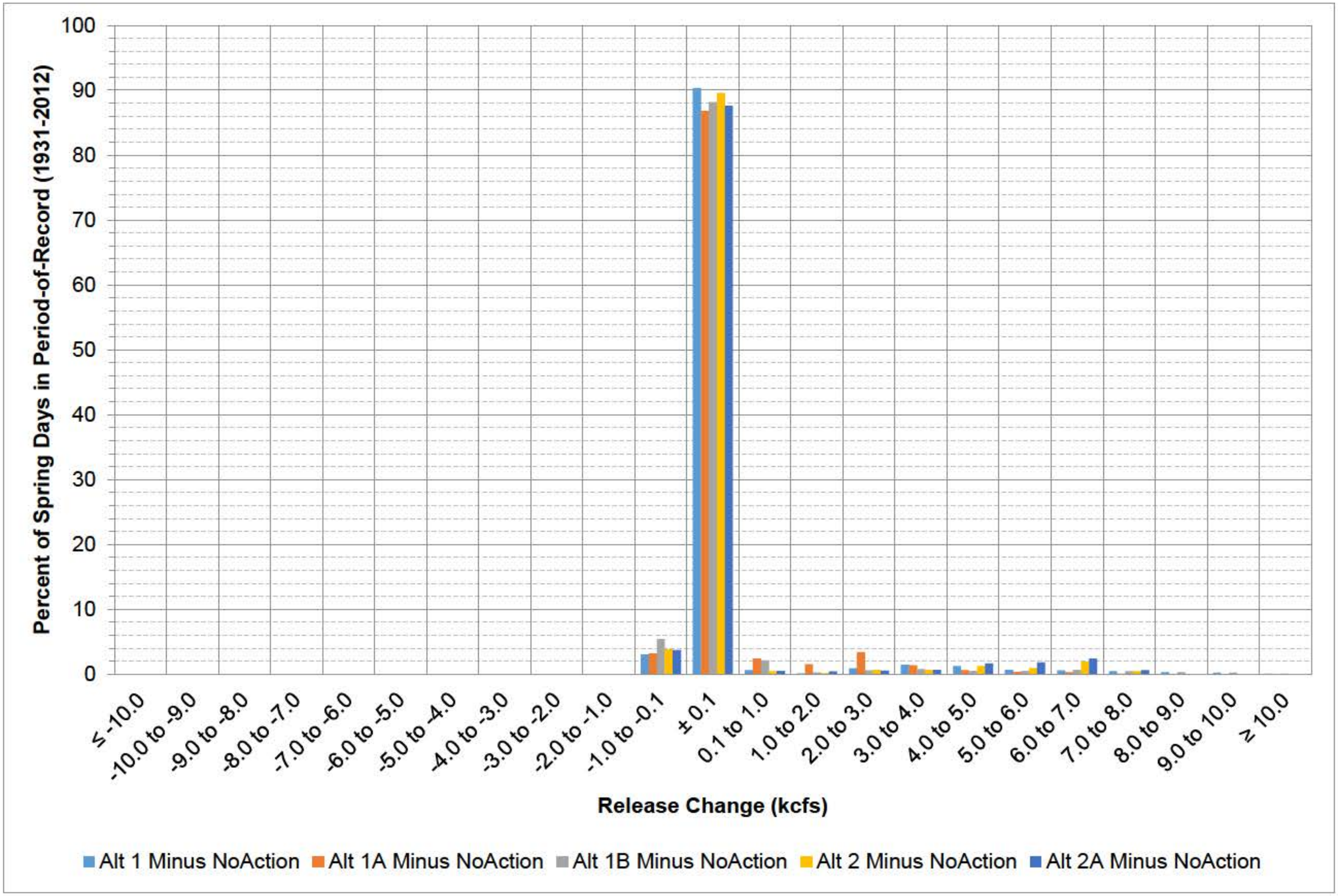

Figure 2-11: Fort Peck release change between each alternative and No Action during March – April.

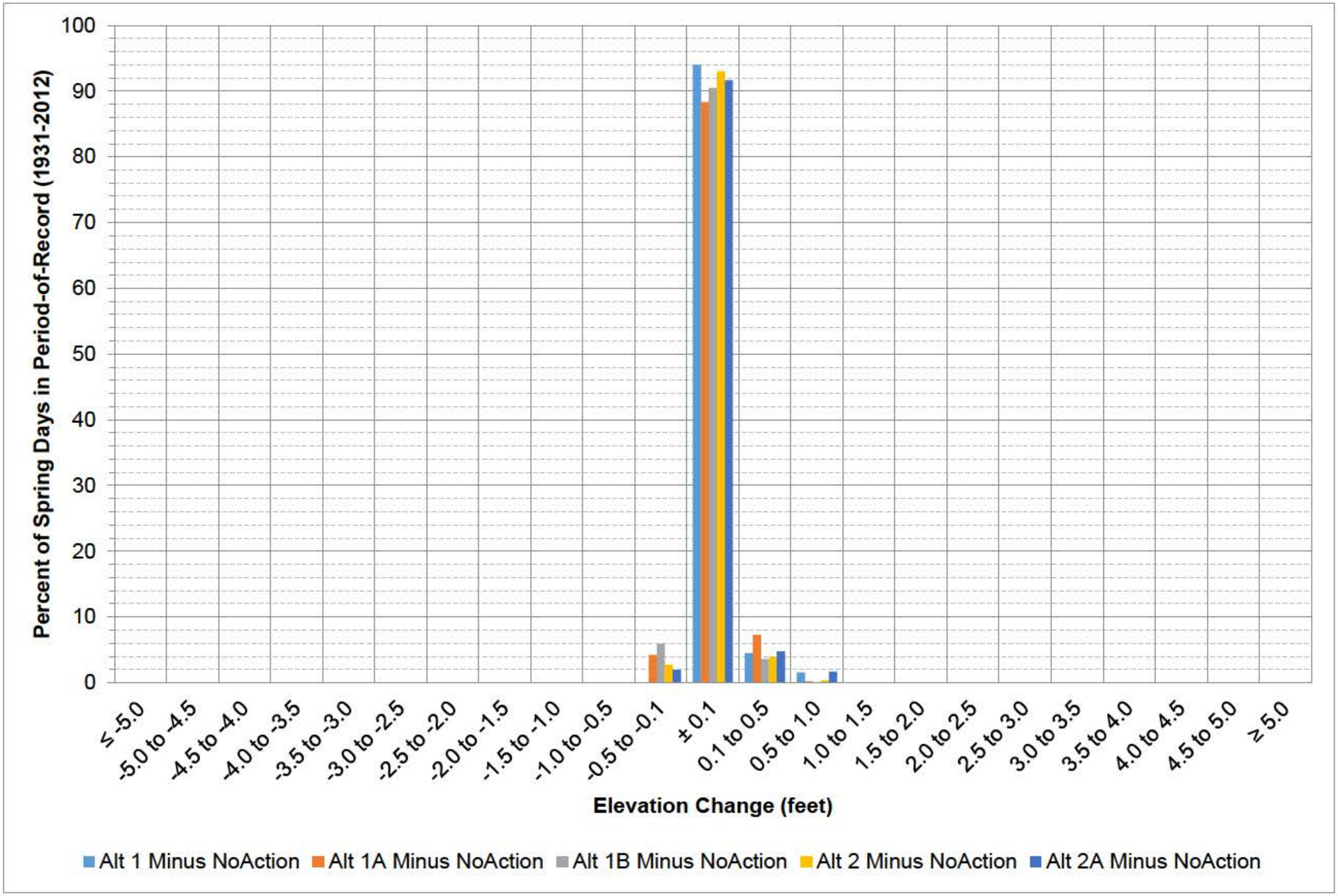

Figure 2-12: Garrison elevation change between each alternative and No Action during March – April.

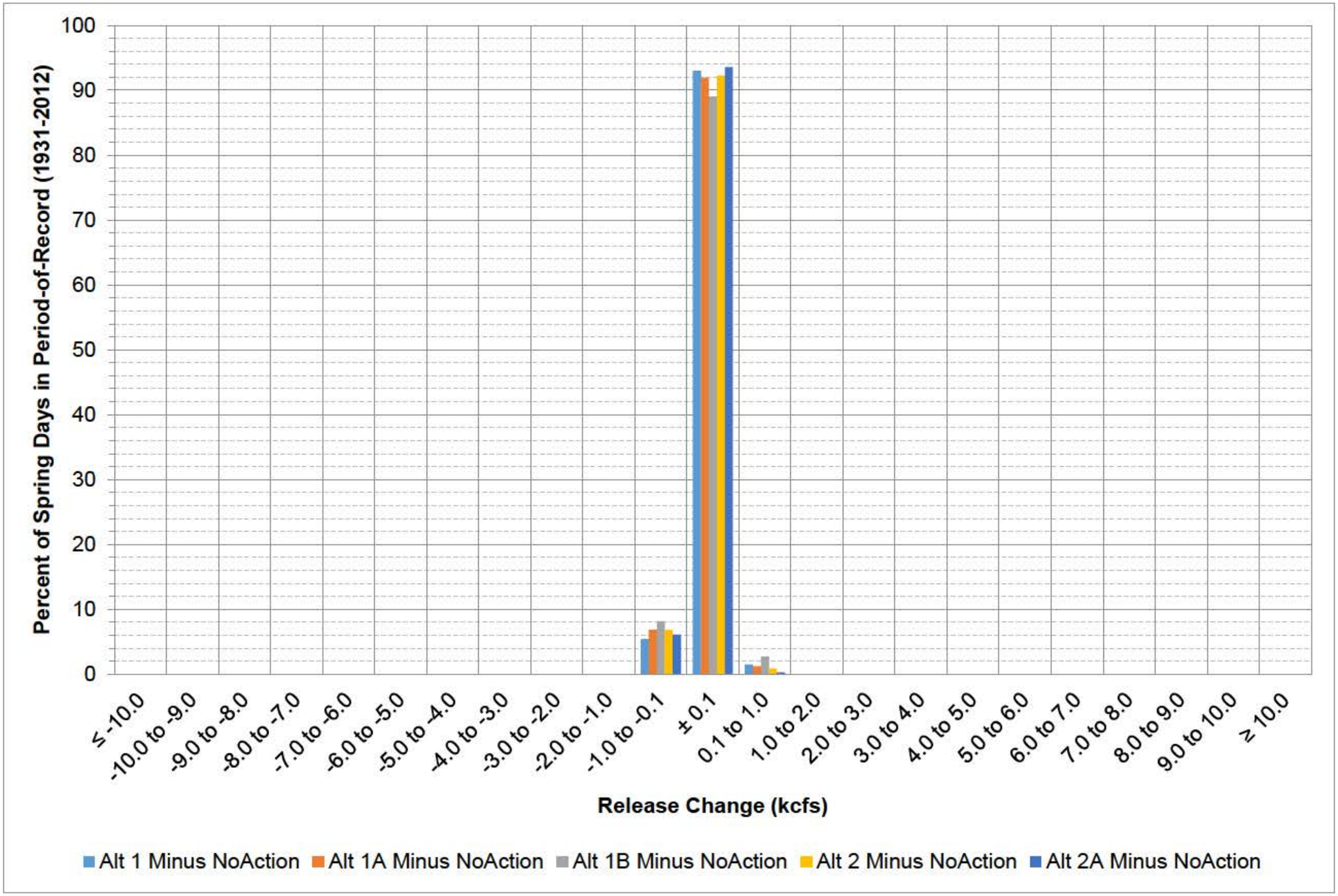

Figure 2-13: Garrison release change between each alternative and No Action during March – April.

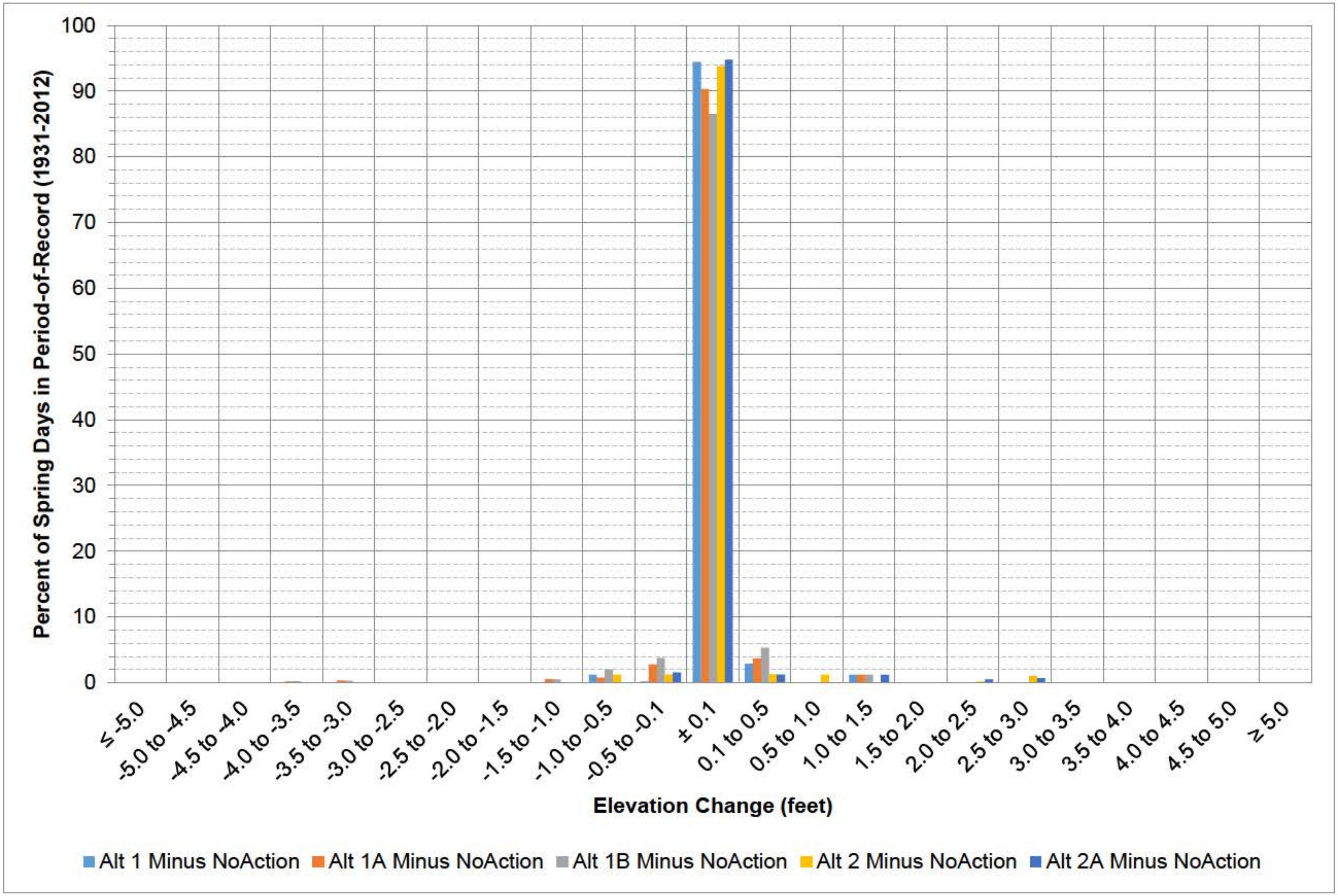

Figure 2-14: Oahe elevation change between each alternative and No Action during March – April.

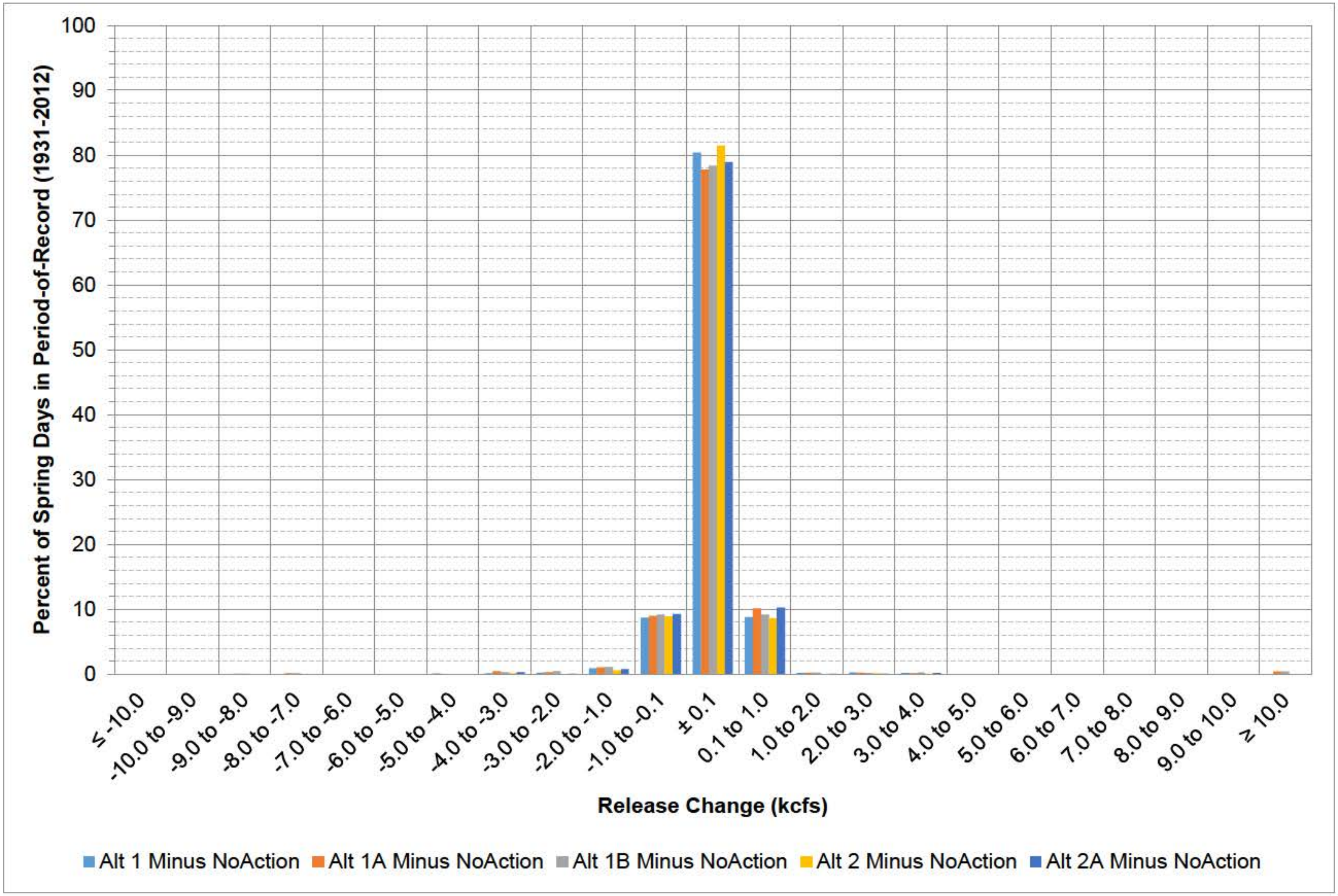

Figure 2-15: Oahe release change between each alternative and No Action during March – April.

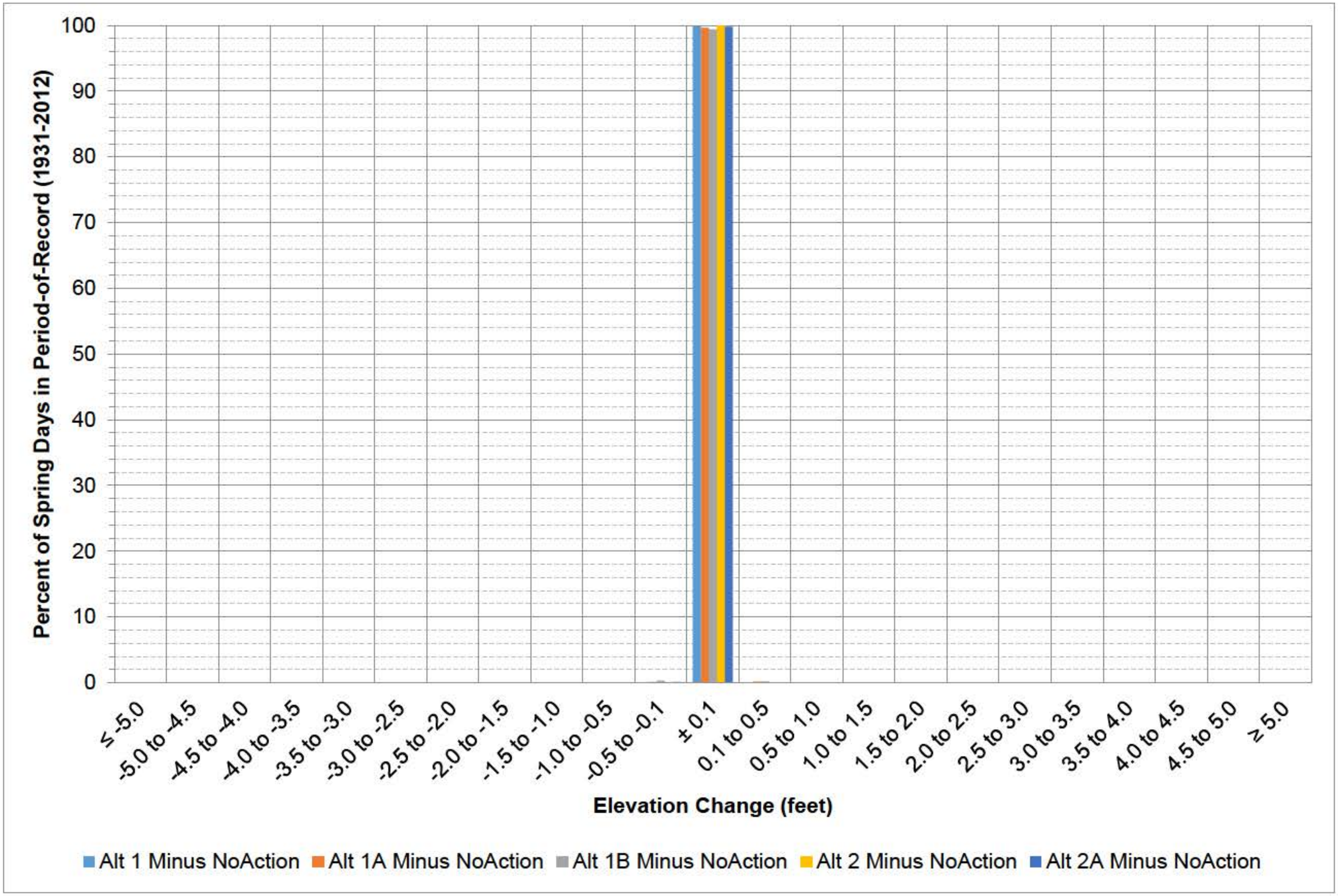

Figure 2-16: Big Bend elevation change between each alternative and No Action during March – April.

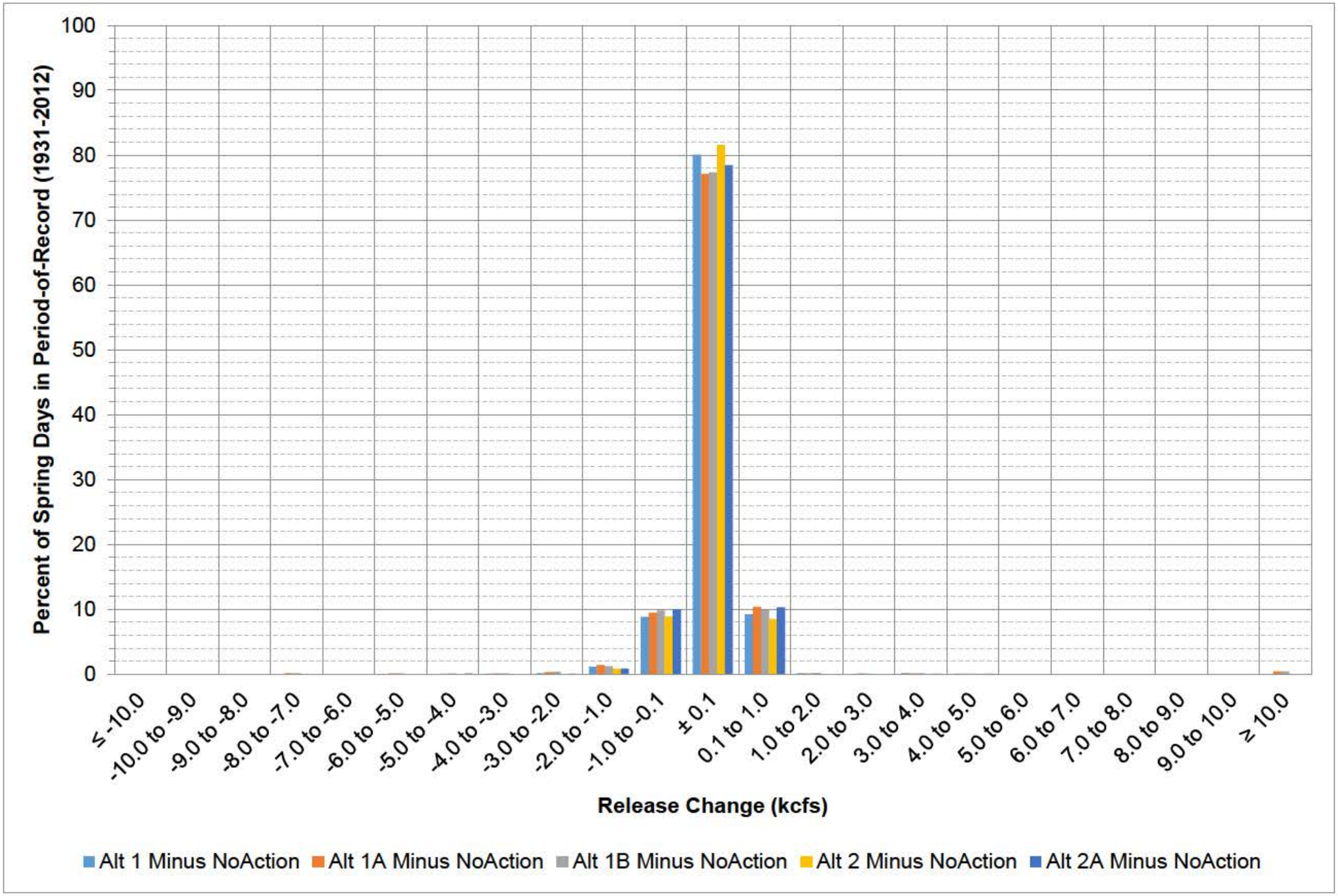

Figure 2-17: Big Bend release change between each alternative and No Action during March – April.

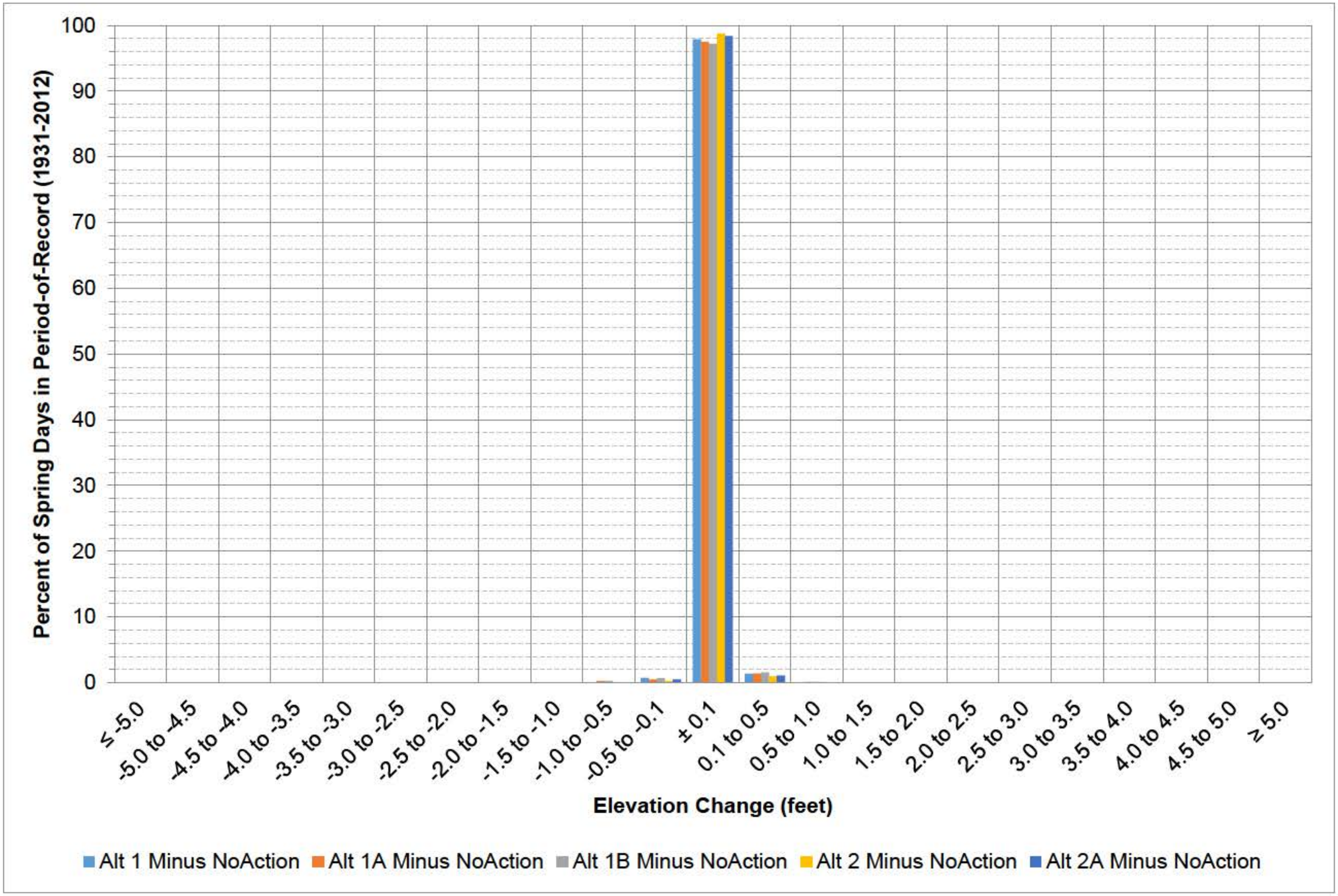

Figure 2-18: Fort Randall elevation change between each alternative and No Action during March – April.

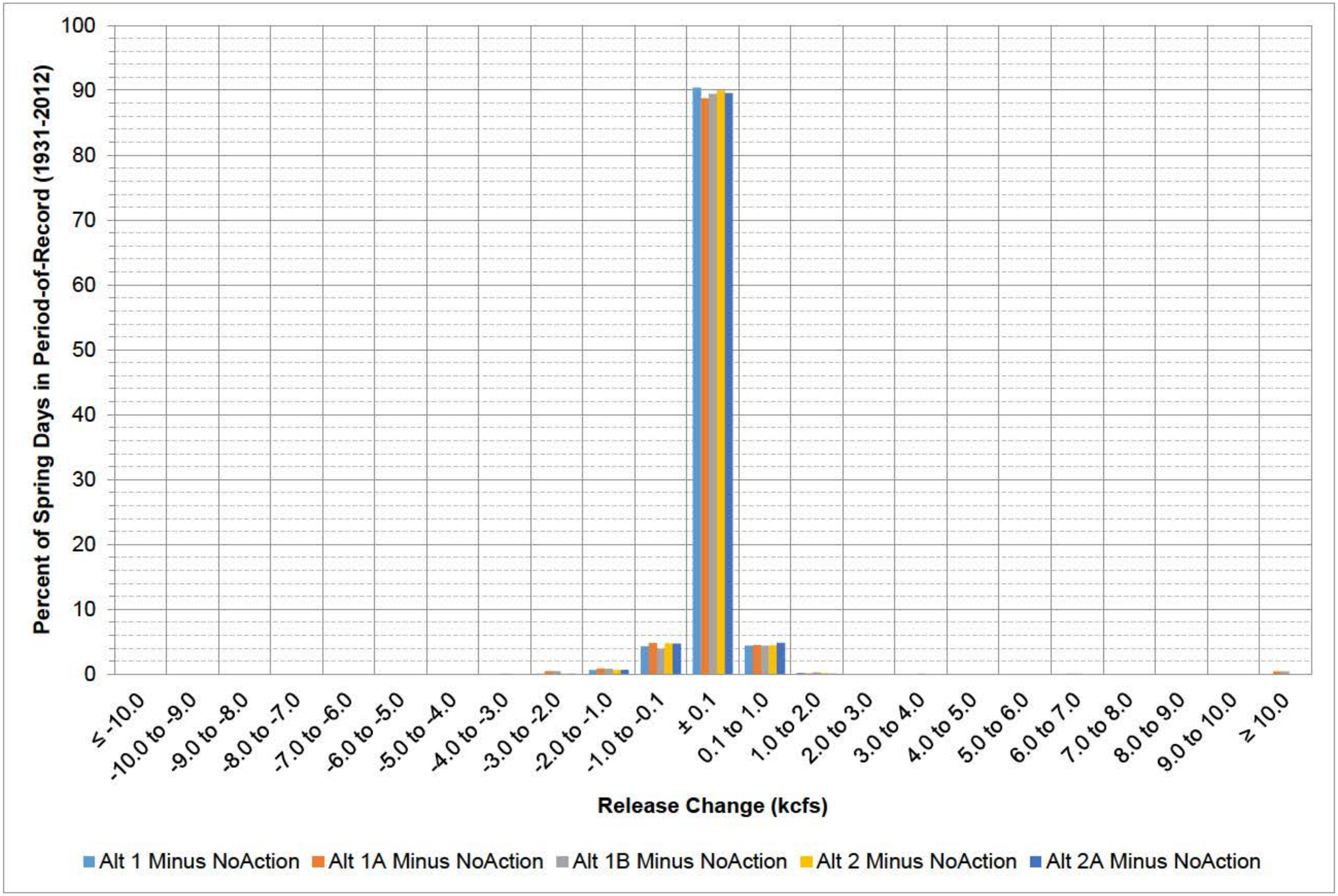

Figure 2-19: Fort Randall release change between each alternative and No Action during March – April.

3 SUMMER: MAY – AUGUST

3.1 DOWNSTREAM OF GAVINS POINT

3.1.1 No Action

For modeling purposes FTT navigation operations are still in effect between May 1 and May 15. Operations shift to a steady release flow-to-target (SRFTT) criteria during the endangered bird species nesting period, which begins on May 15. A steady release is selected based on the forecasted runoff and current service level with the assumption that a higher release will be needed later in the summer to meet navigation targets when downstream tributary flows tend to recede. By selecting a higher release in May, birds are forced to nest higher and ideally, releases will not need to be increased until after the nesting season ends around August 15. For example, if a median runoff was forecasted on May 1 and the System was supporting full-service navigation, a steady release of 31.6 kcfs would be initiated on May 15. Table 3-1 summarizes the steady release criteria. Gavins Point release can be increased if navigation targets will not be met while releasing the steady release. In this case, Gavins Point releases are increased until all navigation targets are met and then releases are held constant at the new steady release. However, if a release higher than Kansas City's navigation target is required to meet all navigation targets, the new steady release is set to Kansas City's navigation target and FTT operations take precedent while higher releases are needed to meet downstream navigation targets. Flood targets are assessed during the steady release and if any of the three targets are forecasted to be exceeded, Gavins Point releases are reduced. Once the flood targets are no longer forecasted to be exceeded, the steady release resumes. Figure 3-1 shows an example of the steady release operations where the System is supporting minimum-service navigation and the forecasted runoff is less than a median runoff, so the initial steady release is set to 28.3 kcfs on May 15. The May 25 downstream forecast indicates that a release greater than 28.3 kcfs is required to meet Kansas City's navigation target, so Gavins Point release is increased to 28.8 kcfs to keep flow at Kansas City above its navigation target. Gavins Point release is again increased at the end of June to ensure flows at Nebraska City and Kansas City remain above their navigation target flows. On July 4, downstream forecasting indicates flood targets are going to be exceeded at downstream locations so Gavins Point releases are reduced and the steady release criteria is ignored. Flows remain high during July so Gavins Point releases do not utilize the steady release criteria for the remainder of the steady release period.

Table 3-1: Steady release criteria. Typical Gavins Point releases needed to meet navigation target flows in July based on 1950 to 1996 data.

	Median, Upper Quartile, Upper Decile Runoff Forecast
Full-service	31.6 kcfs
Minimum-service	25.6 kcfs
	Lower Quartile, Lower Decile Runoff Forecast
Full-service	34.3 kcfs
Minimum-service	28.3 kcfs

Figure 3-1: Example of steady release operations.

System storage is assessed on July 1 and the service level is set for the remainder of the navigation season. Table 2-1 summarizes the System storage and service level relationship. Minimum service is specified if System storage is less than 50.5 MAF. An intermediate service level is specified if System storage is between 50.5 MAF and 57.0 MAF by linear interpolation. Full service is specified if the System storage is at least 57.0 MAF. Figure 3-2 shows an example of the July 1 System storage check. In this example, System storage is greater than 57.0 MAF on July 1, so the service level is set to 35.0 kcfs or full service for the 2nd half of the navigation season.

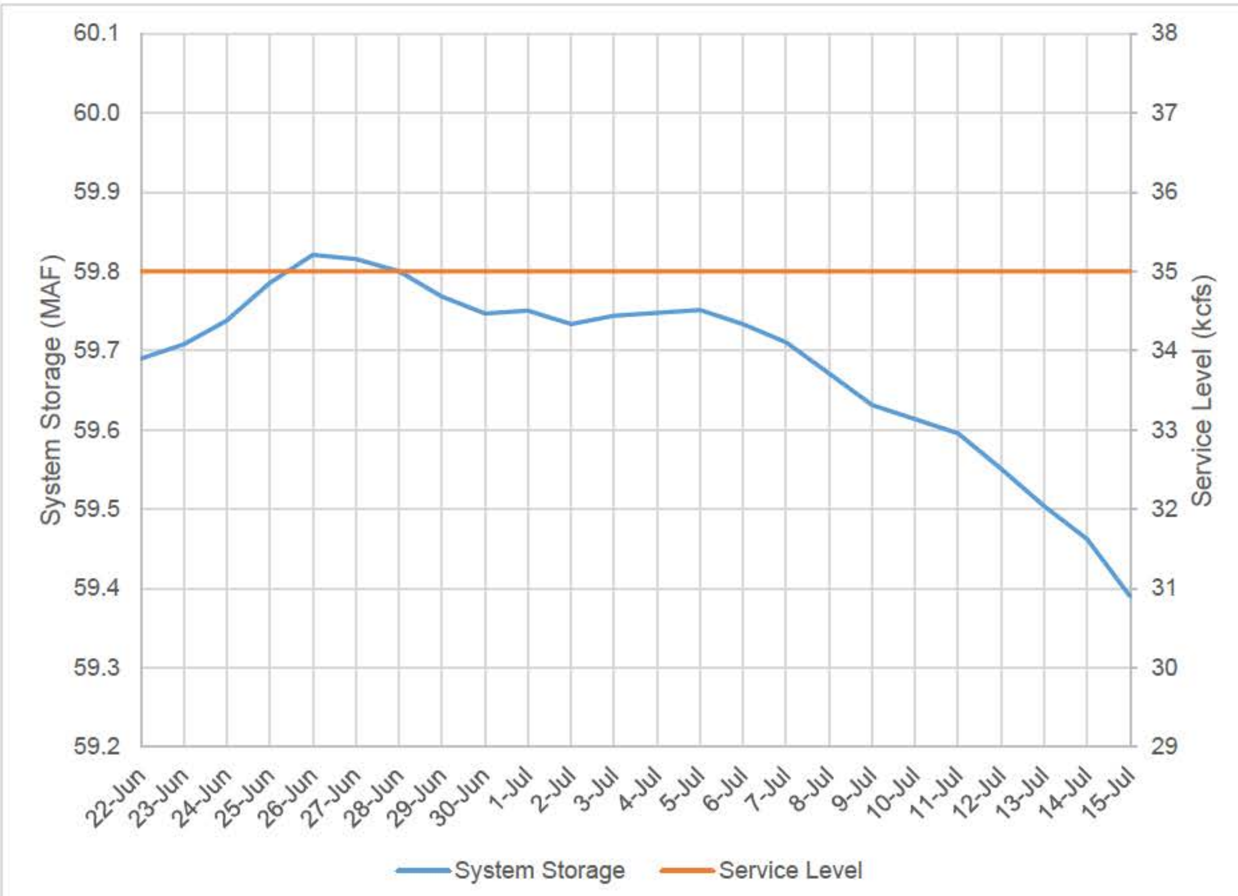

Figure 3-2: Example of July 1 System storage assessment and resulting service level.

The navigation season length is also set based on the July 1 storage assessment. The closure date at the mouth of the Missouri River is December 1 if System storage is 51.5 MAF or greater. The closure date is November 1 if System storage is between 41.0 MAF and 46.8 MAF; the closure date is October 1 if System storage is 36.5 MAF or less. If System storage is between the specified storage criteria, the closure date is linearly interpolated. Table 3-2 summarizes the season length or closure dates for the navigation season on the Missouri River.

Table 3-2: Navigation season length requirements. Summarized from Table VII-3 in the Master Manual (U.S. Army Corps of Engineers, 2018).

Date	System Storage (MAF)	Season Closure Date at Mouth of the Missouri River
July 1	36.5 or less	October 1 (6-month season)
July 1	41.0 – 46.8	November 1 (7-month season)
July 1	51.5 or more	December 1 (8-month season)

The steady release is terminated after August 15 and FTT operations resume allowing Gavins Point releases to be adjusted daily to meet downstream navigation requirements.

If the navigation season is cancelled, System operations continue to support water supply but the minimum water supply requirement is higher than the spring. Gavins Point releases are at least 18.0 kcfs and are also adjusted to ensure a minimum flow of 18.0 kcfs at the three target locations. Figure 3-3 shows an example of summer water supply operations where Kansas City was the critical location. Gavins Point releases began increasing to 18.0 kcfs on May 1 and remained at 18.0 kcfs until the June 5 downstream forecasts indicated flows at Kansas City would fall below 18.0 kcfs. At that point, Gavins Point releases were increased to keep flows at Kansas City above 18.0 kcfs.

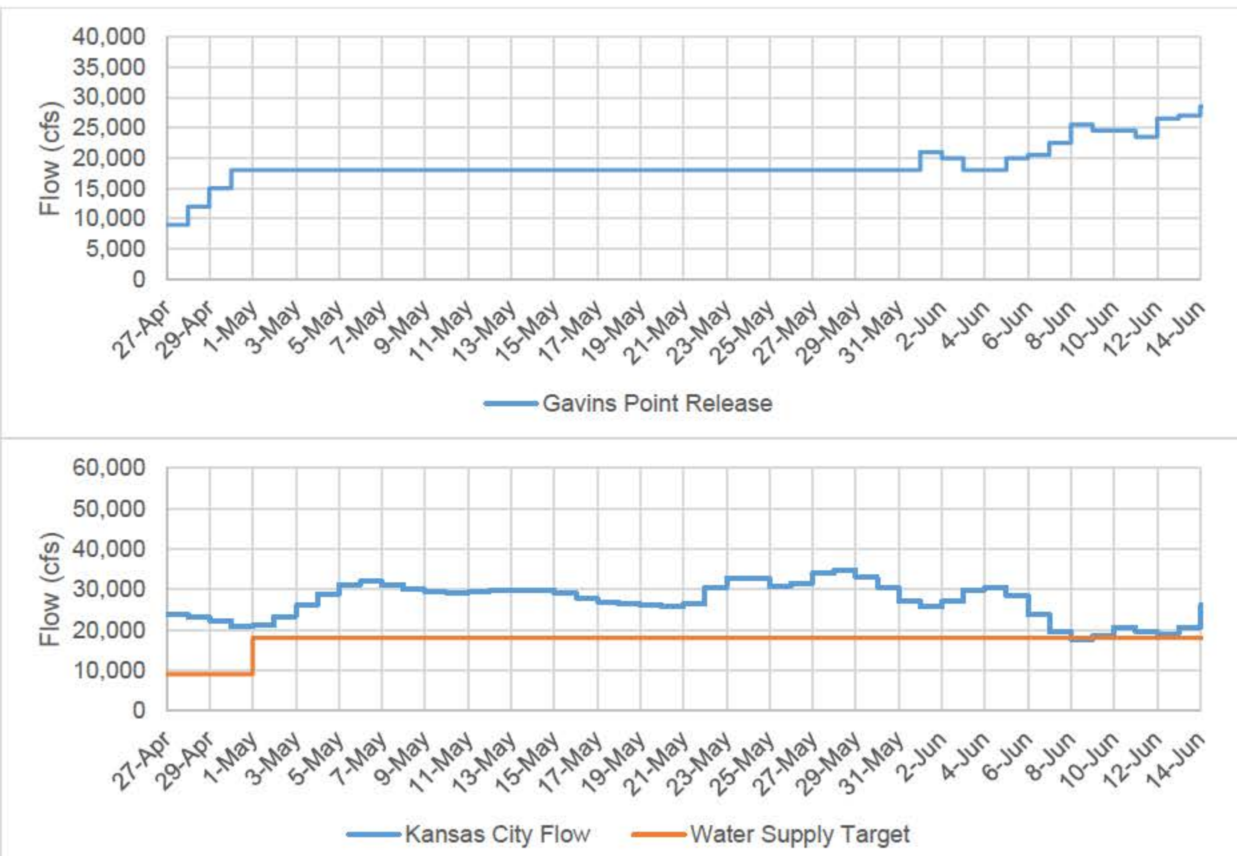

Figure 3-3: Example of summer water supply operations.

3.1.2 Alternatives 1, 1a, 1b, 2, 2a, and 2b

System operations downstream of Gavins Point in all alternatives do not change compared to No Action May – August with the same water supply, navigation, and flood control requirements used in the alternatives.

The operational changes that occur upstream of Gavins Point in the alternatives do not have an impact on Gavins Point pool elevation and releases. The minor changes in summer pool elevation as compared to No Action, shown in Figure 3-4, are a result of ResSim modeling and are not due to operational changes in the alternatives.

The changes in Gavins Point releases that occur in the alternatives, shown in Figure 3-5, are a result of the many simulation rules in ResSim reacting to minor changes in reservoir conditions. During real-time operations, these changes in conditions are too small to alter release decisions. This is especially apparent in high runoff years such as 2011 when a difference of approximately 10,000 acre-feet in System storage, which is approximately 3 days of evaporation on Lake Sakakawea, results in an 8.0 kcfs difference in Gavins Point releases. A storage difference of 10,000 acre-feet would not result in a decrease of 8.0 kcfs from Gavins Point during real-time operations, but because the System model has utilized available storage, it overreacts and decreases Gavins Point releases.

3.1.3 Elevation and Release Changes at Gavins Point during Summer Months for All Alternatives

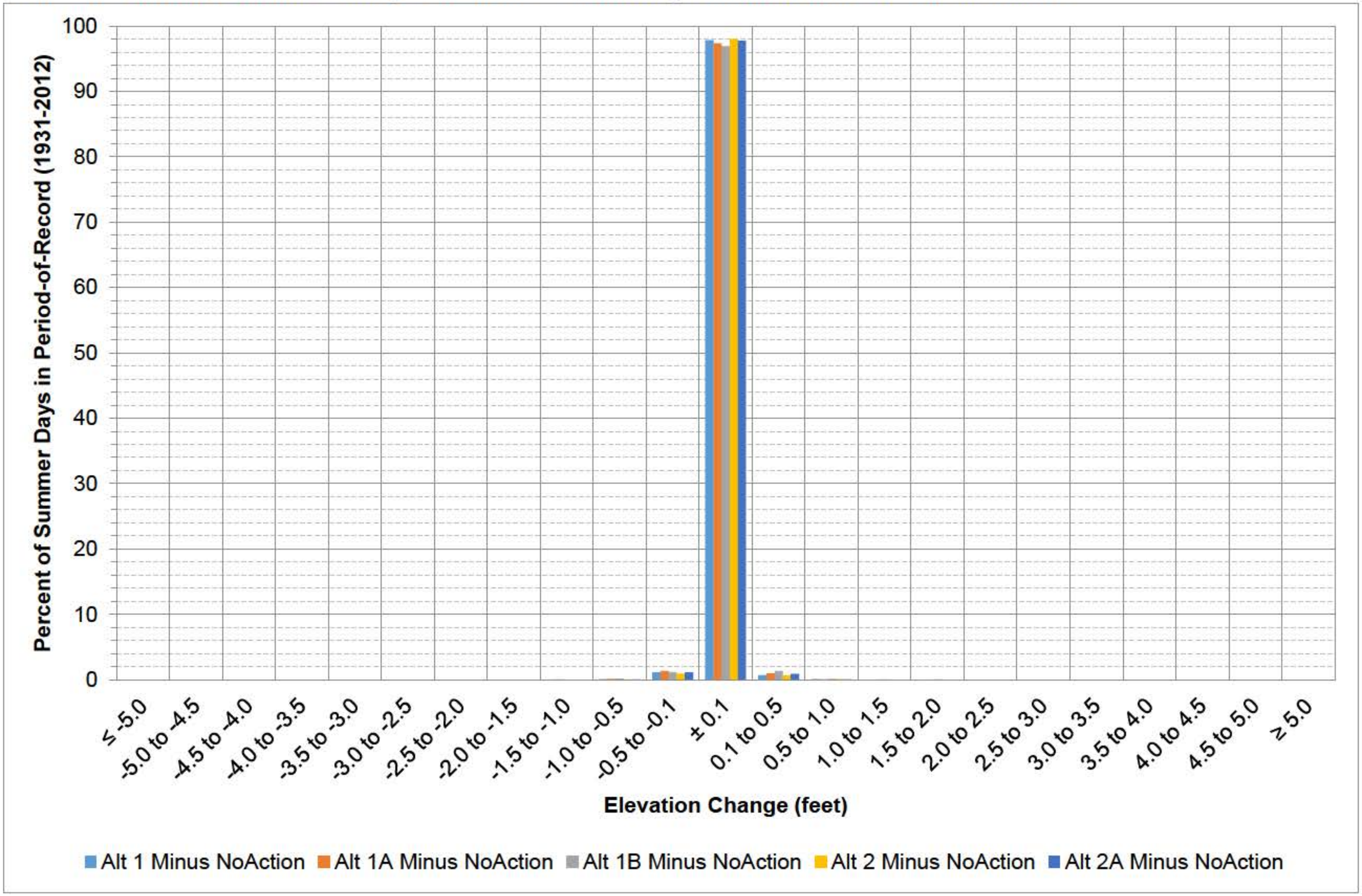

Figure 3-4: Gavins Point elevation change between each alternative and No Action during May – August.

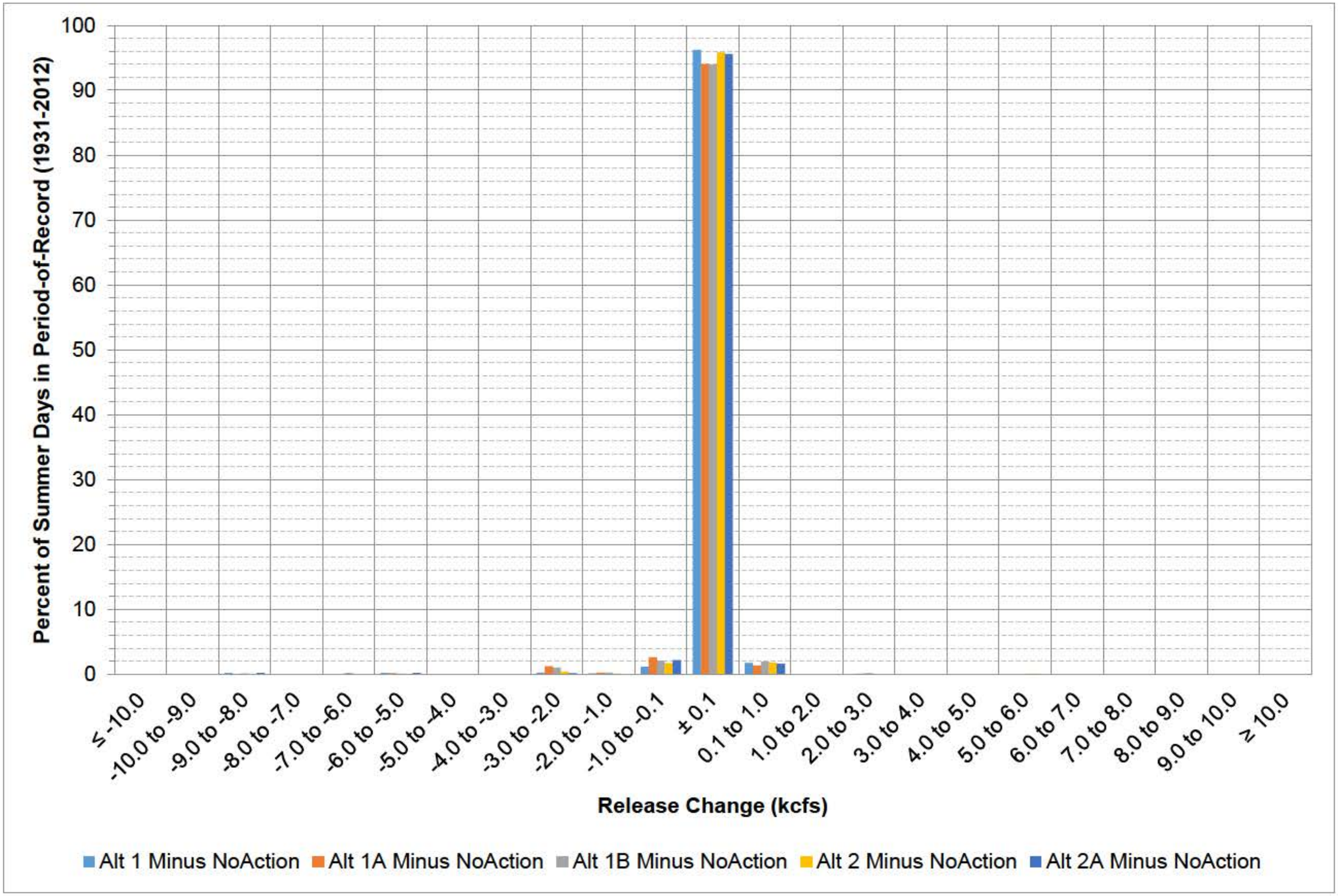

Figure 3-5: Gavins Point release change between each alternative and No Action during May – August.

3.2 UPSTREAM OF GAVINS POINT

3.2.1 No Action

After setting the System or Gavins Point releases, the model focuses on setting releases for storage balancing at Fort Peck, Garrison, and Oahe, water supply flows at Wolf Point, Culbertson, and Bismarck, and guide curve operations at Big Bend, Fort Randall, and Gavins Point.

Fort Peck and Garrison still release water based on the forecasted System storage as the model attempts to balance the occupied storage in the Carryover Multiple Use zones at Fort Peck, Garrison, and Oahe. The selected balancing release specified at Fort Peck and Garrison is maintained from May 15 to September 15 during the endangered bird species nesting season unless adjusted for droughts or flood events. Pool elevation boundaries were established for both Fort Peck and Garrison during the nesting season that allow for adjustments to the steady release during these periods. Drought conservation elevations were established for Fort Peck, Garrison, and Oahe that allow fluctuations in summer releases if either the releasing reservoir's or the downstream reservoir's pool elevation falls below their respective drought conservation elevation. In order to provide flexibility prior to reaching the permanent pool, each reservoir's drought conservation elevation was calculated by adding twenty five percent of the total height of their respective Carryover and Multiple Use Zone to the elevation of their respective permanent pool elevation. For example, Fort Peck's drought conservation elevation was 2160.0 + (2234.0 – 2160.0) * 0.25, which equaled 2178.5 feet (NGVD 29). Garrison's drought conservation elevation was 1790.6 feet (NGVD 29) and Oahe's was 1556.9 feet (NGVD 29). The upper steady release operational boundary for each reservoir was the top of their Annual Flood Control & Multiple Use Zones, which are 2246.0 feet (NGVD 29) at Fort Peck, 1850.0 feet (NGVD 29) at Garrison, and 1620.0 feet (NGVD 29) at Oahe. Using Fort Peck as an example, Fort Peck would have a steady release during the summer if its pool elevation was between 2178.5 feet (NGVD 29) and 2246.0 feet (NGVD 29) and Garrison's pool elevation was greater than 1790.6 feet (NGVD 29). Table 3-3 lists the pool elevation requirements for Fort Peck's and Garrison's steady release.

Table 3-3: Pool requirements for Fort Peck's and Garrison's steady release.

	Fort Peck Steady Release Criteria	Garrison Steady Release Criteria
Fort Peck Pool Elevation (feet) (NGVD 29)	2178.5 – 2250.0	N/A
Garrison Pool Elevation (feet) (NGVD 29)	greater than 1790.6	1790.6 – 1850.0
Oahe Pool Elevation (feet) (NGVD 29)	N/A	greater than 1556.9

Fort Peck's steady release occurs if its pool elevation is greater than 2178.5 feet (NGVD 29), which is 18.5 feet higher than the top of Fort Peck's permanent pool, and less than 2246.0 feet (NGVD 29), which is the top of its Annual Flood Control & Multiple Use Zone. Garrison's steady release occurs if its pool elevation is greater than 1790.6 feet (NGVD 29), which is 15.6 feet higher than the top of its permanent pool, and less than 1850.0 feet (NGVD 29), which is the top of its

Annual Flood Control & Multiple Use Zone. Fort Peck and Garrison releases are allowed to come off of their respective steady releases during droughts or extreme flooding to either conserve water or evacuate flood storage.

After setting releases at Fort Peck and Garrison, minimum flows at Wolf Point, Culbertson, and Bismarck are checked. Releases from Fort Peck are increased to ensure a minimum flow of 3.0 kcfs is forecasted at Wolf Point and Culbertson between May 1 and May 14. The minimum flow requirement at Wolf Point and Culbertson increases to 5.0 kcfs between May 15 and August 31. Releases from Garrison are increased to ensure a minimum flow of 10.0 kcfs is forecasted at Bismarck between May 1 and August 31.

Guide curve operations still govern releases from Oahe, Big Bend, and Fort Randall. Big Bend keeps its pool between 1420.0 feet (NGVD 29) and 1421.0 feet (NGVD 29). Fort Randall's pool elevation remains near 1355.0 feet (NGVD 29) through August 31. Gavins Point's pool elevation is kept near 1206.0 feet (NGVD 29) through September 1, but begins to slowly rise to 1207.5 feet (NGVD 29) by October 1. Figure 3-6 shows Gavins Point rising during September.

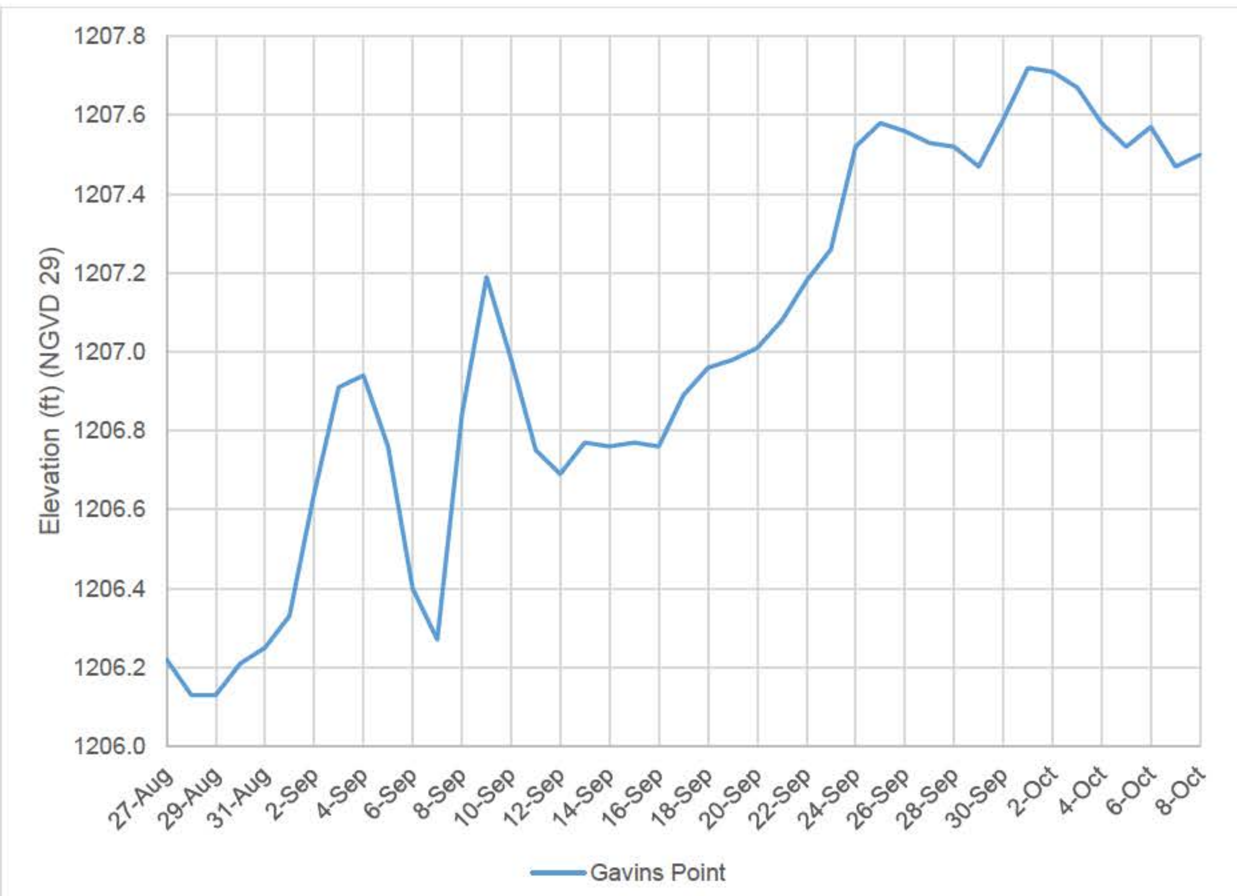

Figure 3-6: Example late summer-early fall Gavins Point pool elevation rise.

3.2.2 Alternative 1, 1a, and 1b

Upstream operations in Alt 1, 1a, and 1b utilize the all of the operations described in the No Action during May – August. Fort Peck and Garrison still operate to balance the storage among Fort Peck, Garrison, and Oahe by the start of next year's runoff season while also ensuring water supply requirements are met at Wolf Point, Culbertson, and Bismarck. Oahe, Big Bend, and Fort Randall operate to keep their reservoirs at their respective guide curve elevations.

In addition to the operations in the No Action, another operation is incorporated into Alt 1, 1a, and 1b during May – August. The operation change is the continuation of the flow regime for the pallid sturgeon. For Alt 1, 1a, and 1b, the flow regime is continuing its retention flow, which is 1.5 times the Fort Peck spring release. The spawning cue begins on May 28 under Alt 1. For the spawning cue, flow is increased by 1.1 kcfs per day until the peak spawning cue flow is reached, which is 3.5 times the Fort Peck spring release. The peak spawning cue flow is held for 3 days and reduced by 1.0 kcfs for a maximum of 12 days. After 12 days, the flow is reduced by 3.0 kcfs per day until a flow of 8.0 kcfs is reached at Wolf Point. The 8.0 kcfs flow at Wolf Point is maintained through August. If the flow regime is cancelled prior to initiating the spawning cue, the 8.0 kcfs flow target is not utilized and releases are made to balance storage among the 3 upper reservoirs: Fort Peck, Garrison, and Oahe. However, if the spawning cue is initiated, the 8.0 kcfs flow target at Wolf Point, MT will be met through August. Due to travel time from Fort Peck to Wolf Point, MT, releases from Fort Peck are increased approximately 2 days prior to the dates listed previously to ensure the flow at Wolf Point, MT follows the dates and pattern described. Spillway releases are only made after the powerhouse has reached its maximum capacity. The same drought and flood criteria described in Section 2.2.2 continued to be used during the retention and spawning portion of the flow regime.

Figure 3-7 shows the retention flow, spawning cue, and summer flows at Wolf Point, MT for Alt 1, 1a, and 1b. For Alt 1 and 1b, Fort Peck spring release is 7.0 kcfs and 6.8 kcfs for Alt 1a. This results in a retention flow of 10.5 kcfs for Alt 1 and Alt 1b and 10.2 kcfs for Alt 1a. The retention flow begins after the attraction flow ends and continues until the spawning cue begins. The three peaks in Figure 3-7 are the spawning cue. Under Alt 1 and Alt 1b, the peak spawning cue flow is 24.5 kcfs while the peak spawning cue flow for Alt 1a is 23.8 kcfs. This is held for 3 days before the flow is reduced to the summer flows. Since the spawning cue was initiated in this year, an 8.0 kcfs target is used during the summer for all alternatives.

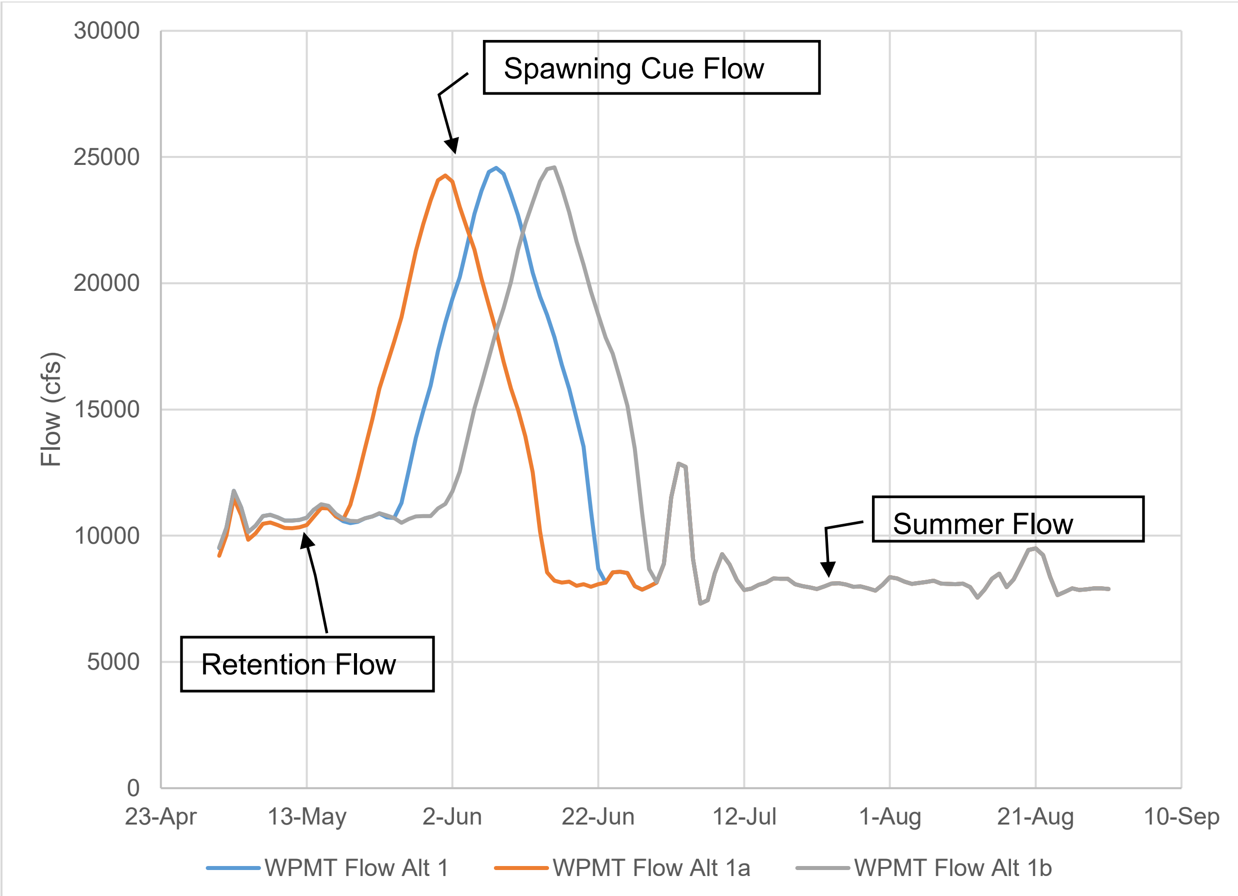

Figure 3-7: Retention flow, spawning cue flow, and summer flows for Alt 1, 1a, and 1b.

The observed changes at Fort Peck downstream to Fort Randall are shown in Figure 3-9 through Figure 3-18. In general, the majority of change from No Action occurs at Fort Peck and decreases as the location moves farther downstream from Fort Peck. Figure 3-9 shows a higher percentage of the summer months with lower elevations at Fort Peck for all alternatives compared to the No Action, which is caused by the retention and spawning cue flows in May and June. As Fort Peck is releasing more water for the flow regime, Garrison tends to have a higher pool elevation in the summer, as shown in Figure 3-11. No significant trends occur at Oahe with over 90 percent of the pool elevations changes being evenly distributed between ±0.5 feet. Big Bend and Fort Randall show little elevation change relative to No Action with approximately 98 percent of the changes falling between ±0.5 feet, which are attributed to their guide curve operations. Figure 3-15 and Figure 3-17 show Big Bend's and Fort Randall's full range of elevation changes, respectively.

Figure 3-10 shows a trend of lower releases at Fort Peck compared to the No Action with small percentages of higher releases. The higher releases are a result of the short duration spawning cues. The trend of lower releases for May – August over the period-of-record are a result of the longer duration summer release of 8.0 kcfs being less compared to the No Action alternative. The extra water released from Fort Peck is mostly stored in Garrison so changes in releases from Garrison are all within ±1 kcfs, as shown in Figure 3-12. Releases from Oahe are highly variable regardless of flow regimes at Fort Peck as water is released to keep Big Bend, Fort Randall, and

Gavins Point at their respective guide curves. Even with the variable releases, over 90 percent of the release differences are within ±1 kcfs. Figure 3-14, Figure 3-16, and Figure 3-18 show the release differences relative to the No Action for Oahe, Big Bend, and Fort Randall, respectively.

3.2.3 Alternative 2, 2a, and 2b

Similar to Alt 1, upstream operations in Alt 2, 2a, and 2b utilize the all of the operations described in the No Action during May – August. Fort Peck and Garrison still operate to balance the storage among Fort Peck, Garrison, and Oahe by the start of next year's runoff season while also ensuring water supply requirements are met at Wolf Point, Culbertson, and Bismarck. Oahe, Big Bend, and Fort Randall operate to keep their reservoirs at their respective guide curve elevations.

In addition to the operations in the No Action, another operation is incorporated into Alt 2, 2a, and 2b. The operation change is the continuation of a flow regime for the pallid sturgeon during May – August, but with a different shape and magnitude than Alt 1. For Alt 2, 2a, and 2b, the flow regime is continuing its retention flow, which is 14.0 kcfs or maximum powerhouse capacity. The spawning cue begins on May 28, May 21, and June 4 under Alt 2, Alt 2a, and Alt 2b, respectively. For the spawning cue, flow is increased by 1.1 kcfs per day until the peak spawning cue flow is reached, which is 2 times the maximum powerhouse release, 28.0 kcfs. The peak spawning cue flow is held for 3 days and reduced by 1.0 kcfs for a maximum of 12 days. After 12 days, the flow is reduced by 3.0 kcfs per day until a flow of 8.0 kcfs is reached at Wolf Point, MT. The 8.0 kcfs flow at Wolf Point, MT is maintained through August. If the flow regime is cancelled prior to initiating the spawning cue, the 8.0 kcfs flow target is not utilized and releases are made to balance storage among the 3 upper reservoirs: Fort Peck, Garrison, and Oahe. However, if the spawning cue is initiated, the 8.0 kcfs flow target at Wolf Point, MT will be met through August. Due to travel time from Fort Peck to Wolf Point, MT, releases from Fort Peck are increased approximately 2 days prior to the dates listed above to ensure the flow at Wolf Point, MT follows the dates and pattern described. Spillway releases are only made after the powerhouse has reached its maximum release. The same drought and flood criteria described in Section 2.2.2 continue to be used during the retention and spawning portion of the flow regime.

Figure 3-8 shows the retention flow, spawning cue, and summer flows at Wolf Point, MT for Alt 2, 2a, and 2b. For all alternatives, the retention flow is 14.0 kcfs. The retention flow begins after the attraction flow ends and continues until the spawning cue begins. The three peaks in Figure 3-8 are the spawning cue. Under all alternatives, the peak spawning cue flow is 28.0 kcfs. Although the peak target flow for the spawning cue is the same, Alt 2a has a larger observed peak, which is caused by higher than forecasted tributary flows. The peak spawning cue flow is held for 3 days before the flow is reduced to the summer flows. Since the spawning cue was initiated in this year, an 8.0 kcfs target is used during the summer for all alternatives.

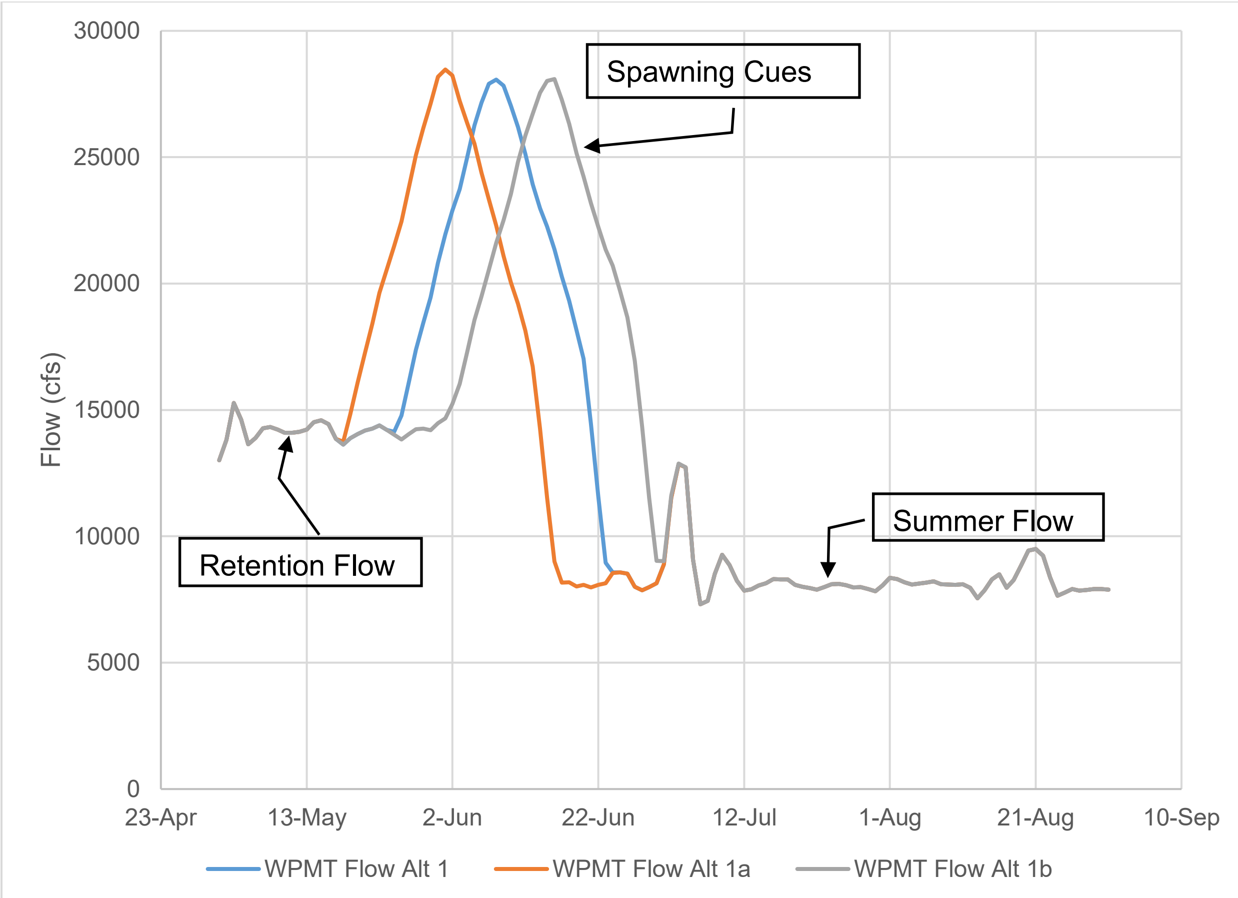

Figure 3-8: Retention flow, spawning cue, and summer flows for Alt 2, 2a, and 2b.

The observed changes at Fort Peck downstream to Fort Randall are shown in Figure 3-9 through Figure 3-18. In general, the same trends described for Alt 1, 1a, and 1b are observed for Alt 2, 2a, and 2b. The majority of change from No Action occurs at Fort Peck and decreases at locations farther downstream. Figure 3-9 shows a higher percentage of the summer months with lower elevations at Fort Peck for all alternatives compared to the No Action, which is caused by the retention flow and spawning cue in May and June. As Fort Peck releases more water for the flow regime, Garrison tends to have a higher pool elevation in the summer, as shown in Figure 3-11. No significant trends occur at Oahe with over 90 percent of the pool elevations changes being evenly distributed between ±0.5 feet. Big Bend and Fort Randall show little elevation change relative to No Action with approximately 98 percent of the changes falling between ±0.5 feet, which are attributed to their guide curve operations. Figure 3-15 and Figure 3-17 show Big Bend's and Fort Randall's full range of elevation changes, respectively.

Figure 3-10 shows a trend of lower releases at Fort Peck compared to the No Action with a small percentage of higher releases. The higher releases are a result of the spawning cues, but the duration of the spawning cue is only a couple weeks; however, the duration of the 8.0 kcfs summer flow is several months. Since releases during the summer target flows are typically less compared to the No Action but are for a much longer duration than the spawning cues, Figure 3-10 shows a trend of lower releases over the entire period-of-record. The extra water released from Fort

Peck during the spawning cue is mostly stored in Garrison so that over 90 percent of changes in releases from Garrison are within ±1 kcfs, as shown in Figure 3-12. Releases from Oahe are highly variable regardless of flow regimes at Fort Peck as water is released to keep Big Bend, Fort Randall, and Gavins Point at their respective guide curves. Even with the variable releases, over 90 percent of the release differences are within ±1 kcfs. Figure 3-14, Figure 3-16, and Figure 3-18 show the release differences relative to the No Action for Oahe, Big Bend, and Fort Randall, respectively.

3.2.4 Elevation and Release Changes Upstream of Gavins Point during Summer Months for Alternative 1 – 6

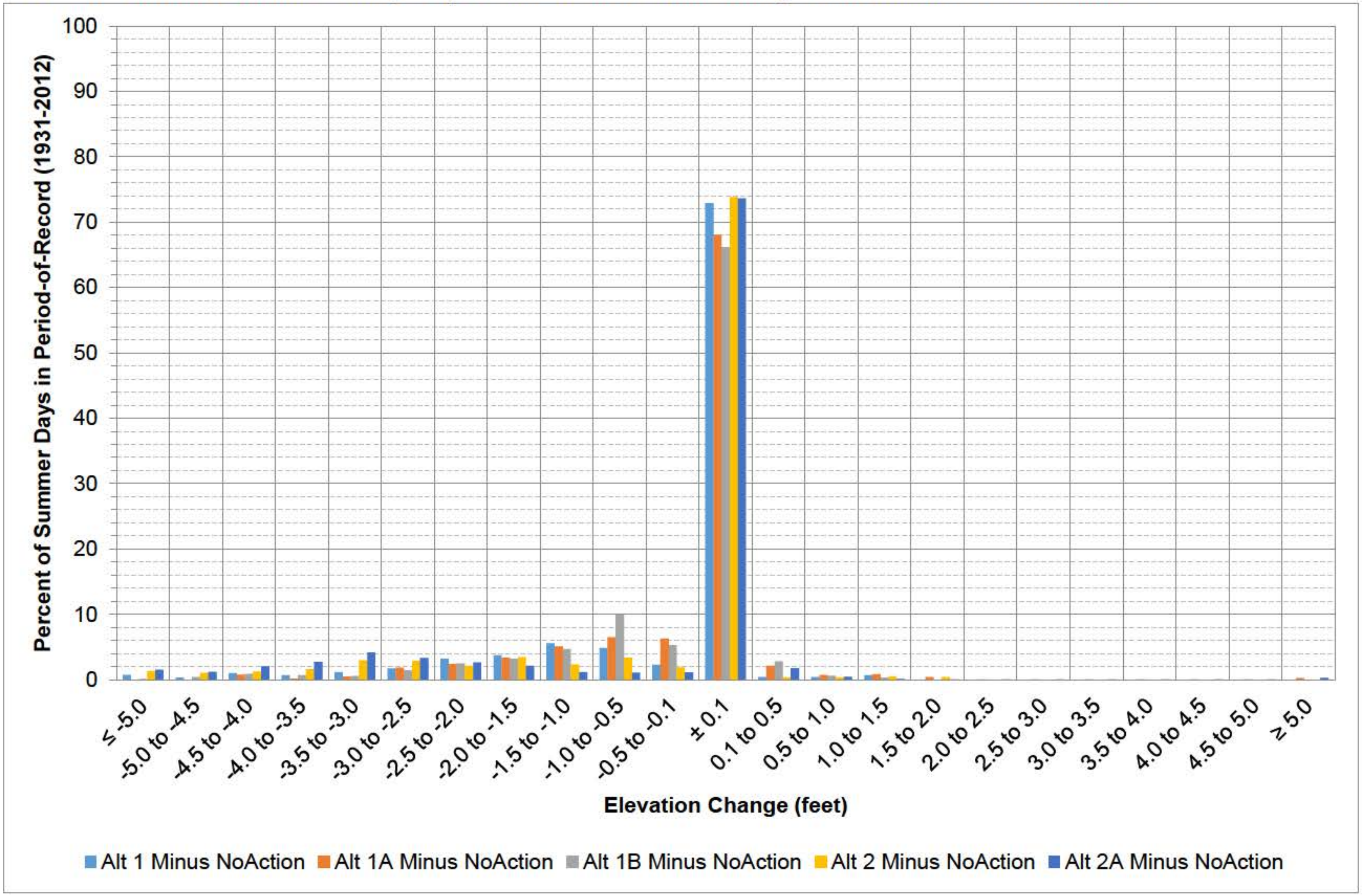

Figure 3-9: Fort Peck elevation change between each alternative and No Action during May – August.

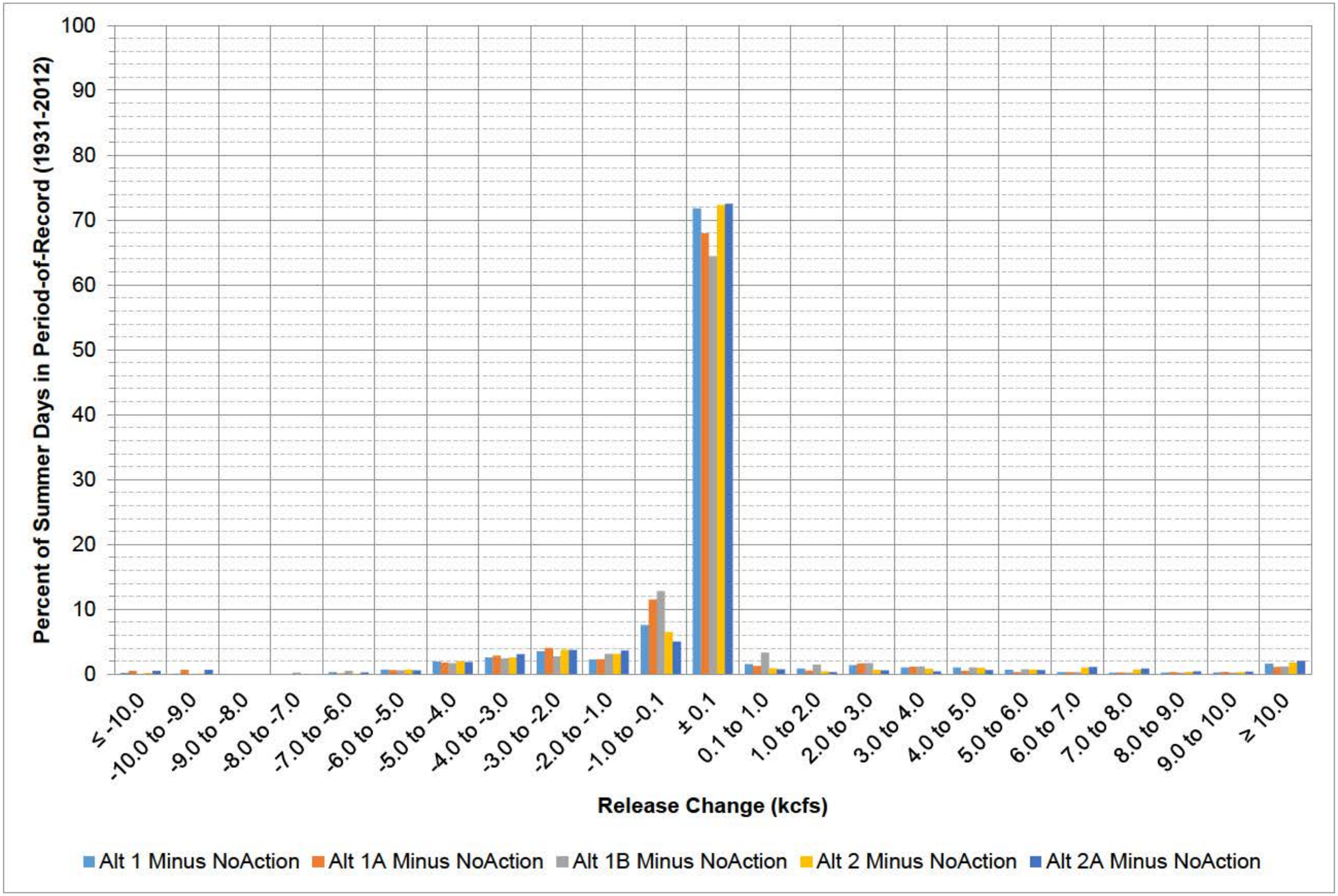

Figure 3-10: Fort Peck release change between each alternative and No Action during May – August.

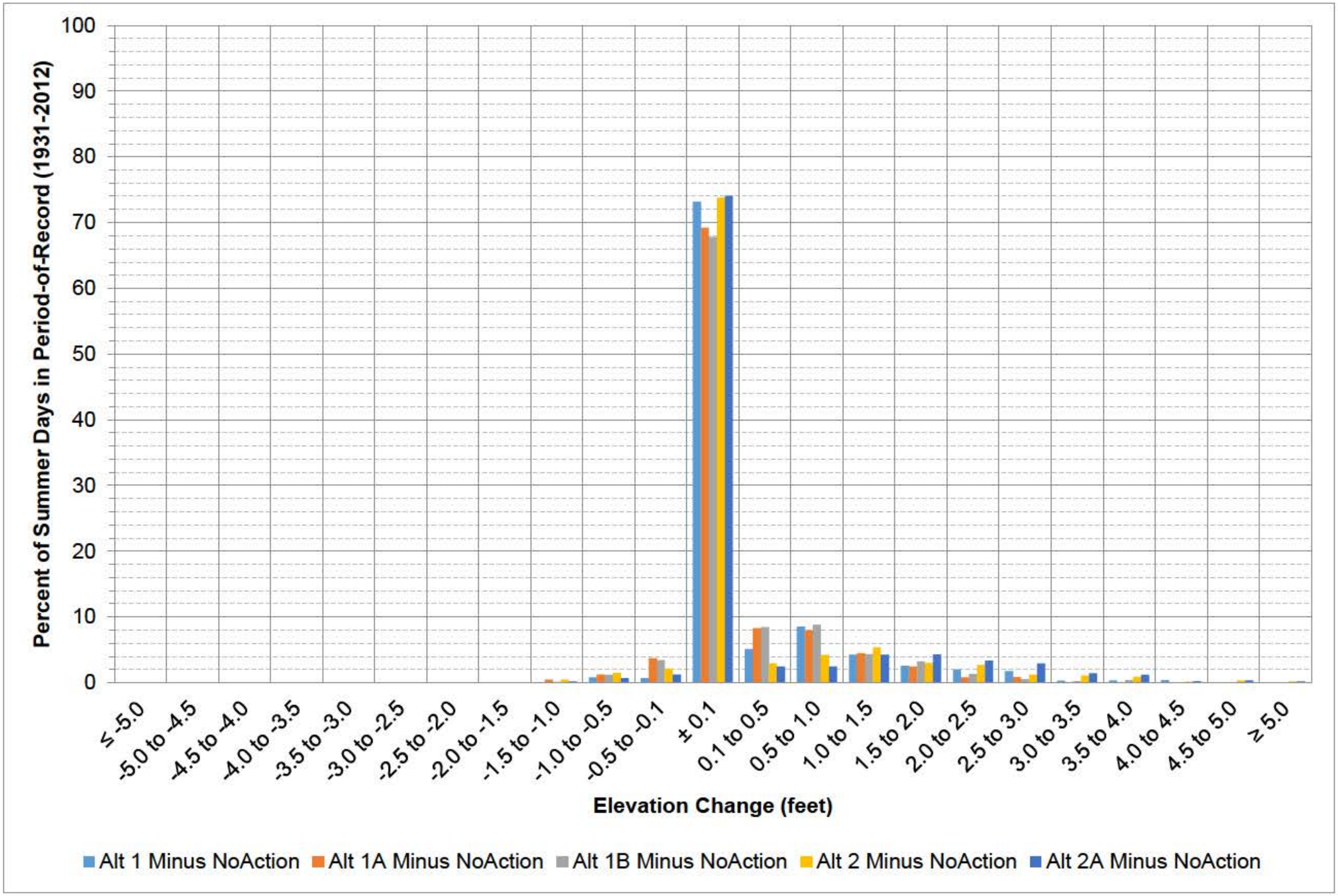

Figure 3-11: Garrison elevation change between each alternative and No Action during May – August.

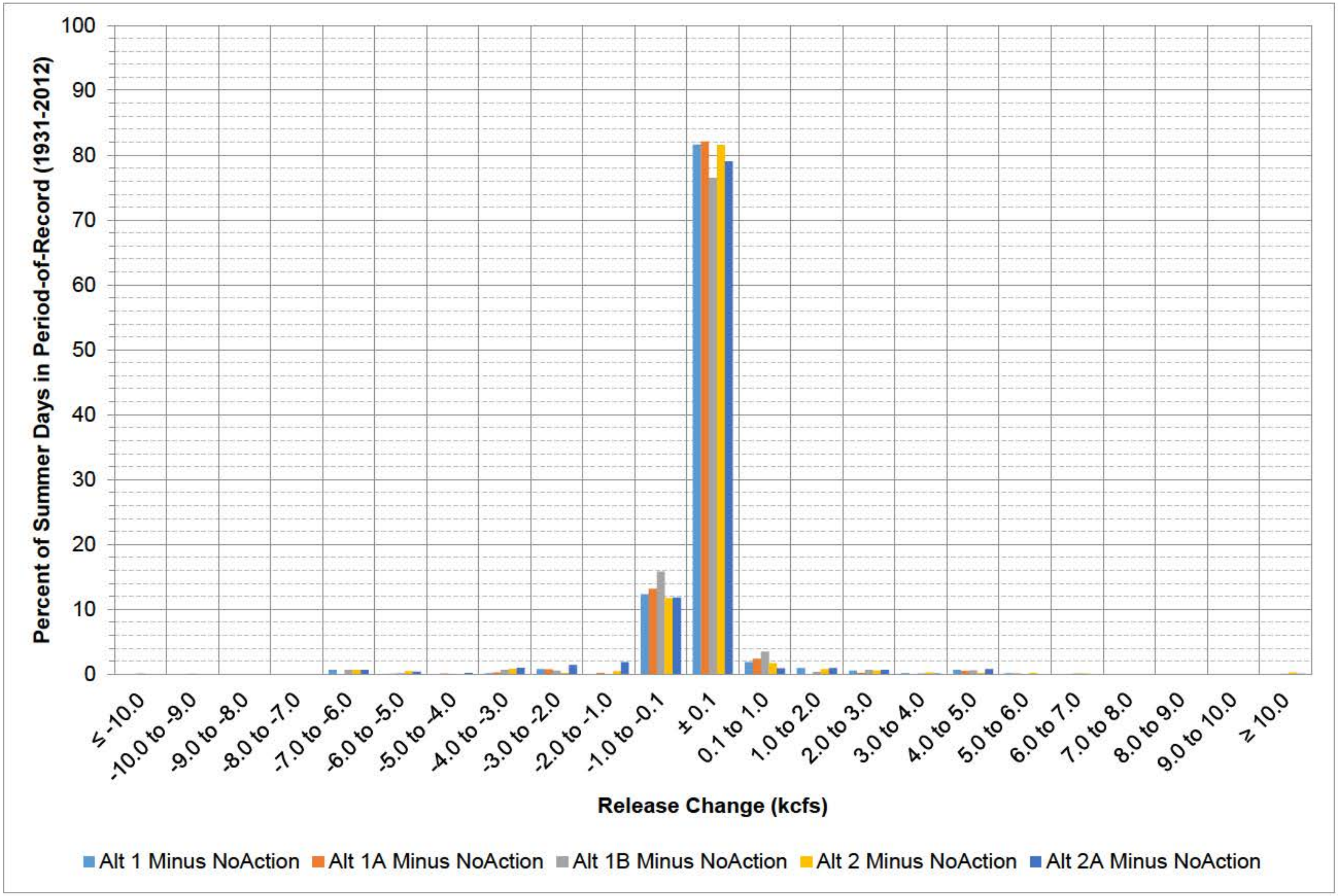

Figure 3-12: Garrison release change between each alternative and No Action during May – August.

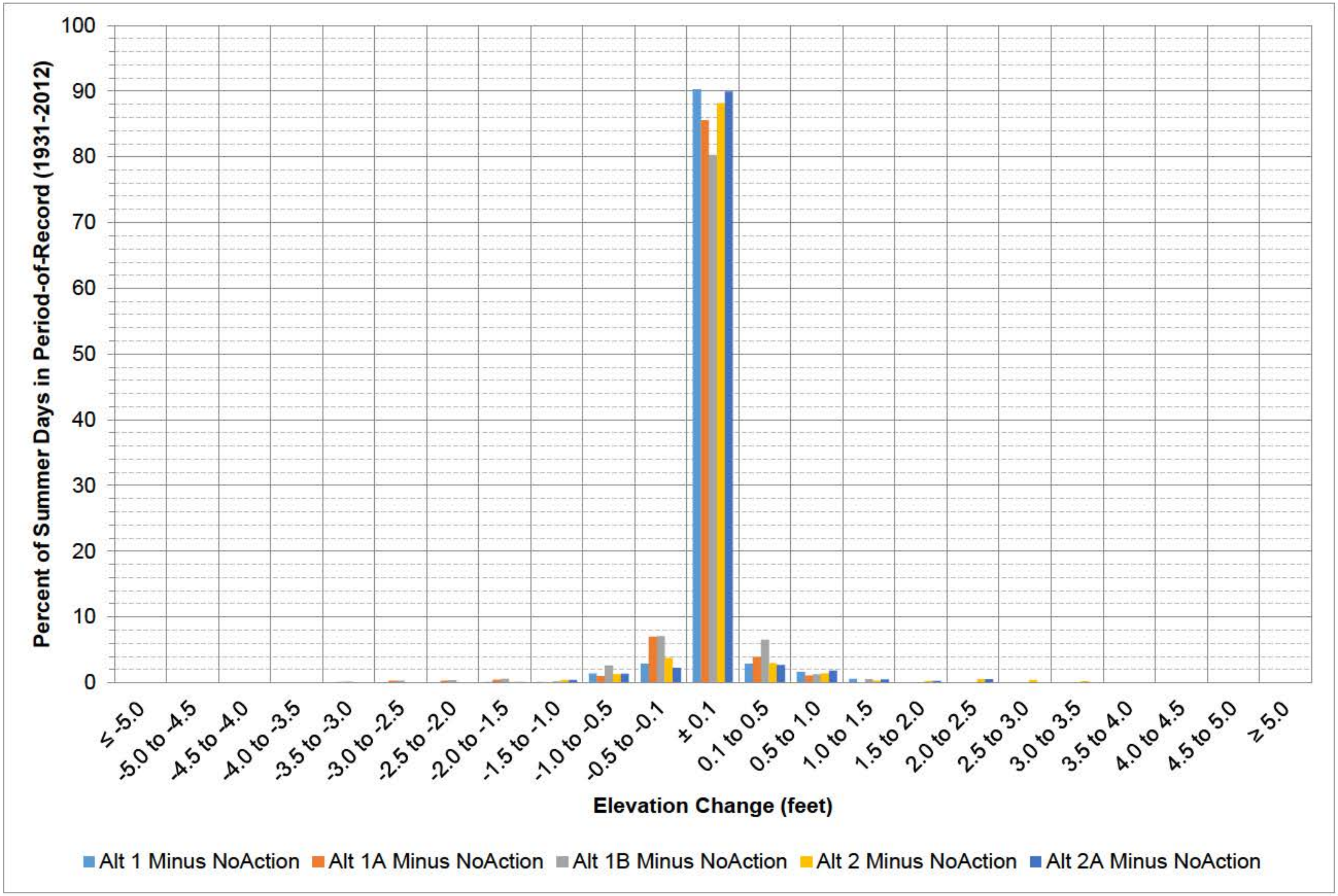

Figure 3-13: Oahe elevation change between each alternative and Alt 1 during May – August.

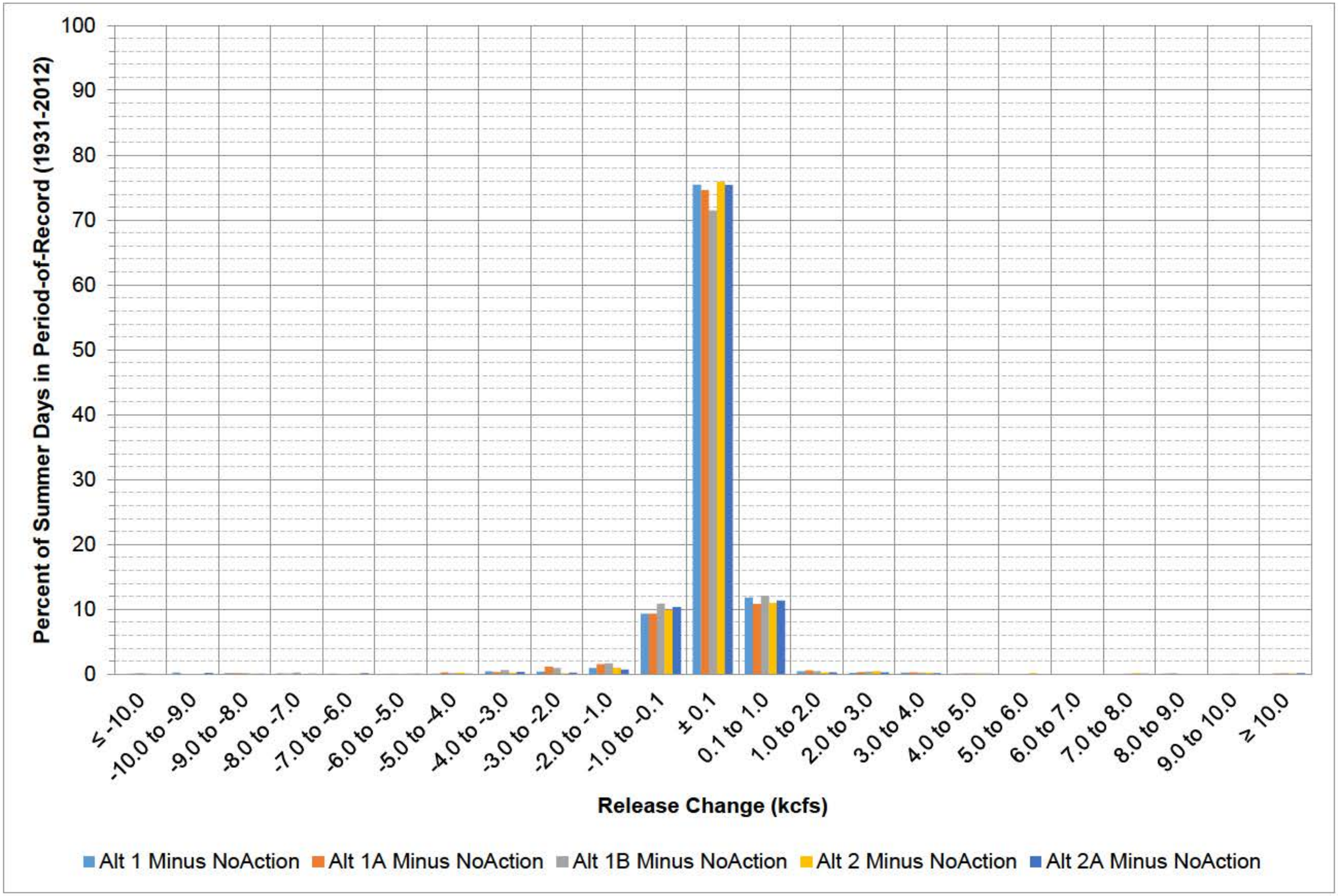

Figure 3-14: Oahe release change between each alternative and No Action during May – August.

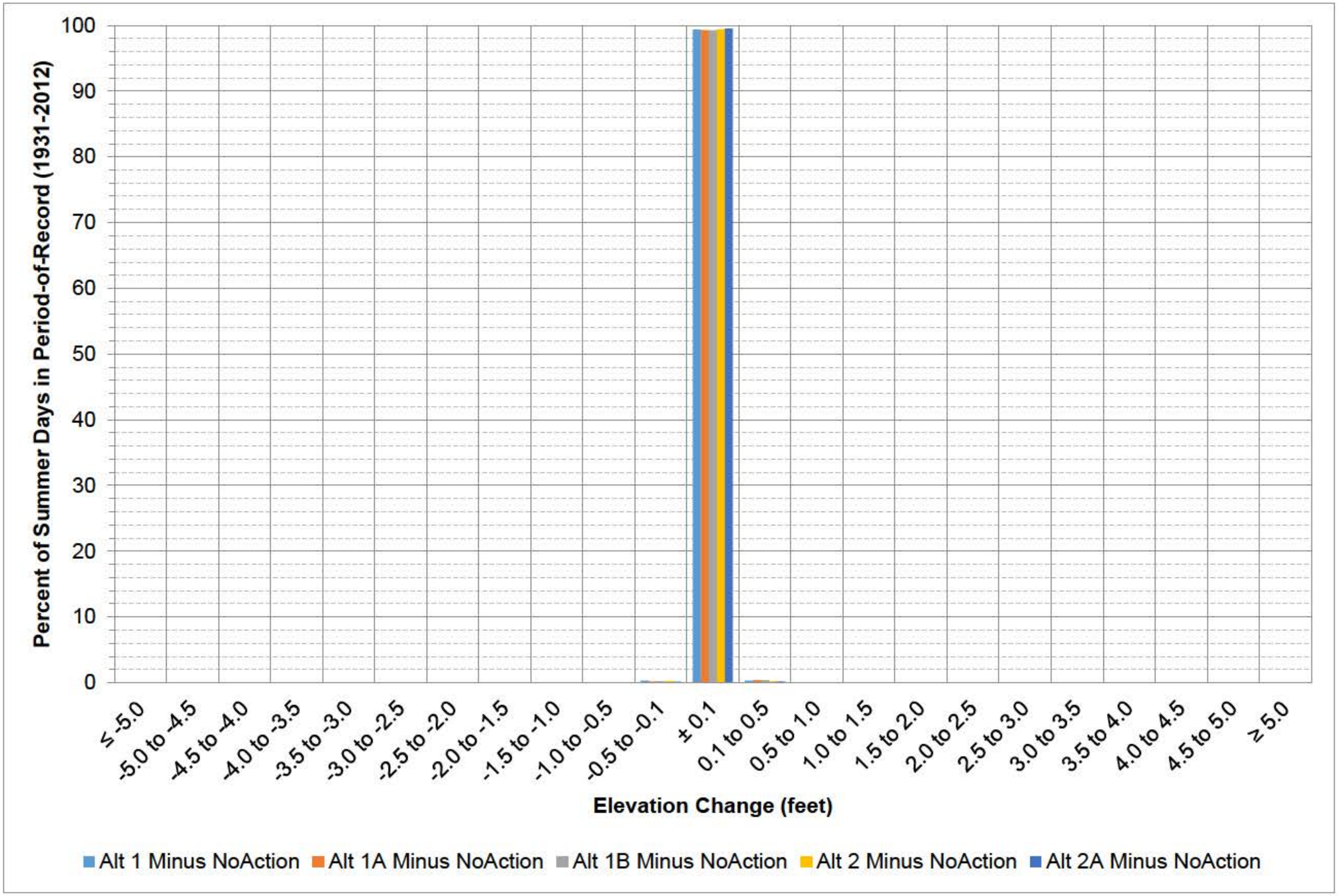

Figure 3-15: Big Bend elevation change between each alternative and No Action during May – August.

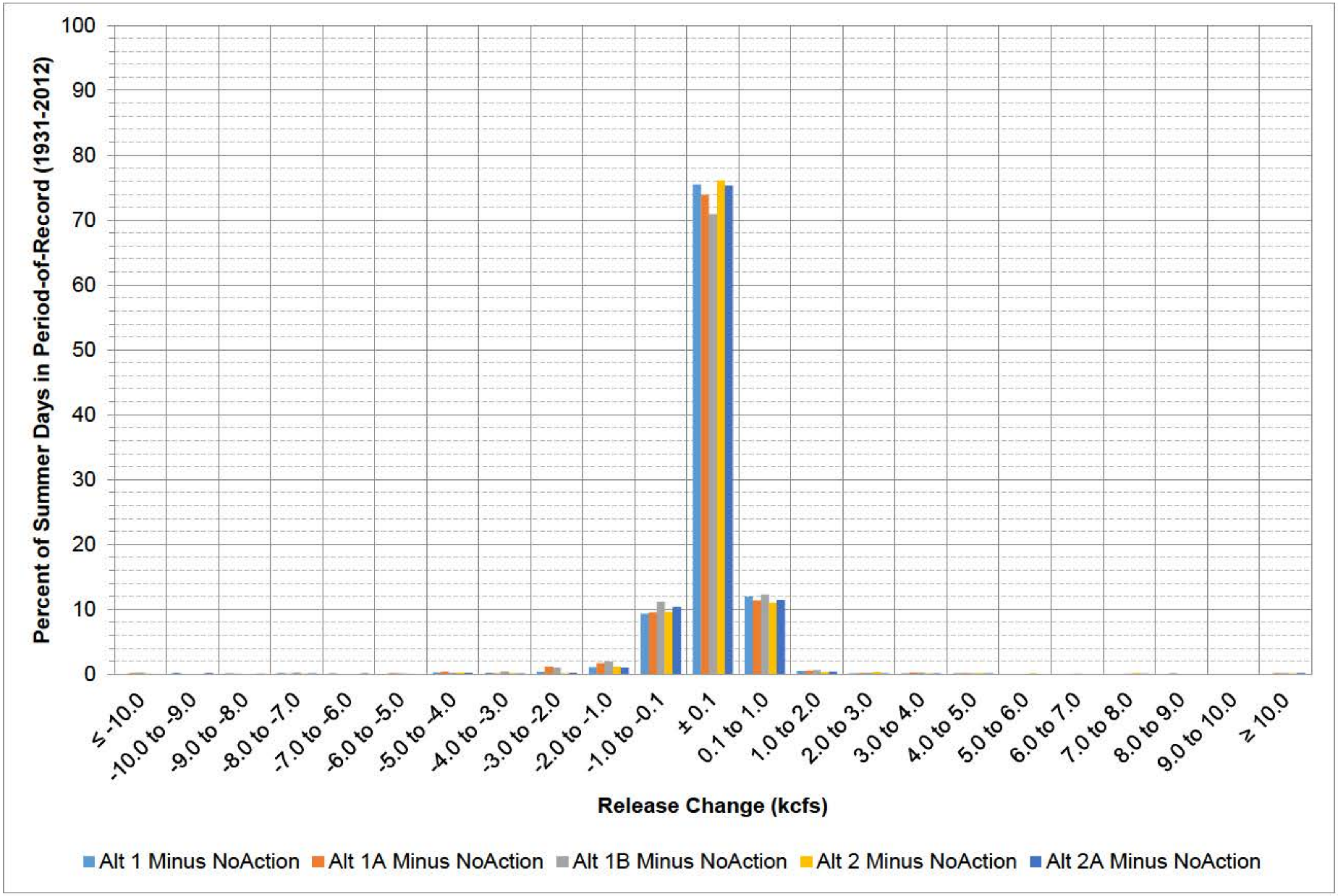

Figure 3-16: Big Bend release change between each alternative and No Action during May – August.

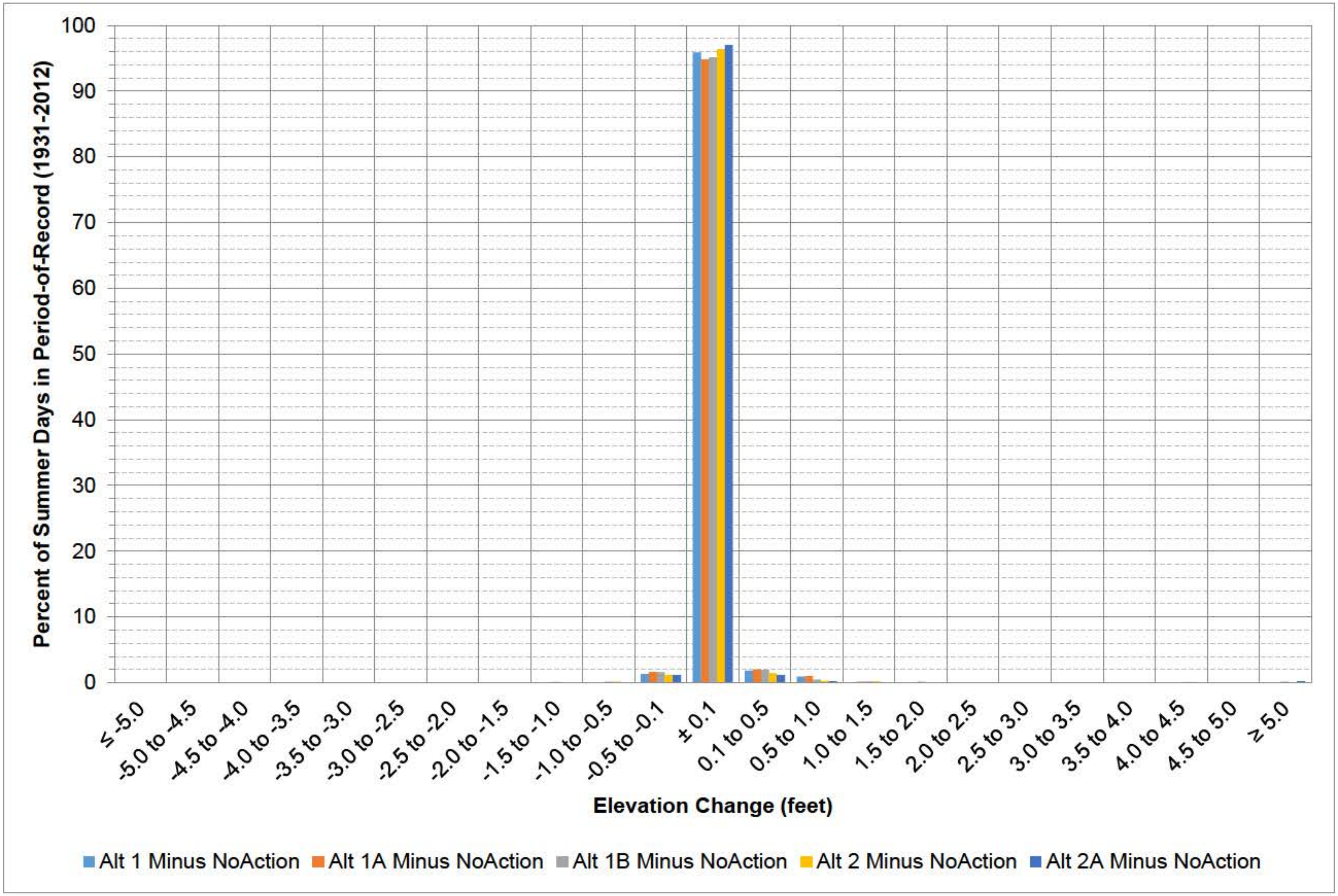

Figure 3-17: Fort Randall elevation change between each alternative and No Action during May – August.

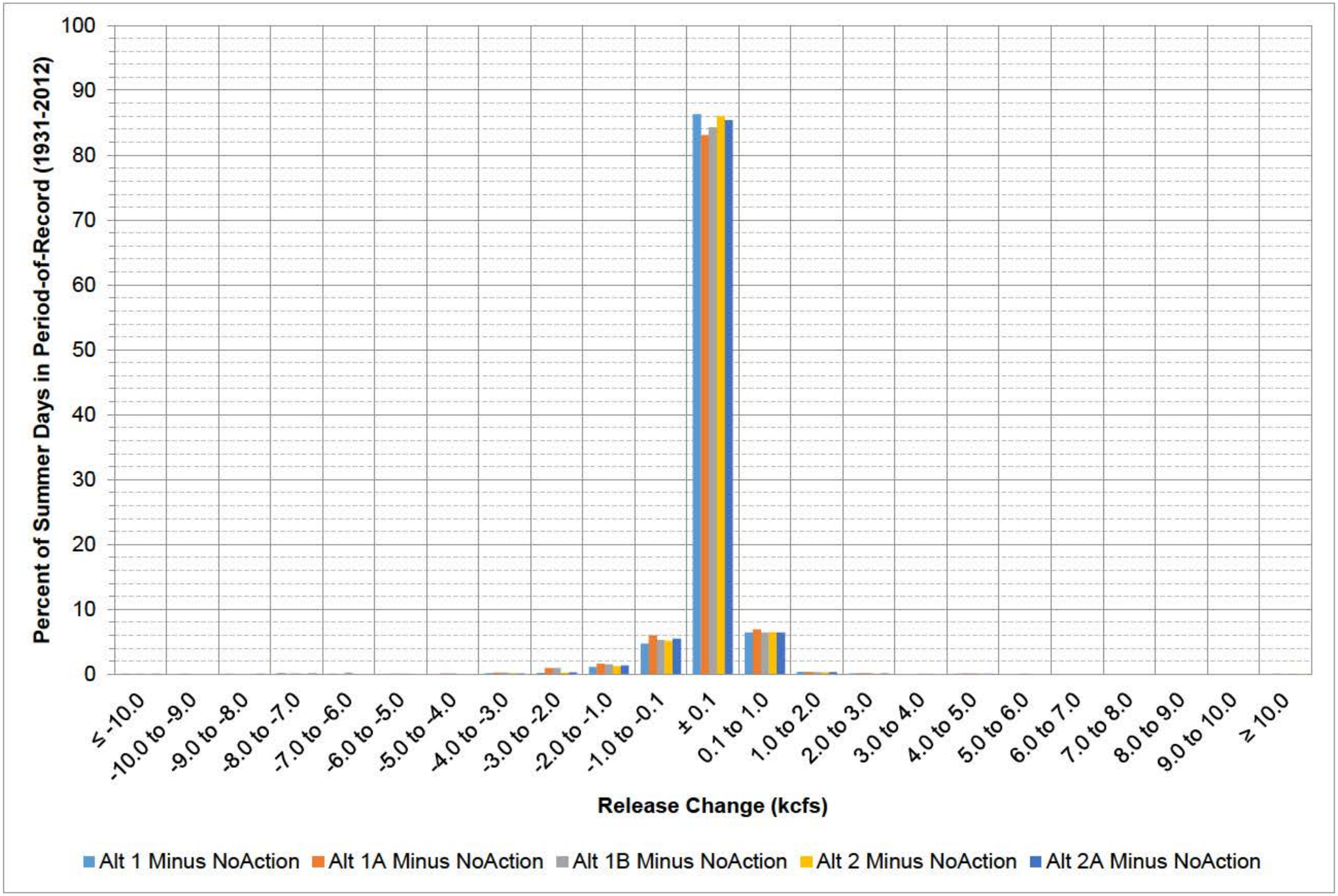

Figure 3-18: Fort Randall release change between each alternative and No Action during May – August.

4 FALL: SEPTEMBER – NOVEMBER

4.1 DOWNSTREAM OF GAVINS POINT

4.1.1 No Action

On September 1, System storage is assessed and the winter release is set based on the criteria summarized in Table 4-1. If System storage is 58.0 MAF or more on September 1, Gavins Point's winter release is set to 17.0 kcfs. If the System storage is 55.0 MAF or less on September 1, Gavins' Point winter release is set to 12.0 kcfs. The winter release is linearly interpolated between 12.0 and 17.0 kcfs if the System storage is between 58.0 and 55.0 MAF.

For modeling purposes, the September 1 System storage check also determines if there will be an extension to the navigation season. If System storage is greater than or equal to 60.0 MAF, ten days are added to the navigation season to evacuate flood storage.

Table 4-1: Winter release criteria. Summarized from Tables VII-5 in the Master Manual (U.S. Army Corps of Engineers, 2018).

September 1 System Storage (MAF)	Average Winter Release from Gavins Point (kcfs)
58.0 or more	17.0
55.0 of less	12.0

Flow-to-Target navigation releases, based on the service level established on July 1, and flood targets based on the criteria described in Section 2.1.1 continue through the remainder of the navigation season.

System operations support water supply when not operating for navigation. Gavins Point releases are a minimum of 9.0 kcfs and are also adjusted to ensure a minimum flow of 9.0 kcfs at Sioux City, Omaha, and Kansas City. Figure 4-1 shows an example of fall water supply operations after a shortened navigation season where Gavins Point releases are reduced to 9.0 kcfs by October 1 and remain near 9.0 kcfs until winter release operations take effect. At the end of October, Gavins Point releases are increased to ensure a minimum of 9.0 kcfs at Omaha, which was the only target location in this example that required more water to reach 9.0 kcfs.

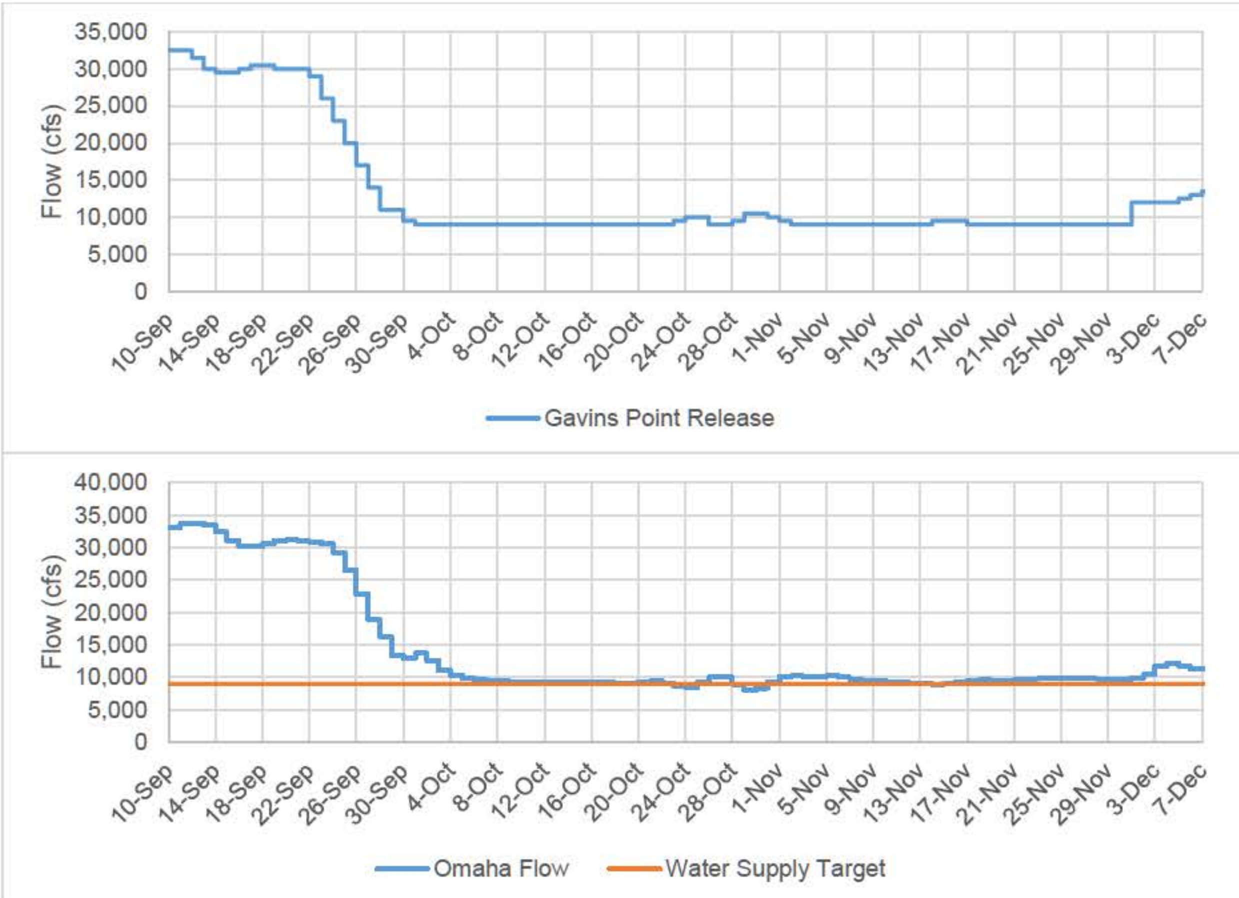

Figure 4-1: Fall water supply operations.

4.1.2 Alternatives 1, 1a, 1b, 2, 2a, and 2b

System operations downstream of Gavins Point in all alternatives do not change compared to No Action September – November with the same water supply, navigation, and flood control requirements used in the alternatives.

The operational changes that occur upstream of Gavins Point in the alternatives do not have an impact on Gavins Point pool elevation and releases. The minor changes in summer pool elevation as compared to No Action, shown in Figure 4-2, are a result of ResSim modeling and are not due to operational changes in the alternatives.

The changes in Gavins Point releases that occur in the alternatives, shown in Figure 4-3, are a result of the many simulation rules in ResSim. During real-time operations, these changes in conditions are too small to alter release decisions. This is especially apparent in high runoff years when most of the System storage has been utilized.

4.1.3 Elevation and Release Changes at Gavins Point during Fall Months for All Alternatives

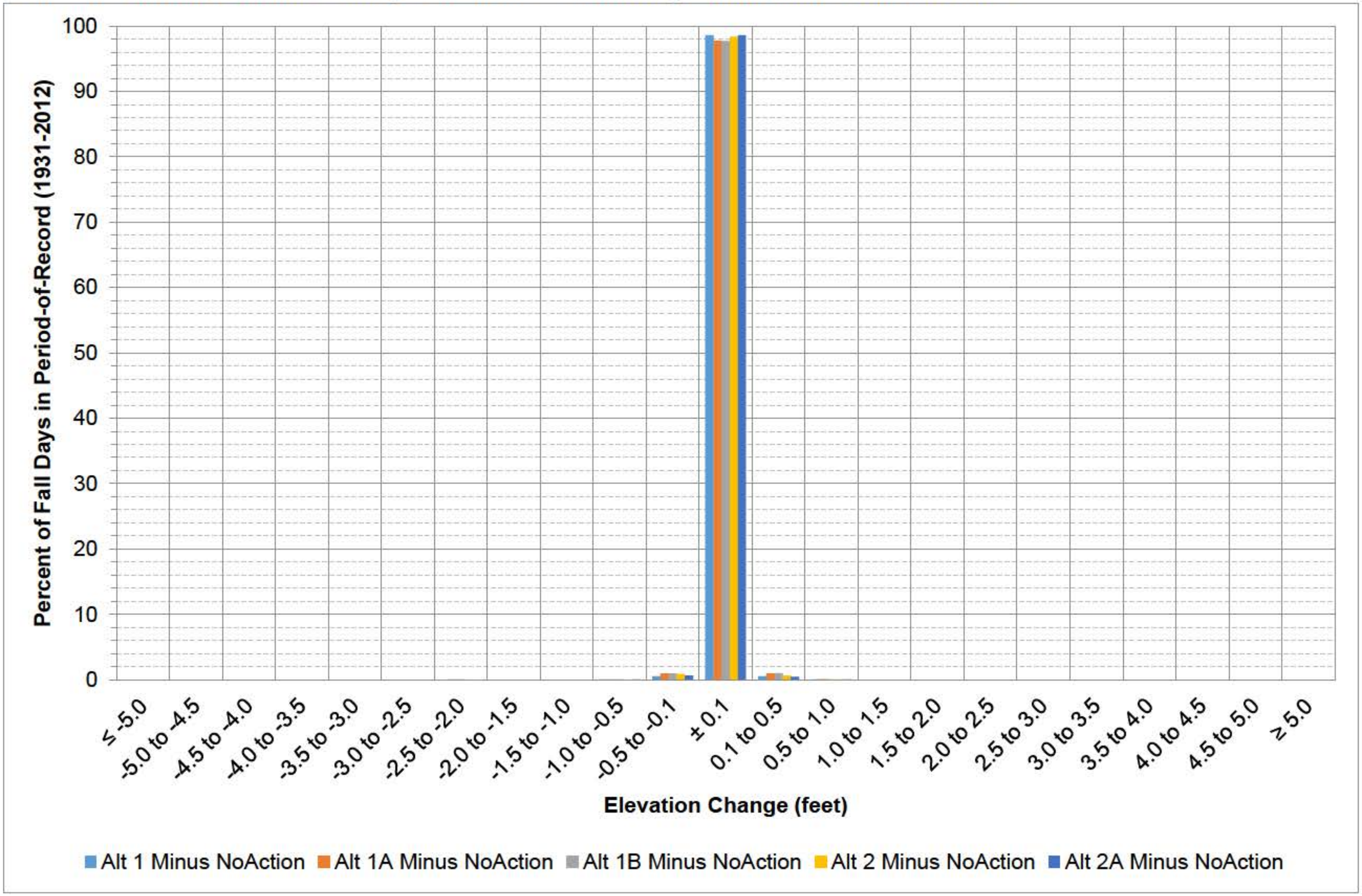

Figure 4-2: Gavins Point elevation change between each alternative and No Action during September – November.

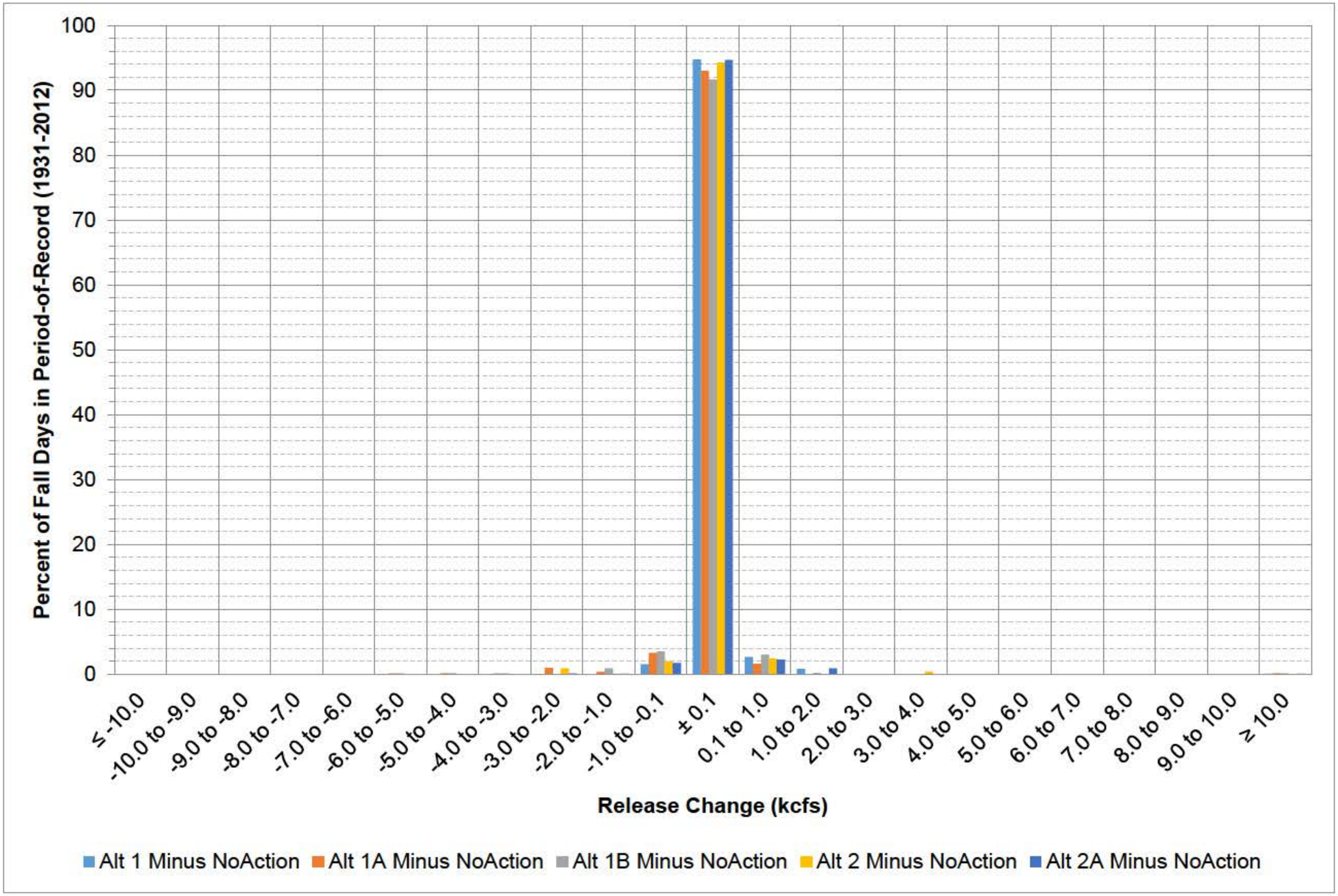

Figure 4-3: Gavins Point release change between each alternative and No Action during September – November.

4.2 UPSTREAM OF GAVINS POINT

4.2.1 No Action

Fort Peck and Garrison still release water based on the forecasted System storage as the model attempts to balance the occupied storage in the Carryover Multiple Use zones at Fort Peck, Garrison, and Oahe prior to the start of the next year's runoff. The Fort Peck and Garrison balancing releases specified on May 15 are maintained through September 15 if possible, during the endangered bird nesting season. Releases can change if the pool elevation requirements listed in Table 3-3 are exceeded.

After setting releases at Fort Peck and Garrison, minimum flows at Wolf Point, Culbertson, and Bismarck are checked. Releases from Fort Peck are increased to ensure a minimum flow of 3.0 kcfs is forecasted at Wolf Point and Culbertson between September 1 and November 30. Releases from Garrison are increased to ensure a minimum flow of 9.0 kcfs is forecasted at Bismarck between September 1 and November 30.

Guide curve operations continue at Big Bend, Fort Randall, and Gavins Point, but Fort Randall begins its fall drawdown on September 1. Fort Randall's pool is drawn down from its summer elevation of 1355 feet (NGVD 29) to 1337.5 feet (NGVD 29) by the end of the navigation season. The reservoir is refilled over the winter for hydropower benefits. The rate of drawdown and refill depends on the navigation end date. Figure 4-4 shows two examples of Fort Randall's drawdown: a drawdown occurring during a full navigation season and a drawdown occurring during a shortened navigation season. Fort Randall begins refilling after the end of the navigation season, so its refilling rate is slower during years with a shortened navigation season as it reaches elevation 1350.0 feet (NGVD 29) on March 1.

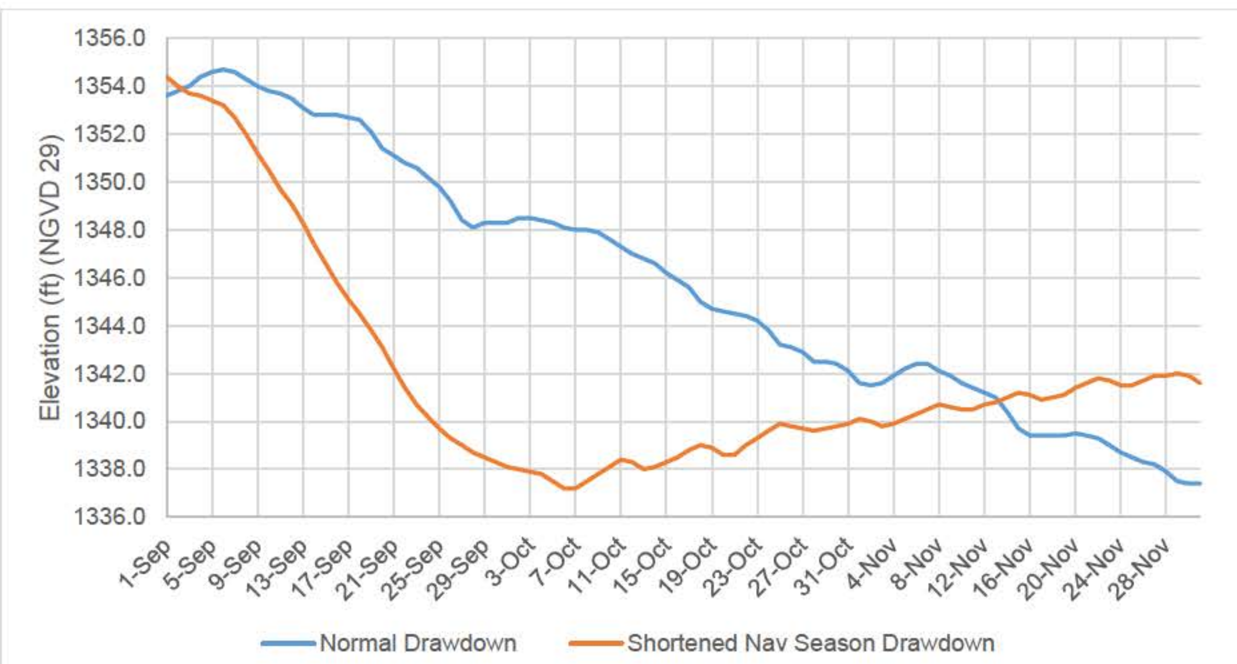

Figure 4-4: Examples of Fort Randall fall drawdown.

4.2.2 Alternative 1, 1a, 1b, 2, 2a, and 2b

No operational changes occur under any of the alternatives during September – November. The differences observed in Figure 4-5 through Figure 4-14 are caused by the changes to the operations at Fort Peck during the spring and summer months. For example, Fort Peck pool elevation tends to be lower than the No Action during the fall under all alternatives. When releasing water for the flow regime during the spring and summer, the Fort Peck Lake is drawn down and Lake Sakakawea rises (see Figure 4-7), which unbalances storage. Since water has been moved from Fort Peck to Garrison, the only way to rebalance storage is to reduce Fort Peck releases, which is shown in Figure 4-6. Beyond reducing Fort Peck releases, no other operational changes need to occur in order to rebalance storage among the upper there reservoirs. This is why there is no trend in release changes relative to the No Action at any of the projects downstream of Fort Peck, as shown in Figure 4-8 through Figure 4-14.

4.2.3 Elevation and Release Changes Upstream of Gavins Point during Fall Months for All Alternatives

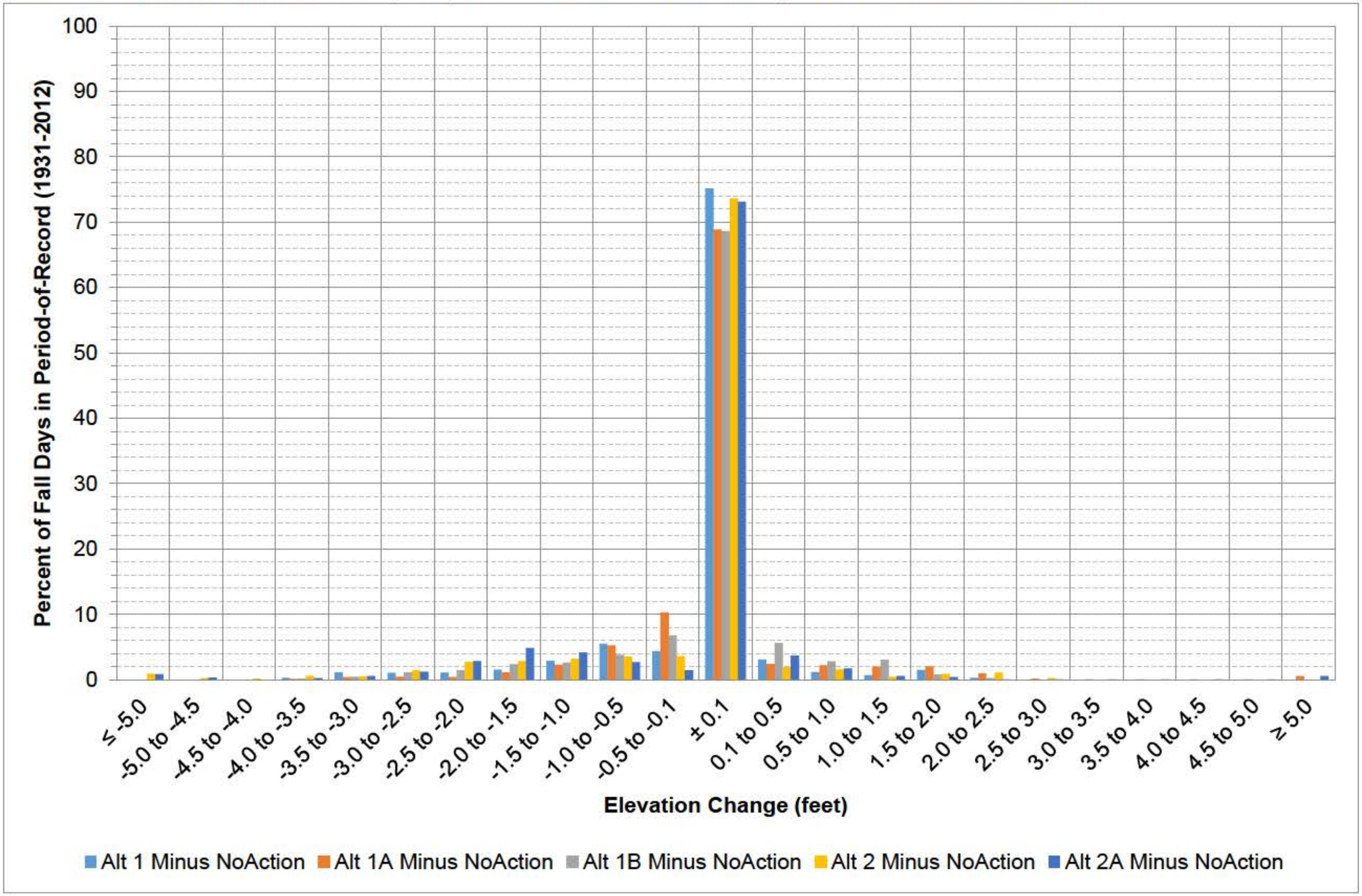

Figure 4-5: Fort Peck elevation change between each alternative and No Action during September – November.

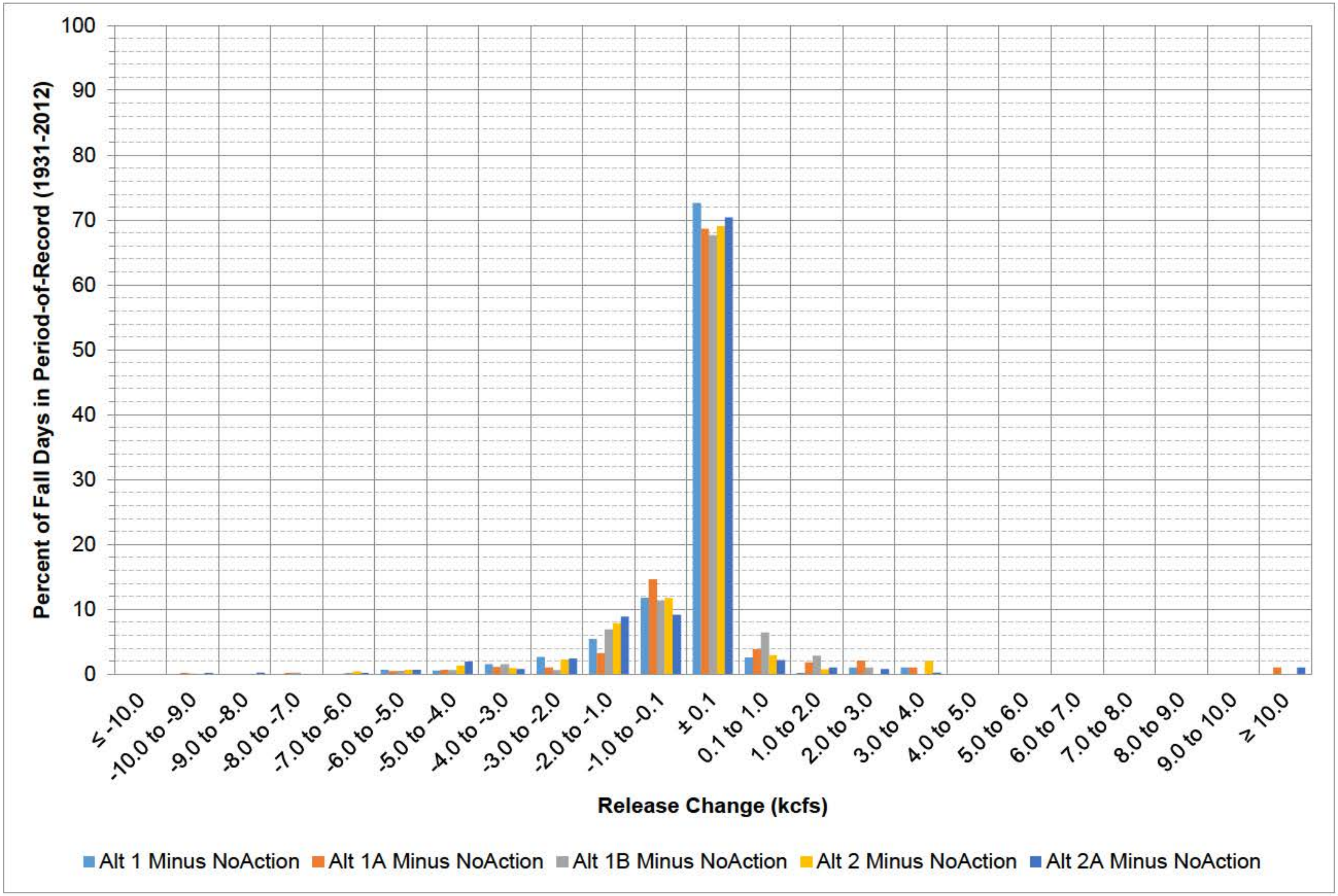

Figure 4-6: Fort Peck release change between each alternative and No Action during September – November.

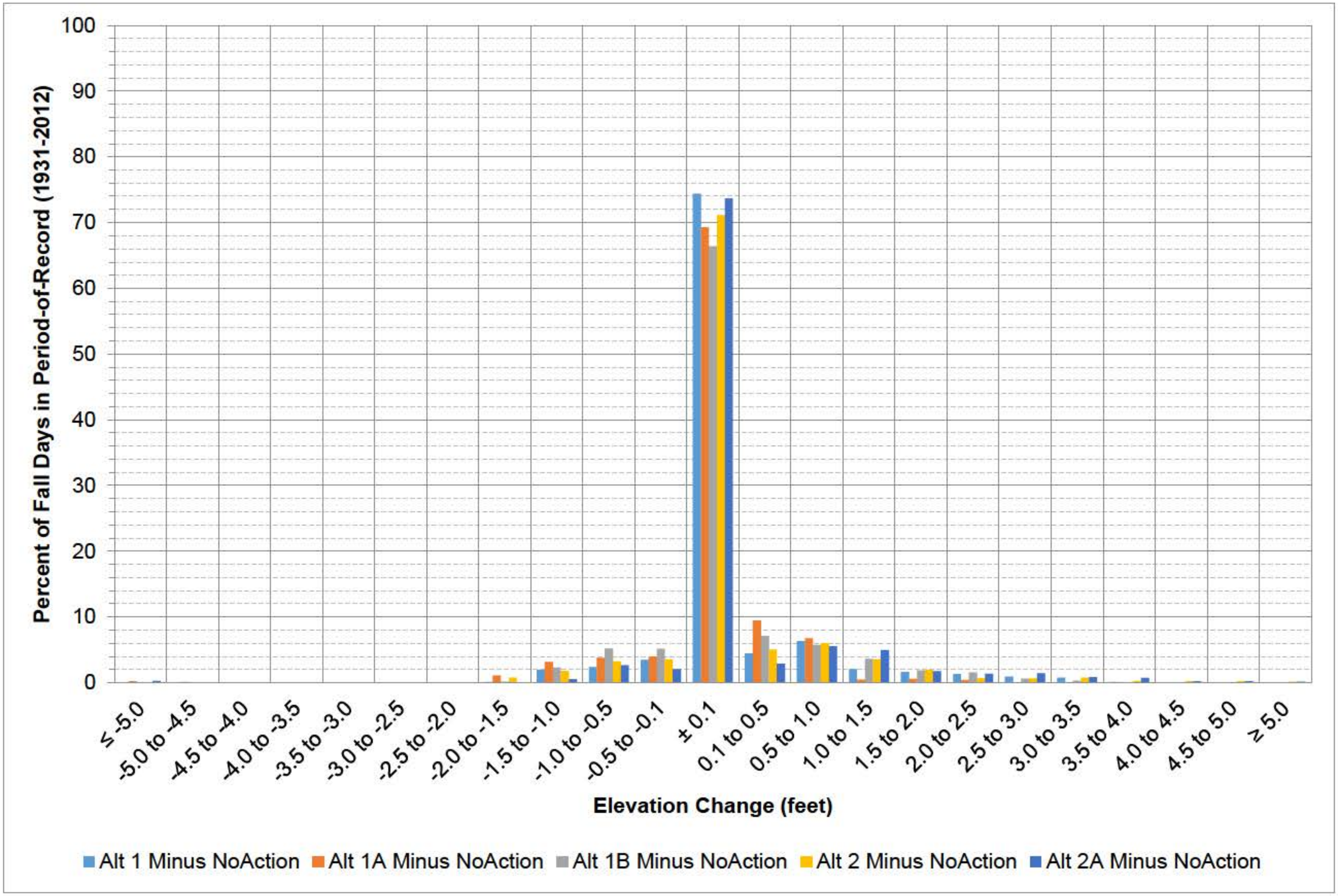

Figure 4-7: Garrison elevation change between each alternative and No Action during September – November.

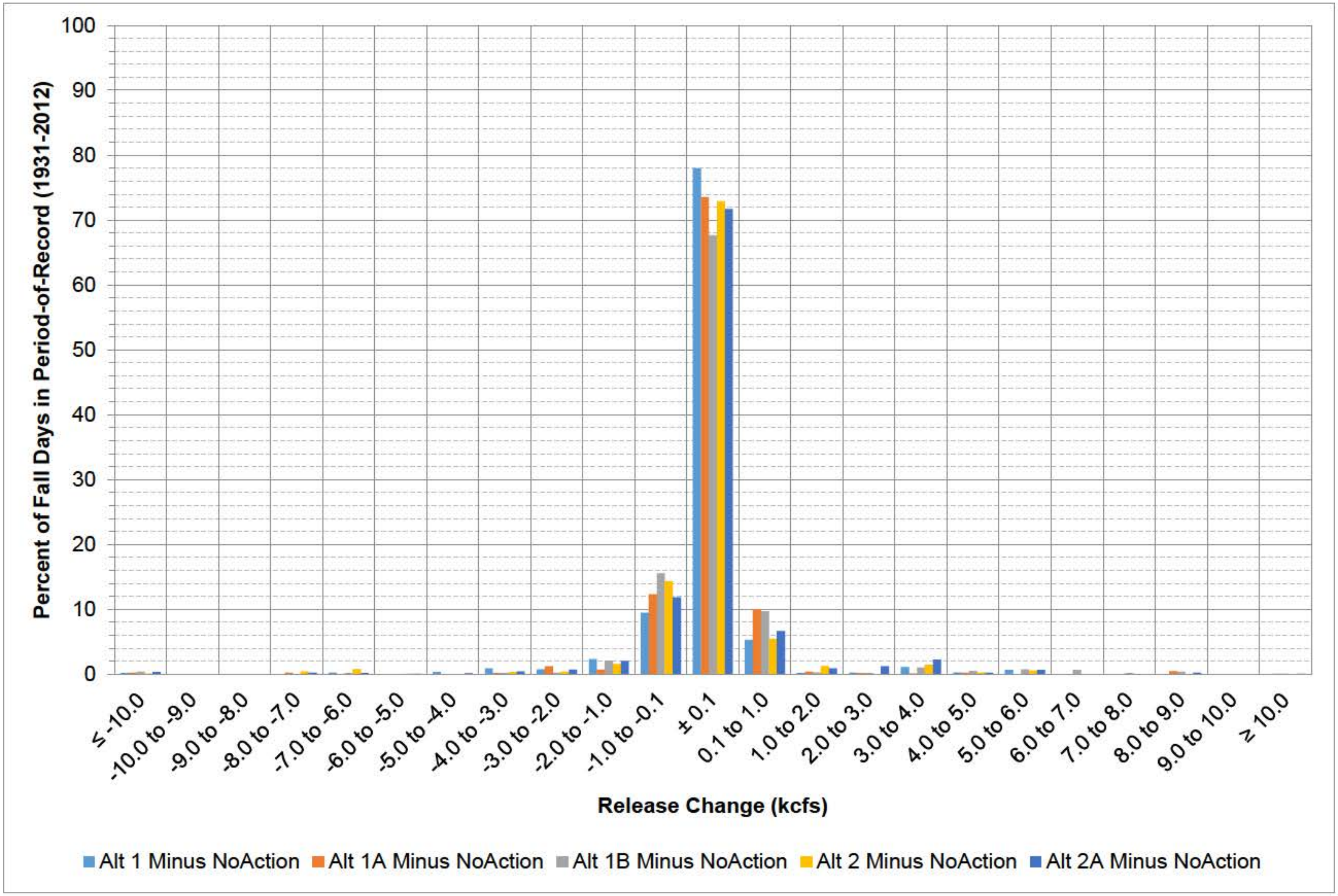

Figure 4-8: Garrison release change between each alternative and No Action during September – November.

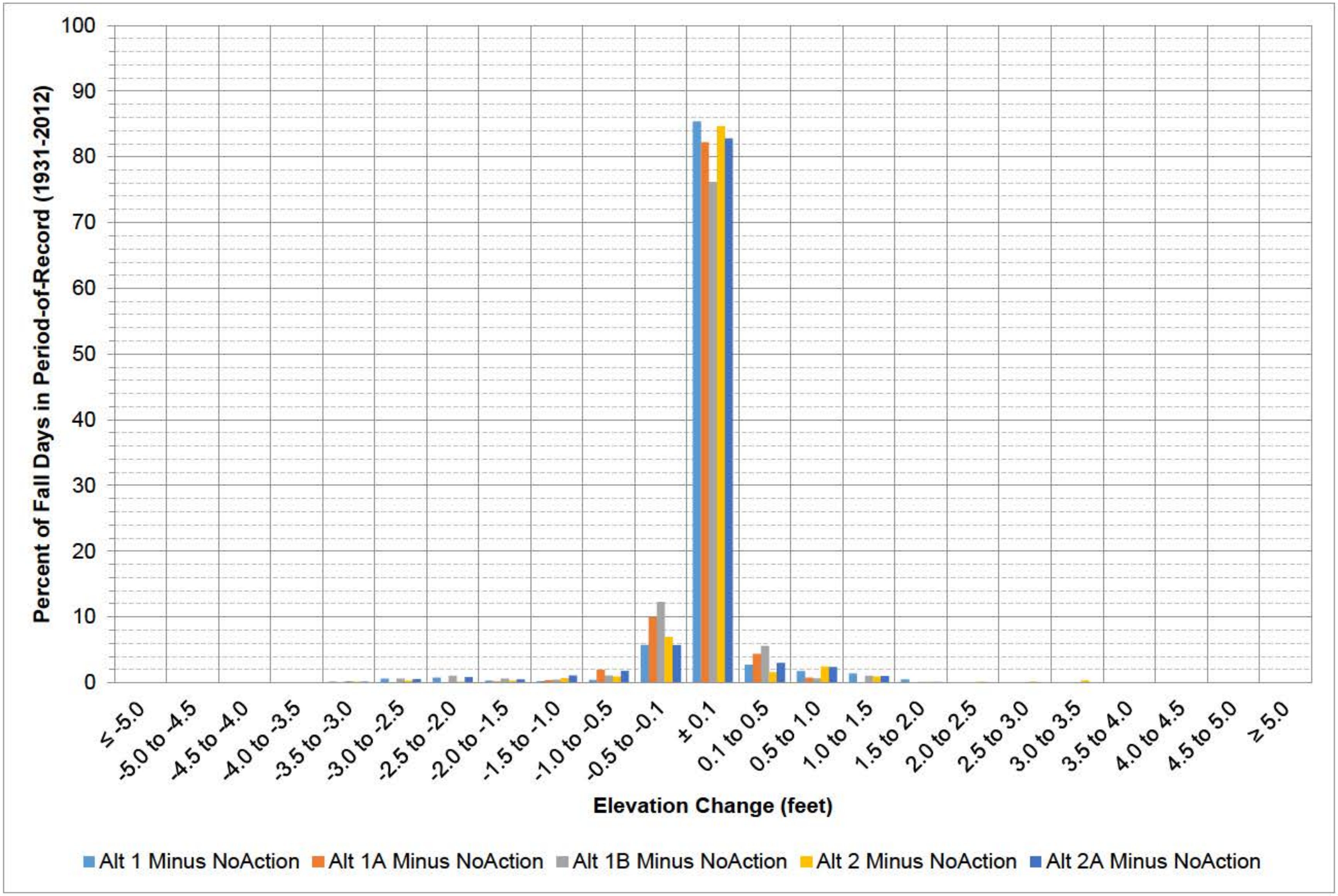

Figure 4-9: Oahe elevation change between each alternative and No Action during September – November.

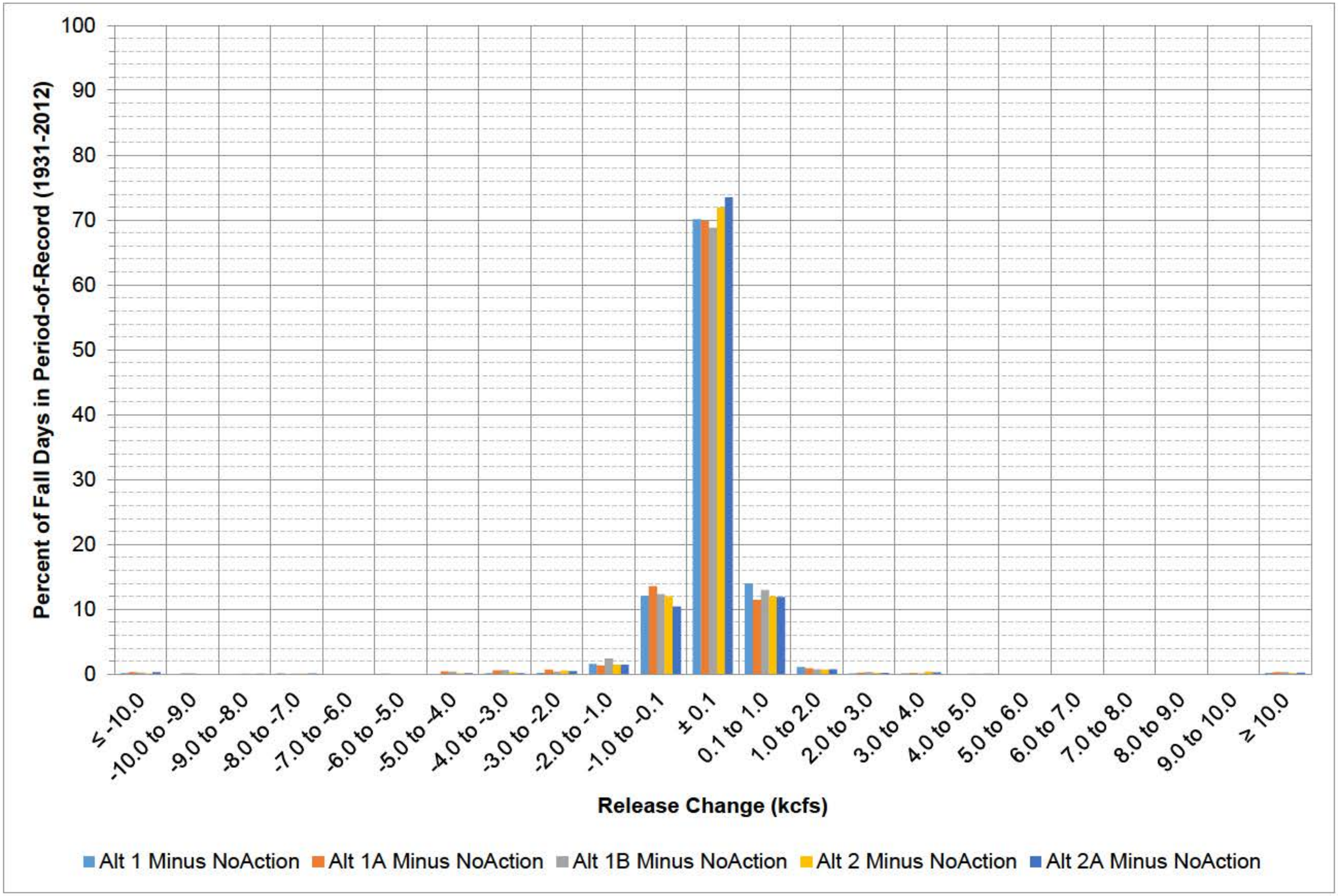

Figure 4-10: Oahe release change between each alternative and No Action during September – November.

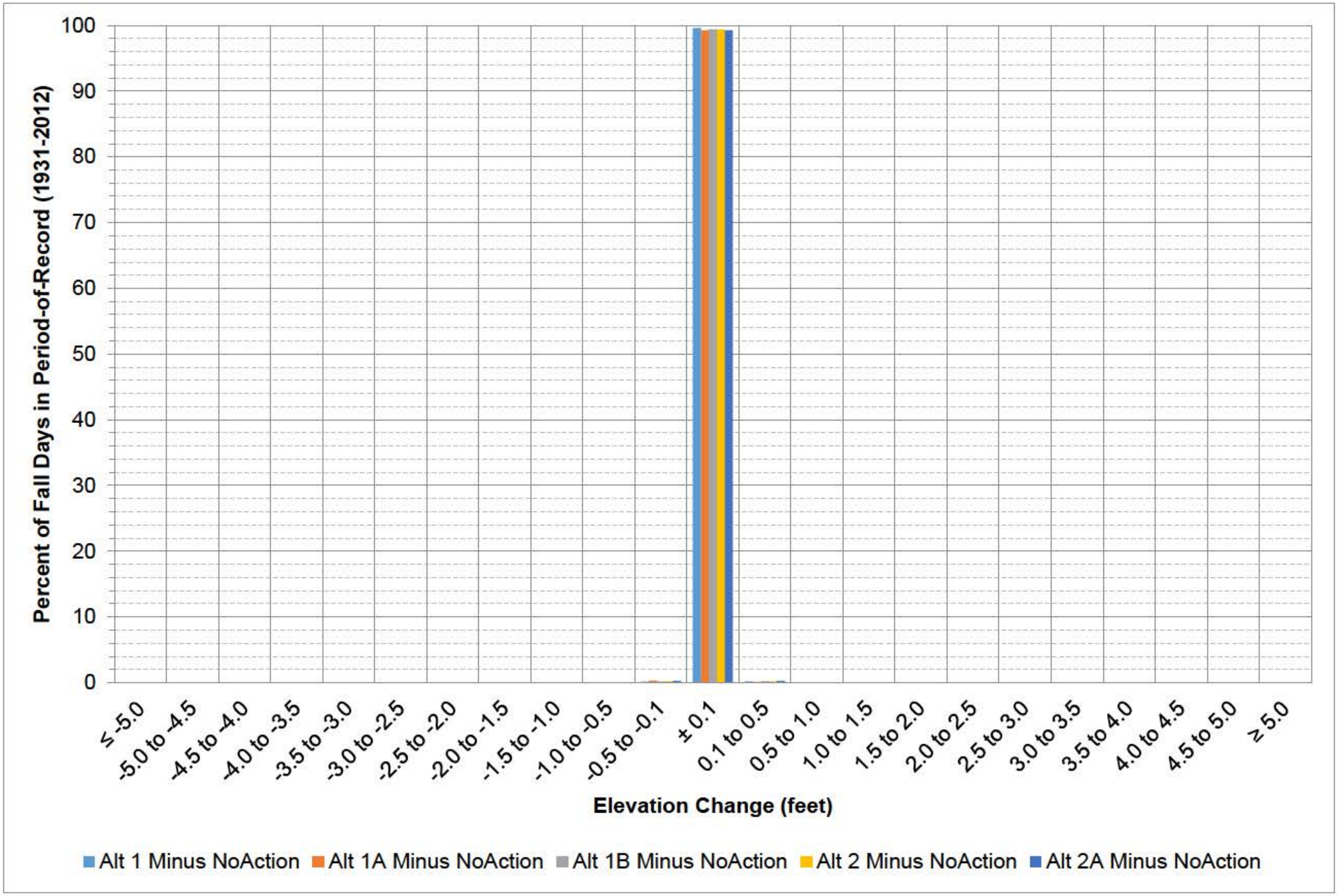

Figure 4-11: Big Bend elevation change between each alternative and No Action during September – November.

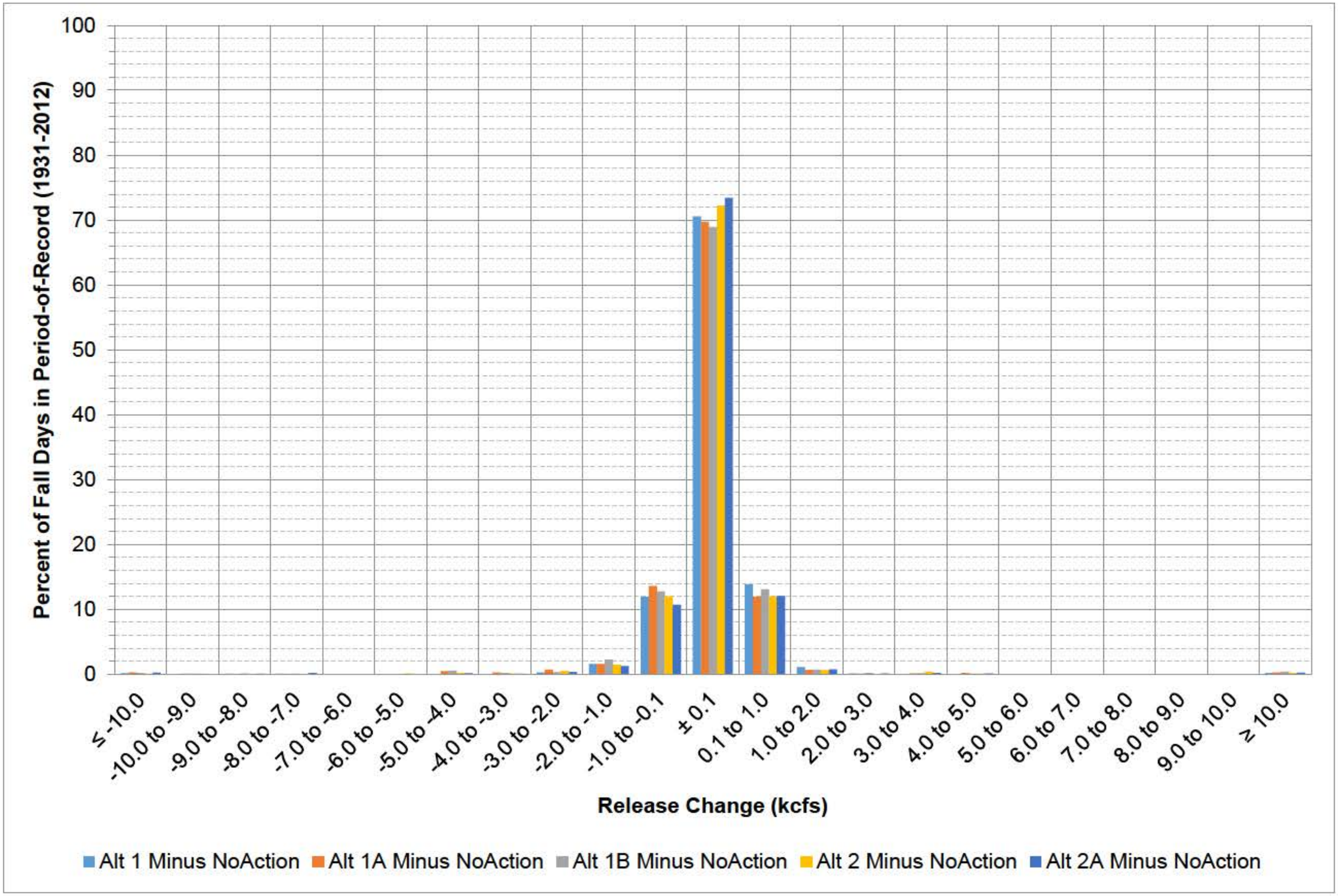

Figure 4-12: Big Bend release change between each alternative and No Action during September – November.

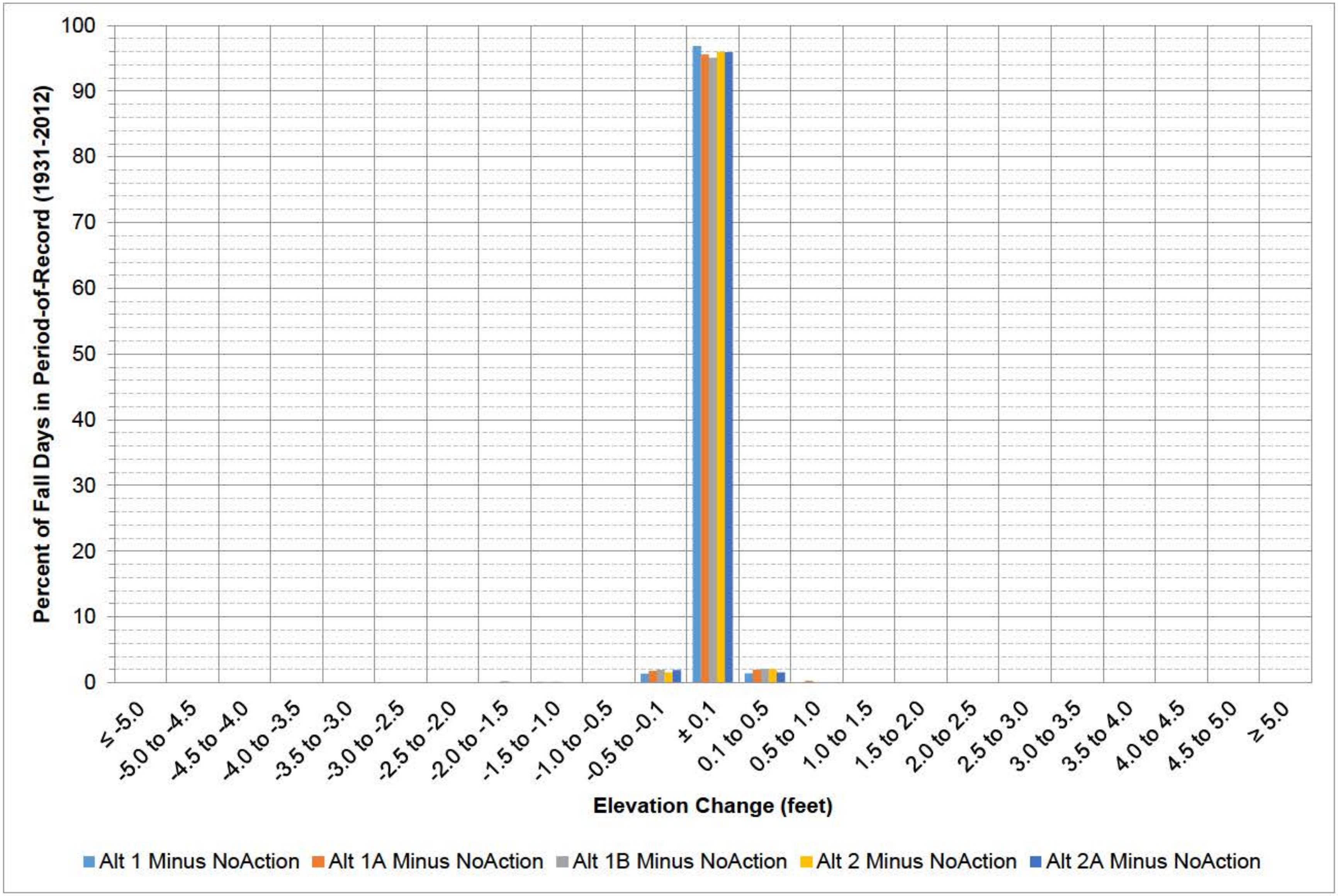

Figure 4-13: Fort Randall elevation change between each alternative and No Action during September – November.

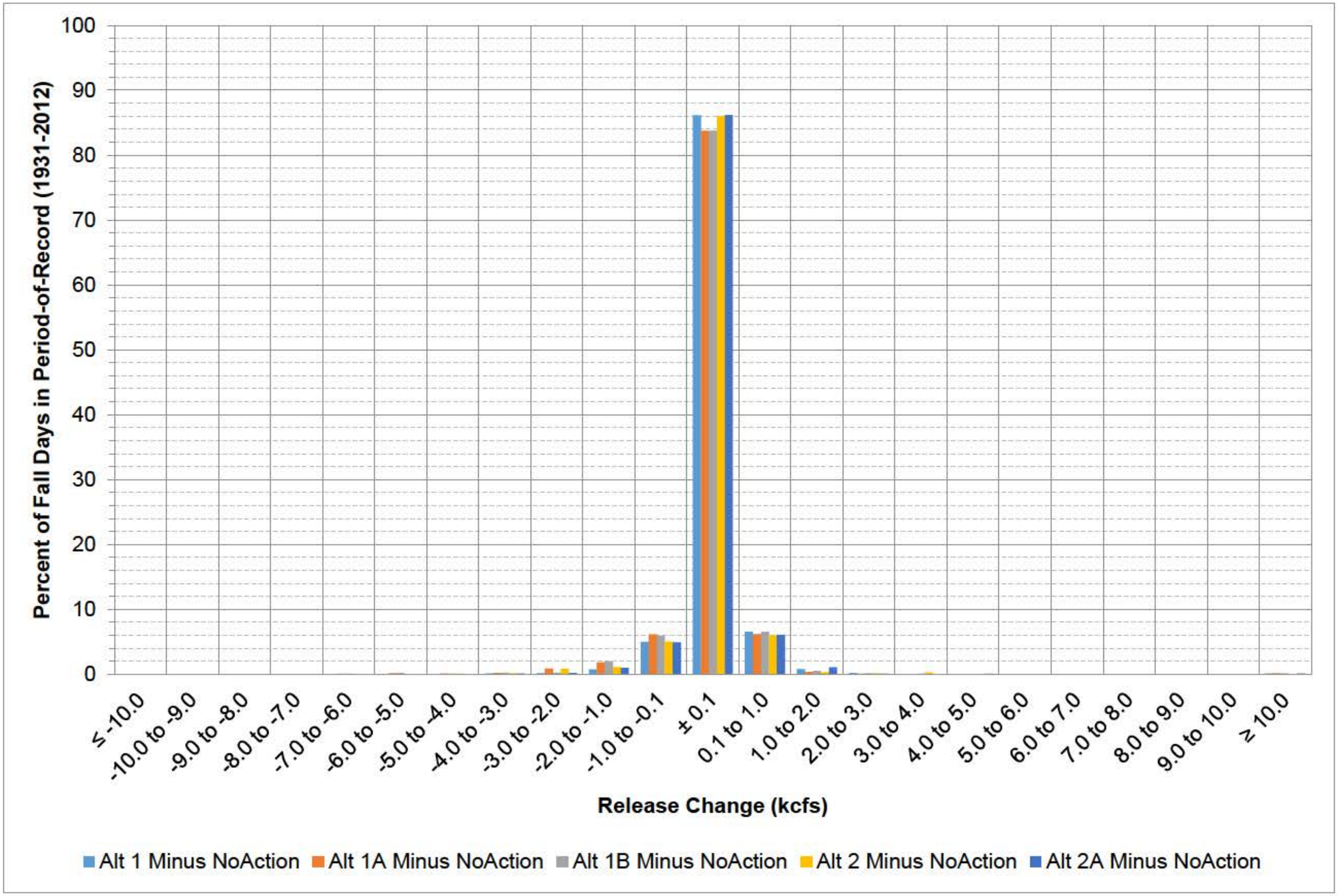

Figure 4-14: Fort Randall release change between each alternative and No Action during September – November.

5 WINTER: DECEMBER – FEBRUARY

5.1 DOWNSTREAM OF GAVINS POINT

5.1.1 No Action

Operations shift to winter releases beginning on December 1 or December 10 if there is a ten day extension to the navigation season. As discussed in Section 4.1.1 Gavins Point winter releases are set based on the September 1 System storage. Releases will be increased above the computed winter release if forecasted inflow indicates that higher releases are required to evacuate all of the System's flood storage by the start of the next runoff season. Winter releases are capped at 27.0 kcfs because extremely high winter flows can cause issues with ice jams below Gavins Point Dam. Figure 5-1 shows an example of high winter releases from Gavins Point Dam. Releases are initially set to 17.0 kcfs but during early January, the model estimates that releases need to be increased in order to evacuate all of the System's flood storage. Releases continue to increase throughout the winter as more inflow enters the System than forecasted, reaching the max winter release of 27.0 kcfs by the end of the February.

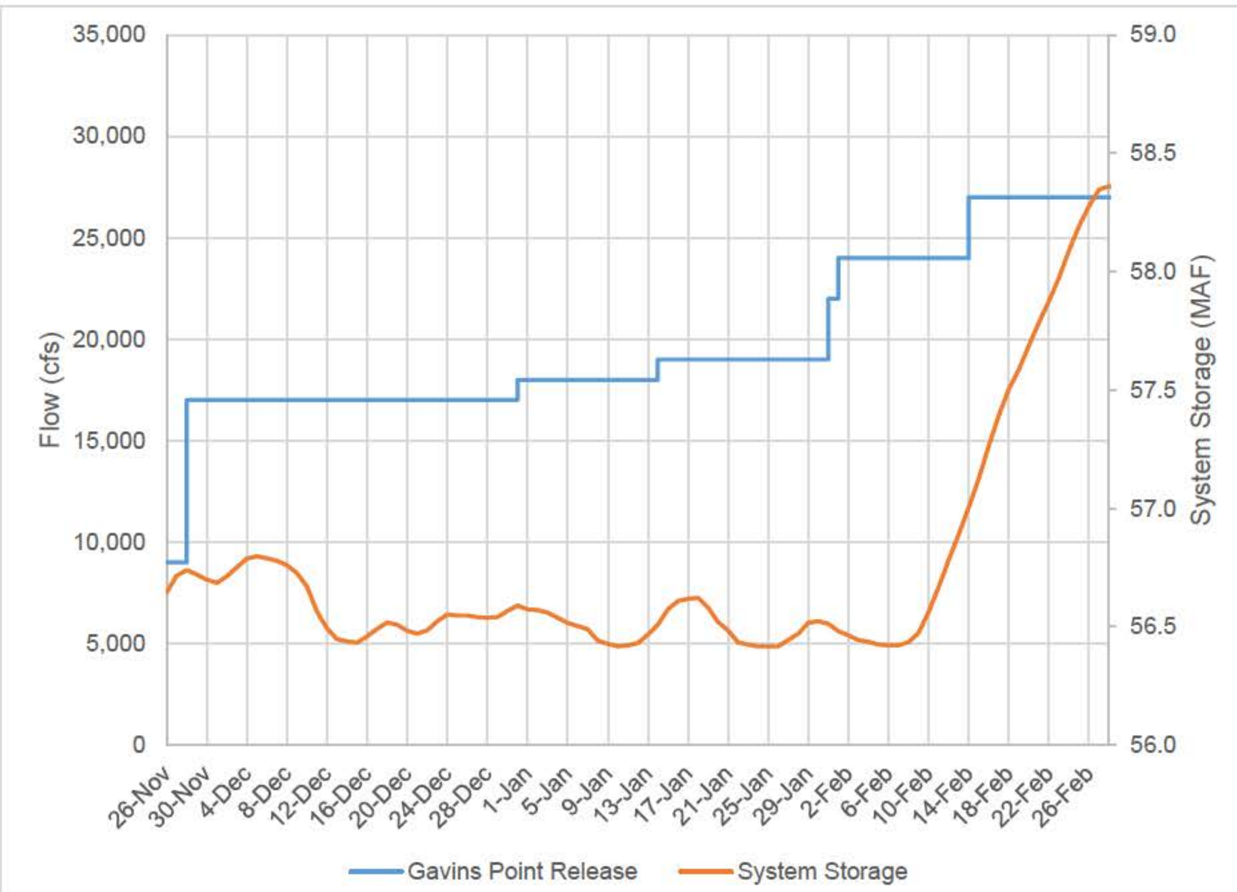

Figure 5-1: High winter releases from Gavins Point Dam.

System operations also support water supply during winter months. The ResSim model ensures that a minimum flow of 12.0 kcfs is observed at Sioux City, Omaha, and Kansas City by increasing Gavins Point releases as needed. Figure 5-2 shows an example of ResSim increasing releases throughout the winter when Omaha's flow is forecasted to fall below 12.0 kcfs.

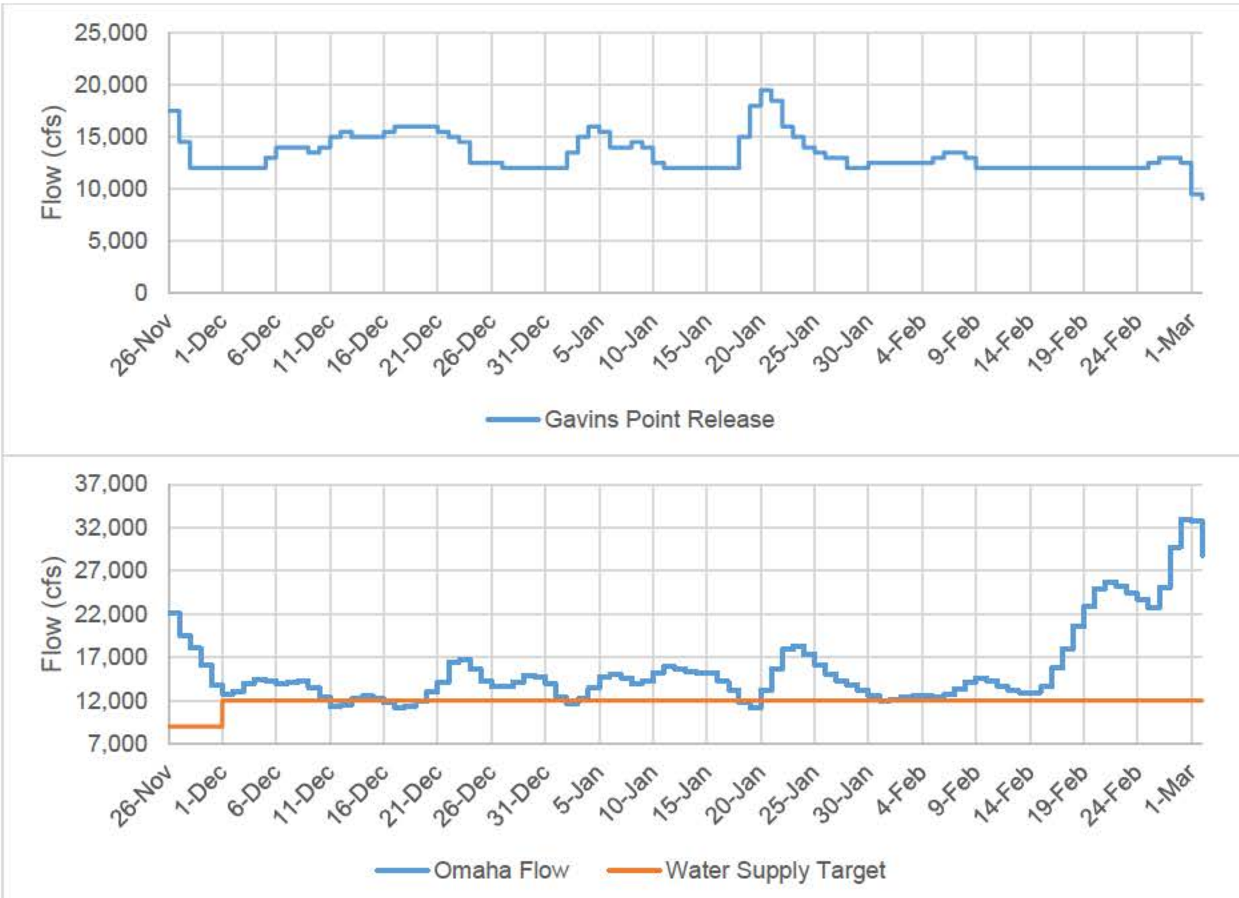

Figure 5-2: Low winter releases from Gavins Point Dam.

5.1.2 Alternatives 1, 1a, 1b, 2, 2a, and 2b

System operations downstream of Gavins Point in all alternatives do not change compared to No Action during December – February with the same water supply, navigation, and flood control requirements used in the alternatives.

The operational changes that occur upstream of Gavins Point in the alternatives do not have an impact on Gavins Point pool elevation and releases. The minor changes in winter pool elevation as compared to No Action, shown in Figure 5-3, are a result of ResSim modeling and are not due to operational changes in the alternatives.

All changes in Gavins Point releases that occur in the alternatives, shown in Figure 5-4, are within 1 kcfs of the No Action, which is well within model uncertainty.

5.1.3 Elevation and Release Changes at Gavins Point during Winter Months for All Alternatives

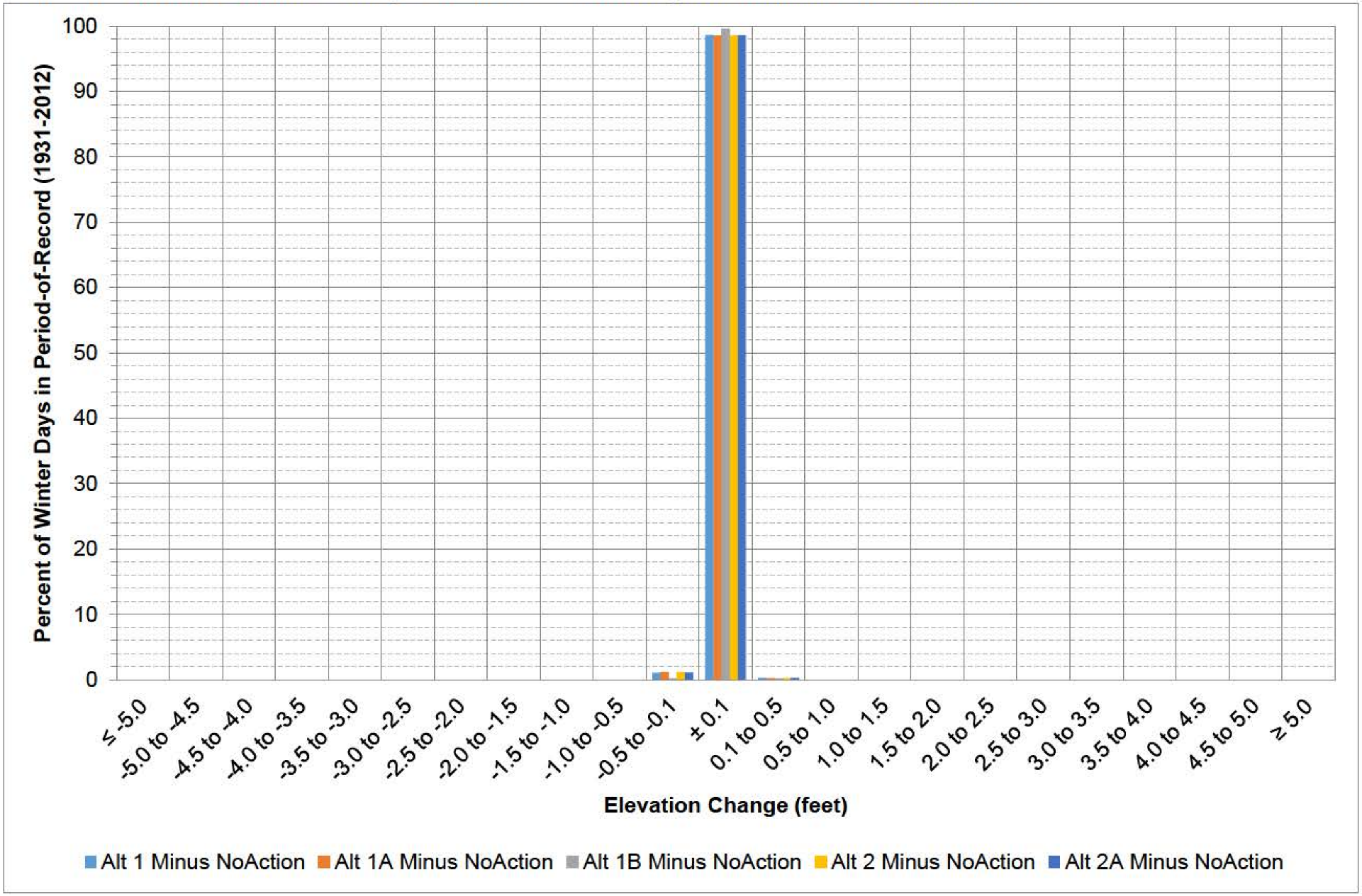

Figure 5-3: Gavins Point elevation change between each alternative and No Action during December – February.

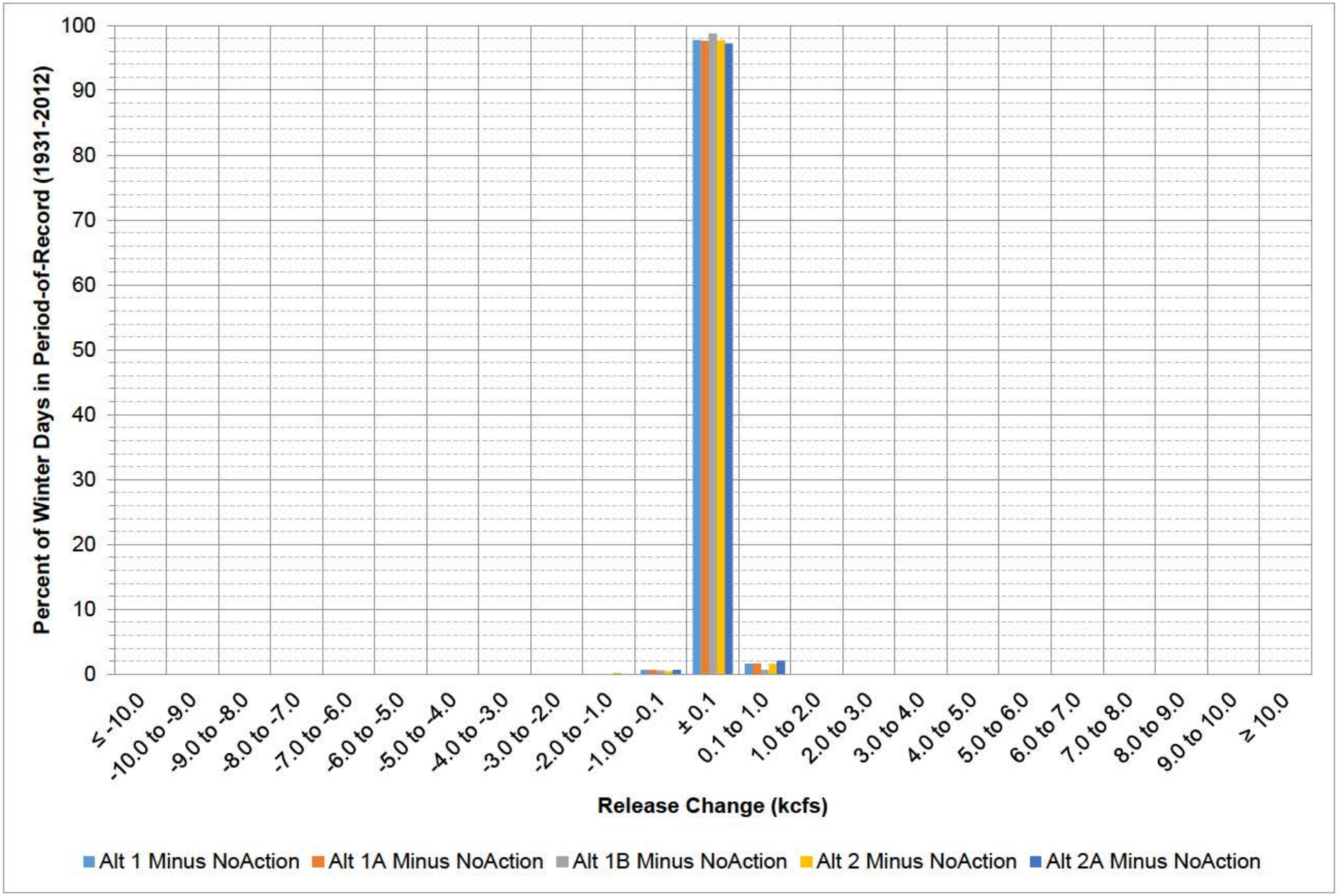

Figure 5-4: Gavins Point release change between each alternative and No Action during December – February.

5.2 UPSTREAM OF GAVINS POINT

5.2.1 Alternative 1 – No Action

Fort Peck and Garrison still release water based on the forecasted System storage as the model attempts to balance the occupied storage in the Carryover Multiple Use zones at Fort Peck, Garrison, and Oahe, prior to the start of the next runoff season.

After setting releases at Fort Peck and Garrison, minimum flows at Wolf Point, Culbertson, and Bismarck are checked. Releases from Fort Peck are increased to ensure a minimum flow of 5.0 kcfs is forecasted at Wolf Point and Culbertson between December 1 and February 28. Releases from Garrison are increased to ensure a minimum flow of 12.0 kcfs is forecasted at Bismarck between December 1 and February 28.

Guide curve operations continue at Big Bend, Fort Randall, and Gavins Point. Fort Randall continues to refill to elevation 1350.0 feet (NGVD 29) by March 1. Gavins Point is lowered from 1207.5 feet (NGVD 29) starting on February 1 to 1206.0 feet (NGVD 29) by March 1.

5.2.2 Alternative 1, 1a, 1b, 2, 2a, and 2b

No operational changes occur under any of the alternatives during December – February. The differences observed in Figure 5-5 through Figure 5-14 are caused by the changes to the operations at Fort Peck during the spring and summer months and are a continuation of the changes that occur in the fall months. For example, Fort Peck releases tend to be lower during the fall as storage is rebalanced after the flow regimes. This pattern continues during the winter months, as lower Fort Peck releases keeps water in Fort Peck and ensures storage is balanced among the upper three reservoirs by the end of February. As with the fall changes, reducing Fort Peck release is the only way to rebalance storage following a flow regime at Fort Peck. The trend of higher Lake Sakakawea elevations compared to the No Action is still present, see Figure 5-7, but the differences are smaller than during the fall months. The remaining downstream projects, Oahe, Big Bend, and Fort Randall (see Figure 5-9 through Figure 5-14), do not have prevalent trends when compared to the No Action.

5.2.3 Elevation and Release Changes Upstream of Gavins Point during Winter Months for All Alternatives

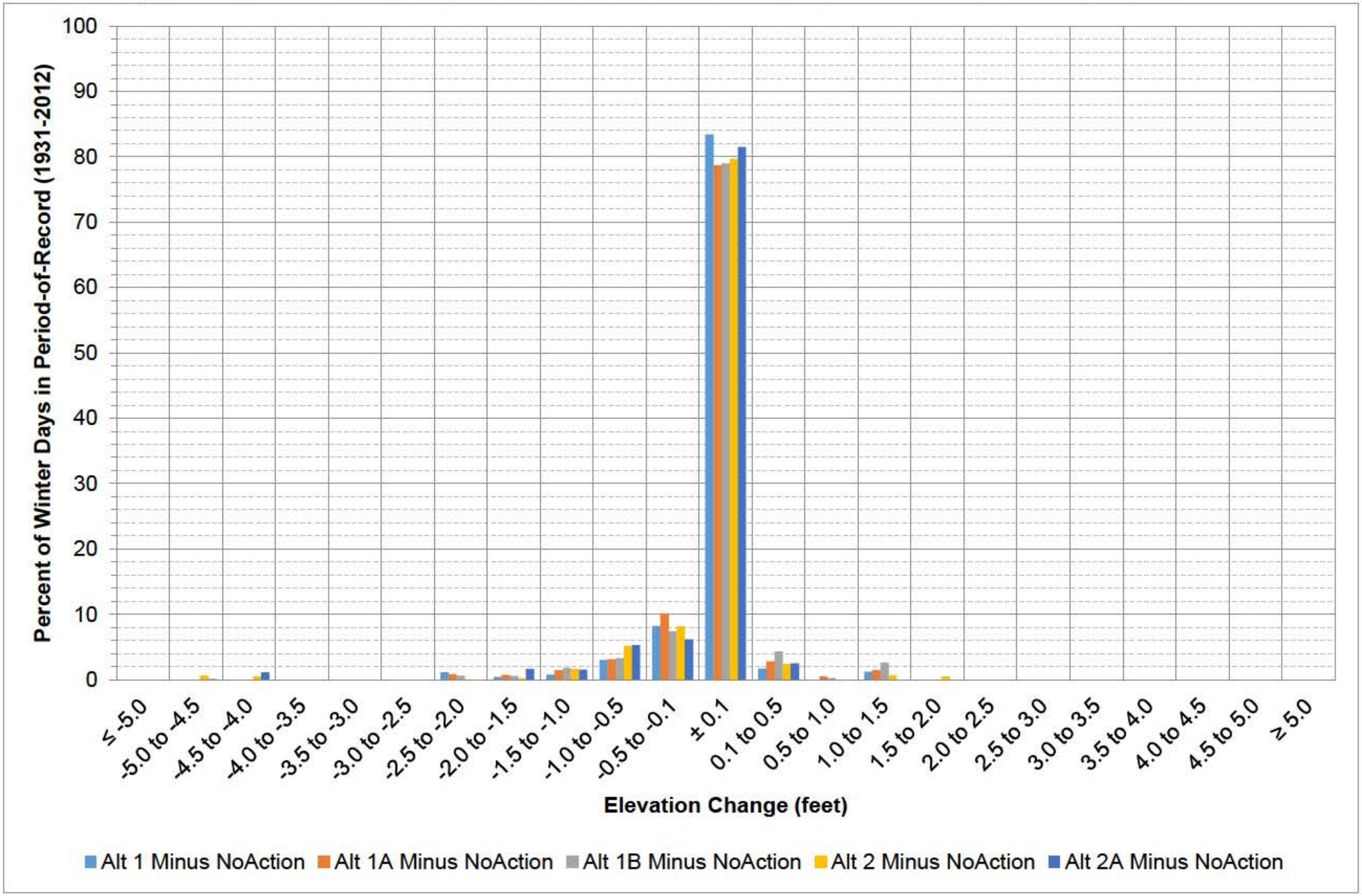

Figure 5-5: Fort Peck elevation change between each alternative and Alt 1 during December – February.

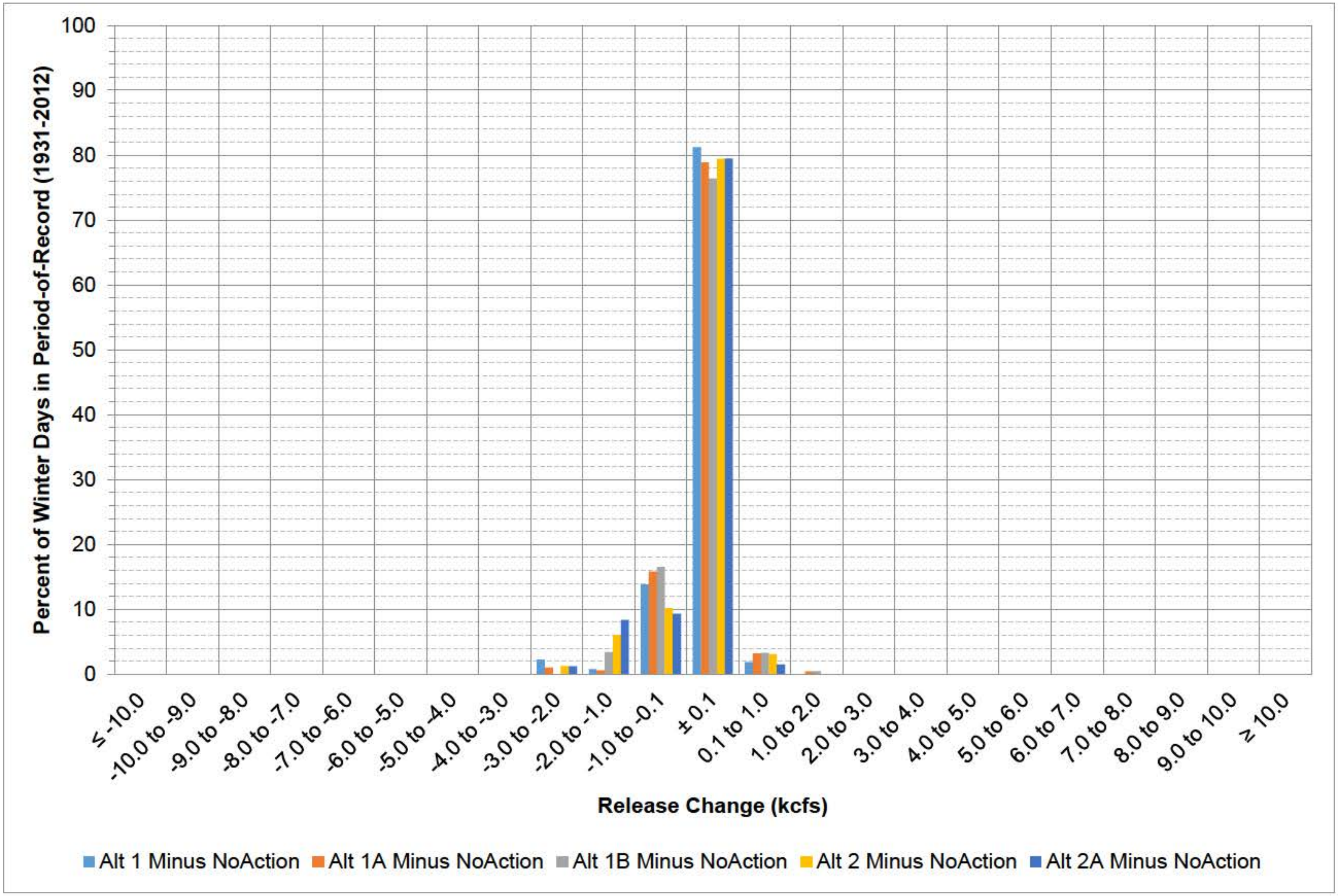

Figure 5-6: Fort Peck release change between each alternative and No Action during December – February.

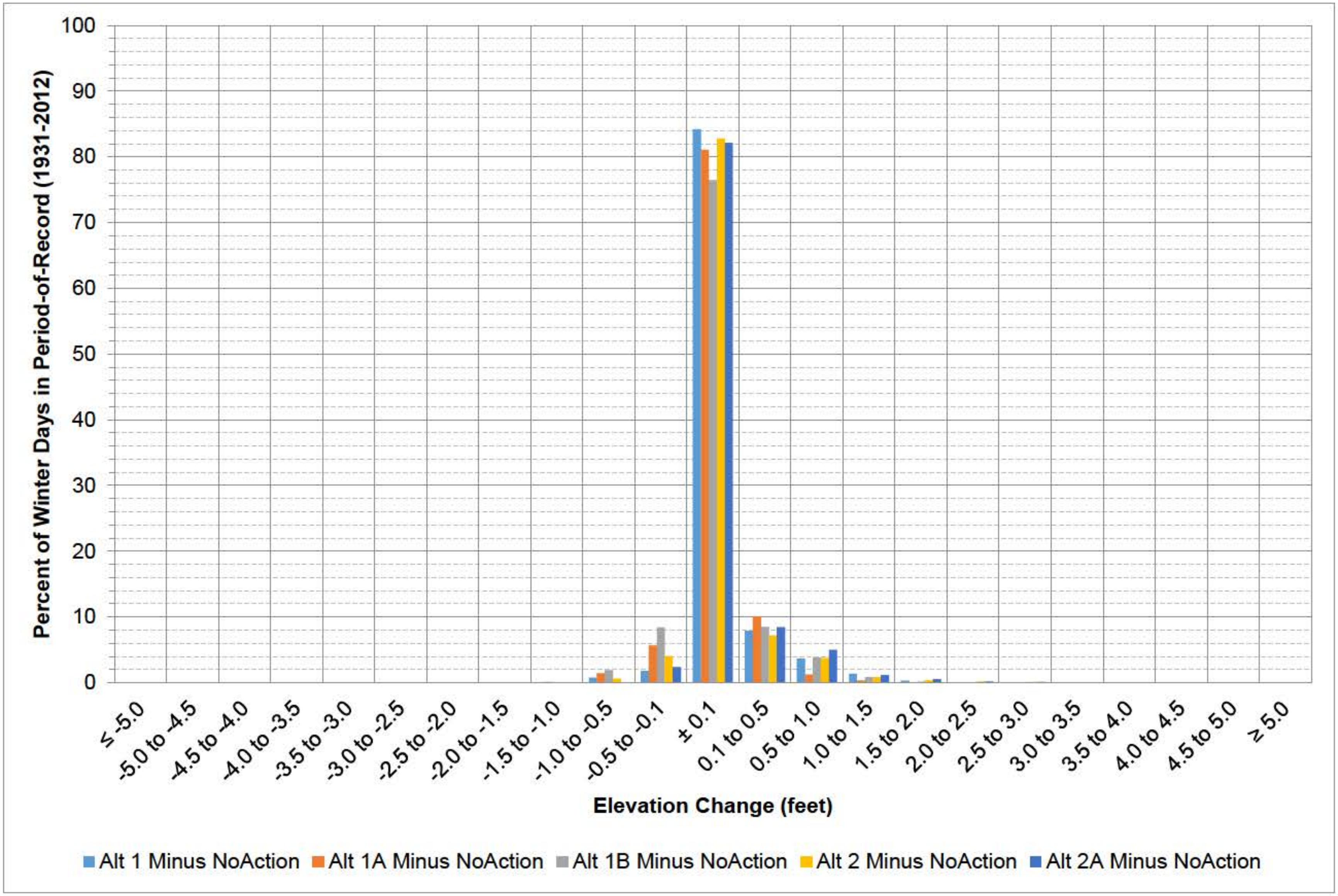

Figure 5-7: Garrison elevation change between each alternative and No Action during December – February.

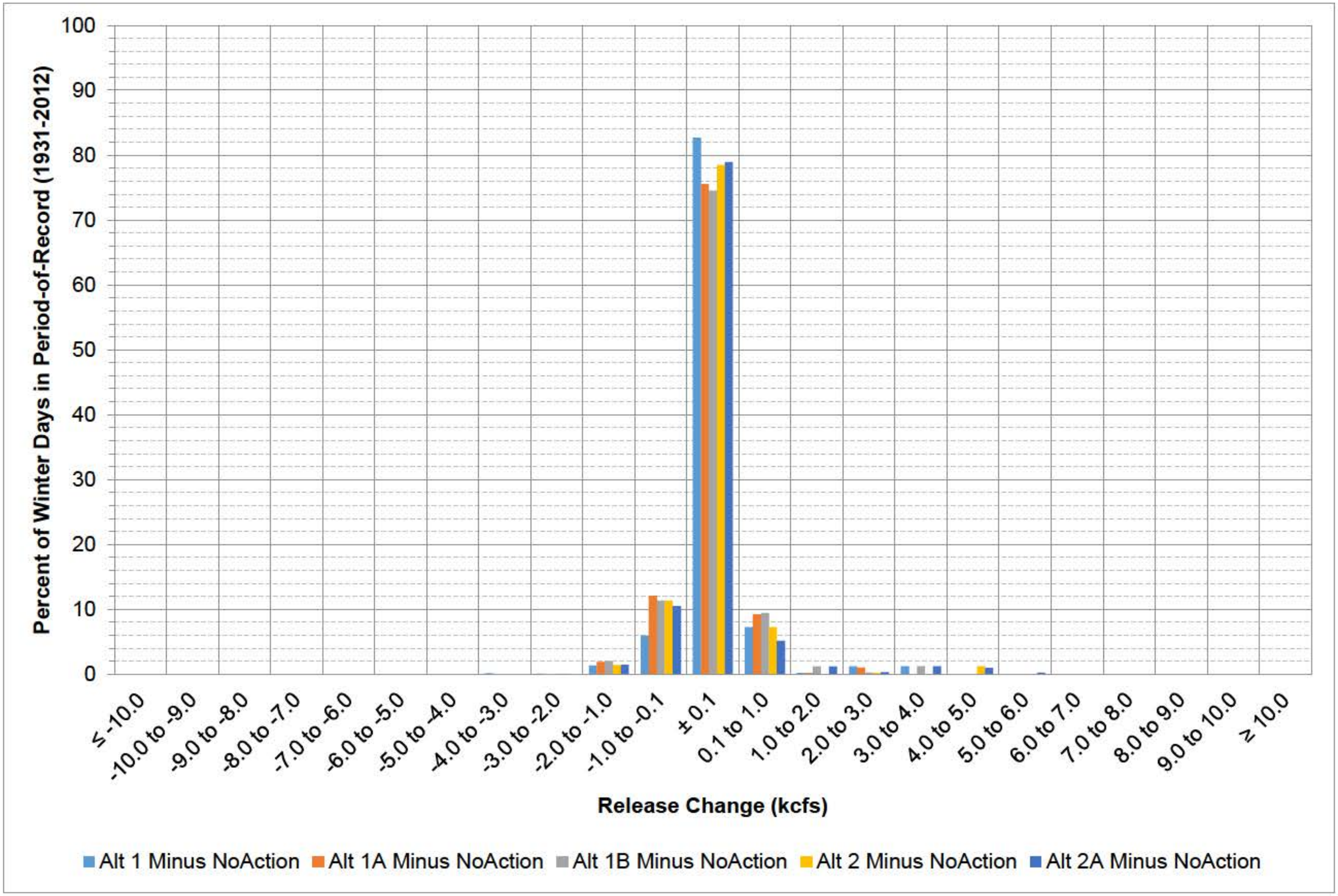

Figure 5-8: Garrison release change between each alternative and No Action during December – February.

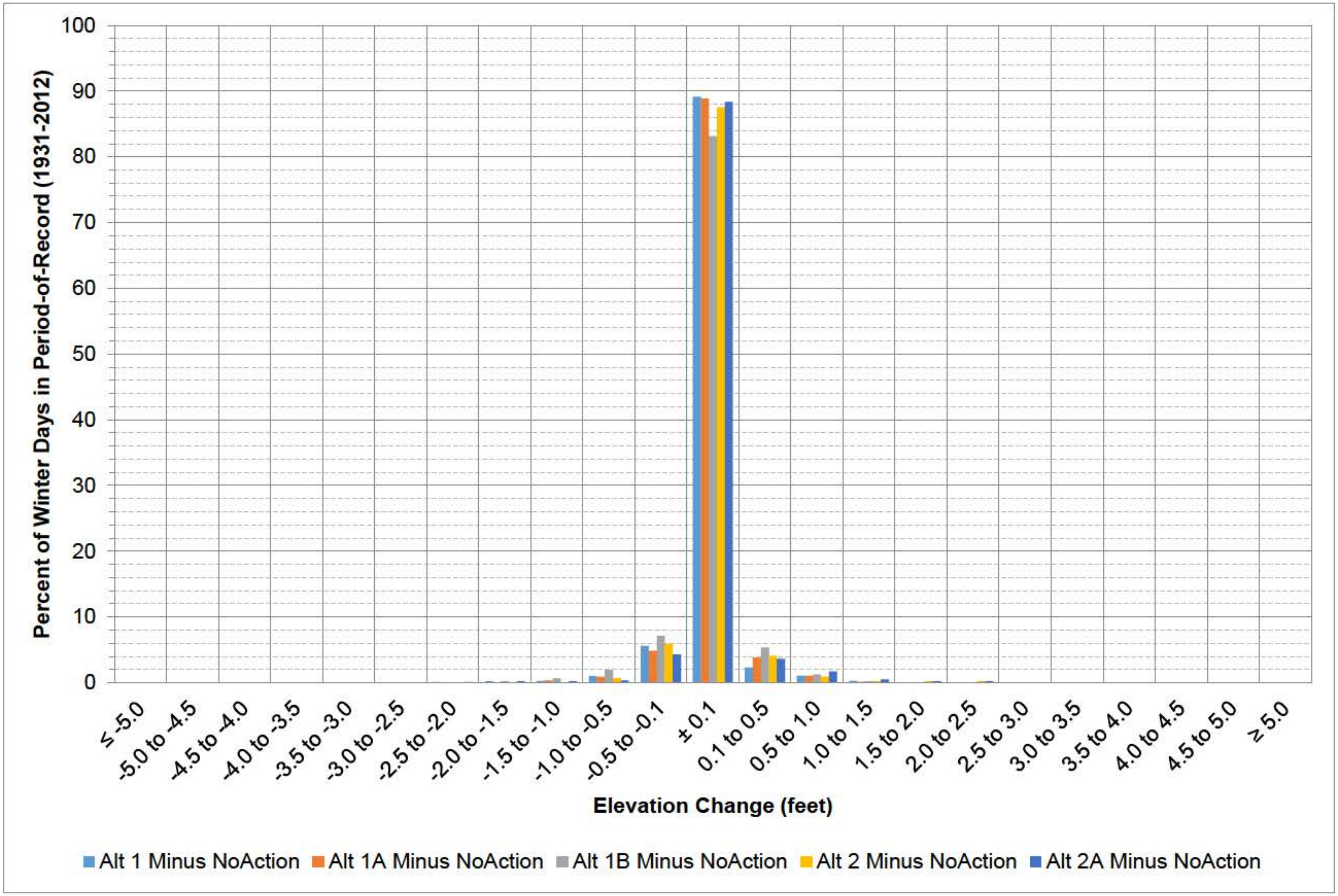

Figure 5-9: Oahe elevation change between each alternative and No Action during December – February.

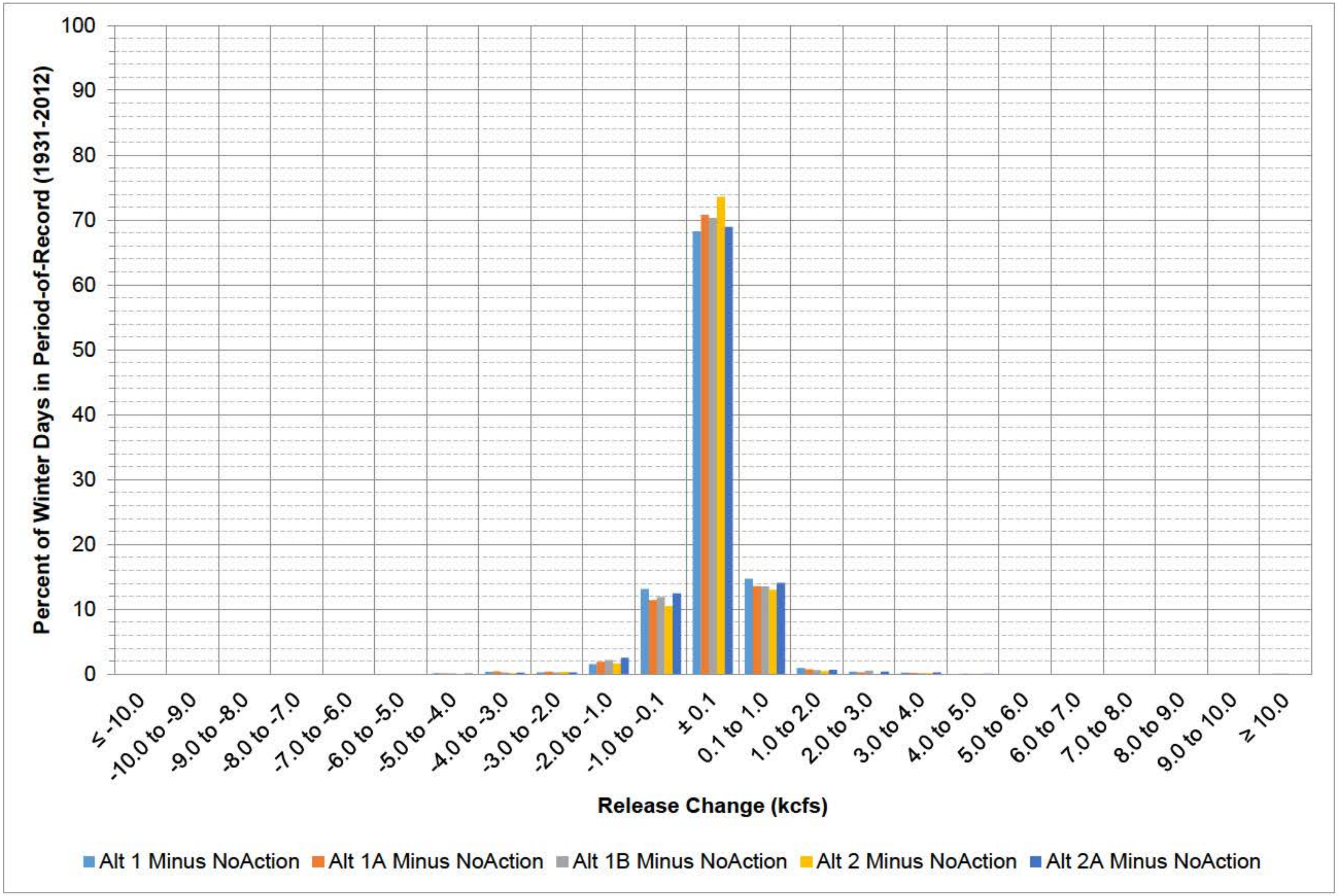

Figure 5-10: Oahe release change between each alternative and No Action during December – February.

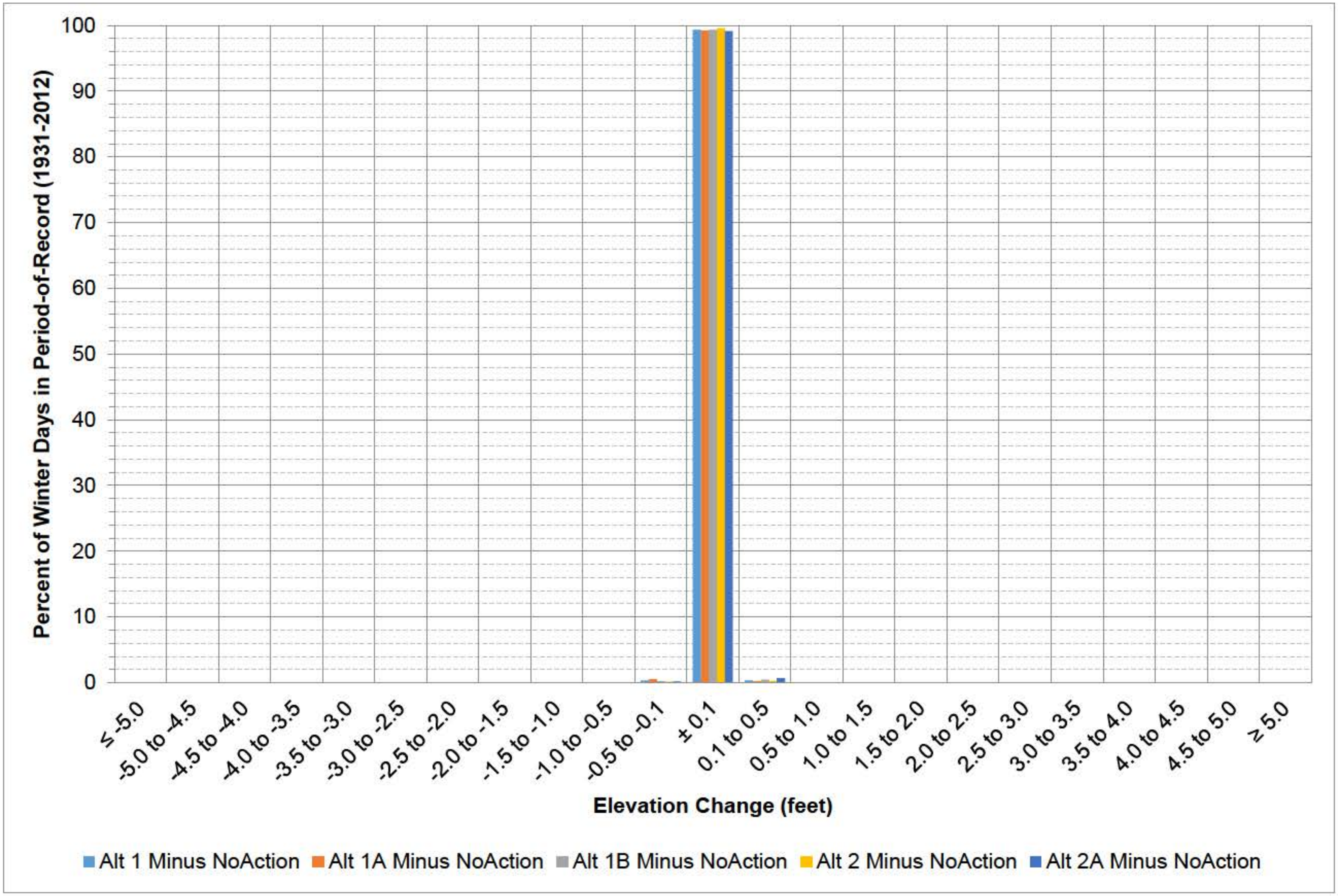

Figure 5-11: Big Bend elevation change between each alternative and No Action during December – February.

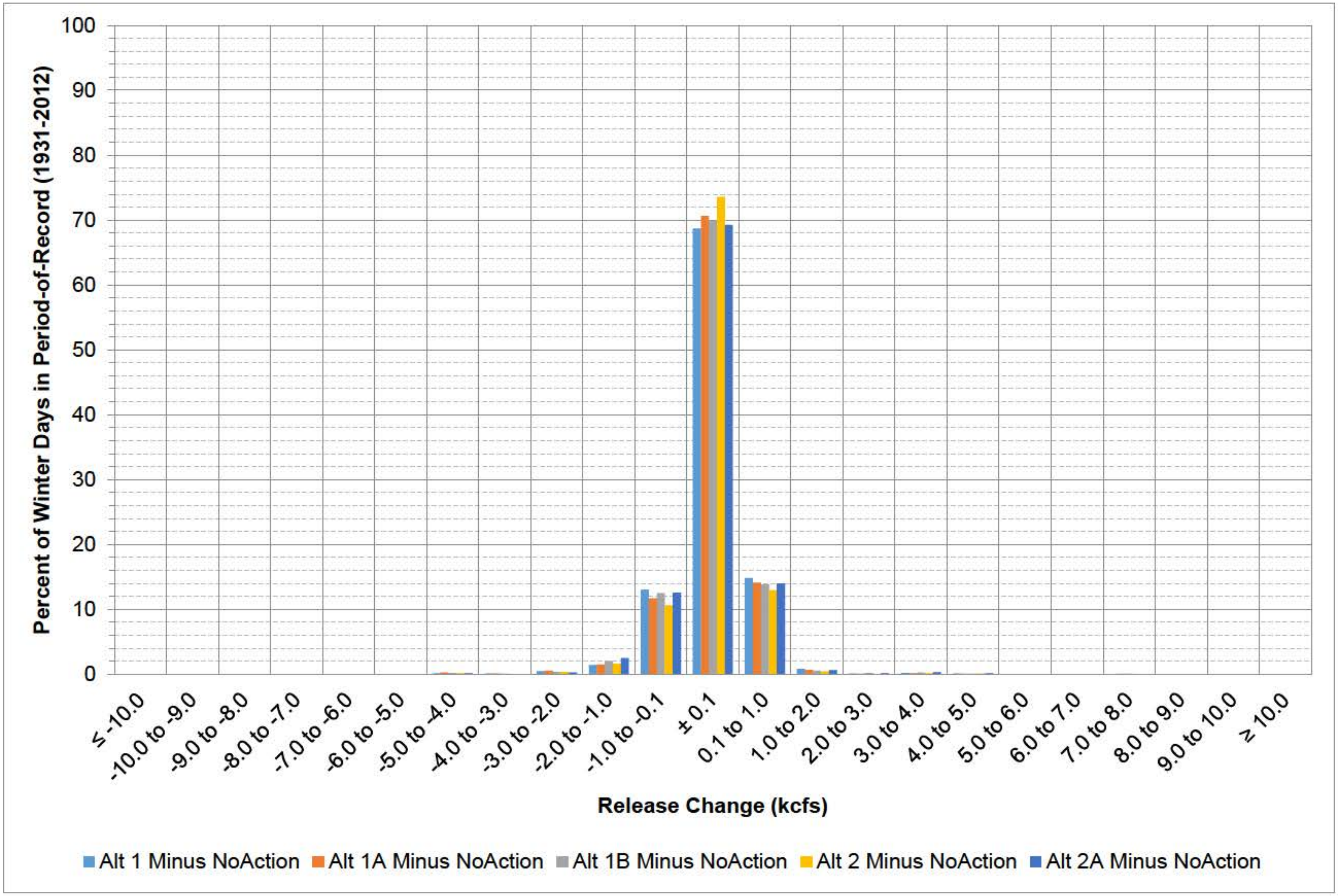

Figure 5-12: Big Bend release change between each alternative and No Action during December – February.

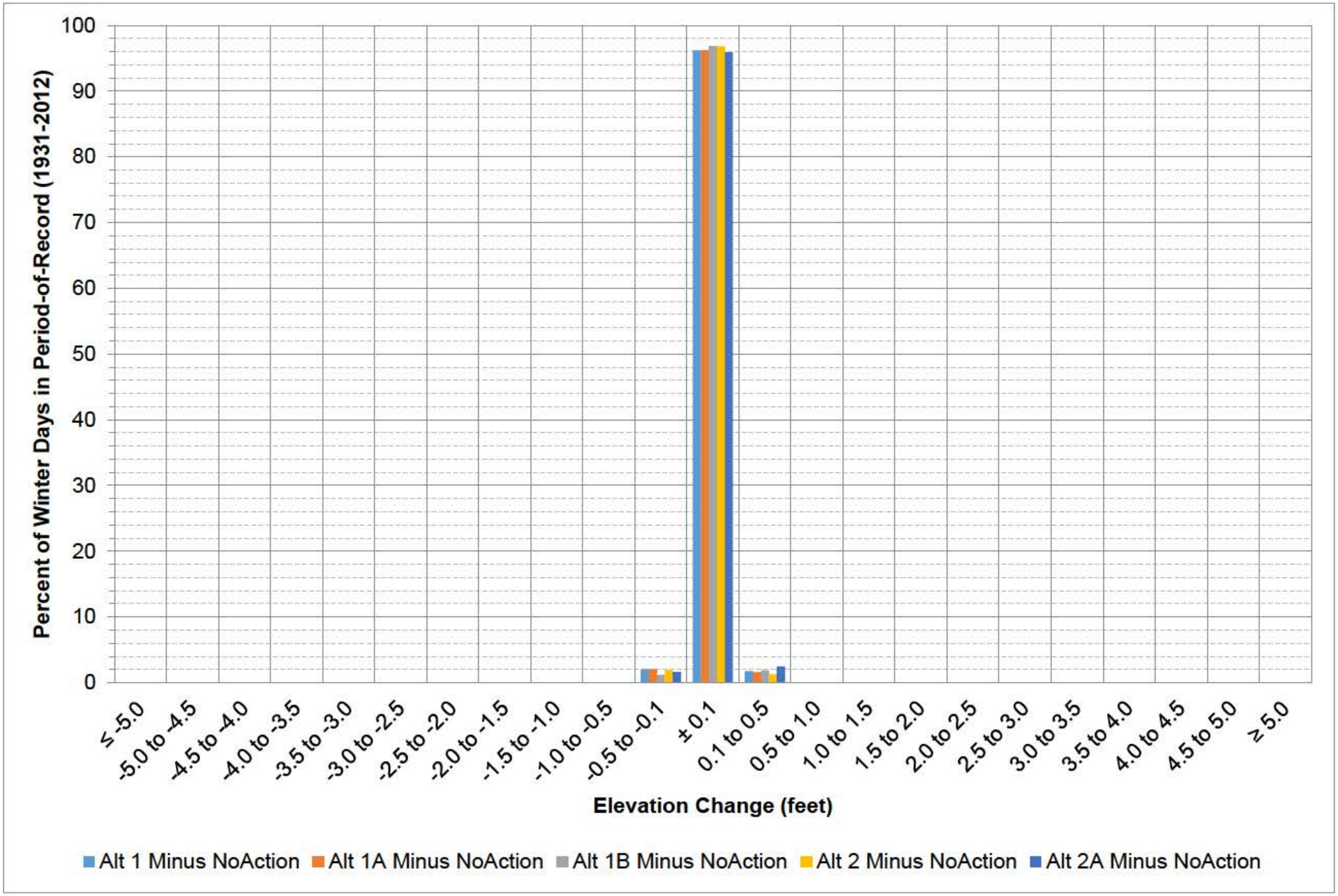

Figure 5-13: Fort Randall elevation change between each alternative and No Action during December – February.

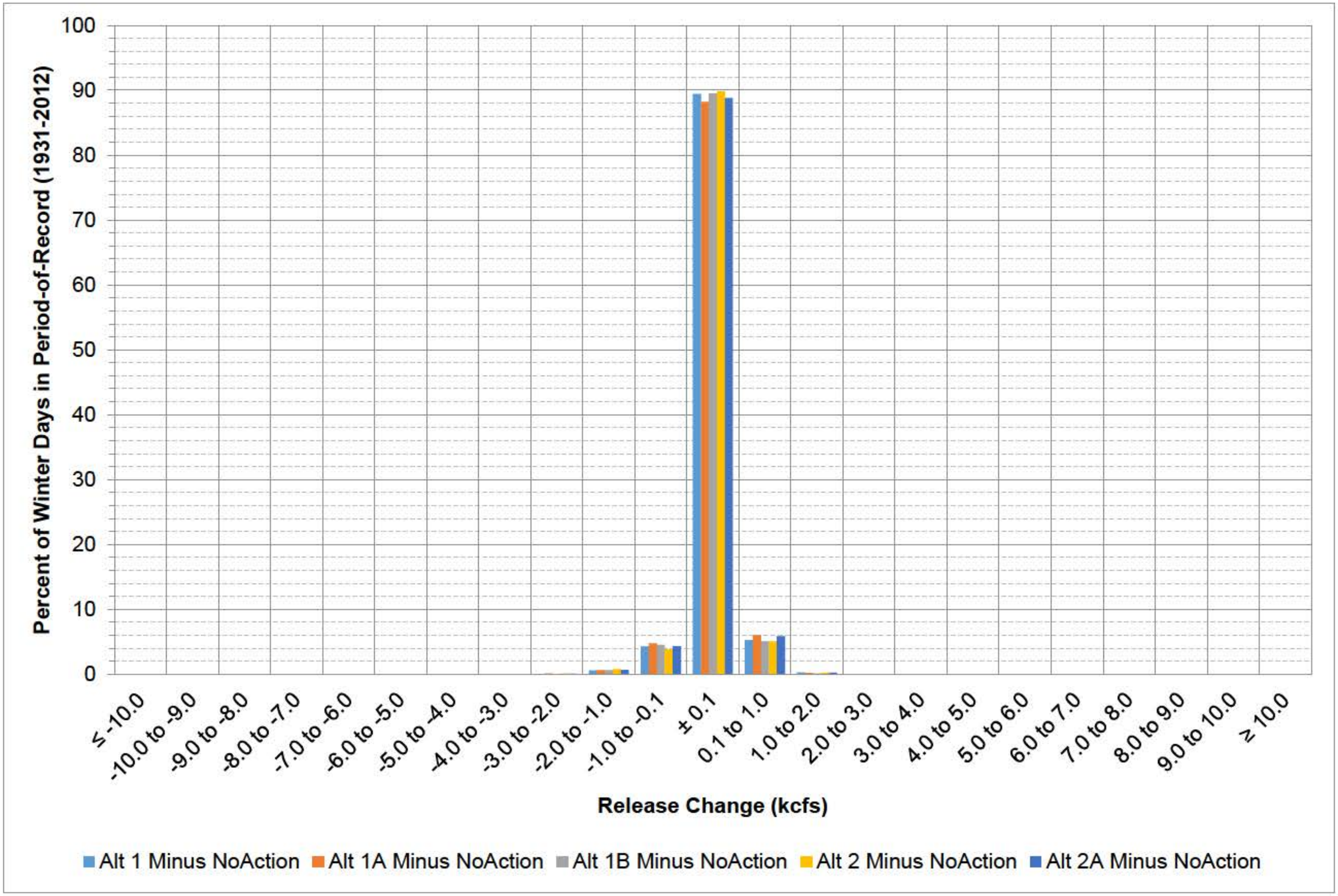

Figure 5-14: Fort Randall release change between each alternative and No Action during December – February.

6 SUMMARY OF PERIOD-OF-RECORD DIFFERENCES

The operational changes described in the previous sections and summarized in Table 6-1 mainly alter pool elevations at Fort Peck and Garrison and releases at Fort Peck. No significant changes occur at Gavins Point. Many of the seasonal trends that were mentioned are also apparent when the entire period-of-record is assessed as shown in Figure 6-1 through Figure 6-12. All alternatives show a trend of lower pool elevations at Fort Peck and higher pool elevations at Garrison when compared to No Action over the period-of-record due to the flow regime at Fort Peck in each alternative. Table 6-2 summarizes the frequency of each alternative's flow regime throughout the period-of-record. Pool elevations at Big Bend, Fort Randall, and Gavins Point remain mostly unchanged as they operate for their respective guide curves. All alternatives have minimal effect on System storage as all of the changes are within ±0.1 MAF.

The flow regimes at Fort Peck under all alternatives lead to higher spring releases and lower summer releases as the 8 kcfs flow target governs operations during the summer. Lower releases at Fort Peck when compared to the No Action continue during the fall and winter months as storage is balanced among the upper three reservoirs. No significant changes occur with Gavins Point releases as the water used for the flow regime at Fort Peck remains within the System.

Table 6-1: Summary of operational changes for each alternative compared to No Action.

Alternative	March - April	May - August	September - November	December - February
Alt 1	Alt 1 flow regime at Fort Peck: attraction and retention flows	Alt 1 flow regime at Fort Peck: retention and spawning cue flows Summer flow target of 8 kcfs	No operational changes	No operational changes
Alt 1a	Alt 1a flow regime at Fort Peck: attraction and retention flows (one week earlier than Alt 1)	Alt 1a flow regime at Fort Peck: retention and spawning cue flows Summer flow target of 8 kcfs	No operational changes	No operational changes
Alt 1b	Alt 1b flow regime at Fort Peck: attraction and retention flows (one week later than Alt 1)	Alt 1b flow regime at Fort Peck: retention and spawning cue flows Summer flow target of 8 kcfs	No operational changes	No operational changes
Alt 2	Alt 2 flow regime at Fort Peck: attraction and retention flows	Alt 2 flow regime at Fort Peck: retention and spawning cue flows Summer flow target of 8 kcfs	No operational changes	No operational changes
Alt 2a	Alt 2a flow regime at Fort Peck: attraction and retention flows (one week earlier than Alt 2)	Alt 2a flow regime at Fort Peck: retention and spawning cue flows Summer flow target of 8 kcfs	No operational changes	No operational changes
Alt 2b	Alt 2b flow regime at Fort Peck: attraction and retention flows (one week later than Alt 2)	Alt 2b flow regime at Fort Peck: retention and spawning cue flows Summer flow target of 8 kcfs	No operational changes	No operational changes

Table 6-2: Summary of ESH-creating and spawning cue releases for each alternative.

Alternative	Frequency during 83-year Period of Record (1930-2012)		
	Eliminated[1]	Partial Completion[2]	Full Completion[3]
Alt 1	61	11	11
Alt 1a	61	6	16
Alt 1b	58	16	9
Alt 2	63	10	10
Alt 2a	63	5	15
Alt 2b	58	16	9

[1] Eliminated: flow regime is not initiated
[2] Partial Completion: flow regime is discontinued prior to peak spawning cue flow being held for 3 days
[3] Full Completion: peak spawning cue flow is held for 3 days

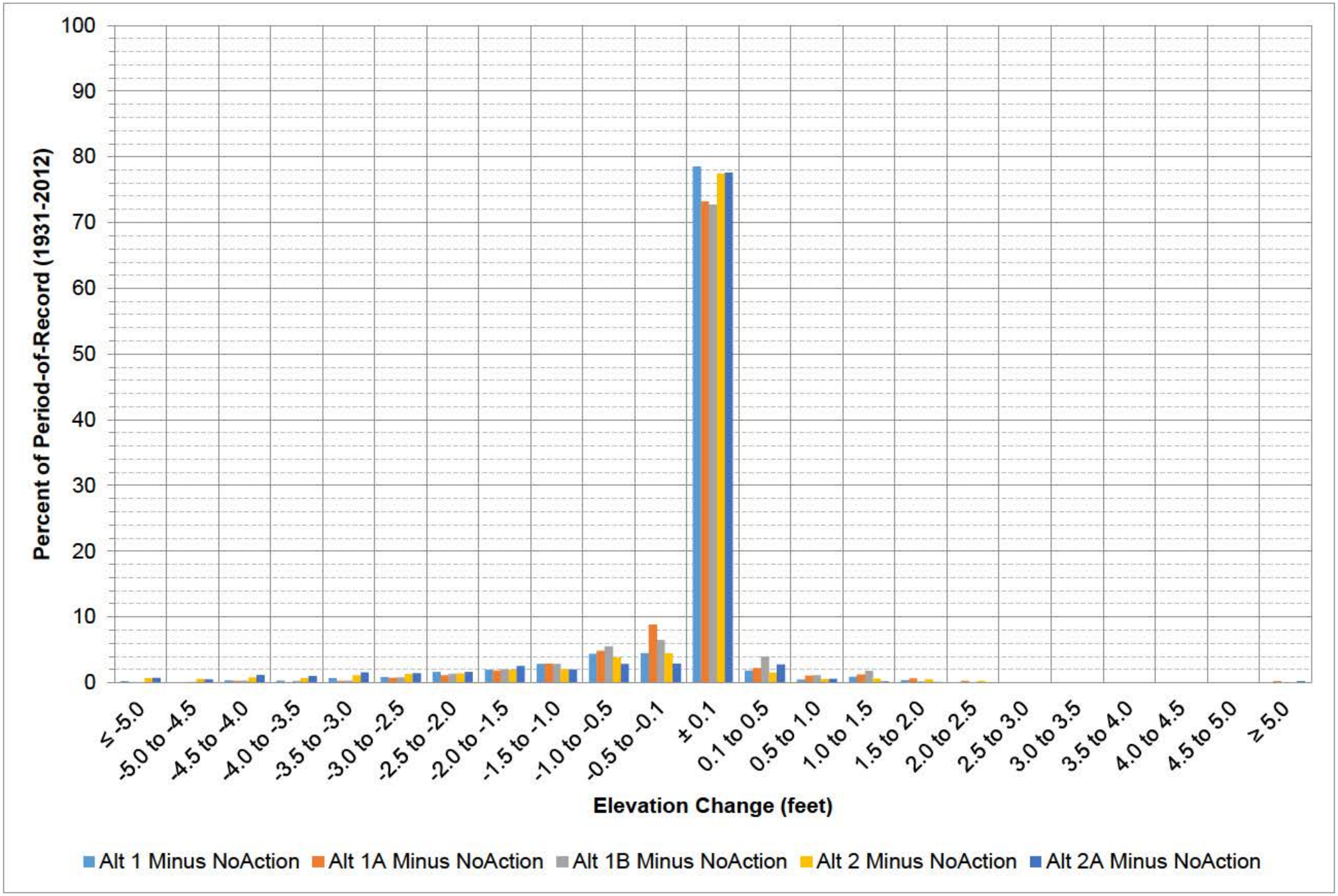

Figure 6-1: Fort Peck elevation change between each alternative and No Action for all days in the period-of-record.

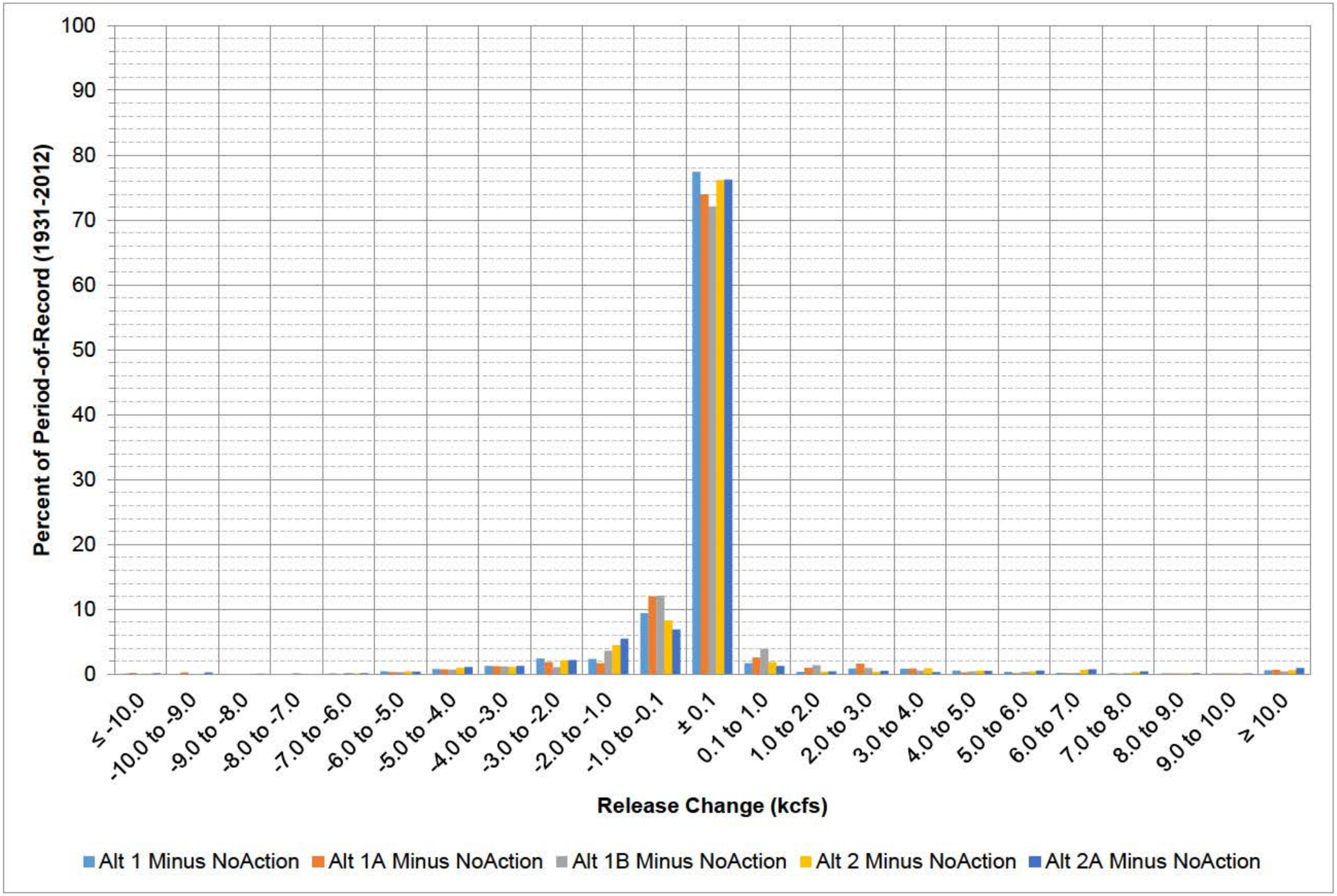

Figure 6-2: Fort Peck release change between each alternative and No Action for all days in the period-of-record.

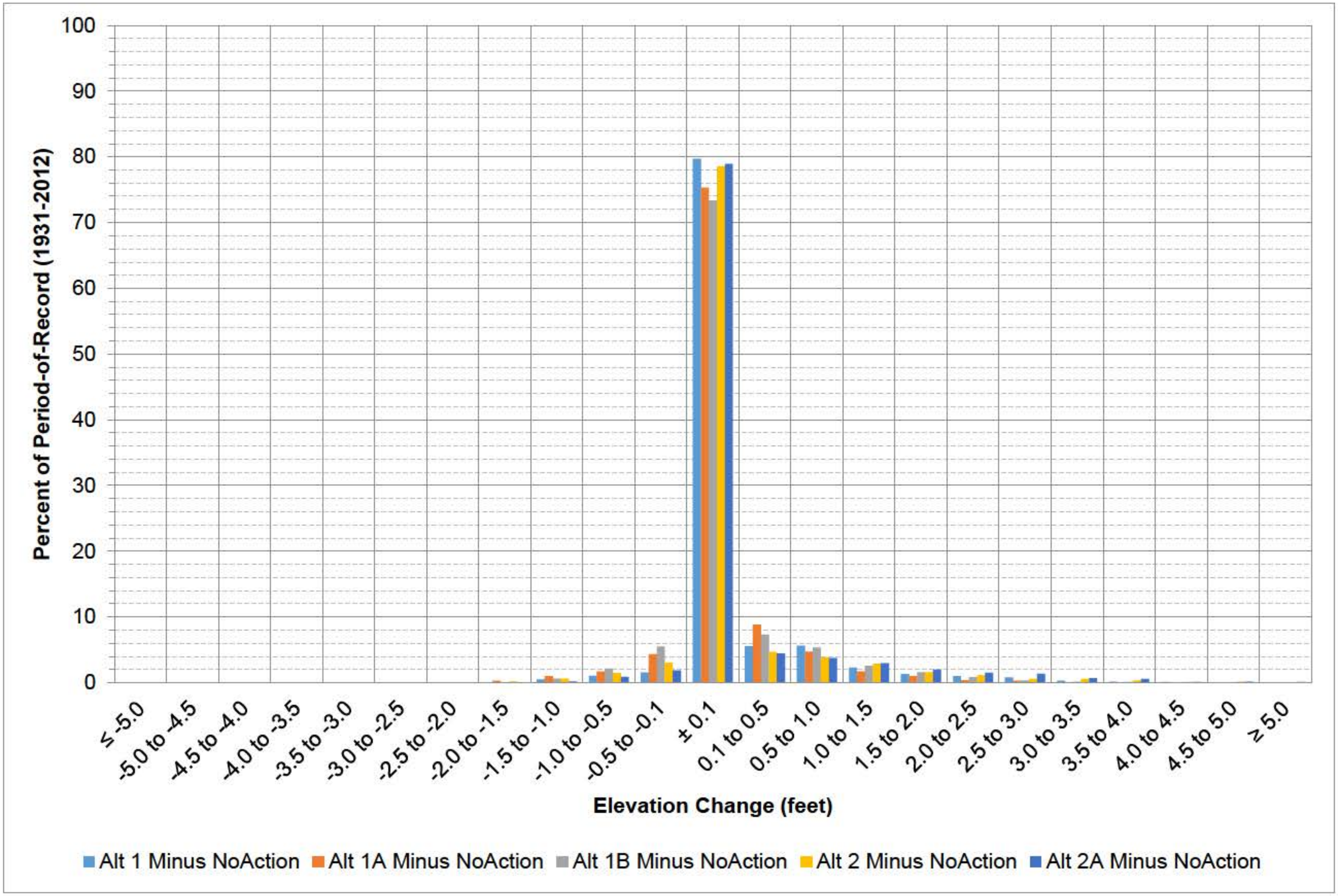

Figure 6-3: Garrison elevation change between each alternative and No Action for all days in the period-of-record.

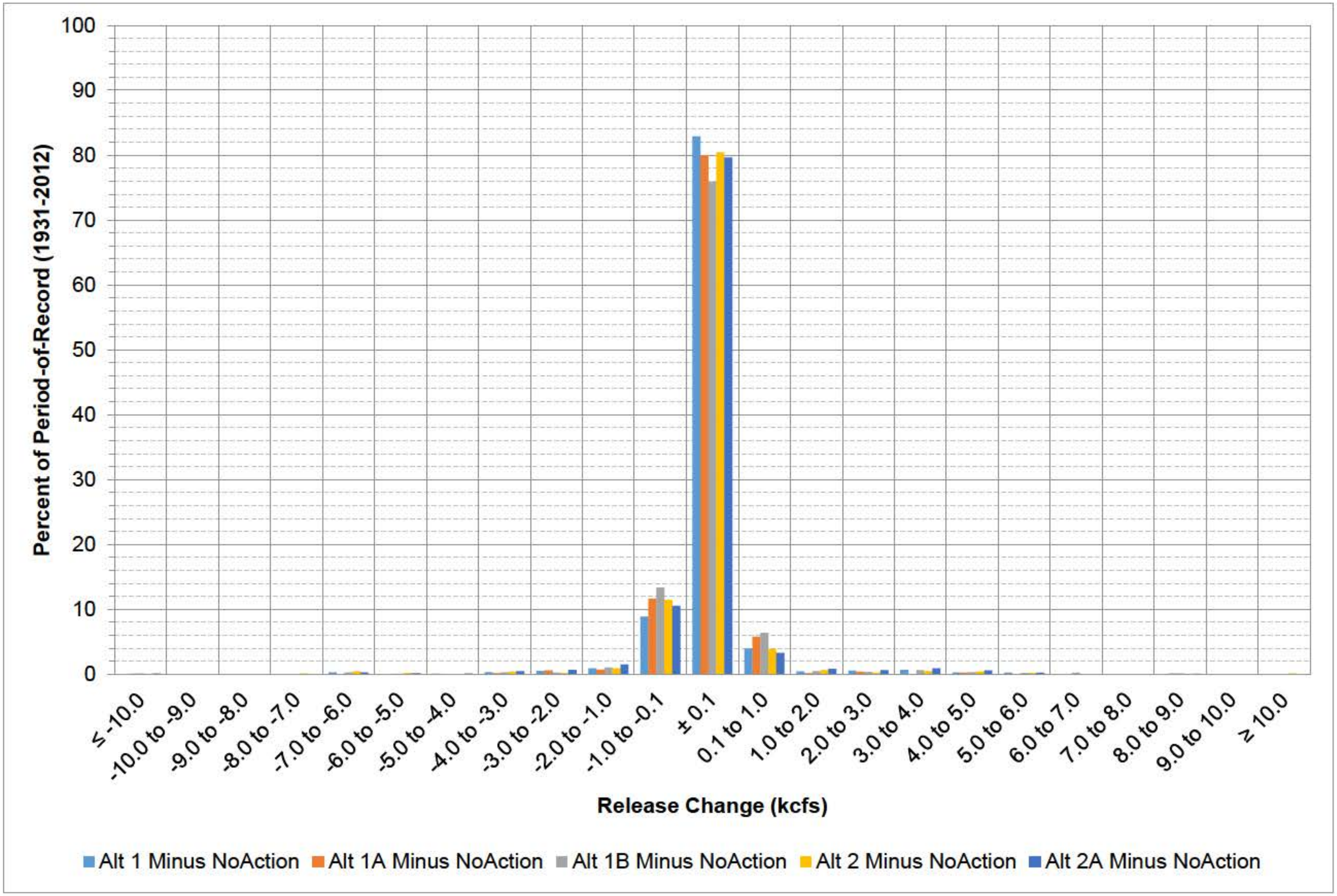

Figure 6-4: Garrison release change between each alternative and No Action for all days in the period-of-record.

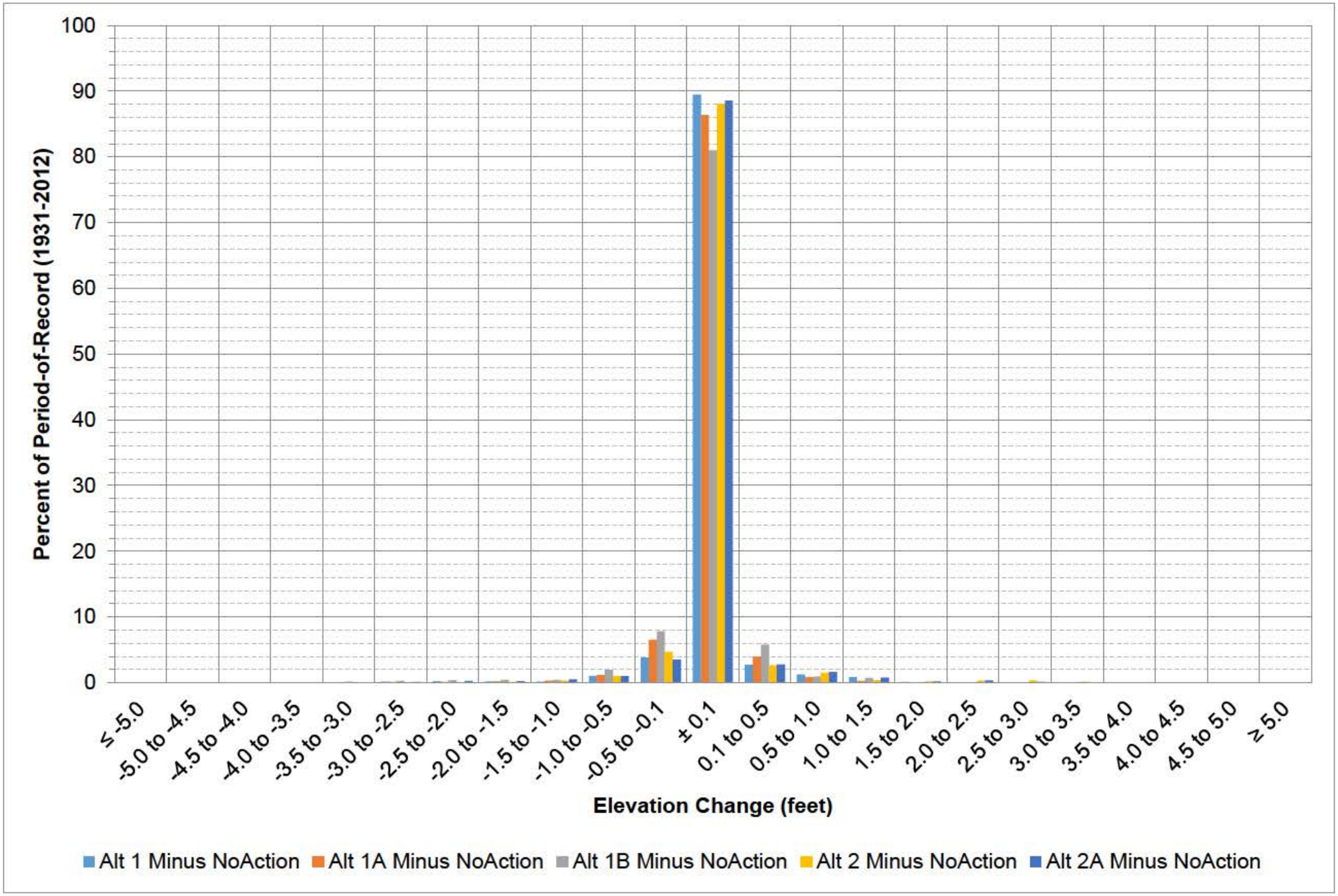

Figure 6-5: Oahe elevation change between each alternative and No Action for all days in the period-of-record.

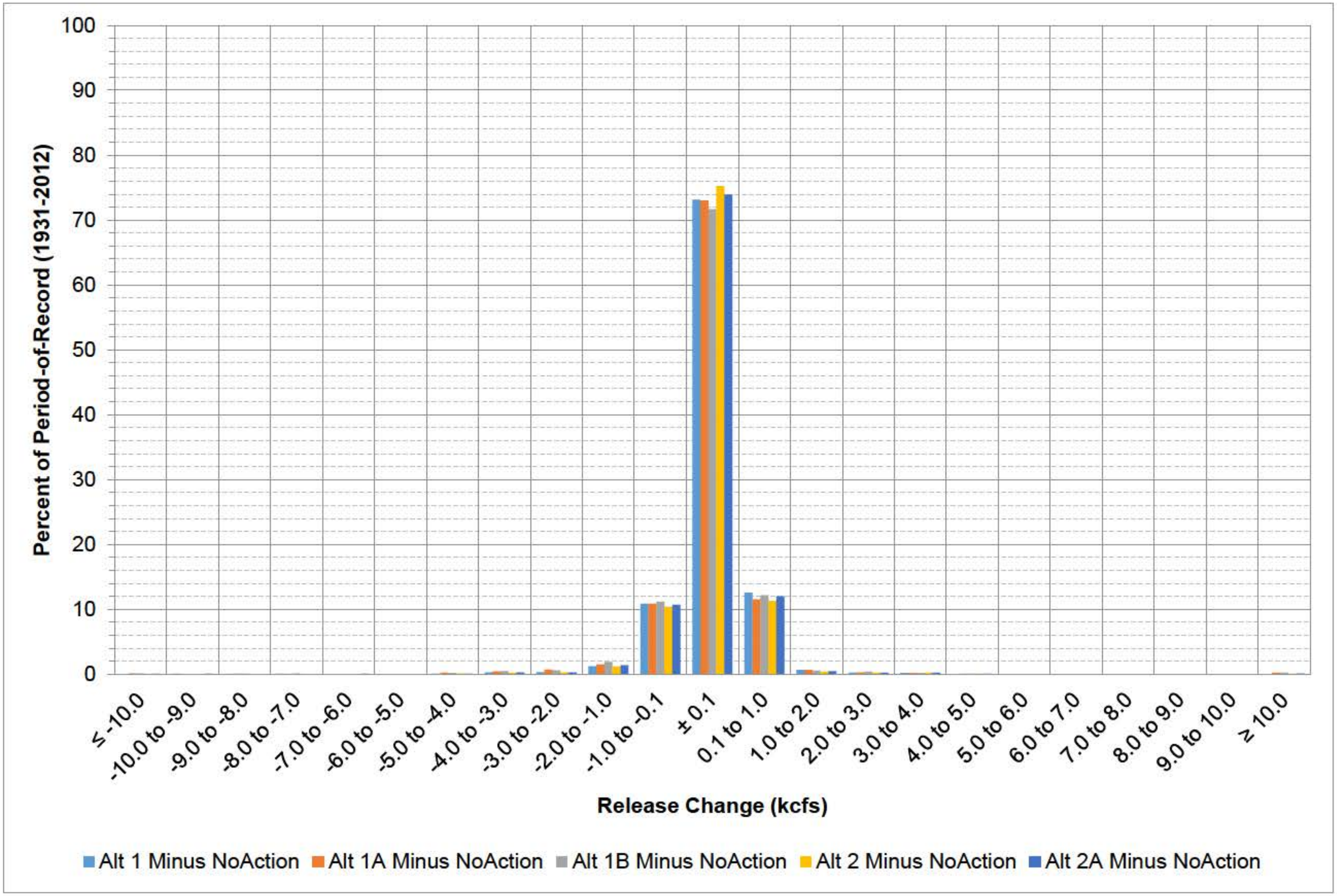

Figure 6-6: Oahe release change between each alternative and No Action for all days in the period-of-record.

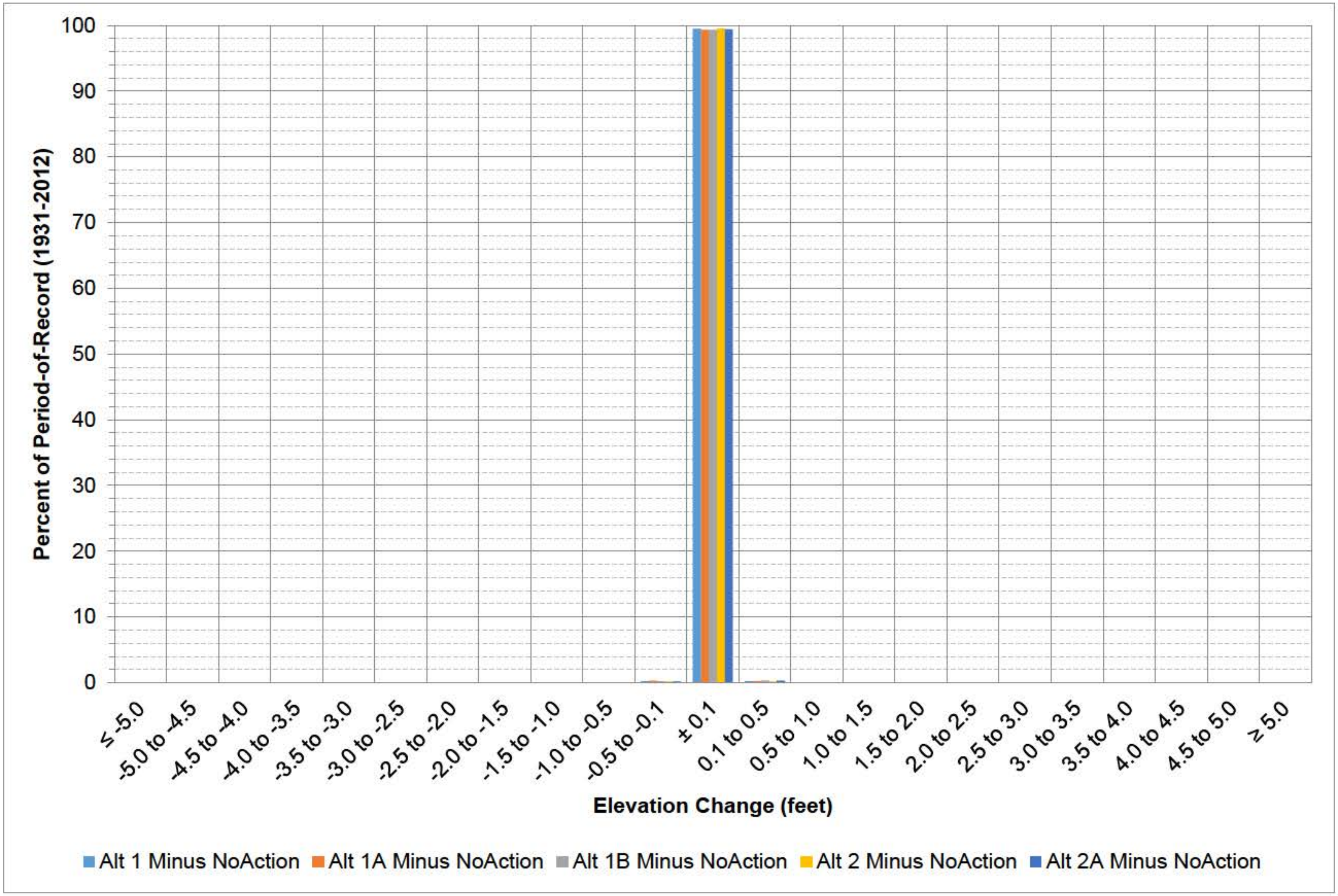

Figure 6-7: Big Bend elevation change between each alternative and No Action for all days in the period-of-record.

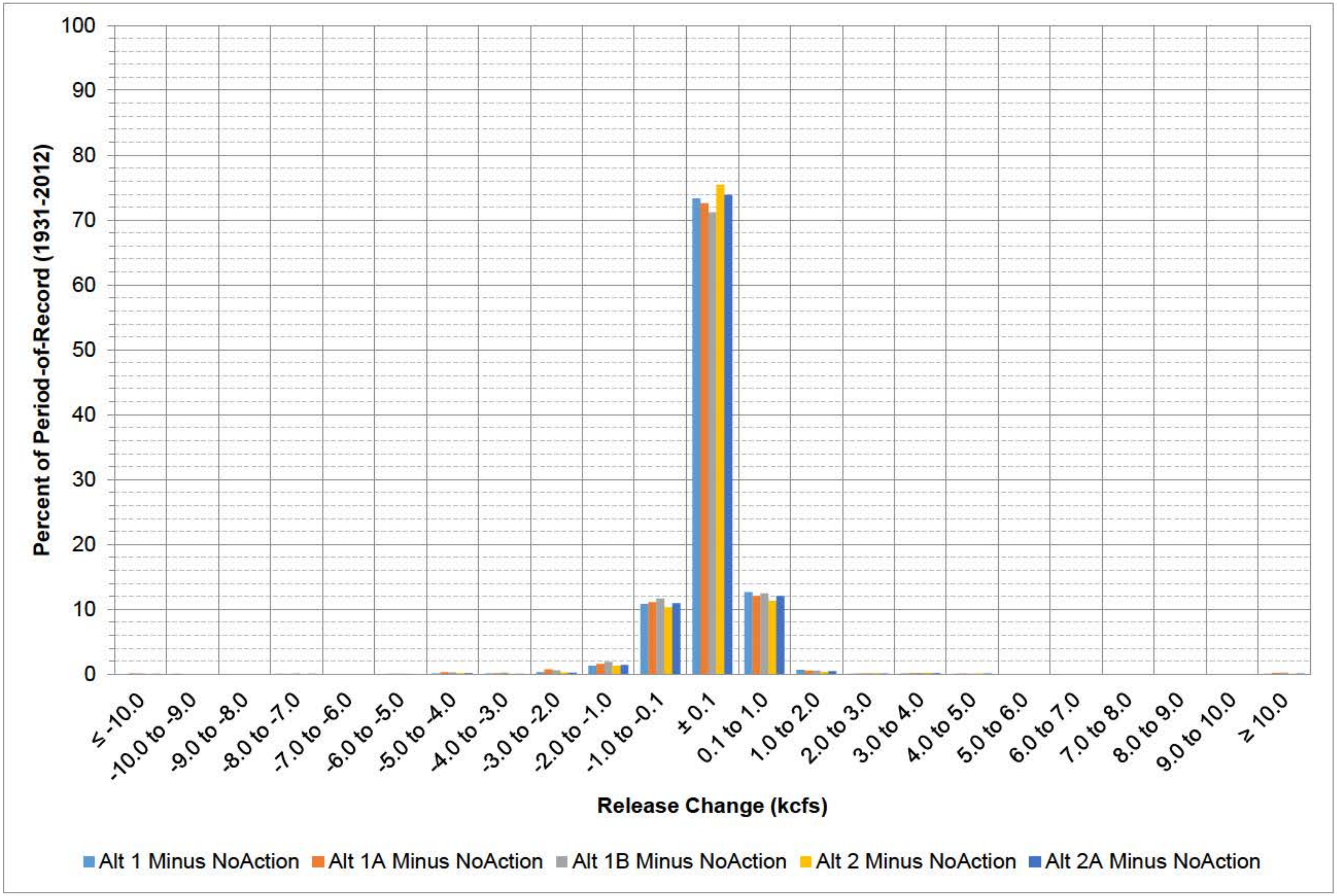

Figure 6-8: Big Bend release change between each alternative and No Action for all days in the period-of-record.

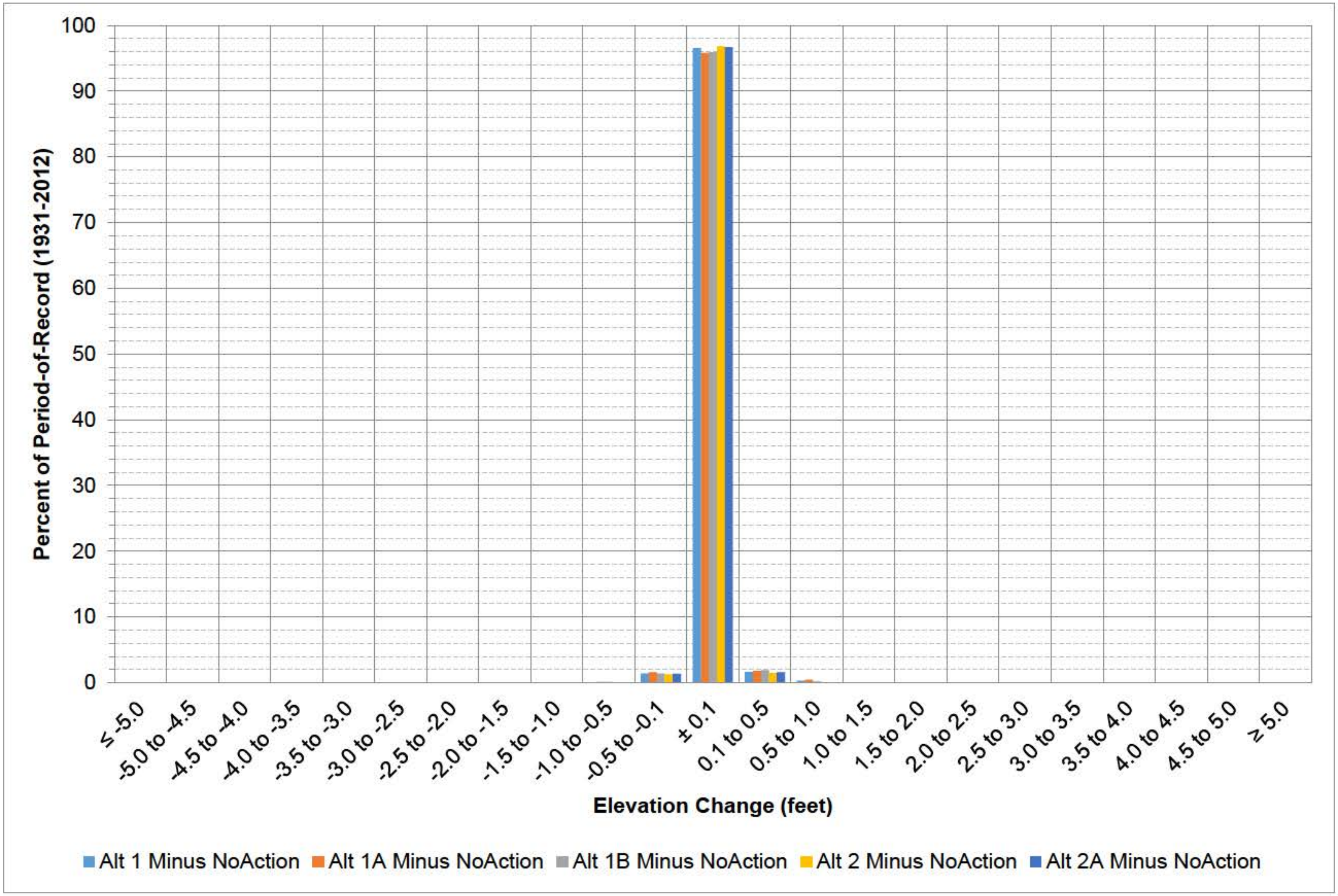

Figure 6-9: Fort Randall elevation change between each alternative and No Action for all days in the period-of-record.

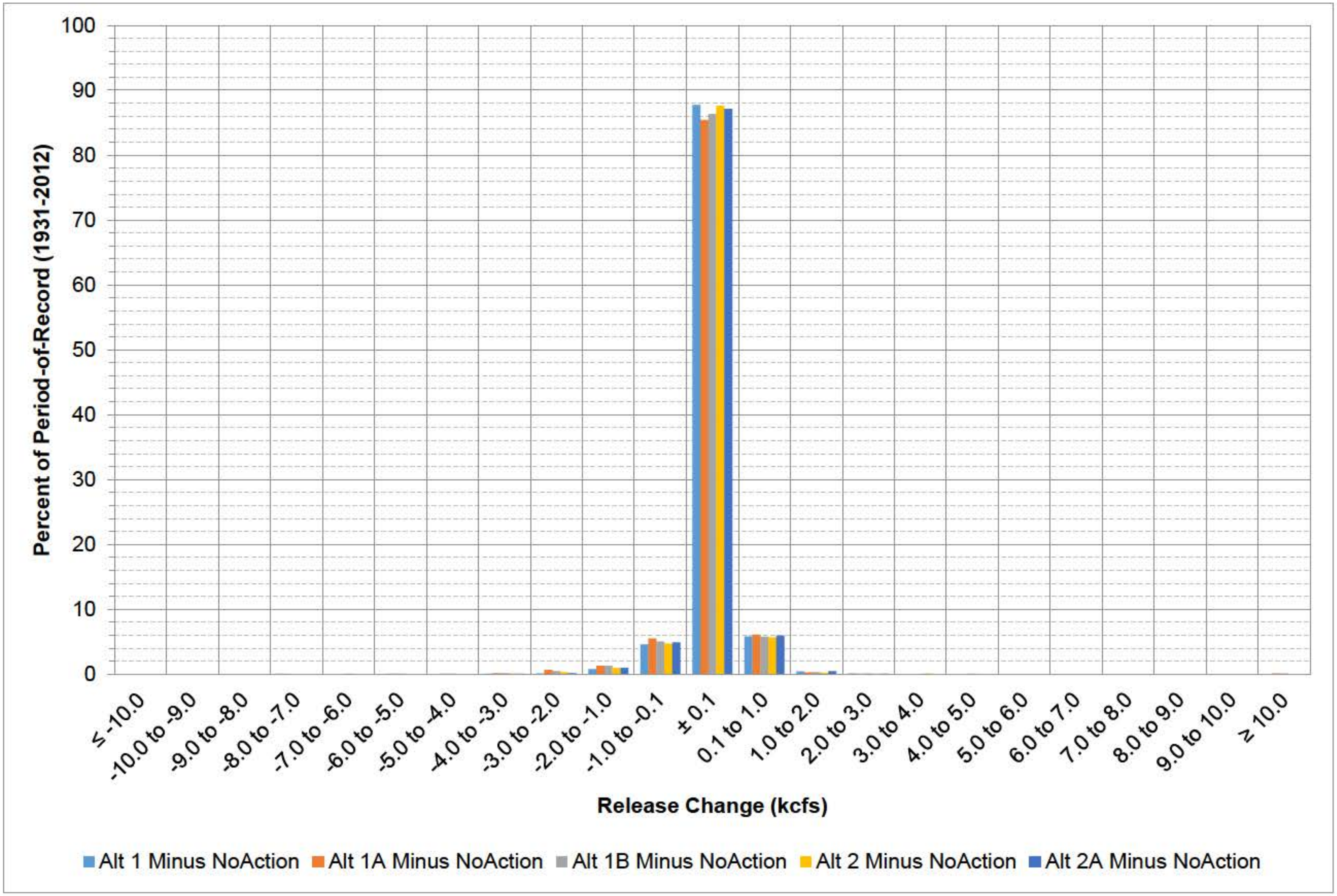

Figure 6-10: Fort Randall release change between each alternative and No Action for all days in the period-of-record.

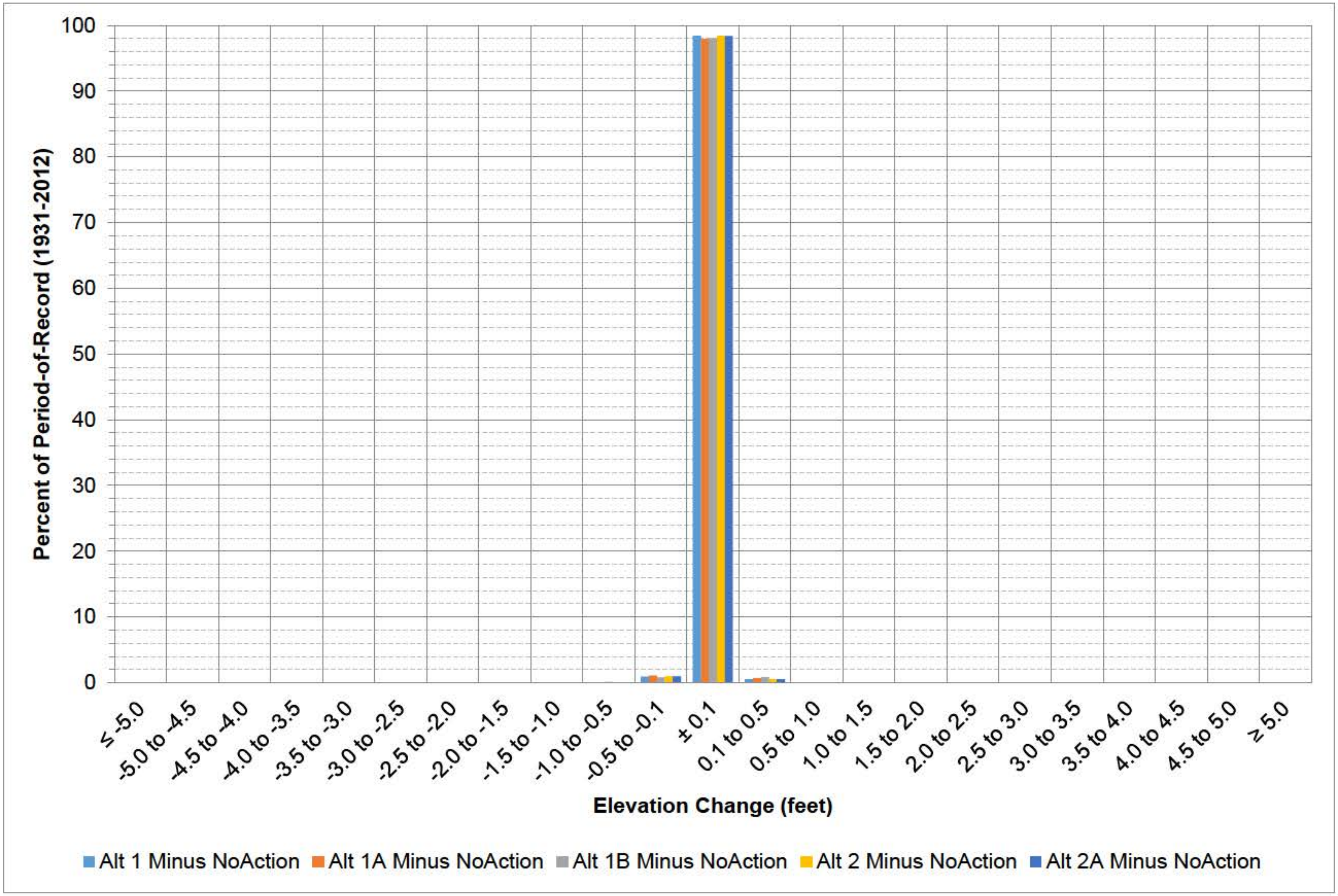

Figure 6-11: Gavins Point elevation change between each alternative and No Action for all days in the period-of-record.

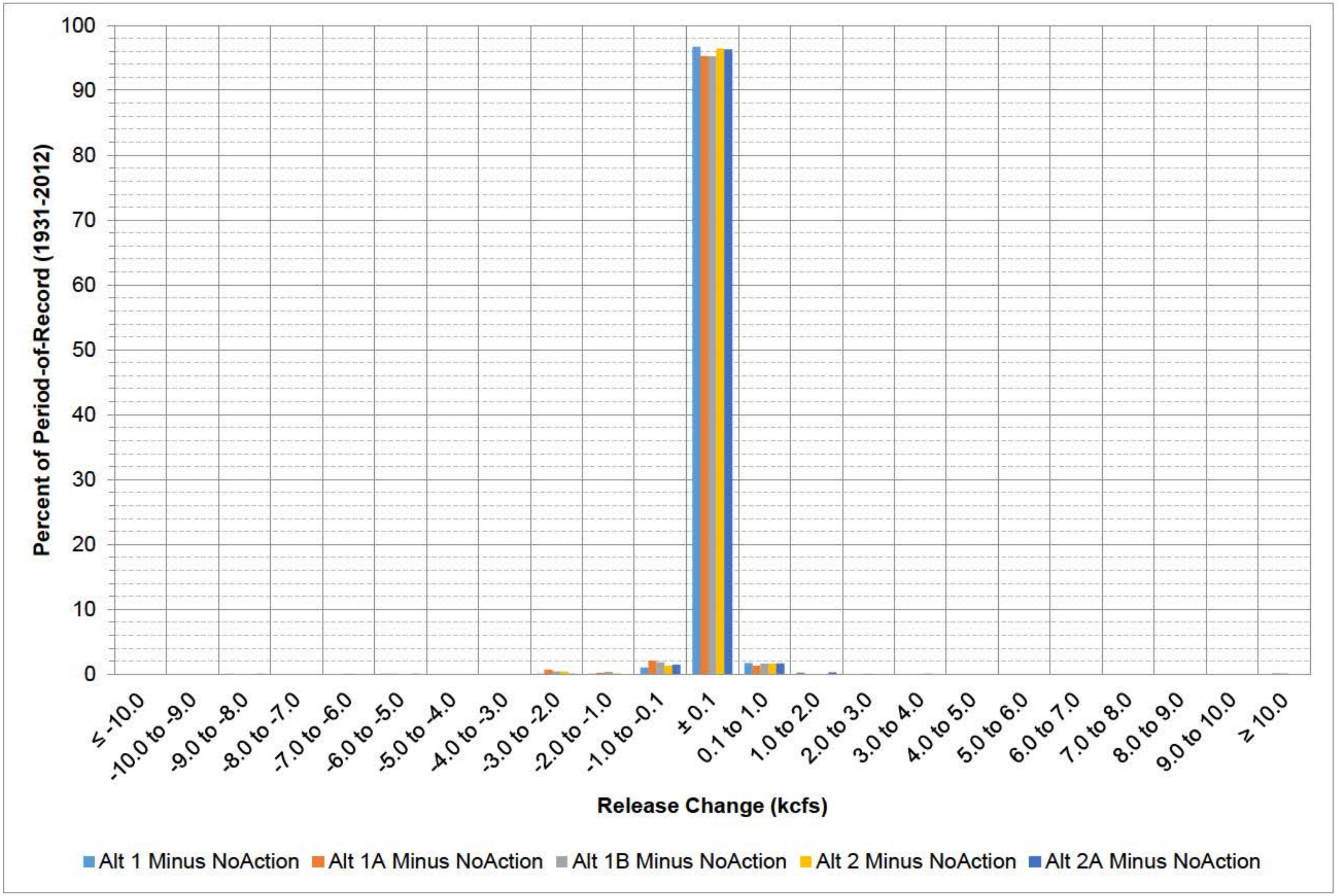

Figure 6-12: Gavins Point release change between each alternative and No Action for all days in the period-of-record.

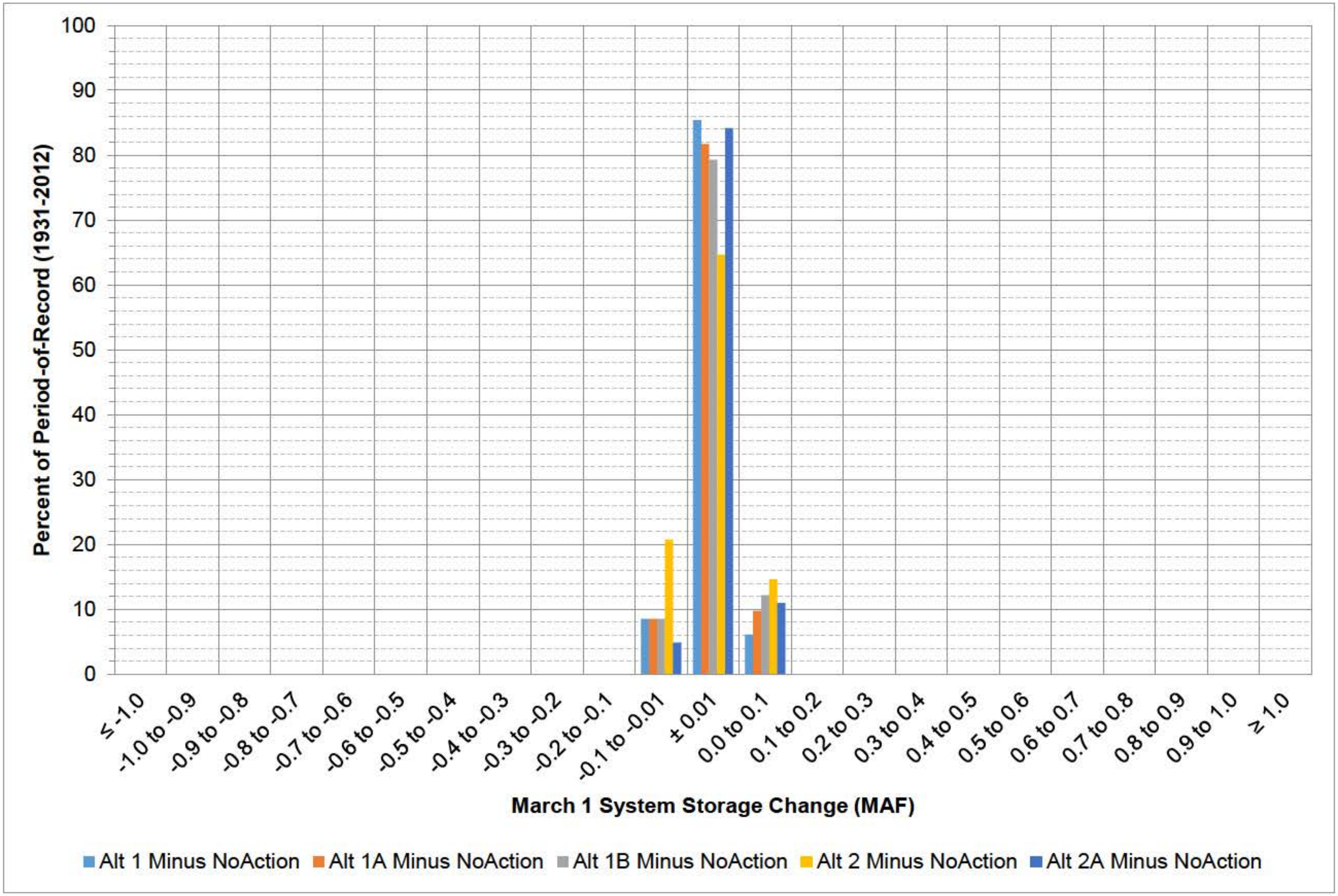

Figure 6-13: March 1 System storage change between each alternative and No Action for all years in the period-of-record.

7 REFERENCES

U.S. Army Corps of Engineers. (2018). *Mainstem Missouri River Reservoir Simulation Report.* Omaha, NE: USACE.

U.S. Army Corps of Engineers. (2018). *Missouri River Mainstem Reservoir System Master Water Control Manual.* Omaha: USACE.

U.S. Army Corps of Engineers. (2020). *Fort Peck Flow Test Environmental Impact Statement.* Omaha: USACE.

8 APPENDIX A – STATISTICS OF ELEVATION AND RELEASE DIFFERENCES

Table 8-1: Summary statistics of elevation change in feet between each alternative and No Action for all days in the period-of-record grouped by mainstem project. The quantiles are listed as 10Q, 25Q, etc., which show non-exceedance values.

		Mean	St Dev	Skew	10Q	25Q	50Q	75Q	90Q
Fort Peck	Alt 1 Minus No Action	-0.2	0.7	-3.3	-0.9	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	-0.1	0.7	0.9	-0.6	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	-0.2	0.7	-3.0	-0.8	0.0	0.0	0.0	0.1
	Alt 2 Minus No Action	-0.3	1.0	-3.2	-1.1	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	-0.3	1.1	-1.8	-1.7	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	-0.4	1.0	-2.9	-1.7	-0.1	0.0	0.0	0.0
Garrison	Alt 1 Minus No Action	0.2	0.5	3.5	0.0	0.0	0.0	0.0	0.6
	Alt 1a Minus No Action	0.1	0.5	-1.0	0.0	0.0	0.0	0.0	0.4
	Alt 1b Minus No Action	0.1	0.5	3.0	-0.1	0.0	0.0	0.0	0.6
	Alt 2 Minus No Action	0.2	0.6	3.6	-0.1	0.0	0.0	0.0	0.7
	Alt 2a Minus No Action	0.2	0.8	2.2	0.0	0.0	0.0	0.0	0.9
	Alt 2b Minus No Action	0.2	0.6	3.0	0.0	0.0	0.0	0.0	0.8
Oahe	Alt 1 Minus No Action	0.0	0.3	-3.4	-0.1	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.3	-6.2	-0.1	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	0.3	-4.4	-0.1	0.0	0.0	0.0	0.1
	Alt 2 Minus No Action	0.0	0.3	3.5	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.3	-0.1	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.1	0.4	1.9	-0.1	0.0	0.0	0.0	0.2
Big Bend	Alt 1 Minus No Action	0.0	0.0	-18.5	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.1	7.1	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	0.0	-0.6	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.0	-9.0	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.1	1.5	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.0	-13.5	0.0	0.0	0.0	0.0	0.0
Fort Randall	Alt 1 Minus No Action	0.0	0.1	-22.3	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.1	16.8	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	0.2	16.2	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.1	15.6	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.2	23.4	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.3	20.7	0.0	0.0	0.0	0.0	0.0

		Mean	St Dev	Skew	10Q	25Q	50Q	75Q	90Q
Gavins Point	Alt 1 Minus No Action	0.0	0.1	-16.1	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.1	-25.2	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	0.1	-1.9	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.1	-33.8	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.1	-16.4	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.1	-20.2	0.0	0.0	0.0	0.0	0.0

Table 8-2: Summary statistics of release change in kcfs between each alternative and No Action for all days in the period-of-record grouped by mainstem project. The quantiles are listed as 10Q, 25Q, etc., which show non-exceedance values.

		Mean	St Dev	Skew	10Q	25Q	50Q	75Q	90Q
Fort Peck	Alt 1 Minus No Action	0.0	1.6	4.3	-0.5	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	1.7	2.6	-0.4	0.0	0.0	0.0	0.1
	Alt 1b Minus No Action	0.0	1.5	4.0	-0.4	0.0	0.0	0.0	0.1
	Alt 2 Minus No Action	0.0	1.8	3.4	-0.9	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	2.1	3.0	-1.2	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	1.7	3.9	-1.0	0.0	0.0	0.0	0.0
Garrison	Alt 1 Minus No Action	0.0	1.3	-28.4	-0.1	0.0	0.0	0.0	0.1
	Alt 1a Minus No Action	0.0	0.8	-5.3	-0.1	0.0	0.0	0.0	0.1
	Alt 1b Minus No Action	0.0	1.7	-20.9	-0.1	0.0	0.0	0.0	0.1
	Alt 2 Minus No Action	0.0	1.1	-1.6	-0.1	0.0	0.0	0.0	0.1
	Alt 2a Minus No Action	0.0	1.5	-19.0	-0.1	0.0	0.0	0.0	0.1
	Alt 2b Minus No Action	0.0	1.1	-3.3	-0.1	0.0	0.0	0.0	0.1
Oahe	Alt 1 Minus No Action	0.0	0.9	13.0	-0.5	0.0	0.0	0.0	0.5
	Alt 1a Minus No Action	0.0	1.6	5.7	-0.5	0.0	0.0	0.0	0.5
	Alt 1b Minus No Action	0.0	1.8	5.0	-0.5	0.0	0.0	0.0	0.5
	Alt 2 Minus No Action	0.0	1.2	-19.4	-0.5	0.0	0.0	0.0	0.5
	Alt 2a Minus No Action	0.0	1.3	2.3	-0.5	0.0	0.0	0.0	0.5
	Alt 2b Minus No Action	0.0	1.4	-6.7	-0.5	0.0	0.0	0.0	0.5
Big Bend	Alt 1 Minus No Action	0.0	0.9	11.1	-0.5	0.0	0.0	0.0	0.5
	Alt 1a Minus No Action	0.0	1.5	6.8	-0.5	0.0	0.0	0.0	0.5
	Alt 1b Minus No Action	0.0	1.7	4.1	-0.5	0.0	0.0	0.0	0.5
	Alt 2 Minus No Action	0.0	1.1	-18.8	-0.5	0.0	0.0	0.0	0.5

		Mean	St Dev	Skew	10Q	25Q	50Q	75Q	90Q
	Alt 2a Minus No Action	0.0	1.3	-4.0	-0.5	0.0	0.0	0.0	0.5
	Alt 2b Minus No Action	0.0	1.4	-7.5	-0.5	0.0	0.0	0.0	0.5
Fort Randall	Alt 1 Minus No Action	0.0	0.6	3.5	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	1.0	19.3	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	1.0	17.6	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.5	10.1	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.6	4.8	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.5	6.8	0.0	0.0	0.0	0.0	0.0
Gavins Point	Alt 1 Minus No Action	0.0	0.4	9.7	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.9	24.8	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	0.8	23.9	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.3	12.3	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.4	11.5	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.3	6.9	0.0	0.0	0.0	0.0	0.0

Table 8-3: Summary statistics of elevation change in feet between each alternative and No Action for spring months grouped by mainstem project. The quantiles are listed as 10Q, 25Q, etc., which show non-exceedance values.

		Mean	St Dev	Skew	10Q	25Q	50Q	75Q	90Q
Fort Peck	Alt 1 Minus No Action	-0.1	0.3	-3.5	-0.1	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	-0.1	0.3	-3.0	-0.3	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	0.3	-2.0	-0.2	0.0	0.0	0.0	0.1
	Alt 2 Minus No Action	-0.1	0.5	-7.0	-0.1	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	-0.1	0.5	-6.0	-0.1	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	-0.1	0.6	-5.4	-0.3	0.0	0.0	0.0	0.0
Garrison	Alt 1 Minus No Action	0.0	0.1	4.3	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.1	1.9	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	0.1	2.0	-0.1	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.1	4.1	-0.1	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.1	4.4	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.1	4.2	0.0	0.0	0.0	0.0	0.0
Oahe	Alt 1 Minus No Action	0.0	0.2	3.5	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.3	-6.8	-0.1	0.0	0.0	0.0	0.0

		Mean	St Dev	Skew	10Q	25Q	50Q	75Q	90Q
	Alt 1b Minus No Action	0.0	0.3	-5.8	-0.1	0.0	0.0	0.0	0.1
	Alt 2 Minus No Action	0.0	0.3	7.0	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.3	7.1	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.1	0.3	5.4	0.0	0.0	0.0	0.0	0.1
Big Bend	Alt 1 Minus No Action	0.0	0.0	-0.7	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	0.0	-0.6	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.0	-1.3	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.0	-1.2	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.0	-4.8	0.0	0.0	0.0	0.0	0.0
Fort Randall	Alt 1 Minus No Action	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	0.1	-0.1	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.0	2.6	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.0	-0.3	0.0	0.0	0.0	0.0	0.0
Gavins Point	Alt 1 Minus No Action	0.0	0.0	5.5	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.0	-4.0	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	0.0	-3.0	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.0	5.5	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.0	5.5	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.0	-2.5	0.0	0.0	0.0	0.0	0.0

Table 8-4: Summary statistics of release change in kcfs between each alternative and No Action for spring months grouped by mainstem project. The quantiles are listed as 10Q, 25Q, etc., which show non-exceedance values.

		Mean	St Dev	Skew	10Q	25Q	50Q	75Q	90Q
Fort Peck	Alt 1 Minus No Action	0.3	1.3	4.7	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.2	0.9	4.2	0.0	0.0	0.0	0.0	0.2
	Alt 1b Minus No Action	0.2	1.2	5.6	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.3	1.3	4.1	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.4	1.5	3.4	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.2	1.1	4.9	0.0	0.0	0.0	0.0	0.0
Garrison	Alt 1 Minus No Action	0.0	0.2	38.5	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.1	-0.2	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	0.2	1.8	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.1	46.3	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.2	33.5	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.3	10.1	-0.1	0.0	0.0	0.0	0.0
Oahe	Alt 1 Minus No Action	0.0	0.4	-4.0	-0.5	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.1	2.1	13.7	-0.5	0.0	0.0	0.0	0.5
	Alt 1b Minus No Action	0.1	2.1	13.7	-0.5	0.0	0.0	0.0	0.5
	Alt 2 Minus No Action	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.4	-0.8	-0.5	0.0	0.0	0.0	0.5
	Alt 2b Minus No Action	0.0	0.4	-0.6	-0.5	0.0	0.0	0.0	0.5
Big Bend	Alt 1 Minus No Action	0.0	0.4	-4.5	-0.5	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.1	2.0	14.3	-0.5	0.0	0.0	0.0	0.5
	Alt 1b Minus No Action	0.1	2.0	14.2	-0.5	0.0	0.0	0.0	0.5
	Alt 2 Minus No Action	0.0	0.3	2.4	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.3	0.1	-0.5	0.0	0.0	0.0	0.5
	Alt 2b Minus No Action	0.0	0.3	0.5	-0.5	0.0	0.0	0.0	0.5
Fort Randall	Alt 1 Minus No Action	0.0	0.3	-6.7	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.1	1.7	16.1	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.1	1.7	15.8	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.3	-6.9	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.3	-6.8	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.2	-2.9	0.0	0.0	0.0	0.0	0.0

		Mean	St Dev	Skew	10Q	25Q	50Q	75Q	90Q
Gavins Point	Alt 1 Minus No Action	0.0	0.1	-13.6	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.1	1.7	15.9	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.1	1.7	15.9	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.1	-14.6	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.1	-11.9	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.0	-3.5	0.0	0.0	0.0	0.0	0.0

Table 8-5: Summary statistics of elevation change in feet between each alternative and No Action for summer months grouped by mainstem project. The quantiles are listed as 10Q, 25Q, etc., which show non-exceedance values.

		Mean	St Dev	Skew	10Q	25Q	50Q	75Q	90Q
Fort Peck	Alt 1 Minus No Action	-0.3	0.8	-3.5	-1.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	-0.2	0.7	-1.0	-0.8	-0.1	0.0	0.0	0.0
	Alt 1b Minus No Action	-0.2	0.7	-3.4	-0.9	-0.1	0.0	0.0	0.1
	Alt 2 Minus No Action	-0.3	1.0	-3.3	-1.2	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	-0.4	1.2	-2.4	-1.9	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	-0.4	1.1	-2.9	-1.7	-0.1	0.0	0.0	0.0
Garrison	Alt 1 Minus No Action	0.2	0.5	4.0	0.0	0.0	0.0	0.0	0.6
	Alt 1a Minus No Action	0.1	0.4	1.0	0.0	0.0	0.0	0.0	0.4
	Alt 1b Minus No Action	0.1	0.5	3.9	0.0	0.0	0.0	0.0	0.5
	Alt 2 Minus No Action	0.2	0.6	4.0	-0.1	0.0	0.0	0.0	0.6
	Alt 2a Minus No Action	0.2	0.8	2.8	0.0	0.0	0.0	0.0	0.9
	Alt 2b Minus No Action	0.2	0.6	3.5	0.0	0.0	0.0	0.0	0.8
Oahe	Alt 1 Minus No Action	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.3	-6.4	-0.1	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	0.3	-4.8	-0.1	0.0	0.0	0.0	0.1
	Alt 2 Minus No Action	0.0	0.3	5.5	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.3	4.5	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.1	0.3	3.4	-0.1	0.0	0.0	0.0	0.1
Big Bend	Alt 1 Minus No Action	0.0	0.0	-4.8	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.0	9.1	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	0.0	21.9	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.0	12.7	0.0	0.0	0.0	0.0	0.0

		Mean	St Dev	Skew	10Q	25Q	50Q	75Q	90Q
	Alt 2a Minus No Action	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.0	20.4	0.0	0.0	0.0	0.0	0.0
Fort Randall	Alt 1 Minus No Action	0.0	0.1	17.7	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.1	5.6	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	0.1	17.7	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.2	25.9	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.2	20.3	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.3	27.1	0.0	0.0	0.0	0.0	0.0
Gavins Point	Alt 1 Minus No Action	0.0	0.0	8.3	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.1	-27.3	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	0.1	7.5	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.1	-32.2	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.0	9.8	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.1	-19.2	0.0	0.0	0.0	0.0	0.0

Table 8-6: Summary statistics of release change in kcfs between each alternative and No Action for summer months grouped by mainstem project. The quantiles are listed as 10Q, 25Q, etc., which show non-exceedance values.

		Mean	St Dev	Skew	10Q	25Q	50Q	75Q	90Q
Fort Peck	Alt 1 Minus No Action	0.1	1.9	4.0	-0.4	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	1.7	1.4	-0.4	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.1	1.7	4.1	-0.3	0.0	0.0	0.0	0.1
	Alt 2 Minus No Action	0.1	2.0	3.4	-0.4	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.1	2.3	2.5	-0.9	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.1	2.0	3.7	-0.5	0.0	0.0	0.0	0.1
Garrison	Alt 1 Minus No Action	0.0	0.7	-0.7	-0.1	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.5	0.4	-0.1	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	1.2	-25.5	-0.1	0.0	0.0	0.0	0.1
	Alt 2 Minus No Action	0.0	0.9	7.8	-0.1	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.9	-2.7	-0.1	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.9	7.8	-0.1	0.0	0.0	0.0	0.1
Oahe	Alt 1 Minus No Action	0.0	0.7	-3.9	-0.5	0.0	0.0	0.0	0.5
	Alt 1a Minus No Action	0.0	1.3	13.1	-0.5	0.0	0.0	0.0	0.5

		Mean	St Dev	Skew	10Q	25Q	50Q	75Q	90Q
	Alt 1b Minus No Action	0.0	1.8	3.3	-0.5	0.0	0.0	0.0	0.5
	Alt 2 Minus No Action	0.0	0.9	5.2	-0.5	0.0	0.0	0.0	0.5
	Alt 2a Minus No Action	0.0	1.0	17.7	-0.5	0.0	0.0	0.0	0.5
	Alt 2b Minus No Action	0.0	1.5	-10.0	-0.5	0.0	0.0	0.0	0.5
Big Bend	Alt 1 Minus No Action	0.0	0.7	-2.4	-0.5	0.0	0.0	0.0	0.5
	Alt 1a Minus No Action	0.0	1.3	12.7	-0.5	0.0	0.0	0.0	0.5
	Alt 1b Minus No Action	0.0	1.8	3.2	-0.5	0.0	0.0	0.0	0.5
	Alt 2 Minus No Action	0.0	0.9	-5.9	-0.5	0.0	0.0	0.0	0.5
	Alt 2a Minus No Action	0.0	1.2	-3.1	-0.5	0.0	0.0	0.0	0.5
	Alt 2b Minus No Action	0.0	1.5	-9.5	-0.5	0.0	0.0	0.0	0.5
Fort Randall	Alt 1 Minus No Action	0.0	1.0	19.2	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.5	-9.7	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	1.0	19.2	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	1.0	17.3	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.5	12.4	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.5	-9.5	0.0	0.0	0.0	0.0	0.0
Gavins Point	Alt 1 Minus No Action	0.0	0.3	-16.3	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.9	25.5	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	0.9	23.4	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.3	19.8	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.3	-17.6	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.3	6.5	0.0	0.0	0.0	0.0	0.0

Table 8-7: Summary statistics of elevation change in feet between each alternative and No Action for fall months grouped by mainstem project. The quantiles are listed as 10Q, 25Q, etc., which show non-exceedance values.

		Mean	St Dev	Skew	10Q	25Q	50Q	75Q	90Q
Fort Peck	Alt 1 Minus No Action	-0.2	0.8	-3.2	-0.9	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	-0.1	0.7	1.0	-0.7	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	-0.2	0.7	-3.0	-0.8	0.0	0.0	0.0	0.1
	Alt 2 Minus No Action	-0.3	1.0	-3.1	-1.3	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	-0.4	1.1	-1.7	-1.8	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	-0.4	1.0	-2.8	-1.7	-0.2	0.0	0.0	0.0
Garrison	Alt 1 Minus No Action	0.2	0.6	3.5	0.0	0.0	0.0	0.0	0.6
	Alt 1a Minus No Action	0.1	0.5	-1.0	0.0	0.0	0.0	0.0	0.4
	Alt 1b Minus No Action	0.1	0.5	3.0	-0.1	0.0	0.0	0.0	0.6
	Alt 2 Minus No Action	0.2	0.7	3.6	-0.1	0.0	0.0	0.0	0.7
	Alt 2a Minus No Action	0.2	0.8	2.1	0.0	0.0	0.0	0.0	1.0
	Alt 2b Minus No Action	0.2	0.6	3.0	0.0	0.0	0.0	0.0	0.9
Oahe	Alt 1 Minus No Action	0.0	0.3	-3.3	-0.1	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.3	-6.1	-0.1	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	0.4	-4.4	-0.1	0.0	0.0	0.0	0.1
	Alt 2 Minus No Action	0.0	0.3	3.4	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.1	0.4	1.8	-0.1	0.0	0.0	0.0	0.2
Big Bend	Alt 1 Minus No Action	0.0	0.0	-18.8	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.1	6.9	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	0.1	-0.6	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.0	-8.7	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.1	1.5	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.0	-13.0	0.0	0.0	0.0	0.0	0.0
Fort Randall	Alt 1 Minus No Action	0.0	0.1	-22.0	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.1	16.6	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	0.2	15.7	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.1	15.1	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.2	22.5	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.3	19.8	0.0	0.0	0.0	0.0	0.0

		Mean	St Dev	Skew	10Q	25Q	50Q	75Q	90Q
Gavins Point	Alt 1 Minus No Action	0.0	0.1	-15.7	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.1	-24.6	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	0.1	-1.8	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.1	-33.1	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.1	-16.0	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.1	-19.6	0.0	0.0	0.0	0.0	0.0

Table 8-8: Summary statistics of release change in kcfs between each alternative and No Action for fall months grouped by mainstem project. The quantiles are listed as 10Q, 25Q, etc., which show non-exceedance values.

		Mean	St Dev	Skew	10Q	25Q	50Q	75Q	90Q
Fort Peck	Alt 1 Minus No Action	0.0	1.7	4.1	-0.5	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	1.7	2.5	-0.4	0.0	0.0	0.0	0.1
	Alt 1b Minus No Action	0.0	1.6	3.8	-0.5	0.0	0.0	0.0	0.1
	Alt 2 Minus No Action	0.0	1.8	3.3	-0.9	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	2.2	2.9	-1.2	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	1.8	3.8	-1.0	0.0	0.0	0.0	0.0
Garrison	Alt 1 Minus No Action	0.0	1.3	-28.0	-0.1	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.8	-5.2	-0.1	0.0	0.0	0.0	0.1
	Alt 1b Minus No Action	0.0	1.8	-20.3	-0.1	0.0	0.0	0.0	0.1
	Alt 2 Minus No Action	0.0	1.1	-1.7	-0.1	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	1.6	-18.9	-0.1	0.0	0.0	0.0	0.1
	Alt 2b Minus No Action	0.0	1.1	-3.2	-0.1	0.0	0.0	0.0	0.1
Oahe	Alt 1 Minus No Action	0.0	0.9	13.2	-0.5	0.0	0.0	0.0	0.5
	Alt 1a Minus No Action	0.0	1.7	5.6	-0.5	0.0	0.0	0.0	0.5
	Alt 1b Minus No Action	0.0	1.8	4.8	-0.5	0.0	0.0	0.0	0.5
	Alt 2 Minus No Action	0.0	1.2	-18.9	-0.5	0.0	0.0	0.0	0.5
	Alt 2a Minus No Action	0.0	1.4	2.2	-0.5	0.0	0.0	0.0	0.5
	Alt 2b Minus No Action	0.0	1.5	-6.5	-0.5	0.0	0.0	0.0	0.5
Big Bend	Alt 1 Minus No Action	0.0	0.9	11.2	-0.5	0.0	0.0	0.0	0.5
	Alt 1a Minus No Action	0.0	1.6	6.7	-0.5	0.0	0.0	0.0	0.5
	Alt 1b Minus No Action	0.0	1.8	4.0	-0.5	0.0	0.0	0.0	0.5
	Alt 2 Minus No Action	0.0	1.2	-18.4	-0.5	0.0	0.0	0.0	0.5

		Mean	St Dev	Skew	10Q	25Q	50Q	75Q	90Q
	Alt 2a Minus No Action	0.0	1.4	-3.9	-0.5	0.0	0.0	0.0	0.5
	Alt 2b Minus No Action	0.0	1.5	-7.2	-0.5	0.0	0.0	0.0	0.5
Fort Randall	Alt 1 Minus No Action	0.0	0.6	3.4	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	1.0	18.7	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	1.0	17.0	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.5	10.1	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.6	4.7	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.6	6.6	0.0	0.0	0.0	0.0	0.0
Gavins Point	Alt 1 Minus No Action	0.0	0.4	9.3	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.9	23.7	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	0.9	22.9	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.3	12.1	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.4	11.1	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.3	6.6	0.0	0.0	0.0	0.0	0.0

Table 8-9: Summary statistics of elevation change in feet between each alternative and No Action for winter months grouped by mainstem project. The quantiles are listed as 10Q, 25Q, etc., which show non-exceedance values.

		Mean	St Dev	Skew	10Q	25Q	50Q	75Q	90Q
Fort Peck	Alt 1 Minus No Action	-0.2	0.7	-3.3	-0.9	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	-0.1	0.7	0.9	-0.6	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	-0.2	0.7	-3.0	-0.8	0.0	0.0	0.0	0.1
	Alt 2 Minus No Action	-0.3	1.0	-3.2	-1.1	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	-0.3	1.1	-1.8	-1.7	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	-0.4	1.0	-2.9	-1.7	-0.1	0.0	0.0	0.0
Garrison	Alt 1 Minus No Action	0.1	0.5	-1.0	0.0	0.0	0.0	0.0	0.4
	Alt 1a Minus No Action	0.2	0.5	3.5	0.0	0.0	0.0	0.0	0.6
	Alt 1b Minus No Action	0.1	0.5	-1.0	0.0	0.0	0.0	0.0	0.4
	Alt 2 Minus No Action	0.1	0.5	3.0	-0.1	0.0	0.0	0.0	0.6
	Alt 2a Minus No Action	0.2	0.6	3.6	-0.1	0.0	0.0	0.0	0.7
	Alt 2b Minus No Action	0.2	0.8	2.2	0.0	0.0	0.0	0.0	0.9
Oahe	Alt 1 Minus No Action	0.0	0.3	-3.4	-0.1	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.3	-6.2	-0.1	0.0	0.0	0.0	0.0

		Mean	St Dev	Skew	10Q	25Q	50Q	75Q	90Q
	Alt 1b Minus No Action	0.0	0.3	-4.4	-0.1	0.0	0.0	0.0	0.1
	Alt 2 Minus No Action	0.0	0.3	3.5	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.3	-0.1	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.1	0.4	1.9	-0.1	0.0	0.0	0.0	0.2
Big Bend	Alt 1 Minus No Action	0.0	0.0	-18.5	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.1	7.1	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	0.0	-0.6	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.0	-9.0	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.1	1.5	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.0	-13.5	0.0	0.0	0.0	0.0	0.0
Fort Randall	Alt 1 Minus No Action	0.0	0.1	-22.3	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.1	16.8	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	0.2	16.2	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.1	15.6	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.2	23.4	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.3	20.7	0.0	0.0	0.0	0.0	0.0
Gavins Point	Alt 1 Minus No Action	0.0	0.1	-16.1	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	0.1	-25.2	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	0.1	-1.9	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.1	-33.8	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.1	-16.4	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.1	-20.2	0.0	0.0	0.0	0.0	0.0

Table 8-10: Summary statistics of release change in kcfs between each alternative and No Action for winter months grouped by mainstem project. The quantiles are listed as 10Q, 25Q, etc., which show non-exceedance values.

		Mean	St Dev	Skew	10Q	25Q	50Q	75Q	90Q
Fort Peck	Alt 1 Minus No Action	0.0	1.6	4.3	-0.5	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	1.7	2.6	-0.4	0.0	0.0	0.0	0.1
	Alt 1b Minus No Action	0.0	1.5	4.0	-0.4	0.0	0.0	0.0	0.1
	Alt 2 Minus No Action	0.0	1.8	3.4	-0.9	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	2.1	3.0	-1.2	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	1.7	3.9	-1.0	0.0	0.0	0.0	0.0
Garrison	Alt 1 Minus No Action	0.0	0.8	-5.3	-0.1	0.0	0.0	0.0	0.1
	Alt 1a Minus No Action	0.0	1.3	-28.4	-0.1	0.0	0.0	0.0	0.1
	Alt 1b Minus No Action	0.0	0.8	-5.3	-0.1	0.0	0.0	0.0	0.1
	Alt 2 Minus No Action	0.0	1.7	-20.9	-0.1	0.0	0.0	0.0	0.1
	Alt 2a Minus No Action	0.0	1.1	-1.6	-0.1	0.0	0.0	0.0	0.1
	Alt 2b Minus No Action	0.0	1.5	-19.0	-0.1	0.0	0.0	0.0	0.1
Oahe	Alt 1 Minus No Action	0.0	0.9	13.0	-0.5	0.0	0.0	0.0	0.5
	Alt 1a Minus No Action	0.0	1.6	5.7	-0.5	0.0	0.0	0.0	0.5
	Alt 1b Minus No Action	0.0	1.8	5.0	-0.5	0.0	0.0	0.0	0.5
	Alt 2 Minus No Action	0.0	1.2	-19.4	-0.5	0.0	0.0	0.0	0.5
	Alt 2a Minus No Action	0.0	1.3	2.3	-0.5	0.0	0.0	0.0	0.5
	Alt 2b Minus No Action	0.0	1.4	-6.7	-0.5	0.0	0.0	0.0	0.5
Big Bend	Alt 1 Minus No Action	0.0	0.9	11.1	-0.5	0.0	0.0	0.0	0.5
	Alt 1a Minus No Action	0.0	1.5	6.8	-0.5	0.0	0.0	0.0	0.5
	Alt 1b Minus No Action	0.0	1.7	4.1	-0.5	0.0	0.0	0.0	0.5
	Alt 2 Minus No Action	0.0	1.1	-18.8	-0.5	0.0	0.0	0.0	0.5
	Alt 2a Minus No Action	0.0	1.3	-4.0	-0.5	0.0	0.0	0.0	0.5
	Alt 2b Minus No Action	0.0	1.4	-7.5	-0.5	0.0	0.0	0.0	0.5
Fort Randall	Alt 1 Minus No Action	0.0	0.6	3.5	0.0	0.0	0.0	0.0	0.0
	Alt 1a Minus No Action	0.0	1.0	19.3	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	1.0	17.6	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.5	10.1	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.6	4.8	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.5	6.8	0.0	0.0	0.0	0.0	0.0
Gavins Point	Alt 1 Minus No Action	0.0	0.4	9.7	0.0	0.0	0.0	0.0	0.0

		Mean	St Dev	Skew	10Q	25Q	50Q	75Q	90Q
	Alt 1a Minus No Action	0.0	0.9	24.8	0.0	0.0	0.0	0.0	0.0
	Alt 1b Minus No Action	0.0	0.8	23.9	0.0	0.0	0.0	0.0	0.0
	Alt 2 Minus No Action	0.0	0.3	12.3	0.0	0.0	0.0	0.0	0.0
	Alt 2a Minus No Action	0.0	0.4	11.5	0.0	0.0	0.0	0.0	0.0
	Alt 2b Minus No Action	0.0	0.3	6.9	0.0	0.0	0.0	0.0	0.0

US Army Corps of Engineers ®

Omaha District

Fort Peck Flow Test Release Environmental Impact Statement

HEC-RAS and Geomorphic Analysis Technical Report

September 2021

HEC-RAS and Geomorphic Analysis

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ACRONYMS

BiOp…………………..Biological Opinion

CFS…………………. Cubic Feet per Second

ESA…………………..Endangered Species Act

ESH…………………..Emergent Sandbar Habitat

FTPTR-EIS…………..Fort Peck Flow Test Release Environmental Impact Statement

HC……………………Human Considerations

HEC .... Hydrologic Engineering Center

MAF………………….. Million acre-feet

MRBWM…………... .. Missouri River Basin Water Management Division (previously RCC)

MRRPMP-EIS…..……Missouri River Recovery Program Management Plan Environmental Impact Statement

NAD 1983………… ... North American Datum of 1983

NAVD 88……………. North American Vertical Datum of 1988

NGVD 29……………. National Geodetic Vertical Datum of 1929

NWK………………… Northwest Division Kansas City District

NWO………………… Northwest Division Omaha District

POR .... Period of Record

RAS.......................... HEC River Analysis System Software (HEC-RAS)

ResSim………………....HEC Reservoir Simulation Software (HEC-ResSim)

RM……………………1960 River Mile

SWH…………………....Shallow Water Habitat

USACE……………….United States Army Corps of Engineers

USFWS……………….United States Fish and Wildlife Service

USGS....................... United States Geological Survey

1 INTRODUCTION

Hydrology and Hydraulic evaluation was performed in support of the Fort Peck Flow Test Release Environmental Impact Statement (FTPTR-EIS). Evaluation was performed to provide hydrologic information for assessment of potential impacts of a range of test flow release alternatives out of Fort Peck Dam designed to benefit recruitment of pallid sturgeon. The hydrologic evaluation performed for the FTPTR-EIS follows after the previously completed modeling for the Missouri River Recovery Management Plan and Environmental Impact Statement (MRRMP-EIS).

The purpose of this document is to provide basic background information on the various hydrologic modeling efforts and the relationships between those modeling efforts. The hydrologic modeling evaluation involved the use of a detailed suite of models for the Missouri River basin. Development of the hydrologic and hydraulic modeling component for FTPTR-EIS consists of three parts:

- Development of reservoir simulation models for managed federal reservoirs that impact management for the three species. These models will be used to assess the benefits and effects of changes in water management (reservoir operations) at these reservoirs. Hydrologic Engineering Center's Reservoir Simulation Model (HEC-ResSim) was chosen for this modeling.
- Development of hydraulic models for free-flowing reaches of the river. Hydrologic Engineering Center's River Analysis System Model (HEC-RAS) was chosen for this modeling. Unsteady RAS will be used to more accurately route discharges from reservoirs and tributaries to points downstream and to simulate impacts of mechanical changes in river channel geometry.
- Development of a complete, sufficiently long period of gage records for the Missouri River and its principle tributaries, to be used in the hydrologic and hydraulic models. Regression methods were used to estimate missing data in older parts of the gage record. The goal was to have a record that realistically represents runoff conditions in the basin back to 1930. The record was also adjusted for depletions and other significant changes in the basin over time.

Outputs from the hydrologic and hydraulic modeling effort are used by conceptual and quantitative ecological models for evaluating species responses to management actions in the Environmental Effects Analysis portion of the study, and evaluation of the effects to basin stakeholder interests and authorized purposes in the Management Plan Analysis. The Human Considerations (HC) team performed an extensive analysis on each of the alternatives for each of the resources (hydropower, cultural resources, fish & wildlife (exclusive of listed species), flood risk, irrigation, recreation, thermal power, and water supply) and provide a detailed comparison of results.

2 ANALYSIS PREVIOUSLY CONDUCTED FOR THE MRRMP-EIS

The hydrologic modeling relied extensively on efforts performed for the previously completed MRRMP-EIS. Previous MRRMP-EIS study documents and incorporation within the FTPFR-EIS analysis components are briefly summarized in Table 2-1.

Table 2-1. Previous Analysis Completed for the MRRMP-EIS

MRRMP-EIS Analysis	Status Within FTPTR-EIS
Hydrologic Analysis Summary Report	No change
Period of Record Development	
Sediment Calibration	
Sediment Alternatives	
Water Quality	
Climate Change Assessment	
Interior Drainage Analysis	
Channel Capacity Analysis	Revised and documented within this EIS
HEC-ResSim Calibration Report	
HEC-ResSim Alternatives Report	
HEC-RAS Calibration Report	
HEC-RAS Alternatives Report	

2.1 PERIOD OF RECORD DEVELOPMENT

The FTPTR-EIS used the same POR data set for hydrologic analysis as that developed for the MRRMP-EIS. A POR modeling approach was selected for use with the RAS and ResSim modeling effort and subsequent hydrologic analyses. As used in hydrologic models for flood-runoff analysis, period of record analysis refers to applying a hydrologic model to simulate a continuous period of record of streamflow.

Regarding the POR flow data set:

- Various methods were used to assemble the POR flow record for each model.
- All flows were corrected to current level depletions to reflect water use within the basin. Therefore, comparison of hydrologic model results from either ResSim or RAS to observed conditions is not possible.
- Although the hydrologic models provide results from a portion of 1930, an 82 year POR was used for HC analysis from 1931 through 2012.

Detailed documentation of the data development methods and data sources conducted to create the POR for all hydrologic models is provided in *Missouri River Recovery Management Plan Time Series Data Development for Hydrologic Modeling* (USACE 2018e).

2.2 SEDIMENT CALIBRATION AND SEDIMENT ALTERNATIVES

No sediment transport or future condition modeling was performed for the FTPTR-EIS. Sediment transport models were developed to evaluate the effect of MRRMP-EIS flow change alternatives and to support the year 15 analysis. For the MRRMP-EIS, the baseline or existing conditions models were modified to represent a future condition under the No Action and action alternatives. However, the previous analysis did not consider that sediment transport modeling was necessary for Fort Peck to Lake Sakakawea since no flow change alternatives were considered. Refer to

Missouri River Recovery Management Plan – HEC-RAS Alternatives Report (USACE 2018c) for additional details regarding the previously conducted sediment transport modeling and year 15 analysis.

2.3 Water Quality

Water quality modeling performed for the MRRMP-EIS consisted of water temperature models developed for five Missouri river reaches (e.g., Fort Peck Dam to Garrison Dam; Garrison Dam to Oahe; Fort Randall Dam to Gavins Point Dam; Gavins Point Dam to Rulo, NE; and Rulo, NE to the mouth of the Missouri River. These models were not revised for this analysis primarily due to the minor impacts determined in the previous effort. Refer to the report *Water Temperature Models Developed for the Missouri River Recovery Management Plan and Environmental Impact Statement* (ERDC 2018) for additional details.

2.4 Interior Drainage

Interior drainage refers to the conveyance of flow from interior, or landward side, of the levee to the Missouri River channel. Typical Missouri River levee systems have culverts or pump stations to allow local drainage to exit the interior of the levee and drain to the river. Although the Fort Peck to Lake Sakakawea reach of the Missouri River includes a levee system at Williston, ND, an interior drainage analysis was not conducted. The levee system at Williston includes a pumping station that is federally owned and operated by USACE Omaha District. Analysis of potential impacts to levee risk was evaluated as discussed within this document. Refer to *Missouri River Recovery Management Plan – HEC-RAS Alternatives Report* (USACE 2018c) for details regarding the previous evaluation.

2.5 Channel Capacity Analysis

Channel capacity estimates were performed to provide an indication of the flow rate at which bank elevations are overtopped and flow begins to leave the main channel and enter the floodplain. Channel capacity was compared to alternative flow condition reservoir releases and downstream channel condition. Channel capacity estimates were updated for this study for the Fort Peck reach only. The other reach's estimates remain unchanged from the MRRMP-EIS Previous documentation regarding the channel capacity analysis from the MRRMP-EIS can be found in *Missouri River Recovery Management Plan – HEC-RAS Alternatives Report* (USACE 2018c).

2.6 HEC-ResSim Analysis

HEC-ResSim (ResSim) is a reservoir operations model developed by the USACE Hydrologic Engineering Center (HEC). The model incorporates user defined rules with other conditions (i.e., inflow, pool elevation, and downstream flows) to determine reservoir outflow. The model also performs downstream hydrologic channel routing. Water managers, water control manuals, and other documentation all help in determining the rules necessary to simulate a reservoir within the model.

Previous documentation regarding ResSim calibration and alternatives analysis was provided in the MRRMP-EIS (USACE 2018a and 2018b). Additional ResSim analysis performed for the Fort

Peck Dam alternatives is documented in this report, appendix *Missouri River Mainstem HEC-ResSim Modeling for the Fort Peck EIS*. HEC-RAS modeling used results from the ResSim modeling.

2.7 HEC-RAS Analysis

HEC-RAS (RAS) is designed to perform one-dimensional hydraulic calculations for a full network of natural and constructed channels. Common outputs include stage, duration/timing of inundation, water velocities, flow areas/routes, water temperature, and sediment loads. Unsteady flow analysis was chosen as the method of hydraulic modeling due to the need to analyze time series stage and flow data. Both the biological considerations (e.g., seasonal habitat requirements) and the human considerations (e.g., potential agricultural impacts) are affected by the timing of river flows. RAS was used to more accurately route discharges from reservoirs and tributaries to points downstream and to simulate impacts of mechanical changes in river channel geometry. These models simulate how proposed alternatives and management actions would impact river stage and discharge over a wide range of basin hydrologic conditions.

RAS modeling was performed to create a baseline that closely represents current river conditions and to provide a tool to evaluate potential hydraulic changes resulting from proposed management actions or alternatives (e.g. channel reconfiguration and/or flow management). The baseline or existing conditions models were modified to represent a future condition under the No Action and action alternatives. Outputs of the RAS models were used to perform human consideration impacts analysis.

Previous documentation regarding RAS calibration and alternatives analysis was provided in the MRRMP-EIS (USACE 2015a and 2018c). Additional RAS analysis performed for the Fort Peck Dam alternatives is documented in this report.

3 ALTERNATIVES DESCRIPTION

A Hydrologic Engineering Center Reservoir Simulation (HEC-ResSim) model was used to assess the benefits and effects of changes in water management (reservoir operations) for the System. Seven alternatives, including the No Action alternative, were simulated in ResSim. The computed dam outflow and pool elevations were then passed on to the HEC-RAS models as input. The alternatives are briefly summarized below and more information can be found in the report, *Missouri River Mainstem HEC-ResSim Modeling for the Fort Peck EIS, Mainstem Missouri River Reservoir Simulation Alternatives Technical Report* (USACE 2020). Additional alternative description is also provided in Chapter 2 of the Fort Peck Flow Test EIS (U.S. Army Corps of Engineers, 2020).

3.1 No Action

Under No Action (NA), the Missouri River Mainstem Projects would continue to operate as they are currently. Operations within the ResSim model were set up to closely follow the Master Manual (U.S. Army Corps of Engineers, 2018) that is used during real-time operations of the System; however, the model does have limitations and cannot capture all real-time decisions that occur.

For a more complete description of the No Action, refer to Chapter 2 of the Fort Peck Flow Test EIS (U.S. Army Corps of Engineers, 2020).

3.2 Alternative 1 – Fort Peck Flow Test Scaled to Fort Peck Spring Release

Alt 1 does not change water supply, navigation, and flood target operations compared to No Action during March and April.

Alternative 1 (Alt 1) represents an operational change at Fort Peck that includes a flow regime for the pallid sturgeon based on target flows at Wolf Point, MT. The flow regime begins on April 16 with an attraction flow. Flows at Wolf Point are increased by 1,700 cubic feet per second (cfs) per day until the peak attraction flow of 2 times the Fort Peck spring release is reached. The peak flow is maintained for three days and then decreased by 1,300 cfs per day for a maximum of 12 days. After 12 days, the flow is reduced by 3,000 cfs per day until the retention flow is reached. If the retention flow is reached within the first 12 days of flow reduction, the retention flow is maintained. The retention flow is 1.5 times the Fort Peck spring release and is held until the spawning cue begins on May 28. For the spawning cue, flow is increased by 1,100 cfs per day until the peak spawning cue flow is reached, which is 3.5 times the Fort Peck spring release. The peak spawning cue flow is held for 3 days and reduced by 1,000 cfs for a maximum of 12 days. After 12 days, the flow is reduced by 3,000 cfs per day until a flow of 8,000 cfs is reached at Wolf Point, MT. The 8,000 cfs flow at Wolf Point, MT is maintained until September 1. If the flow regime is cancelled prior to initiating the spawning cue, the 8,000 cfs flow target is not utilized and releases are made to balance storage among the 3 upper reservoirs: Fort Peck, Garrison, and Oahe. However, if the spawning cue is initiated, the 8,000 cfs flow target at Wolf Point, MT will be met through August. Due to travel time from Fort Peck to Wolf Point, MT, releases from Fort Peck are increased approximately 2 days prior to the dates listed previously to ensure the flow at Wolf Point, MT follows the dates and pattern described. Spillway releases are only made after the powerhouse has reached its maximum capacity.

Several criteria were developed to minimize impacts during the flow regime. If Fort Peck pool elevation is currently or is forecasted to fall below 2227.0 feet, the flow regime will not be started or stopped due to inadequate head for spillway releases. The flow regime will not begin if the May – June Fort Peck to Garrison forecasted monthly runoff exceeds an upper quartile year. If the flow at Wolf Point, MT or Culbertson, MT is forecasted to exceed 35,000 cfs, the flow regime will be stopped. If forecasted stages at Williston, ND exceed flood stage, 22.0 feet, the flow regime will be stopped. The flow regime will be eliminated if water surface elevations exceed 1853.5 feet at the downstream portion of the Williston Levee, which is approximately 6.4 feet of freeboard. The last criterion that will eliminate the flow regime is based on the forecasted pool elevation at Lake Sakakawea. If the forecasted pool elevation exceeds 1850.0 feet (bottom of exclusive flood control zone), the flow regime will be stopped. For a more complete description of Alt 1, refer to Chapter 2 of the Fort Peck Flow Test EIS (U.S. Army Corps of Engineers, 2020).

3.3 Alternative 1a – Fort Peck Flow Test Scaled to Fort Peck Spring Release One Week Earlier than Alternative 1

Alternative 1a (Alt 1a) is not a separate alternative in the Fort Peck Flow Test EIS. It is a sensitivity analysis for Alt 1. The same flow regime and elimination criteria described for Alt 1 are used, but the flow regime begins 1 week earlier. The attraction flow begins on April 9 and the spawning cue begins on May 21.

3.4 Alternative 1b – Fort Peck Flow Test Scaled to Fort Peck Spring Release One Week Later than Alternative 1

Alternative 1b (Alt 1b) is similar to Alt 1a in that it is not a separate alternative in the Fort Peck Flow Test EIS. It is a sensitivity analysis for Alt 1. The same flow regime and elimination criteria described for Alt 1 are used, but the flow regime begins 1 week later. The attraction flow begins on April 23 and the spawning cue begins on June 4. Alternative 2 – Fort Peck Flow Test Scaled to Fort Peck Powerhouse Capacity

Alternative 2 (Alt 2) represents an operational change at Fort Peck that includes a flow regime for the pallid sturgeon based on target flows at Wolf Point, MT. Unlike Alt 1, the peak target flows for the attraction and spawning cue is based on the powerhouse capacity. For purposes of this study, the powerhouse capacity was estimated at 14,000 cfs. Under current restrictions for the hydropower units at Fort Peck, the maximum powerhouse capacity is closer to 13,000 cfs. The flow regime begins on April 16 with an attraction flow. Flows at Wolf Point are increased by 1,700 cubic feet per second (cfs) per day until the peak attraction flow equal to the maximum powerhouse flow of 14,000 cfs is reached. The peak attraction flow is equal to the retention flow, 14,000 cfs, so no reduction in flow occurs following the peak attraction flow. The retention flow is held until the spawning cue begins on May 28. For the spawning cue, flow is increased by 1,100 cfs per day until the peak spawning cue flow is reached, which is 2 times the maximum powerhouse capacity, or 28,000 cfs. The peak spawning cue flow is held for 3 days and reduced by 1,000 cfs for a maximum of 12 days. After 12 days, the flow is reduced by 3,000 cfs per day until a flow of 8,000 cfs is reached at Wolf Point, MT. The 8,000 cfs flow at Wolf Point, MT is maintained until September 1. If the flow regime is cancelled prior to initiating the spawning cue, the 8,000 cfs flow target is not utilized and releases are made to balance storage among the 3 upper reservoirs: Fort Peck, Garrison, and Oahe. However, if the spawning cue is initiated, the 8,000 cfs flow target at Wolf Point, MT will be met through August. Due to travel time from Fort Peck to Wolf Point, MT, releases from Fort Peck are increased approximately 2 days prior to the dates listed previously to ensure the flow at Wolf Point, MT follows the dates and pattern described. Spillway releases are only made after the powerhouse has reached its maximum capacity. The same criteria developed to minimize impacts during the flow regime that are described in Alt 1 are utilized for Alt 2.

3.5 Alternative 2a – Fort Peck Flow Test Scaled to Fort Peck Powerhouse Capacity One Week Earlier than Alternative 2

Alternative 2a (Alt 2a) is not a separate alternative in the Fort Peck Flow Test EIS. It is a sensitivity analysis for Alt 2. The same flow regime and elimination criteria described for Alt 2 are used, but the flow regime begins 1 week earlier. The attraction flow begins on April 9 and the spawning cue begins on May 21.

3.6 Alternative 2b – Fort Peck Flow Test Scaled to Fort Peck Powerhouse Capacity One Later Earlier than Alternative 2

Alternative 2b (Alt 2b) is not a separate alternative in the Fort Peck Flow Test EIS. It is a sensitivity analysis for Alt 2. The same flow regime and elimination criteria described for Alt 2 are used, but the flow regime begins 1 week earlier. The attraction flow begins on April 23 and the spawning cue begins on June 4.

3.7 HEC-RAS Alternative Simulation.

Similar to the MRRMP-EIS as previously described (2018f), the ResSim model was used to simulate system operations for each alternative. Output from the ResSim analysis provides the reservoir release and downstream reservoir pool elevations for use with the RAS modeling of alternatives. RAS simulates river flow and elevation within the model. An example of RAS computed flow that illustrates the differences between each alternative for the simulation year 1966 at Wolf Point is provided in Figure 3-1 . The year 1966 was selected since each alternative had a full pulse.

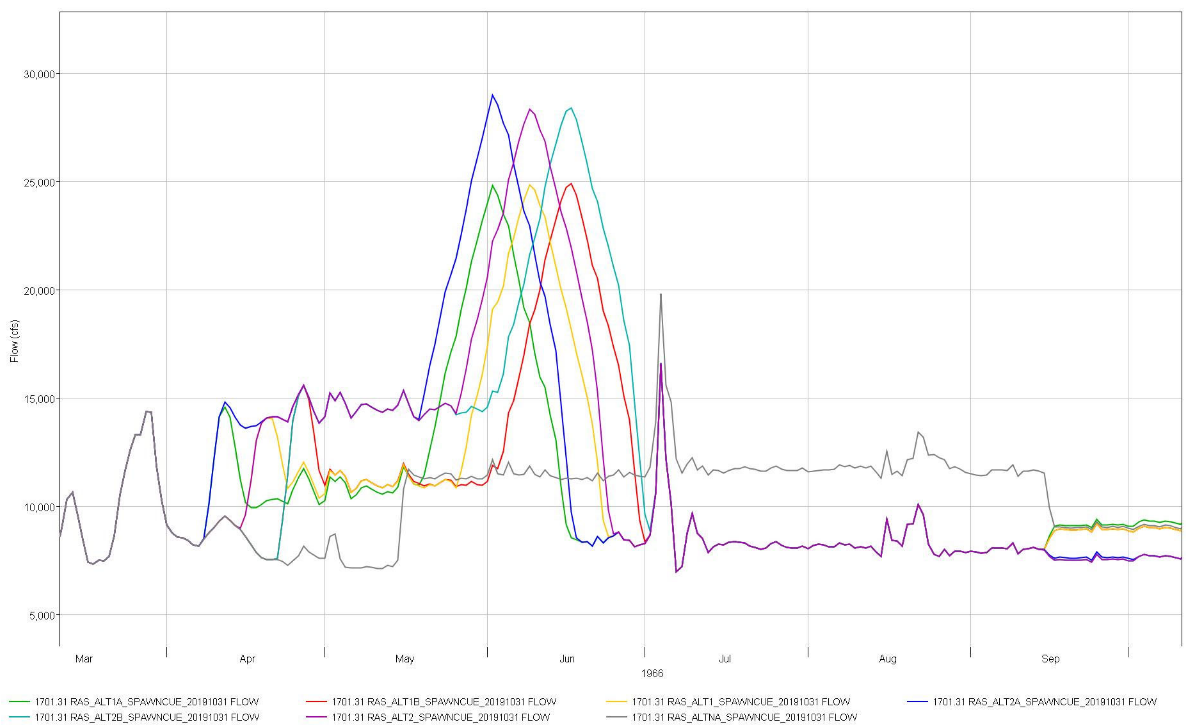


Figure 3-1. Example Hydrographs during a Year (1966) when all Alts had a Full Pulse

4 MISSOURI RIVER - FORT PECK DAM TO LAKE SAKAKAWEA

The Missouri River from Fort Peck Dam flows in an easterly direction for over 200 miles as an unchannelized river before entering the headwaters of Garrison reservoir downstream of Williston, ND. Major tributary streams entering the Missouri River on the north side of the valley between Fort Peck Dam and the Yellowstone River include the Milk River, Little Porcupine Creek, Wolf Creek, Poplar River, and Big Muddy Creek. The main tributaries entering from the south include Prairie Elk Creek and Redwater Creek along with numerous other smaller tributaries. The most important tributary in this reach is the Yellowstone River. The other tributaries are minor with a total contribution to the river flow in this reach that is generally less than about five percent.

The channel in this reach exhibits a meandering pattern with occasional straight reaches. The channel width ranges from about 450 ft to nearly 3000 ft with an average width of about 1000 ft. The energy slope for the Fort Peck reach, calculated from the HEC-RAS analysis, ranges from about 0.0003 to 0.0005 ft/ft. Bank heights in this reach generally range from about 10 ft to over 40 ft with an average bank height of about 20 ft (Biedenharn et al, 2001). Channel characteristics of this river reach include many sandbars, islands and side channels. Abandoned channels and several oxbow lakes remain in the floodplain. The configuration of the uplands on the south side of the river is very broken and in several places badland topography exists. Upstream of Brockton, MT (RM 1660), the floodplain is about 4 miles wide and is bordered by rolling grasslands, dryland crops and rangelands. Downstream from this point, the floodplain narrows to a 1-mile wide valley. The river flows through this valley in broad sweeping meanders alternately crossing the valley from side to side. Although the meandering pattern is well developed throughout the reach, several straight segments of river channel are also encountered.

The bottomland through which the river flows possesses a topography that clearly defines the different flow levels and the intricate channel courses the river has assumed throughout recent times. It is characterized by several distinct terraces which rise one above the other to a maximum height of approximately 10 feet above the present high water level of the river. The uppermost terrace defines the maximum stage of valley aggradation which occurred after the retreat of the last glacial ice-sheet from the region. The surface of this high terrace is uniformly level in a trans-valley profile and has a slope of approximately 1.3 to 1.5 feet per mile in a longitudinal direction. Generally, this terrace is devoid of tree or willow growth and since the materials of which the terrace is composed consist of fine grained sands and silts, it is readily susceptible to the erosive action of the river in instances where the river impinges directly against this terrace. The younger terraces, which mark various stages of valley degradation during recent times, are generally covered with dense growths of cottonwood trees and willows. The lowest terrace consists of a maze of accretion deposits and small islands which have their surface only a few feet above the present high water surface of the regulated river (USACE 2013a).

Since Fort Peck Dam entraps all upstream contributed sediment, the downstream river remains relatively free of suspended sediment until the Milk River confluence, which enters the Missouri River about 10 miles downstream of the dam, and other tributaries introduce their individual load contributions into the Missouri River.

Bed material in the reach is predominately sand. Outcrops of gravel, cobbles, and dense clay are occasionally observed. Bed material tends to be coarser in the reach immediately downstream of the dam (Simon et al. 1999).

4.1 Datums Employed

All HEC-ResSim models are constructed using the NGVD 29 datum. Use of the 1929 vertical datum was used for consistency with reported reservoir elevations within the Master Manual and operating decisions. All HEC-RAS models are constructed based on the NAVD 88 vertical datum to match current practice along the Missouri River for reporting river flow elevation. Use of two vertical datums within the study area was necessitated for presentation of results in a meaningful manner to the various stakeholder groups. Human consideration evaluations were performed in the appropriate datum for each individual resource.

The conversion between NGVD 29 to NAVD 88 varies by geographic location. The variable elevation difference between the two datums is provided in Table 4-1.

Table 4-1. Conversion of Datums for Dams Discussed in EIS

Minimum and Maximum Operating Pool Elevations in Reservoirs		
Location	**Pool Range (NGVD 29)**	**Conversion from NGVD 29 to NAVD 88 (ft)**
Fort Peck Lake	2,160 to 2,250	+2.07
Lake Sakakawea	1,775 to 1,854	+1.31
Lake Oahe	1,540 to 1,620	+1.23
Lake Sharpe	1,415 to 1,423	+1.07
Lake Francis Case	1,320 to 1,375	+0.98
Lewis and Clarke Lake	1,204.5 to 1,210	+0.67
USGS Gages along the Missouri River		
Location	**Conversion from NAVD 88 to NGVD 29 (ft)**	**Gage Datum (NAVD 88)**
Williston, North Dakota	-1.64	1,831.8
Bismarck, North Dakota	-1.34	1,619.6
Sioux City, Iowa	-0.55	1,060.00
Omaha, Nebraska	-0.39	948.97
Nebraska City, Nebraska	-0.35	905.61
Kansas City, Missouri	-0.28	706.68
St. Louis, Missouri	-0.05	379.58

4.2 GEOMORPHOLOGICAL PROCESSES

Sediment is an integral part of geomorphological processes and important for building and sustaining habitats in a river system. The amount, size, and type of sediments in the river system affect the kinds of plants and animals occupying the various river habitats. Although sediment is trapped in the upper river by the reservoirs, the Missouri River continues to be a large source of sediment to the Mississippi River.

Sediment is transported by the river either as suspended sediment in the water column or as bedload on the channel floor. The suspended sediment load in the river is directly related to the turbidity of the water, which affects the types and densities of aquatic organisms. Bedload consists of coarser-grained sediment particles (sand and gravel), which can either be suspended for short periods of time or are rolling along the riverbed, depending on the flow velocity. Bedforms in the river include sandbars that change over time through flow-driven erosion and deposition processes.

Primary geomorphological processes that are relevant for the proposed management actions consist of degradation and bank erosion, reservoir sediment deposition and aggradation, sandbar erosion and deposition occurring within the river channel and in the Lake Sakakawea headwaters, reservoir shoreline erosion, and ice dynamics.

Discussion of geomorphic processes presented in this report is focused on the Fort Peck Dam to Lake Sakakawea reach. Refer to the previous Management Plan EIS (USACE 2018g) for further information regarding overall Missouri River basin geomorphic processes.

4.2.1 Sandbar Erosion and Deposition

The formation of sandbars is common in rivers with high sediment loads such as the Missouri River. Sandbars form within the river channel as well as in the delta of the river flowing into the reservoirs. Sandbars are highly dynamic. Their formation and changes over time are affected by variables such as channel width, streamflow, sediment load in the river, grain size, vegetation, and man-made infrastructure. In the managed system of the Missouri River, sandbars form and change both naturally and as a result of deliberate management actions as discussed in various sections within Chapter 2 (see also Fischenich et al. 2014).

The river downstream from Wolf Point is characterized as depositional with numerous shifting sand bars. Despite depositional characteristics, several gravel bars occur in this reach. For example, Gardner and Stewart (1987) identified 14 gravel areas between Wolf Point and Nohly varying in length from 61 m to 183 m (200 - 600 yards). Liebelt (1996) similarly identified gravel and cobble areas near Nohly. A detailed analysis of sandbar location and migration rate has not been performed although field observations support that bar movement does occur and is a function of the river flow rate. A typical sandbar location along the Missouri River is shown in Figure 4-1.

Figure 4-1. Typical Missouri River Sandbar near RM 1690
(80 river miles downstream of Fort Peck Dam)

4.2.1 Bed Material

Overall, bed material near the dam is coarser and more varied, with a median bed material size ranging from 0.2 mm to 13 mm. Downstream of RM 1720, the bed becomes uniformly finer, with the median bed material size remaining relatively consistent at 0.2 mm for all years, except for 1978. These bed samples indicate the most recently deposited or exposed sediments at the sampling location at the time of the sample, and do not necessarily represent the bed sediment loads for the river. It should also be noted that no bed material data has been collected since 1984; therefore, recent trends seen in the water surface profiles and gage trends would also likely be reflected in changes to bed material size.

4.2.2 Bank Erosion Fort Peck Dam to Lake Sakakawea

Numerous studies of Missouri River bank erosion downstream of Fort Peck Dam have been conducted (ND and MT, 1991; Simon et al, 1999; USACE 2008, USACE 2013a, USACE 2018g). Bank erosion is typically described as a function of stream bed lowering, soil type, soil drainage, ice effects, and site river flow conditions. A study conducted by the USDA (Simon et al 1999) concluded that important issues affecting streambank erosion along the Missouri River in the study reach are pore-water pressure effects from sustained high flows, ice-related effects, and the direct effects of an ice cover. Ice effects are particularly significant in channel-bed shifting and, therefore, the silting of pump sites along the river. A further study (Collison et al 2002) concluded that the effects of an elevated flow release followed by a period of low flow is likely to have a detrimental effect on bank stability. They identified bank erosion impacts by both rapid drawdown and toe erosion during the sustained high flow levels. The different studies present many conclusions regarding bank erosion causes and future Missouri River bank erosion trends that are conflicting in some cases. A typical location along the Missouri River illustrating bank erosion is shown in Figure 4-2.

Figure 4-2. Typical Missouri River Bank Erosion Sites near RM 1680 (90 river miles downstream of Fort Peck Dam)

Bank erosion rates were determined from Fort Peck Dam to the Yellowstone River using data from 1975, 1983, and 1990 (USACE 2013a). There was an observed increase in the erosion rate for the 1983 to 1990 period compared with the 1975 to 1983 period. The average total annual erosion rate from 1975 to 1983 was approximately 88 acres per year, while the erosion rate from 1983 to 1990 was 127 acres per year. Using an average bank height of 15 to 20 feet, bank erosion rates are approximately 1-2 ac-ft/river mile/yr. Erosion rates for other periods were not determined due to limited data availability.

A previous study, *Bank Stabilization Cumulative Impact Technical Analysis, Ft Peck, Garrison, Fort Randall, and Gavins Point Study Reaches*, USACE 2008, determined a total bank and channel erosion rate of 13 ac-ft/river mile/year for the Fort Peck Dam to Lake Sakakawea reach using the most recent available data set from 1978 to 1994. The bank erosion rates determined in the two studies illustrate a wide range.

4.2.3 Degradation and Aggradation Stage Trends

The measurement, evaluation, and reporting of changes to the geomorphology and the associated stage of the Missouri River from Montana to the Mississippi River have been performed routinely by the Corps of Engineers at irregular intervals since the dam construction era. Stage trends were affected by the record discharges from all six main stem dams in 2011 (USACE 2012a).

Trends in river stages have been measured in tailwater locations (immediately downstream of dams that affect power generation), degradation reaches downstream of each dam, aggradation reaches in the headwaters of each reservoir, and the navigation channel. To summarize stage trend terminology and trends:

- Degradation reaches within the open river reach downstream of the dam are subject to scour, generally resulting in a lowering of the river stages over time.
- Due to the downstream reservoir level pool level and limited length open river reach, the degradation reach downstream of both Oahe and Big Bend Dams are short and stage trends in those reaches are minor or not measurable.
- Aggradation within the delta headwater locations are subject to sediment deposition, resulting in an increase in river stages within the delta and upstream over time.
- Reservoir pool levels impact both the location and magnitude of deposition in the aggradation zones.
- Certain locations along the navigation channel have been subject to various influences that have led to increases or decreases in stages over time (USACE, 2012a).

4.2.3.1 Degradation Trends

Although most of the bed degradation below Fort Peck Dam occurred before 1966, some degradation continues in the upper and center portions of the 204-mile reach, causing some streambank erosion (USACE 2006). Degradation below the dam (RM 1772) occurs at differing degrees to about RM 1650. Downstream of RM 1650, minor degradation has occurred during recent high flow events. The width of the river channel has not increased much as a result of streambank erosion. Streambank erosion rates for the entire reach were about 97 acres per year from 1975 to 1983 (USACE 2006).

A study, *Missouri River Fort Peck Project Downstream Channel and Sediment Trends Study* (USACE 2013a), was conducted to evaluate trends in the degradation reach downstream of Fort Peck Dam, roughly defined as Fort Peck Dam to Culbertson, using data collected by USACE since Fort Peck Dam closure in 1937. The study report documents historical channel and sediment data for the Missouri River degradation reach below Fort Peck Dam (USACE 2013a). The study used sediment trend data collected between 1936 and 2012 for the 175-mile reach of the Missouri River downstream of the Fort Peck Dam in Montana. The study evaluated degradation in the river bed and overbanks and bank erosion since the closure of Fort Peck Dam in 1937.

The data analyzed were primarily cross-section geometry from numerous field surveys conducted from 1936 to 2012 on 47 sediment ranges located in the reach. Sediment samples at the ranges were also collected for the survey years 1960, 1966, 1973, 1978, and 1984. Water surface profiles for selected years, which were calculated independently, were compared to determine overall elevation trends in the reach. The survey data were used to establish various river characteristics, which indicate how the channel has changed over time in terms of bed elevation, top width, and degradation or aggradation at individual sediment ranges.

Adjusted water surface profiles for three discharges (10,000 cfs, 20,000 cfs, and 30,000 cfs) were analyzed.

- Overall, the water surface profiles have decreased between 1950 and 2012. However, the decrease has not been steady over the entire period or study reach. Decreases occurred from 1950 to 1966 and 1975 to 1984, while increases occurred from 1966 to 1975, and 1984 to 1995. The largest decreases occurred from 1995 to 2012, as a result of the high flow years of 1996-97 and the extreme flows of 2011.

- From 1950 to 2012 at the 10,000 cfs flow, the reach average decrease was 2.4 feet, of which 1.3 feet (or 54%) occurred in the 1995 to 2012 period. At 20,000 cfs, the 1950 to2012 reach average decrease was 3.1 feet, of which 2.3 feet (or 74%) occurred in the 1995 to 2012 period. At 30,000 cfs, the 1950 to 2012 reach average decrease was 3.4 feet. However, for this flow, the water surface profile decreased 4.6 feet in the 1995 to 2012 period, which more than offset the significant increase (3.5 feet) observed in the 1984 to 1995 period. A summary of the average change in water surface elevation (feet) for the entire study reach is shown below for each adjusted water surface profile in Table 4-2.

Table 4-2. Average Change in Water Surface Elevation, Fort Peck Degradation Reach

Adjusted Flow	1950 to 1958	1958 to 1966	1966 to 1975	1975 to 1984	1984 to 1995	1995 to 2012	1950 to 2012
10,000 cfs	-0.8	+0.2	-0.2	-0.7	+0.4	-1.3	-2.4
20,000 cfs	-0.6	-0.9	+0.8	-0.8	+0.7	-2.3	-3.1
30,000 cfs	-0.4	-1.8	+0.4	-0.7	+3.5	-4.6	-3.4

A stage-trend analysis was performed at stream gage locations along the study reach: West Frazer Pump Plant (RM 1751.33, approximately 18 miles downstream of Fort Peck Dam), Wolf Point (RM 1701.31, 68 miles downstream of the dam), Culbertson (RM 1620.76, 148 miles downstream of the dam).

- Significant stage fluctuations were seen at the West Frazer gage, particularly for the higher flows. This gage is located 10 miles downstream of the Milk River confluence and 11 miles below the Fort Peck spillway. Trends are likely influenced by both sediment-laden Milk River flows and extreme events with spillway discharge. Overall, from 1950 to 2011 there is a downward stage trend, with decreases of 2.4 feet (10,000 cfs), 2.8 feet (20,000 cfs), and 2.6 feet (30,000 cfs). The 2011 event did not appear to have a major impact at the West Frazer gage.
- At the Wolf Point gage, there is a downward stage trend from 1950 to 2011, with decreases of 3.0 feet for the 10,000 cfs flow, 4.5 feet for the 20,000 cfs flow, and 5.3 feet for the 30,000 cfs flow. The Wolf Point gage experienced larger decreases in stage than at the other two gages, and less fluctuation than the West Frazer gage. While data

between 1985 and 2011 was limited for the higher flows, the 2011 event appeared to cause a decrease in stage at this gage.

- For the Culbertson gage, from 1950 to 2011, there are decreases of 1.1 feet at 10,000 cfs, 2.0 feet at 20,000 cfs, and 2.7 feet at 30,000 cfs. Overall, the Culbertson gage station experienced smaller decreases in stage than the Wolf Point gage and smaller (or similar) decreases compared to the West Frazer gage. However, of the three gages, Culbertson had the most significant decrease in stage from the 2011 event compared to previous periods.

A summary of the change in stage (feet) between 1950 and 2011 is provided below in Table 4-3.

Table 4-3. Stage Trend Summary at Available Gage Stations, Fort Peck Degradation Reach

Flow	West Frazer RM 1751.33	Wolf Point RM 1701.31	Culbertson RM 1620.76
10,000 cfs	-2.4	-3.0	-1.1
20,000 cfs	-2.8	-4.5	-2.0
30,000 cfs	-2.6	-5.3	-2.7

4.2.3.2 Reservoir Sediment Deposition and Aggradation

The aggradation reach occurs when river flows enter the ponded or slack water area of a reservoir. As a result, flow velocity decreases and sediment particles begin to fall out of transport. The coarsest sediments deposit first continuing downstream in a progressive manner, until all sand sizes, followed by the silt and finally the clay size particles have deposited, building a delta within the reservoir headwaters. The delta grows in both the downstream and upstream direction. The delta location also shifts as pool levels vary due to the interaction between river flow velocity, reservoir pool depth, and sediment transport. Aggradation causes an upward shift of the river stage-flow relationship (the river flows at a higher stage for the same flow).

An aggradation study (USACE 2014) developed an estimated 50-yr future water surface level for a range of Lake Sakakawea and Missouri River flow conditions. This study determined an increase in the future condition water surface levels due to aggradation. Water level rise rates downstream of the Yellowstone River were estimated to be in the range of 0.1 to 0.2 ft/yr. A stage trend analysis was also performed at the Williston, ND, USGS gage station using available data. Results are shown in Figure 4-3.

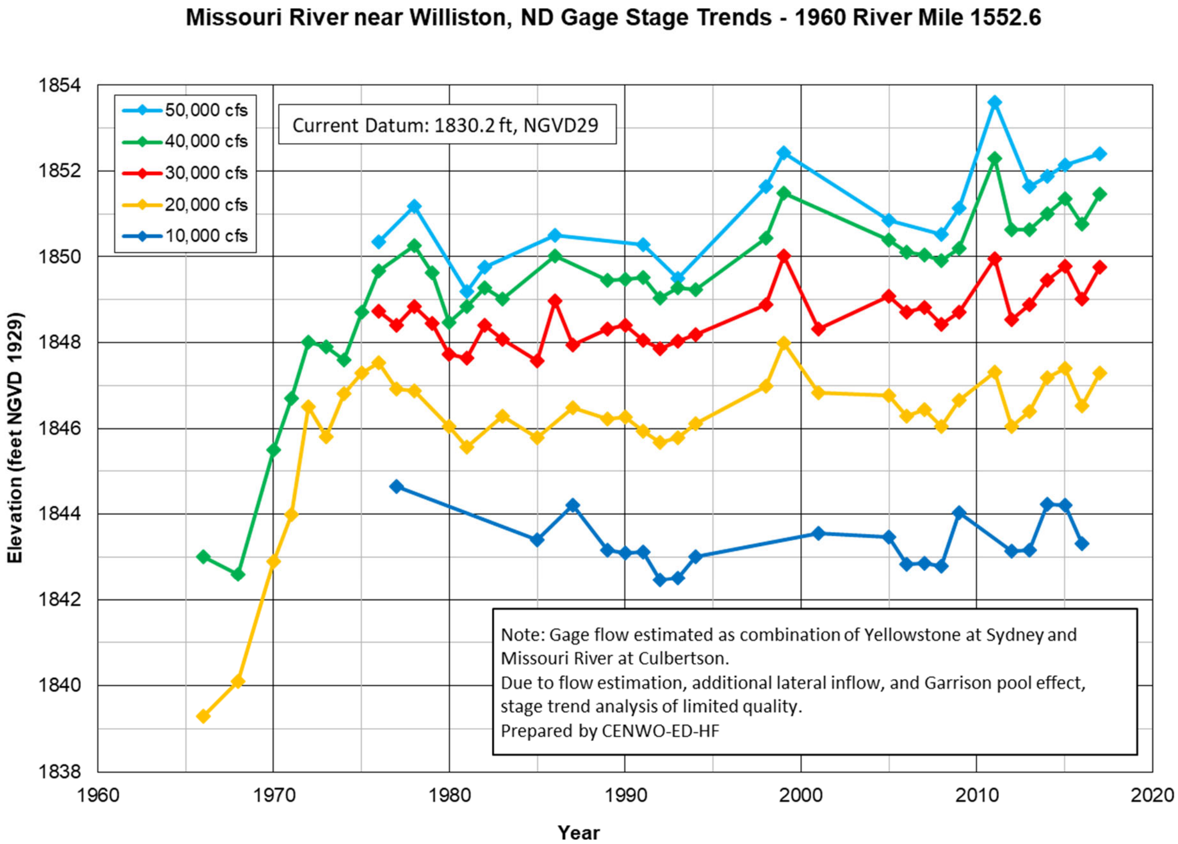


Figure 4-3. Williston, ND USGS Gage Stage Trends

4.2.4 Reservoir Shoreline Erosion

The uppermost layer near the top of the reservoirs tends to be highly erodible silt, wind-blown soils of the plains, particularly along Lakes Sakakawea and Oahe. In addition, wave and ice actions lead to accelerated erosion in the form of slumping cut-banks. The cut-banks are continually slumping into the reservoirs at rates as high as 20 feet per year. At such rates, protective vegetation does not have sufficient opportunity to take root and protect the cut-banks from further erosion.

Bank erosion rates are affected by seasonal and annual water-level fluctuations as a result of reservoir regulation. Generally, the erosion rates are much higher at higher reservoir elevations. However, some shoreline segments with more consolidated and coarser-grained material experience lower erosion rates. For example, high gravel or cobble content in the soil results in armoring at the toe of the cut banks and reduced erosion rates. Lower water elevation exposes silt deposits; subsequent drying causes hardened soils that do not revegetate. Lower water elevations also allow waves to erode shorelines and terraces that were previously protected by higher reservoir elevations. Erosion during lower reservoir elevations may further undermine cut-banks and possibly lead to larger slides or bank cave-ins (USACE 2006).

Long-term shoreline erosion rates in most areas have decreased substantially since dam closures. However, erosion of the reservoir shorelines is expected to continue to some extent throughout the life of the projects. The majority of eroded material usually remains immediately offshore, forming a flat beach slope. As a result, the perimeters of the reservoirs are slowly becoming shallower and wider. In some cases, sediment moves along shore in the direction of the prevailing wind or current and collects in deeper channels of tributary arms. Some reservoir arms are filling and being cut off by these reservoir sediments and collapsing cut-banks. Erosion of shorelines adversely affects recreation facilities and numerous historic and cultural properties. The thousands of miles of shorelines in the reservoirs remain largely unprotected because the costs of protection are high.

4.2.5 Ice Dynamics

River ice dynamics refer to the pattern of ice formation, breakup, and movement on the Missouri River. Aspects of ice dynamics, such as the time and duration of ice formation and the location and size of ice cover, play a role in physical and biological processes. Moving ice sheets can scour riverbanks and shallow parts of the channel and disturb shoreline vegetation. When ice forms on the river during extreme low-flow conditions, it can limit oxygen supply to the covered waters. Ice jams interfere with river flows and can cause temporary, localized flooding (upstream) and flow depletion (downstream), and their break-up can cause temporary, localized high-flow events. Ice jams can also affect water supply. Ice dynamics within reservoirs can result in reservoir bank damage and accelerated erosion rates. Altering reservoir levels, combined with delta location, are factors in the location and severity of spring ice jams and breakup processes. Alteration of river ice dynamics therefore can disturb a river ecosystem. Altering Lake Sakakawea reservoir levels and Missouri River flow rates may change the rate of ice jam formation and location within the delta region.

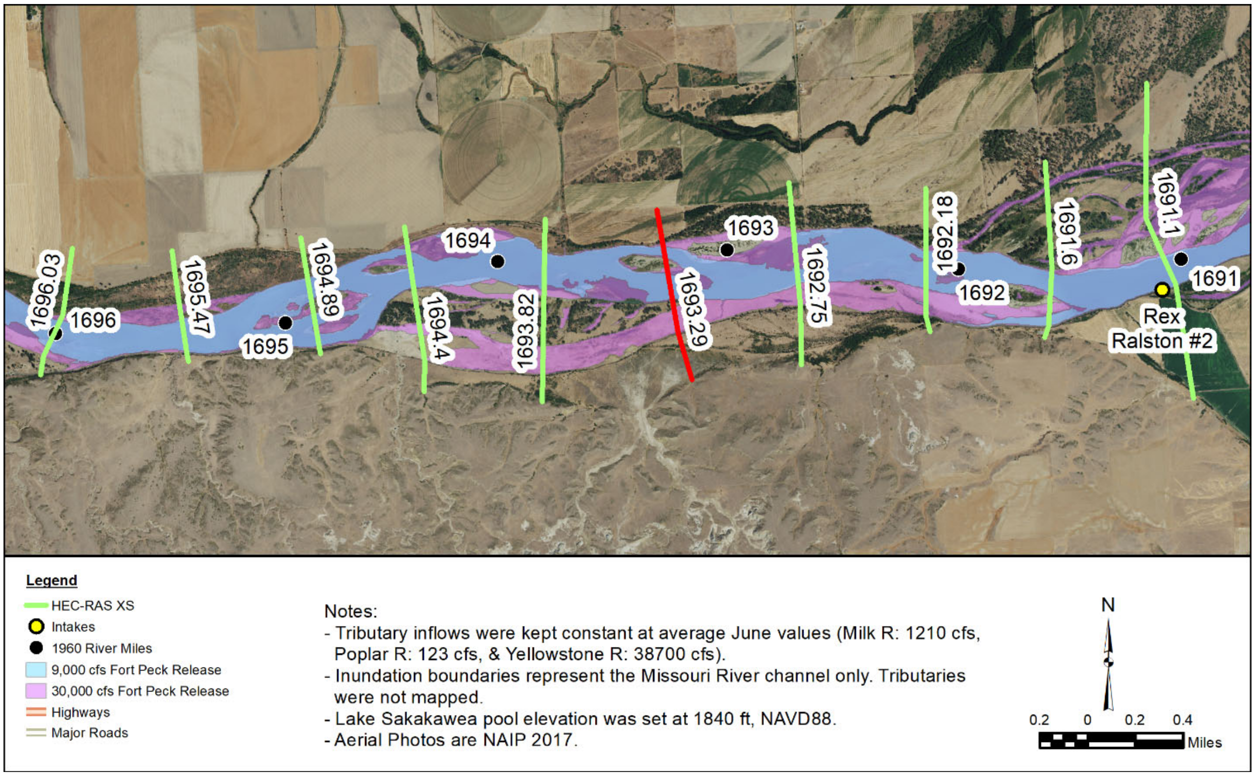
USACE operates the Mainstem reservoir releases in winter to minimize problems with ice; however, sometimes problems cannot be averted. The potential for ice cover and resulting problems at any given location along the Missouri River is a function of cold weather intensity and flow discharge at particular locations. River ice is more prevalent in the upper river, but it is also a factor in the lower river. Mainstem dam releases are adjusted to consider ice conditions; minimum releases from Gavins Point Dam are 3,000 cfs higher during the winter (December through February) than during any non-navigation periods before and after to adequately serve water supply intakes downstream.

Although ice-induced flooding can occur anywhere along the Missouri River, ice dynamics is of heightened concern for the Bismarck-Mandan area in North Dakota. At the beginning of winter when ice cover is forming, river stage usually rises several feet in a short period of time. During the ice-out period, there is a high risk of ice jams and river stages can fluctuate drastically with little to no warning. Typically, USACE would temporarily reduce releases from Garrison Dam to prevent ice-induced flooding during freeze-in and ice-out periods as conditions permit. The travel time distance from Fort Peck Dam to the Lake Sakakawea headwaters reduces the potential that a reduction in Fort Peck Dam releases could affect ice jams in the Williston, ND, reach.

4.2.6 Fort Peck Aggradation and Degradation Typical Geometry

Within the Fort Peck Dam to Lake Sakakawea reach, degradation extends from the dam downstream until tapering off between Brockton and Culbertson, MT. The Lake Sakakawea aggradation influence reach is generally considered to extend from Lake Sakakawea to upstream of the Yellowstone River confluence.

The degradation reach downstream of Fort Peck Dam has relatively high bank heights with greater channel capacity. A typical plan view and cross section within the Fort Peck degradation reach is shown in Figure 4-4. The figure includes an illustration of the inundation area at two flows as well as a cross section illustrating the main channel and floodplain. Refer to the previous Management Plan EIS (USACE 2018g) for further information.



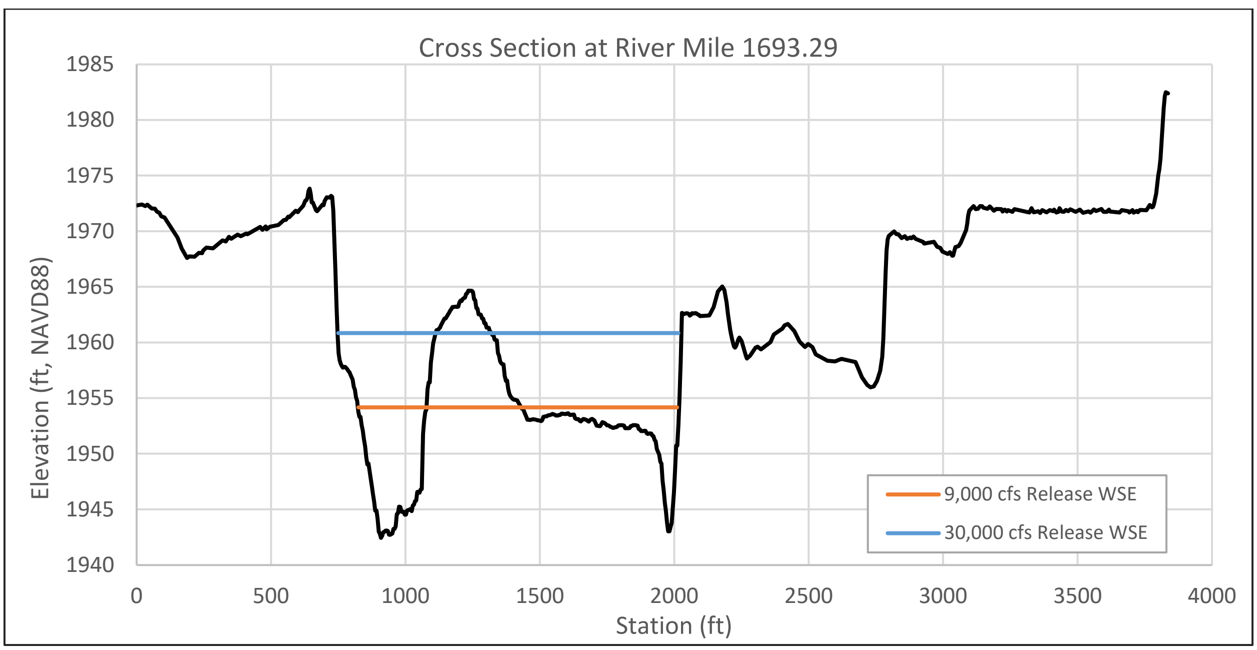


Figure 4-4. Missouri River Plan View and Typical Cross Section, Degradation Reach

Typical geometry within the aggradation reach in the Lake Sakakawea headwaters has lower bank heights and a wide floodplain. A typical plan view and cross section within the Fort Peck aggradation reach is shown in Figure 4-5. The figure includes an illustration of the inundation area at two flows as well as a cross section illustrating the main channel and floodplain. Refer to Section 5 and the previous Management Plan EIS (USACE 2018g) for further information.

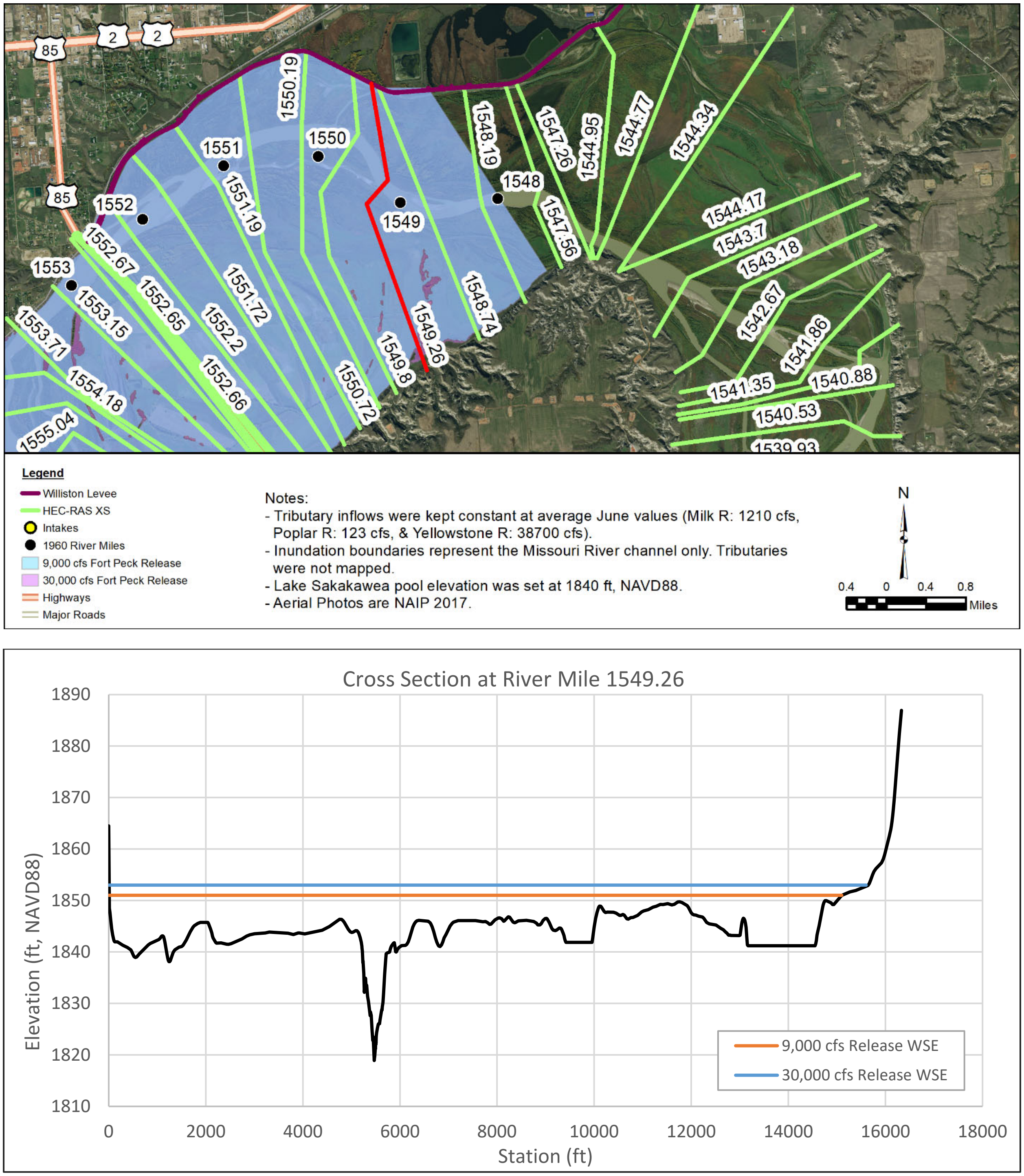


Figure 4-5. Missouri River Plan View and Typical Cross Section, Aggradation Reach

4.3 River Affected Environment

Pertaining to hydrologic processes, evaluation of the river and reservoir environment was conducted in support of determining effects of the proposed management actions. Refer to the previously conducted affected environment analysis for the MRRMP-EIS (2018g) for additional detail.

4.3.1 Groundwater

Groundwater elevation is a key factor in the composition and spatial distribution of vegetation communities and their associated fauna across the floodplain. Groundwater in the alluvial sediments of the floodplain, also referred to as the alluvial aquifer, supplies water to floodplain plant and wetland communities (e.g., cottonwood floodplain forests), particularly during dry, late summer periods. The elevations of the groundwater table in the alluvial aquifer vary in response to factors such as river stage, precipitation, and evapotranspiration. These elevations are also affected by human activities such as groundwater pumping, intentional drainage of floodplain soils, and alterations to the shape and hydrology of the Mainstem and side channels of the river.

Specific groundwater analysis for the Fort Peck Dam to Lake Sakakawea reach was not conducted. Inferences regarding a change in groundwater levels may be inferred from a change in river levels for each of the various alternatives.

4.3.2 River Floodplain and Channel Capacity

The river floodplain downstream of Fort Peck Dam has intermittent levels of protection. In general, the channel capacity is higher near the dam and decreases with downstream distance. Within the reach downstream of the Yellowstone River in the aggradation zone of Lake Sakakawea, channel capacity is much lower.

The HEC-RAS Alternatives Analysis (USACE 2018c) evaluated channel capacity to provide an indication of reaches susceptible to flooding and if any of the alternatives may alter flood risk. Within selected model reaches, the minimum flow that exceeded bank elevations was determined at a representative area. The minimum channel capacity identified within the Fort Peck reach was 35,000 to 40,000 cfs in the area downstream of the Yellowstone River. Channel capacities in the upper reaches were higher; 60,000 to 70,000 cfs from Fort Peck to Wolf Point, MT and 40,000 to 50,000 cfs from Wolf Point, MT to around RM 1604.

4.3.3 Levee at Williston, ND

The Williston Levee System (WLS) construction was completed in 1961 and is a component of the Garrison Dam and Reservoir Project. The WLS is federally owned, operated and maintained. The USACE original levee design documentation (USACE 1954) states the purpose of the project is the protection of low lying portions of the City of Williston and facilities of the Great Northern Railway against damages from floods in the backwater reach of Garrison Reservoir. The original levee design was based on an estimated river level that considered inflow, backwater effect from Lake Sakakawea, and aggradation (Missouri River flows enter the pool and sediments deposit to form the delta). The original design (USACE 1954) does not state the levee elevation as providing protection from specific frequency flood event (i.e. 100-year or 500-year). The levee was constructed at elevation of 1862 feet NGVD 1929 at the Little Muddy Creek confluence and 1863 feet NGVD 1929 near Hwy 85 to provide 3 feet of freeboard during reservoir operations. The original levee construction elevation included an allowance for 5 feet of water level raise to accommodate Missouri River aggradation due to the effects of the Lake Sakakawea pool backwater effects in the Williston vicinity. A schematic of the WLS and the HEC-RAS model cross sections are shown in Figure 4-6.

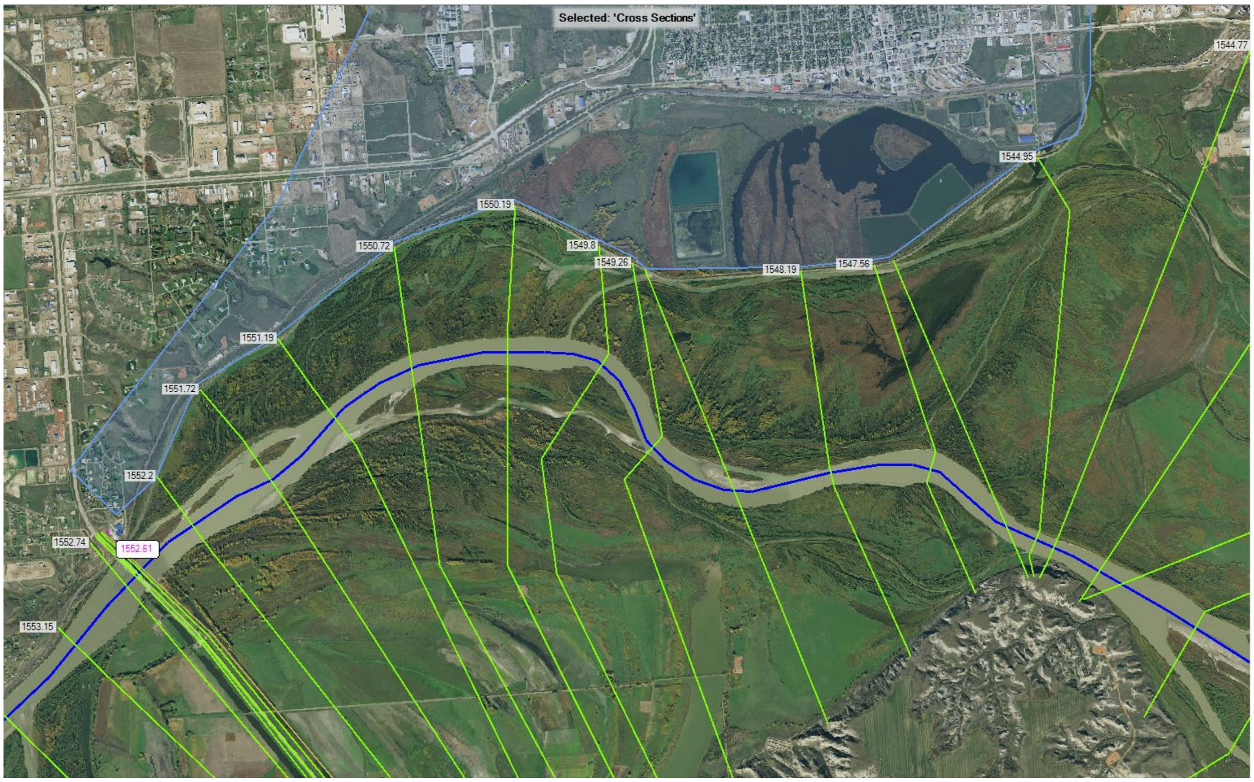


Figure 4-6. Williston, ND Levee System Schematic

The original levee design (USACE 1954) recognized that a levee raise would be required to offset future sediment deposition and meet Garrison Project operation needs. The design estimated a need for a future levee raise of 8 feet at Hwy 85 and 6 feet at Little Muddy Creek, as well as two new short span levees and additional relief wells.

An aggradation study (USACE 2014) developed an estimated 50-yr future water surface level for a range of Lake Sakakawea and Missouri River flow conditions. Information from that study provides estimated future aggradation Missouri River water levels in the Williston, ND, and vicinity. HEC-RAS model. The aggradation study used and HEC-RAS model to compute profiles for a 2012 current condition calibrated model, a 50-year future condition with aggradation estimated water levels (USACE 2014), and 2011 event observed water levels. Computed profiles are shown in Figure 4-7.

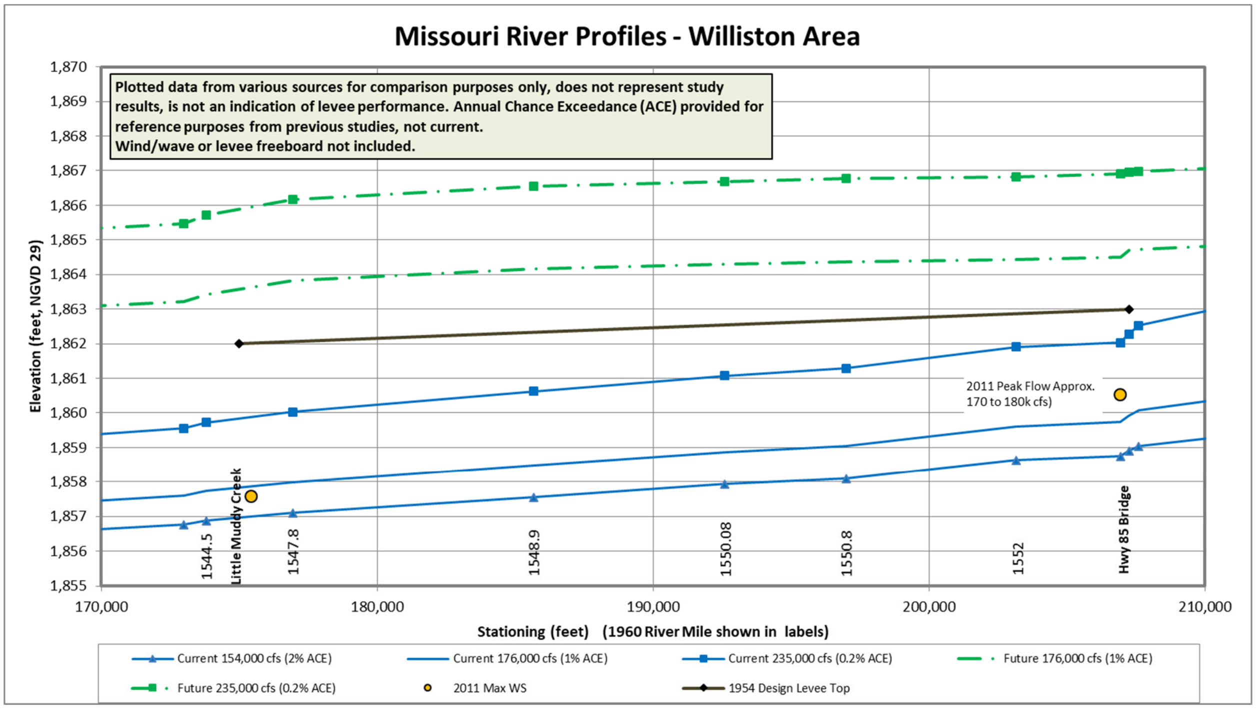


Figure 4-7. Comparison of Missouri River Profiles at Williston, ND

Performance of the WLS was considered to develop alternative constraint criteria. The Omaha District Dam Safety office developed criteria was based on observations during recent events with high Missouri River water levels. Dam Safety identified the following performance-based risks/requirements for the WLS as:

a) Loading (both elevation/stage and duration) shall not appreciably increase risk.
b) Loading (including contributions from tributaries) shall not exceed the post 2011 maximum elevation set in March 2019 (1858.4 feet NGVD 29 referencing NOAA gage WLTN8); performance above this elevation is uncertain and therefore risks are not well characterized.
c) Under existing conditions, acceptable levee performance is expected/substantiated for loadings up to elevation 1856.0 NGVD 29 (summer 2018 flood event). However, foundation distress (boil activity) has been observed in the relief well channel at elevations approaching 1858.4 NGVD 29 (March 2019). Based on loading duration, this condition is not expected to threaten the integrity of the levee and/or its foundation but loading above elevation 1856.0 should be avoided to minimize risk.
d) Increased monitoring and surveillance of the Williston Levee is prescribed for elevations exceeding 1854.0 NGVD 29. Target elevations above 1854.0 places additional demand on already constrained Engineering Division resources (both funding and staffing) to perform surveillance activities.

Agricultural lands within the landward side of federal levee areas are affected by the ability to drain interior runoff into the Missouri River. High water can result in poor drainage, higher groundwater, blocked access, and associated damage and inconvenience. More details on the hydraulic and geotechnical analyses can be found within *Fort Peck Flow Alternatives Williston Area Steady RAS Flows for ResSim* (Attachment 2).

4.3.4 Williston Gage and Flood Impacts

The Williston gage (USGS 06330000) is at RM 1552.6, located about 100 feet downstream of the Hwy 85 Bridge on the right descending (south) bank. The gage datum is 1831.84 ft, NAVD88. The NWS flood stages and impacts at the Williston, ND, gage are shown in Table 4-4. Gage level flood impacts provide an additional source of information regarding alternative constraints.

Table 4-4. Williston, ND NWS Flood Stages and Impacts

Stage	Elevation (ft, NAVD88)	Flood Categories	Flood Impacts
33	1864.84		Levees surrounding Williston are likely to be topped without additional measures taken to temporarily raise the flood protection levels.
32.5	1864.34		Missouri River begins to overtop small stretch of levee near Highway 85 bridge and Williston Water Treatment Plant.
30.75	1862.59		Missouri River begins to cover Highway 85 south of Williston.
30.5	1862.34		At 30.5 ft, water is near the top of Highway 58 in areas between Fairview and Trenton.
30	1861.84		Water covers portions of 13th Avenue East and 11th Avenue East along the Little Muddy River.
28	1859.84		Water backing up into the Little Muddy River begins to cover 54th Street Northwest on the east side of Williston.
26	1857.84	Major	
24	1855.84	Moderate	Water begins to cover oil well location south of Williston. Wildlife management areas are flooded. City of Williston does not flood.
22	1853.84	Flood Stage	Low-lying farmland and access roads to oil well sites near Trenton are flooded. City of Williston does not flood.
20	1851.84	Action Stage	Ditches in the vicinity of the river will fill and wildlife management lands along the south banks will begin to flood.

The Williston gage flood levels and the Geotech levee constraints were evaluated in comparison to model computed flow levels with the RAS model. The resulting table provides levels at which inflows and downstream pool levels are estimated by the model to infringe on the established constraints. The results can be used as a guide for alternative screening to limit impacts. Table 4-5 presents model results for various combinations of total flow and downstream Lake Sakakawea pool levels. Shading is provided to highlight combinations above the Action Stage elevation of 1851.84 NAVD 88, the Flood Stage elevation of 1853.84, and the Geotech levee constraint elevation of 1855.31 (NAVD 88). More details on the hydraulic and geotechnical analyses can be found within *Fort Peck Flow Alternatives Williston Area Steady RAS Flows for ResSim* (Attachment 2).

Table 4-5. Williston, ND Gage Water Surface Elevation Constraints

Model Computed Water Surface Elevation at RM 1552.61 Downstream of Hwy 85									
	Lake Sakakawea Pool Elevation								
NGVD 29	**1837.5**	**1840**	**1842**	**1844**	**1846**	**1848**	**1850**	**1852**	**1854**
NAVD 88	**1838.81**	**1841.31**	**1843.31**	**1845.31**	**1847.31**	**1849.31**	**1851.31**	**1853.31**	**1855.31**
Q Total	Model Computed Water Surface Elevation (NAVD 88)								
30,000	1850.05	1850.03	1850.05	1850.04	1850.35	1851.26	1852.46	1853.97	1855.71
40,000	1851.45	1851.45	1851.46	1851.51	1851.73	1852.37	1853.13	1854.43	1856.02
50,000	1852.9	1852.91	1852.91	1852.95	1852.92	1853.16	1853.95	1854.98	1856.4
60,000	1853.5	1853.51	1853.54	1853.53	1853.73	1854.08	1854.62	1855.56	1856.76
70,000	1854.53	1854.54	1854.56	1854.62	1854.67	1854.7	1855.29	1856.15	
80,000	1855.05	1855.06	1855.08	1855.12	1855.25	1855.52	1856.02		
90,000	1855.92	1855.92	1855.94	1855.98	1856.08				
Q Total is the total river flow at Williston (cfs)									

4.3.5 Irrigation Intakes

Numerous water intakes exist in the Missouri River from Fort Peck Dam downstream to Lake Sakakawea that could be affected by Fort Peck alternative releases. High river flows could damage intakes, increase risk of damage from river processes such as sediment deposition and bank erosion, and low flows could prevent intake operation. A typical pump intake site is illustrated in Figure 4-8.

Figure 4-8. Floating Suction Pump, RM 1616.7, Richland County, MT – 14th July 2020

4.3.5.1 2002 Intake Data Report

Intake data was collected in 2001 and is summarized in the report *Inventory of Pumps and Intakes on the Missouri River between Fort Peck Dam and the North Dakota Border* (Roosevelt County Conservation District 2002). Between June and August 2001, an inventory of the irrigation pumps and intakes between Fort Peck Dam and the North Dakota border was conducted by the Roosevelt County Conservation District as contracted by USACE. The purpose of this inventory was "intended to serve as baseline data as the Army Corps of Engineers considered changes in the operation of the Fort Peck Dam, to assist in determining the potential impacts of proposed operational changes, and to serve as a baseline for monitoring conditions in the event that operational changes are effected". These potential changes were due to the USACE's Revised Draft Environmental Impact Statement (RDEIS) being written. During this survey, a total of 143 pump sites were surveyed to some extent during the inventory, which was believed to comprise the majority of the pumps being used in the area at that time. From the results of the inventory, it was found that 101 pump sites were experiencing some bank erosion and 62 pump sites were expected to have problems operating when the flows exceeded 23,000 cfs as laid out in the RDEIS.

4.3.5.2 July 2020 Intake Survey

A scope and methodology was developed to collect data at a limited number of irrigation pump sites along the Missouri River between Fort Peck Dam and Williston, North Dakota. At each site, easting, northing, and elevation (XYZ) data points were collected to determine the pump site characteristics and potential damage levels for high flow events. Participating landowners had the opportunity to identify site specific critical features such as electrical panels or pump operating levels as well as share concerns about the alternatives during the survey.

Through coordination between USACE, the Missouri River Conservation District Council, and the Roosevelt County Conservation District, 69 sites were surveyed. The sites covered six counties in Montana and North Dakota from Fork Peck Dam (RM 1771.0) to RM 1576.5, or about 25 river miles upstream of Williston, North Dakota. Prior to the survey, coordination was done between local coordinators, conservation districts, and landowners to gain additional site information and to arrange access to the irrigation pump sites.

Site surveys were conducted from July 8th through July 15th, 2020 using two separate survey teams. USACE personnel for each team included one member from the Hydrologic Engineering Branch and two to three members from the Omaha District survey crew. Each team also included a state specific local coordinator. These were individuals familiar with the area that were involved with pump site landowners. Data was collected at a total of 69 sites in the July 2020 survey. A schematic of survey data collected at each site is shown in Figure 4-9.

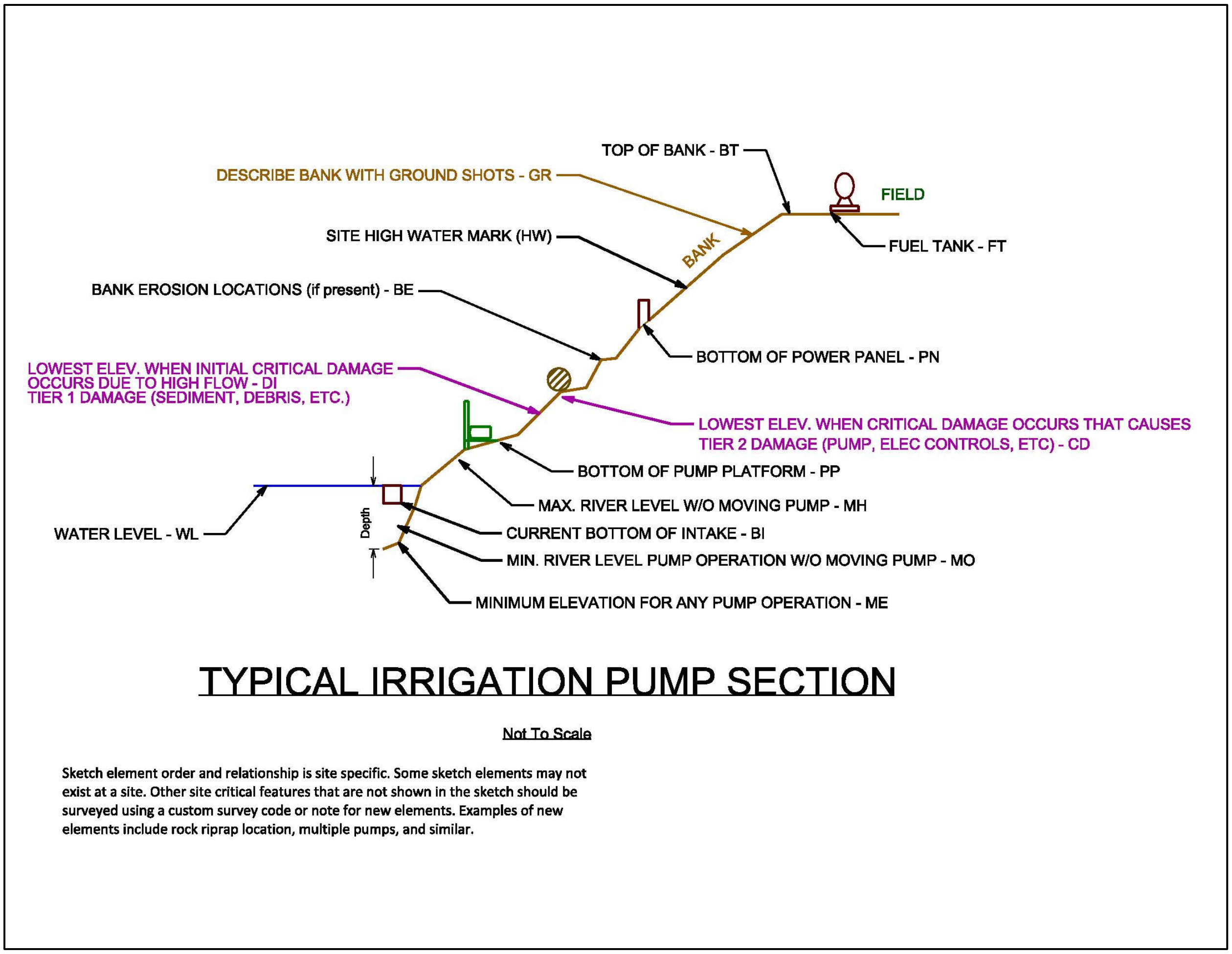


Figure 4-9. Irrigation Intake Survey Schematic

The members of each of the two survey teams had different roles and objectives during the survey. The team member from the Hydrologic Engineering Branch was tasked with filling out a data form in collaboration with the landowner while the Omaha District survey crew members were tasked with collecting various XYZ data on key features from each site. The local coordinator served as the primary point of contact to landowners prior to the field team's arrival. They also coordinated site access and arranged a meeting time between the landowners and the survey teams.

A total of 69 sites were surveyed with 62 sites located in Montana and seven located in North Dakota. The irrigation pump and intake sites were fairly well distributed within the approximately 200 mile long survey area. The pump sites were located on both the north and south banks of the Missouri River. Several sites were larger pump intakes serving multiple irrigators.

A condensed summary table of the key information collected during the survey is located in Attachment 5. Further analysis of data collected during the survey is also included in Attachment 4, the survey data report.

4.3.5.3 August 2020 Intake Survey

Following the survey in July 2020, the US Fish and Wildlife Service (US FWS) collaborated with Montana Fish, Wildlife & Parks (MT FWP) to perform additional surveys on approximately 50 irrigation pump sites along the Missouri River in eastern Montana. Data collection followed the format of the July 2020 survey.

4.3.5.4 Irrigator Provided Information

Information was collected from the irrigator owner / operators who were present at each site during data collection. Detailed information regarding information and analysis of responses is provided in Attachment 4, the survey data report. Responses are summarized in Table 4-6.

Table 4-6. Intake Site Data Query and Responses

Data Query	Top Responses
Concerns Regarding Fort Peck Releases	1) Bank erosion and/or land loss at the pump site and adjacent fields 2) Crop implications and capital costs of loss (i.e., insufficient water, submerging of fields, and partial or complete loss of crop yields) 3) Loss of the pump site operation capability due to low Missouri River flows
Normal O&M Costs	1) Pump movement 2) General maintenance (checking the pump, oil changes, motor greasing) 3) Minor dredging
Larger O&M Costs	1) Pump replacement 2) Pump rebuild 3) Electrical work
Planted Crops	1) Alfalfa 2) Corn 3) Wheat

4.3.5.5 Minimum Pump Operating Level

The minimum elevation for successful intake operation was surveyed or estimated at each site. In most cases, the estimate was based on local owner / operator input as the number of feet below the current river level at which the pump could still be operated. When applicable, the minimum operating level was estimated for both the current site and if the pump were relocated to the extent practical.

4.3.5.6 Damage Level at Intake Sites

Data collection included water surface elevation and damage levels at the site for use with the economic analysis. Damage levels were defined in the field based on input from the local owner / operator of the intake as described in Table 4-7.

Table 4-7. Irrigation Intake Damage Level Descriptor

Damage Level	Description
Tier 1	Lowest river level at which debris/sediment deposition typically begins to significantly affect pump operation. This elevation is qualitative and relies on owner / operator input.
Tier 2	The lowest site elevation when critical damage occurs at the pump site to a fixed feature (pump, electrical panel, other supporting equipment). Tier 2 is a higher elevation and damage level than Tier 1).

4.3.5.7 Stability Observations.

During the intake site surveys, the survey team member would briefly analyze the surrounding area of the pump intake to identify indicators that relayed information about the pump site's streambank stability. These indicators, such as streambank mass wasting or sandbar formation, were documented with photos and brief notes at each site. While most sites were stable enough to support reliable pumping operations, several recurring indicators spoke to the susceptibility of the site to bank erosion and sandbar movement.

Site conditions were assessed by looking for the presence of river process indicators that are often associated with stability. The presence of high streambanks was a common indicator throughout the surveyed river reach, as multiple sites had varying degrees of streambank steepness and vegetation coverage. Pump intakes near the main channel often had more undercutting of the streambank toe and prevalence of mass wasting. Pump intakes near side channels generally were subjected to smaller flows and exhibited greater vegetation coverage and less streambank height. However, this was not always the case. Similarly, due to the prevalence of mass wasting throughout the reach, floating debris was observed at the time of the survey and/or documented as a concern by the landowner.

The presence of sandbars at or near the pump sites also highlighted the river's sediment movement potential. Several sites had sandbars adjacent or near the pumps, or visible from the site. While no exact sediment analysis was done at each site during the course of these surveys, the visual prevalence of silt and sand sediment types indicates bank vulnerability to rapid drawdown due to pore-water pressure buildup following sustained high flows. The below figures highlight a few of the streambank stability indicators observed throughout the pump intake surveys.

Figure 4-10. W. Reid Upstream Streambank, RM 1682.5, Roosevelt Co., MT, 13th July 2020

Figure 4-11. C. Paulson Site, Yellowstone River RM 1.7, McKenzie Co., ND, 15th July 2020

Figure 4-12. Tveit Land & Cattle Intake Site, RM 1624.2, Roosevelt Co., MT, 8th July 2020

Figure 4-13. S. McGowan Upstream Site, RM 1697.95, Roosevelt Co., MT, 13th July 2020

From the above figures, a few of the streambank stability indicators observed throughout the pump intake surveys can be seen. In Figure 4-10, a lack of vegetative cover is visible on the river bank along with the extent of streambank height just upstream of the pump site. Figure 4-11 illustrates the high presence of jammed debris found upstream of the pump site, approximately 1.7 miles upstream of the confluence of the Yellowstone and Missouri Rivers. In Figure 4-12, the formation of several sandbars adjacent to the pump's floating suction can be seen. Figure 4-13 shows greater vegetated coverage along the river bank and a lack of high streambanks alongside the pump site that is found within a side channel of the Missouri River.

4.3.5.8 Assessment of All Intake Sites

The 2020 July and August surveys collected data at a representative number of intakes along the Missouri River from Fort Peck Dam to Lake Sakakawea. Many additional intakes are permitted for use than were surveyed. The number of water rights permits was the best information available to estimate the permitted number of irrigation intakes in the reach. It should be noted that one water right permit does not necessarily equal one intake. Similarly, one intake can be shared between multiple water rights users.

For Montana, the online water rights database was used and is located at: https://mslservices.mt.gov/Geographic_Information/Data/DataBundler/. A filter was used to only show the pertinent intakes; those filters included: WR_STATUS = 'ACTV' AND SRCTYPE = 'SURFACE' AND (SRCNAME = 'MISSOURI RIVER' OR SRCNAME = 'MISSOURI') AND (MEANOFODIV = 'DIKE' OR MEANOFODIV = 'DITCH' OR MEANOFODIV = 'ELECTRIC PUMP' OR MEANOFODIV = 'FUELED PUMP' OR MEANOFODIV = 'PUMP') For North Dakota, a polygon shapefile of active points of diversion was provided by the State of North Dakota from their water rights database. It included all water uses, such as commercial or industrial, so the entries were filtered to only include those with irrigation uses. The provided information within the database only contains the maximum permitted water withdrawal. It does not indicate the precise location of the intake nor the current operation status.

The number of intakes in current operation is difficult to determine with certainty. Input from Montana water users indicate that the 119 sites surveyed in 2020 is a high percentage of the total number of active irrigation intake sites. This number is slightly less than the 2002 pump inventory report (Roosevelt 2002) that listed 143 active pumps but is significantly less than the total number of permitted intakes collected from the Montana and North Dakota water rights database. Assessment of the 143 sites reduced this by 1 to a total of 142 sites. A detailed inventory including a float trip on the Missouri River along with aerial photo collection and assessment was not performed. For the purposes of this analysis, the 142 pump sites cataloged in the report prepared by Roosevelt County (2002) was adopted as the number of active irrigation intakes within MT. The number of surveyed intakes and the total number of intakes is summarized in Table 4-8.

Table 4-8. Surveyed and Total Number of Intakes Summary

Intake Database / Survey	No. Intakes MT	No. Intakes ND	Total
			82%
Estimated Number of Operating Intakes in MT	142+		
* Not all sites had sufficient survey data for RAS evaluation. 98 reflects the sites used in the RAS modeling of the 119 surveyed. + Number of sites estimated from evaluation of the Roosevelt County Report (2002)			

4.4 Reservoir Operations and Flood Risk Management

The Missouri River Reservoir System as currently operated provides substantial flood damage reduction and benefits to the entire basin. Study alternatives include modifying operations of the Missouri River Reservoir System with increased reservoir releases during select periods for species habitat benefits.

4.4.1 Operations

The usual reservoir operation is to store flood inflows, which generally extend from March through July, and to release them during the remainder of the year. Most of these releases are made before December. Winter releases are restricted due to the formation of ice bridges and the associated higher river stages. The objective is to have reservoir levels lowered to the bottom of the annual flood control and multiple use zone by March 1 of each year. Upstream from Gavins Point, releases from Fort Peck, Garrison, Oahe, and Fort Randall Dams are reduced during periods of ice formation until an ice cover is formed, after which releases can be gradually increased. Minimal ice problems exist directly downstream from Big Bend Dam due to its proximity to Lake Francis Case. Refer to the previous Management Plan EIS (USACE 2018g) for further information.

4.4.2 Evaluation of Flood Risk Management Impacts

The Missouri River System as currently operated provides substantial flood damage reduction and benefits to the entire basin. Operation of the reservoirs for flood risk management must take into account highly variable flows from numerous tributaries. During any flood season, the existence of upstream tributary storage reduces Mainstem flood volumes to some extent. Normally, the natural crest flows on the Mainstem reservoirs will also be reduced by the existence of tributary reservoir storage, provided significant runoff contributing to the crest flows originates above the tributary projects.

4.5 DAM SAFETY AND FORT PECK SPILLWAY

The document *Ft Peck Dam, Spillway Test Flow Proposed Repairs and Modifications*, Omaha District, Sep 2019, describes the spillway and operating concerns. Fort Peck Dam spillway is located about three miles east of the main embankment right abutment. The primary function of the spillway is to release surplus water from the reservoir to prevent overtopping and possible failure of the dam.

The Fort Peck outlet works does not function as originally intended. Control of flow through the outlet works with the cylinder gates (ring gates) proved to be unreliable and revealed many operational problems that resulted in high maintenance costs. It was last operated at a maximum flow rate of approximately 20,000 CFS in the 1970's according to an NWO Report entitled, "Ft. Peck Spillway Damage/Operation Scenario July 1997". According to current operating practice, all releases that are greater than powerhouse capacity are released through the emergency spillway.

The spillway was not designed to be used for regular releases. During periods of prolonged drought, the spillway crest elevation will be above the lake elevation and spillway releases are not possible. Using the Fort Peck annual pool probability relationship presented in the *Hydrologic Statistics Technical Report* (USACE 2013b), the spillway crest elevation is exceeded about 65 to 70% of the time annually. Pool levels vary monthly.

Normal releases are through the powerplant which has a maximum release capacity of about 14,000 to 16,000 cfs depending on pool elevation and other factors. The Fort Peck project also includes a separate outlet works with four flood tunnels. However, due to extreme cavitation and vibration problems, the outlet works is not considered as a reliable flow release mechanism.

4.5.1 Spillway Structure

The spillway consists of an approach channel, a reinforced concrete gate structure, a reinforced concrete lined discharge channel, a concrete cutoff structure at the end of the discharge channel and an unlined channel to the Missouri River.

> Gate Structure - The spillway crest elevation is 2225 local project datum (LPD). The reinforced concrete gate structure is 820 feet long and set on a curved line. It consists of

seventeen piers between which are sixteen electrically operated vertical lift steel gates, each 25 feet high and 40 feet wide. The piers support a highway bridge, a service bridge, walkways, and a gate operation platform.

Discharge Channel - The 5,030 foot concrete-lined discharge channel varies in width from 800 feet at the gate structure to 130 feet at the downstream end. There is a sub-drain system which was designed to relieve uplift pressures beneath the discharge channel slab. The channel terminates at elevation 2011.0 feet LPD with a cutoff wall.

Cutoff Wall Structure - The cutoff wall structure is located at the end of the spillway discharge channel and was constructed using cellular concrete. The wall extends to a depth 70 feet below the original spillway channel invert to elevation 1941.0 feet LPD, and also includes wing walls. The main section of the cutoff structure which spans the channel is 229 feet wide. The wing walls extend 260 feet at an angle of 45 degrees.

RCC Plunge Pool - An RCC plunge pool structure was constructed immediately downstream of the cutoff wall structure after the 2011 high water event to improve the stability of the existing cutoff structure. A significant portion of the scour hole was filled with Roller Compacted Concrete (RCC) and tieback anchors were installed through the existing cutoff wall. In addition, training walls were installed to facilitate placement of backfill to support the existing cutoff structure wing walls and to help divert erosive flow away from the cutoff structure. This resulted in the creation of a 350-foot-long RCC apron at the downstream end of the cutoff structure that was anchored into the underlying Bearpaw shale foundation and covered with a 2-foot-thick reinforced concrete cap.

Downstream Unlined Channel - Downstream of the spillway discharge channel and cutoff structure, an unlined discharge channel continues for a length of approximately 2700 feet to the Missouri River. Channel excavation consisted of a bottom width of 130 feet, side slopes of 2H on 1V, and a flat gradient at an elevation of 2010 feet LPD. After exiting the shale bluff, a 12 foot wide pilot channel was excavated through the river floodplain to the Missouri River. Following construction, spillway flows have significantly altered the channel cross-section. Sustained spillway operation is projected to continue to erode the spillway discharge channel within the weathered Bearpaw shale.

4.5.2 Previous Spillway Operations

The spillway at Fort Peck has been used to evacuate flood pool when flows above the powerhouse capacity is required. Filling of the Missouri River Mainstem Reservoir System storage is regarded to have occurred in 1967 (USACE 2018). Since that time, flood releases to supplement the powerhouse has been necessary on multiple occasions. In 2011, Fort Peck Dam was subjected to large inflows and resulting high pools that required spillway operation for approximately 4 months at record discharge rates, with a peak discharge of 52,000 cfs. Operations prior to 1980 include a combination of spillway and outlet works releases. Since operations now avoid using the outlet works, the historic releases from both the spillway and outlet works were combined to indicate the frequency when flows in addition to powerhouse capacity were needed to manage reservoir pool levels. Operation details since 1967 are provided in Table 4-9 and illustrated in Figure 4-14.

Table 4-9 Fort Peck Summary of Historic Operations

Number of Years in Period (1967-2019)	Number Years Operated*	% Years Operated*	Total Days Operated*
59	9	15%	886

* Does not include test flow periods of operation with spillway flow less than 1000 cfs; tabulated values are from the combined historic operations of spillway and outlet works.

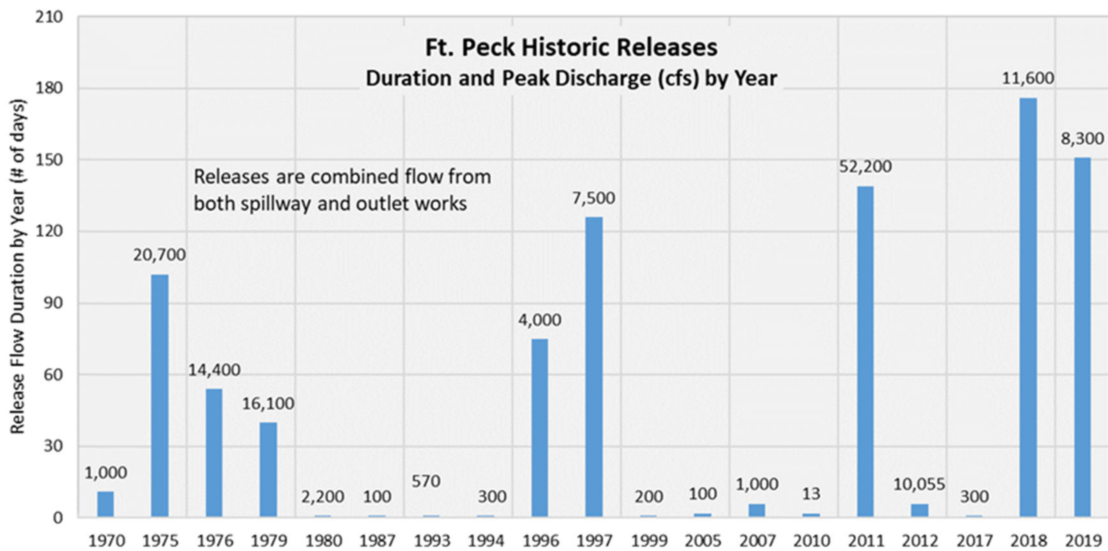


Figure 4-14. Fort Peck Non-Powerhouse Operations Since 1967

As shown in Figure 4-14, there have been 8 years since 1967 with sustained releases above powerhouse capacity that were longer than 30 days.

4.5.3 2011 Flood Damage and Repairs

Following the 2011 sustained high flows, substantial repairs were required. Repairs were authorized to return the spillway to pre-flood conditions, and did not increase the reliability of the spillway or return it to pristine conditions. Repairs of the spillway structure included welding repairs to the gates, removal and replacement of specified spillway drainage structures, and repair of vent pipes that support the spillway sub-drain system. Flow releases created a large scour hole downstream of the spillway exit. The scour hole exposed much of the cutoff structure supporting the spillway discharge channel. There was less than 30 feet of embedment remaining of the original 70 feet. Repairs were performed to stabilize the cutoff structure by constructing an RCC lined plunge pool. This work was completed in 2016. Approximate repair cost total was $52M.

4.5.4 Discharge Channel and Spillway Slab Stability Concerns

Design Memorandum No. MFP-109 Spillway Rehabilitation, dated September 1966, discusses differential movements in certain areas of the Fort Peck Spillway concrete lined discharge channel. The differential movement became apparent before the end of construction and has continued up to the present time. A portion of the spillway channel was filled in 1970 with excavated material from the side slopes in an attempt to halt the movement of the downstream spillway chute and to arrest the rebound within the concrete channel. The fill was washed out during the 1975 spillway releases.

Studies were conducted in 1997 and 2000 (USACE 2019) to evaluate the spillway slab performance. These studies identified that changes in the spillway profile geometry due to existing domes in the chute slab do not cause large scale cavitation problems. However, vertical offsets or rotational deformations accompanying the dome formation may cause failure of the water stop and precipitate a structural failure due to uplift. Offsets at the joints may cause some local cavitation damage. Slab instability will result in the lower portion of the chute if the drains don't have the required efficiency to relieve uplift conditions.

A semi-quantitative risk assessment was conducted by USACE in 2014. This study concluded that the emergency spillway structure was designed with a high level of redundancy resulting in a remote likelihood of failure. However, the emergency spillway at Fort Peck is the last line of defense in preventing catastrophic failure with extremely high life and economic loss of national significance. A proper functioning spillway sub-drain system is vital to the stability and performance of the spillway.

4.5.5 Current Condition

An inspection was conducted in 2019 (USACE 2019) with pertinent details as follows:

> Spillway Discharge Channel and Walls - As documented in previous inspection reports, the spillway slab has experienced significant rebound between Station 34+00 and Station 41+00. Maximum rebound is on the order of 2½ feet. Joint separation is common. Exposed dowels, which are losing section due to exposure (rust), and key separation between adjacent joints are common. Surface scaling, spalling at joints and cracks within the slabs area also common.
>
> Sub-drain System - The spillway sub-drain system which was designed to relieve uplift pressures beneath the slab remains in disrepair with known segments of collapsed, displaced or cracked pipe.
>
> Plunge Pool - The recently completed roller compacted concrete training walls within the plunge pool were observed from the end of each spillway access road. No issues were noted with the concrete. Continued erosion/scour of the cut bank slopes adjacent to and downstream of the concrete training walls was noted. Future discharges within the spillway could potentially lead to additional erosion and slope failures without riprap protection.

Provided below is a summary of spillway recommendations developed as a result of the 2019 Periodic Inspection (USACE 2019) and discussions with Operations Division staff stationed at Fort Peck Dam:

- Installation of new infrastructure to provide access to the spillway sub-drain system in order to perform a comprehensive inspection of the drain and provide access for repairs.
- Perform spillway chute concrete maintenance and spall repair.
- Perform a geotechnical investigation of both spillway abutments and install survey monitoring points to aid in evaluating/monitoring abutment wall movement.
- Erosion was noted immediately upstream of the riprap placed along the left abutment approach wall. The area measured approximately 50 feet wide. The project office, with assistance from Dam Safety, should add riprap and bedding to this area to prevent further erosion.
- The project office should repair the area of significant spalling that has exposed rebar in the spillway chute slab at the exit of the chute for Gate #4 prior to spillway releases to prevent section loss of the rebar.
- Install instrumentation to monitor flows in the under slab drainage system. In 2019, a flow meter was installed, however, project personnel have no way to monitor it while the spillway is in operation. A readout box mounted on top of the west spillway wall is needed to monitor sub-drain flows.

The recommended actions have not been completed at this time. Funding for these actions must compete with other USACE Operation and Maintenance priorities with an unknown outcome. No funding has been identified in the immediate future.

4.5.6 Summary

The spillway concrete lined discharge channel has concerns with spillway slab performance that will be exacerbated with sustained spillway flow. The risk of potential slab damage will likely be a function of both spillway flow and duration. Past spillway repair expenses and the recommended repair items illustrate concerns with future spillway performance.

If damage to the spillway slabs would occur, repair would likely be extensive and not limited to a single slab or small area due to the high spillway flow velocities and the change in flow hydraulics as a result of slab uplift. The spillway slab and sub-drain system repairs would be difficult, expensive, and likely constrained by time in order to address dam safety due to loss of spillway operation as quickly as possible. Depending on damage extent and allowable repair time period, repair cost is estimated to be in the range of $20 to $40M. The test flow releases would increase the likelihood these repairs would be needed because they increase the use of the spillway.

5 HEC-RAS ALTERNATIVES MODELING

The previously conducted MRRMP-EIS developed five separate Missouri River unsteady HEC-RAS models that were documented (USACE 2018c). The models were developed to assist in the assessment of a suite of actions to meet Endangered Species Act (ESA) responsibilities for the piping plover, the interior least tern, and the pallid sturgeon using USACE authorities. The model geometry development and calibration for the existing conditions is documented in *Missouri River Unsteady HEC-RAS Model Calibration Report* (USACE 2015a).

Seven alternatives, including the No Action alternative, were simulated in RAS with a period of record analysis (POR) from March 1930 to December 2012. Development of inflow records at current depletion levels to use as boundary conditions for the HEC-ResSim and RAS models was previously performed as described in the report, *Missouri River Recovery Management Plan Time Series Data Development for Hydrologic Modeling* (USACE 2018e).

Additional modeling was performed for this Fort Peck Dam test release EIS analysis. The objective of the additional HEC-RAS modeling is to simulate the Fort Peck Dam flow release changes relative to the No Action alternative.

Three of the five HEC-RAS models developed for the Management Plan study were used to evaluate the Fort Peck Dam Test Release alternatives. The models were updated to run in the 5.0.6 version of HEC-RAS. No further changes were made to the Garrison and Fort Randall models. The Fort Peck model geometry was updated with 2018 and 2019 USGS high density bathymetry from RM 1701.48 to 1679.47 and was re-calibrated to 2014 and 2018 data.

5.1 Fort Peck Dam to Garrison Dam

The Fort Peck Dam to Garrison Dam RAS model was the primary tool used for this study. The model previously developed for the MRRMP-EIS was revised to include new information received during the study. New observed water surface profiles (WSP), gage data, and the collection of the USGS high density bathymetry prompted major updates to the model geometry and calibration. Hydrologic and geotechnical analyses for the Williston, ND levee were performed to help aid in the selection of maximum stage in the Williston area for use with ResSim model criteria. More details on the model re-calibration can be found in Attachment 1.

5.1.1 Re-Calibration

The primary source of calibration data was observed stage and flow hydrographs on the main stem Missouri river gages and field measured water surface profile data from 2014 and 2018. The 2018 WSP did not cover the entire reach and only spanned from the Culbertson gage down to Lake Sakakawea Pool. Peak stage for the 2011 event was also considered. Daily average releases from Fort Peck Dam were around 9,000 to 12,000 cfs for the July 2014 WSP and about 16,000 cfs for the August 2018 WSP. Due to the degradation and aggradation trends that occur in the Fort Peck Dam to Lake Sakakawea reach, using historical data for alternative analysis is not recommended.

5.1.1.1 Calibration Update

First, the model was re-calibrated for low flow conditions using 2014 to 2018 data. The primary data used for the low flow calibration was the 2018 partial WSP. Channel n-values were adjusted to match the model with the 2018 WSP and gage stage data. The WSP and gage data sometimes did not agree, so the model calibration parameters were adjusted to provide the best fit between the two data sets. Second, the flow roughness factors were re-adjusted to maintain the calibration to high flows in 2011. Previously calculated ungaged flows were included for the 2011 high flow calibration. Ineffective flow areas were double checked for consistency.

The calibration goal was to achieve a water surface elevation within 1 ft for the entire reach and within 0.5 ft for most of the reach for both the measured water surface profiles and the observed gage data for 2011 and 2018, excluding periods of ice.

5.1.1.2 Calibration Results

Model calibration results are within the desired range with most locations within 0.5 to 1 foot of observed stages. In general, comparison of model results to gage station hydrographs was reasonable. The measured profile calibration also provides confidence in model performance between the gage station locations. The measured profile WSP data point spacing (0.1 mile) for 2014 is much less than the density of the RAS model cross section data which is based on the sediment range interval of 3 to 5 miles. As shown in Attachment 1, the calibration results illustrate that differences occur between the modeled water surface slope and the WSP measured data slope in many places with the greatest difference in the upper part of the modeled reach. The upper part of the reach was also missing WSP for 2018 so most of this section in the model was not re-calibrated since there was little information to compel changes. A comparison of peak stages for the 2011 flood are shown in Table 5-1.

Table 5-1. 2011 Flood Peak Stage Comparison

Location	Date	Peak Stage Difference (ft)
RM 1763.54 – below Fort Peck	M	M
RM 1750.99 – W Frazer Pump Plant	13Jun2011	-0.04
RM 1701.31 – Wolf Point	14Jun2011	-0.05
RM 1620.65 – Culbertson	21Jun2011	0.13
RM 1597.40 – No. 4 nr Nohly	22Jun2011	-0.13
RM 1588.95 – No. 5 nr Nohly	22Jun2011	0.02
RM 1582.01 – No. 5A at Buford	21Jun2011	0.90
RM 1577.03 – No. 6 nr Buford	M	M
RM 1552.61 – Williston	22Jun2011	-0.07
RM 1546.20 – No. 9 at Williston	22Jun2011	0.08

*M – denotes gage peak stage data is missing

*Peak stages were manually estimated due to minor timing issues and bad data points.

5.1.2 Ice Affects

Ice affected conditions including ice cover, ice breakup, and ice jams occur annually within the basin. Ice formation conditions typically occur in late November to late December with iceout typically occur in the early spring, usually in the March to April time frame. Ice jams and ice cover can result in ice affected stages that are much higher than would normally occur for an open water condition. No ice parameters were included in the model development or calibration. Therefore, winter condition model calibration results should be viewed with caution and recognize that results do not reflect observed conditions.

5.1.3 USGS 2018 and 2019 High-Resolution Bathymetry Geometry Update

The USGS collected high density single beam bathymetry (15 m spacing) in June 2018 over a short reach that is about 13 river miles in length. The high density reach is located just upstream from the Poplar River confluence (RM 1692.18 to 1679.47). This reach is about 80 river miles downstream of Fort Peck Dam which is located at RM 1771.5. The bathymetry was combined with September 2018 LiDAR of the channel banks and November 2011 LiDAR of the floodplain to create a DEM. A new model geometry was created using the USGS data merged into the MRRMP-EIS model.

In 2019, the USGS expanded the reach of high density data upstream about 10 additional river miles. The high density data was extended to proceed from around Wolf Point downstream to the Poplar River confluence (RM 1701.48 to 1679.47). The bathymetry was again combined with September 2018 LiDAR of the channel banks and November 2011 LiDAR of the floodplain to create a DEM (provided by the USGS). A new model geometry was created using the 2018 and 2019 USGS data merged into the MRRMP-EIS model.

A water surface profile was also collected with the 2019 data on 01 July 2019 between river miles 1701 and 1679. Daily flow from 01 July 2019 was 12,300 cfs according to the Wolf Point USGS gage record. A comparison of the observed water surface points and the model output, shown in Figure 5-1 and Figure 5-2, shows that the modified model geometry matches very well to the observed WSP.

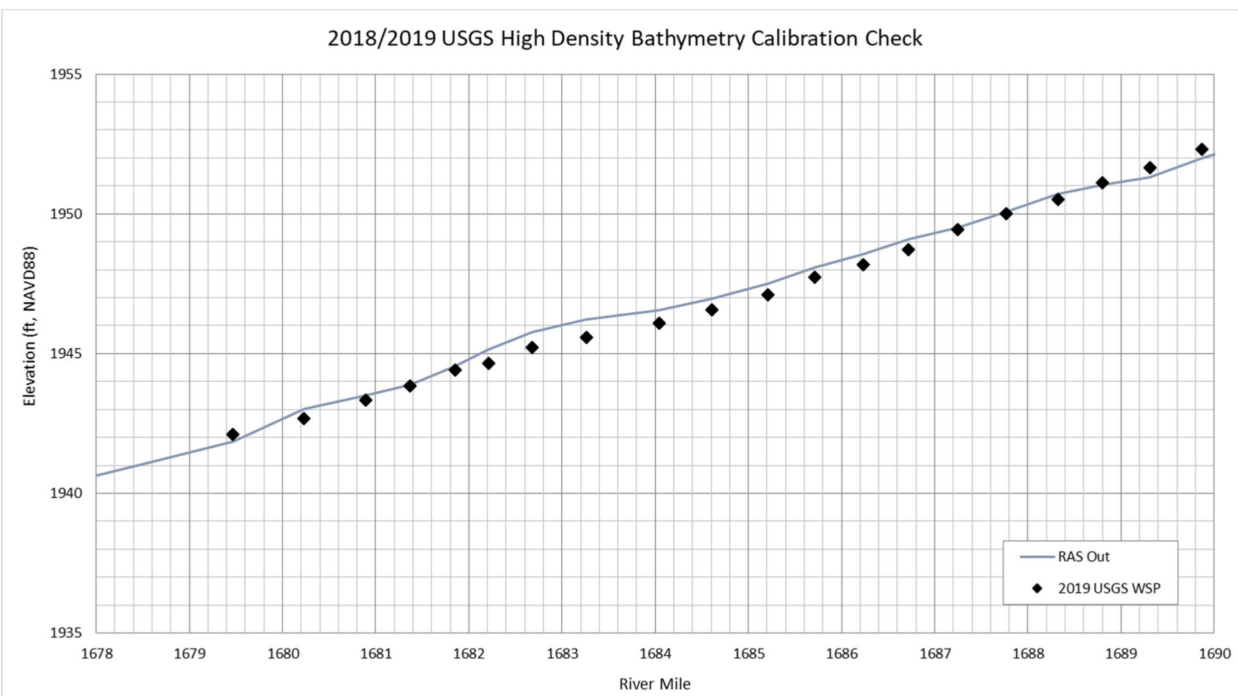


Figure 5-1. 2018/2019 High Density Bathymetry Calibration Check with 2019 Profile – RM 1690 to 1678

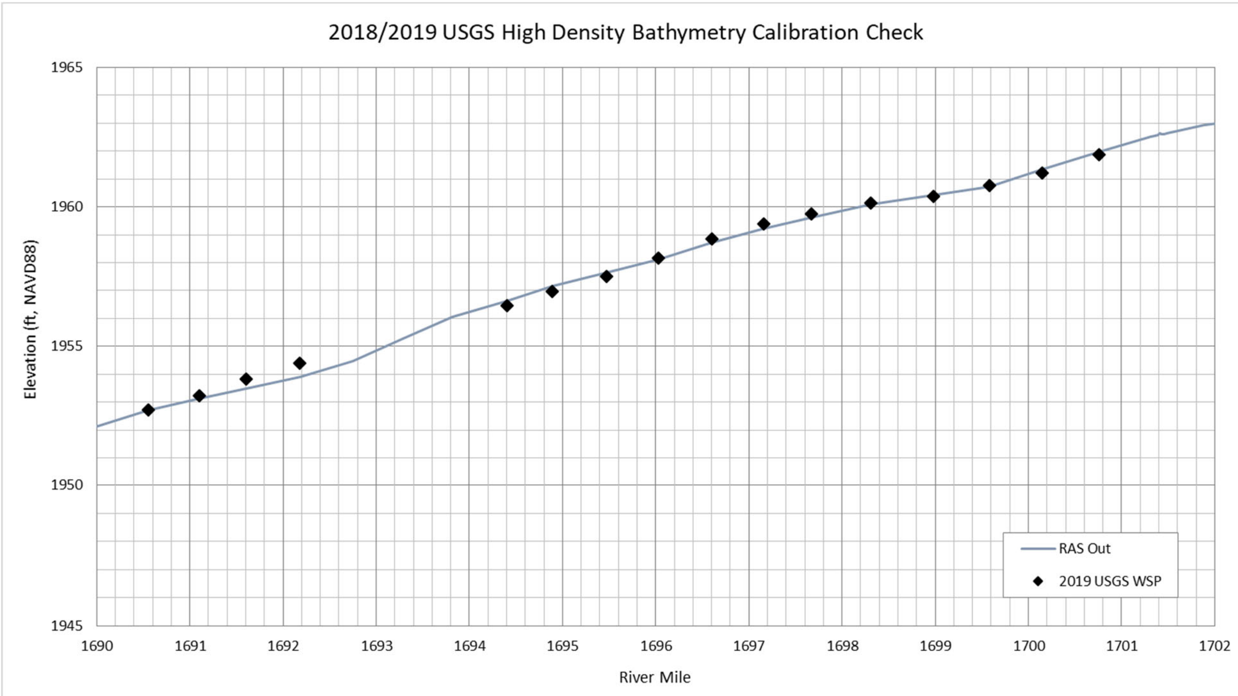


Figure 5-2. 2018/2019 High Density Bathymetry Calibration Check with 2019 Profile – RM 1702 to 1690

5.1.4 Comparison of MRRMP-EIS Geometry to Updated High Density Geometry

A sensitivity analysis was conducted to compare the impact on water surface elevation due to the change in model geometry. The models used the same setup parameters. Steady flow modeling was performed for low flows of 4000, 6000, and 8000 cfs. These low flows were selected to correspond with the minimum flows that are being considered for the Fort Peck flow test release alternatives. Minimum flow is the most likely to have an impact on irrigation intakes. Separate analysis were run with the 2018 USGS data and the 2018/2019 combined USGS data.

Comparison of the model results illustrated that the current MRRMP-EIS model geometry has performance issues at these low flows. The 2018 and 2019 high density data provided a different, less smooth profile than the 2012 data. Figure 5-3 through Figure 5-6 illustrate a profile difference of 1 to 2 feet.

- Using the model to identify irrigation intake impacts based on water surface elevation will include a high degree of uncertainty.
- Model results with the high density data illustrated wide variation from the average slope.
- The high level of variation between the two models reduces confidence in using the incremental change between low flow profiles.

Model results could be influenced by long term geometry variation. However, the gage trend analysis at Wolf Point and Culbertson do not indicate this is occurring to a significant degree.

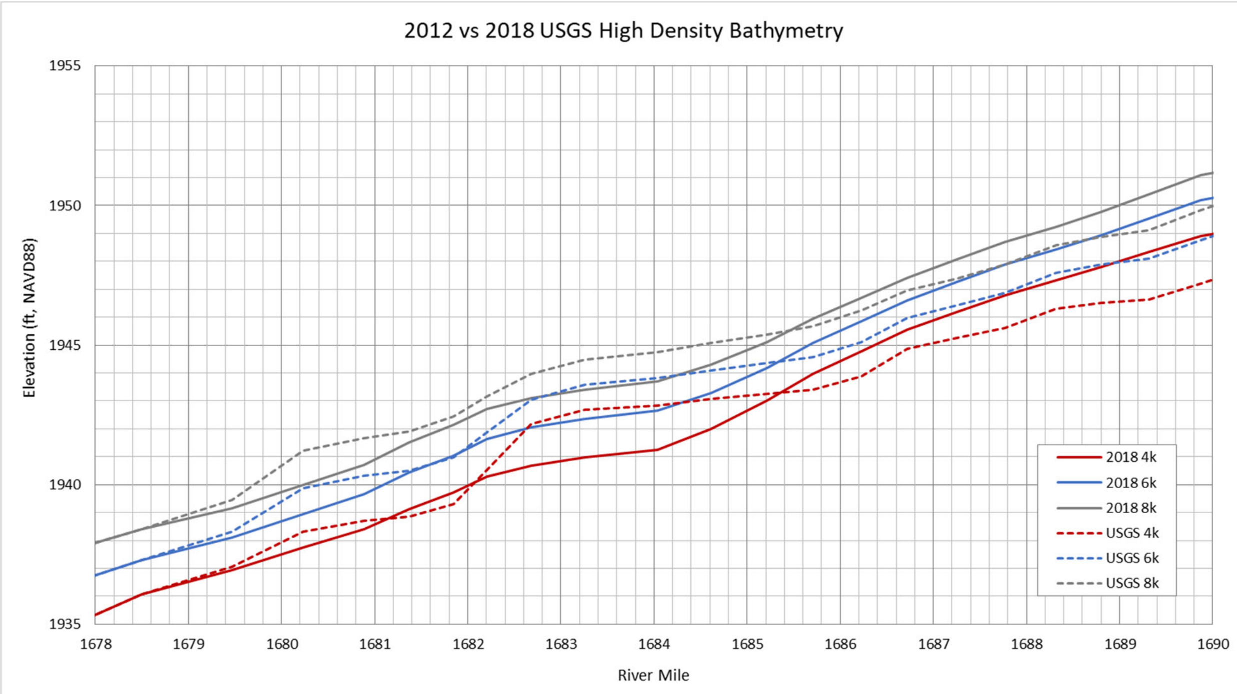


Figure 5-3. 2012 vs 2018 Profile Comparison – RM 1690 to 1678

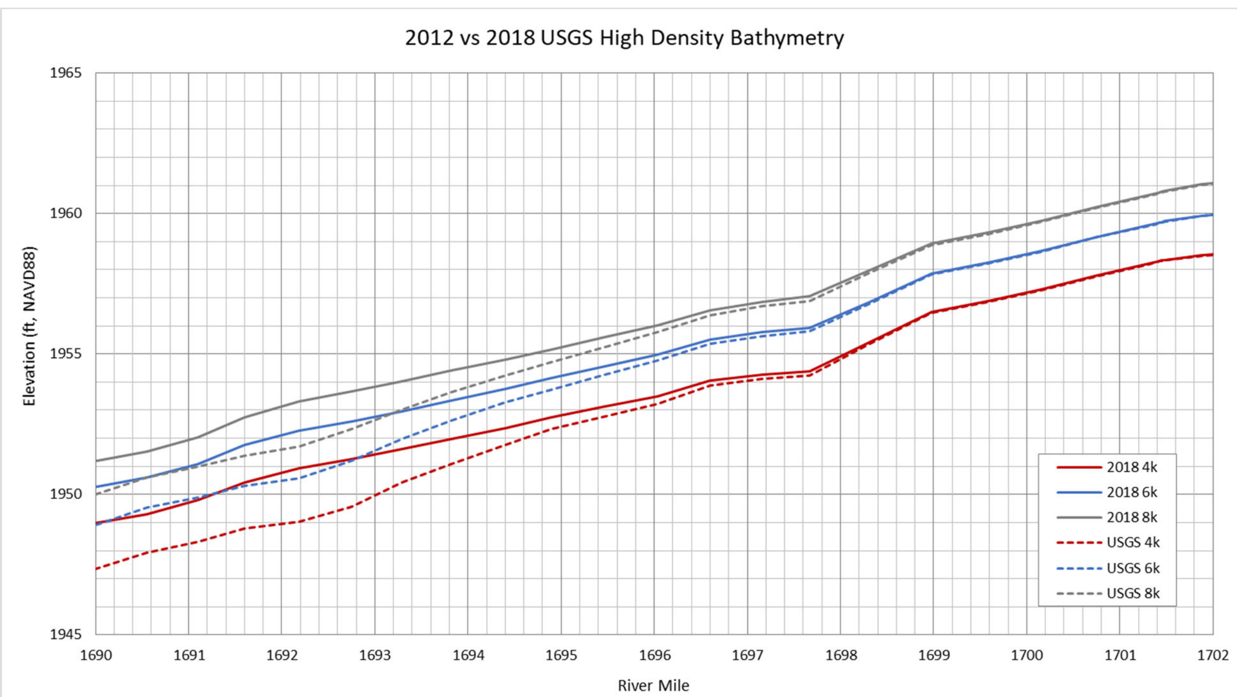


Figure 5-4. 2012 vs 2018 Profile Comparison – RM 1702 to 1690

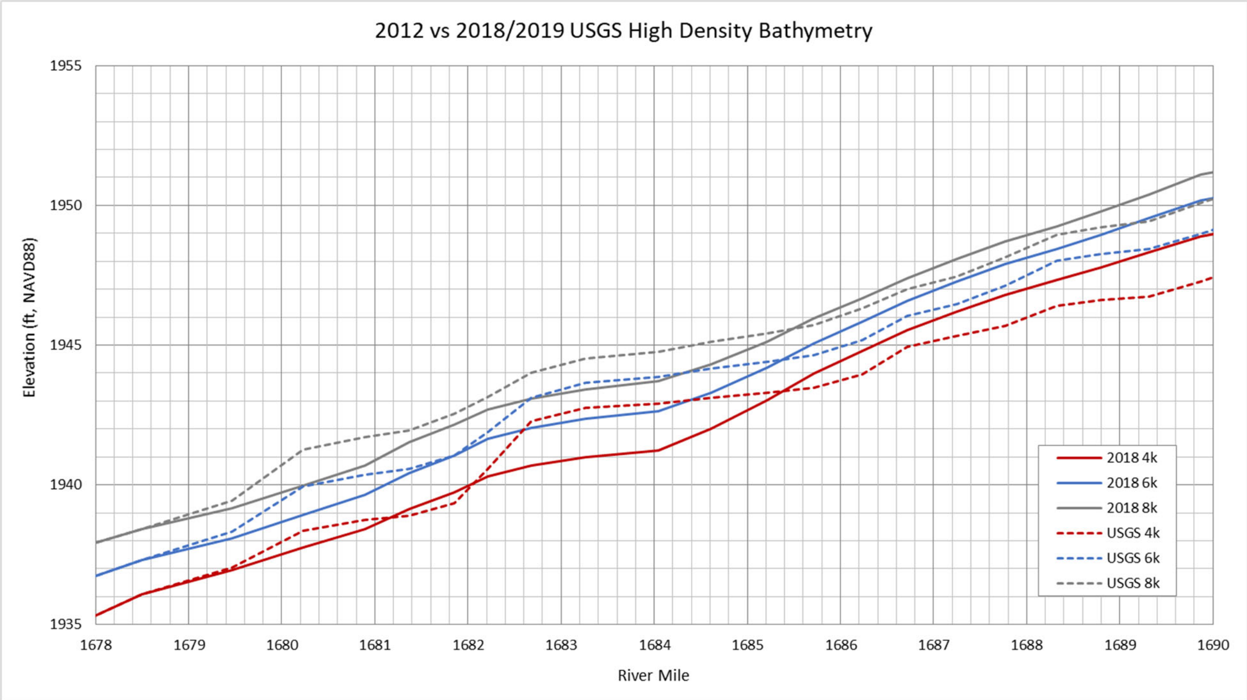


Figure 5-5. 2012 vs 2018/2019 Profile Comparison – RM 1690 to 1678

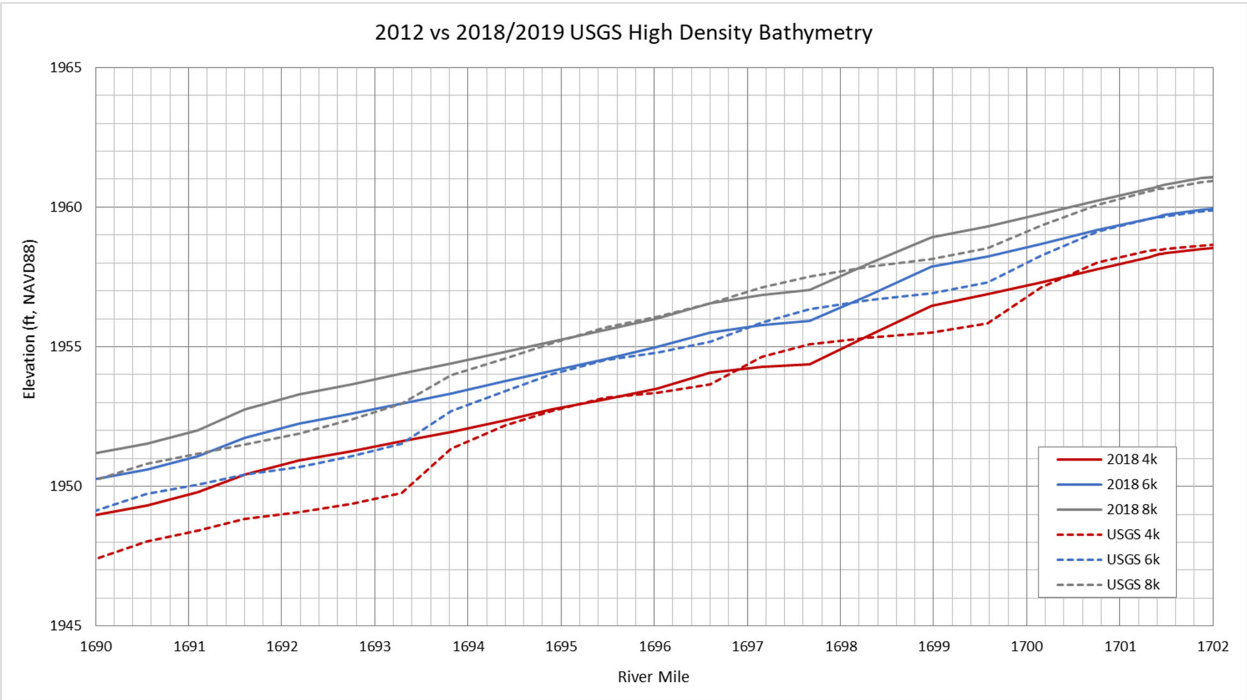


Figure 5-6. 2012 vs 2018/2019 Profile Comparison – RM 1702 to 1690

5.1.5 Williston Levee Evaluation

An analysis was performed to assess the potential for alternatives to affect levee performance in the Williston, ND area. The analysis used the RAS model to evaluate Williston levee reach river levels for various river flow and Lake Sakakawea pool combinations. The river level analysis was combined with input from Geotech regarding river elevations at which no levee deficiencies would be foreseen. The results provide constraints for use with Fort Peck flow alternatives at Williston due to levee restrictions. Geotech recommended that a peak river elevation of 1854.0 ft NGVD 29 (or 1855.31 ft NAVD88) be used so that weekly surveillance is not frequently initiated due to Fort Peck releases. A table was produced that showed the RAS results for the various flow and pool elevation combinations with highlights where the recommended peak elevation was exceeded. More details on the hydraulic and geotechnical analyses can be found in the report, *Fort Peck Flow Alternatives Williston Area Steady RAS Flows for ResSim* (Attachment 2).

5.1.6 Flood Inundation Mapping for Impact Analysis

Flood inundation mapping was performed to illustrate the increased inundation area between normal (No Action) and peak flows during the maximum release for the alternatives. A value of 30,000 cfs was chosen for the peak flow and 9,000 cfs for the No Action flow. These two flows were mapped from Fort Peck Dam to Williston, ND, due to the main interest being the illustration of additional inundation area for the assessment of cultural resources. Flow was incremented using the average June tributary inflow as shown in Table 5-2.

Table 5-2. Flow Profiles (in cfs) Used for Inundation Mapping

Reach	River Miles	9,000 cfs Profile	30,000 cfs Profile
Fort Peck Dam to Milk River	1769.04 – 1761.68	9,000	30,000
Milk River*		1,210	1,210
Milk River to Poplar River	1761.22 – 1679.47	10,210	31,210
Poplar River*		123	123
Poplar River to Yellowstone River	1678.5 – 1582.01	10,333	31,333
Yellowstone River*		38,700	38,700
Yellowstone River to Garrison Dam	1581.35 – 1391.08	49,033	70,033
Garrison Pool Elevation (ft, NAVD88)	1391.08	1840	1840

*Tributaries used average June flow values obtained from the USGS.

Inundation maps of the study reach were prepared for the 9,000 cfs and 30,000 cfs profiles. A typical location is shown in Figure 5-7. Mapping for the entire reach from Fort Peck Dam to Williston, ND, are included in Attachment 3. The area of inundation for the two flows was summed for three reaches: Fort Peck Dam to Wolf Point, MT, Wolf Point, MT to Culbertson, MT, and Culbertson, MT to Williston, ND. A summary of the inundated area for each reach and flow and the difference between 30,000 cfs and 9,000 cfs is shown in Table 5-3.

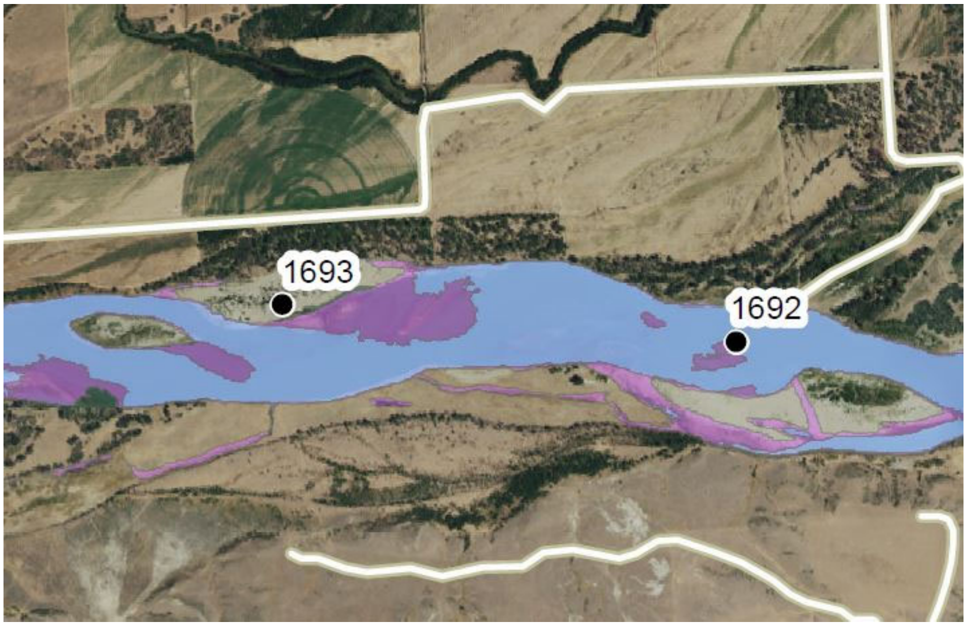


Figure 5-7. Typical Inundation Mapping

Table 5-3. Inundation Mapping Area Summary

Reach	River Miles	9,000 cfs (acres)	30,000 cfs (acres)	Inundated Area Change (acres)
Fort Peck Dam to Wolf Point	1771.5 – 1701.31	6,601	9,878	3,276
Wolf Point to Culbertson, MT	1701.31- 1620.65	7,027	12,271	5,244
Culbertson, MT to Williston, ND	1620.65- 1552.61	34,628	43,029	8,401
Total	**1771.5- 1552.61**	**48,256**	**65,177**	**16,921**

5.1.7 Irrigation Intake Analysis

Irrigation intakes from Fort Peck Dam to Lake Sakakawea were analyzed to provide the HC team with data for their economic models. At the beginning of the process, the best available data was from a 2001 data collection effort. Subsequently, USACE proceeded to acquire new survey data (see Section 4.3) of a representative number of the irrigation intakes and the analysis was updated. Although the 2001 survey included more sites, data from that survey was not used due to river changes since data collection. The HEC-RAS model was used with the July 2020 intake survey data analysis to provide Tier 1 and Tier 2 flow values to the HC team. Water surface elevation points were taken during both the July and August surveys and were checked against the calibration of the model. More information on the irrigation intake surveys can be found in the survey data report included in this report as Attachment 4.

5.1.7.1 Water Surface Elevation Points Collected in 2020 Surveys

Water surface elevation (WSE) points were collected during the July and August 2020 surveys. These points were compared to the RAS profiles for the time they were collected. Flows during the July and August surveys ranged from 10,000 cfs to 12,000 cfs. The August 2020 WSE points were used to the extent possible. Some points were screened out because they appeared to be bad data points.

Plots of the July and August 2020 WSE points and the corresponding profiles from RAS can be seen in Plate 1 through Plate 12.

5.1.7.2 Calculation of Tier 1 and Tier 2 Flow Estimates

The HC team requested the calculation of flow for the Tier 1 and Tier 2 elevations to use as input to their economic models. The calibrated RAS model was used to provide a rating curve for each cross section which was ultimately used to transform the Tier 1 and Tier 2 elevations into a flow estimate. Tier 1 and Tier 2 elevations and flow estimates are shown in Attachment 5.

A wide range of steady flows (4,000 to 85,000 cfs) was used to create a table of output for each location and flow. The Tier 1 and Tier 2 flows were linearly interpolated from this table of output. Some of the intakes calculated a flow above 85,000 cfs. Since this flow is much greater than the alternative pulse peak flow and model calibration data, critical flows at these locations were noted as “greater than 85,000 cfs”. These values were provided to the irrigation HC team for further analysis.

5.1.7.3 Minimum River Flow Estimated for Intake Operation

Survey data collected in 2020 included an estimation of the minimum elevation at which irrigation intake operation was feasible. Similar to the analysis performed for the Tier 1 and Tier 2 levels, the minimum operation elevation was used with the calibrated RAS model to develop an estimation of the corresponding Missouri River flow at each site. Of all the 2020 survey sites, 51 had an estimated elevation that could be used with the RAS model. Estimated minimum flows are shown in the intake summary table in Attachment 5.

5.1.8 Channel Capacity Analysis

Channel capacity estimates were performed for the Fort Peck to Lake Sakakawea reach to provide an indication of the flow rate at which bank elevations are overtopped and flow begins to leave the main channel and enter the floodplain. Channel capacity estimates were performed with the one-dimensional RAS model that was calibrated to 2014/2018 conditions by comparing steady flow profiles with top of bank elevations at each cross section combined with reviewing the best available floodplain topography. Floodplain flow connectivity was not assessed. The estimated channel capacity does not necessarily correlate with the onset of flood damage. In addition, channel capacity is typically highly variable along the channel bank due to wide variation in bank elevations. The quality of the channel capacity estimate is affected by numerous factors including how representative the model cross sections are of river geometry, local channel geometry variation, low spots in bank elevations, and the floodplain topography accuracy. Within the reservoir delta areas where the river enters the downstream lake, the channel capacity estimate is not meaningful.

A Monte Carlo risk analysis methodology capable of assessing impacts to dam safety and flood risk as a result of flow release changes would be required to fully assess how an alternative impacts potential flood risk. Refer to the Summary of Hydrologic Engineering Analysis (USACE 2018e) for additional details on the risk analysis methodology.

Channel capacity estimates were performed to provide an indication of reaches susceptible to flooding and if any of the alternatives may alter flood risk. The Fort Peck to Lake Sakakawea reach was divided into three reaches for this analysis: Fort Peck to Wolf Point, MT (RM 1701), Wolf Point, MT (RM 1701) to RM 1604, and RM 1604 to Lake Sakakawea. A summary of the channel capacity estimates is provided in Table 5-4.

Table 5-4. Channel Capacity Estimates

Location	From RM	To RM[1]	Channel Capacity Estimate (kcfs) [2]
Fort Peck Dam to Wolf Point, MT	1771.5	1701.31	60 to 70
Wolf Point, MT to RM 1604	1701.31	1604	40 to 50
RM 1604 to Lake Sakakawea	1604	-	35 to 40

1 Downstream boundaries that are reservoir pools are not a static location and change with pool elevations.
2 The channel capacity estimate is based on an evaluation of hydraulic model results. The estimated channel capacity refers to the flow level at which significant water levels exceed bank elevations (may represent ponding water and not necessarily flow through connectivity). Values vary considerably within the reach and may change over time.

5.2 Garrison Dam to Oahe Dam & Fort Randall Dam to Gavins Point Dam

The Garrison and Fort Randall models were updated to run in HEC-RAS 5.0.6. The models were not re-calibrated from the previous RAS alternatives modeling effort described within the MRRMP-EIS (USACE 2018c). The models were executed with ResSim output to provide updated information for the human considerations evaluation regarding the FTPTR-EIS.

6 RESULTS AND EVALUATION

All alternative modeling was performed with HEC-RAS version 5.0.6. Model output contains a considerable amount of information, not easily condensed to simple conclusions. Each of the seven alternative runs produced 82 years (March 1930 – December 2012) of daily stage and flow hydrographs. To express the changes compared with the No Action alternative, the model results were evaluated by statistical evaluation and duration analysis plots.

Results from the 82-year runs for the seven alternatives were provided to the HC team for analysis. They used the daily (instantaneous 2400 value for each day) flow and water surface elevation output to analyze effects to various resources that include: hydropower, cultural resources, fish & wildlife (exclusive of listed species), flood risk, irrigation, recreation, thermal power, and water supply. The HC team performed an extensive analysis on each of the alternatives for all of the resources and provide a detailed comparison of results. For this report, only the hydraulic model output is presented.

6.1 Statistics

For the statistical evaluation, daily flow and water surface elevation results were analyzed to compare the differences between the No Action Alternative and the remaining six alternatives. All of the alternatives show minor changes to both flow and water surface elevation. Tables showing the differences between calculated statistics for both flow and water surface elevation for twelve locations are shown in Plate 13 through Plate 22. The statistics calculated include: the 10th, 25th, 50th, 75th, and 90th- Percentiles, and the Minimum and Maximum. It should be noted that the percentile statistics calculated are from a duration analysis and not a Bulletin 17C (USGS 2019) flow frequency analysis.

The minimum and maximum are the lowest daily flow or stage and the highest daily flow or stage output for each alternative over the period of record. For model stability, a minimum flow of 2,500 cfs was used for Fort Peck outflow in RAS. As seen in the tables, the minimum flow did not vary at all between the alternatives while the maximum flow varied slightly, especially in the Garrison and Fort Randall reaches.

Stage statistics have been rounded to the nearest tenth of a foot, which is equivalent to 1.2 inches. This helps demonstrate how flow changes impact river elevations between the alternatives. For example, the 50th percentile flow for Williston in Alternative 1B was 111 cfs lower than the No Action Alternative. For that flow difference, there is less than an inch of impact to the water surface elevation of the river, and therefore zero stage change is tabulated. The relationship between flow and stage does vary through the study area and results should be interpreted with care.

It is also important to note that the RAS alternative models, although they have a 30 minute computation interval, have been configured to report one value per 24 hour period, and unfortunately that one value is not a daily average. The RAS model reports the value that lands on 2400 of each day. The most reasonable output interval was chosen as daily due to the size of watershed being modeled, POR length, and the number of hydrograph locations necessary for HC analysis. This means that slight shifts in timing from alternative to alternative can carry over into the results as small fluctuations in the reported flow. Changes in timing are a small factor, not likely to significantly impact any results evaluation, but should be kept in mind when making comparison at a precise level such as in the statistics tables.

Caution should be used when trying to draw conclusions from the statistics alone. Comparing daily statistics over the entire POR will reduce the impact of the pulses that occur over a relatively short time period.

6.2 Seasonal Duration Plots

A duration analysis was also performed for the alternative output. Seasonal duration plots for key main stem locations are shown in Plate 23 through Plate 70. Seasonal dates chosen for the duration analysis coincide with the current System operational seasons: spring (1Mar to 30Apr), summer (1May to 31Aug), fall (1Sep to 30Nov), and winter (1Dec to 28Feb). There are minimal changes in all seasons for most of the locations. Differences decrease with distance downstream from Fort Peck and are generally negligible downstream of Oahe Dam. As with the statistics analysis, the seasonal duration evaluation for the entire POR will reduce the impact of the short duration pulses.

6.3 Maximum Stage Change

The maximum flow and stage change were determined for each alternative during June which is the main pulse period. Differences were determined for each of the full and partial pulses at Wolf Point and Culbertson as summarized in

Table 6-1 and Table 6-2. The date of the pulse peak, for each alternative, was used to compare to the no action alternative and is shown in the tables. The full tables of stage values for the alternatives and the no action that were compared can be found in Attachment 6.

At Wolf Point, full pulses, shaded green, result in a significant stage increase of 4 to 6 feet greater than No Action during the period of the peak flow pulse. Partial pulses, shaded yellow, also result in a significant stage increase during the pulse period. Although generally smaller, several of the partial pulses have a stage change as large as the full pulse. Further downstream, at Culbertson, the differences are slightly less but still range between 3 to 5 feet for the full pulses and between 1 to 3 feet for the partial pulses. Due to the statistically small number of pulses, a significant difference between alternatives is not apparent.

Table 6-1. Peak Elevation Alternative Change from No Action at Wolf Point, MT

	Difference Between Alt Peak & No Action (ft)					
	Alt 1	Alt 1A	Alt 1B	Alt 2	Alt 2A	Alt 2B
			15 Jun			15 Jun
1930			5.25			6.60
			15 Jun			16 Jun
1947			3.95			5.76
			14 Jun			14 Jun
1949			4.84			6.56
	2 Jun	2 Jun	2 Jun	2 Jun	1 Jun	2 Jun
1953	1.71	2.66	-0.14	2.36	4.26	-0.14
	7 Jun	15 Jun	15 Jun	1 Jun	24 May	15 Jun
1954	4.92	-0.04	4.81	3.75	3.51	3.68
	8 Jun	1 Jun	16 Jun	8 Jun	1 Jun	16 Jun
1966	4.86	4.72	5.12	5.94	6.02	6.18
	8 Jun	1 Jun	7 Jun	6 Jun	2 Jun	6 Jun
1967	4.80	3.38	1.92	5.63	5.38	2.54
	9 Jun	2 Jun	10 Jun	9 Jun	2 Jun	10 Jun
1968	6.16	4.39	3.88	5.73	5.80	4.05

	Difference Between Alt Peak & No Action (ft)					
	Alt 1	**Alt 1A**	**Alt 1B**	**Alt 2**	**Alt 2A**	**Alt 2B**
	30 May	30 May	29 May	30 May	29 May	29 May
1970	2.31	3.89	0.78	2.23	5.01	0.72
	31 May	30 May	30 May	30 May	29 May	30 May
1973	2.09	4.46	0.00	2.83	5.67	1.35
		29 May			29 May	
1974		1.55			3.06	
1975	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]
		25 May			29 May	
1976		2.08			3.12	
						5 Jun
1977	N/A[2]	N/A[2]	N/A[2]			2.33
1978	N/A[2]		N/A[2]	N/A[2]		N/A[2]
	10 Jun	1 Jun	17 Jun	9 Jun	31 May	15 Jun
1980	5.69	5.12	5.74	6.51	6.33	6.59
	6 Jun	2 Jun	12 Jun	8 Jun	2 Jun	12 Jun
1982	2.76	4.37	2.78	4.67	5.16	4.46
	12 Jun	2 Jun	18 Jun	8 Jun	2 Jun	16 Jun
1983	7.36	4.70	7.38	6.40	6.19	6.46
	8 Jun	1 Jun	9 Jun	8 Jun	1 Jun	9 Jun
1984	6.04	4.75	3.30	6.13	6.16	3.82
	11 Jun	31 May	18 Jun	8 Jun	31 May	15 Jun
1985	6.97	4.97	7.03	6.40	6.11	6.52
	8 Jun	1 Jun	8 Jun	7 Jun	1 Jun	8 Jun
1986	5.55	4.01	2.79	6.34	5.56	3.97
	8 Jun	2 Jun	15 Jun	8 Jun	2 Jun	15 Jun
1987	5.85	5.97	5.89	7.23	7.31	7.30
	8 Jun	1 Jun	13 Jun			10 Jun
1994	5.04	5.26	4.10			5.35
	11 Jun	2 Jun	18 Jun	9 Jun	2 Jun	15 Jun
1998	5.92	4.62	5.88	6.01	6.06	6.02
	1 Jun		2 Jun	4 Jun		3 Jun
1999	3.54		1.17	4.28		0.92
	7 Jun	1 Jun	14 Jun	5 Jun	27 May	9 Jun
2000	5.87	4.96	5.69	5.56	4.42	3.85
	10 Jun	2 Jun	12 Jun	9 Jun	1 Jun	12 Jun
2012	5.82	4.01	4.03	5.06	5.18	4.19
Ave Full	**5.42**	**4.34**	**5.19**	**5.75**	**5.56**	**5.74**
Ave Partial	**4.15**	**2.77**	**3.04**	**4.44**	**4.58**	**3.39**

1: 1975 was a high flow year, June peaks were similar
2: Partial pulses in April not June

Table 6-2. Peak Elevation Alternative Change from No Action at Culbertson, MT

	Difference Between Alt Peak & No Action (ft)					
	Alt 1	Alt 1A	Alt 1B	Alt 2	Alt 2A	Alt 2B
			17 Jun			17 Jun
1930			4.30			5.23
			17 Jun			17 Jun
1947			3.18			4.19
			16 Jun			16 Jun
1949			4.03			5.02
	3 Jun	3 Jun	4 Jun	4 Jun	3 Jun	4 Jun
1953	0.99	1.81	-0.08	1.41	2.59	-0.08
	8 Jun	17 Jun	16 Jun	2 Jun	17 Jun	17 Jun
1954	4.10	-0.03	3.55	3.50	-0.72	2.93
	10 Jun	3 Jun	17 Jun	10 Jun	3 Jun	17 Jun
1966	3.68	3.64	3.85	4.45	4.56	4.63
	10 Jun	2 Jun	8 Jun	8 Jun	2 Jun	7 Jun
1967	3.82	2.62	1.77	4.19	3.83	2.34
	11 Jun	3 Jun	11 Jun	10 Jun	3 Jun	11 Jun
1968	4.32	3.32	2.87	4.16	4.25	2.95
	31 May	1 Jun	30 May	31 May	30 May	30 May
1970	2.13	2.89	0.71	2.07	3.46	0.65
	1 Jun	31 May	31 May	31 May	30 May	31 May
1973	2.00	3.60	0.01	2.69	4.24	1.31
		30 May			30 May	
1974		0.74			1.67	
1975	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]
		26 May			30 May	
1976		1.23			1.80	
1977	N/A[2]	N/A[2]	N/A[2]			2.15
1978	N/A[2]		N/A[2]	N/A[2]		N/A[2]
	10 Jun	3 Jun	19 Jun	10 Jun	2 Jun	17 Jun
1980	4.37	4.08	4.31	4.99	4.84	5.01
	7 Jun	3 Jun	13 Jun	9 Jun	4 Jun	14 Jun
1982	1.89	2.86	2.10	3.08	3.26	2.95
	14 Jun	3 Jun	20 Jun	10 Jun	3 Jun	17 Jun
1983	5.57	3.70	5.57	4.86	4.64	4.89
	9 Jun	2 Jun	10 Jun	8 Jun	3 Jun	10 Jun
1984	4.41	3.63	2.84	4.36	4.60	3.10
	12 Jun	2 Jun	20 Jun	10 Jun	2 Jun	17 Jun
1985	5.23	3.89	5.30	4.88	4.80	4.90
	9 Jun	2 Jun	9 Jun	8 Jun	2 Jun	9 Jun
1986	4.29	3.11	2.59	4.76	4.12	3.45
	10 Jun	3 Jun	17 Jun	10 Jun	3 Jun	17 Jun
1987	4.64	4.66	4.71	5.56	5.58	5.64
	10 Jun	2 Jun	14 Jun			12 Jun
1994	3.90	4.38	3.25			3.85

	Difference Between Alt Peak & No Action (ft)					
	Alt 1	**Alt 1A**	**Alt 1B**	**Alt 2**	**Alt 2A**	**Alt 2B**
	12 Jun	3 Jun	19 Jun	10 Jun	3 Jun	17 Jun
1998	4.37	3.54	4.31	4.42	4.47	4.43
	2 Jun		3 Jun	6 Jun		4 Jun
1999	2.61		1.05	2.93		0.80
	9 Jun	3 Jun	16 Jun	7 Jun	28 May	10 Jun
2000	4.40	3.88	4.22	4.22	3.69	3.34
	11 Jun	3 Jun	13 Jun	11 Jun	3 Jun	13 Jun
2012	3.99	2.51	2.76	3.40	3.34	2.83
Ave Full	**4.2**	**3.3**	**4.1**	**4.3**	**3.9**	**4.42**
Ave Partial	**3.09**	**1.92**	**2.36**	**3.32**	**2.79**	**2.62**

1: 1975 was a high flow year, June peaks were similar

2: Partial pulses in April not June

6.4 Volume Comparison

A comparison of the volume for the period during the pulse (the months of May and June) was performed for the No Action alternative and the six action alternatives for three locations: Wolf Point, Culbertson, and Williston. Only years when there was either a full pulse or partial pulse were compared. The percent change from the No Action alternative for the three locations are shown in Table 6-3 through Table 6-5. Full pulse years are highlighted in green and the partial pulse years are highlighted in orange. The full tables of the calculated volumes for the three locations can be found in Attachment 7.

Table 6-3. Wolf Point Pulse Volume Percent Change Between Alternatives and No Action

	Full and Partial Pulse Years					
	Difference between Alt and No Action (percent)					
	Alt 1	Alt 1A	Alt 1B	Alt 2	Alt 2A	Alt 2B
1930	-	-	42%	-	-	81%
1947	-	-	24%	-	-	55%
1949	-	-	37%	-	-	75%
1953	4%	4%	-4%	14%	25%	4%
1954	39%	6%	42%	55%	47%	65%
1966	35%	30%	38%	65%	58%	71%
1967	16%	13%	-2%	22%	36%	8%
1968	32%	14%	16%	33%	37%	18%
1970	-7%	-6%	4%	-8%	1%	4%
1973	4%	18%	11%	23%	37%	32%
1974	-	0%	-	-	21%	-
1975	-1%	-1%	0%	-1%	-2%	0%
1976	-	-26%	-	-	-22%	-
1977	8%	5%	10%	-	-	62%
1978	1%	-	1%	8%	-	7%
1980	55%	40%	58%	81%	72%	88%
1982	20%	26%	10%	48%	51%	35%
1983	80%	31%	70%	67%	49%	65%
1984	35%	23%	19%	41%	48%	26%
1985	82%	38%	78%	75%	68%	82%
1986	27%	27%	12%	42%	47%	28%
1987	73%	70%	76%	116%	108%	124%
1994	38%	42%	46%	-	-	58%
1998	48%	24%	40%	57%	51%	53%
1999	2%	-	20%	1%	-	8%
2000	53%	29%	47%	53%	39%	47%
2012	28%	6%	11%	23%	27%	13%
Full Avg	**49%**	**26%**	**49%**	**64%**	**51%**	**77%**
Part Avg	**12%**	**-1%**	**16%**	**18%**	**7%**	**26%**

Table 6-4. Culbertson Pulse Volume Percent Change Between Alternatives and No Action

	Full and Partial Pulse Years					
	Difference between Alt and No Action (percent)					
	Alt 1	Alt 1A	Alt 1B	Alt 2	Alt 2A	Alt 2B
1930	-	-	46%	-	-	88%
1947	-	-	25%	-	-	57%
1949	-	-	38%	-	-	77%
1953	6%	5%	-3%	17%	27%	6%
1954	41%	7%	43%	58%	50%	68%
1966	38%	32%	41%	68%	62%	74%
1967	16%	13%	-2%	23%	36%	8%
1968	34%	16%	19%	36%	40%	20%
1970	-5%	-5%	5%	-6%	3%	4%
1973	5%	19%	12%	26%	39%	34%
1974	-	1%	-	-	23%	-
1975	-1%	-1%	0%	-1%	-2%	0%
1976	-	-25%	-	-	-20%	-
1977	10%	6%	12%	-	-	68%
1978	1%	-	1%	9%	-	8%
1980	58%	43%	61%	85%	77%	92%
1982	19%	24%	10%	46%	48%	34%
1983	80%	31%	71%	67%	50%	66%
1984	37%	24%	22%	43%	50%	28%
1985	87%	40%	83%	80%	73%	86%
1986	29%	29%	13%	45%	50%	31%
1987	70%	67%	73%	112%	104%	119%
1994	37%	41%	45%	-	-	57%
1998	49%	25%	42%	59%	53%	55%
1999	3%	-	20%	3%	-	8%
2000	55%	30%	49%	55%	41%	49%
2012	29%	7%	13%	24%	28%	15%
Full Avg	**50%**	**27%**	**51%**	**65%**	**53%**	**80%**
Part Avg	**14%**	**0%**	**18%**	**19%**	**9%**	**27%**

Table 6-5. Williston Pulse Volume Percent Change Between Alternatives and No Action

	Full and Partial Pulse Years Difference between Alt and No Action (percent)					
	Alt 1	Alt 1A	Alt 1B	Alt 2	Alt 2A	Alt 2B
1930	-	-	18%	-	-	34%
1947	-	-	7%	-	-	16%
1949	-	-	12%	-	-	23%
1953	3%	3%	0%	8%	13%	4%
1954	15%	3%	16%	22%	19%	26%
1966	18%	15%	19%	32%	29%	33%
1967	4%	4%	0%	6%	10%	3%
1968	11%	5%	7%	11%	13%	7%
1970	-1%	-1%	2%	-1%	2%	2%
1973	2%	6%	4%	8%	12%	10%
1974	-	1%	-	-	8%	-
1975	0%	0%	0%	0%	-1%	0%
1976	-	-8%	-	-	-6%	-
1977	4%	3%	6%	-	-	28%
1978	0%	-	0%	2%	-	2%
1980	19%	14%	20%	29%	26%	29%
1982	7%	9%	4%	17%	18%	13%
1983	29%	12%	26%	25%	19%	24%
1984	13%	8%	8%	15%	17%	10%
1985	40%	19%	37%	37%	34%	38%
1986	8%	8%	4%	13%	14%	9%
1987	28%	27%	29%	46%	43%	47%
1994	14%	15%	16%	-	-	21%
1998	20%	11%	18%	24%	22%	22%
1999	2%	-	7%	2%	-	3%
2000	20%	11%	19%	20%	16%	18%
2012	13%	4%	7%	11%	13%	7%
Full Avg	**20%**	**10%**	**19%**	**26%**	**20%**	**31%**
Part Avg	**5%**	**0%**	**7%**	**6%**	**3%**	**9%**

The May / June total flow volume at Wolf Point, Culbertson, and Williston, varies significantly between alternatives. Flow volume for a partial pulse is much less than that for a full pulse. The flow volume change at Wolf Point and Culbertson is similar while less at Williston. This is likely due to the influence of the Yellowstone River which enters between Culbertson and Wolf Point. A summary table of the averages was prepared to illustrate the differences between alternatives as shown in Table 6-6.

Table 6-6. Average Pulse Volume Percent Change Between Alternatives and No Action

	Pulse Average Volume Change Difference between Alt and No Action (percent)					
	Alt 1	Alt 1A	Alt 1B	Alt 2	Alt 2A	Alt 2B
Wolf Point Full Avg	49%	26%	49%	64%	51%	77%
Partial Avg	12%	-1%	16%	18%	7%	26%
Culbertson Full Avg	50%	27%	51%	65%	53%	80%
Partial Avg	14%	0%	18%	19%	9%	27%
Williston Full Avg	20%	10%	19%	26%	20%	31%
Partial Avg	5%	0%	7%	6%	3%	9%

Results illustrate very large average volume change for all alternatives. Alternative 1A and Alternative 2A have less change. However, it is not possible to determine if this difference is statistically significant or due to the small sample size. The large volume change during the pulse period indicates that small, temporary, and long-term impacts to geomorphic processes such as bank erosion, sandbar movement, degradation, and aggradation would occur. The bank erosion, degradation, and geomorphic process change impacts could be large and adverse locally.

6.5 Irrigation Intakes Tier 1 and Tier 2 Damage Levels

A summary of irrigation intake analysis results is provided in Table 6-7. A detailed table of irrigation intake information and analysis results is provided in Attachment 5. Results show that a little over half of the intakes could be impacted with the pulse peak flow exceeding the Tier 1 flow at 53% of the intake locations. Data was not available to conduct the analysis at all sites. None of the MT FWP sites had complete information and the USACE data set was also limited. The maximum Tier 2 flow was capped at 85,000 cfs although it was likely higher at a number of sites.

Table 6-7. Irrigation Intakes Summary Statistics

Statistic	Tier 1	Tier 2
Number Sites Included in Analysis	57	64
Average Flow (cfs)	31,279	56,823
Minimum Flow (cfs)	13,177	22,316
Maximum Flow (cfs)	71,760	85,000*
25th Percentile Flow (cfs)	23,313	34,834
75th Percentile Flow (cfs)	36,654	85,000
Number Sites Tier Flow Less than 25,000 cfs	19	5
Percent of Sites Tier Flow Less than 25,000 cfs	33%	8%
Number Sites Tier Flow Less than 30,000 cfs	30	11
Percent of Sites Tier Flow Less than 30,000 cfs	53%	17%
* Note: Tier 2 flow is capped at a maximum of 85,000 cfs. Actual flow may be higher at some sites.		

Plots showing the Tier 1 and Tier 2 flows in a variety of formats are shown in Figure 6-1 through Figure 6-3.

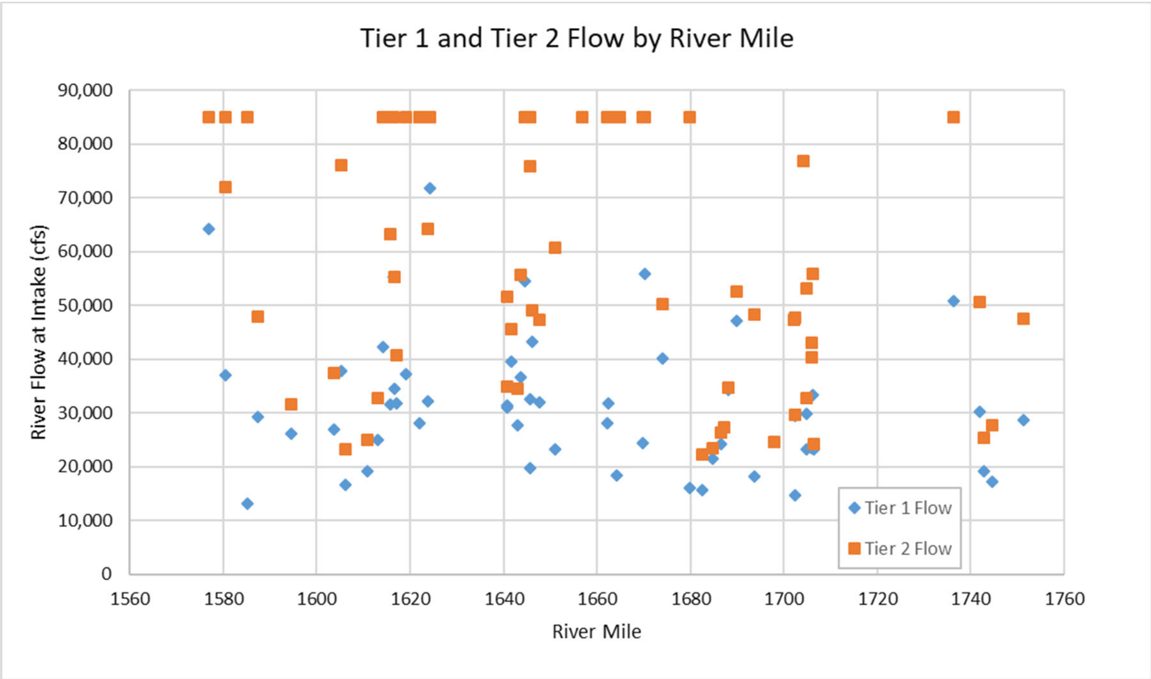


Figure 6-1. Tier 1 & Tier 2 Flow by River Mile

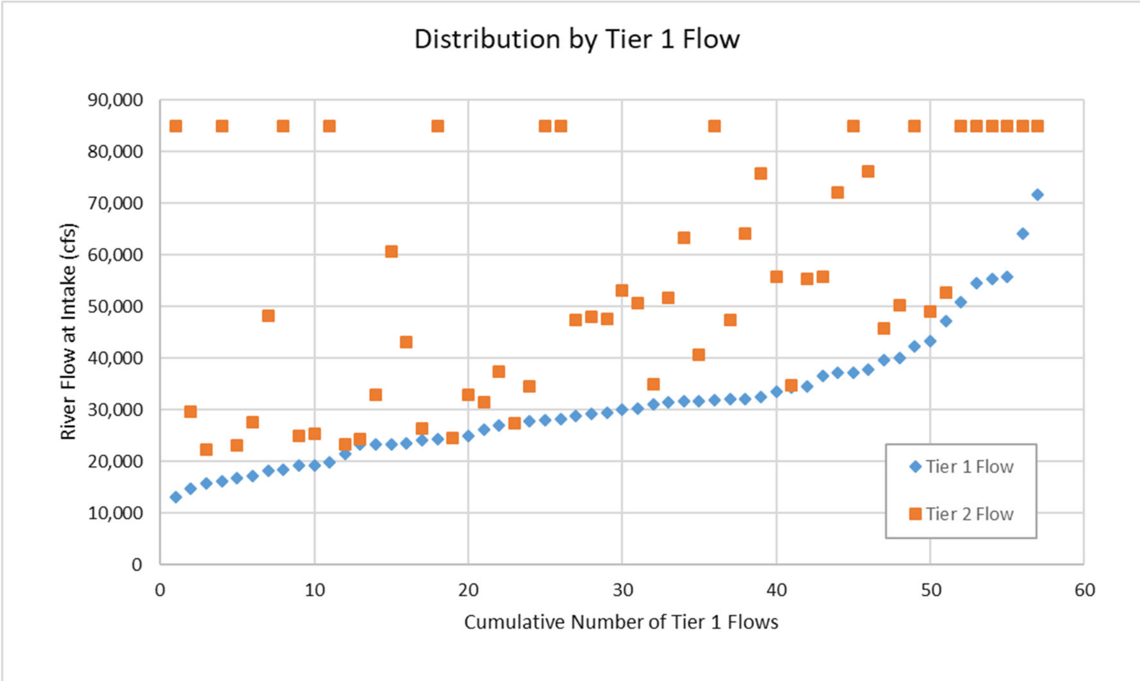


Figure 6-2. Cumulative Distribution by Tier 1 Flow

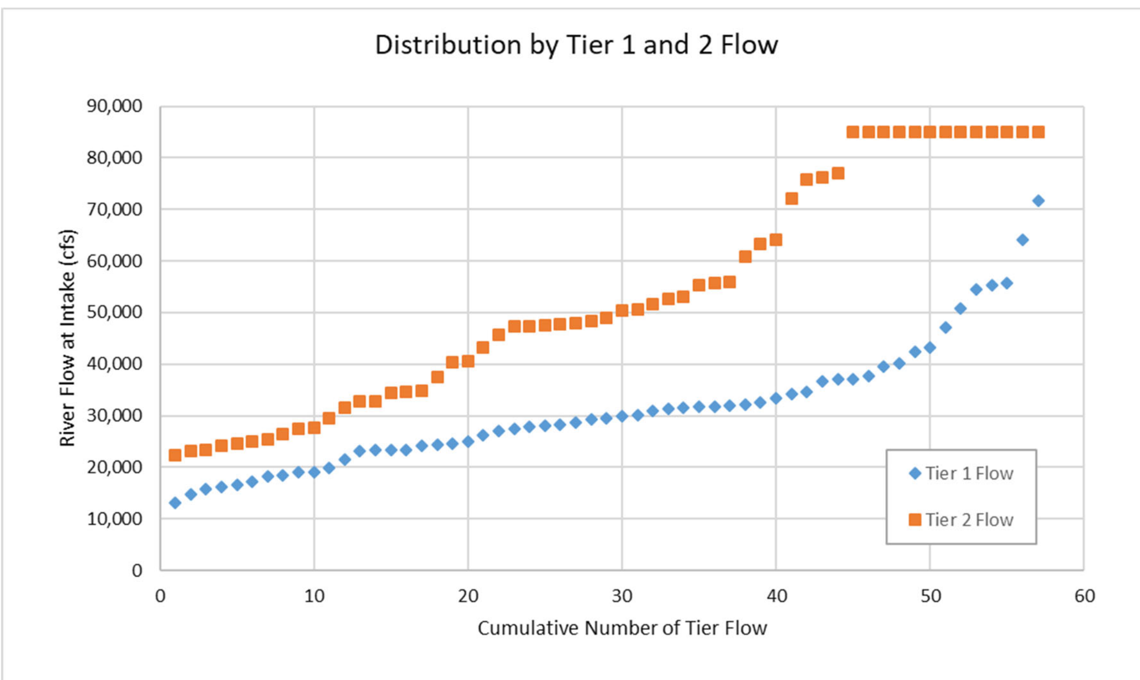


Figure 6-3. Cumulative Distribution by Tier 1 & 2 Flow

6.6 MINIMUM RIVER FLOW ESTIMATED FOR INTAKE OPERATION

Estimates for a minimum Missouri River water surface level required for intake operation were available for 38 of the sites surveyed in 2020. Similar to the methodology used to estimate the Tier 1 and Tier 2 flows, the RAS model was used to derive a flow equivalent to the estimated minimum operating elevation collected during the site surveys.

The evaluation determined several factors that affected reliability of the intake low flow operation.

- Data was available for only 51 of the intake sites and may not be representative of all sites.
- RAS model accuracy at flows in this range is limited as river elevations can be affected by local geometry that is not reflected in the RAS model widely spaced cross sections.
- The stage-flow relationship is non-linear in many locations which reduces accuracy of the interpolation based methodology.
- The minimum operating elevation could not be directly surveyed during the site visit in 2020. The elevation was estimated by the site operator as the number of feet below the site river level. At some locations, a flow estimate was provided by the operator rather than an elevation.
- Intake owners often indicated that the minimum intake operating elevation could be lowered by several feet by moving the intake to a nearby location. Intake movement was not included in the evaluation.
- River flow correlates with total flow at the site and includes Fort Peck release and all downstream tributary inflows.
- Locations downstream of the Yellowstone River were not included in the analysis.
- Data includes several outliers with flow estimates above 10,000 cfs that are likely suspect accuracy. River flow at the time of survey was in that range and all intakes were capable of operating.

Results determined that the average minimum river flow at each site required for operation was about 7,200 cfs. Of the 51 sites evaluated, 17 (33%) had a minimum flow necessary for intake operation of 8,000 cfs or greater. Results are summarized in Table 6-8. A plot illustrating the distribution of the minimum river flow required for intake operation by river mile is shown in Figure 6-4.

Table 6-8. Minimum Flow for Intake Operation Evaluation Summary

Statistic	Result
Number Sites	51
Average Minimum Operating Flow (cfs)	7,186
Minimum Flow (cfs)	4,000*
Maximum Flow (cfs)	13,952
25th Percentile Flow (cfs)	5,386
75th Percentile Flow (cfs)	8,642
Number of Sites with Minimum Flow for Operation Greater than 8,000 cfs	17
% Surveyed Sites with Minimum Operating Flow Greater than 8,000 cfs	33%
* Minimum flow not estimated lower than 4,000 cfs.	

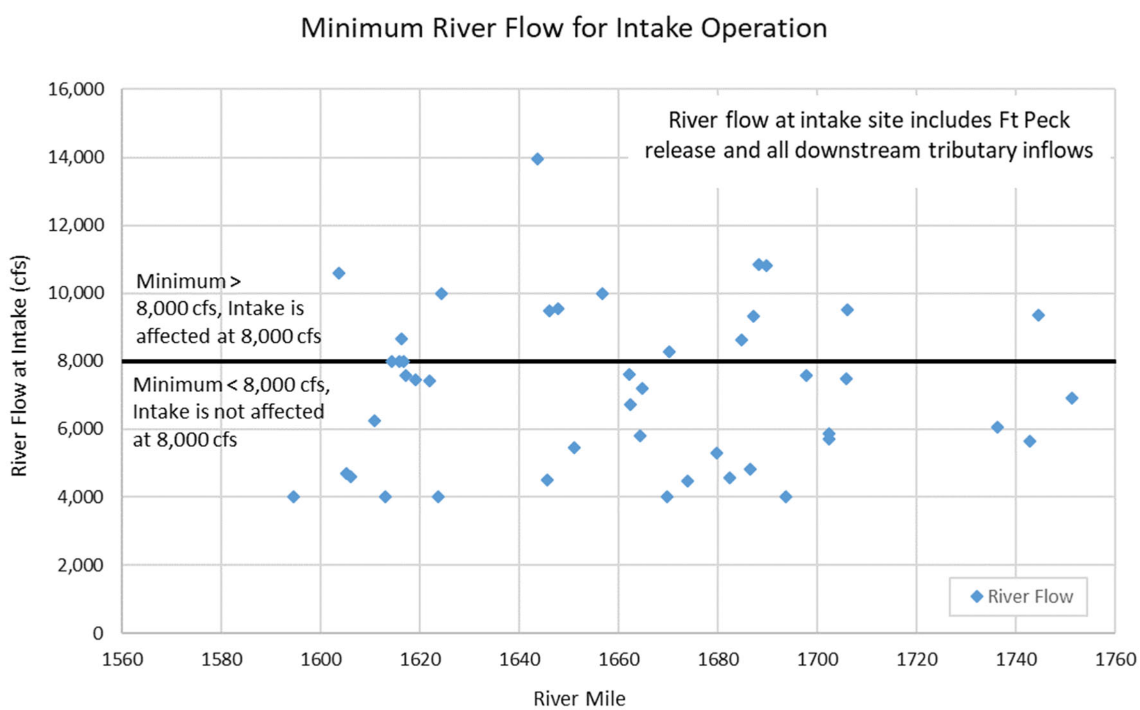


Figure 6-4. Minimum River Flow Estimated for Intake Operation by River Mile

6.7 Side Channel Intake Location

Irrigation intakes in the reach are located either on the main channel or in a side channel connection. The results of the survey were used to determine the number of intakes located on the main channel and on side channels. Side channels were assigned for both naturally occurring side channels (perhaps around a sandbar or island) and constructed channels (perpendicular to river flow, for intake use). Classification of some sites is fairly ambiguous due to the presence of bars and islands. Examples of side channel locations are shown in Figure 6-5.

Figure 6-5. Example of Irrigation Intake Located on Side Channel

Side channel locations are susceptible to channel siltation and deposition. The larger gradation size material (fine sands) within the Missouri River sediment load is typically 2 to 3 feet below the river water level. Observations indicate that this sediment often deposits in the form of bars across side channel connections. If this occurs, sediment removal would be required in order to operate the intake. Sediment removal would be complicated by the saturated soil conditions and likely high volume of sediment. Operation of mechanical equipment on top of the deposited bar material may not be possible until water levels recede and drying occurs. This could be a significant time period.

Location information was available for all of the 2020 surveys by USACE and MT FWP except for one, leaving a total of 118 sites. For Montana only, the total number of side channel intakes was classified as 24 of 111 sites or approximately 21.6%. Using the 2002 report total number of sites, this number could be extrapolated to all intake Montana sites to provide an estimate of potential impacts as shown in Table 6-9.

Table 6-9. Side Channel Connection Intakes within Montana

	Number of Intakes	Side Channel Connection	Side Channel Connection %
Located MT Sites (2020 survey inventory)	111	24	21.6%
Estimated MT Operating Sites (from 2002 inventory)	142	31	
All Permitted Intake Sites in Montana and North Dakota	395	78	

6.8 QUALITATIVE STABILITY EVALUATION

A qualitative stability evaluation was performed for use in evaluating streambank stability risks that may occur as a result of the Fort Peck EIS test flows. This evaluation used a simple procedure to qualitatively rate stability at each site and by no ways should be interpreted as an absolute indicator of individual site stability. A detailed geomorphic assessment study would be required to further evaluate individual site stability and define risk to multiple factors.

Site visit observations tabulated the presence of indicators consisting of high streambanks, streambank mass wasting, sandbar formation, and floating debris. These factors were the primary stability indicators that were considered for the site stability rating.

Figure 6-6 presents the total number of visual citations of these indicators at the surveyed pump sites. For example, the presence of high streambanks (streambanks with a height of approximately 10 feet or greater from the water surface) were observed at approximately 80 of the 119 total sites surveyed. The results, as shown in Figure 6-6, suggest that multiple instability indicators were present at each of the pump sites, and their combined contributions should be considered when evaluating site stability.

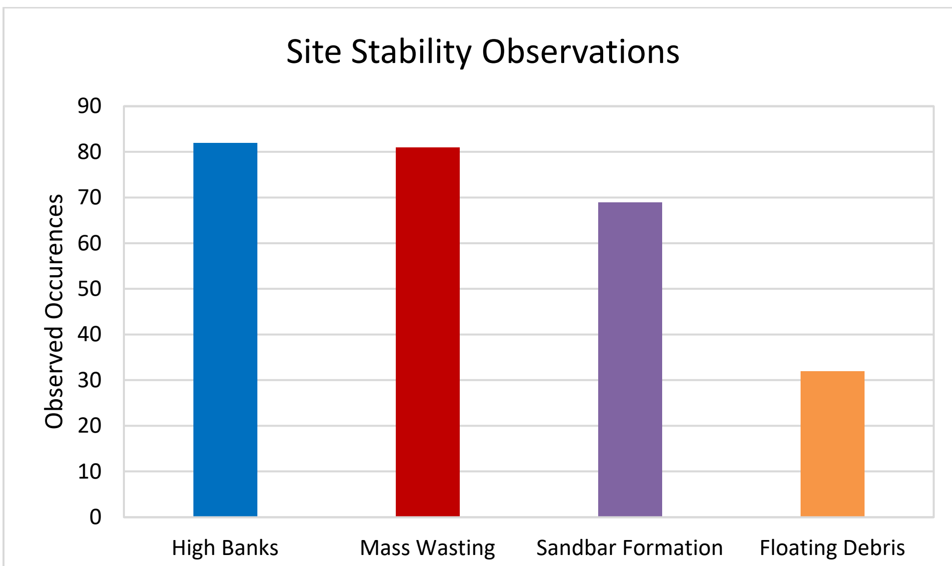


Figure 6-6. Presence of Streambank Stability Indicators at Surveyed Irrigation Pump Sites

The bank steepness at each site was classified as either vertical, steep, or not steep. Results for all sites is shown in Figure 6-7. Nearly half of all sites have vertical banks.

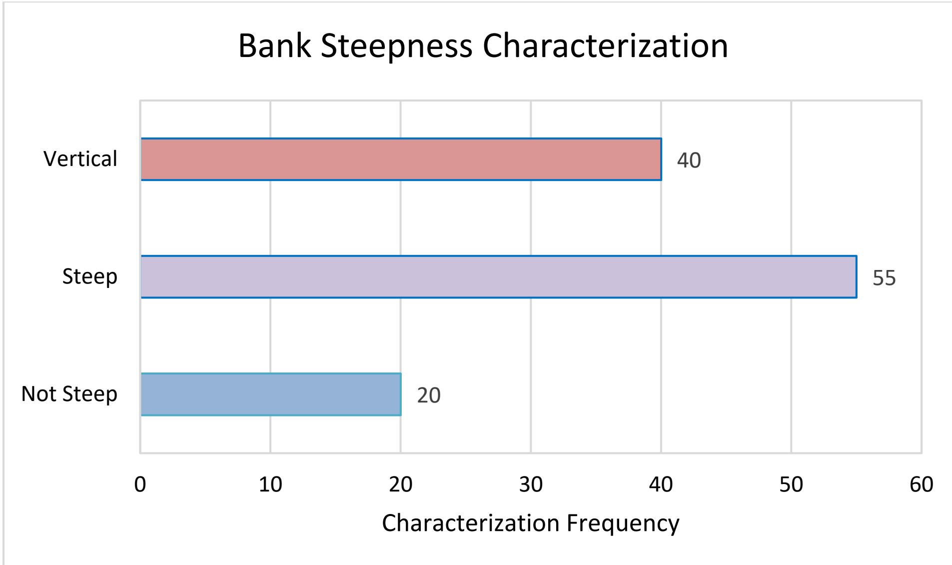


Figure 6-7. Observations of Stream Steepness

A qualitative stability rating was created to estimate stability at each site with the objective to reflect the risk of geomorphic process impacts on intake operation occurring due to a high flow event. Three categories of stability were developed consisting of stable, intermediate, and unstable. Table 6-10 outlines the various visual indicators used to estimate site stability within each category.

Table 6-10. Qualitative Streambank Stability Indices and Associated Site Observations

Stability Rating	Associated Visual Observations
Stable	-Not steep to steep streambank(s) -Little to no mass wasting present throughout visible reach -No undercut or fallen debris observed -Significant vegetative cover on streambanks -Pump site more likely to be a side channel than on the main channel
Intermediate	-Steep to vertical streambank(s) -Mass wasting observed in small to moderate segments of visible reach -Sparse undercut and fallen debris observed -Low to moderate vegetative cover on streambanks
Unstable	-Vertical streambank(s) -Mass wasting present throughout large segments of visible reach -Several undercut and fallen trees throughout area -Little to no vegetative cover on streambanks -Pump site more likely to be the main channel than on a side channel

Using the stated visual indicators, a qualitative rating was assigned to each site. The intermediate sites often had one or more stability risk factors and may have moderate risk of erosion and pump site impacts during a single event. The unstable sites often had steep to vertical streambanks, little to no vegetative cover, and continuous observations of mass wasting throughout the reach, both upstream and downstream of the pump intake. The unstable sites would likely pose a higher risk of pump site and farming operation impacts during a single event.

The assigned site stability ratings reflect the results of a qualitative assessment that was based on a rapid assessment of observed site conditions during the July 2020 and August site visits. Assigned site stability ratings are suitable only for use as a qualitative indicator on a large group basis of all pump intake sites and do not reflect any type of computational or geomorphic analysis.

The stability relationship for the surveyed sites could be extrapolated to all irrigation intake sites to develop a qualitative estimate of potential impact as a result of alternative flow releases. The stability ratings for the surveyed sites could be extrapolated to all sites using the same ratio. For the extrapolation, the number of MT intakes is the most appropriate. North Dakota sites are affected by different geomorphic processes that were not included in the qualitative stability evaluation. Table 6-11 provides a summary of the intake stability ratings.

Table 6-11. Summary of Site Stability Ratings

	Number of Intakes	Number of Sites Within Each Category		
		Stable (23% of Sites)	Intermediate Stability (54% of Sites)	Unstable (23% of Sites)
Surveyed Intake Sites with Stability Information	119	28	63	28
Estimated Number of MT Sites from 2002 Inventory	142	33	76	33
Montana Permitted Sites	365	86	193	86

6.9 FORT PECK SPILLWAY OPERATION

The operation of the Fort Peck spillway would be required to achieve flow releases for the proposed alternatives. Spillway operation has occurred previously to evacuate storage volume when discharge greater than the powerhouse release capacity was needed. Combining both spillway and outlet works flows, the historic period from 1967 through 2019 resulted in 9 years of operation (15% of the total number of 59 years) for a total of 886 days and a maximum discharge of 52,000 cfs (refer to section 4.5 Dam Safety and Fort Peck Spillway for details). Since current operations practice is to avoid using the outlet works, all future releases will be from the spillway when flows in addition to powerhouse capacity are needed to manage reservoir pool levels.

An evaluation was conducted of spillway operation for the no action and alternative conditions. This evaluation was conducted using the period of record (POR) simulation from 1930 to 2012 over a total of 83 years. Since the period of record simulation is for the 2012 water development condition, the results do not resemble the historic spillway operation. Comparison of the no action and alternative condition provide information pertaining to the change in spillway operations that would occur to achieve the desired test flow alternative flow peak and duration. Spillway flow release occurs for each test flow alternative whenever powerhouse capacity is exceeded.

Using the 1930 – 2012 POR simulation, the total number of years that spillway operation is required, the total number of days of spillway operation, and the total flow volume was compared for each alternative to the No Action. Results are provided in Table 6-12.

Table 6-12. Spillway Operation Alternative Summary Comparison to No Action

Alt	Number Years Operated[1]	% Years Operated[1]	Total Days Operated[1]	Operation Days % Change	Rank[2]	Total Flow Volume (ac-ft/yr)	Volume % Change	Rank[2]
No Action	15	18%	1,269			44,965		
Alt 1	31	37%	1,654	30%	1	56,936	27%	2
Alt 1A	30	36%	1,494	18%	6	56,001	25%	4
Alt 1B	33	40%	1,620	28%	2	53,194	18%	6
Alt 2	30	36%	1,550	22%	4	56,996	27%	2
Alt 2A	30	36%	1,608	27%	3	60,962	36%	1
Alt 2B	35	42%	1,536	21%	5	54,694	22%	5

1 Summary of total number of years and days of spillway operation from the 1930 to 2012 POR simulation, not historic data

2 Rank order for % change from no action, 1 largest change to 6 smallest change

The Operation Days change from no action Days of operation and volume change are all significant. Since they do not change consistently, the rank order provides an indication of which alternative may have the largest potential risk for spillway damage. Using the rank order metric, Alternative 1, which ranks 1 and 2 in these categories, has the greatest degree of change from No Action.

The data in the above table can also be visualized by days of spillway operation for each alternative as shown in Figure 6-8. This stacked bar chart visually displays the number of days of spillway operation by decade for the No Action and each alternative. For the No Action and all alternatives, the decade of 1970 – 1979 has the most days of spillway operation.

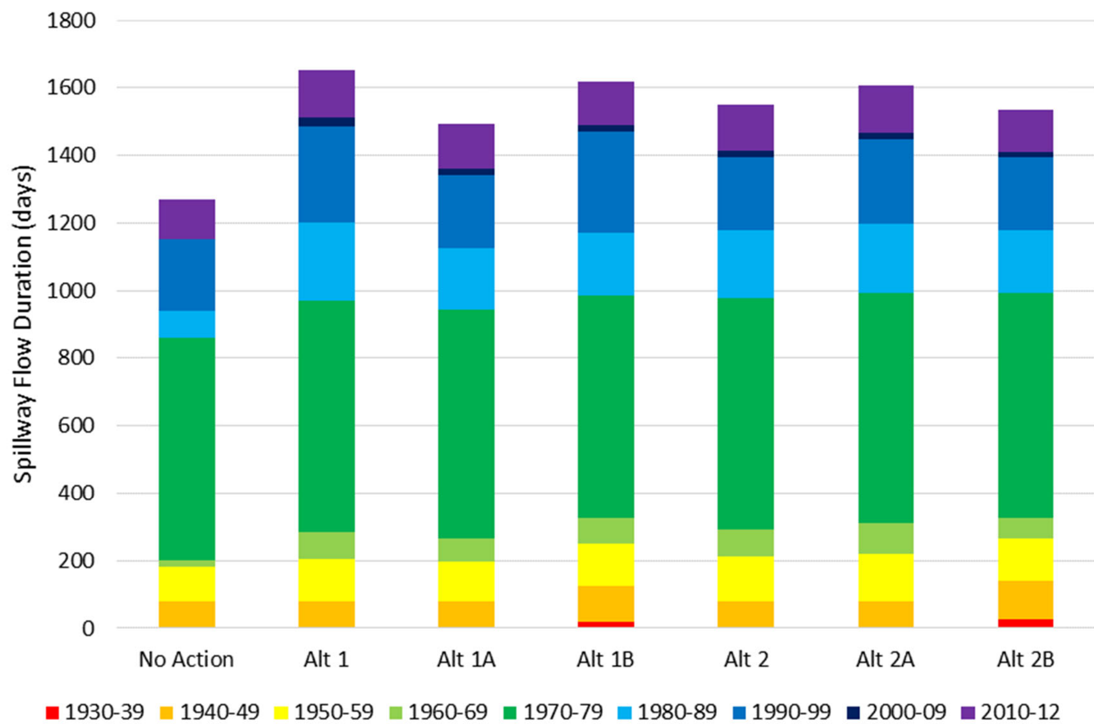


Figure 6-8. Spillway Operation Days for each Alternative by Decade

The change in spillway flow days compared to the no action for each alternative and by year during the 1930-2012 POR is shown in Figure 6-9. Most increases are in the range of 10 to 30 days for any given year.

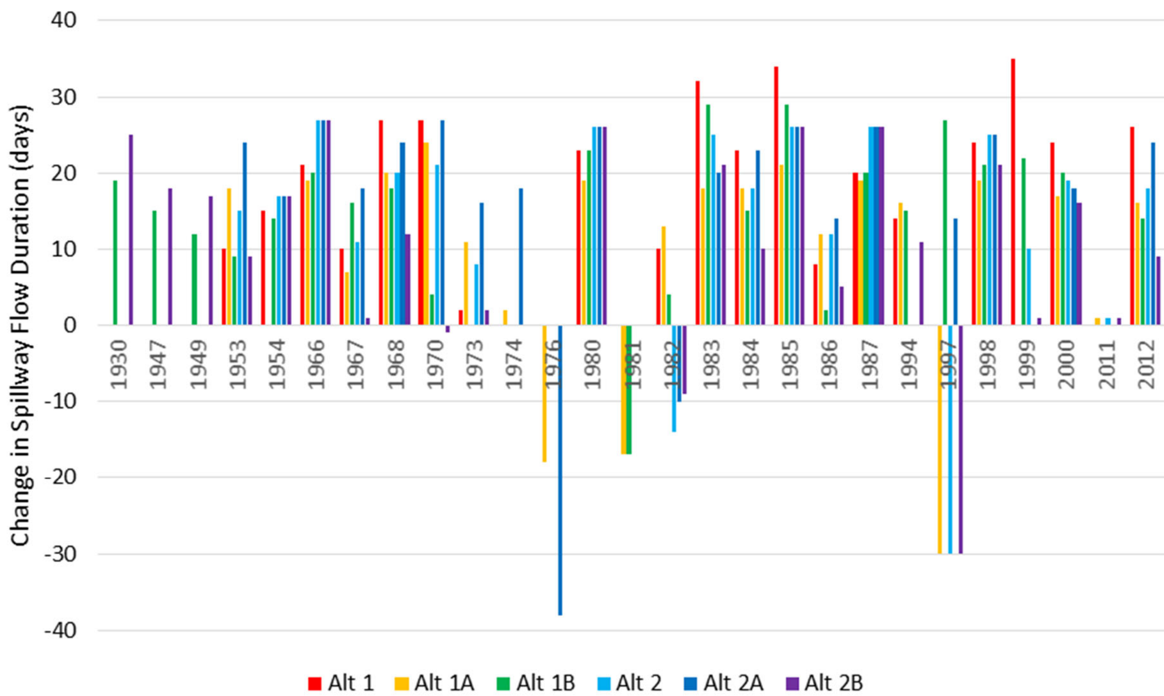


Figure 6-9. Spillway Flow Duration Change for each Alternative Relative to No Action

The change in spillway peak flow compared to the no action for each alternative and by year during the 1930-2012 POR is shown in Figure 6-10. Most increases are in the range of 10,000 to 15,000 cfs for any given year.

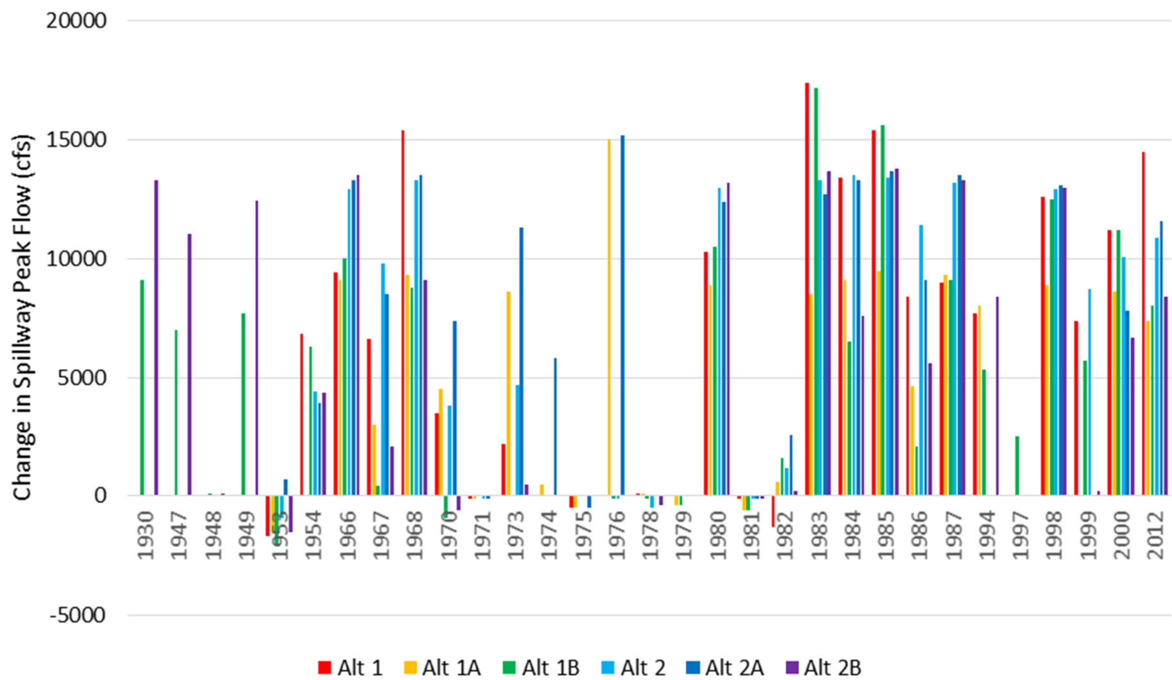


Figure 6-10. Spillway Peak Flow Change for each Alternative Relative to No Action

In summary, the analysis illustrates a significant increase in the spillway operation for all alternatives. Increased frequency of Fort Peck spillway operation could provide additional risk to the spillway reliability, damage spillway features, and affect spillway operation and maintenance costs. Each alternative results in a significant change in the number of days of spillway operation, the spillway flow volume, and the spillway peak flow.

- Compared to no action, the number of years with spillway operation are about double for each alternative.
- The increase in days of operation ranges from 18% to 30% and the increase in spillway total volume ranges from 18 to 36%.
- Comparing the alternatives, it is not clear that any are preferred to reduce spillway operation damage risk.
- The timing change between the A and B alternatives does not result in a consistent variation between the alternative 1 and 2. While the magnitude of change in flow duration and operation may not be large, using ranked order alternative 1 does appear to have the greatest potential to increase spillway damage risk.

6.10 Garrison Dam to Oahe Dam & Fort Randall Dam to Gavins Point Dam

The Garrison and Fort Randall models were executed with ResSim output to provide updated information for the human considerations evaluation regarding the FTPTR-EIS. Results from these models is not presented in this report.

6.11 PHYSICAL MONITORING DURING FLOW TEST

Physical monitoring of the affected environment is necessary to evaluate performance and potential impacts. Monitoring will be performed during the flow test for the purposes of evaluating potential impacts to bank erosion, flood extent, water intakes, Fort Peck Dam spillway, and similar concerns. General goals and methods of the monitoring plan are as follows:

- Bank Erosion. Ten to twenty representative locations will be selected for bank erosion monitoring. Repetitive channel and bank surveys will be used to evaluate conditions before, during, and after the flow test.
- Water Intakes. Twenty to thirty representative municipal and irrigation water intakes will be monitored to evaluate sandbar migration, turbidity, and similar geomorphic processes to evaluate potential impact on function. Other areas identified as critical features will be monitored on an as-needed basis.
- Water Surface Elevation Profiles. A water surface profile before, during, and after the flow test will be collected to evaluate hydraulic model accuracy, flood inundation extent, and to identify changes in water surface elevations in the reach.
- Aerial Photography. A before, during, and after test set of aerial photos will be collected for use in identifying bank erosion.
- Fort Peck Dam Spillway.
    - Installation of equipment to monitor flow within the discharge channel sub-drain system to help estimate uplift pressures due to the test flow.
    - Surveys of the new RCC structure walls to determine if they move as a result of the test flow.
    - Surveys of the downstream unlined channel to determine the amount of channel scour and bank erosion due to the test flow.
    - Flow measurement and velocity information will be collected with the spillway exit channel and the Missouri River to assess velocity distribution and magnitude. This information will be used to evaluate risk during sustained releases and drawdown.

Spillway monitoring equipment installation and monitoring is estimated to cost in the range of $200,000 to $400,000. Missouri River channel profiles and aerial photos are estimated to cost in the range of $300,000 to $600,000. Total physical monitoring cost is estimated in the range of $500,000 to $1,000,000. Costs will vary with the number of test flows implemented.

Monitoring data will be used to further inform on flow test implementation regarding impacts downstream within the Missouri River channel to concerns including bank erosion, water intake operations, and river flow levels. Fort Peck spillway monitoring information will be used assess dam safety and spillway reliability. These are critical components for assessing the capability to conduct future flow tests.

6.12 FLOOD RISK MANAGEMENT

The Missouri River Reservoir System as currently operated provides substantial flood damage reduction and benefits to the entire basin. Study alternatives include modifying operations of the

Missouri River Reservoir System with increased reservoir releases during select periods for species habitat benefits.

6.12.1 Results Overview

The current HEC-ResSim and HEC-RAS analysis shows the potential for negative impacts to flood risk management for alternatives that include changes in reservoir flow releases. The current study methodology, which employs an 82-year period of record, is suitable for alternative comparison and providing an indication of change in flood risk. However, the methodology does not simulate a sufficient number of events and possible runoff combinations within the large Missouri River basin to evaluate potential change in downstream flood risk. Prior to implementing any management action that alters reservoir operations, a comprehensive flood risk evaluation will be conducted per USACE requirements. The level of additional hydrologic analysis will be based on USACE guidance and requirements and will identify the change in reservoir pool probability, reservoir release frequency, river stage- frequency, and river stage-duration.

Changing flows has the potential to affect flood risk management, the Williston levee and gage derived flood impacts, and Fort Peck spillway operation and maintenance. As a result of the flow release changes, small, temporary, and long-term impacts have the potential to occur to flood risk management and dam safety since analysis is limited to the combination of events that occur within the POR as previously described. The POR analysis results indicate that for the past limited number of event combinations when the flow releases were altered, the proposed alternatives did not cause significant impacts to flood risk management because these flooding effects are mostly a result of the natural hydrologic cycles of precipitation and snow pack.

6.12.2 Fort Peck Spillway Operation

The spillway concrete lined discharge channel has concerns with spillway slab performance that will be exacerbated with sustained spillway flow. The POR results show a significant increase in spillway operation. Increased frequency of Fort Peck spillway operation could provide additional risk to the spillway reliability, damage spillway features, or affect long term spillway operation and maintenance costs. Each alternative results in a significant change in the number of days of spillway operation, the spillway flow volume, and the spillway peak flow.

- Compared to no action, the number of years with spillway operation are about double for each alternative.
- The increase in days of operation ranges from 18% to 30% and the increase in spillway total volume ranges from 18 to 36%.
- Comparing the alternatives, it is not clear that any are preferred to reduce spillway operation damage risk.
- Fort Peck spillway experienced significant damage due to flow releases in 2011. Repairs were conducted as previously described. Spillway slab concerns were noted in a 2019 inspection report (USACE 2019). These recommended repairs have not been performed.
- If damage to the spillway slabs would occur, repair would likely be extensive and not limited to a single slab or small area due to the high spillway flow velocities and the

change in flow hydraulics as a result of slab uplift. The spillway slab and sub-drain system repairs would be difficult, expensive, and likely constrained by time in order to address dam safety due to loss of spillway operation as quickly as possible. Depending on damage extent and allowable repair time period, repair cost is estimated to be in the range of $20 to $40M. The test flow releases would increase the likelihood these repairs would be needed because they increase the use of the spillway.

- The risk of spillway slab damage in the future is likely cumulative and related to both spillway operation frequency and flow. Since flow release implementation significantly alters the spillway operation frequency, spillway repair costs are not solely a Fort Peck operation and maintenance expense and should be proportionally shared. This is consistent with agreements with Western Area Power Administration (WAPA).
- While the magnitude of change in flow duration and operation may not be large, using ranked order alternative 1 does appear to have the greatest potential to increase spillway damage risk.

6.12.3 Additional Risk Evaluation

The current HEC-ResSim and HEC-RAS analysis shows the potential for negative impacts to flood risk management for alternatives that include changes in reservoir flow releases. The current study methodology, which employs an 82-year period of record, is suitable for alternative comparison and providing an indication of change in flood risk. However, the methodology does not simulate a sufficient number of events and possible runoff combinations within the large Missouri River basin to evaluate potential change in downstream flood risk. Prior to implementing any management action that alters reservoir operations, a comprehensive flood risk evaluation will be conducted per USACE requirements. The level of additional hydrologic analysis will be based on USACE guidance and requirements and will identify the change in reservoir pool probability, reservoir release frequency, river stage-frequency, and river stage-duration. Risk analysis would evaluate changes in reservoir pool levels, downstream flood risk, impacts to flood risk management projects (e.g. levees and floodwalls), and possible implications for dam safety.

A Monte Carlo risk analysis methodology capable of assessing impacts to dam safety and flood damage reduction as a result of flow release changes has been initiated but the study is several years from completion. Analysis products will identify the change in reservoir pool probability, reservoir release frequency, river stage-frequency, and river stage-duration. The Monte Carlo risk analysis procedures are in accordance with risk based plan formulation and evaluation regulations described in USACE guidance materials, in particular ER 1105-2-101 (*Risk Analysis for Flood Damage Reduction Studies*, USACE, 2006) and ER 1105-2-100 (*Planning Guidance Notebook*, USACE, 2000). Risk evaluation principles employed in scope development follow procedures further explained within EM 1110-2-1619 *(Risk Analysis for Flood Risk Management Studies, USACE 2012b).* The risk analysis primary components include further development of the period of record flow data set, ResSim and RAS model modifications, development of levee fragility curves, assignment of uncertainty, assembly and debugging of models, Monte Carlo simulation, analysis of results, and reporting. The Monte Carlo methodology properly assesses the effects of the alternative operation changes because it increases the sample size of flow data and number of combinations of flow periods that may occur in the future so that impacts can be characterized with greater confidence. Without such analysis, the impacts of operational changes will only be known for events and combinations of events that have already occurred. Statistics calculated based on the 82-years of record should therefore be used with caution, and with the understanding of the consequences of using only a small sample of years.

- The conducted hydrologic and HC evaluation is suitable for alternative comparison but does not allow quantification of change in flood risk
- Potential impacts to flood risk management were identified by evaluation of the outputs from the ResSim and RAS analysis
- Prior to adopting any alternative or adaptive management plan that alters reservoir operations, an additional system wide flood risk evaluation will be conducted.

6.13 LIMITATIONS

The analysis relies on the simulation of the 82-year period of record using daily average outflows from a ResSim model input into a fixed bed RAS model, with stage and flow output. While the analysis coupled with species and human considerations models can be used to show relative benefits and potential impacts based on historic flows, there are limitations in the conclusions that can be drawn based on some of the simplifying assumptions.

- **POR Methodology** - An 82-year period of record, adjusted to current level of depletions, was used and may not be comparable to future conditions. A climate change assessment of the Missouri River basin indicates increases to both temperature and precipitation along with increasing trends in extreme floods and droughts (USACE 2018d). The conditions during a pulse year in the future could vary greatly from the small sample of pulse events included in the POR analysis.
- **No Risk Analysis** - The Missouri River system as currently operated provides substantial flood damage reduction and benefits to the entire basin. The current ResSim and RAS analysis, which employs an 82-year period of record simulation, shows the potential for negative impacts to flood damage reduction and dam safety for alternatives that include changes in reservoir flow releases. Refer to section 6.12.3 Additional Risk Evaluation for further details.
- **Stable Bed and Floodplain** - The hydraulic modeling to date is based on the existing conditions geometry. The analysis does not account for how the bed of the Missouri River may respond to flow changes. Additionally, the analysis does not try to project where sediment may accumulate in the floodplain or include projections of future change in floodplain roughness that could occur during the POR simulation. This carries with it the necessary assumptions that any bed and floodplain changes would be either negligible or similar between each alternative.
- **RAS Computational Uncertainty** – The hydraulic models are suitable for the comparison of differences between the Alternatives and the No Action Alternative but care should be taken when comparing absolute elevations to the model output. Due to limitations of the underwater bathymetry, the confidence in model accuracy during low

flows (less than 6,000 to 8,000 cfs) is lower. Confidence in the routed flow from the model is higher than with the computed stage.

- **Flood Inundation Mapping –** Flood inundation mapping was performed for two steady flows (9,000 and 30,000 cfs) for the Fort Peck reach only. Due to the limitations discussed above, these inundation extents should be viewed as approximate. The purpose of the mapping was primarily for the comparison between the two flows.
- **Irrigation Intake Analysis** – An irrigation intake analysis was conducted using the best available information. The analysis only included information for approximately 64 intakes. There is evidence that this is only a fraction of the number of intakes in this reach. Along with the uncertain number of intakes, extrapolating the analysis results to all intakes relies on the assumption that the survey used a representative set of intakes. The process of transforming the elevation data to a flow estimate also introduces more uncertainty on top of the RAS model computation uncertainty noted above.
- **Fort Peck HEC-RAS Model High Density Data Comparison** - The HEC-RAS model was calibrated to best available conditions using the best available data. High density data for a short 20 mile long reach was inserted into the HEC-RAS model. The high density model results were compared to the original model that used widely spaced channel surveys and to an observed water surface profile from 2018. Results illustrated that the high density data significantly improved the water surface elevation computed by the model. While the RAS model is suitable for use with comparative difference from the No Action and between alternatives, this comparison illustrates that model lacks the critical accuracy for defining elevation related impact thresholds (such as whether or not an irrigation intake will function) without additional model data and / or calibration.

7 CLIMATE CHANGE ASSESSMENT

A qualitative climate change assessment for the FTPTR-EIS was performed by USACE in accordance with *Engineering and Construction Bulletin (ECB) 2018-14: Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects* (USACE 2018h). The study region for this analysis consists of the upper Missouri River basin, located primarily within the states of MT, WY, and ND. Study area drainage basins contribute inflow to the USACE operated Fort Peck and Garrison dams.

Previously, the MRRMP-EIS conducted a climate change analysis for the Missouri River Management Plan (USACE 2018h) following previous guidance (USACE 2016c). Additional analysis was conducted for the purposes of the FTPTR-EIS in accordance with ECB 2018-14. The objective of the FTPTR-EIS climate change assessment is to provide a qualitative analysis of existing literature, data trends, climate projections, and to discuss potential impacts to climatic variables of interest. An understanding of the potential impacts of climate change can help inform and reduce FTPTR-EIS vulnerabilities.

7.1 Climate Change Analysis Guidance From ECB 2018-14

ECB 2018-14 guidance states the climate for which the project was designed can change over the full lifetime of that project and may affect its performance, or impact operation and maintenance activities. Climate change analysis is performed to articulate the uncertainty of environment factors over the project lifetime (not to be confused with the period of analysis). ECB 2018-14 specifies a project lifetime analysis period of up to 100 years. Since most current climate model datasets typically end at year 2100 or earlier, the year 2100 is considered to approximate the 100-year planning horizon until longer model datasets become available.

7.1.1 FTPTR-EIS Scoping Considerations

Guidance within ECB 2018-14 was used to determine the appropriate scope for the FTPTR-EIS climate change analysis. For the typical lifetime analysis period of 100 years into the future recommended by the guidance, it is possible that climate change could affect Fort Peck flow regimes and consequently alter the frequency of future operations to conduct releases for pallid sturgeon recruitment.

However, the action considered in this EIS is a test flow regime that is anticipated to be run a few times over a short period in the relatively near future (e.g., during the next 5-15 years). If it is determined that the test flow regime is beneficial to the pallid sturgeon, a new study would be conducted to determine benefits and impacts for a longer-term or permanent Ft Peck flow regime change. That new study would involve a more detailed climate assessment and likely have revised flows for study objectives related to the pallid sturgeon and human considerations.

Specific provisions within ECB 2018-14 applicable to the FTPTR-EIS are that 1) the analysis level of effort is scalable to the project complexity, its consequences, and the sensitivity of the alternatives and/or project to climate variability and change; 2) the level of detail and complexity of the analysis will depend on the uncertainty and risks associated with the impact of climate on alternatives.

Application of these provisions with respect to establishing an appropriate scope for the FTPTR-EIS climate change analysis are summarized as:

- The test flows that are being considered are not a permanent change to the water control plan. The test flows will be conducted over a short period (with respect to climate change analysis) of the next 5-15 years while USACE climate guidance considers a much longer time frame (typical lifetime analysis period of 100 years into the future).
- After test flows following the FTPTR-EIS are completed, USACE would reassess to determine if the test flow should become permanent. Prior to adopting a permanent Fort Peck flow release, an entirely new analysis would need to be completed that would include evaluation of a longer period that would address many factors including the effects of climate change.
- It is likely that the test flow biologic and physical monitoring will result in significant changes to the desired Fort Peck operations to optimize release objectives and limit impacts. Any conclusions regarding climate change FTPTR-EIS that could be derived at this time have a high degree of uncertainty.
- Neither the No Action nor any of the alternatives has a significant flow difference such that total annual volume is virtually identical for all cases.

7.2 PREVIOUSLY CONDUCTED BASIN WIDE ANALYSIS FOR THE MRRMP-EIS

Climate change assessment was previously conducted for the MRRMP-EIS. The analysis was performed following guidance previously issued in 2016, ECB 1016-25 (USACE 2016c). The MRRMP-EIS included a full suite of flow change alternatives. Flow changes considered for the FTPTR-EIS are much smaller in magnitude than those previously considered for the MRRMP-EIS. Therefore, the previously determined climate change variables affected by flow change alternatives provide a larger and more comprehensive set of impact analysis than what is anticipated for any of the Fort Peck flow modifications. See *Missouri River Recovery Management Plan - Climate Change* (USACE 2018d) for more details regarding the climate change and relevant conclusions.

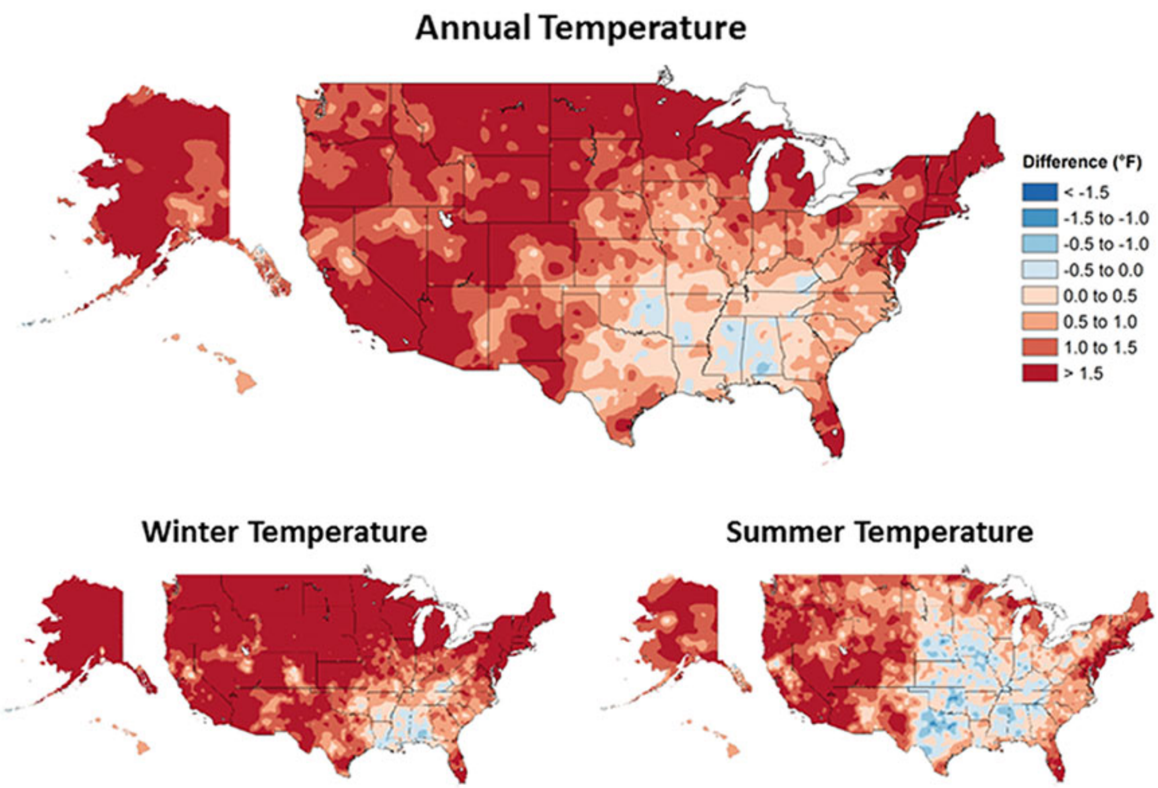
7.3 LITERATURE REVIEW: OBSERVED AND PROJECTED TRENDS

The current climate in the Basin consists of large temperature fluctuations and extremes, due to its mid-continent location. Winters are generally cloudy and cold over the majority of the area, while summers range from fair to very hot and humid. Temperature extremes range from winter lows of -60 degrees Fahrenheit (°F) in Montana to summer highs of 120 °F in the lower basin (U.S. Army Corps of Engineers 2006). The Basin experiences tremendous variability in runoff, ranging from numerous periods of extreme droughts to numerous periods of extreme floods. Most recently, the Basin was dramatically impacted by the sudden 2012 drought immediately following the 2011 record runoff year. In 120 years of record keeping, the upper Missouri River basin runoff, as measured at Sioux City, IA, for the decade from 2010 - 2019 was the highest on record. This decade included the first (2011), second (2019), and fourth (2018) highest annual runoff years (USACE 2019).

Numerous publications from varying sources were reviewed and summarized for the MRRMP-EIS climate change analysis (USACE 2018d). For this study, an additional literature review was conducted of primary references within the FTPTR-EIS study area to summarize peer reviewed science segmented into observed trends and model projected trends in the study region. Climate variables considered included temperature, precipitation, stream flow, and snowpack. Two main sources of information for this review included the *Climate Science Special Report from the Fourth National Climate Assessment* (USGCRP 2017), referred to here on as the *Fourth National Climate Assessment,* and the *Recent US Climate Change and Hydrology Literature Applicable to US Army Corps of Engineering Missions Missouri River Region 10* (USACE 2015b), referred to here on as the *USACE Region 10 Report*.

7.3.1 Observed Trends in Temperature

The *Fourth National Climate Assessment* (USGCRP, 2017) shows that mean annual temperatures within the study area have increased slightly over time. Present-day (1986-2016) annual mean temperatures have increased by over 1.5°F for the majority of the study area in comparison with the first part of the last century (1901-1960). Observed winter temperatures have increased over 1.5°F for the present-day (1986-2016) in comparison with the first part of the last century (1901-1960). Summer temperatures have increased less dramatically. These increases are shown in Figure 7-1 (USGCRP 2018). Figure 7-1 shows the study area has experienced increases in annual and winter temperatures of over 1.5°F. Increases in temperature during the winter could result in less snowpack and more precipitation occurring as rainfall.



Observed changes in annual, winter, and summer temperature (°F). Changes are the difference between the average for present-day (1986–2016) and the average for the first half of the last century (1901–1960 for the contiguous United States, 1925–1960 for Alaska and Hawai'i). Estimates are derived from the nClimDiv dataset. [12], [13] (Figure source: NOAA/NCEI).

Figure 7-1. Observed changes in temperature between the first half of the last century (1901-1960) and present day (1986-2016) (USGCRP, 2018).

The USACE *Region 10 Report* (USACE 2015b) also supports a positive upward trend in temperature for most seasons for the study area. A positive statistically significant increasing trend in observed temperature from 1950-2000 was determined for all months but September through November (SON) (USACE 2015b). The strongest increase in temperature was in the winter (December-February) and spring (March-May). The left side of Figure 7-2 shows these trends (Wang et al, 2009).

The *USACE Region 10 Report* found that the state of North Dakota exhibited the "fastest increase in annual average temperature compared to all other states nationwide over the past 130 years" at a statistically significant level for all seasons. The authors also found that the freeze-free season length has increased an average of 6 days over the course of the last sixty years (USACE 2015b).

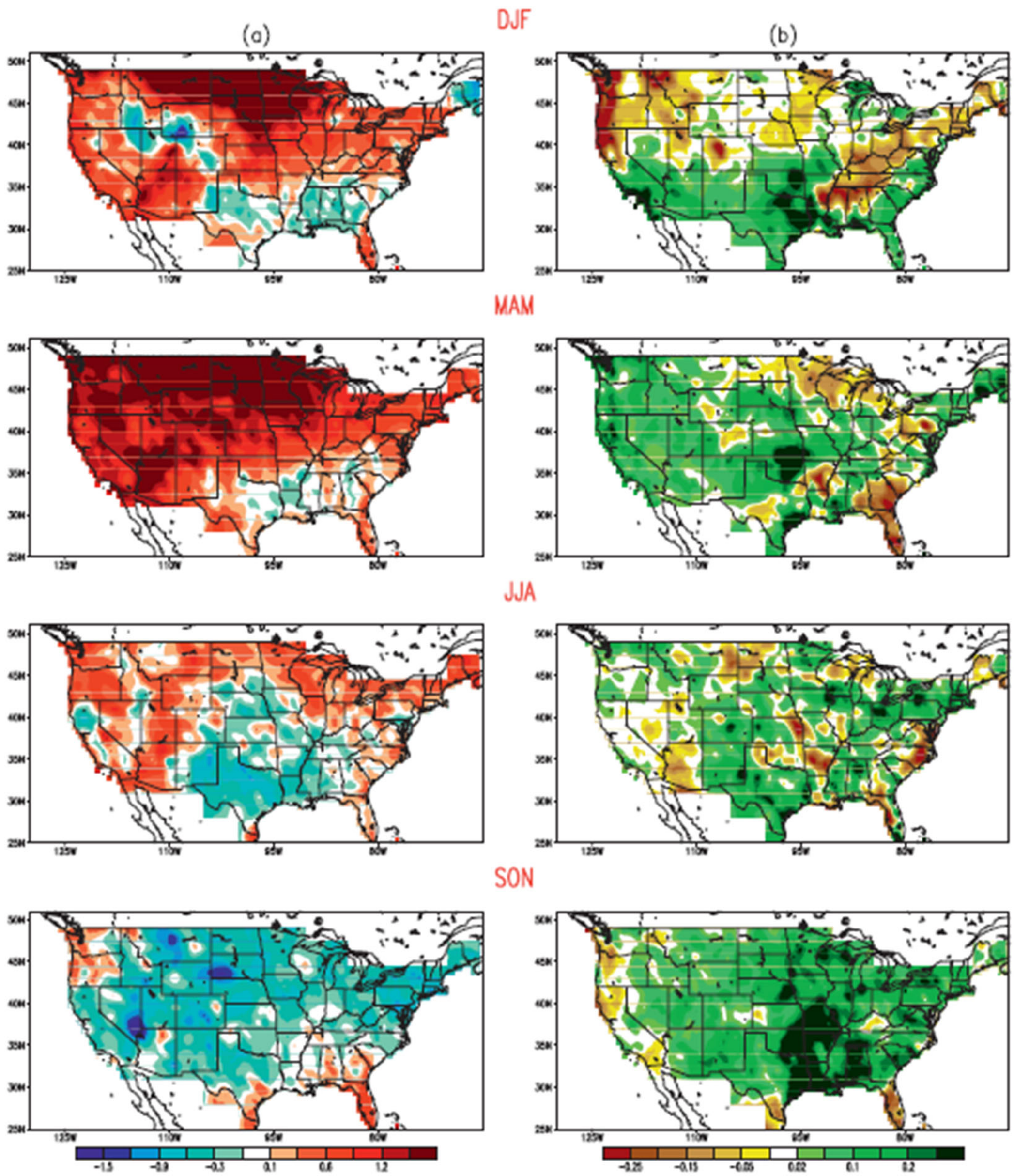
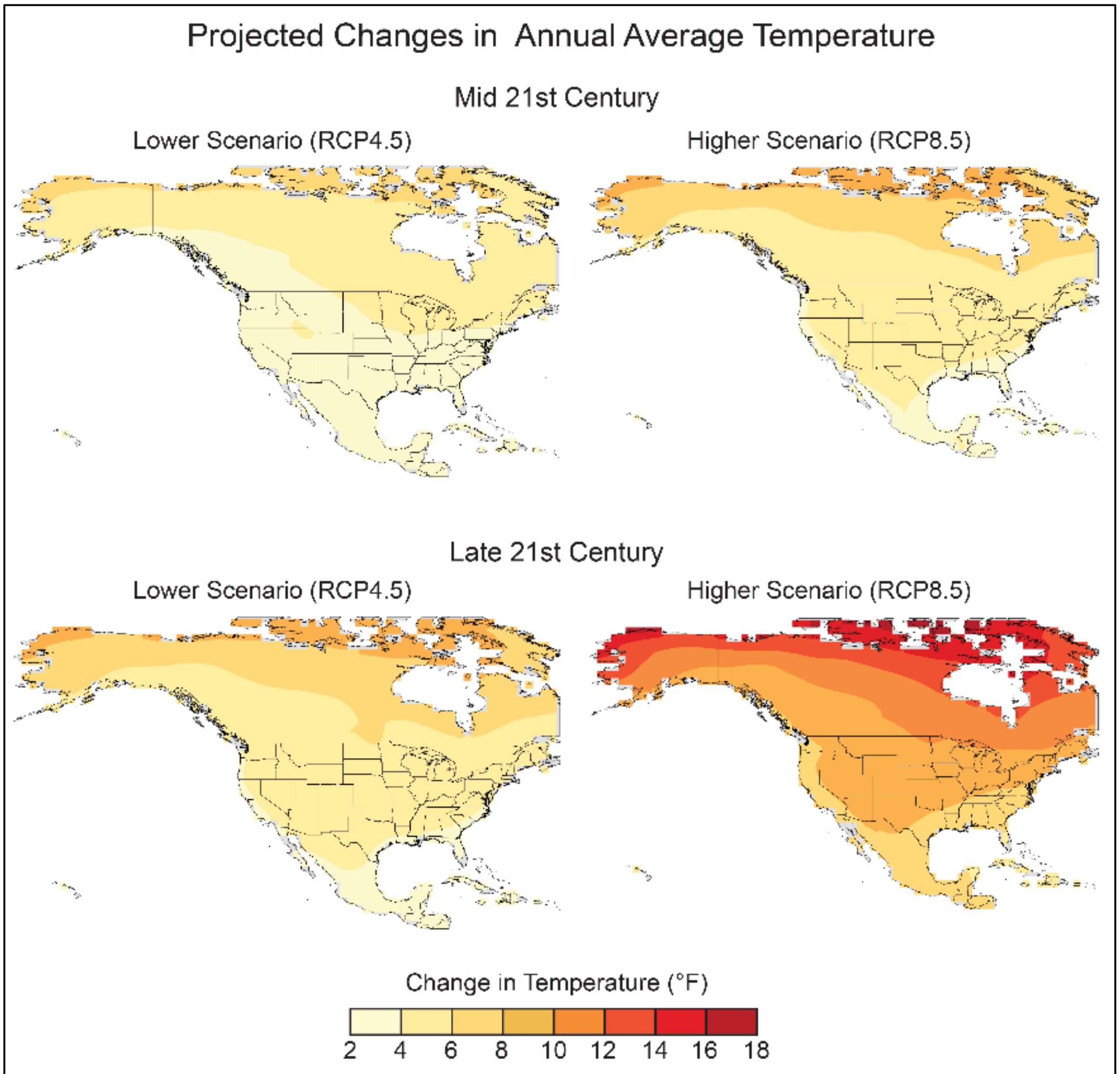


FIG. 1. Linear trends of (a) surface air temperature (K) and (b) precipitation (mm day^{-1}) over the United States during 1950–2000 for seasonal means over December–February (DJF), March–May (MAM), June–August (JJA), and September–November (SON). The data are from the dataset known as the CRU TS2.1 (Mitchell and Jones 2005).

Figure 7-2. Observed seasonal changes in precipitation (Wang et al, 2009). Air temperature increases in Kelvin.

7.3.2 Projected Trends in Temperature

According to the *Fourth National Climate Assessment* (USGCRP 2017), the mean temperature in the study area is forecasted to increase between 4°F to 8°F in the period 2036-2065 and from 6 to 10°F in the period 2071-2100 in comparison with the 1976-2005 average. These trends are shown in Figure 7-3. These projected trends are generated from global climate models manufactured using sophisticated computers to simulate complex mathematical, physical, chemical, and biological processes involved in climate change.



Projected changes in annual average temperatures (°F). Changes are the difference between the average for mid-century (2036–2065; top) or late-century (2070-2099, bottom) and the average for near-present (1976–2005). Each map depicts the weighted multimodel mean. Increases are statistically significant in all areas (that is, more than 50% of the models show a statistically significant change, and more than 67% agree on the sign of the change[78]). (Figure source: CICS-NC and NOAA NCEI).

Figure 7-3. Projected changes in annual average temperature (USGCRP 2018).

The *USACE Region 10 Report* also referenced several studies predicting increases in temperature with time. Figure 7-4 shows projected changes in seasonal maximum air temperature for 2041-2070 compared with 1971-2000 by season. Summer seasonal maximum air temperature are forecasted to increase the most in the study area (~3.5-4 degrees C) followed by fall (~3-4 degrees C), winter (~2-3 degrees C), and spring (~1.5-2 degrees).

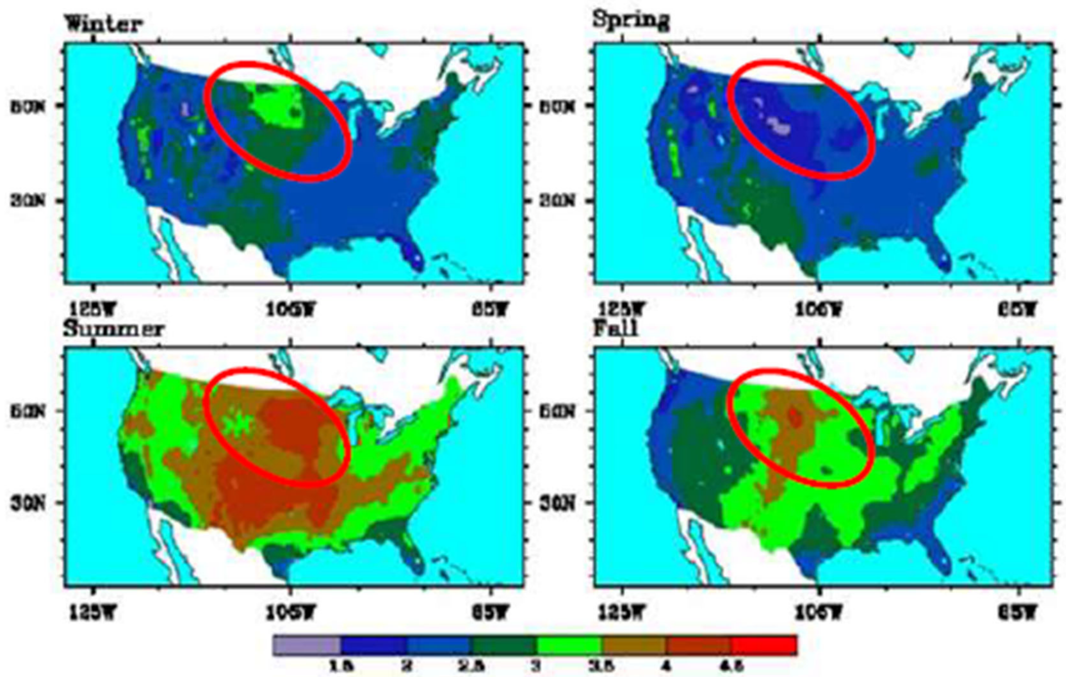
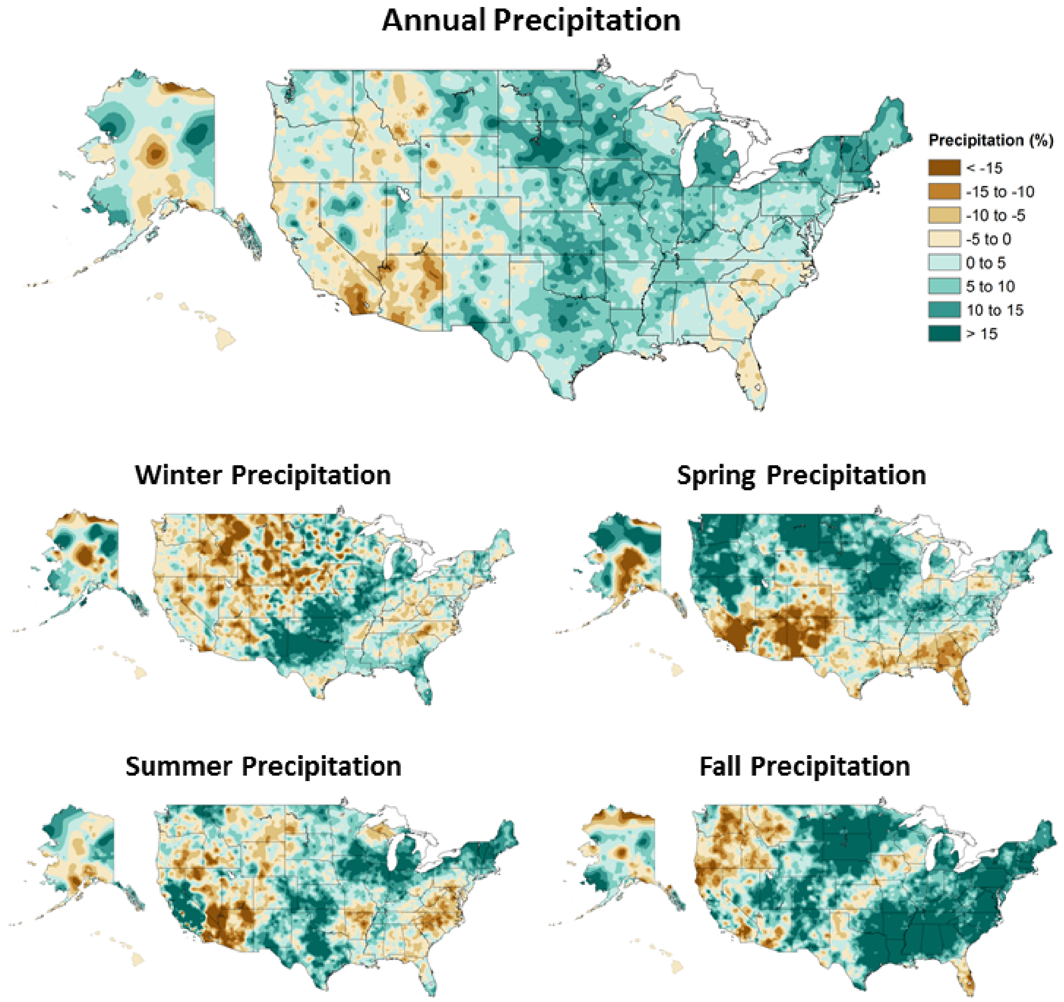


Figure 7-4. Projected changes in seasonal maximum air temperature (degrees C), 2041-2070 vs 1971-2000 (USACE 2015b).

7.3.3 Observed Trends in Precipitation

The *USACE Region 10 Report* literature review found consensus among multiple authors that there is a statistically significant increasing trend in the lower portion of the Missouri River basin regarding both observed precipitation and intensity, while the upper portion of the region is exhibiting a significant decreasing trend in both the frequency and intensity of precipitation events based on recent historical records (USACE 2015b). Figure 7-5 shows that the current day (1986-2016) winter and summer precipitation in the study area has decreased in comparison with the first half of the last century (1901-1960). This is especially the case for the winter precipitation which has decreased as much as 15%. It also shows that spring and fall precipitation have increased over 15%.

The *Fourth National Climate Assessment's* precipitation projections (USGCRP 2017) provide a similar outlook. In the study, the authors note a 10%-30% increase in spring precipitation in the lower portion of the region, with 25% to 45% declines in the fraction of precipitation falling as snow in the mountainous portion of the region. The study anticipates an increase in droughts due to rising temperatures despite the projected increases in precipitation.



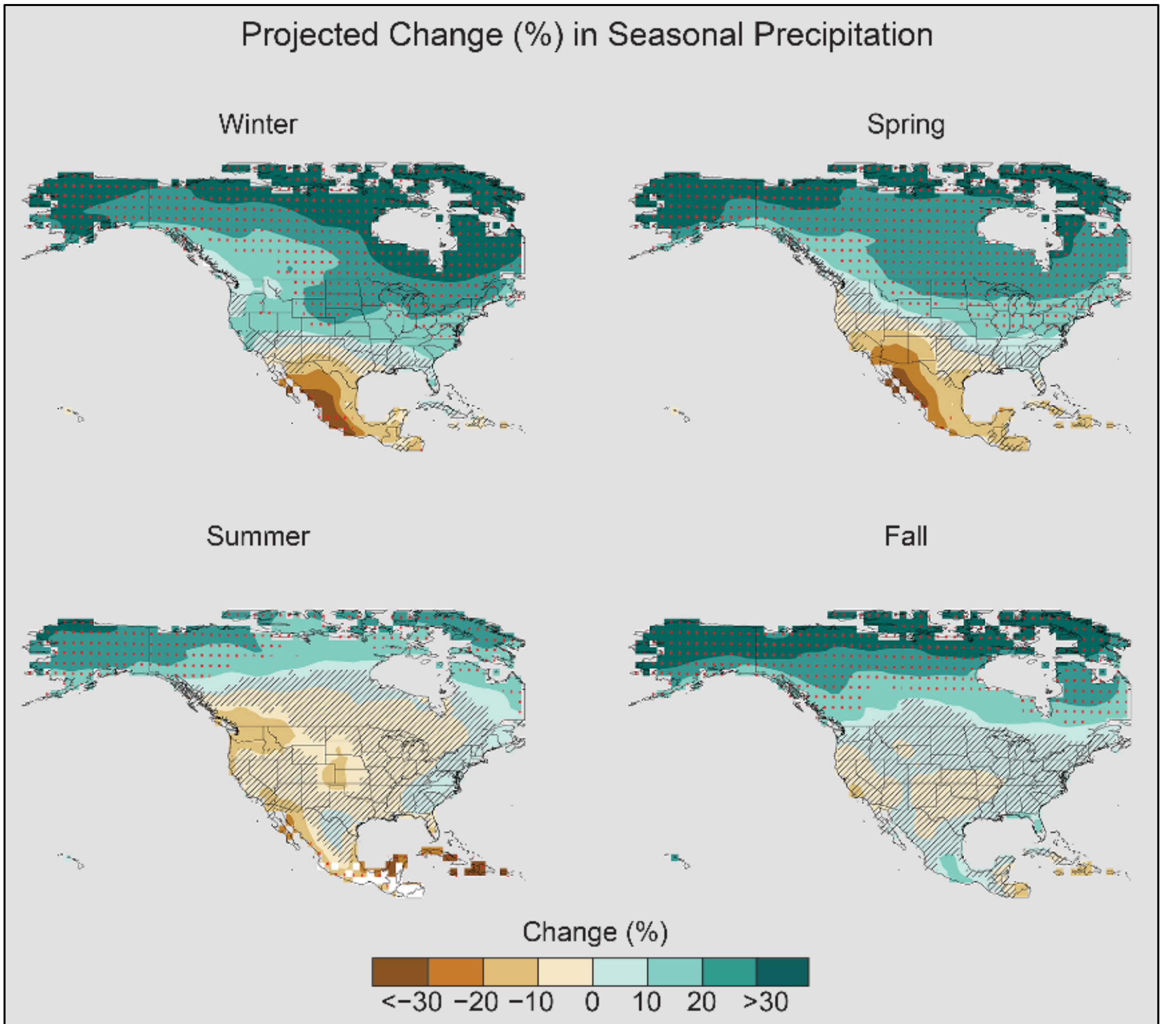
Annual and seasonal changes in precipitation over the United States. Changes are the average for present-day (1986–2015) minus the average for the first half of the last century (1901–1960 for the contiguous United States, 1925–1960 for Alaska and Hawai'i) divided by the average for the first half of the century. (Figure source: [top panel] adapted from Peterson et al. 2013,[6] © American Meteorological Society. Used with permission; [bottom four panels] NOAA NCEI, data source: nCLIMDiv].

Figure 7-5. Changes in precipitation between the first half of the last century (1901-1960) and the present day (1986-2016) (USGCRP 2018).

7.3.4 Projected Trends in Precipitation

Figure 7-6 from the *Fourth National Climate Assessment* shows that precipitation over the study area is projected to increase for the winter and spring between 20-30% while summer precipitation is predicted to decrease slightly (0-10%).

Figure 7-7 from the *USACE Region 10 Report* shows winter precipitation may increase in parts of the Garrison basin and decrease in others. Spring precipitation is projected to increase while summer and fall precipitation is projected to decrease in the future.



Projected change (%) in total seasonal precipitation from CMIP5 simulations for 2070–2099. The values are weighted multimodel means and expressed as the percent change relative to the 1976–2005 average. These are results for the higher scenario (RCP8.5). Stippling indicates that changes are assessed to be large compared to natural variations. Hatching indicates that changes are assessed to be small compared to natural variations. Blank regions (if any) are where projections are assessed to be inconclusive. Data source: World Climate Research Program's (WCRP's) Coupled Model Intercomparison Project. (Figure source: NOAA NCEI).

Figure 7-6. Projected change in precipitation. Years 2070 to 2099 compared with 1976-2005 average (USGCRP 2018).

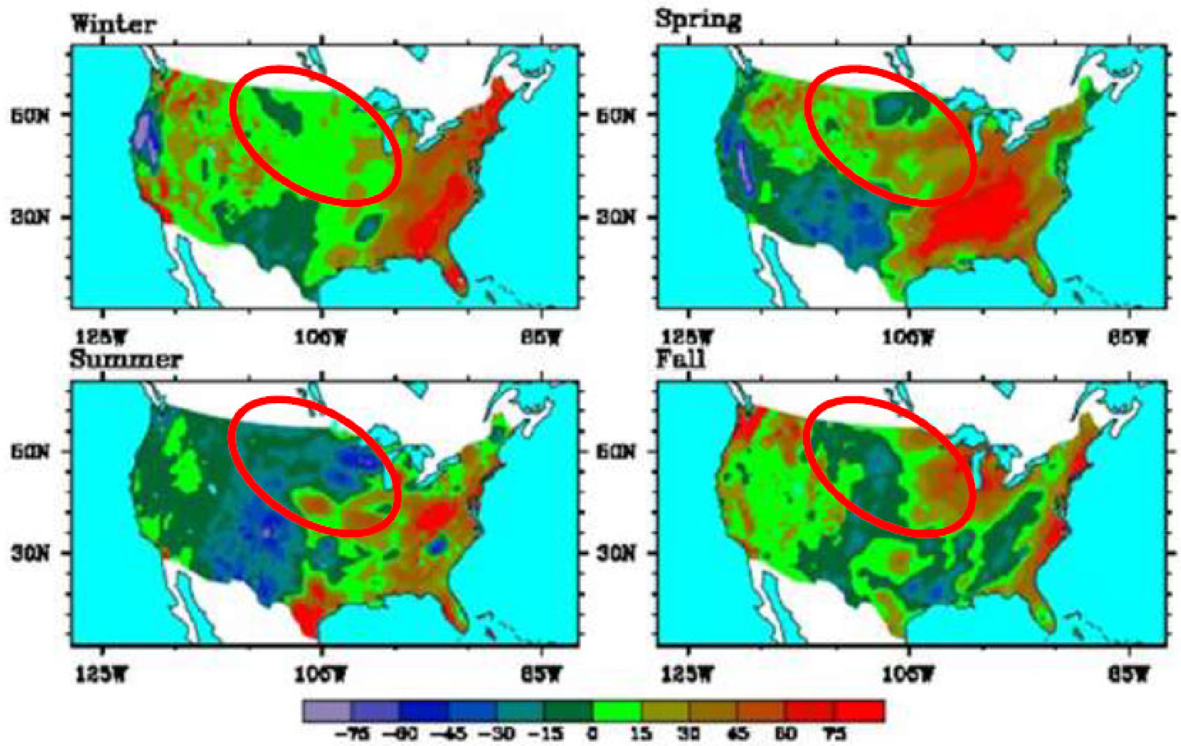


Figure 7-7. Projected changes in seasonal precipitation, 2055 vs. 1985 (USACE 2015b)

7.3.5 Extreme Precipitation

Several studies forecast that extreme precipitation event intensity will likely increase at rates much larger than that of mean precipitation events for parts of the United States. The *Fourth National Climate Assessment's* authors find an increase in the frequency of extreme events (greater than 1 inch per day of rainfall), stating "changes in extreme events are likely to overwhelm average changes in both the eastern and western regions of the Northern Great Plains" (USGCRP 2018).

7.3.6 Observed Stream Flow Trends

According to the *Fourth National Climate Assessment*, "trends in annual runoff across the region over the past 50 years show a distinct east–west difference where the western portions show a decrease and eastern areas show an increase" (USGCRP 2018). This finding is consistent with the USGS data that identifies statistically significant and differing trends between stream flows in the east of the region as compared to the west. Figure 7-8 documents the trends identified in the evaluation of 227 stream gages in the Missouri River watershed. Here, the widespread negative trends in the western, more mountainous parts of the region contrast starkly with the positive trends in the east (Norton et al., 2014).

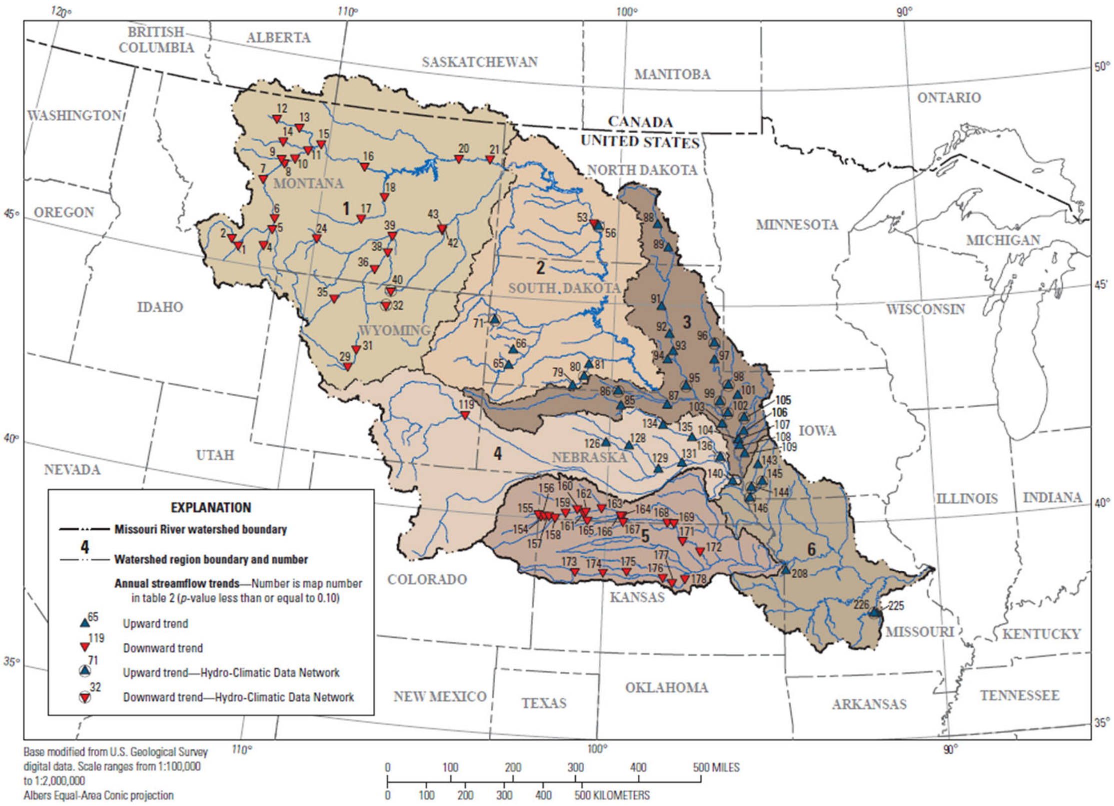


Figure 11. Streamgages in the Missouri River watershed with statistically significant trends in annual streamflow for water years 1960–2011.

16 Trends in Streamflow Characteristics at 227 Streamgages in the Missouri River Watershed, Water Years 1960–2011

Figure 7-8. USGS stream gages in the Missouri River watershed with statistically significant trends in annual stream flow for water years 1960-2011. (Norton et al 2014)

7.3.7 Projected Stream Flow Trends

The literature review state there exists a “mild upward trend in mean stream flow in the Missouri River Region” but acknowledges a lack of consensus regarding trends in the upper portion of the region (USACE 2015b). Trend direction is dependent on the selection of GCM models used for temperature and precipitation, the emission scenario, and the hydrologic model used. Uncertainty is large in the hydrologic models used.

7.3.8 Observed and Projected Snowpack Trends

According to the *Fourth National Climate Assessment,* an analysis of “seasonal maximum snow depth for 1961-2015 over North American indicates a statistically significant downward trend of 0.11 standardized anomalies per decade and a trend toward the season maximum snow depth occurring earlier—approximately one week earlier on average since the 1960s”. Snow cover extent in the spring has decreased since the 1960 and is believed to be partially due to higher temperatures.

Mote et al. (2017) observed that snow water equivalent (SWE) in the mountains above Fort Peck dam has declined up to 80% from 1955 to 2016.

Siler et al. (2019) note that while snowpack in the United States has not declined substantially since the 1980s, as would be expected based on warming trends, that once natural variability produced by atmospheric circulation is removed through modeling, declines are robust specifically in months of early accumulation (October-November).

Siler et al. (2019) hypothesize that snowpack loss will likely accelerate in coming decades as natural variability in the atmospheric circulation pattern that slowed snowpack decreases since the 1980s shifts.

7.3.9 State Climate Summaries

State climate summaries were released in 2017 to meet a demand for state-level information. The summaries address historical climate variations and trends, future climate model projections of climate conditions during the 21st century, and past and future conditions of sea level and coastal flooding. The state summary web content is routinely updated and are available at:

https://statesummaries.ncics.org/

Content for the study states (MT, WY, and ND) is summarized as: The average annual temperature has increased between 1.4°F and 2°F since the early 20th century. This increase is most evident in winter warming, which has been characterized by a below average occurrence of very cold days since 2000. Winter and spring precipitation is projected to increase. Heavier spring precipitation, combined with a shift from snow to rain, could increase the potential for flooding. Higher temperatures will increase evaporation rates and decrease soil moisture, leading to more intense future droughts.

7.4 Changes to Regional Hydrology and Assessment of Vulnerability

Evaluation was conducted of projected changes in the study area and watershed(s) of interest using various tools. The USACE Nonstationarity Detection Tool applies a series of statistical tests to assess the stationarity of annual instantaneous peak streamflow data series. The USACE Climate Hydrology Assessment Tool identifies projected changes in annual maximum monthly flows for the Hydrologic Unit Code (HUC) 4 watershed(s) most relevant to the project. The USACE Vulnerability Assessment (VA) Tool provides a nationwide, screening-level assessment of climate change vulnerability related to the USACE mission, operations, programs, and projects.

The information developed in this section can be used to help identify opportunities to reduce potential vulnerabilities and increase resilience as a part of the project's authorized operations and also identify any caveats or particular issues associated with the data. The information gathered in this assessment can be included either in risk registers or separately in a manner consistent with risk characterization in planning and design studies, depending on the project phase. It should be noted that developing conclusions related to hydrology, such as streamflow response, from climate change is very difficult due to significant uncertainties associated with global climate models and the additional uncertainties generated when these results are combined with hydrologic models, which also carry their own uncertainty. See *Missouri River Recovery Management Plan - Climate Change* (USACE 2018d) for previous analysis details pertaining to the Missouri River basin regarding projected changes.

7.4.1 Basis for Selection of Analysis Variables

Analysis variable were selected related to the purpose of the FTPTR which is fully described within several sections of the main document of this EIS. Broadly stated, the FTPTR purpose is to evaluate the potential for achieving pallid sturgeon spawning and recruitment on the upper Missouri River (UMR) using periodic Fort Peck Dam releases that better replicate historical flows and temperatures. The human considerations analysis evaluated potential impacts from test flows related to flood risk, geomorphic impacts (aggradation, degradation, stream bank erosion), and river infrastructure (Fort Peck dam spillway, river stability structures, and operation of irrigation intakes). Hydrologic components of the analysis conducted to evaluate impacts are affected by Fort Peck reservoir inflows and releases, Garrison reservoir pool levels, and downstream tributary inflows.

Climate change variables that may affect FTPTR objectives include increased air temperature, increased spring precipitation and streamflow, earlier snowmelt date and decreased snow accumulation season duration, increased sedimentation, decreased peak snow water equivalent, and the increased occurrence and irregularity of floods and droughts.

For the assessment of climate change variables related to the study purpose and human considerations analysis components stated above, peak streamflow was selected as the most relevant variable using the nonstationarity detection tool and the CHAT tool. The pulses being released will have the most significant impact the high flow regime. Using the same criteria, ecosystem restoration and flood risk management were selected as the most relevant business lines. The incremental area from Fort Peck Dam to Garrison Dam was considered the study area because that is the location downstream of the test releases. The area above Fort Peck Dam was not considered in the analysis although reservoir levels are a component of being able to conduct the test flow. As previously stated, neither the No Action nor any of the alternatives has a significant flow difference such that total annual volume is virtually identical for all cases.

7.4.2 Preparatory Data Analysis

This section examines the gage records used in this analysis to look for overall trends and build an overall understanding of changes in the gage watersheds. Gages used in this assessment were: the Yellowstone River at Sidney, MT; Missouri River at Culbertson, MT; and the Milk River at Nashua, MT. Figure 7-9 shows the gage locations.

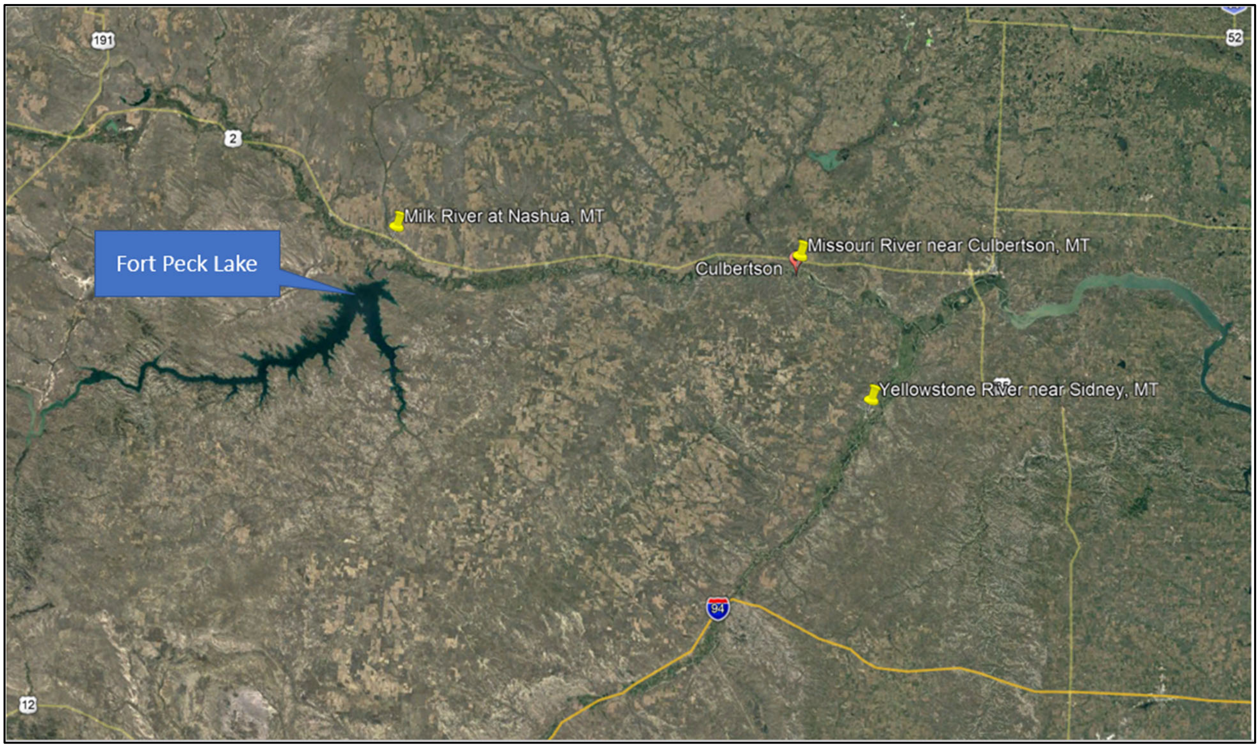


Figure 7-9. Gage Locations.

Figure 7-10 below shows the peak flow record for the Yellowstone near Sidney, MT gage. The USGS water-year summary of the gage states the flow is regulated to some extent by Bighorn Lake on the Tributary Bighorn River. In addition, there are significant upstream irrigation diversions for about 1.25 million acres. The gage annual peak flow period of record is from October 1910 to September 1931 (published as “at Intake”) and October 1933 to the current year. The drainage area upstream of the gage is 69,099 square miles with an estimated 692 square miles not contributing. The Yellowstone River is tributary to the Missouri River. It joins the Missouri River below Culbertson and upstream of Willison, MT.

Increases in the holdouts of Bighorn lake (and other impoundments) as well as an increase in diversions for agricultural water use may be sources of known nonstationarity in the observed, annual peak streamflow record. USGS gage history states that the gage was moved from a site 32 miles upstream in September of 1931.

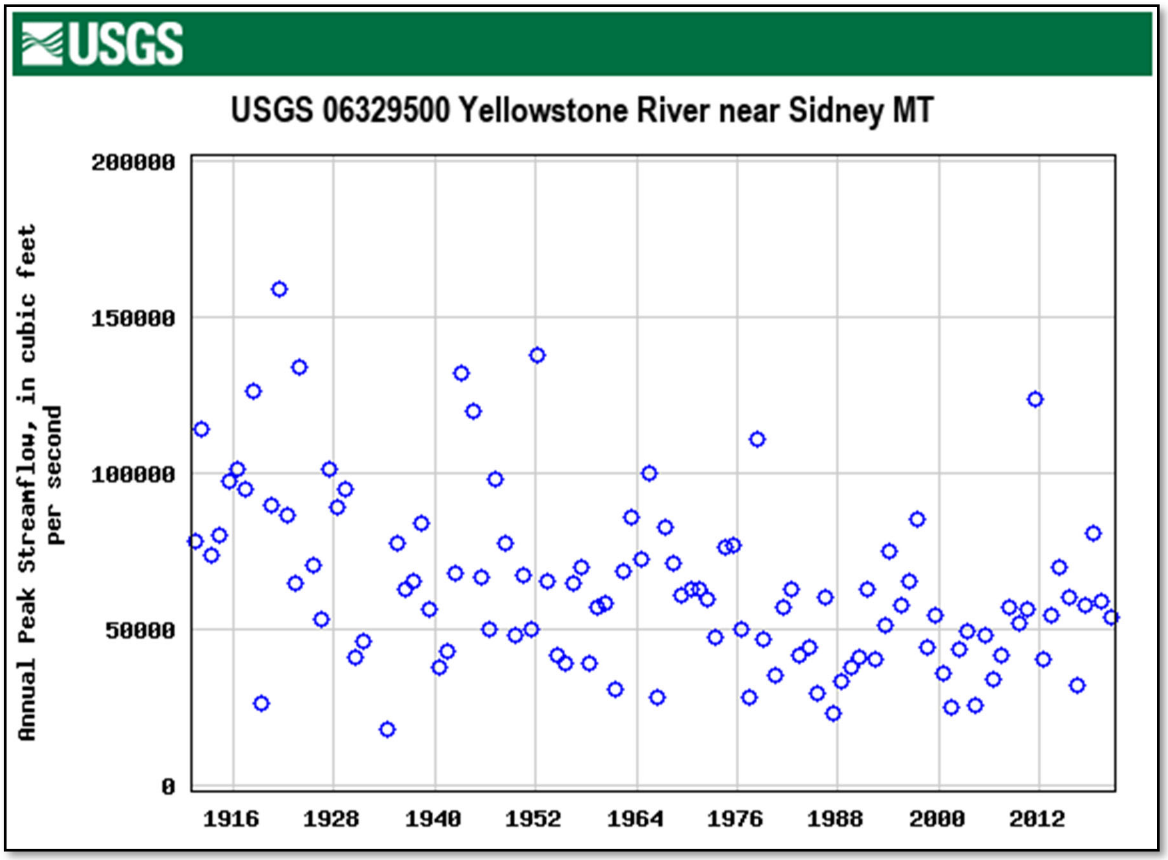


Figure 7-10. Yellowstone River near Sidney Peak Annual Peak Flows Period of Record

Figure 7-11 shows the Missouri River near Culbertson, MT gage annual peak flows. The contributing drainage area for this gage is 89,858 square miles, which includes the Fort Peck Dam drainage area. The period of record of the gage for the peak flows is 1942-2020. The Fort Peck Dam was completed in the 1930s so the gage has always had some regulation. This gage is about 90 miles downstream of the Fort Peck Dam and includes flow from the Milk River tributary.

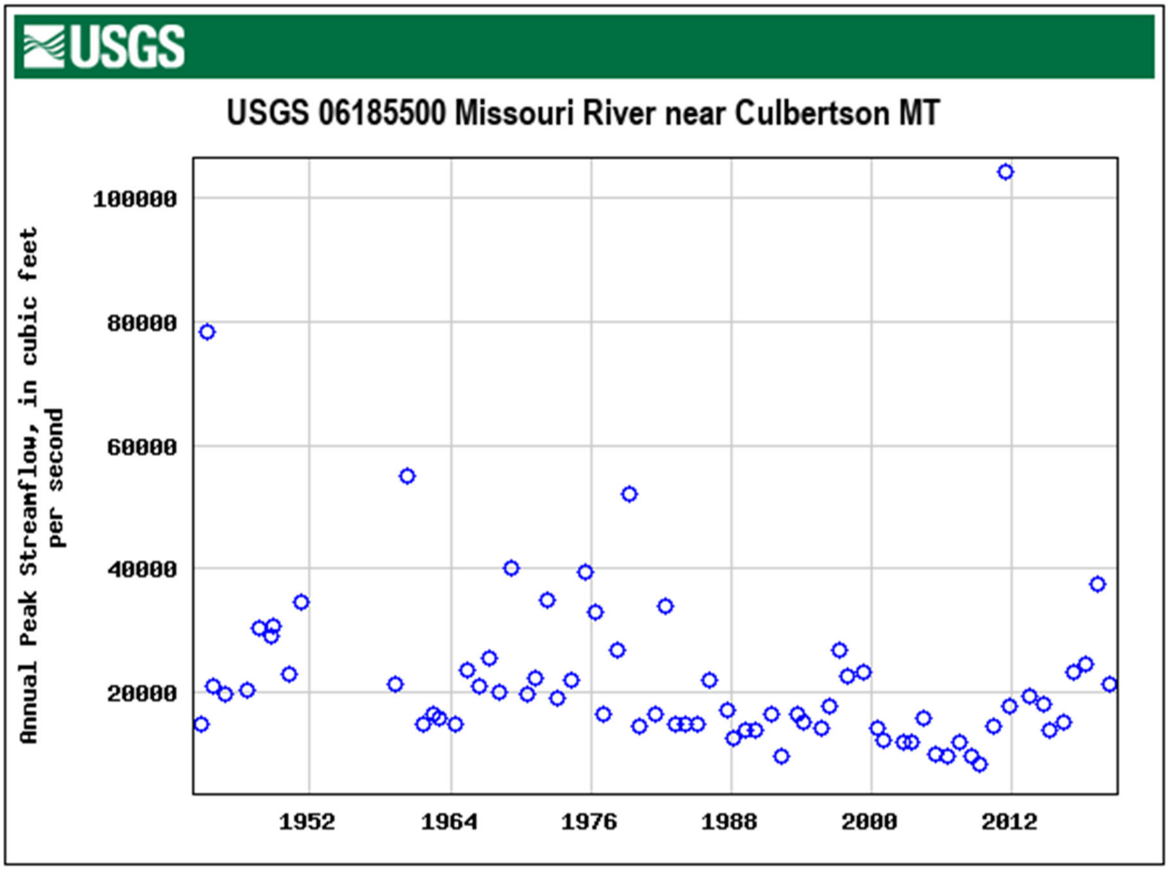


Figure 7-11. Missouri River near Culbertson, MT Annual Peak Flows – Period of Record

Figure 7-12 shows the Milk River at Nashua, MT. The Milk River is a large tributary that joins the Missouri River a few miles below the Fort Peck Dam. The gage has a contributing drainage area of 20,254 square miles (2,198 square miles of which is likely non-contributing). Flow is regulated by Fresno Reservoir, two reservoirs in Lodge Creek basin and four reservoirs in Frenchman River basin. Both the Lodge Creek and Frenchman River reservoirs are in Saskatchewan. The gage has a period of record from October 1939 to the current year.

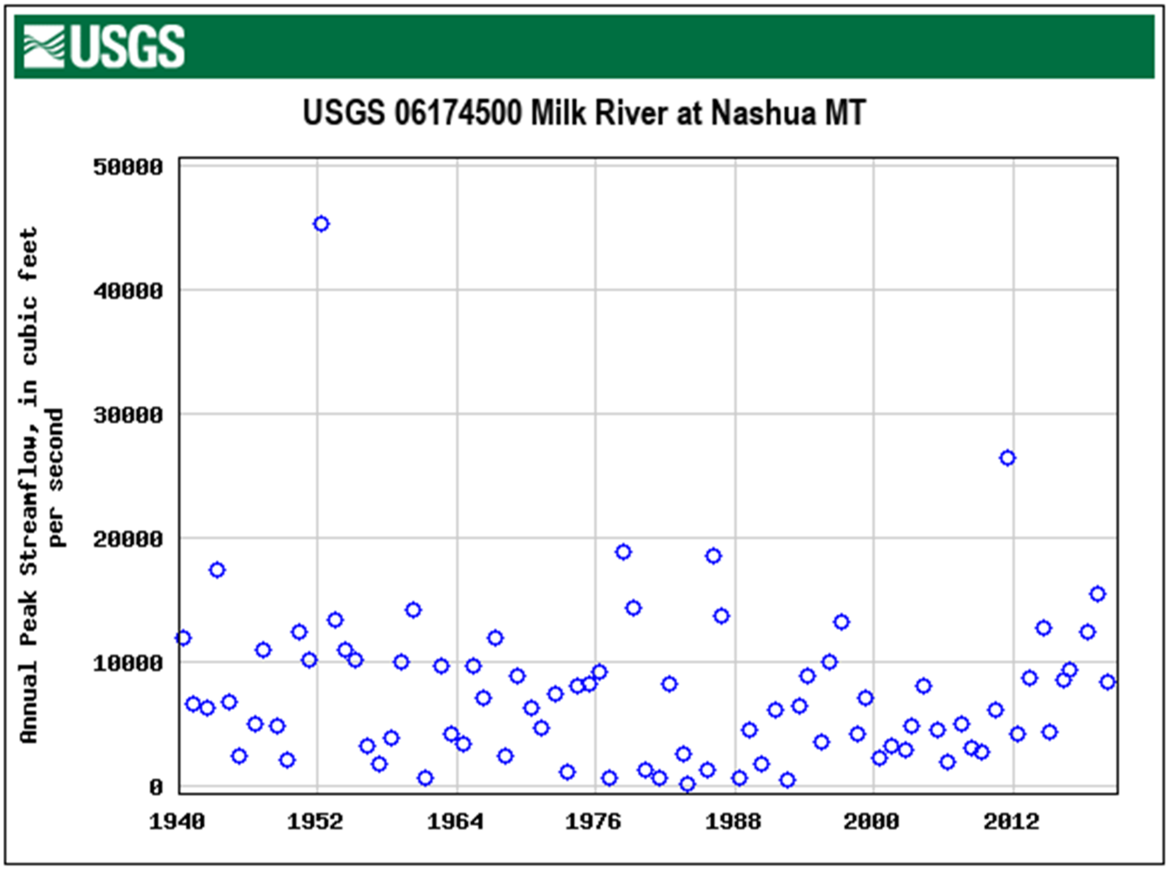


Figure 7-12. Milk River at Nashua, MT Peak Annual Peak Flows Period of Record

7.4.3 Nonstationarity Detection Tool

The USACE Nonstationarity Detection (NSD) Tool was used to examine the hydrologic time series at select study area stream gages. This tool aids in identifying continuous periods of statistically homogenous (stationary) annual instantaneous peak streamflow datasets that can be adopted for further analysis. The NSD Tool helps to identify if the record of annual peak stream flows are impacted by anthropogenic activities (e.g. dam construction, urbanization, climate change etc.). Water development projects in the study area, including irrigation withdrawals and the operation of Fort Peck and Garrison reservoirs, are known to have altered historic streamflow records.

For a nonstationarity to be considered strong, it must trigger two or more tests within a range of five years for the same statistic (distribution, mean, etc.) to show consensus, it must trigger two or more tests within a range of five years for different statistics to show robustness, and it must show a significant change in the magnitude of the standard deviation and/or mean. The monotonic trend analysis portion of the NSD tool was used to check for statistically significant trends in the data. For a trend to be considered statistically significant, it should typically have a p-value of 0.05 or less. A p-value of 0.05 is most often selected as the standard significance threshold within statistical literature (USACE, 2017a).

Three stations were selected to represent the incremental drainage area between Fort Peck and Garrison dams. Selected stations were the Milk River at Nashua, MT, the Yellowstone River at Sidney, MT, and the Missouri River at Culbertson, MT. Results from the nonstationarity analysis and monotonic trend analysis as conducted using the USACE NSD tool are included in Plates 71 - 81. Possible reasons for the nonstationarities detected are documented in **Table 7-1**.

The Yellowstone River at Sidney, MT, had a strong nonstationarity (three tests for distribution, one for mean, and one for variance as well as a significant change in mean) around the 1930. This gage has a long period of record from 1911 through 2014 (last year included in the NSD tool) but there is a two year break in the record between 1932 and 1933. This should not impact the result too significantly. There is also evidence of a strong nonstationarity in the late 1970s with two tests indicating a shift in mean and two tests indicating a shift in overall distribution. There is also a somewhat significant decrease in the sample mean circa 1978.

Although data is available for the Missouri River near Culbertson (USGS No. 06185500) station between 1942 and present, the period of record was limited to 1959 through present for the nonstationarity detection analysis due to a gap in data of more than 5 years (1952-1958). There appears to be some strong evidence of nonstationarity within the period of record with a significant decrease in mean circa 1981. Within a five year period, between 1979 and 1982 two test targeted at detecting a change in mean and one targeted at detecting a change in overall statistical distribution indicate nonstationarity. The Culbertson gage and its flow is highly regulated due to its location downstream of the Fort Peck Dam.

The nonstationarities identified on the Yellowstone River and the Missouri River circa 1980 may be the result of naturally occurring long-term persistent (LTP) climate trends thought to occur in the region which can be characterized as cyclic fluctuations between significantly wetter periods that vary from over twenty years to a little less than ten.

The Milk River at Nashua (USGS No. 06174500) station did not have any strong nonstationarities detected in its period of record analyzed (1940-2019).

The nonstationarity detection tool was applied to conduct a monotonic trend analysis at each gage. Results are listed in **Table 7-2**.

Table 7-1. Nonstationarities and Possible Triggers

Gage	Nonstationarity	Possible Trigger
Yellowstone River near Sidney, MT	1930	Several dams were constructed around the 1930s on the Yellowstone and Bighorn Rivers (tributary to the Yellowstone). These included Pilot Butte on the Yellowstone (1928), Bull Lake on the Bighorn (1936), and Mystic Lake on the Yellowstone (1925). The gage was moved circa 1931.
	1978	No prior knowledge of Nonstationarity, potentially can be attributed to naturally occurring Long-term Persistent (LTP) Climate Trends. The dates of dams constructed and a plot of the annual inflows to Garrison Dam were referenced. No evidence that these two drivers could have created this nonstationarity.
Missouri River near Culbertson, MT	1981	No prior knowledge of Nonstationarity, potentially can be attributed to naturally occurring Long-term Persistent (LTP) Climate Trends

Table 7-2. Monotonic Trends

Gage	Record Analyzed	Trend	Statistically Significant?
Yellowstone River near Sidney, MT	1911-2020	Decreasing	Yes
	1911-1931	No Trend	No
	1932-2020	Decreasing	Yes
	1979-2020	No Trend	No
Missouri River near Culbertson, MT	1959-2019	Decreasing	Yes
	1959-1980	No Trend	No
	1981-2019	No Trend	No

7.4.4 Climate Hydrology Assessment Tool – Stream Flow Trends

The USACE Climate Hydrology Assessment Tool (CHAT) detects trends in observed annual maximum daily flow from a selected USGS gage, as well as projected future trends in annual maximum monthly flow for a selected HUC-4 watershed. Plates 82 through 94 in the Appendix show the CHAT analysis results for the three gages and five HUC-4 watersheds analyzed as part of this analysis.

The CHAT tool applies the parametric student t-test to evaluate observed annual peak datasets for trends, while the NSD tool results (presented in the preceding section) apply the non-parametric Mann-Kendall and Spearman Rank Order tests to evaluate peak flow data for monotonic trends. Based on the student t-test, only the Yellowstone at Sidney gage had a statistically significant trend. When the whole period of record (1942-2014) was analyzed for the Missouri River near Culbertson, MT no statistically significant trends were identified. When the continuous period of record was analyzed post 1959, a statistically significant decreasing trend with a p-value of 0.02 is present in the dataset observed near Culbertson. These downward trends are likely due to the construction of dams and irrigation above the gages. These could affect ecosystems due to decreases in natural peak flows that could decrease the already weak spawning cues for the pallid sturgeon. CHAT tool results are consistent with NSD tool results (see Plates 87-89).

Table 7-3. Peak Annual Flows- Observed Trends- CHAT

USGS Gage	Peak Steam Flow Trend	Statistically Significant?
Milk River at Nashua, MT	No Trend	No
Yellowstone River near Sidney, MT	Decreasing	Yes
Missouri River near Culbertson, MT	Decreasing	No

The CHAT was also used to determine trends in unregulated simulated, historic (1950-1999) and projected (after 2000-2100) streamflow for hydrologic unit codes (HUCs)-4 watersheds within the study area. The year 2000 separates the model simulations conducted where emissions were reconstructed to be consistent with historic emissions levels (1950-1999) versus the model runs where various projected pathways of emissions are being applied (2000-2099). The projected climate changed hydrology shows statistically significant increasing trends, but the uncertainty associated with these projections is large. Plates 90 through 94 in the appendix show statistically significant positive trends for the Upper Yellowstone, Lower Yellowstone, Milk River, Missouri-Poplar, and Bighorn HUC-4s representing the incremental area between Fort Peck and Garrison Dams. There are no statistically significant trends in the simulated, historic flows from 1950-1999. **Table 7-4** summarizes these trends.

Table 7-4. Simulated Historic & Projected Unregulated Annual Max. Monthly Flow Trends

Gage	Before 2000 (Historic Simulation)		After 2000 (Climate Changed Simulation)	
	Tend	Statistically Significant?	Tend	Statistically Significant?
1005-Milk	None	No	Increasing	Yes
1006-Missouri-Poplar	None	No	Increasing	Yes
1007-Upper Yellowstone	None	No	Increasing	Yes
1008-Bighorn	None	No	Increasing	Yes
1010-Lower Yellowstone	None	No	Increasing	Yes

Large amounts of uncertainty are inherent in climate model projections. This is illustrated by the large range of projections (yellow area) shown in Plates 82-86. The projected HUC scale hydrology trends available with the CHAT were produced from the Global Circulation Model (GCM) Coupled Model Intercomparison Project Phase 5 (CMIP-5) suite of model simulations of temperature and precipitation, downscaled from the global scale to the HUC-4 watershed scale using the Bias Correction and Spatial Downscaling (BCSD) method, based on 93 combinations of GCMs and Representative Concentration Pathway of Greenhouse Emissions (RCP) translated to a hydrologic response using the U.S. Bureau of Reclamation's CONUS wide Variable Infiltration Capacity (VIC) model. Thus, while the observed streamflow records demonstrated with no trend or a decreasing trend, the HUC-04 level projections imply increases in streamflow in the future.

7.4.5 Sedimentation Trends

No long term studies to define sedimentation trends are available. Higher streamflow levels and spring rainfall events would generally be expected to correlate with higher river sediment loads. Higher sediment loads could result in additional storage capacity loss within Fort Peck and Garrison reservoirs.

Two previous USACE studies conducted for Garrison Dam (USACE 2012c, 2014) indicated increasing sediment loads in the future. The aggradation study (USACE 2014) determined a significant impact to river water levels as a result of increased sediment loads in the Lake Sakakawea headwaters. The climate change study on sediment yield impacts (USACE 2012c) used statistically downscaled regional climate projections for five different climate scenarios: drier and cooler, drier and warmer, wetter and cooler, wetter and warmer, and a median future precipitation and temperature condition. Key findings were:

- All climate change scenarios evaluated resulted in an increase in sediment loading and inflows.

- Climate-adjusted flows can have a large impact on pool elevations and releases for all climate scenarios evaluated.

- Impacts from changing sedimentation rates on flood regulation would be minor for this large mainstem reservoir, but hydrologic changes could potentially be significant.

7.4.6 Vulnerability Assessment

The USACE Vulnerability Assessment (VA) tool was used for both the ecosystem restoration and flood risk reduction business lines for this assessment. The periodic release for the Pallid Sturgeon will be made from Fort Peck and eventually end up in Garrison Dam's pool. Ecosystem restoration is important because that is the purpose of the pulse release (improve Pallid Sturgeon habitat). Flood risk reduction is important because the pulse should not impact landowners through flooding downstream of Fort Peck.

The VA Tool provides a nationwide, screening-level assessment of climate change vulnerability related to the USACE mission, operations, programs, and projects (USACE 2016b). This tool was used to examine the vulnerability of the region to future flood risk. The tool can be used to assess the relative vulnerability of a specific USACE business line, such as Flood Risk Reduction, Ecosystem Restoration, and Navigation, to projected climate change impacts. There is a great deal of uncertainty with the results given by the vulnerability assessment tool due to the level of uncertainty the tool's many inputs introduce.

The vulnerability score is calculated using a weighted order weighted area (WOWA) method based on a series of indicator variables. Vulnerability is flagged if that watershed HUC 4 vulnerability score falls within the top 20% of vulnerability scores as compared to the other 201 HUC 4 watersheds in the contiguous United States (CONUS).The tool uses climate changed hydrology determined using 93 traces of CMIP5 GCM based climate outputs converted to a hydrologic response using the U.S. Bureau of Reclamations CONUS wide Variable Infiltration Capacity (VIC) models. The uncertainty in the modeling is partially communicated by providing output for two epochs of time and for both the top 50% of traces of flow (WET scenario) and bottom 50% of traces (Dry scenario) (USACE 2016b). The default national standard settings were used in the tool.

The five HUC-4s representing the incremental area between Fort Peck Dam and Garrison Dam (Upper Yellowstone, Lower Yellowstone, Milk River, Missouri-Poplar, and Bighorn) were analyzed because these HUC-04s will be most impacted by the planned, periodic releases. Ecosystem restoration VA tool output is illustrated in **Figure 7-13**. The results show that only the Missouri River – Popular HUC-4 is considered vulnerable by USACE criteria for the ecosystem business line. This is for all epochs and both the wet and dry subsets of projections.

Flood risk vulnerability scores are illustrated in **Figure 7-14** for the same five HUC-4s. These results show that only the Big Horn Basin HUC-4 is relatively, vulnerable for the Flood Risk business line and that it is only projected to be vulnerable for the wet subset of future conditions. The Upper Yellowstone, Lower Yellowstone, Milk River and Missouri-Poplar are not relatively vulnerable to increased flood risk, even for the wettest subset of projections. The dominate indicators driving vulnerability for both business lines are summarized in Figures **Figure 7-15** and **Figure 7-16** and **Table 7-5**.

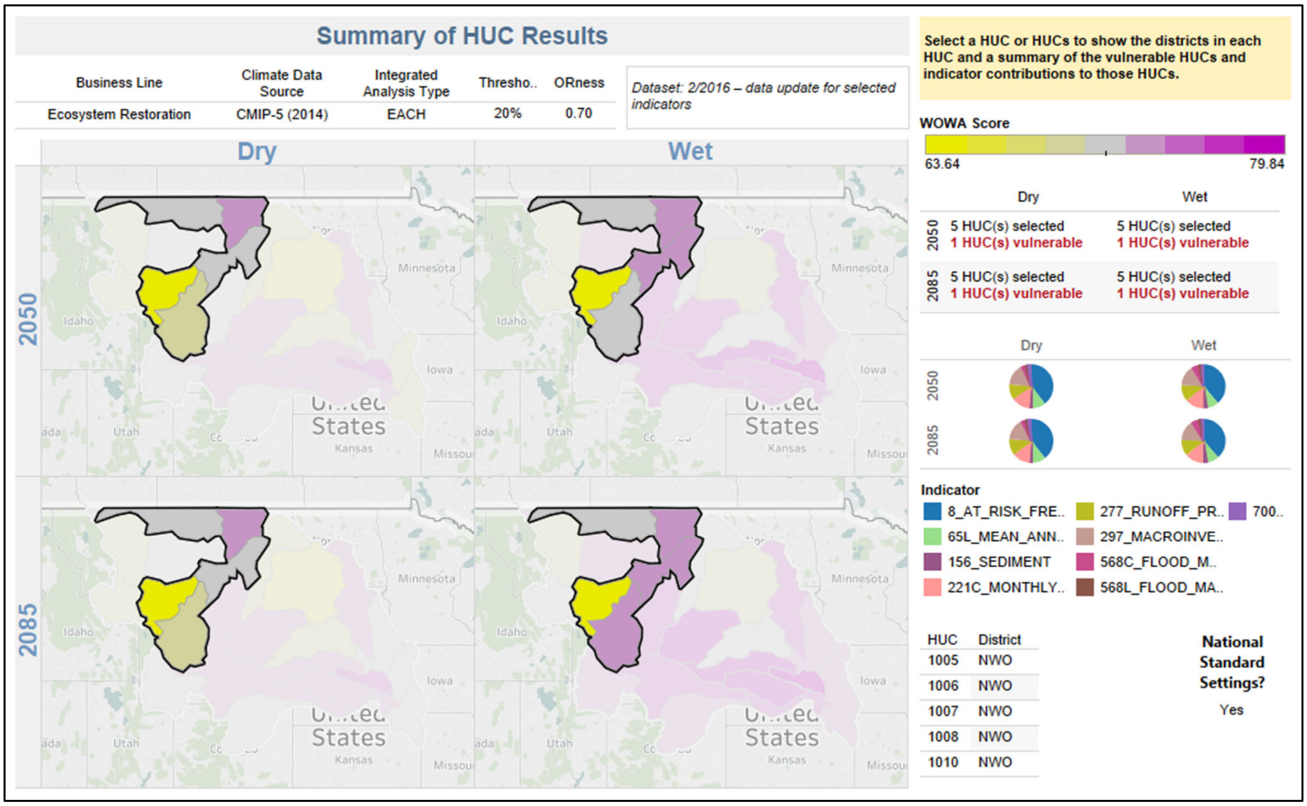


Figure 7-13. Projected Ecosystem Restoration Vulnerability Scores

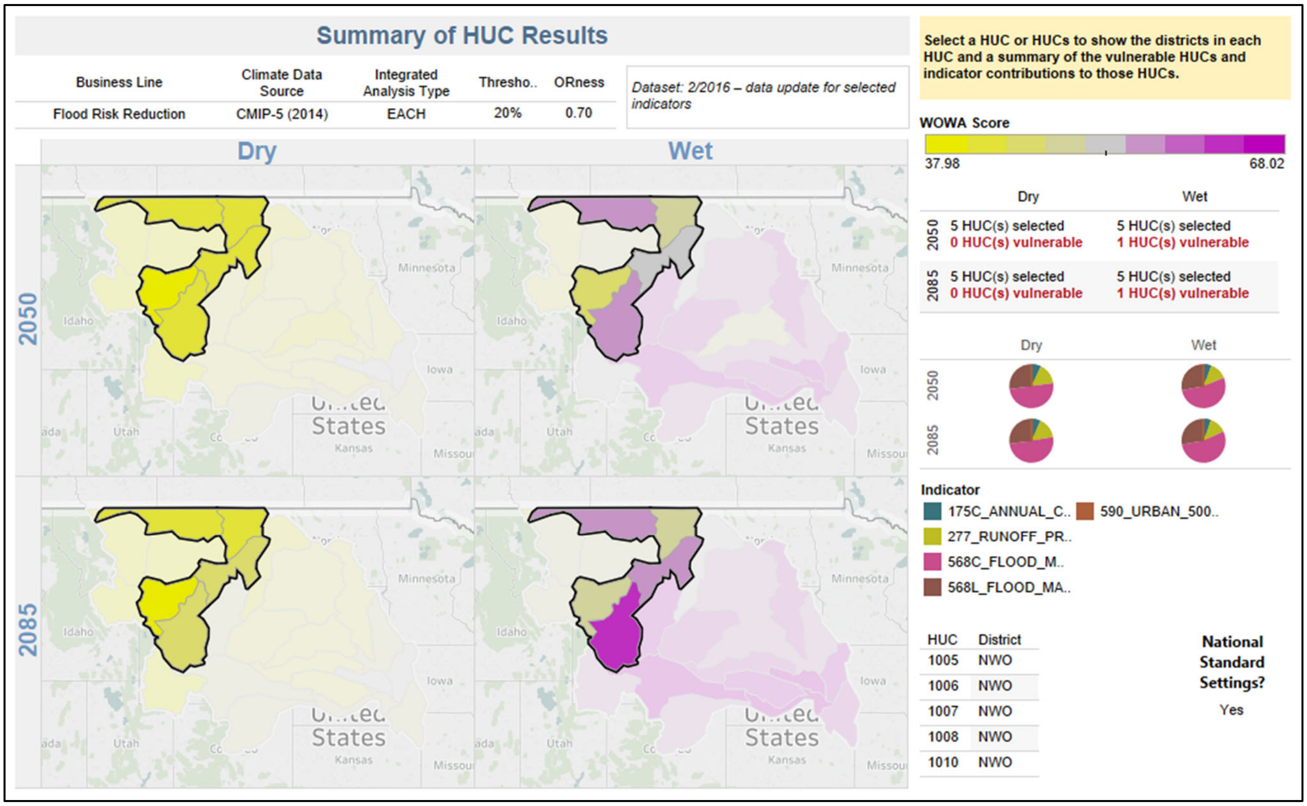


Figure 7-14. Projected Flood Risk Reduction Vulnerability Scores

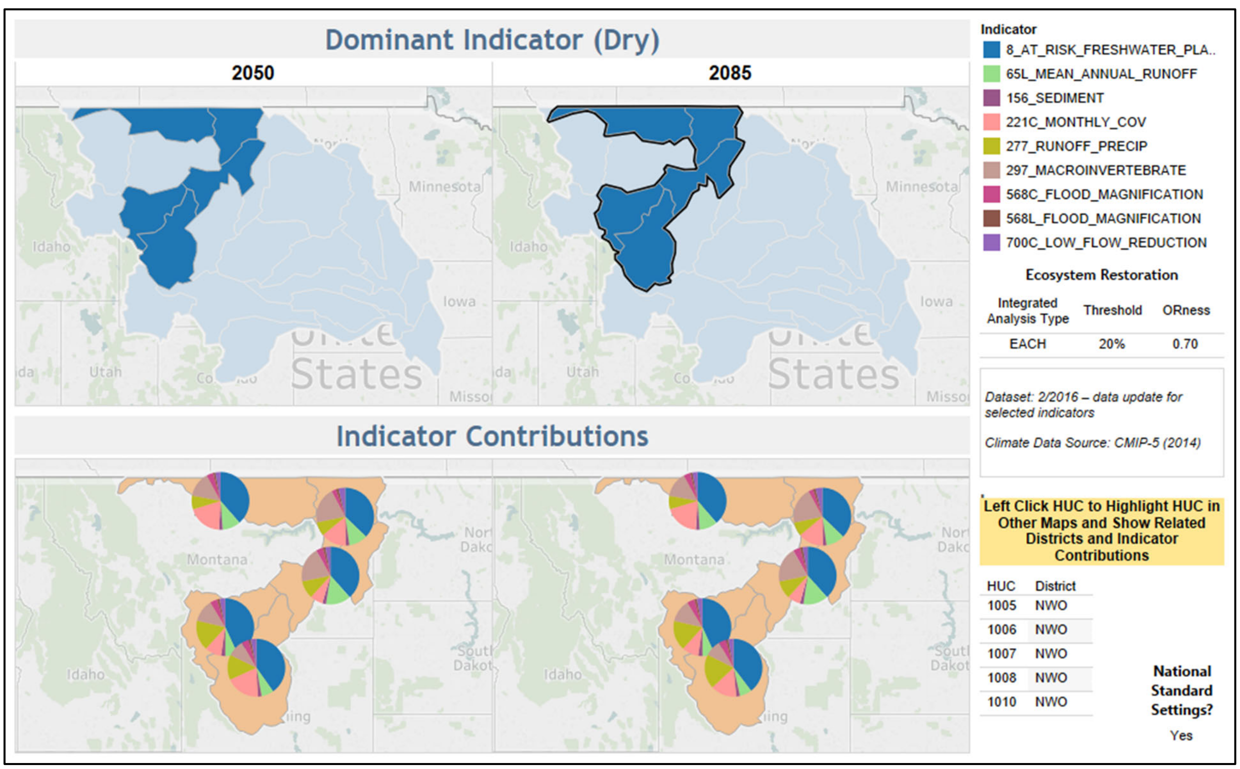


Figure 7-15. Dominant Indicators for Ecosystem Business Line (Dry Conditions)

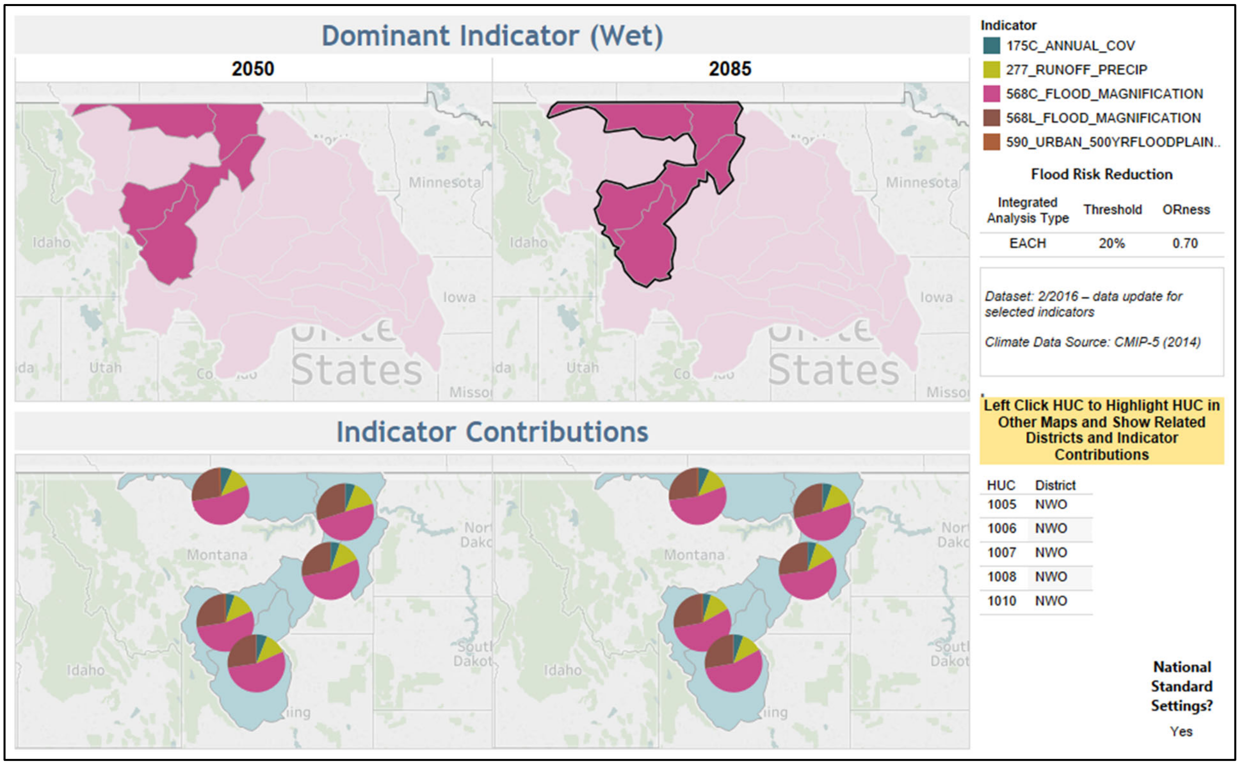


Figure 7-16. Dominant Indicators for Flood Risk Business Line (Wet Conditions)

Table 7-5. Dominant Indicators Driving Vulnerability Scores

Ecosystem
8-Percent of Freshwater Plant Communities at Risk 65L-Decrease in Mean Annual Local Runoff 156-Change in sediment load due to change in future precipitation
Flood Risk
568C-Flood Magnification: expected increase in the monthly flow exceeded 10% of the time 175C-Variability in annual runoff within the HUC and HUCs upstream 277-Percent change in runoff divided by percent change in precipitation: watershed has a larger increase in runoff compared with the increase in rainfall

7.5 Climate Potential Risks

Potential residual risks due to human-driven climate change were evaluated for the FTPTR. Broadly stated, the FTPTR purpose is to evaluate the potential for achieving pallid sturgeon spawning and recruitment on the upper Missouri River (UMR) using periodic Fort Peck Dam releases that better replicate historical flows and temperatures. Risks to be avoided for the FTPTR include impacts to human considerations related to flood risk, geomorphic impacts (aggradation, degradation, stream bank erosion), and river infrastructure (Fort Peck dam spillway, river stability structures, and operation of irrigation intakes).

7.5.1 Potential Risks Summary

The literature review of USACE climate change guidance and most references from other sources for the Missouri River basin agree that future climate trends will likely consist of increased temperatures and precipitation. Increased precipitation may result in higher streamflow for some periods, while increased temperatures will likely result in earlier spring snowmelt, decreased snowmelt season duration, and decreased peak snowmelt flows. Increased air temperatures could also have impacts on water temperatures and water quality, which could be exacerbated by low summer flows. Rainfall events will likely become even more sporadic for the entire Missouri River basin. Large rain events will likely become more frequent and interspersed by longer relatively dry periods. Extremes in climate will likely also magnify periods of wet or dry weather, resulting in longer, more severe droughts, and larger more extensive flooding.

Based on an evaluation of observed streamflow records collected in the study area, the area contributing to and containing the Missouri River reach where flow increases are planned is ***not likely to be impacted by additional flood risk due to climate change in the near-term***. Two stream gages located along the Missouri and Yellowstone Rivers near where the planned pallid sturgeon release will occur from Fort Peck Dam showed a decrease in annual peak flows with time. A strong nonstationarity was found in the 1930s on the Yellowstone River and was likely due to dam construction on the Yellowstone River and its large tributary, the Bighorn River. Both the Missouri River at Culbertson and Yellowstone River gages exhibit evidence of decreasing trends and a nonstationarity circa 1980. This nonstationarity may be the result of long-term persistent, naturally occurring fluctuations in climate that are known to occur in the region.

The regional scale (HUC-4) future projections for 2000-2100 showed a statistically significant increase in maximum monthly stream flows for all the HUCs considered. Historic simulations of unregulated streamflow for the period 1950-1999 showed no statistically significant trends.

Results from the USACE vulnerability analysis showed that the Bighorn River HUC-4 was vulnerable in the wet scenarios to increased flood risk. Ecosystem restoration vulnerability scores showed the Missouri-Poplar was vulnerable to climate change. The main indicators driving the ecosystem restoration vulnerability scores were the percent of plant communities at risk, a decrease in local annual runoff, and changes in sediment load due to changes in future precipitation.

- While the literature review and assessment of projected, climate changed hydrology for HUC-4s in the study area indicate possible increases in flood risk with time, there is no evidence within observed streamflow records recorded in the study area that flood risk is increasing.
- ***If the test flow is deemed effective for pallid sturgeon recruitment, the climate change assessment of residual risk should be revisited. With additional years of gaged data, and innovations in climate change science and modeling methods further insight into how climate change may impact the study area might be obtained. The adaptation management plan should reflect these possible changes in risk due to climate change***.
- It is recommended the area be monitored for changing climate trends. Additional resilience measures should be considered if changes at the site become statistically significant, when the final long-term plan is selected, and/or if new actionable science related to climate change and relevant to the study area becomes available.

7.5.2 Climate Potential Risks Related to the Affected Environment

Climate change potential risks were evaluated by resource topic to support the affected environment and environmental consequences analysis. Refer to section 3.0 of the main document of the EIS for additional details. The climate change evaluation for the effected environment considered six climate change variables that are expected to have an impact on flow change alternatives: increased air temperature; increased precipitation and stream flow; decreased peak snow water equivalent; earlier snowmelt date and decreased snow accumulation season duration; increased sedimentation; and increased irregularity of floods and droughts. While the climate change assessment highlighted many likely impacts, the assessment did not illustrate a meaningful difference between the No Action and any alternative being considered as part of this study.

Hydrology: Flow releases may increase in frequency if system storage rises earlier in the year because a greater proportion of the precipitation in the mountains is expected to fall as rain. In that case, proposed flow pulses from Fort Peck Dam may occur less frequently if downstream constraints are exceeded more often. Conversely, early evacuation of system storage coupled with more frequent droughts in the summer could result in less frequent flow releases. Forecasting calendar year runoff could become less accurate because forecasting runoff based on rainfall may become much more difficult than forecasting runoff based on snowmelt. In addition, climate change could result in lower service levels in the second half of the navigation season if runoff falls as rain in late winter while the system is being evacuated to provide spring runoff storage volume.

Geomorphology*:* Higher natural annual flows and a higher number of peak flow events would likely result in higher sediment erosion rates in the Missouri River watershed. As a result, the Mainstem and tributaries would carry larger volumes of sediment. Rates of degradation, streambank erosion, and aggradation would increase in the inter-reservoir reaches; degradation and streambank erosion would increase in the active degradation reaches. In addition, geomorphological impacts from the release changes would mirror the changes in hydrology.

Specifically, more frequent and longer flow releases would result in an incremental increase in geomorphological impacts during that period within the reaches affected by elevated flow. Higher air temperatures and higher sporadic flood flows would also affect ice dynamics, resulting in altered flooding patterns from ice jams.

Riverine Infrastructure: Higher natural annual flow rates and more frequent peak flows would increase the impacts (i.e., erosion, wear and tear from frequent overtopping, burial) on river infrastructure. Riverine infrastructure impacts from release changes would also mirror the changes in hydrology. Rainfall events are likely to become even more sporadic for the study area. Large rain events are likely to become more frequent and interspersed by longer relatively dry periods. More frequent and longer Fort Peck flow releases would result in an incremental increase in riverine infrastructure impacts during that period affected by elevated flow.

Groundwater: More frequent natural peak flows and more prolonged droughts could result in greater variability in groundwater elevations throughout the year under all alternatives in the floodplain and land adjacent to the river, which could affect wetlands and croplands. In addition, groundwater impacts from higher flow releases would also mirror the changes in hydrology. Specifically, more frequent and longer flow releases would result in an incremental increase in groundwater impacts during that period within the reaches affected by elevated flow.

Pallid Sturgeon: Climate change potential risks were assessed specific to the broad project objectives of pallid sturgeon spawning and recruitment on the upper Missouri River (UMR) using periodic Fort Peck Dam releases. As described within the main report of this EIS, uncertainty associated with the effects of management actions on pallid sturgeon populations begets greater uncertainty regarding how the effects of test flow releases from Fort Peck Dam to benefit pallid sturgeon would be influenced by climate change. Increased precipitation and streamflow, with unknown aggregate impacts related to test flow objectives and constraints, may influence the ability to conduct test flow releases. Increasing air and water temperatures could benefit pallid sturgeon during the drift phase of the hydrograph. Growth and development rate of young pallid sturgeon could increase and reduce drift distance required to achieve first exogenous feeding a survival to juvenile stage. However, increased air and water temperatures above the optimal level could also stress pallid sturgeon during the larval drift and growth stages. Altered spring runoff patterns, with early snowmelt seasons, may elevate Fort Peck release water temperature that could benefit pallid sturgeon. Conversely, earlier runoff may require higher pool evacuation releases that would reduce system storage and result in lower flow releases at critical times for pallid growth. In summary, it is unclear how climate change may impact test flow objectives as the impact of altered test release frequency as well as air and water temperatures on the pallid sturgeon response is also unknown.

Flood Risk Management: Increased air temperature (without considering how this may influence hydrologic processes) was identified as not being a risk to flood risk management. Decreased peak snow water equivalent may reduce the risk to flood risk management by lowering reservoir elevations. However, an earlier snowmelt date and decreased snow accumulation could have either an adverse or beneficial impact on flood risk management depending on the location and season. Both of the climatic change variables for increased sedimentation and flood severity would increase the risk of adverse impacts to flood risk management by potentially exceeding flood targets more frequently or increasing the number of extreme weather events and reducing the overall reliability of the system.

Hydropower: Increased precipitation and streamflow has the potential to increase hydropower generation. Decreased peak snow water equivalent could potentially decrease hydropower production and reliability, especially during peak seasons. Decreased snow accumulation and the associated runoff reduction would lead to decreased hydropower generation and reliability. Increased sedimentation could increase O&M at the dams, which would impact hydropower operations, generation, and reliability. Increased sporadic nature of droughts could potentially lead to less reliable and less overall hydropower production during drought years. More extreme drought or flood conditions could reduce reservoir elevations at the upper three reservoirs as System operations become more difficult to forecast. Short term adverse impacts associated with partial test releases may occur. The timing of test flow releases may both increase and decrease hydropower benefits under the alternatives relative to No Action during peak production. Since the No Action and alternatives have negligible difference in annual volume, no significant difference in hydropower is expected.

Irrigation: Climate change would likely have an increasing influence on irrigators. Earlier spring snowmelt and lower summer flows could reduce irrigators' access to water. More irregular rainfall could also result in irrigators needing to rely more on the Missouri River and other water sources for irrigation. Longer duration of lower river flows or increased higher river flows may adversely impact access to water for irrigation or result in increased operations and maintenance costs. More extreme rain events could adversely impact irrigation intakes through sediment deposition and increased river flows; these impacts could be exacerbated during spring or fall releases under Alternatives 1 and 2.

Water Supply: Drought periods along with decreased peak snow water equivalent would result in difficulties forecasting runoff and System storage. Higher spring runoff would result in higher spring System storage, leading to early spring releases in order to meet System criteria. However, relatively lower late summer and fall river flows may have adverse impacts to water supply access with increased periods when water surface elevations fall below critical thresholds. Given a possibility for longer, drier periods, water supply access could be affected with an increase in the number of days that water surface elevations would fall below critical thresholds for intakes.

Impacts of climate change under Alternatives 1 and 2 would be similar to those described under No Action. With earlier snowmelt, the Fort Peck Dam test flow releases under Alternatives 1 and 2 may be able to run more frequently because System storage would rise earlier in the year. More frequent and larger flows relative to No Action may result in lower river flows in the fall and winter compared to No Action, especially if the releases are followed by drought or drier conditions. Longer and lower river flows would adversely impact water supply access, especially in the fall and winter months when flows are at their lowest levels.

Water Quality: Higher air temperatures would likely influence water temperature especially in areas of low river flow or low reservoir elevations resulting in warmer water temperatures that could influence the amount of time that the mainstem reservoirs are thermally stratified. Periods of intense rain could increase runoff, mobilize land-based particulates, and increase sediment and pollutant loading in the Missouri River. The general impacts of climate change under the No Action and all alternatives would consist of adverse impacts from altered water temperature regimes and, by association, dissolved oxygen conditions, as well as potential increases in sediment loading and nutrient and other pollutant loading.

Recreation: Earlier snowmelt may cause spring System storage targets at the upper three reservoirs to be met more frequently which may alter releases under the No Action and alternatives. Drought conditions may affect recreation access and fishing opportunities at Fort Peck Lake from lower reservoir elevations and could also reduce river access and recreation opportunities. Increased runoff may raise reservoir levels and Fort Peck releases that could benefit recreation opportunities. However, more sporadic large rain events and flooding could adversely impact access to recreation resources. These impacts could be exacerbated during the test flow releases. In contrast, some river boating recreation opportunities will benefit from high river levels and risk to large rain events will be reduced following the alternatives peak flow period.

Fish and Wildlife: An increase in the frequency of spring flows or flooding that would inundate fish and wildlife habitat more frequently could cause changes in the acres of individual habitat classes with increases in wetter habitats (i.e., open water, emergent wetland, scrub shrub wetland, and riparian woodland/forested wetland) and decreases in drier habitats (i.e., forest and upland grassland) if precipitation and streamflow increase. Maintenance of aquatic habitats could also occur more frequently for sustaining important breeding and foraging habitat for fish and wildlife species. Decreases in the frequency of spring flows, increased drought conditions, or decreased frequency of all flows due to decreased System storage from increased sedimentation could have the opposite effect (i.e., increases in drier habitats and decreases in wetter habitats). Since the No Action and alternatives have negligible difference in volume, no significant difference is expected.

Cultural Resources: The more extreme flood and drought periods may result in difficulties forecasting runoff and System storage. Higher spring runoff would result in higher spring System storage, leading to early spring releases in order to meet System criteria and resulting in relatively lower late summer and fall river flows. Given a possibility for longer, drier periods, cultural resources sites located below the normal reservoir operating elevations could be affected by decreasing reservoir elevations.

Environmental Justice: Natural climatic conditions that result in flooding or droughts can have direct and indirect adverse impacts on environmental justice populations, especially when weather events are extreme. Substantial variability in hydrologic conditions occur within the basin including periods of drought (i.e., 1930s) and high runoff (i.e., 1997, 2011). This variation results in substantial variability in impacts to all populations, including populations of concern. These impacts would not represent a disproportional impact. The forecasted effects of climate change are not expected to change the effects to environmental justice populations and their variations and are not expected to lead to more disproportionate impacts on environmental justice populations.

Thermal Power: The more extreme flood and drought periods may result in difficulties forecasting runoff and System storage. For drier periods under climate change, river stages would be reduced with the potential for a greater number of days below critical operating thresholds for thermal power plants.

7.6 Risk Assessment Summary

A risk assessment was performed to evaluate the resilience of the selected alternative to expected changes in climate and hydrology and identify risks that have not been addressed during formulation due to knowledge and data uncertainties. Specific project factors are considered when assessing risk. The FTPTR-EIS is considering short term test flows that are not a permanent change to the water control plan. The test flows will be conducted over a short period of 5-15 years. Relative to the No Action, none of the alternatives being considered will generate a significant difference in total flow being released from Fort Peck annually. Total annual volume being retained and released by the reservoir annually is virtually identical for all cases. Thus, the proposed alternatives are unlikely to cause negative impacts that would be acerbated by climate change relative to the no action alternative.

The results of the vulnerability assessment point to an increase in potential ecosystem restoration and flood risk reduction vulnerabilities for some sub-watersheds in the study area for future years. Projected climate changed hydrology studied, specific to the study area, as well as excerpts from the literature review imply that the study area could be impacted by increased flow peaks in the future. Extremes in climate will magnify periods of wet or dry weather resulting in longer, more severe droughts, and larger, more extensive flooding. These increased sporadic flood and drought periods could prove challenging for reservoir regulation and have impacts to the No Action and all proposed alternatives.

While potential climate change impacts on basin hydrology were identified, the climate change assessment did not illustrate a meaningful difference nor provide information on alternative formulation that could alter FTPTR-EIS vulnerabilities to climate change, relative to the no action alternative. No significant difference is noted between the No Action and any of the alternatives. No residual risk for any of the alternatives was identified. The results of the risk assessment summary are shown in Table 7-6.

Table 7-6. Summary of Risk from Climate Change for No Action and Alternatives

Project Feature	Trigger	Hazard / Harm	Qualitative Residual Risk Rating	Justification for Rating
Fort Peck Test Flow Release	Increased Air Temperature	During the summer, low river levels could have water quality issues if water temperatures increase. Increased air and water temperatures may benefit pallid during the drift phase and growth; increased temperatures may also stress pallid if above optimum	Low	No significant variation is expected from No Action for any alternative due to climate change 1) The test flows will be conducted over a short period of the next 5-15 years 2) Neither the No Action nor any of the alternatives has a significant flow difference and total annual volume is virtually identical 3) A long term climate change assessment did not illustrate a meaningful difference nor provide information on alternative formulation that could alter FTPTR-EIS vulnerabilities to climate change.
	Increased Spring Precipitation and Streamflow	Fort Peck and Garrison operations may be constrained by higher pool levels and inflows; may be able to run spring flows more often due to increased System storage. However, the frequency of a completed flow would likely decrease due to exceeding flow targets. The effect of altered frequency of flow releases on pallid is unknown.	Low	
	Earlier Snowmelt Date and Decreased Snow Accumulation Season Duration	System storage may rise earlier in the year and may be able to run flows more frequently; this may affect Fort Peck and Garrison operations due to higher pool levels earlier in the season, may result in lower navigation service levels for the second half of the season if storage is evacuated during spring runoff. Higher Fort Peck release temperatures may benefit pallid growth while lower system storage may reduce long term flows and reduce pallid habitat.	Low	
	Increased Sedimentation	Decreased System storage may lead to decreased frequency of all releases (assuming release requirements remain the same and sedimentation is not addressed); loss of storage may affect System flood risk reduction operations. Decreased flows may reduce pallid habitat.	Low	
	Decreased Peak Snow Water Equivalent	Forecasting season runoff may become less accurate since runoff from precipitation is more difficult to forecast than snowpack; less accurate forecasts may result in an increased risk of System impacts due to flows (i.e., lower reservoir elevations, higher releases, lower storage levels) due to runoff uncertainty; releases may be seasonally altered with unknown pallid effects.	Low	
	Increased Occurrence and Irregularity of Floods and Droughts	Accuracy of downstream forecasting may decrease, resulting in more frequent flood impacts caused by flows. Has a greater potential to affect System storage with flows if more droughts occur; releases may be seasonally altered with unknown pallid effects.	Low	

8 SUMMARY

Hydrology and Hydraulic evaluation was performed in support of the Fort Peck Flow Test Release Environmental Impact Statement (FTPTR-EIS). Evaluation was performed to provide hydrologic information for assessment of potential impacts of a range of test flow release alternatives out of Fort Peck dam designed to benefit recruitment of pallid sturgeon. The hydrologic evaluation performed for the FTPTR-EIS follows after the previously completed modeling for the Missouri River Recovery Management Plan and Environmental Impact Statement (MRRMP-EIS).

Analysis used an unsteady RAS model to systematically evaluate differences in river elevations for various alternatives. Results illustrated and described in Section 6 highlighted minor changes between alternatives over the 82 year POR. Volume and stage differences during the pulse period is large within the Fort Peck Dam to Lake Sakakawea reach. The large stage change, peak stages, and volume change during the pulse period indicates that small, temporary, and long-term impacts to irrigation intakes and geomorphic processes such as bank erosion, sandbar movement, degradation, and aggradation would occur.

- The operation of the Fort Peck spillway would be required to achieve flow releases for the proposed alternatives. The spillway concrete lined discharge channel has concerns with spillway slab performance that will be exacerbated with sustained spillway flow. The risk of potential slab damage will likely be a function of both spillway flow and duration. Compared to no action, the number of years with spillway operation are about double for each alternative. The spillway slab and sub-drain system repairs would be difficult, expensive, and likely constrained by time in order to address dam safety due to loss of spillway operation as quickly as possible. Depending on damage extent and allowable repair time period, repair cost is estimated to be in the range of $20 to $40M. The test flow releases would increase the likelihood these repairs would be needed because they increase the use of the spillway. Since flow release implementation significantly alters the spillway operation frequency, spillway repair costs are not solely a Fort Peck operation and maintenance expense and should be proportionally shared. This is consistent with agreements with Western Area Power Administration (WAPA).
- A representative number of intakes were surveyed in 2020 to provide information for use with intake impact evaluation. At each site, easting, northing, and elevation (XYZ) data points were collected to determine the pump site characteristics and potential damage levels for high flow events. Landowners also identified site specific critical features such as electrical panels or pump operating levels and stated concerns regarding the flow alternatives.
- The irrigation intake, bank erosion, degradation, and geomorphic process change impacts could be large and adverse locally. Results show that a large number of intakes could be impacted with the alternative flow levels exceeding the Tier 1 and Tier 2 critical flow levels. Side channel connection intakes could also be impacted.
- 2020 intake survey data and observations was used to perform a qualitative stability analysis that determined a large number of intakes exhibit stability concerns. Geomorphic processes that affect intake operation and maintenance may be aggravated by alternative test flow releases.

- Limitations also presented in Section 6.13 should be considered when evaluating results. The model results can be used by additional species and human considerations models that employ flow and stage differences, such as HEC-FIA, to screen alternatives for relative benefits and potential economic impacts. The outputs should be carefully examined and considering the model limitations and judgment applied where needed to mitigate hydraulic analysis limitations.
- If flow change alternatives are considered for implementation, additional risk and uncertainty analysis is recommended to more comprehensively quantify risk of pulse flows.
- The climate change assessment did not illustrate a meaningful difference nor provide information on alternative formulation that could alter FTPTR-EIS vulnerabilities to climate change. No residual risk was identified for any of the alternatives.

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HEC-RAS AND GEOMORPHIC ANALYSIS

PLATES

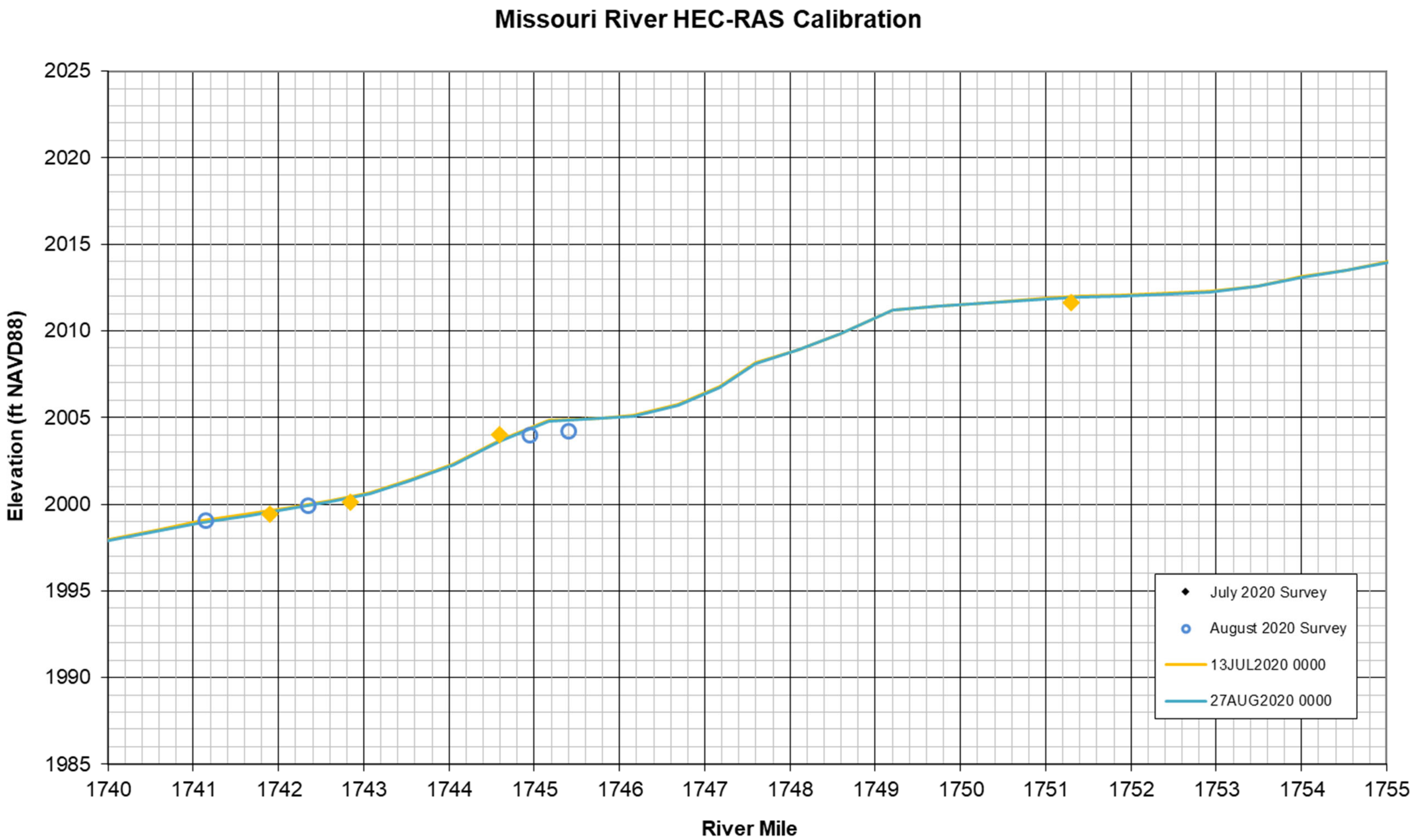


Plate 1. 2020 Survey WSE Points and RAS Profiles – RM 1755 to 1740

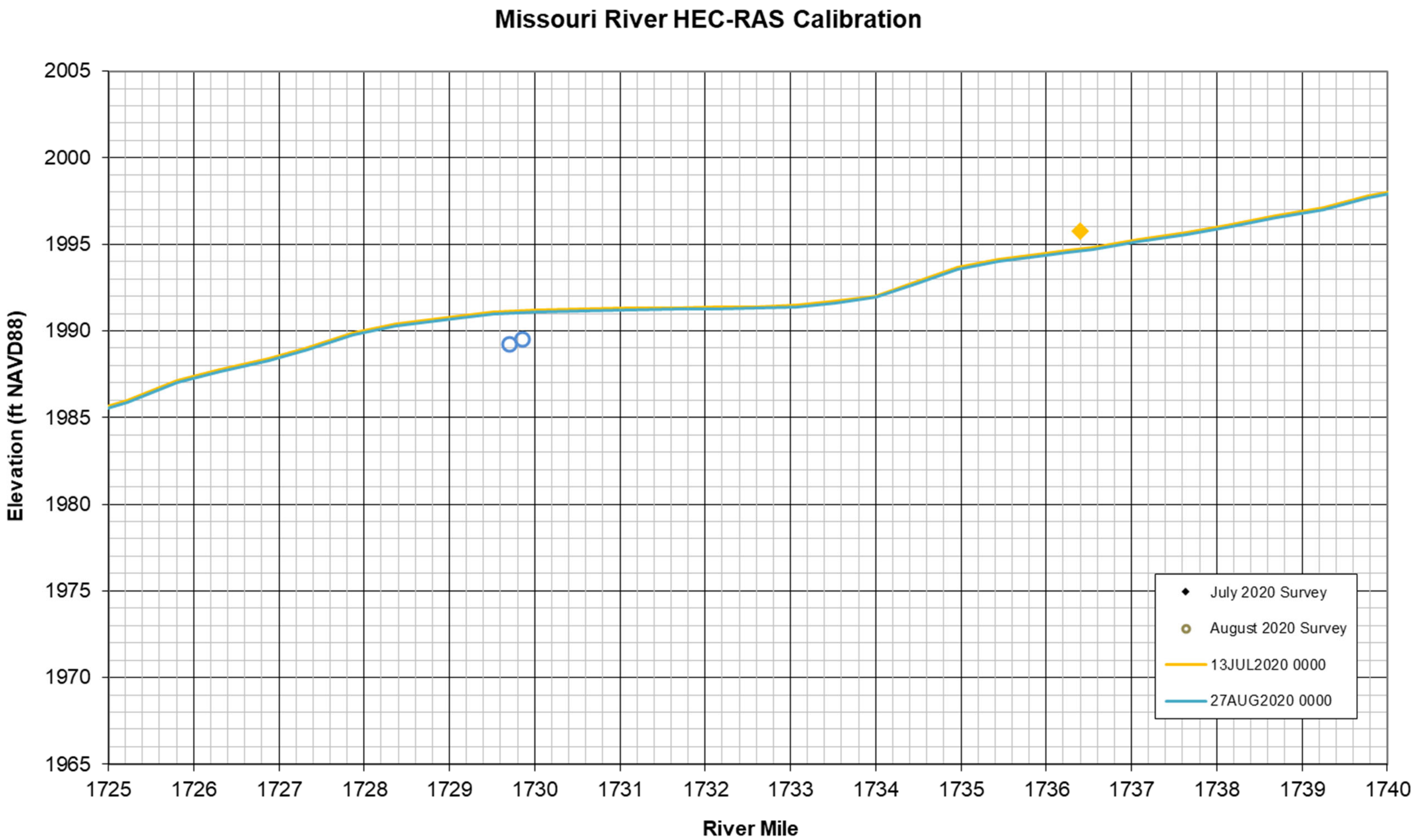


Plate 2. 2020 Survey WSE Points and RAS Profiles – RM 1740 to 1725

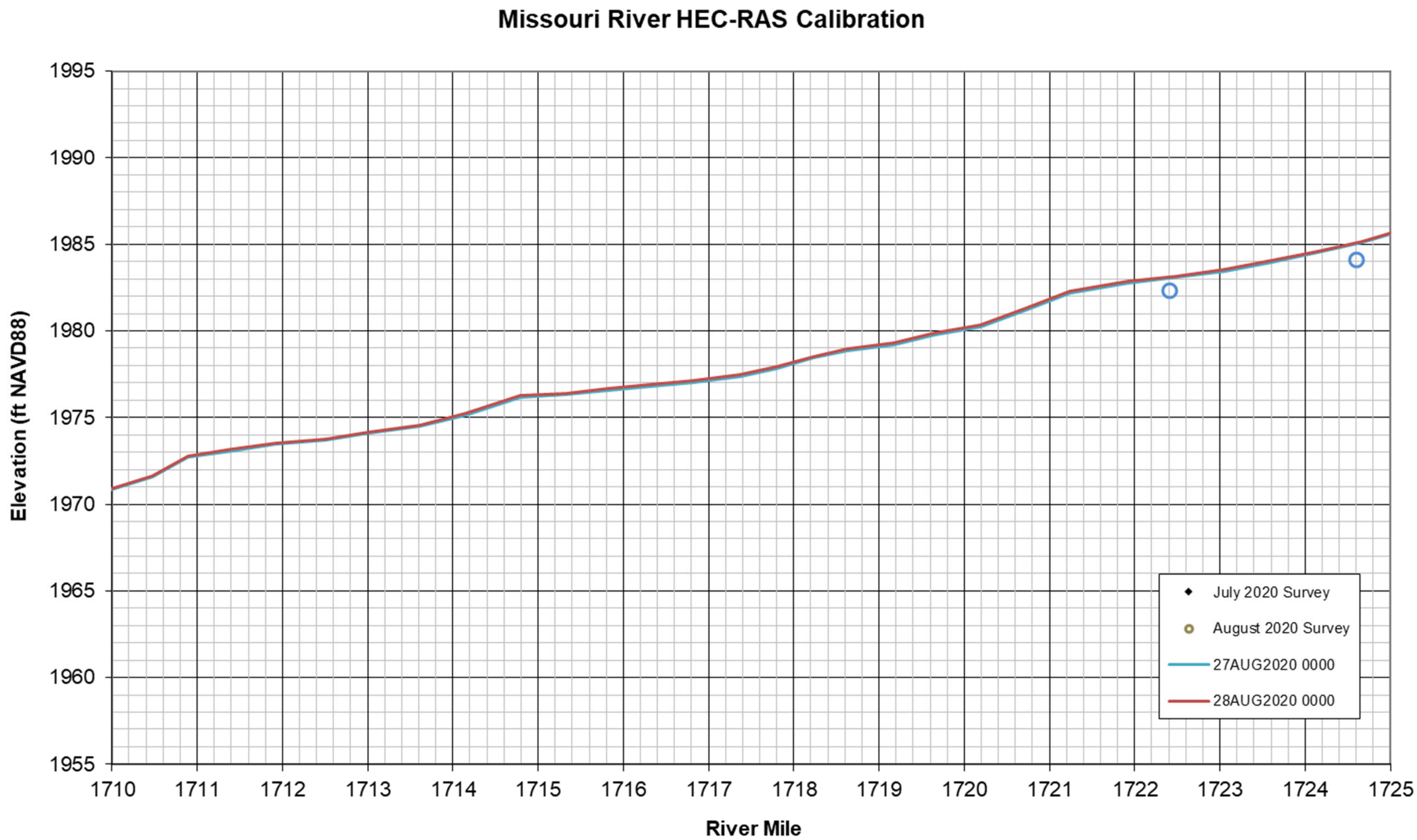


Plate 3. 2020 Survey WSE Points and RAS Profiles – RM 1725 to 1710

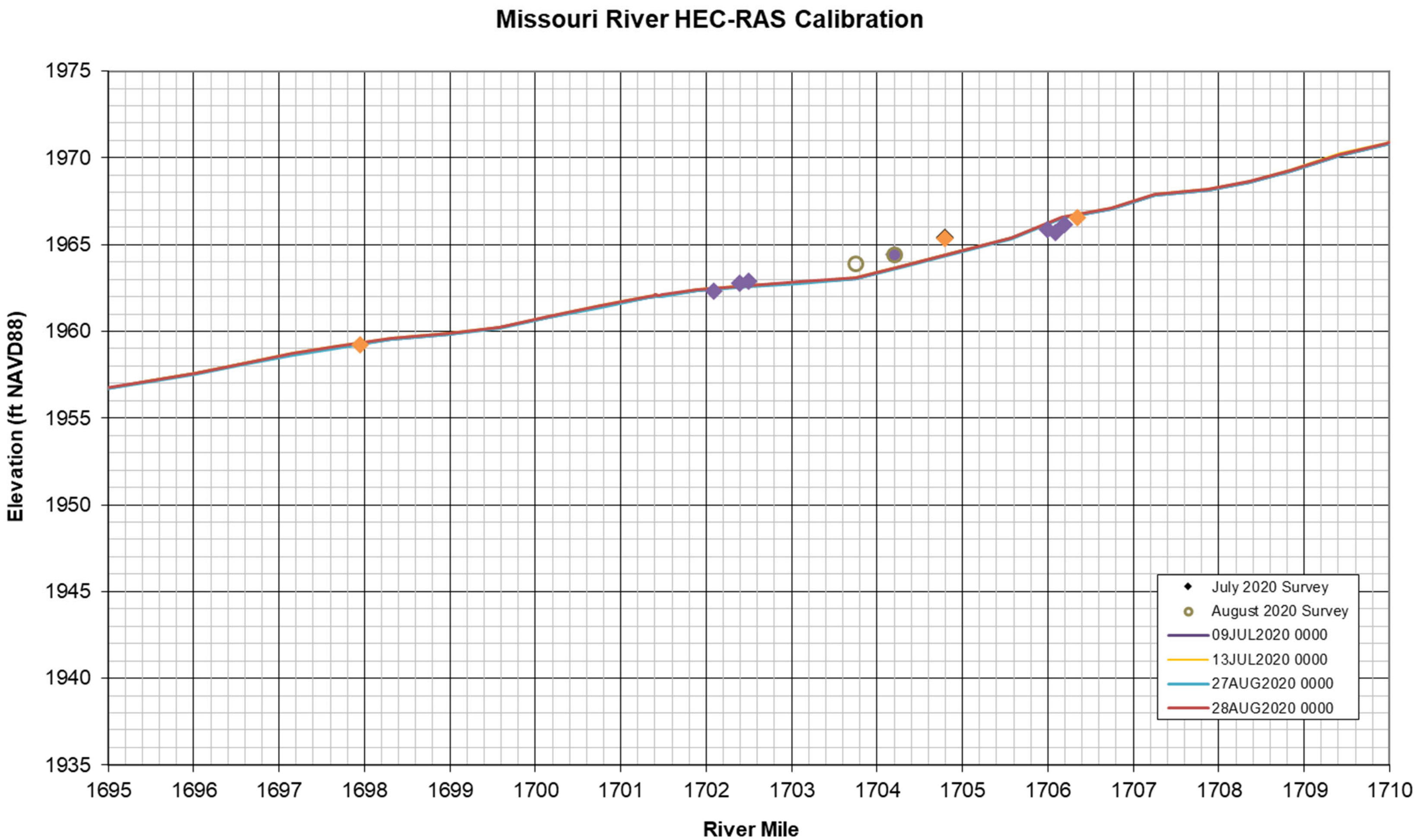


Plate 4. 2020 Survey WSE Points and RAS Profiles – RM 1710 to 1695

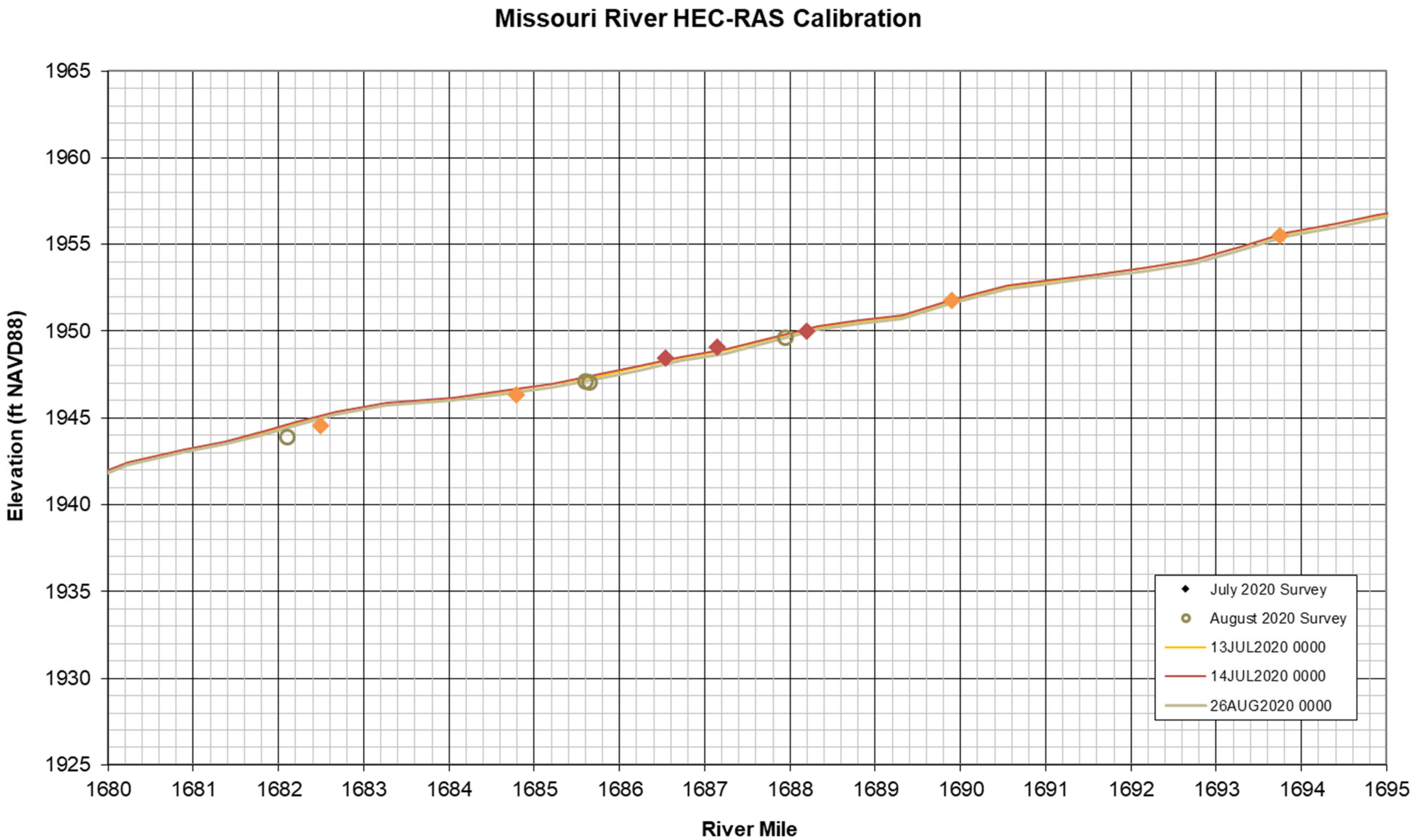


Plate 5. 2020 Survey WSE Points and RAS Profiles – RM 1695 to 1680

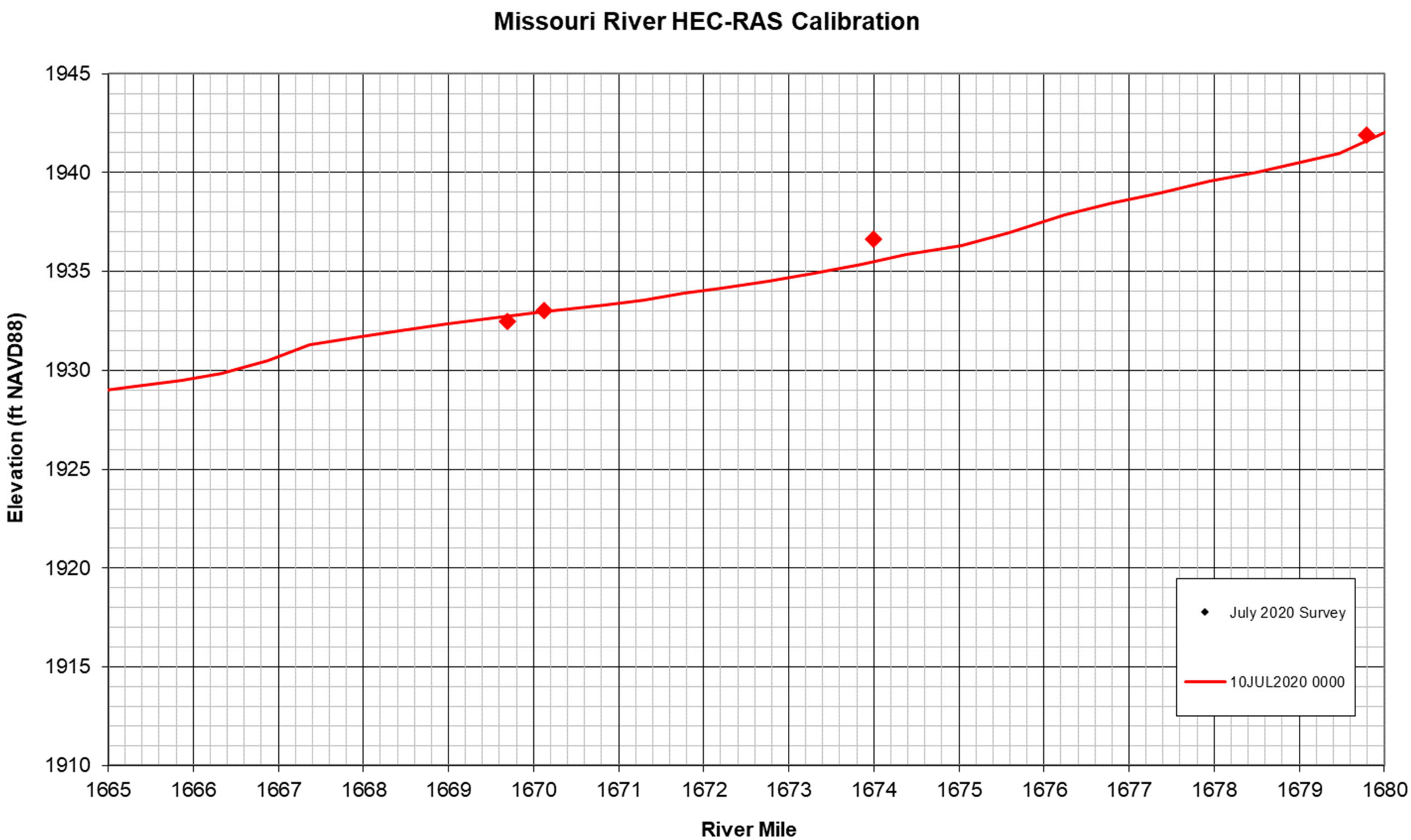


Plate 6. 2020 Survey WSE Points and RAS Profiles – RM 1680 to 1665

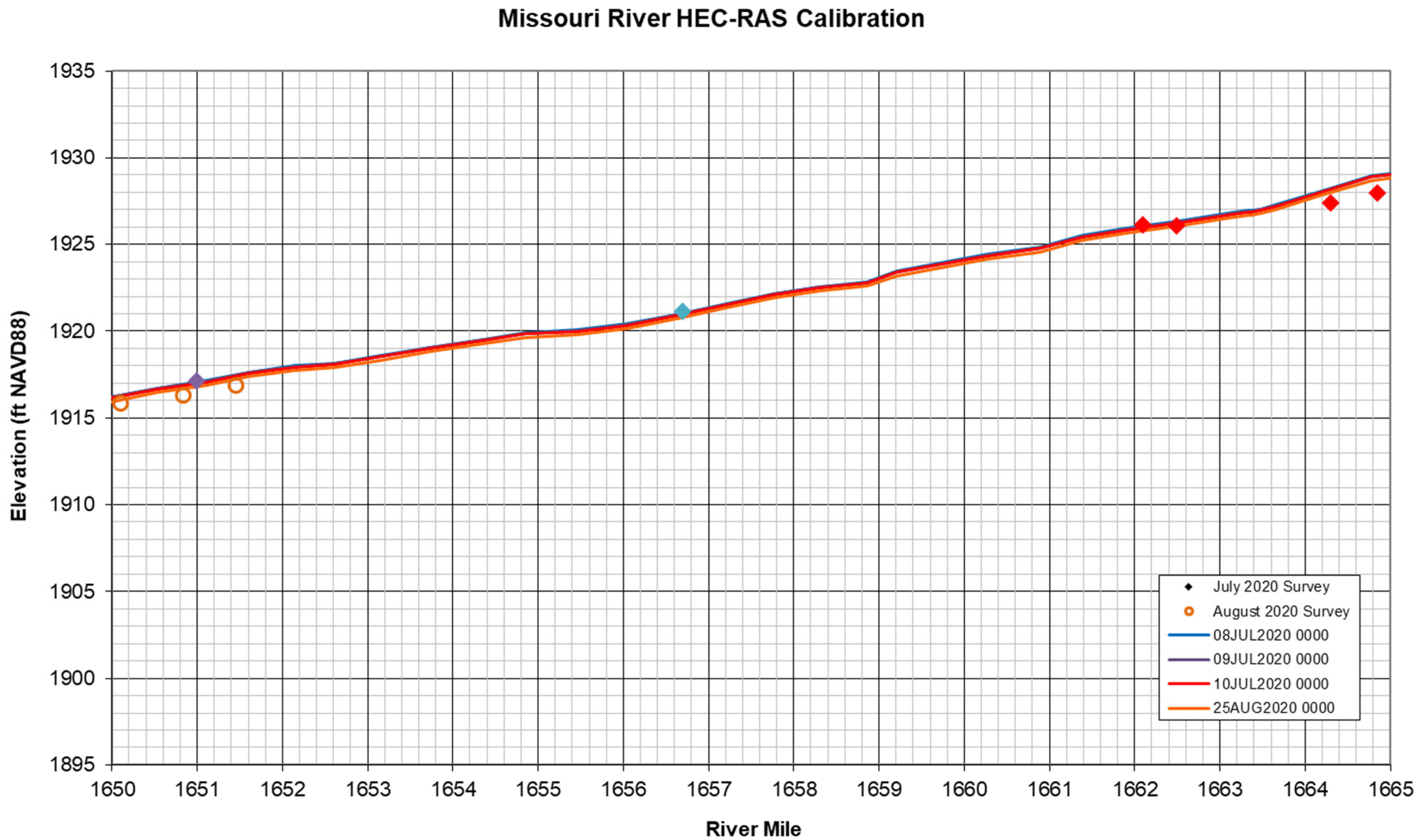


Plate 7. 2020 Survey WSE Points and RAS Profiles – RM 1665 to 1650

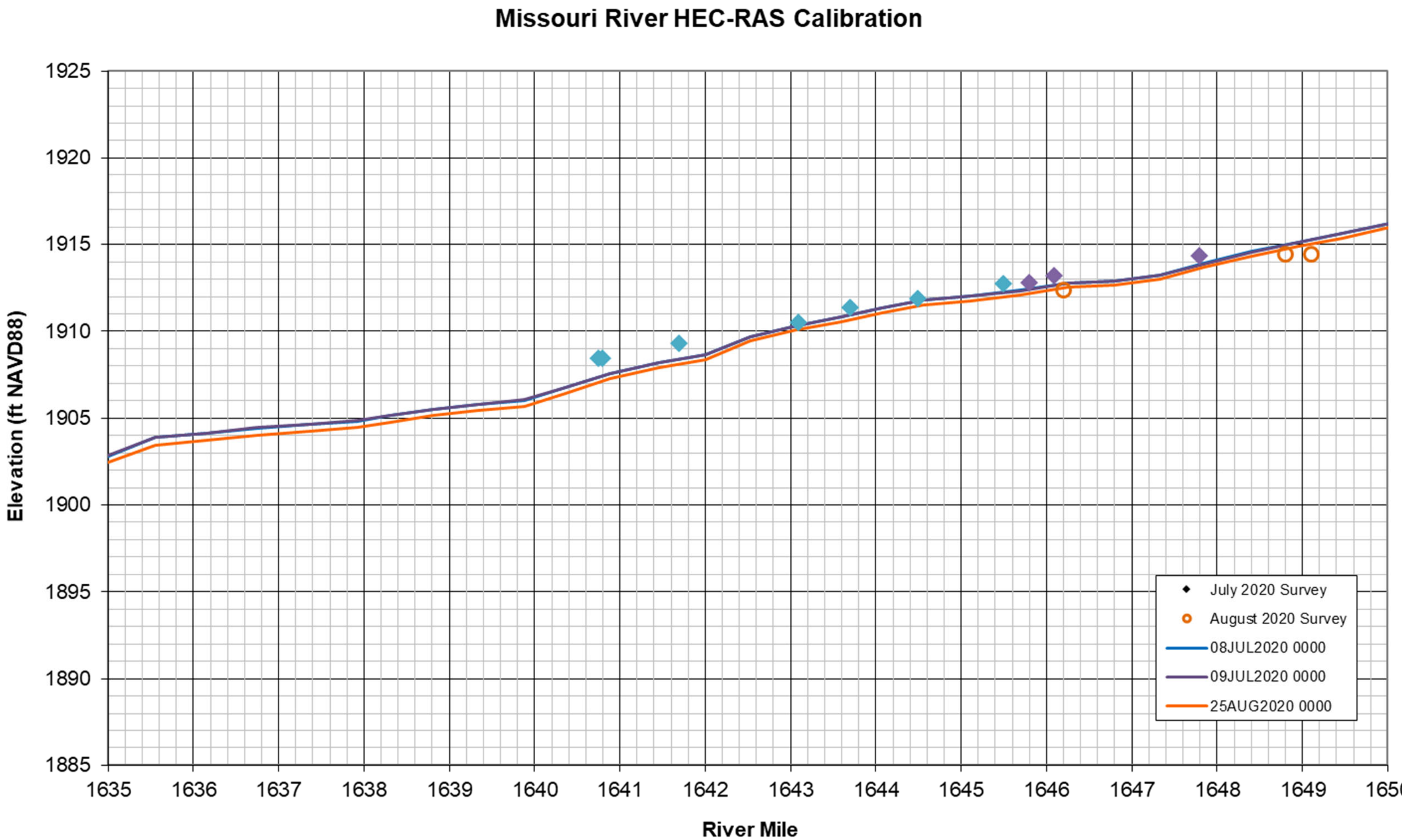


Plate 8. 2020 Survey WSE Points and RAS Profiles – RM 1650 to 1635

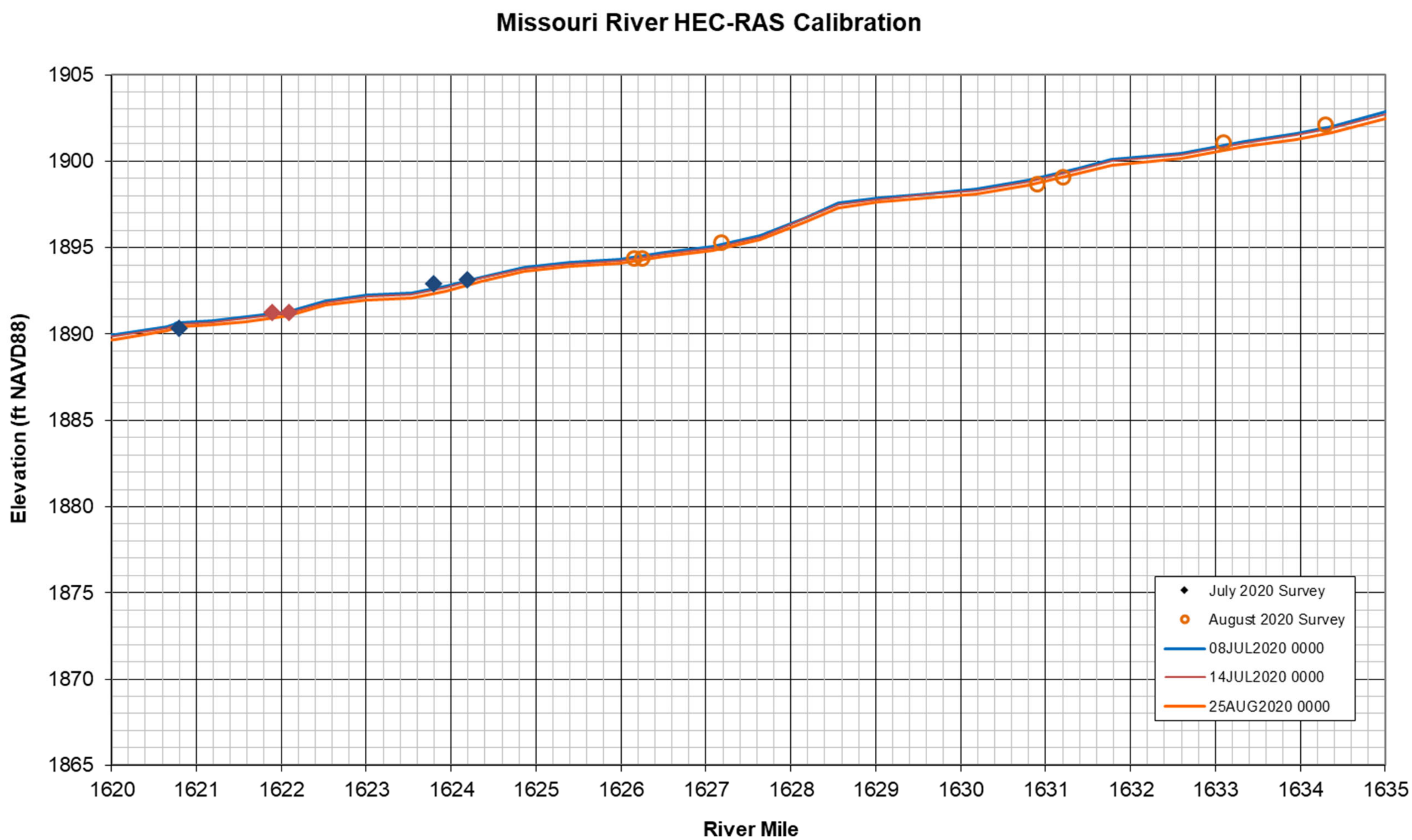


Plate 9. 2020 Survey WSE Points and RAS Profiles – RM 1635 to 1620

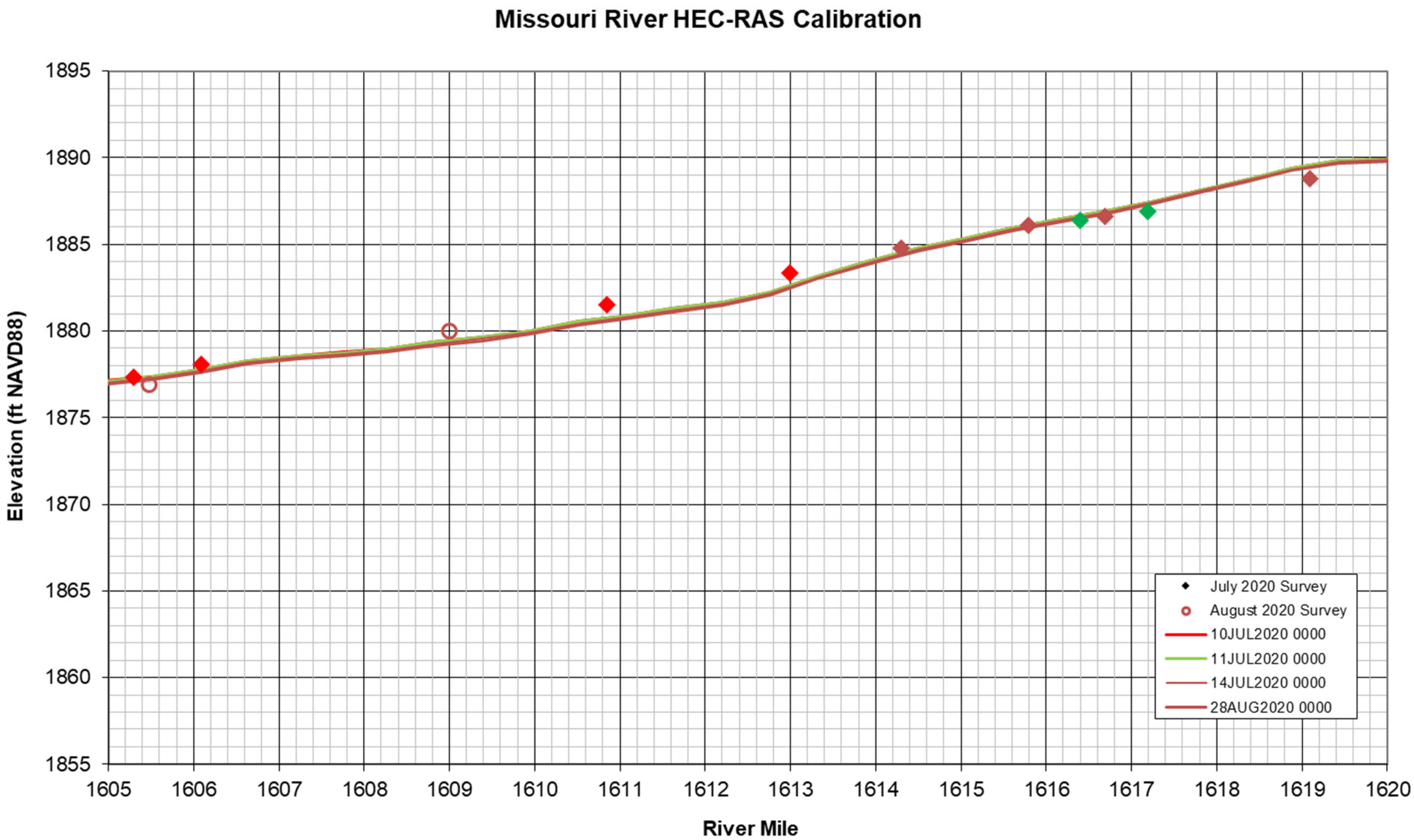


Plate 10. 2020 Survey WSE Points and RAS Profiles – RM 1620 to 1605

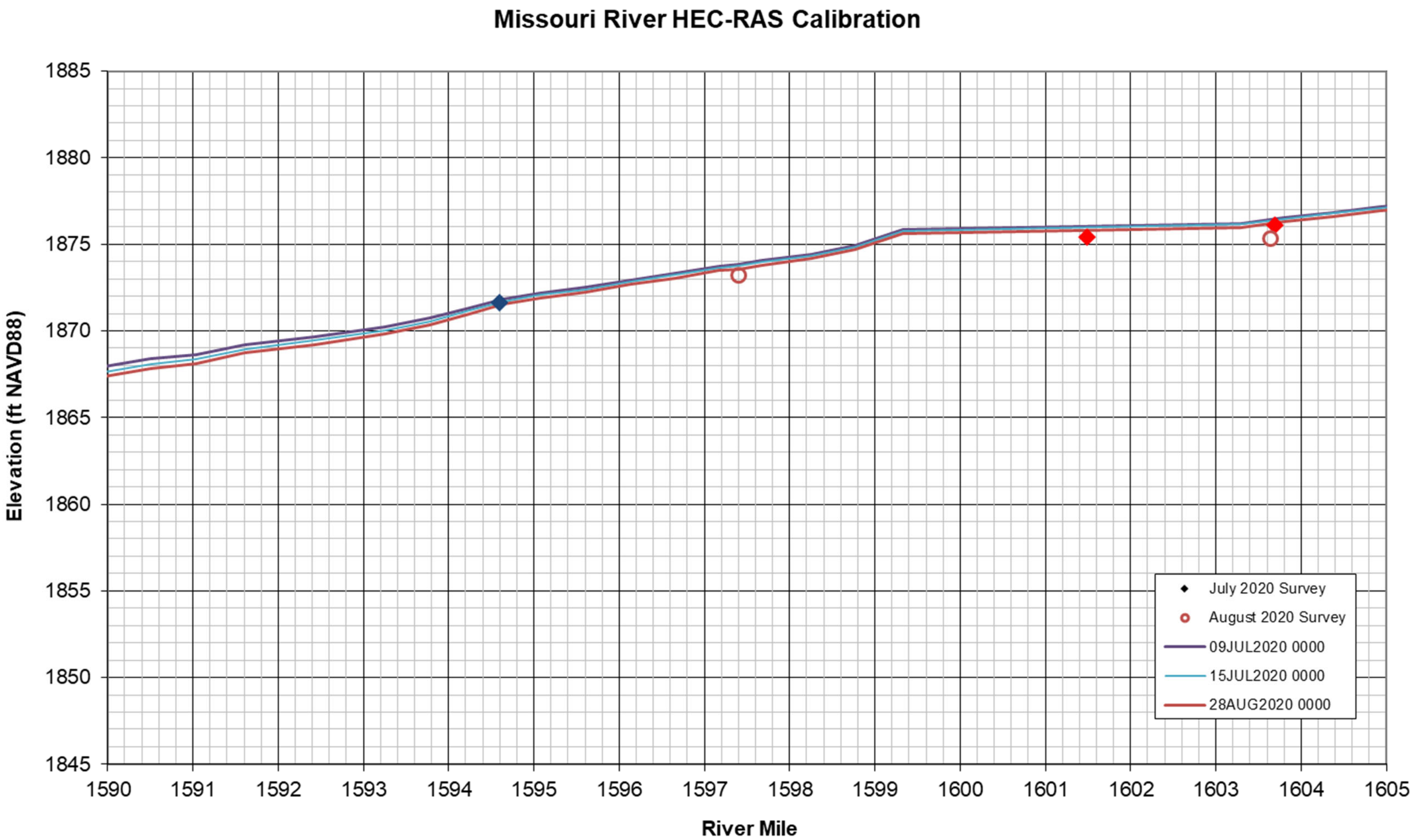


Plate 11. 2020 Survey WSE Points and RAS Profiles – RM 1605 to 1590

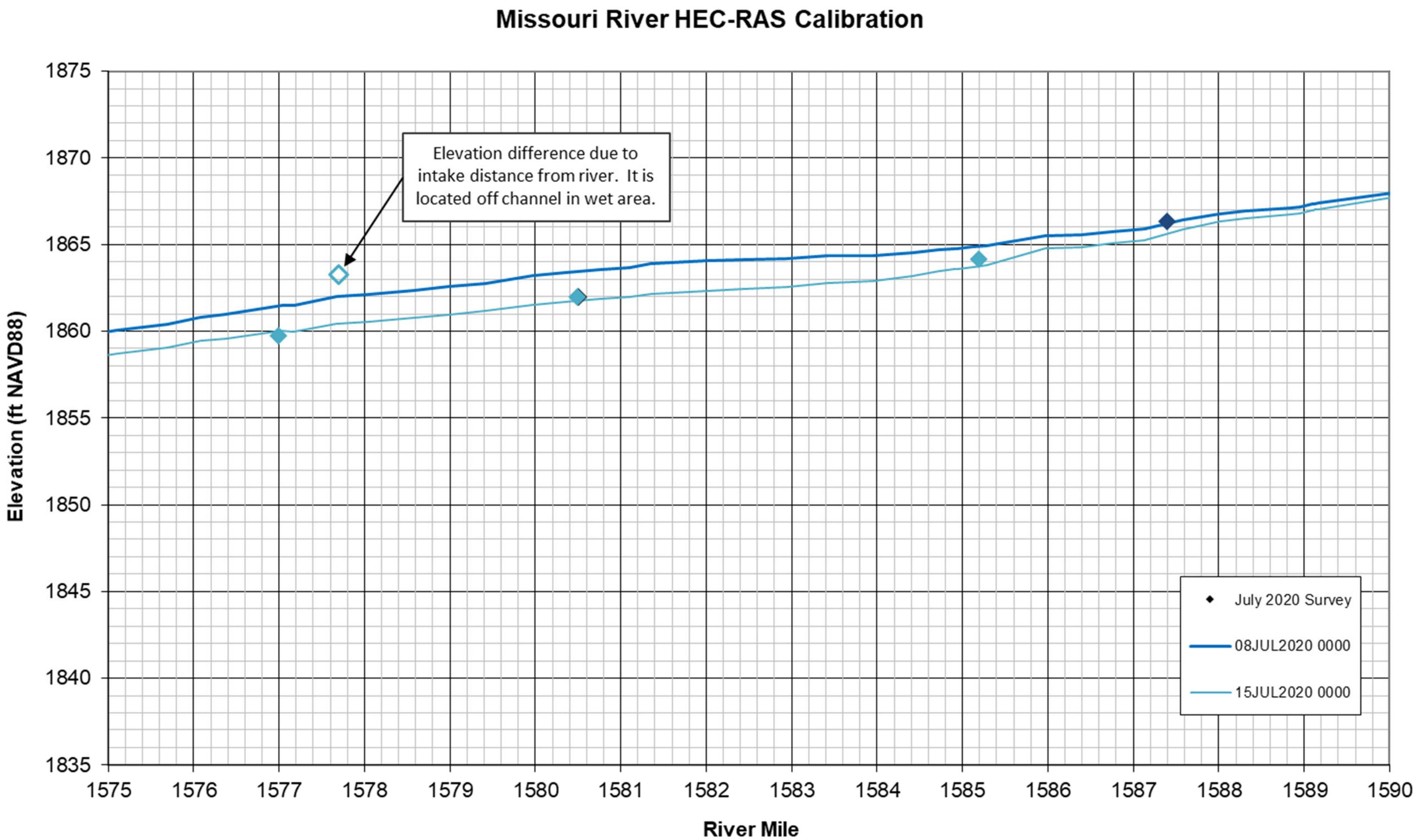


Plate 12. 2020 Survey WSE Points and RAS Profiles – RM 1590 to 1575

Flow (cfs)							
	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	Min	Max
Fort Peck - XS 1769.04							
Alt NA	5,000	6,100	7,800	9,900	12,700	3,000	77,000
Alt 1	4,900	6,100	7,600	9,700	13,000	3,000	77,000
Change from Alt NA	-100	0	-200	-200	300	0	0
Alt 1A	5,000	6,100	7,800	9,700	12,700	3,000	77,000
Change from Alt NA	0	0	0	-200	0	0	0
Alt 1B	4,900	6,000	7,700	9,800	13,000	3,000	77,000
Change from Alt NA	-100	-100	-100	-100	300	0	0
Alt 2	5,000	6,100	7,600	9,600	13,000	3,000	77,000
Change from Alt NA	0	0	-200	-300	300	0	0
Alt 2A	4,900	6,100	7,600	9,500	13,000	3,000	77,000
Change from Alt NA	-100	0	-200	-400	300	0	0
Alt 2B	4,700	6,000	7,500	9,700	13,000	3,000	77,000
Change from Alt NA	-300	-100	-300	-200	300	0	0
Wolf Point - XS 1701.31							
Alt NA	5,180	6,414	8,396	10,783	13,567	2,347	100,241
Alt 1	5,071	6,372	8,209	10,542	13,978	2,347	100,241
Change from Alt NA	-108	-42	-187	-242	411	0	0
Alt 1A	5,089	6,375	8,294	10,527	13,703	2,347	100,241
Change from Alt NA	-91	-39	-102	-256	136	0	0
Alt 1B	5,076	6,338	8,221	10,667	14,047	2,347	100,241
Change from Alt NA	-104	-76	-175	-116	480	0	0
Alt 2	5,113	6,389	8,190	10,469	14,230	2,347	100,241
Change from Alt NA	-67	-25	-206	-315	663	0	0
Alt 2A	5,039	6,360	8,183	10,447	14,172	2,347	100,241
Change from Alt NA	-140	-54	-213	-336	605	0	0
Alt 2B	4,980	6,322	8,127	10,719	14,350	2,347	100,241
Change from Alt NA	-199	-92	-269	-65	784	0	0

Plate 13: Flow Statistics for Fort Peck and Wolf Point

Flow (cfs)							
	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	Min	Max
Culbertson - XS 1620.65							
Alt NA	5,363	6,554	8,458	10,964	14,067	1,879	106,523
Alt 1	5,271	6,511	8,243	10,795	14,524	1,879	106,523
Change from Alt NA	-92	-43	-215	-169	457	0	0
Alt 1A	5,294	6,517	8,330	10,756	14,264	1,879	106,523
Change from Alt NA	-69	-37	-128	-208	198	0	0
Alt 1B	5,268	6,456	8,267	10,931	14,608	1,879	106,523
Change from Alt NA	-95	-98	-191	-33	541	0	0
Alt 2	5,285	6,531	8,232	10,685	14,662	1,879	106,523
Change from Alt NA	-79	-23	-226	-279	596	0	0
Alt 2A	5,243	6,486	8,221	10,649	14,640	1,879	106,523
Change from Alt NA	-120	-69	-237	-315	573	0	0
Alt 2B	5,197	6,424	8,189	11,019	14,757	1,879	106,523
Change from Alt NA	-166	-130	-269	55	690	0	0
Williston - XS 1552.61							
Alt NA	10,880	13,148	16,784	23,344	37,272	4,746	182,499
Alt 1	10,780	12,951	16,689	23,404	37,607	4,746	182,512
Change from Alt NA	-100	-197	-96	61	335	0	13
Alt 1A	10,797	12,992	16,748	23,235	37,671	4,746	182,501
Change from Alt NA	-83	-156	-36	-109	399	0	2
Alt 1B	10,783	12,937	16,674	23,418	37,533	4,746	182,523
Change from Alt NA	-97	-211	-111	74	260	0	24
Alt 2	10,807	12,960	16,631	23,439	37,722	4,746	182,525
Change from Alt NA	-73	-189	-154	95	450	0	26
Alt 2A	10,800	12,921	16,619	23,446	37,857	4,746	182,500
Change from Alt NA	-80	-228	-166	102	585	0	1
Alt 2B	10,734	12,836	16,604	23,623	37,890	4,746	182,512
Change from Alt NA	-147	-312	-180	279	618	0	13

Plate 14: Flow Statistics for Culbertson and Williston

Flow (cfs)							
	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	Min	Max
Garrison - XS 1388.30							
Alt NA	12,200	15,500	19,500	23,400	27,600	9,000	168,000
Alt 1	12,400	15,400	19,600	23,500	27,600	9,000	168,000
Change from Alt NA	200	-100	100	100	0	0	0
Alt 1A	12,300	15,500	19,600	23,500	27,500	9,000	168,000
Change from Alt NA	100	0	100	100	-100	0	0
Alt 1B	12,300	15,500	19,600	23,500	27,700	9,000	168,500
Change from Alt NA	100	0	100	100	100	0	500
Alt 2	12,200	15,400	19,500	23,600	27,500	9,000	168,500
Change from Alt NA	0	-100	0	200	-100	0	500
Alt 2A	12,200	15,500	19,600	23,500	28,300	9,000	168,000
Change from Alt NA	0	0	100	100	700	0	0
Alt 2B	12,200	15,500	19,600	23,600	27,600	9,000	168,500
Change from Alt NA	0	0	100	200	0	0	500
Bismarck - XS 1314.80							
Alt NA	13,237	16,473	20,915	24,945	30,866	7,283	167,686
Alt 1	13,278	16,494	20,943	25,050	30,773	7,283	167,685
Change from Alt NA	41	21	29	105	-93	0	0
Alt 1A	13,218	16,498	20,959	24,980	30,763	7,283	167,685
Change from Alt NA	-20	25	45	35	-102	0	-1
Alt 1B	13,208	16,477	20,909	24,989	30,840	7,283	168,189
Change from Alt NA	-29	4	-6	44	-26	0	503
Alt 2	13,240	16,419	20,881	25,086	30,766	7,283	168,189
Change from Alt NA	2	-54	-34	140	-100	0	503
Alt 2A	13,226	16,455	20,924	25,075	30,947	7,283	167,685
Change from Alt NA	-11	-19	10	129	81	0	-1
Alt 2B	13,226	16,412	20,909	25,057	30,840	7,283	168,189
Change from Alt NA	-11	-61	-6	112	-26	0	503

Plate 15: Flow Statistics for Garrison and Bismarck

Flow (cfs)							
	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	Min	Max
Fort Randall - XS 879.04							
Alt NA	12,200	15,500	19,500	23,400	27,600	9,000	168,000
Alt 1	12,400	15,400	19,600	23,500	27,600	9,000	168,000
Change from Alt NA	200	-100	100	100	0	0	0
Alt 1A	12,300	15,500	19,600	23,500	27,500	9,000	168,000
Change from Alt NA	100	0	100	100	-100	0	0
Alt 1B	12,300	15,500	19,600	23,500	27,700	9,000	168,500
Change from Alt NA	100	0	100	100	100	0	500
Alt 2	12,200	15,400	19,500	23,600	27,500	9,000	168,500
Change from Alt NA	0	-100	0	200	-100	0	500
Alt 2A	12,200	15,500	19,600	23,500	28,300	9,000	168,000
Change from Alt NA	0	0	100	100	700	0	0
Alt 2B	12,200	15,500	19,600	23,600	27,600	9,000	168,500
Change from Alt NA	0	0	100	200	0	0	500
Niobrara - XS 842.93							
Alt NA	13,237	16,473	20,915	24,945	30,866	7,283	167,686
Alt 1	13,278	16,494	20,943	25,050	30,773	7,283	167,685
Change from Alt NA	41	21	29	105	-93	0	0
Alt 1A	13,218	16,498	20,959	24,980	30,763	7,283	167,685
Change from Alt NA	-20	25	45	35	-102	0	-1
Alt 1B	13,208	16,477	20,909	24,989	30,840	7,283	168,189
Change from Alt NA	-29	4	-6	44	-26	0	503
Alt 2	13,240	16,419	20,881	25,086	30,766	7,283	168,189
Change from Alt NA	2	-54	-34	140	-100	0	503
Alt 2A	13,226	16,455	20,924	25,075	30,947	7,283	167,685
Change from Alt NA	-11	-19	10	129	81	0	-1
Alt 2B	13,226	16,412	20,909	25,057	30,840	7,283	168,189
Change from Alt NA	-11	-61	-6	112	-26	0	503

Plate 16: Flow Statistics for Fort Randall and Niobrara

Water Surface Elevation (ft, NAVD88)							
	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	Min	Max
Fort Peck - XS 1769.04							
Alt NA	2028.9	2029.5	2030.3	2031.2	2032.3	2027.6	2043.0
Alt 1	2028.9	2029.5	2030.2	2031.1	2032.4	2027.6	2043.0
Change from Alt NA	0.0	0.0	-0.1	-0.1	0.1	0.0	0.0
Alt 1A	2028.9	2029.5	2030.3	2031.1	2032.2	2027.6	2043.0
Change from Alt NA	0.0	0.0	0.0	-0.1	0.0	0.0	0.0
Alt 1B	2028.9	2029.5	2030.3	2031.1	2032.4	2027.6	2043.0
Change from Alt NA	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Alt 2	2028.9	2029.5	2030.2	2031.1	2032.4	2027.6	2043.0
Change from Alt NA	0.0	0.0	-0.1	-0.1	0.1	0.0	0.0
Alt 2A	2028.9	2029.5	2030.2	2031.0	2032.4	2027.6	2043.0
Change from Alt NA	-0.1	0.0	-0.1	-0.2	0.1	0.0	0.0
Alt 2B	2028.8	2029.5	2030.2	2031.1	2032.4	2027.6	2043.0
Change from Alt NA	-0.2	0.0	-0.1	-0.1	0.1	0.0	0.0
Wolf Point - XS 1701.31							
Alt NA	1959.2	1959.9	1960.8	1961.8	1962.8	1957.4	1976.2
Alt 1	1959.2	1959.9	1960.7	1961.7	1962.9	1957.4	1976.2
Change from Alt NA	-0.1	0.0	-0.1	-0.1	0.1	0.0	0.0
Alt 1A	1959.2	1959.9	1960.8	1961.7	1962.9	1957.4	1976.2
Change from Alt NA	0.0	0.0	0.0	-0.1	0.0	0.0	0.0
Alt 1B	1959.2	1959.9	1960.7	1961.8	1963.0	1957.4	1976.2
Change from Alt NA	-0.1	0.0	-0.1	0.0	0.2	0.0	0.0
Alt 2	1959.2	1959.9	1960.7	1961.7	1963.0	1957.4	1976.2
Change from Alt NA	0.0	0.0	-0.1	-0.1	0.2	0.0	0.0
Alt 2A	1959.1	1959.9	1960.7	1961.7	1963.0	1957.4	1976.2
Change from Alt NA	-0.1	0.0	-0.1	-0.1	0.2	0.0	0.0
Alt 2B	1959.1	1959.8	1960.7	1961.8	1963.1	1957.4	1976.2
Change from Alt NA	-0.1	-0.1	-0.1	0.0	0.3	0.0	0.0

Plate 17: Elevation Statistics for Fort Peck and Wolf Point

Water Surface Elevation (ft, NAVD88)							
	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	Min	Max
Culbertson - XS 1620.65							
Alt NA	1887.8	1888.4	1889.3	1890.2	1891.3	1885.7	1903.1
Alt 1	1887.8	1888.4	1889.2	1890.2	1891.5	1885.7	1903.1
Change from Alt NA	0.0	0.0	-0.1	-0.1	0.1	0.0	0.0
Alt 1A	1887.8	1888.4	1889.2	1890.2	1891.4	1885.7	1903.1
Change from Alt NA	0.0	0.0	-0.1	-0.1	0.1	0.0	0.0
Alt 1B	1887.8	1888.4	1889.2	1890.2	1891.5	1885.7	1903.1
Change from Alt NA	-0.1	0.0	-0.1	0.0	0.2	0.0	0.0
Alt 2	1887.8	1888.4	1889.2	1890.1	1891.5	1885.7	1903.1
Change from Alt NA	0.0	0.0	-0.1	-0.1	0.2	0.0	0.0
Alt 2A	1887.8	1888.4	1889.2	1890.1	1891.5	1885.7	1903.1
Change from Alt NA	-0.1	0.0	-0.1	-0.1	0.2	0.0	0.0
Alt 2B	1887.7	1888.4	1889.2	1890.3	1891.5	1885.7	1903.1
Change from Alt NA	-0.1	-0.1	-0.1	0.0	0.2	0.0	0.0
Williston - XS 1552.61							
Alt NA	1843.0	1844.1	1845.6	1848.4	1851.5	1838.9	1862.8
Alt 1	1843.0	1844.0	1845.6	1848.5	1851.5	1838.9	1862.8
Change from Alt NA	0.0	-0.1	0.0	0.1	0.1	0.0	0.0
Alt 1A	1843.0	1844.0	1845.6	1848.4	1851.5	1838.9	1862.8
Change from Alt NA	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Alt 1B	1843.0	1844.0	1845.6	1848.5	1851.5	1838.9	1862.8
Change from Alt NA	0.0	-0.1	0.0	0.1	0.1	0.0	0.0
Alt 2	1843.0	1844.0	1845.6	1848.5	1851.6	1838.9	1862.8
Change from Alt NA	0.0	-0.1	0.0	0.1	0.1	0.0	0.0
Alt 2A	1843.0	1844.0	1845.6	1848.6	1851.6	1838.9	1862.8
Change from Alt NA	0.0	-0.1	0.0	0.2	0.1	0.0	0.0
Alt 2B	1843.0	1844.0	1845.6	1848.6	1851.6	1838.9	1862.8
Change from Alt NA	-0.1	-0.1	0.0	0.2	0.1	0.0	0.0

Plate 18: Elevation Statistics for Culbertson and Williston

Water Surface Elevation (ft, NAVD88)							
	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	Min	Max
Lake Sakakawea - XS 1391.08							
Alt NA	1806.1	1817.5	1832.4	1839.2	1843.2	1775.2	1856.9
Alt 1	1806.0	1817.5	1832.6	1839.4	1843.7	1775.2	1856.9
Change from Alt NA	0.0	0.0	0.2	0.2	0.5	0.0	0.0
Alt 1A	1806.0	1817.5	1832.6	1839.3	1843.4	1775.2	1856.9
Change from Alt NA	0.0	0.0	0.2	0.1	0.2	0.0	0.0
Alt 1B	1806.1	1817.5	1832.6	1839.3	1843.6	1775.2	1856.8
Change from Alt NA	0.0	0.0	0.2	0.1	0.4	0.1	-0.1
Alt 2	1806.0	1817.5	1832.5	1839.4	1843.7	1775.2	1856.8
Change from Alt NA	0.0	0.0	0.1	0.2	0.5	0.0	-0.1
Alt 2A	1806.0	1817.5	1832.5	1839.5	1843.9	1775.2	1856.9
Change from Alt NA	0.0	0.0	0.1	0.3	0.7	0.0	0.0
Alt 2B	1806.1	1817.5	1832.7	1839.4	1843.8	1775.2	1856.8
Change from Alt NA	0.0	0.0	0.3	0.2	0.5	0.1	0.0
Garrison - XS 1388.30							
Alt NA	1668.1	1669.0	1669.9	1670.8	1671.7	1667.0	1687.4
Alt 1	1668.1	1669.0	1669.9	1670.9	1671.7	1667.0	1687.4
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alt 1A	1668.1	1669.0	1669.9	1670.8	1671.7	1667.0	1687.4
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alt 1B	1668.1	1669.0	1669.9	1670.8	1671.7	1667.0	1687.4
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alt 2	1668.1	1668.9	1669.9	1670.9	1671.7	1667.0	1687.4
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alt 2A	1668.1	1669.0	1669.9	1670.8	1671.8	1667.0	1687.4
Change from Alt NA	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Alt 2B	1668.1	1669.0	1669.9	1670.9	1671.7	1667.0	1687.4
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Plate 19: Elevation Statistics for Lake Sakakawea and Garrison

Water Surface Elevation (ft, NAVD88)							
	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	Min	Max
Bismarck - XS 1314.80							
Alt NA	1622.8	1623.6	1624.6	1625.5	1627.0	1621.1	1639.2
Alt 1	1622.8	1623.6	1624.6	1625.6	1626.9	1621.1	1639.2
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alt 1A	1622.8	1623.6	1624.6	1625.5	1626.9	1621.1	1639.2
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alt 1B	1622.8	1623.6	1624.6	1625.6	1627.0	1620.9	1639.2
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	-0.2	0.0
Alt 2	1622.8	1623.6	1624.6	1625.6	1626.9	1621.1	1639.2
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alt 2A	1622.8	1623.6	1624.6	1625.6	1627.0	1621.1	1639.2
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alt 2B	1622.8	1623.6	1624.6	1625.6	1627.0	1621.1	1639.2
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lake Oahe - XS 1073.04							
Alt NA	1570.3	1583.2	1599.3	1607.8	1611.9	1530.7	1621.1
Alt 1	1570.3	1583.2	1599.3	1607.7	1611.9	1530.7	1621.1
Change from Alt NA	0.0	0.0	0.0	-0.1	0.0	0.0	0.0
Alt 1A	1570.3	1583.2	1599.2	1607.8	1611.8	1530.7	1621.1
Change from Alt NA	0.0	0.0	-0.1	0.0	-0.1	0.0	0.0
Alt 1B	1570.2	1583.2	1599.3	1607.7	1611.8	1530.7	1621.1
Change from Alt NA	0.0	0.0	0.0	-0.1	-0.1	0.1	0.0
Alt 2	1570.3	1583.2	1599.3	1607.8	1611.9	1530.7	1621.1
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alt 2A	1570.3	1583.2	1599.3	1607.8	1611.9	1530.7	1621.1
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alt 2B	1570.2	1583.2	1599.4	1607.9	1611.9	1530.7	1621.1
Change from Alt NA	0.0	0.0	0.2	0.1	0.0	0.1	0.0

Plate 20: Elevation Statistics for Bismarck and Lake Oahe

Water Surface Elevation (ft, NAVD88)							
	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	Min	Max
Fort Randall - XS 879.04							
Alt NA	1229.1	1230.3	1233.0	1235.0	1236.0	1226.4	1249.5
Alt 1	1229.1	1230.3	1233.0	1235.0	1236.0	1226.4	1249.7
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Alt 1A	1229.1	1230.3	1233.0	1235.0	1236.0	1226.4	1249.5
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
Alt 1B	1229.1	1230.3	1233.0	1235.0	1236.0	1226.4	1249.6
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Alt 2	1229.1	1230.3	1233.0	1235.0	1236.0	1226.4	1249.8
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Alt 2A	1229.1	1230.3	1233.0	1235.0	1236.0	1226.4	1249.7
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Alt 2B	1229.1	1230.3	1233.0	1235.0	1236.0	1226.4	1249.8
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Niobrara - XS 842.93							
Alt NA	1214.0	1215.1	1218.0	1219.6	1220.5	1210.8	1228.2
Alt 1	1214.0	1215.1	1218.0	1219.6	1220.5	1210.8	1228.2
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Alt 1A	1214.0	1215.2	1218.0	1219.6	1220.5	1210.8	1228.2
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alt 1B	1214.0	1215.2	1218.0	1219.6	1220.5	1210.8	1228.2
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alt 2	1214.0	1215.1	1218.0	1219.6	1220.5	1210.8	1228.3
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Alt 2A	1214.0	1215.1	1218.0	1219.6	1220.5	1210.8	1228.2
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Alt 2B	1214.0	1215.1	1218.0	1219.6	1220.5	1210.8	1228.3
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.2

Plate 21: Elevation Statistics for Fort Randall and Niobrara

Water Surface Elevation (ft, NAVD88)							
	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	Min	Max
Lewis & Clark Lake - XS 812.74							
Alt NA	1206.6	1206.8	1207.3	1208.2	1208.4	1201.9	1212.7
Alt 1	1206.6	1206.8	1207.3	1208.2	1208.4	1201.9	1212.7
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alt 1A	1206.6	1206.8	1207.3	1208.2	1208.4	1201.9	1212.7
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alt 1B	1206.6	1206.8	1207.3	1208.2	1208.4	1201.9	1212.7
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alt 2	1206.6	1206.8	1207.3	1208.2	1208.4	1201.9	1212.7
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alt 2A	1206.6	1206.8	1207.3	1208.2	1208.4	1201.9	1212.7
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alt 2B	1206.6	1206.8	1207.3	1208.2	1208.4	1201.9	1212.7
Change from Alt NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Plate 22: Elevation Statistics for Lewis & Clark Lake

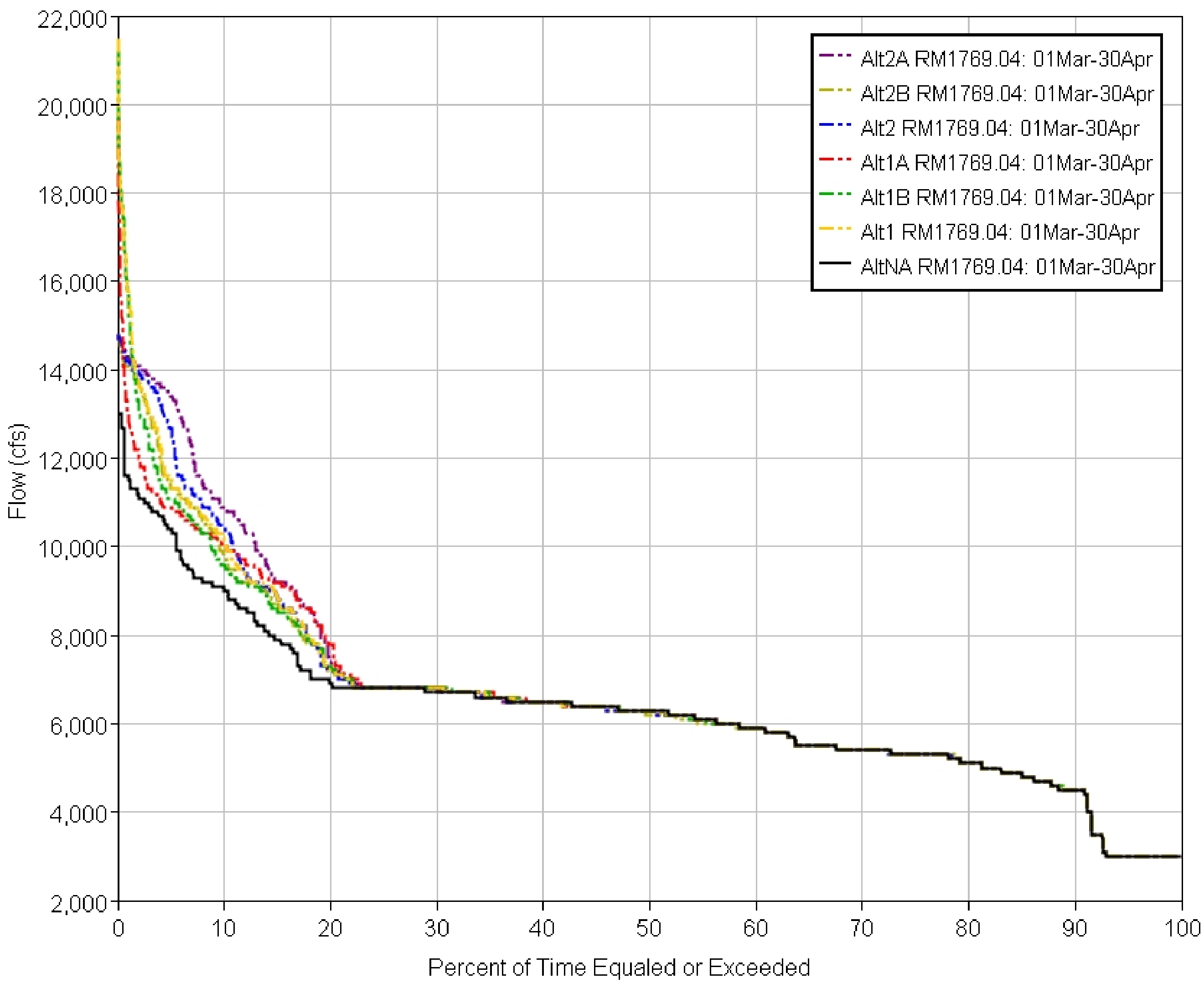


Plate 23: Fort Peck Spring Duration

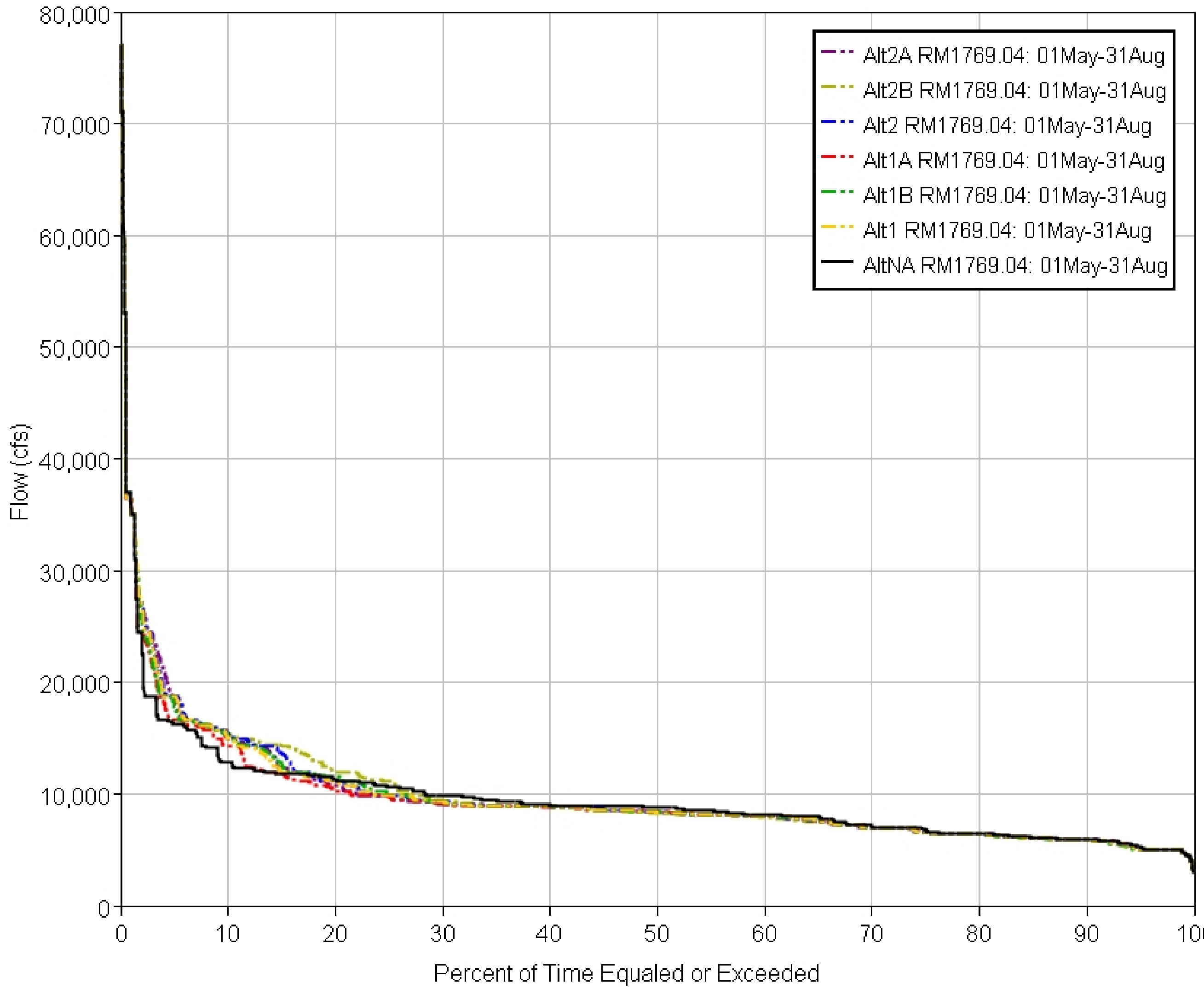


Plate 24: Fort Peck Summer Duration

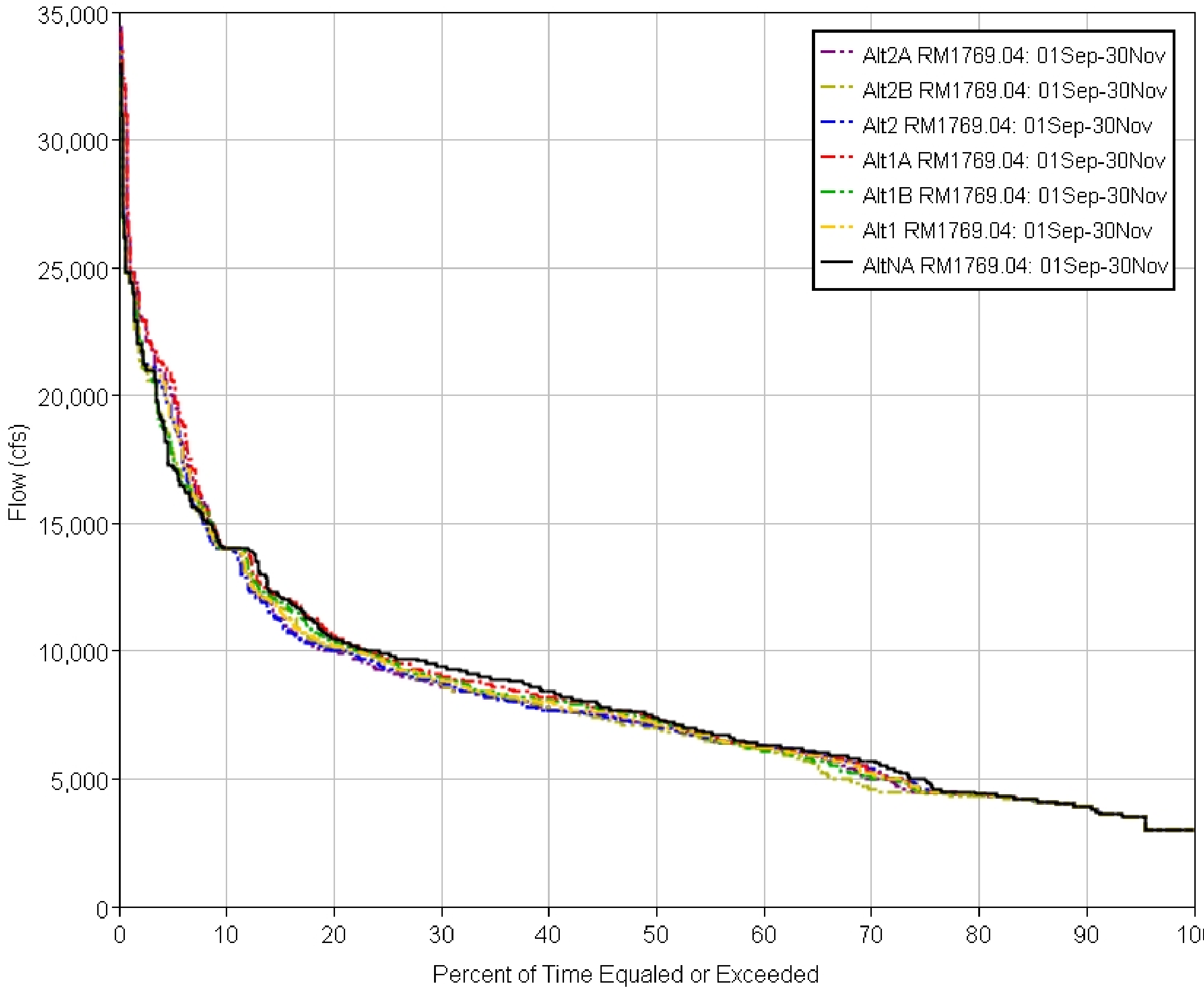


Plate 25: Fort Peck Fall Duration

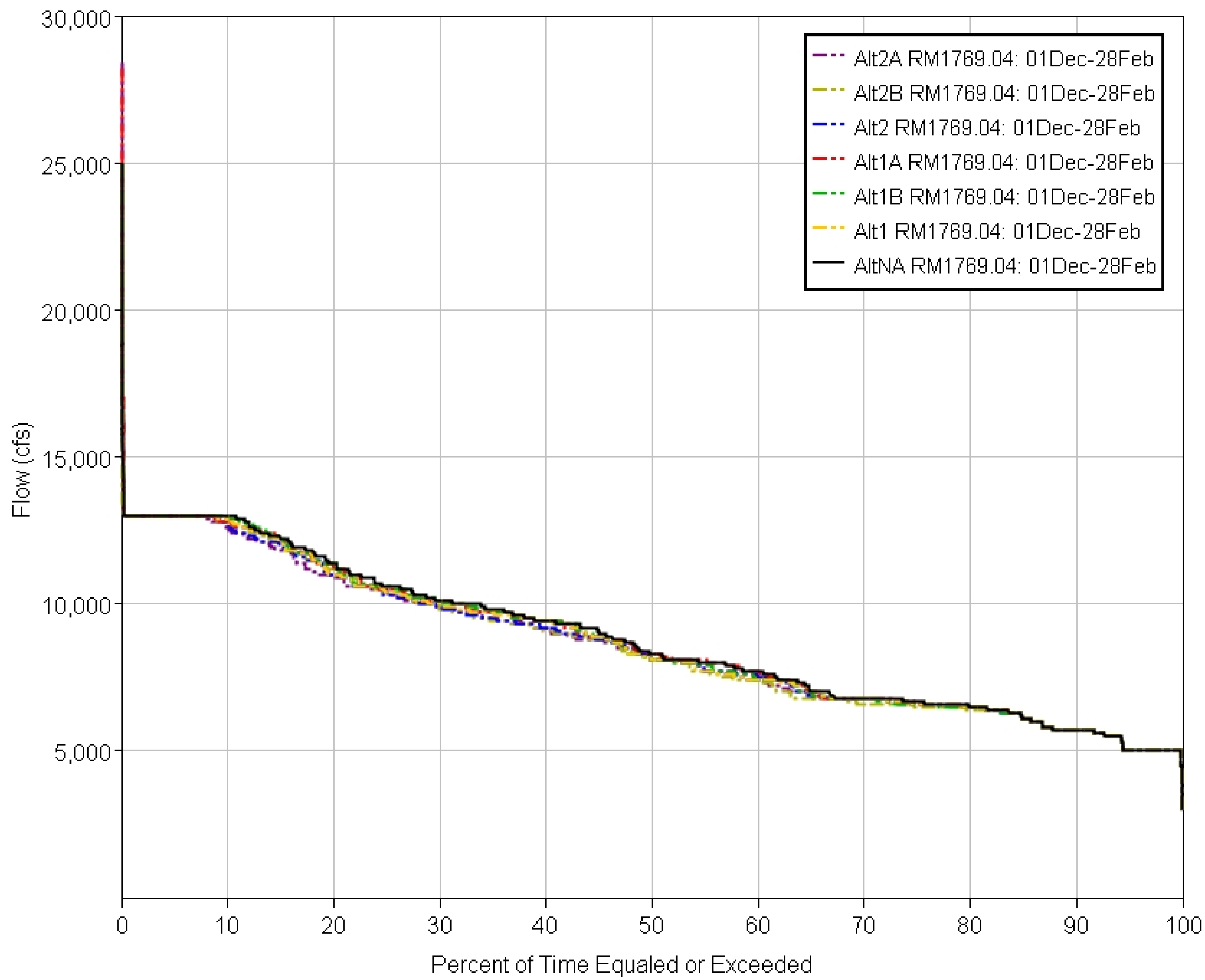


Plate 26: Fort Peck Winter Duration

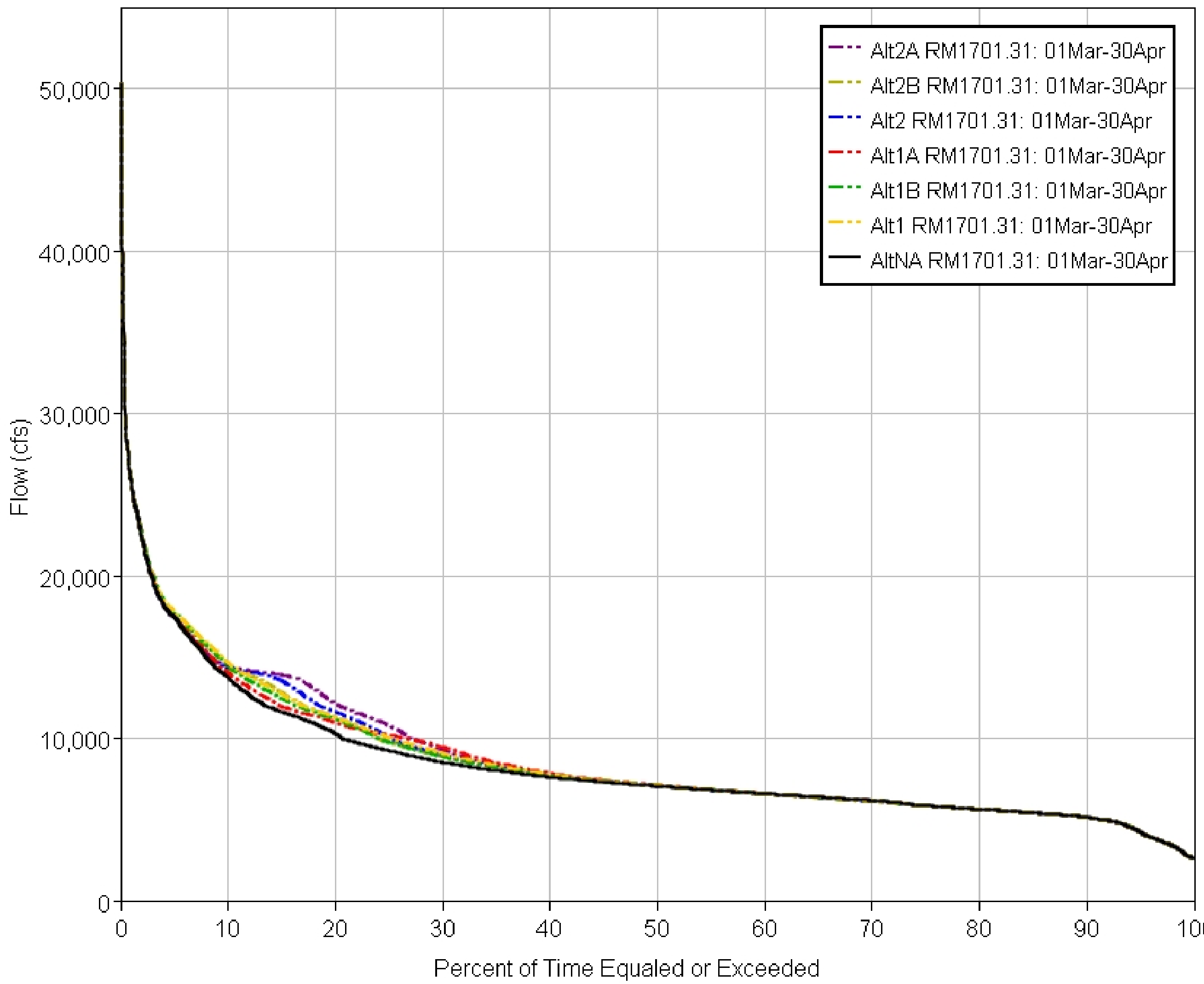


Plate 27: Wolf Point Spring Duration

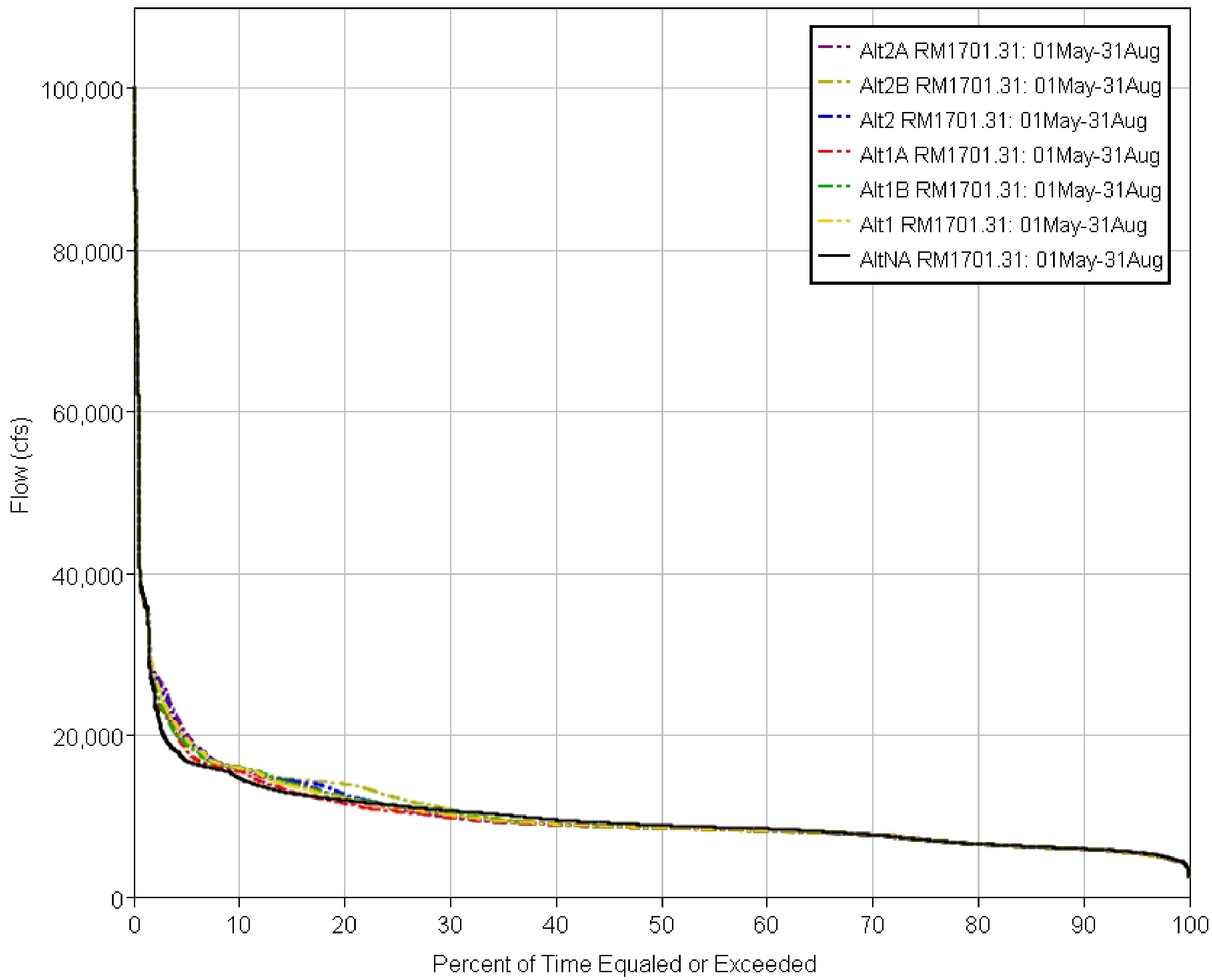


Plate 28: Wolf Point Summer Duration

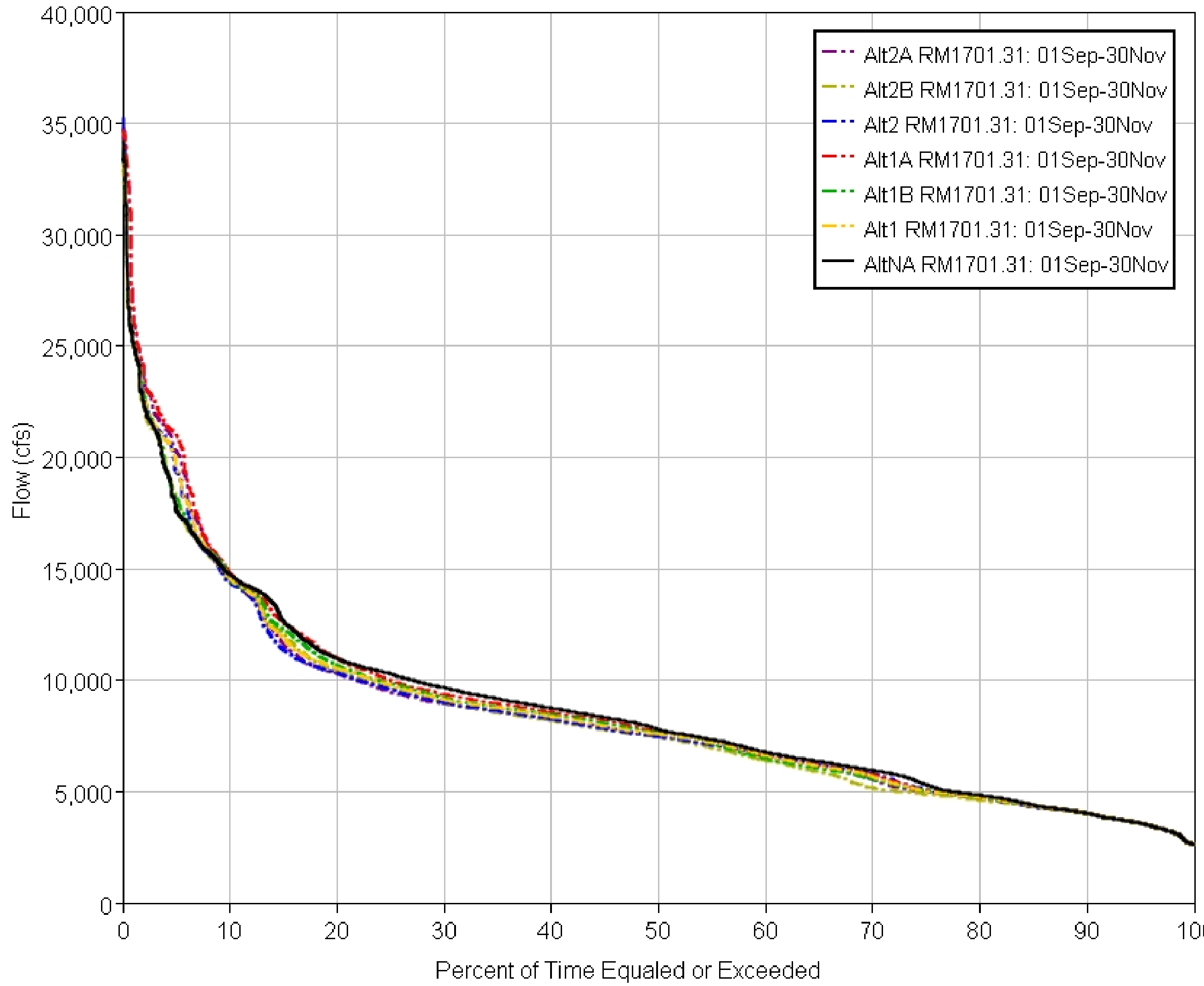


Plate 29: Wolf Point Fall Duration

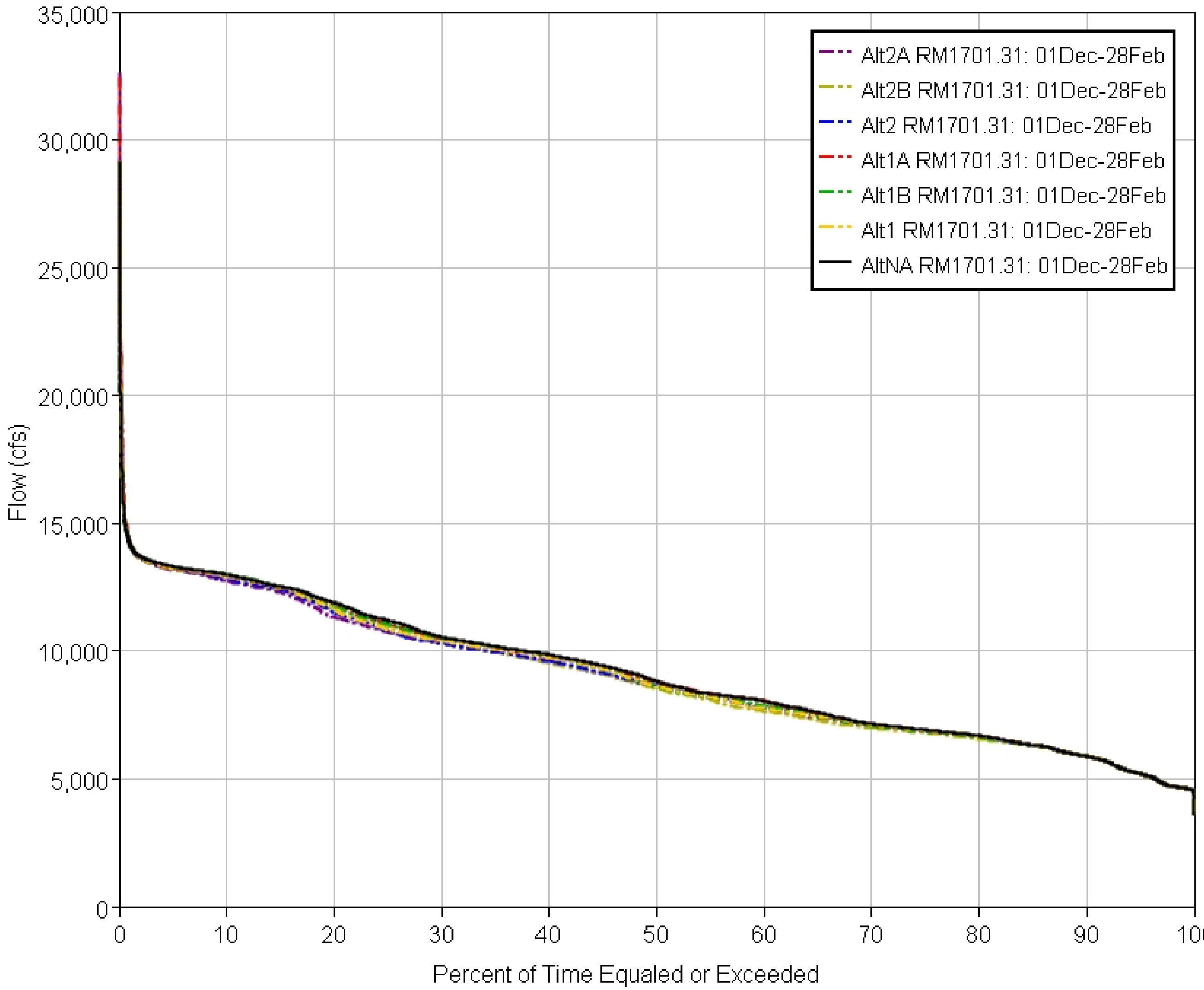


Plate 30: Wolf Point Winter Duration

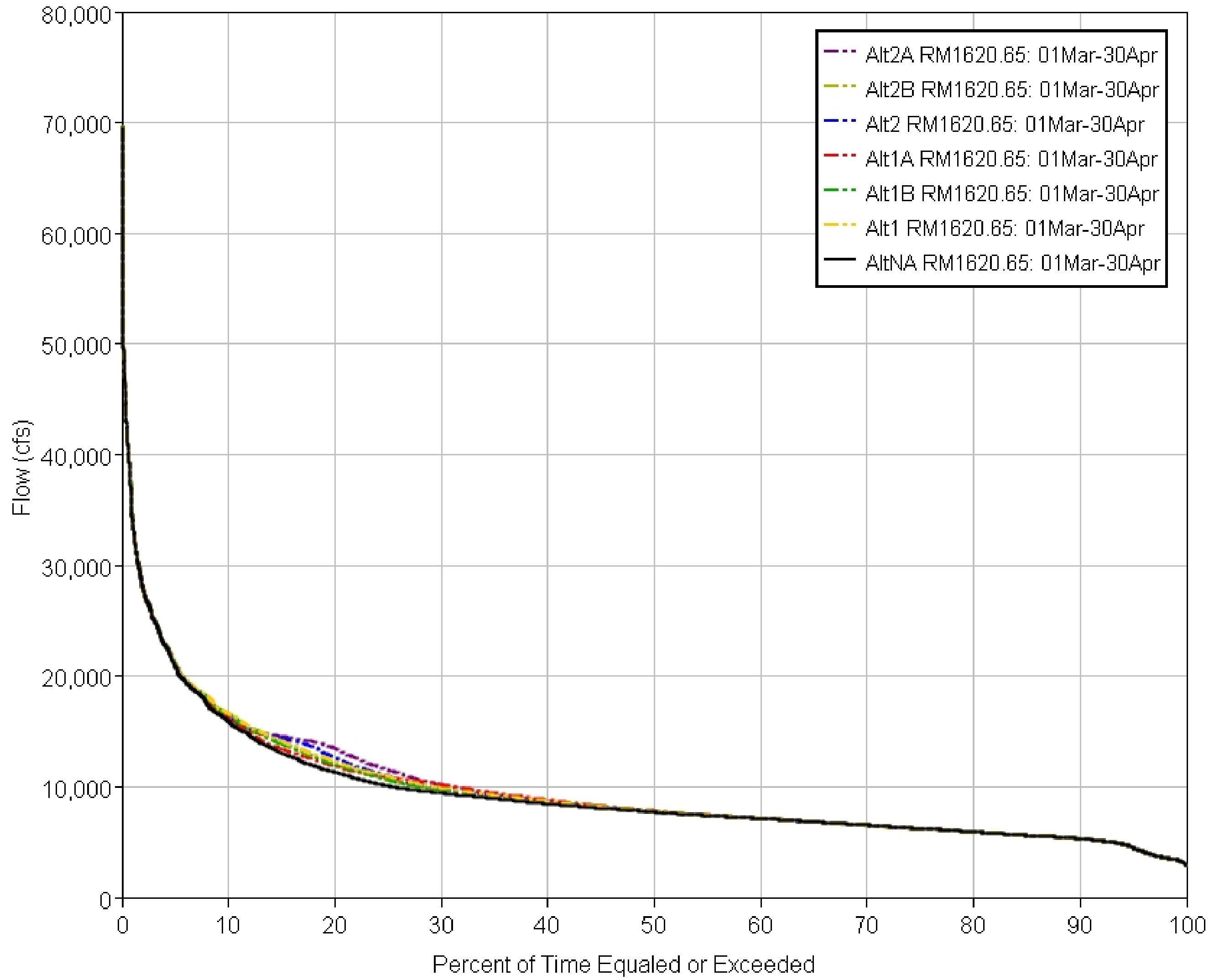


Plate 31: Culbertson Spring Duration

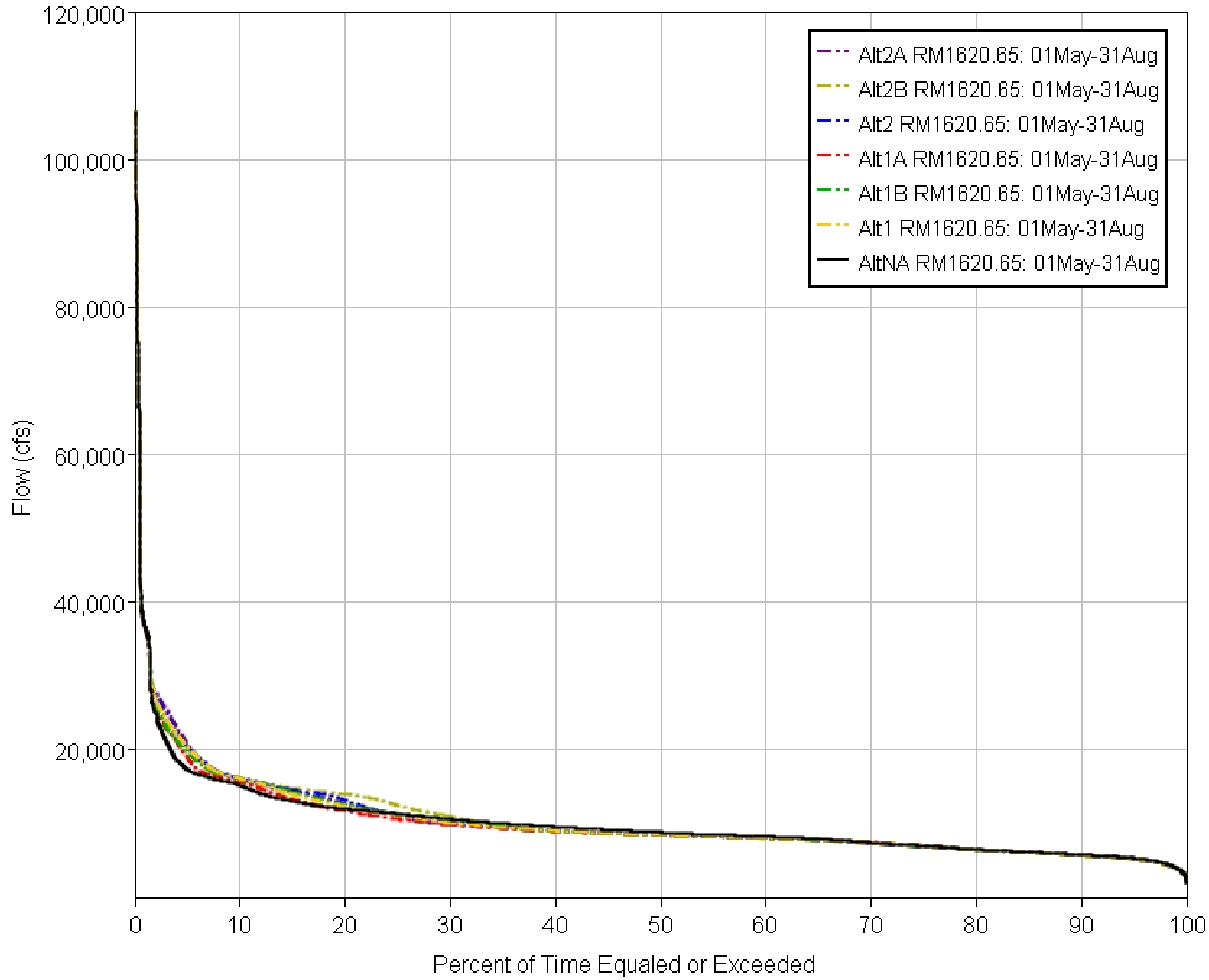


Plate 32: Culbertson Summer Duration

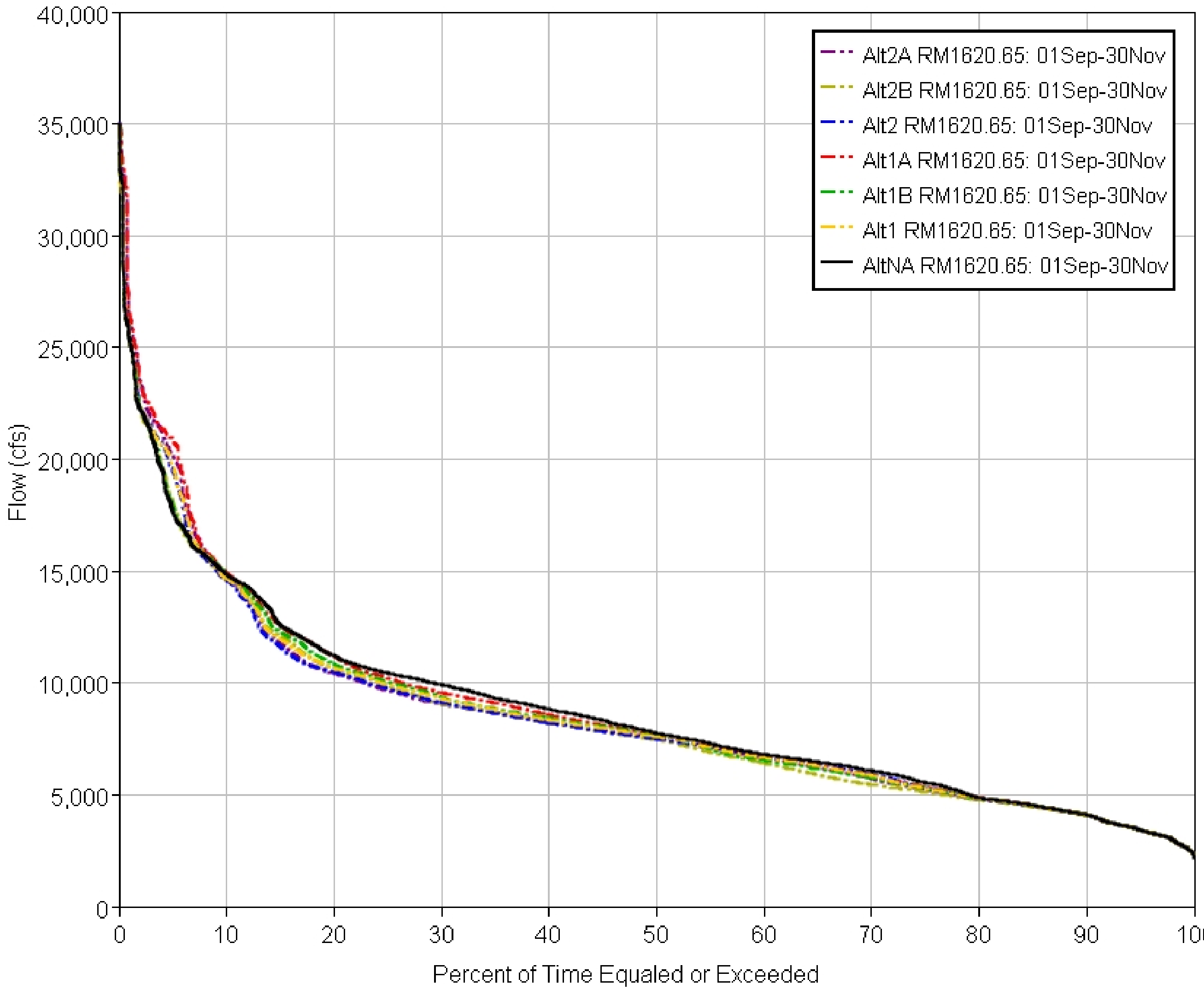


Plate 33: Culbertson Fall Duration

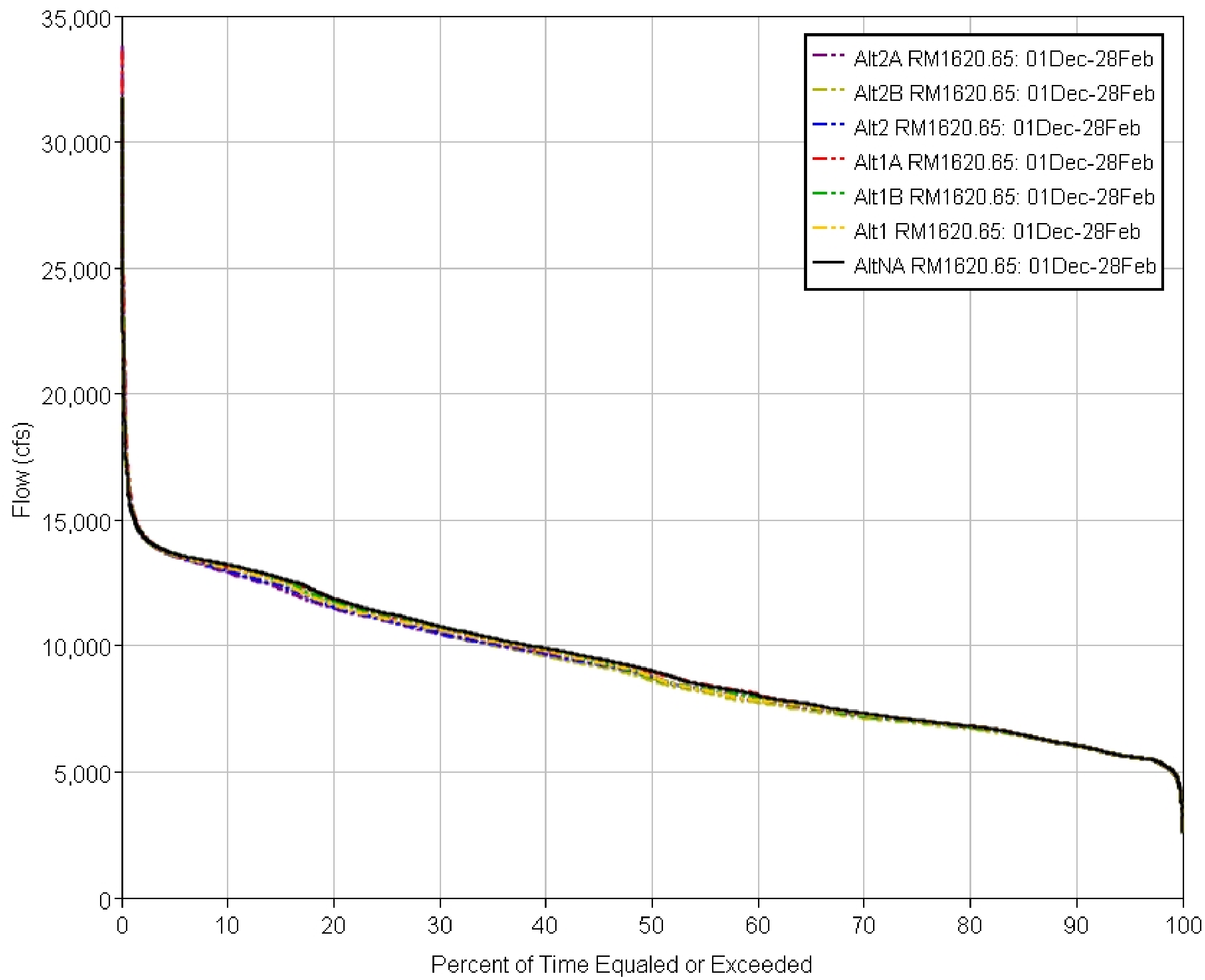


Plate 34: Culbertson Winter Duration

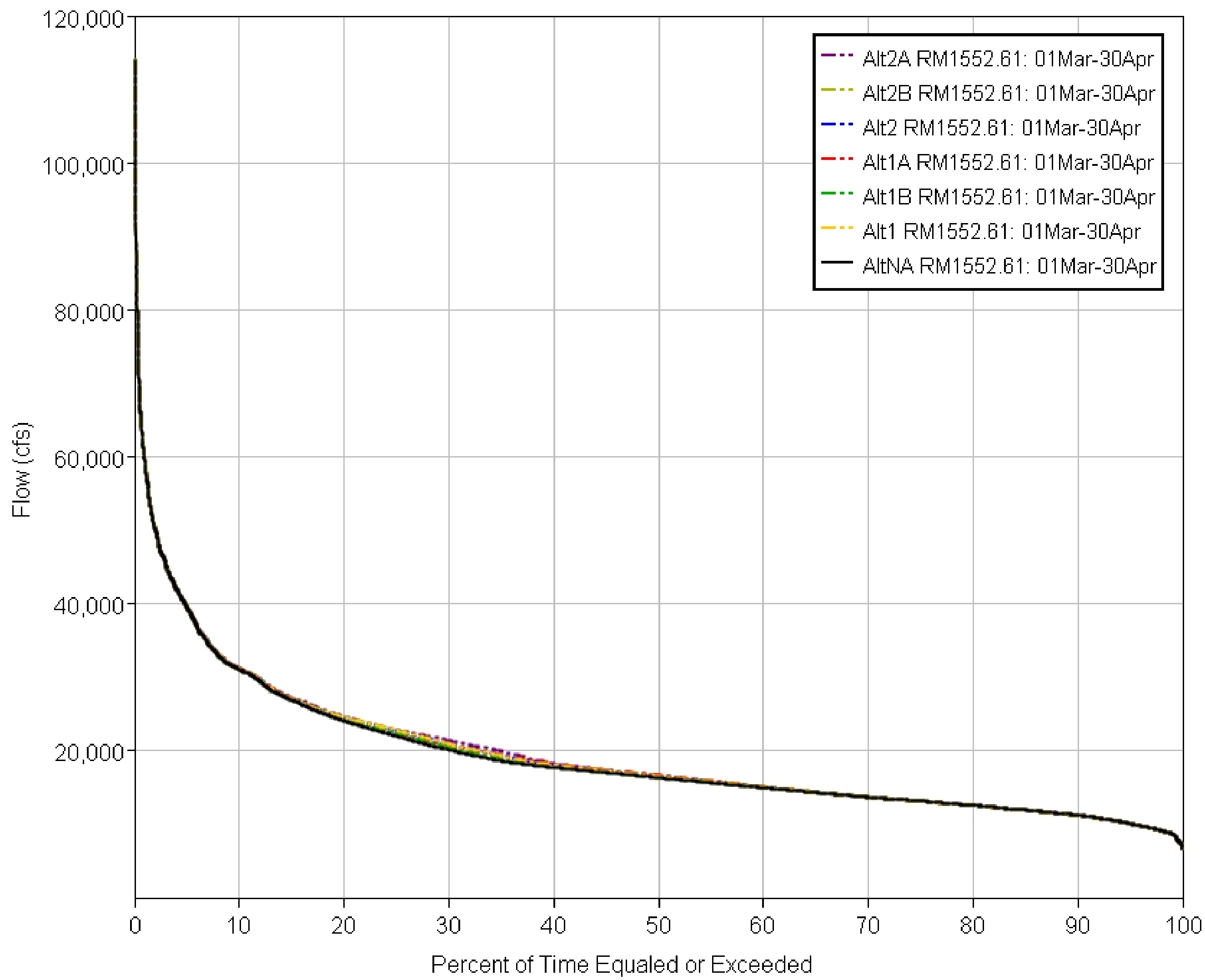


Plate 35: Williston Spring Duration

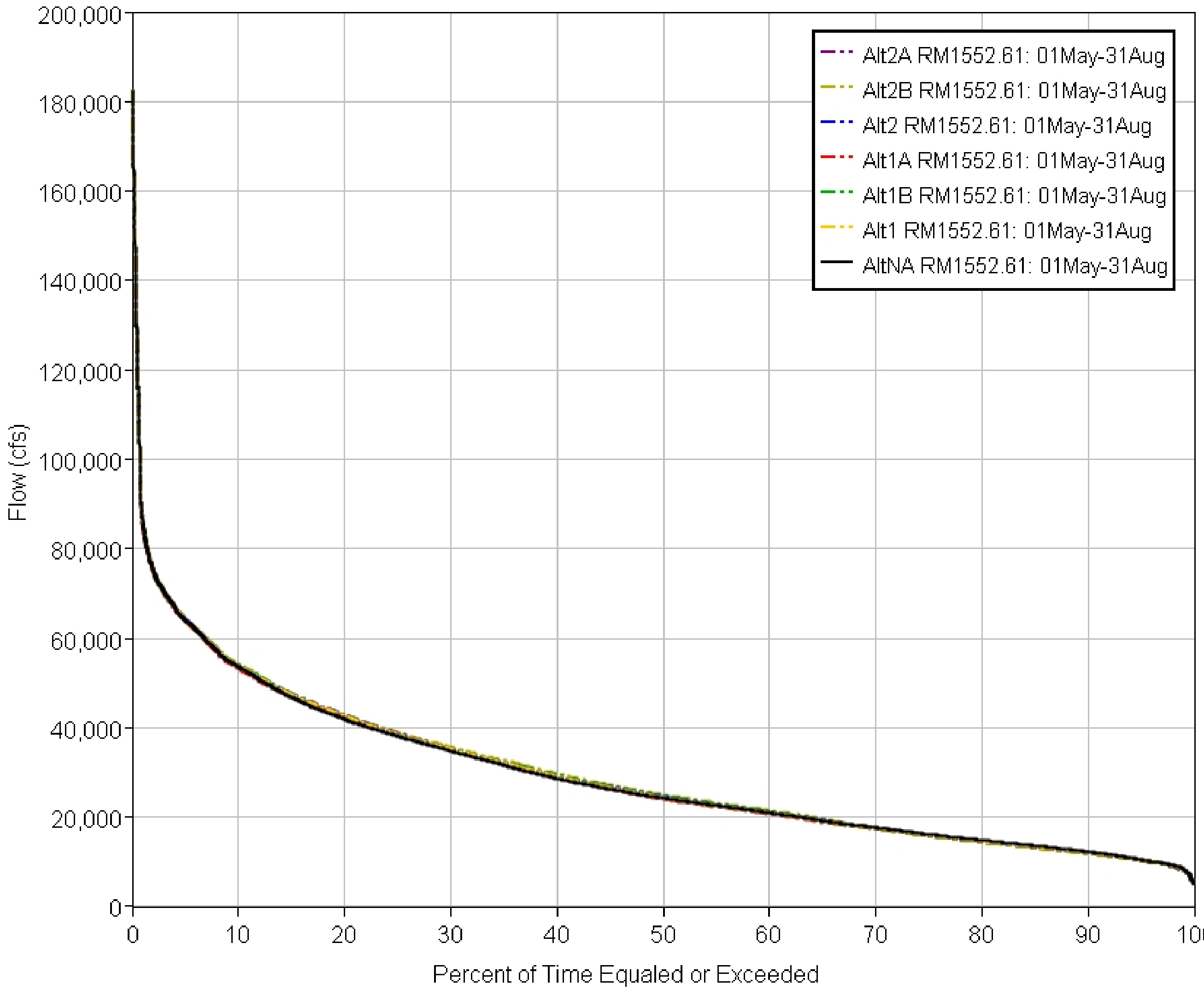


Plate 36: Williston Summer Duration

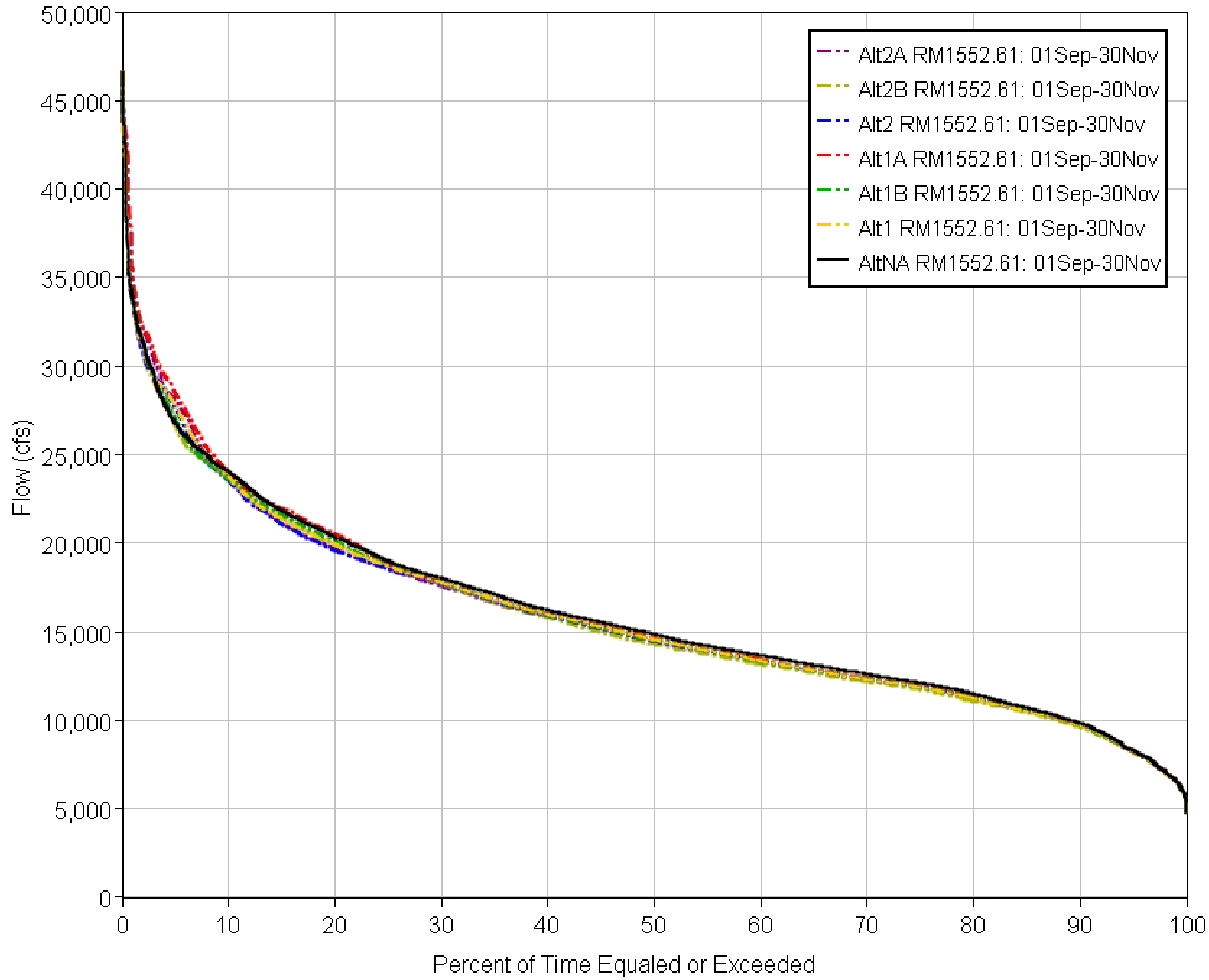


Plate 37: Williston Fall Duration

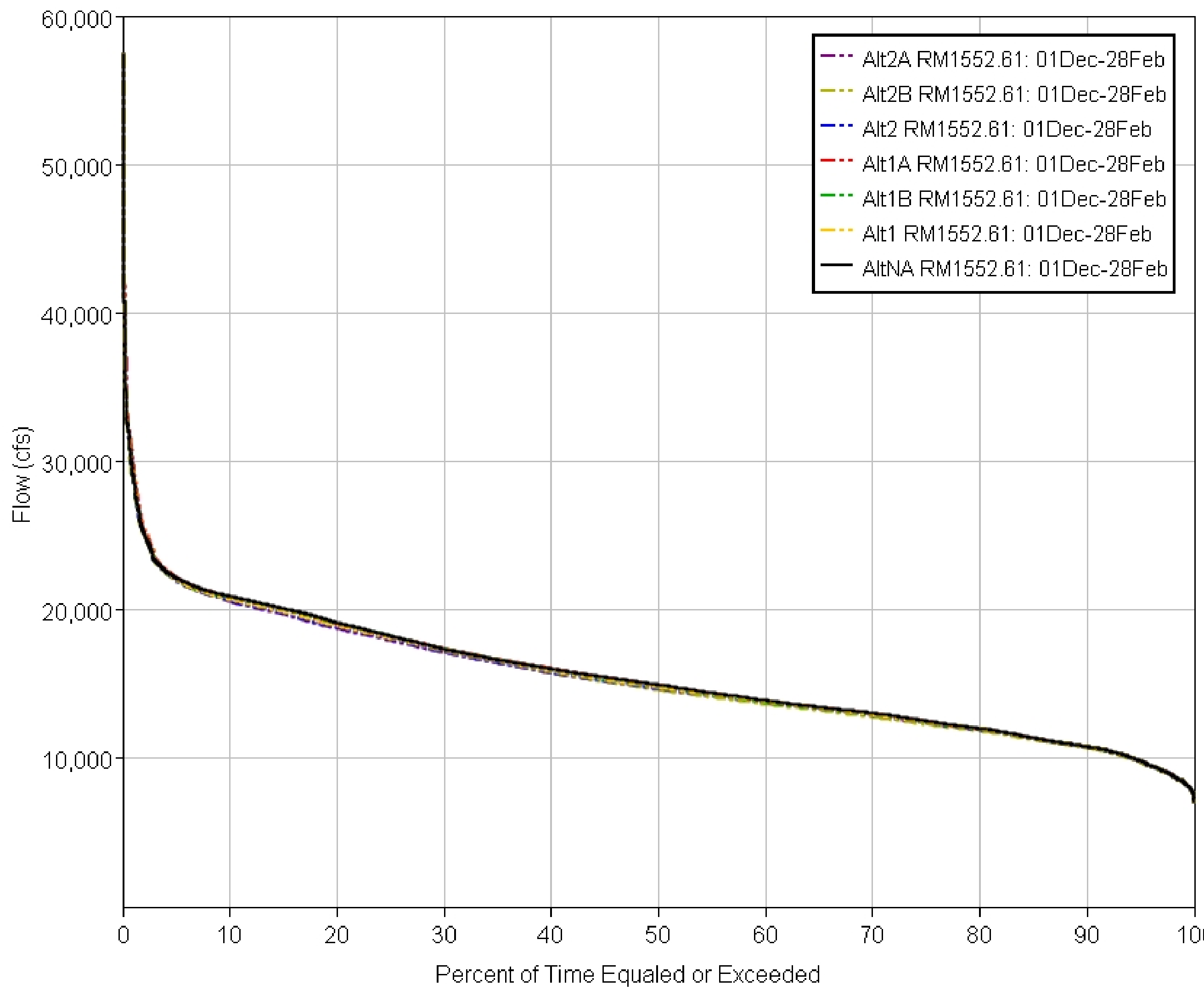


Plate 38: Williston Winter Duration

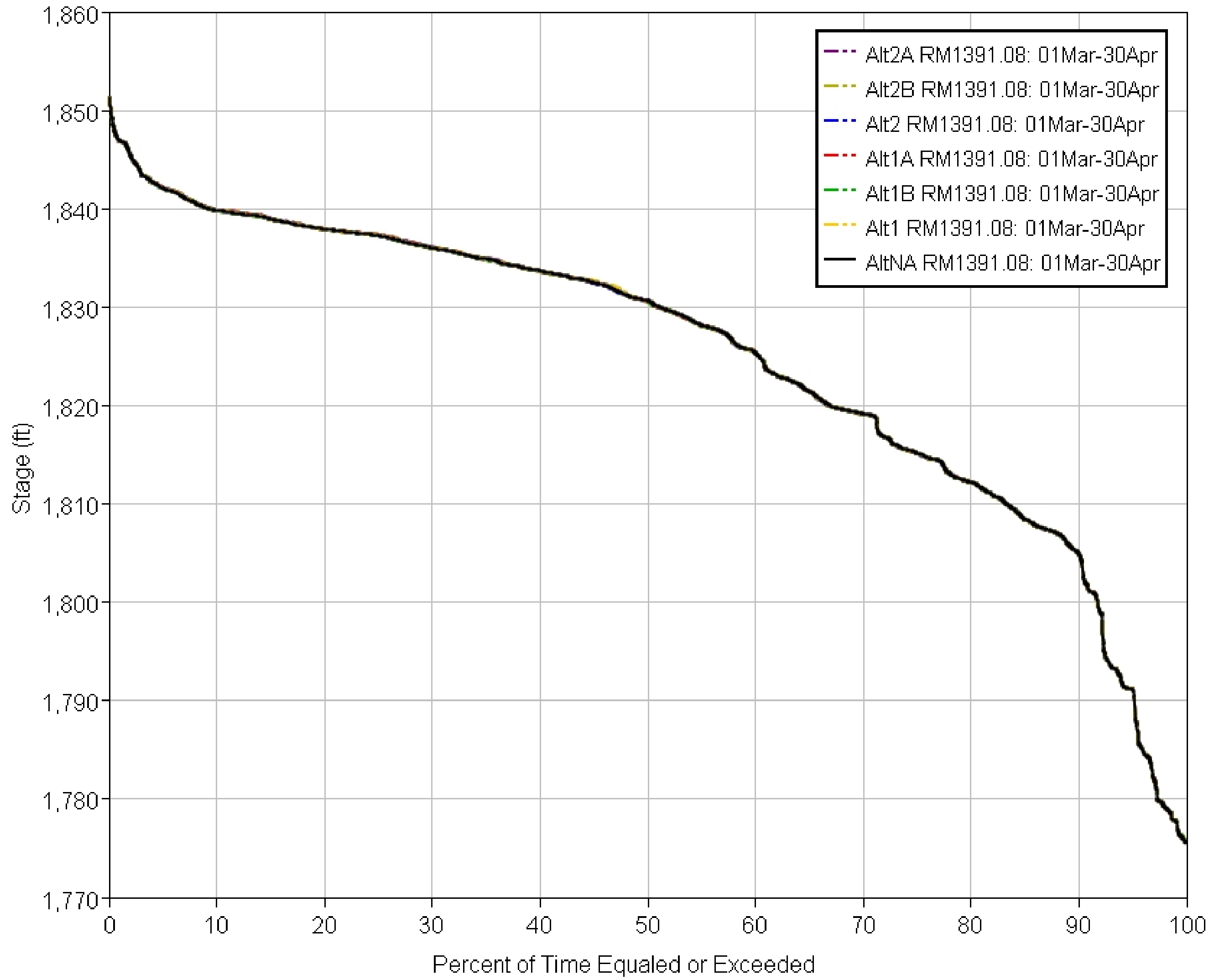


Plate 39: Lake Sakakawea Spring Duration

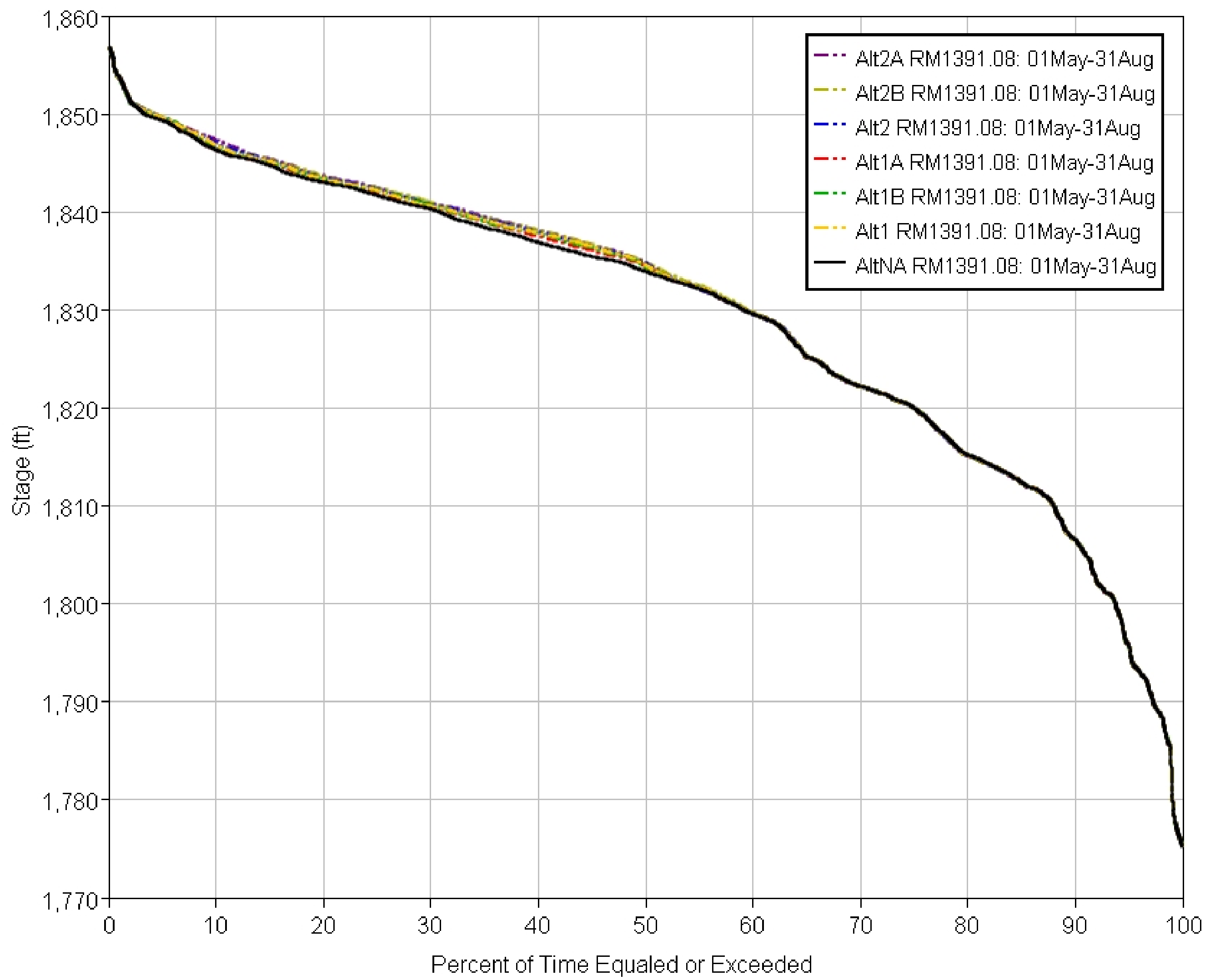


Plate 40: Lake Sakakawea Summer Duration

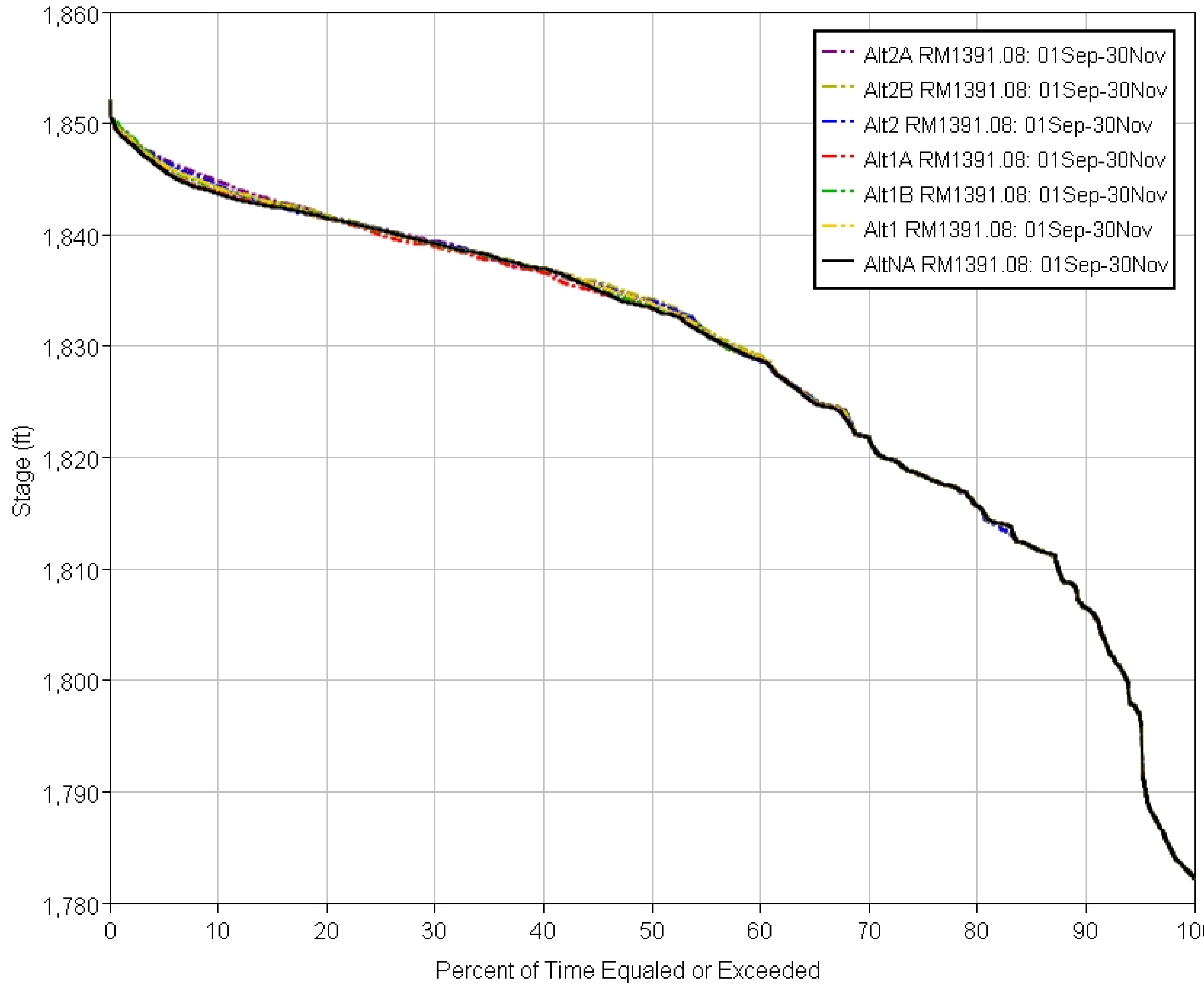


Plate 41: Lake Sakakawea Fall Duration

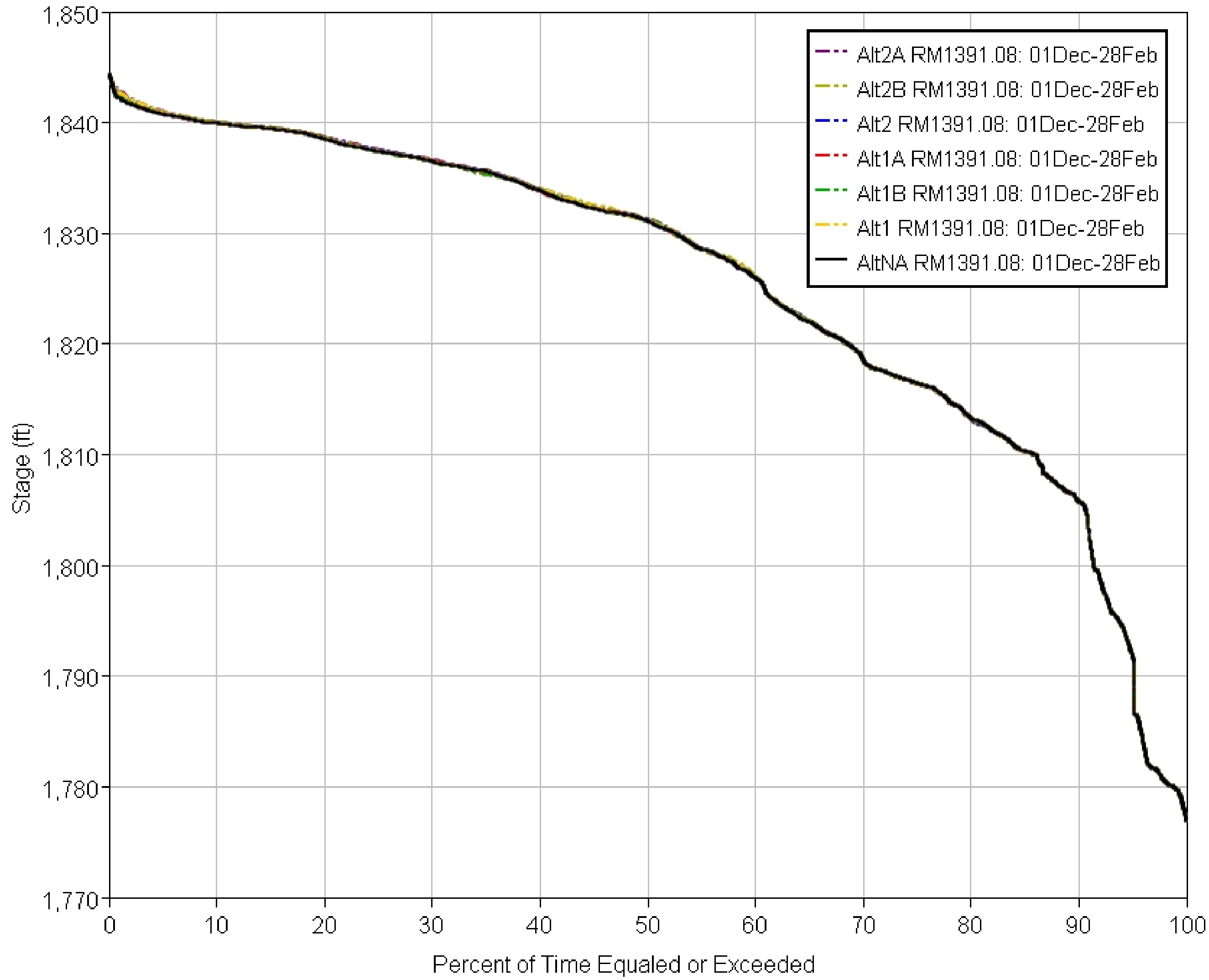


Plate 42: Lake Sakakawea Winter Duration

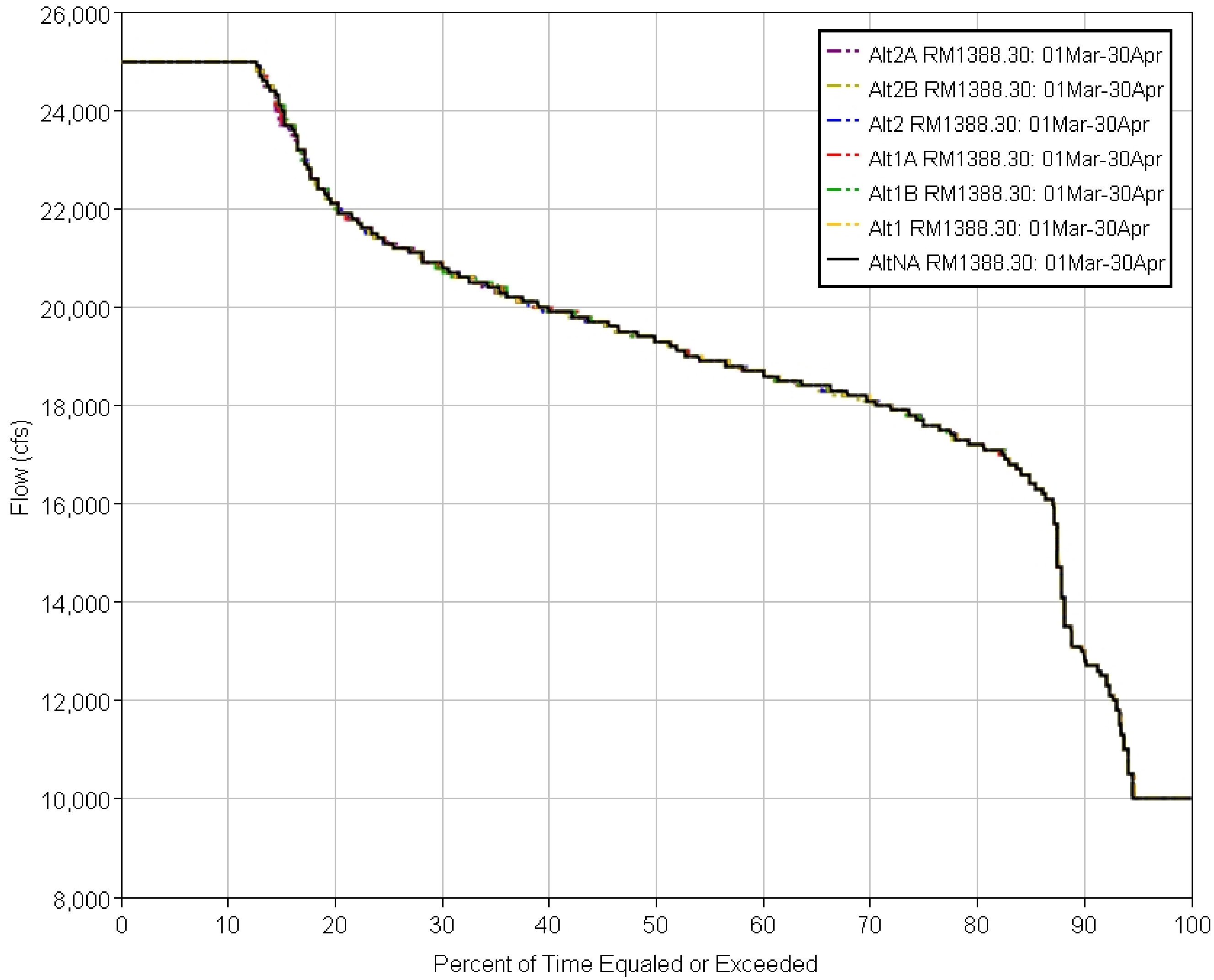


Plate 43: Garrison Spring Duration

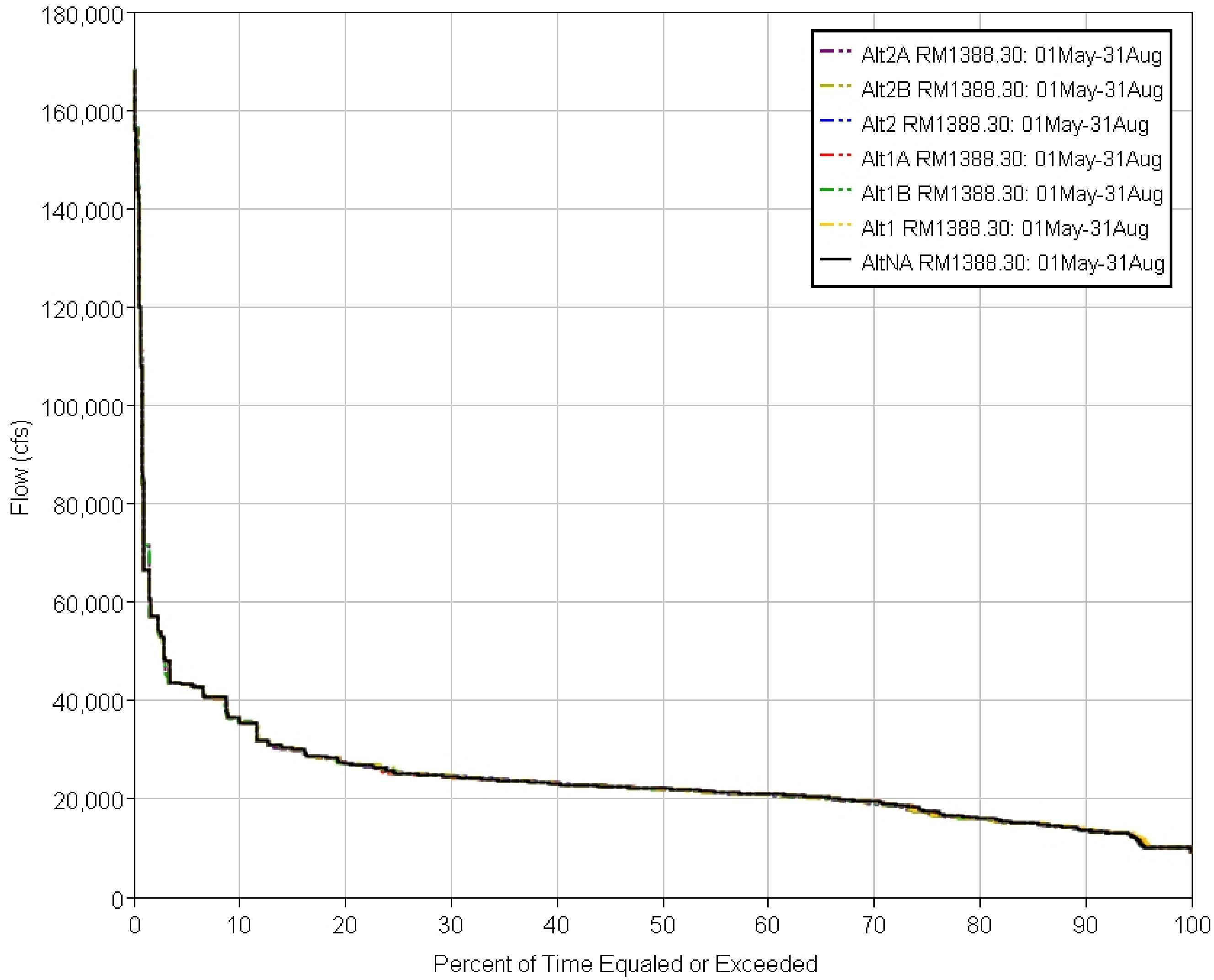


Plate 44: Garrison Summer Duration

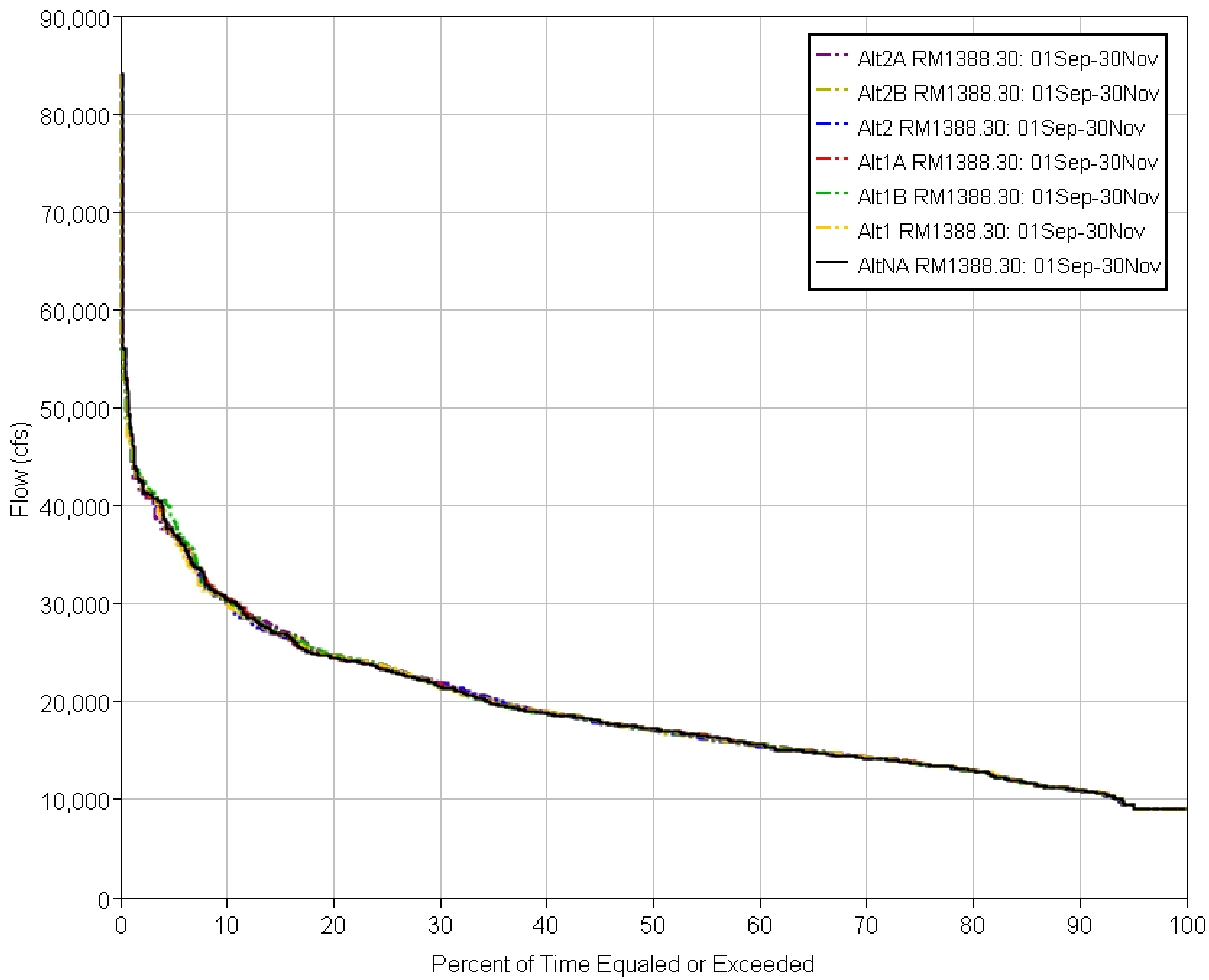


Plate 45: Garrison Fall Duration

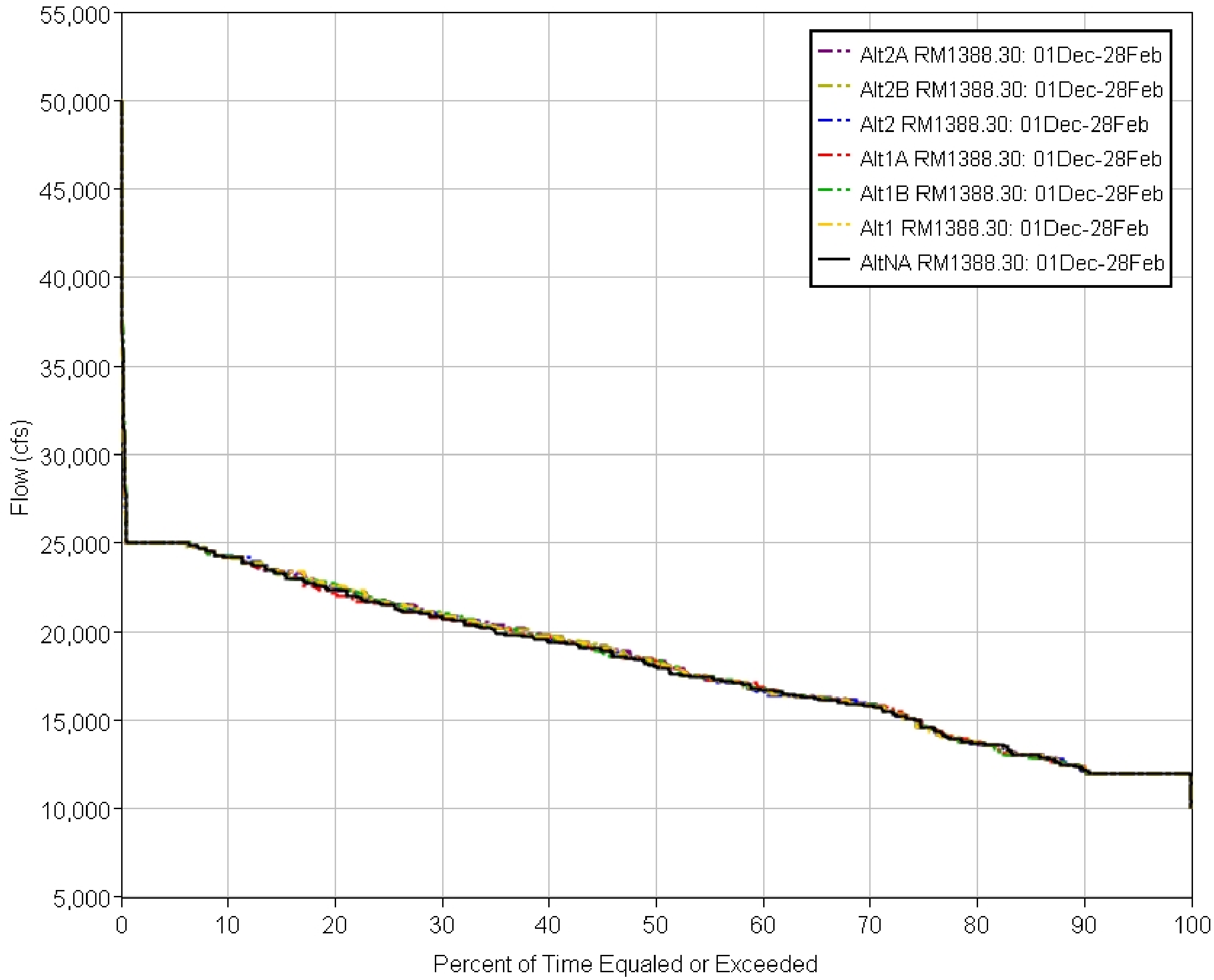


Plate 46: Garrison Winter Duration

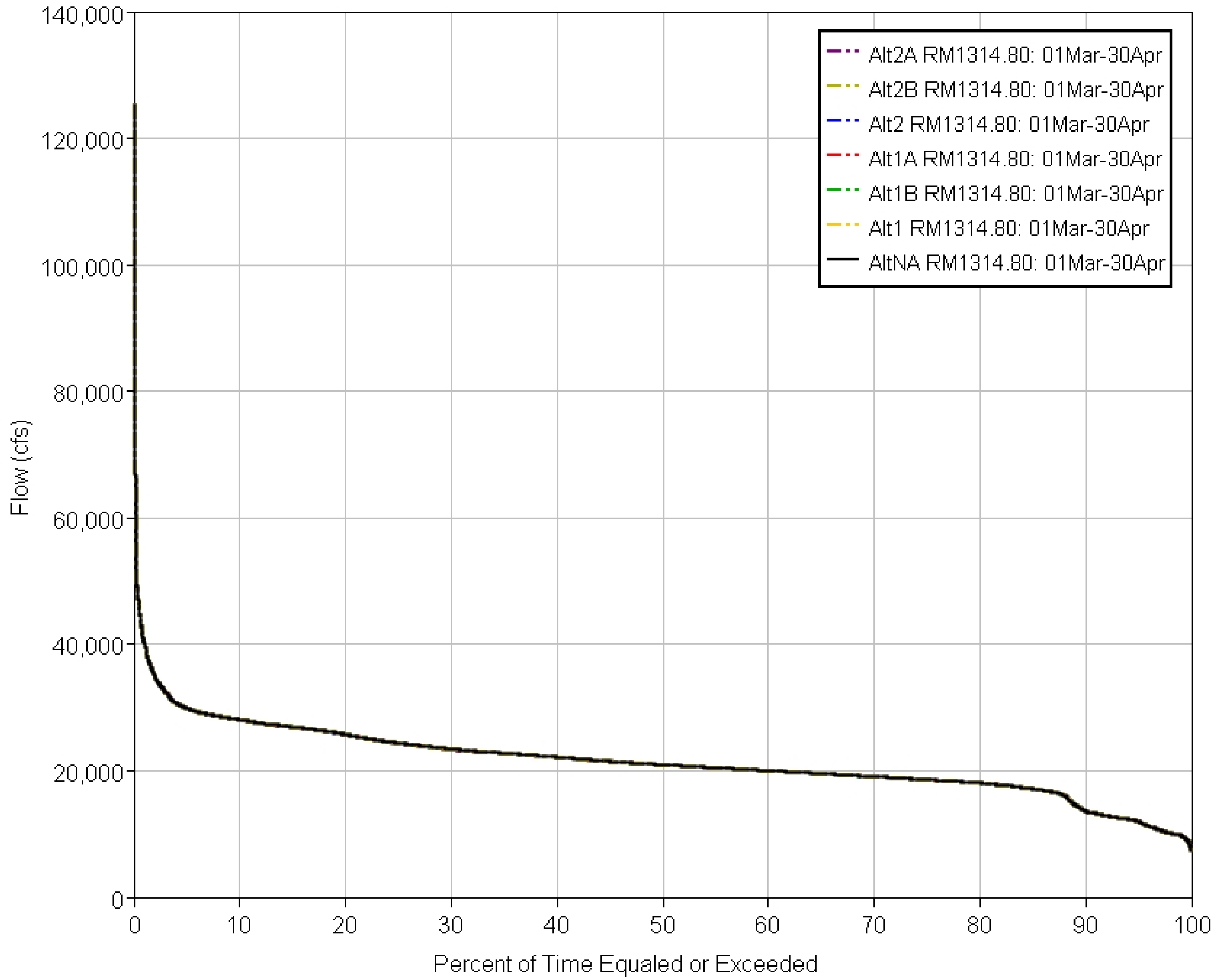


Plate 47: Bismarck Spring Duration

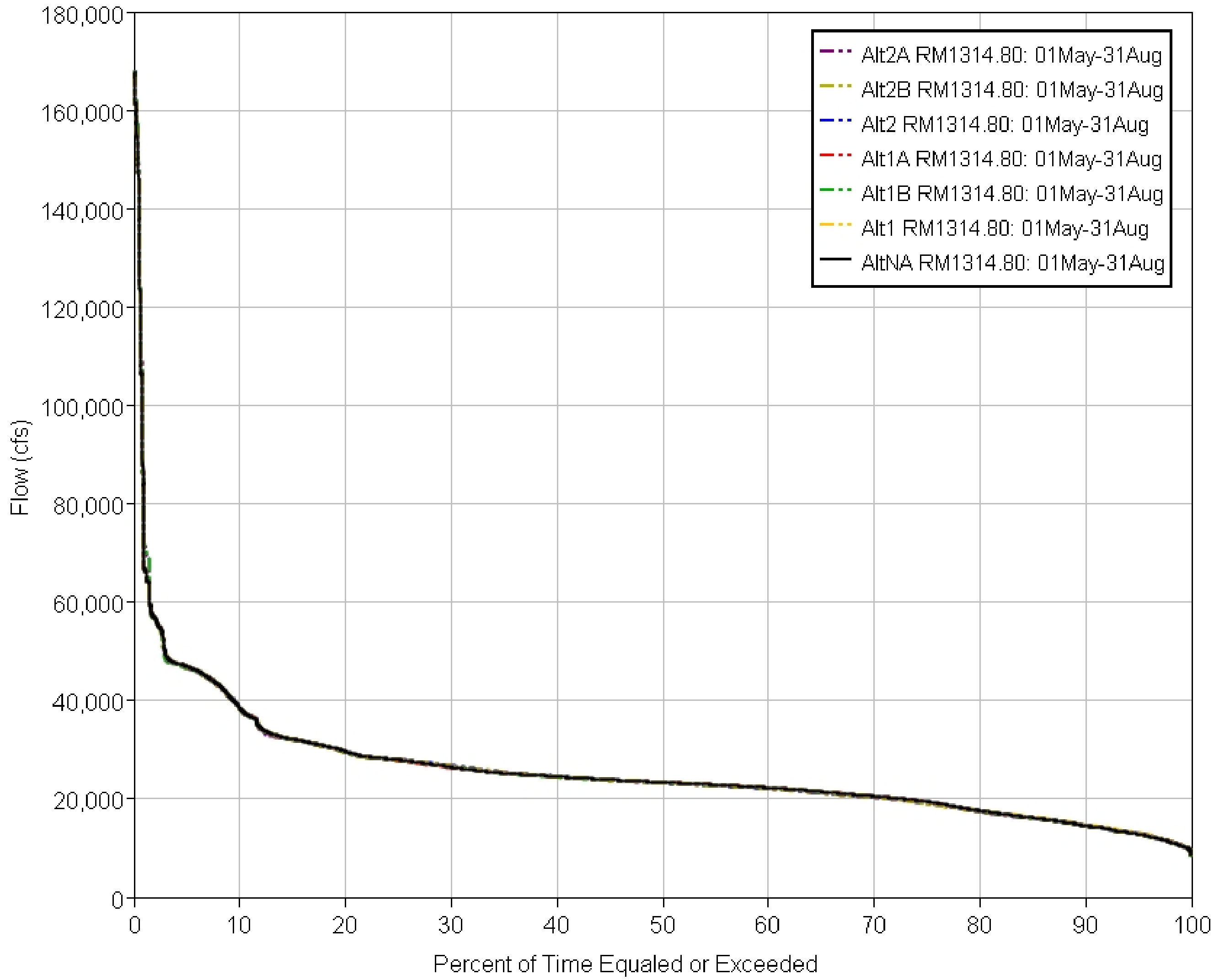


Plate 48: Bismarck Summer Duration

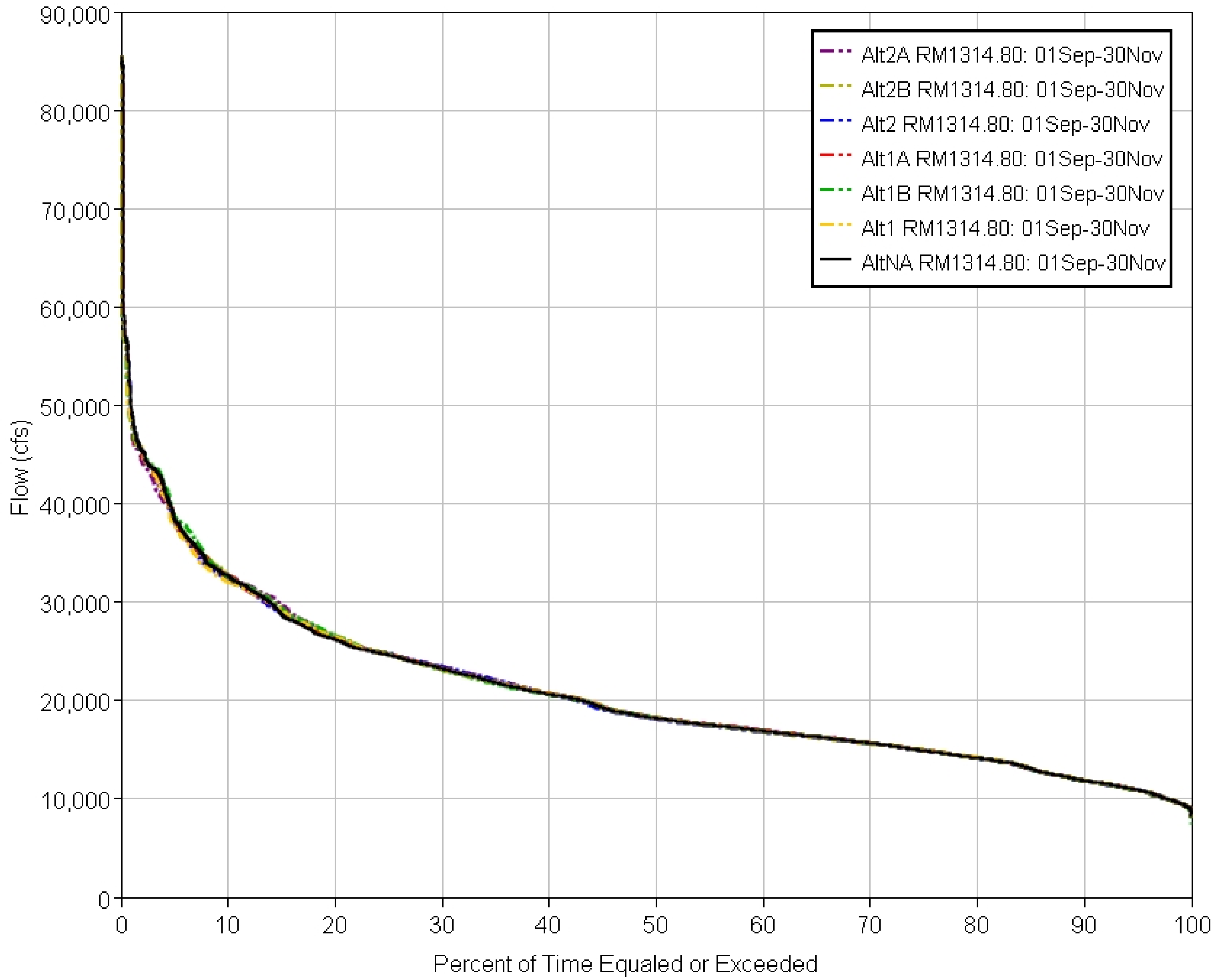


Plate 49: Bismarck Fall Duration

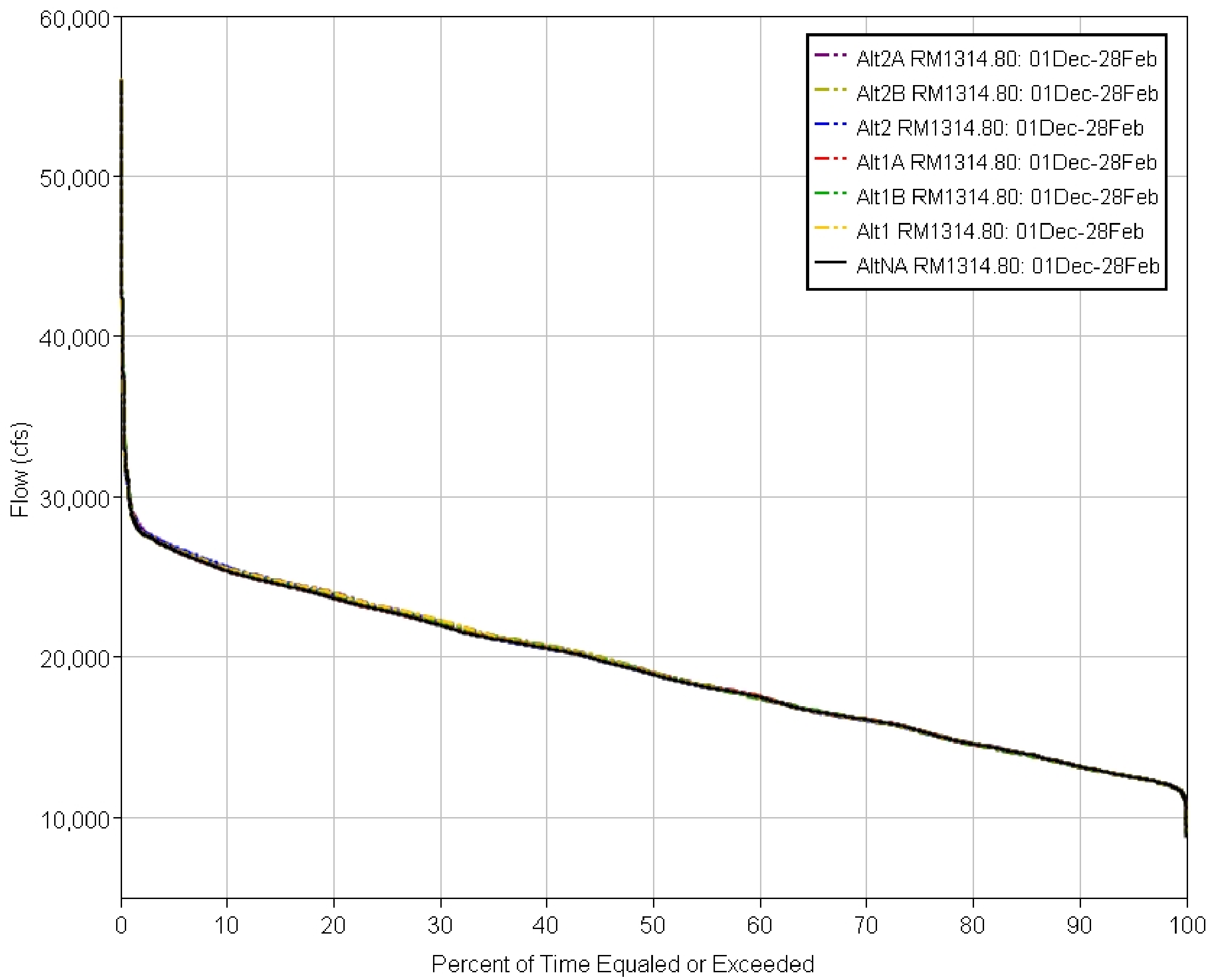


Plate 50: Bismarck Winter Duration

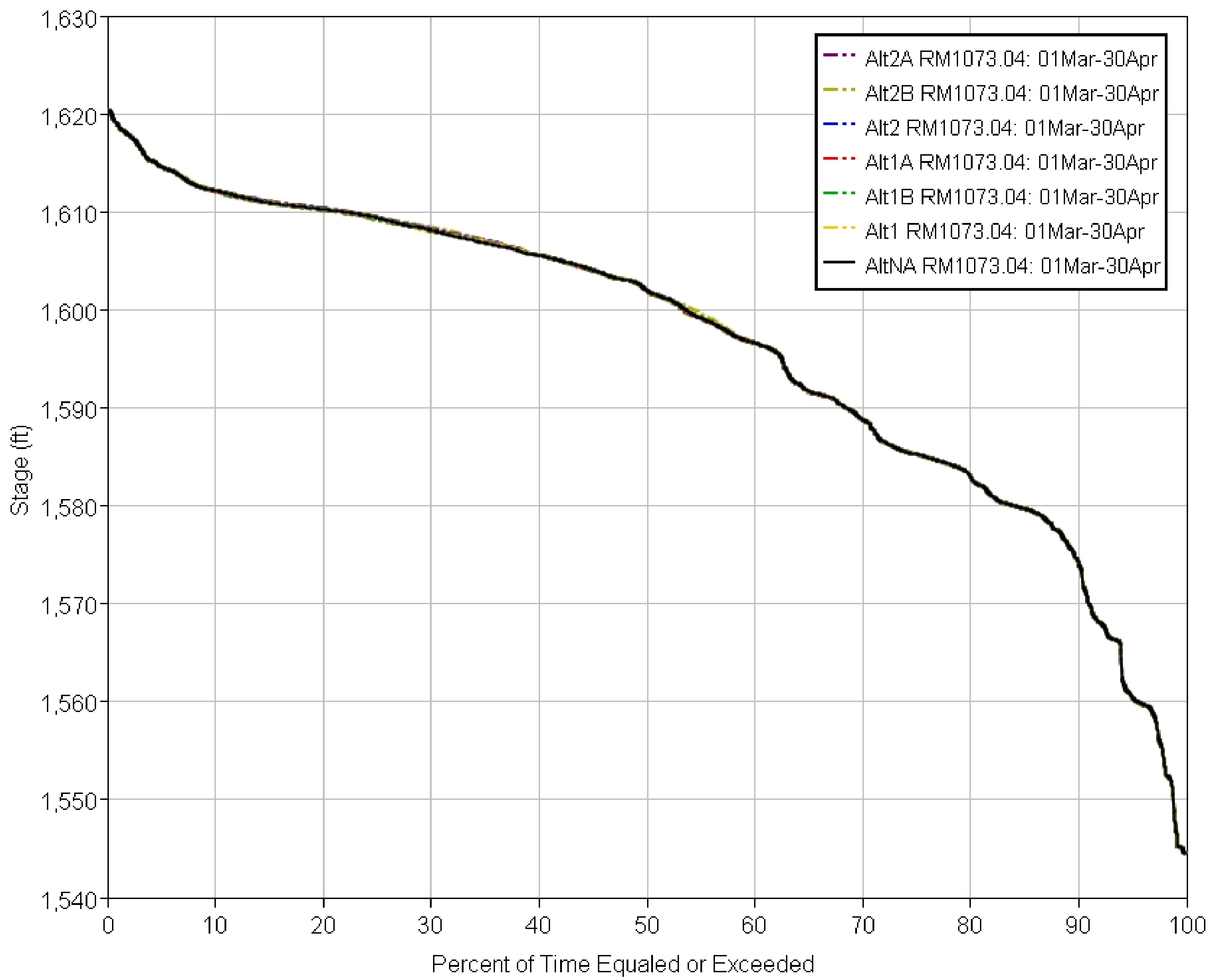


Plate 51: Lake Oahe Spring Duration

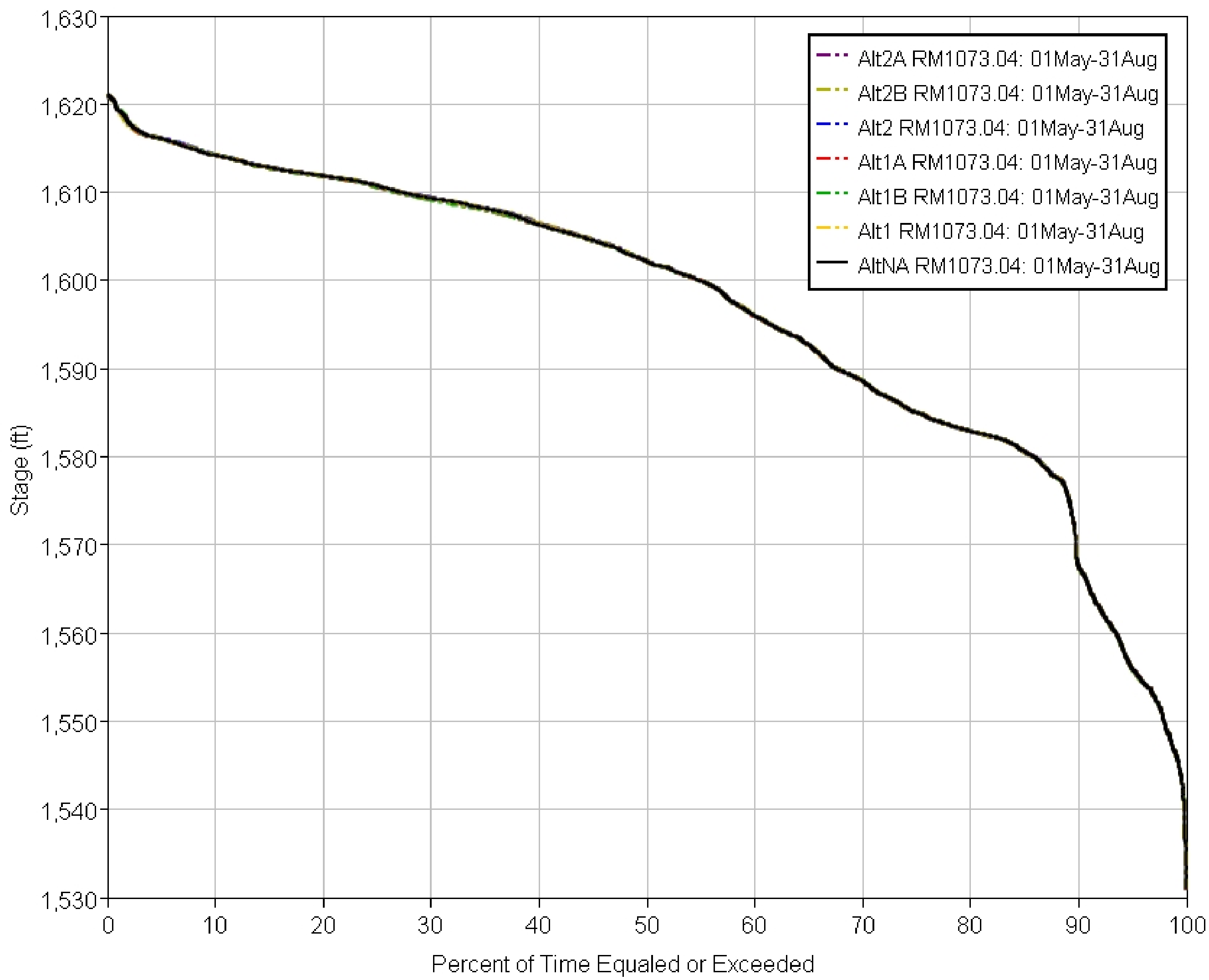


Plate 52: Lake Oahe Summer Duration

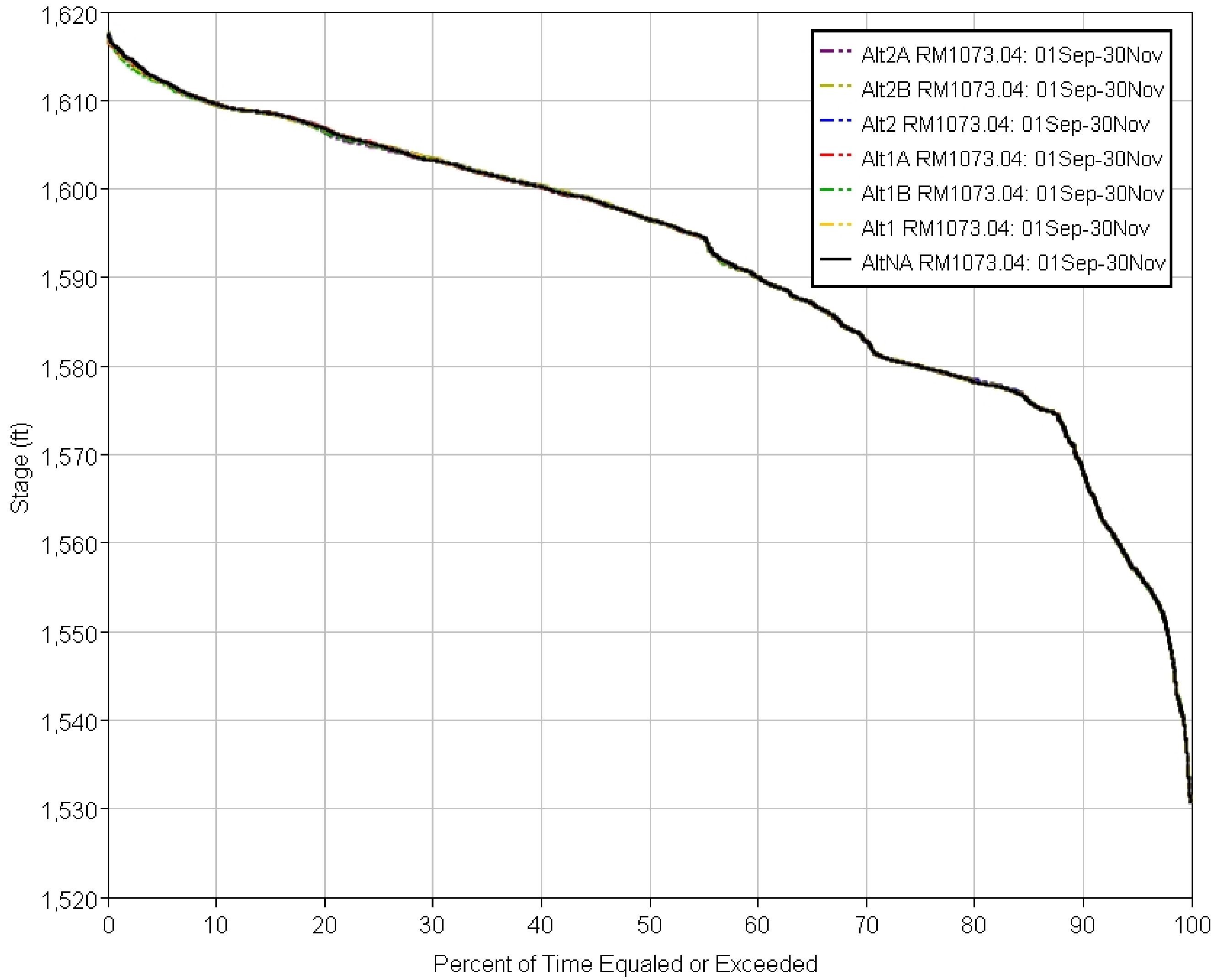


Plate 53: Lake Oahe Fall Duration

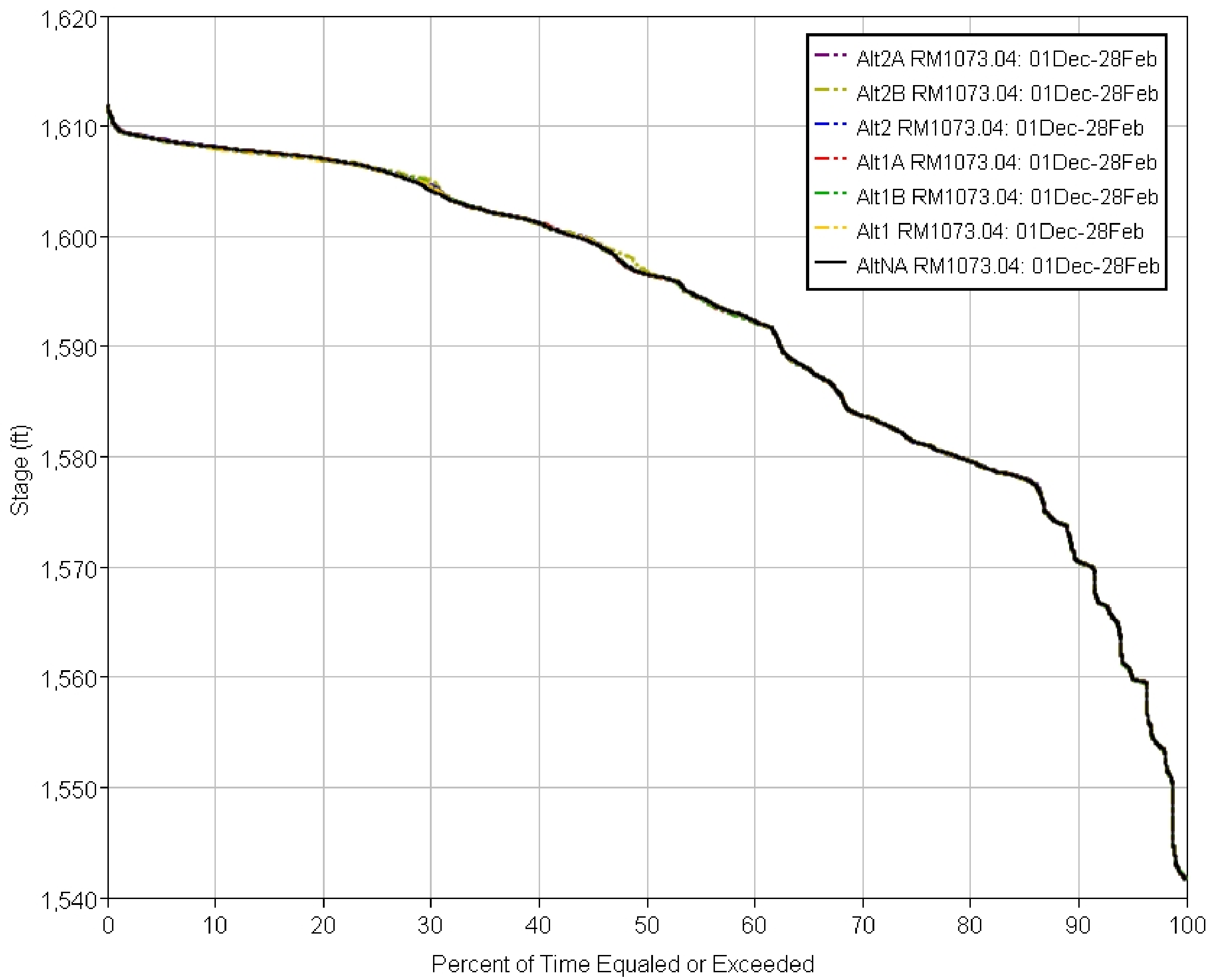


Plate 54: Lake Oahe Winter Duration

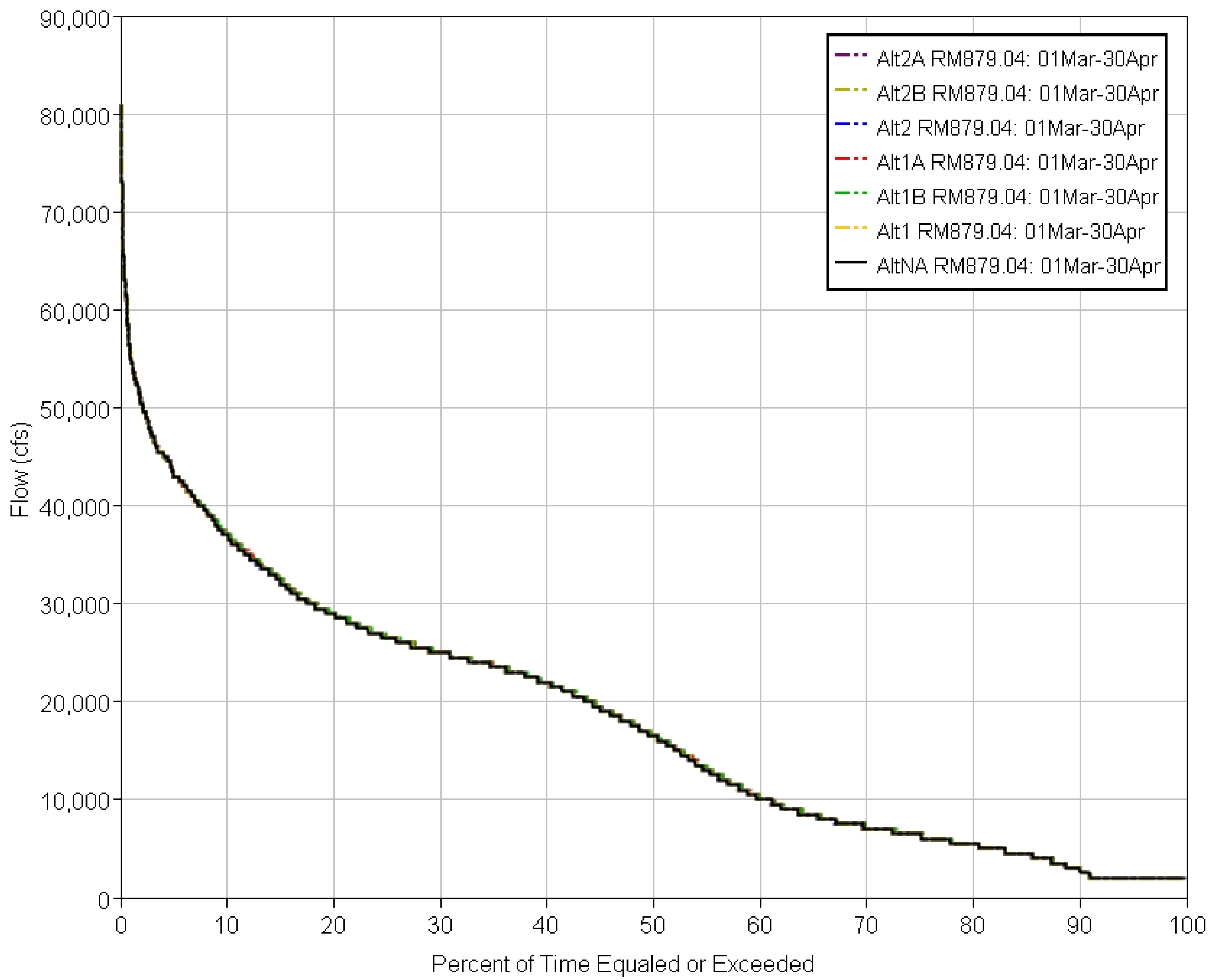


Plate 55: Fort Randall Spring Duration

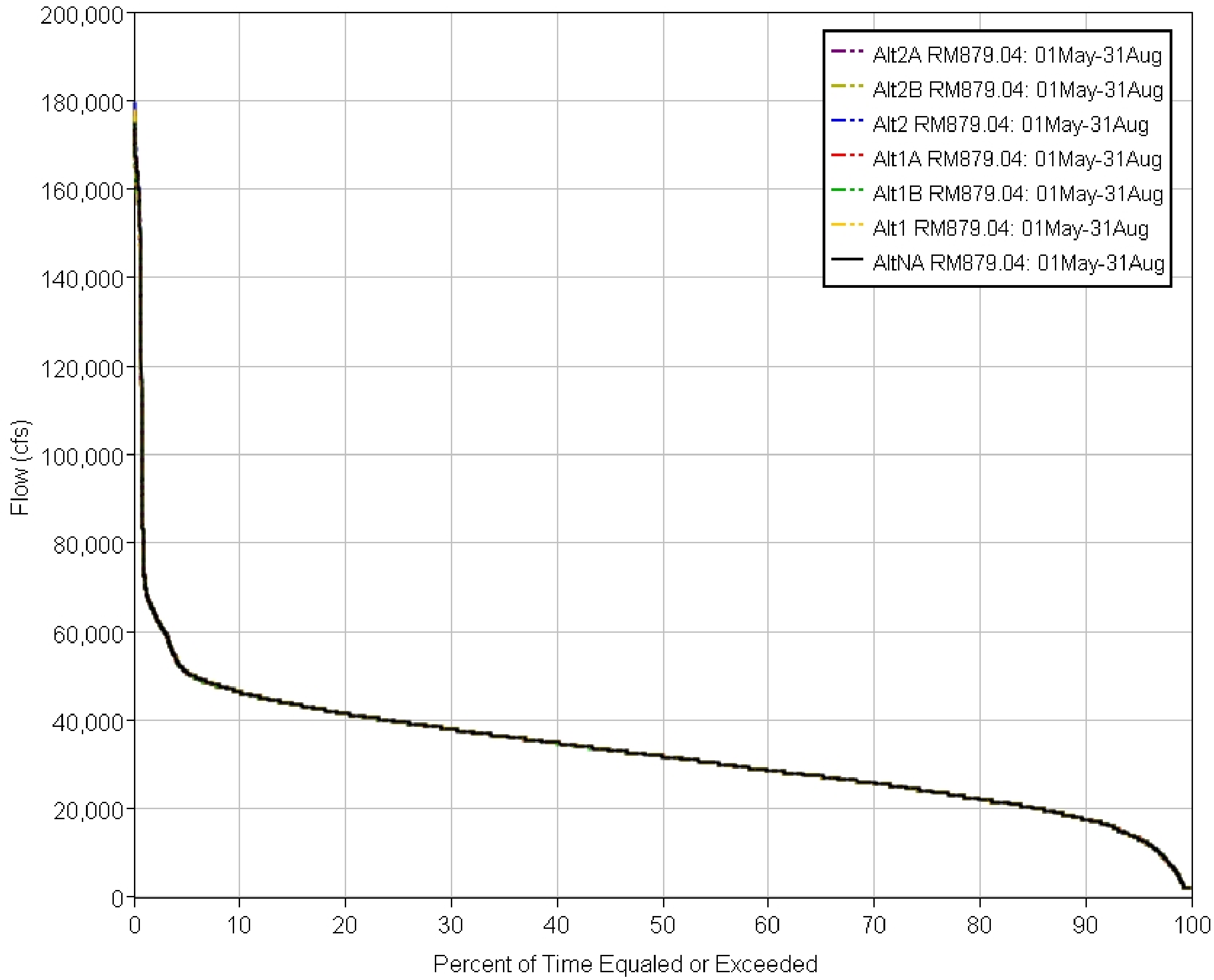


Plate 56: Fort Randall Summer Duration

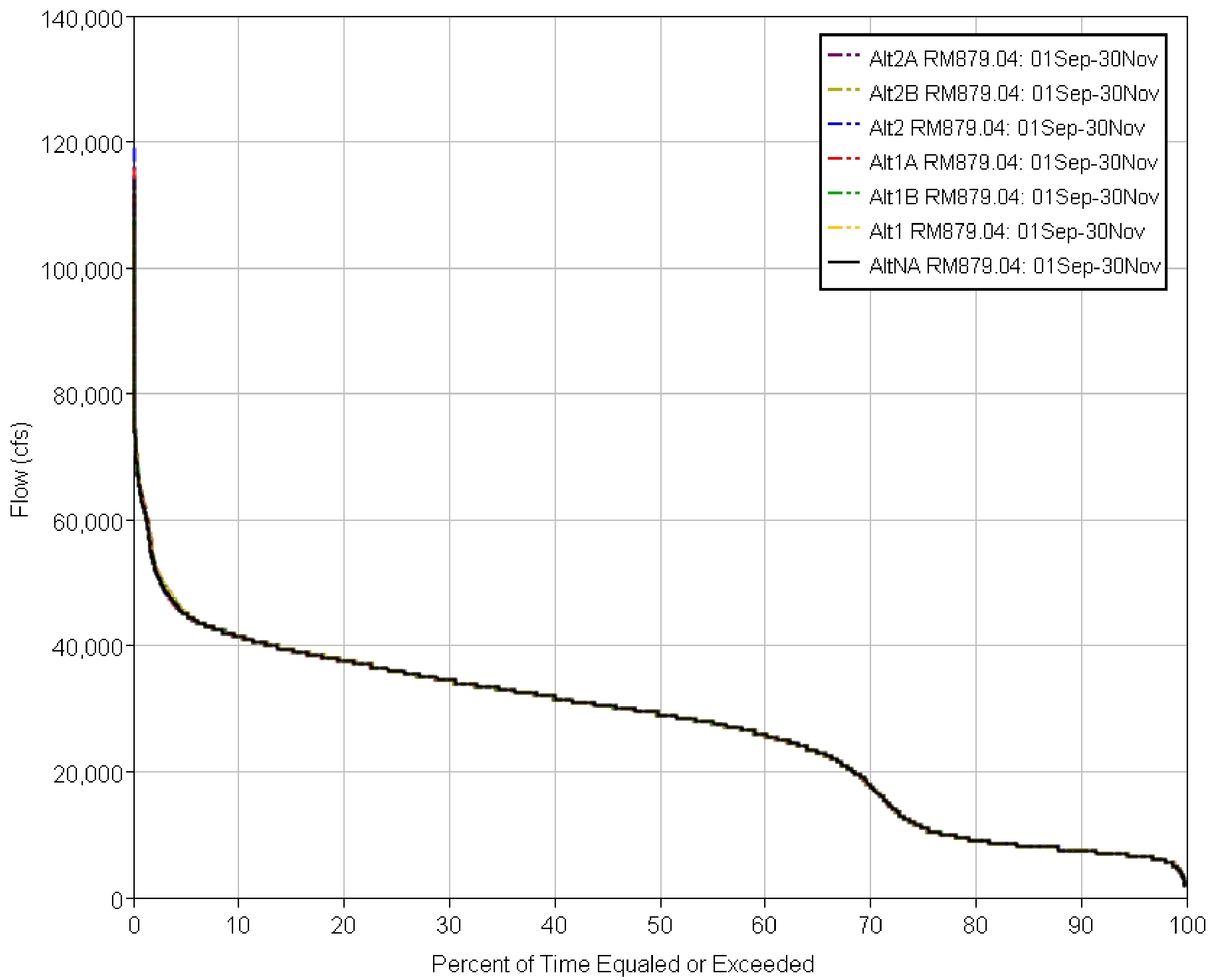


Plate 57: Fort Randall Fall Duration

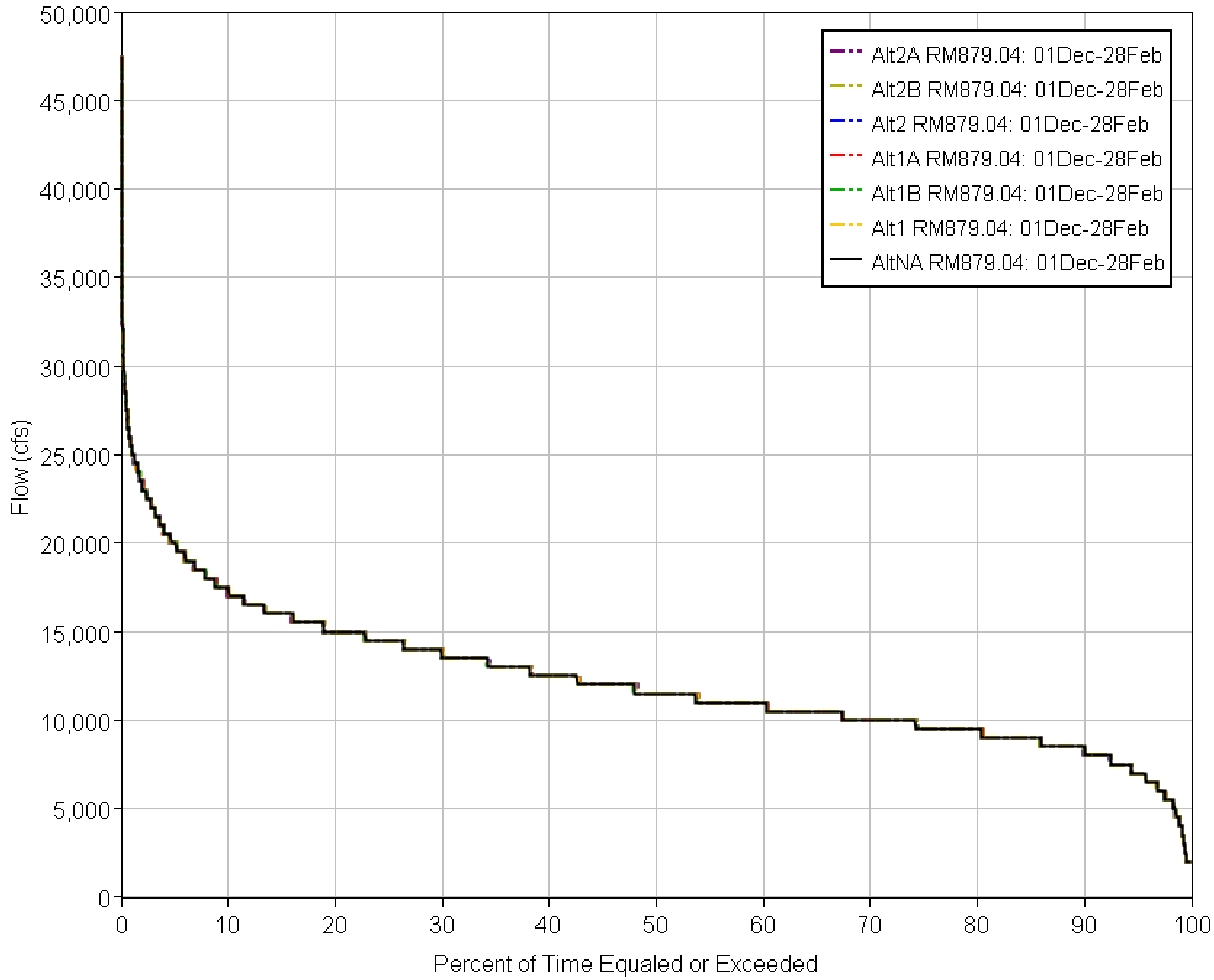


Plate 58: Fort Randall Winter Duration

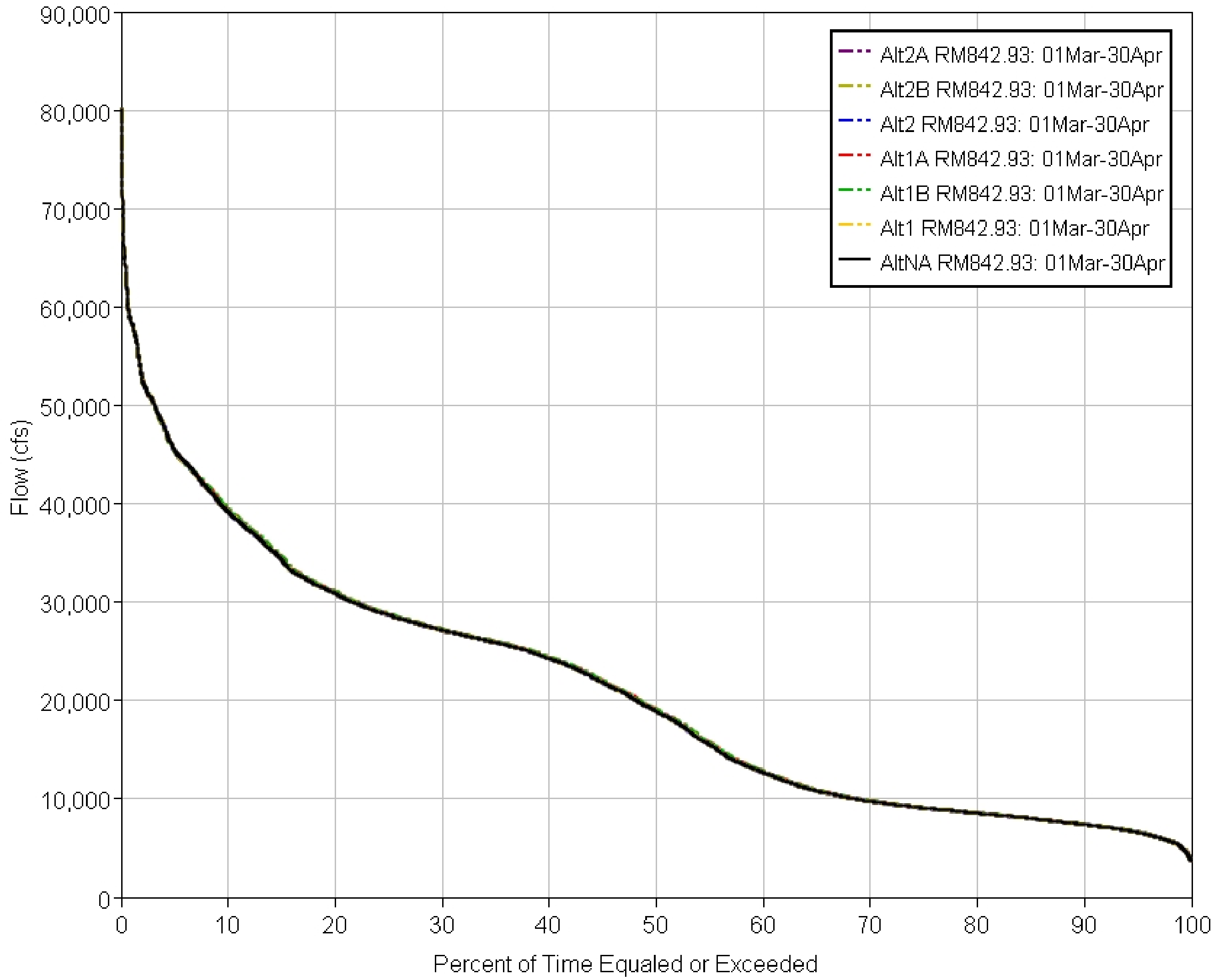


Plate 59: Niobrara Spring Duration

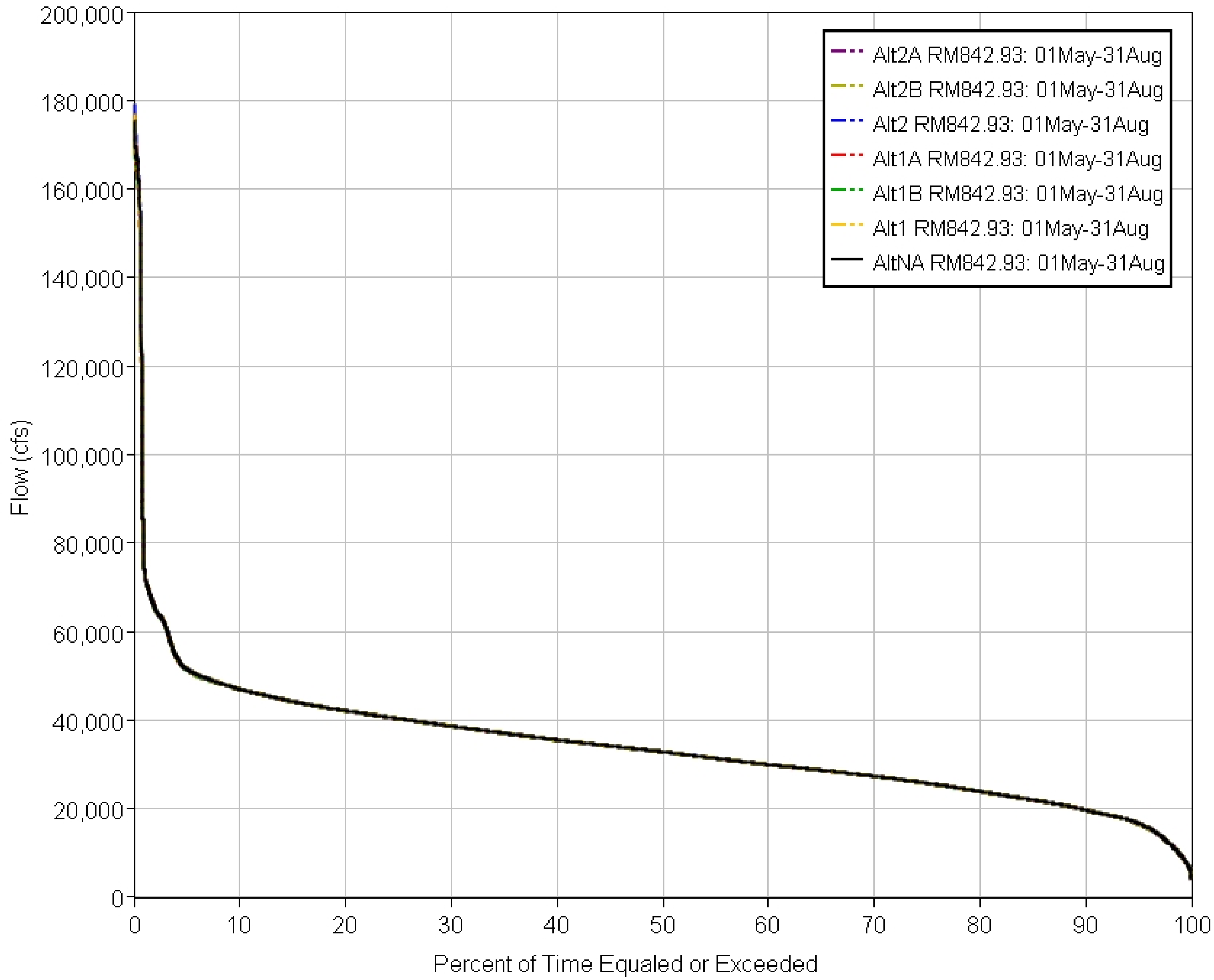


Plate 60: Niobrara Summer Duration

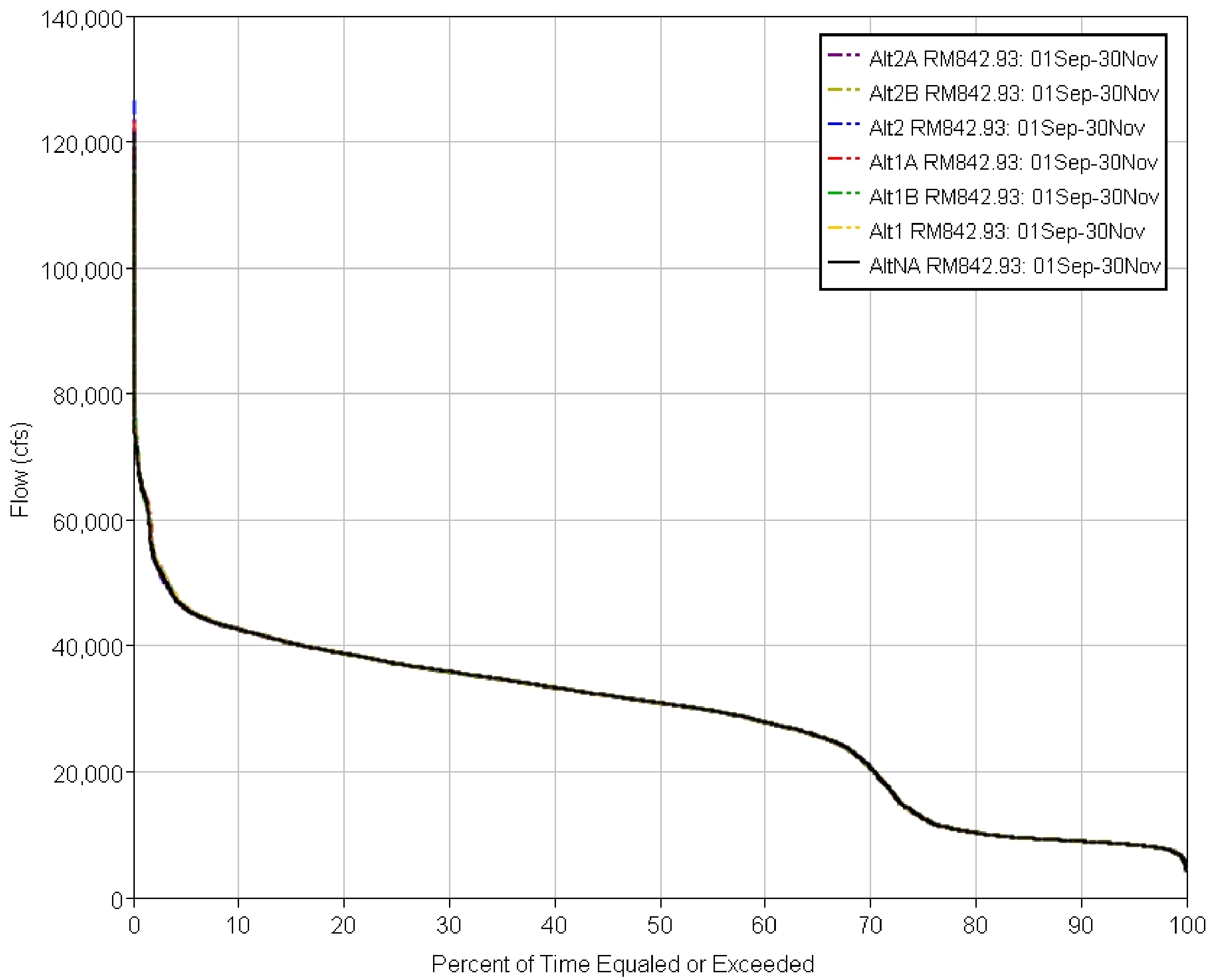


Plate 61: Niobrara Fall Duration

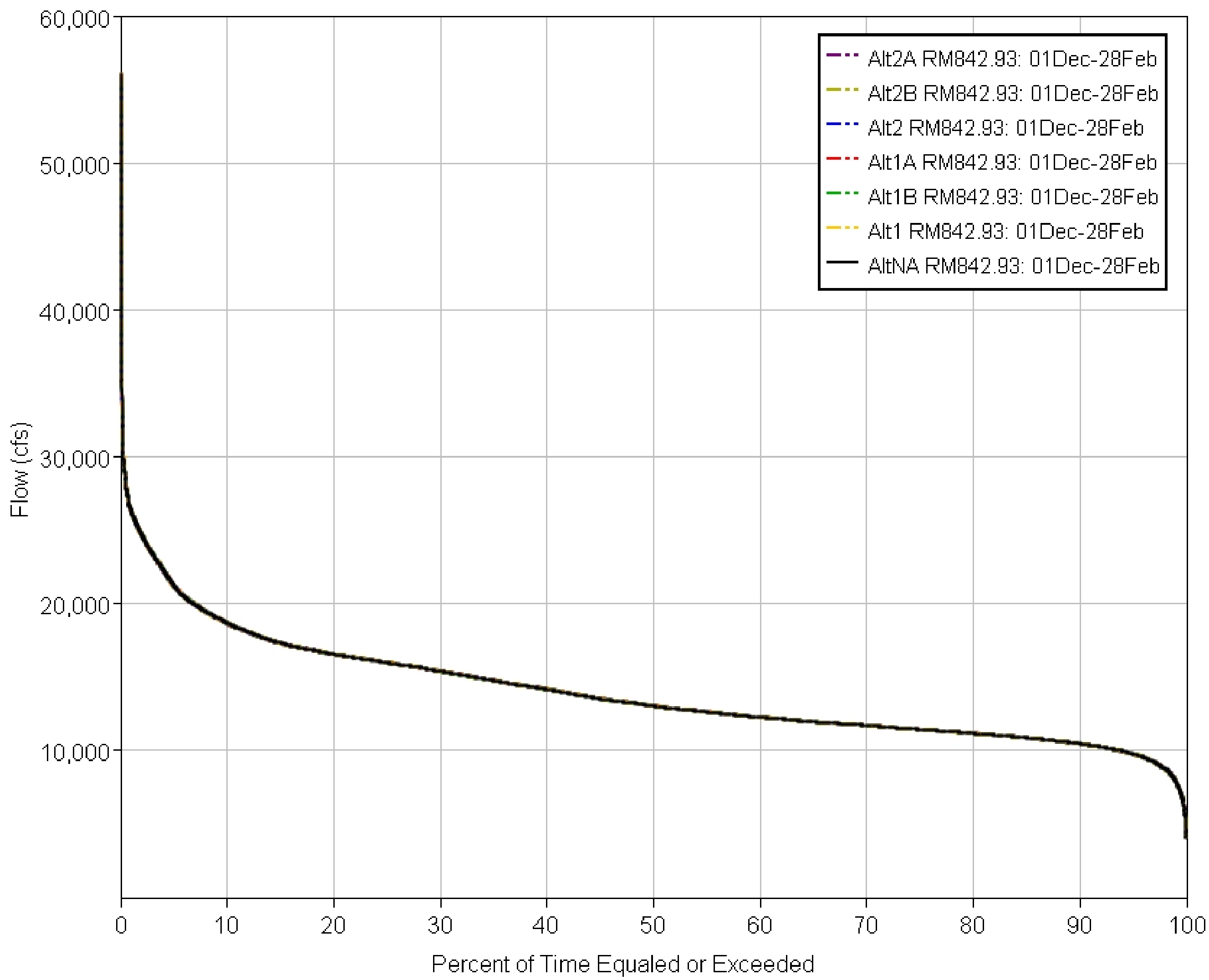


Plate 62: Niobrara Winter Duration

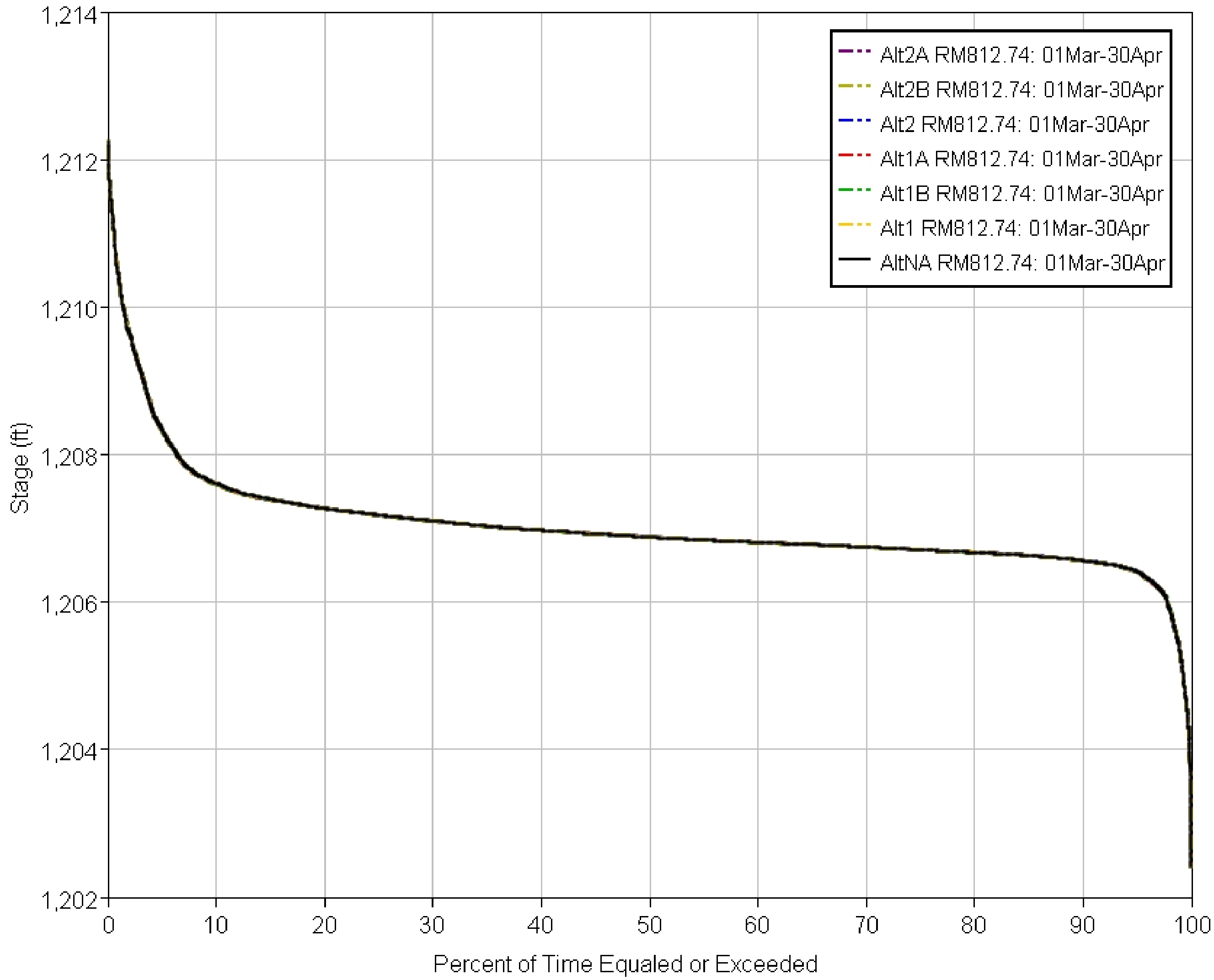


Plate 63: Lewis and Clark Lake Spring Duration

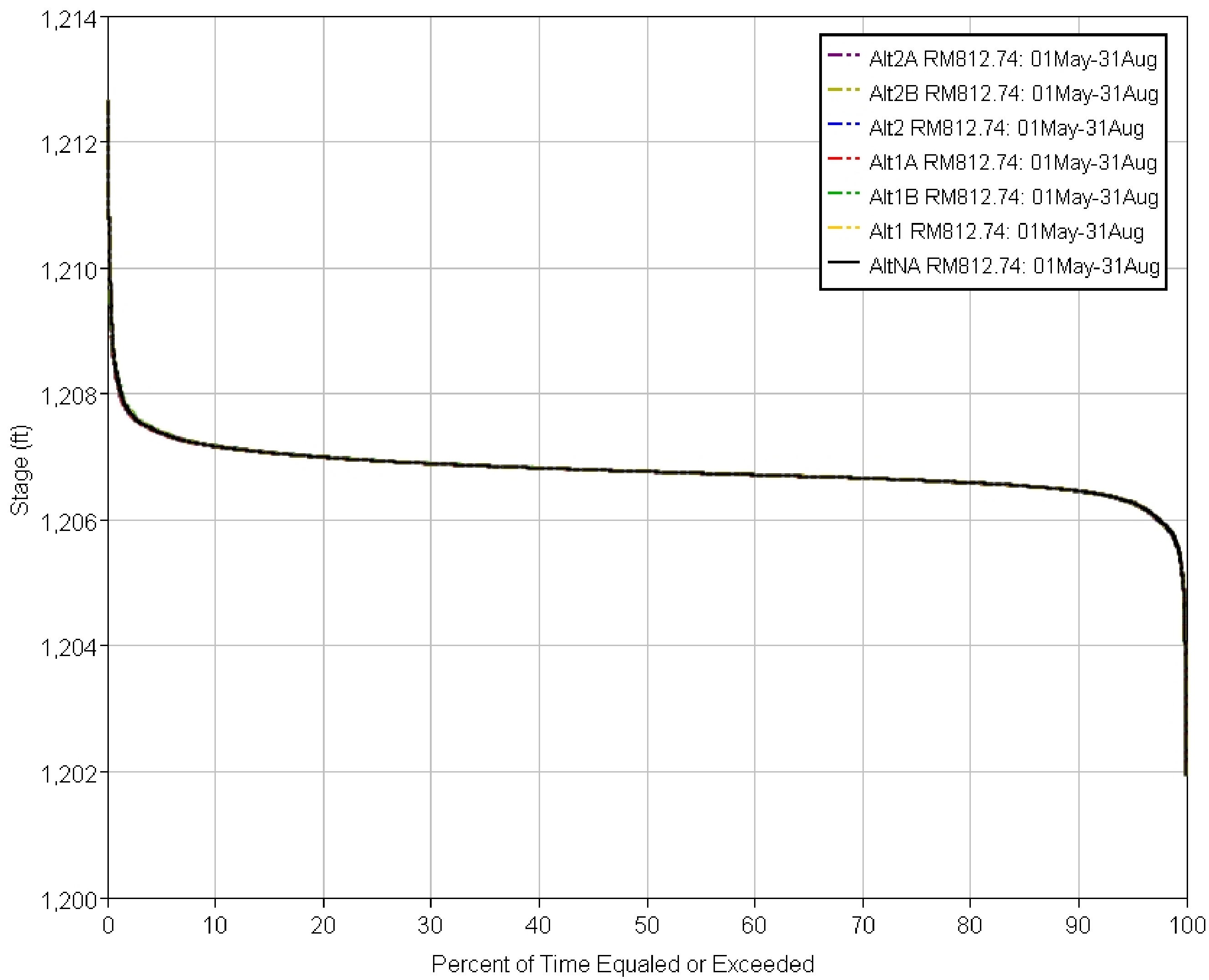


Plate 64: Lewis and Clark Lake Summer Duration

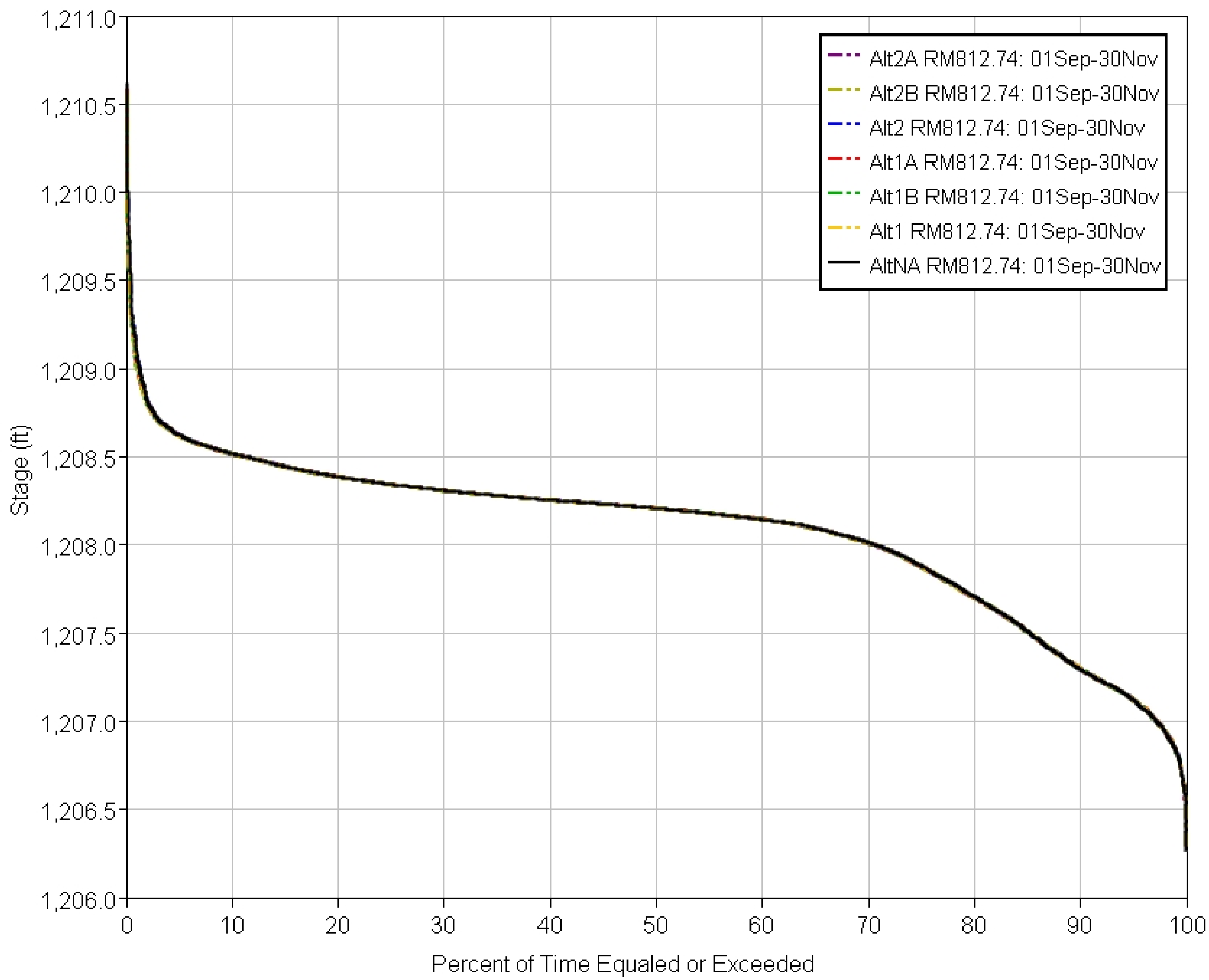


Plate 65: Lewis and Clark Lake Fall Duration

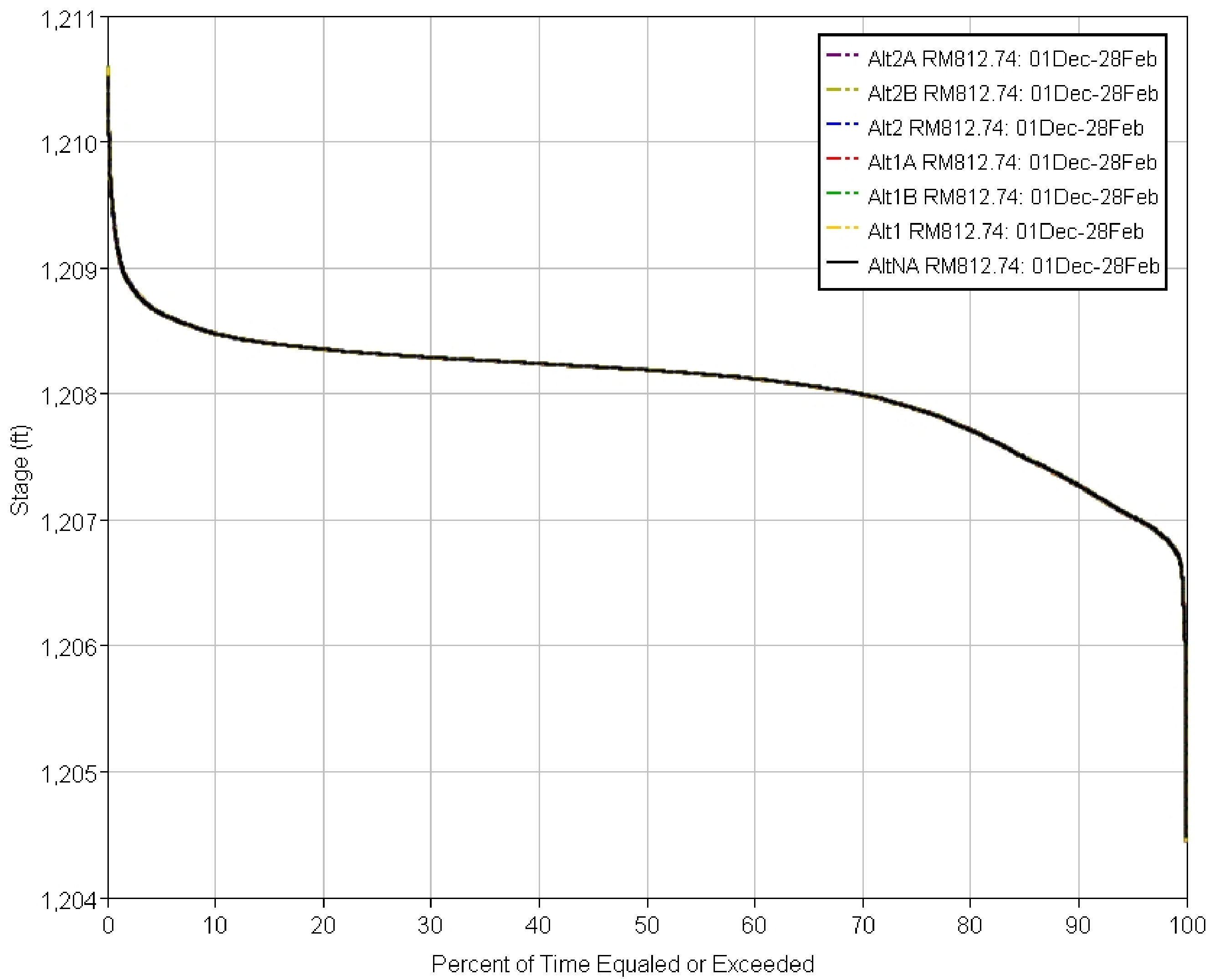


Plate 66: Lewis and Clark Lake Winter Duration

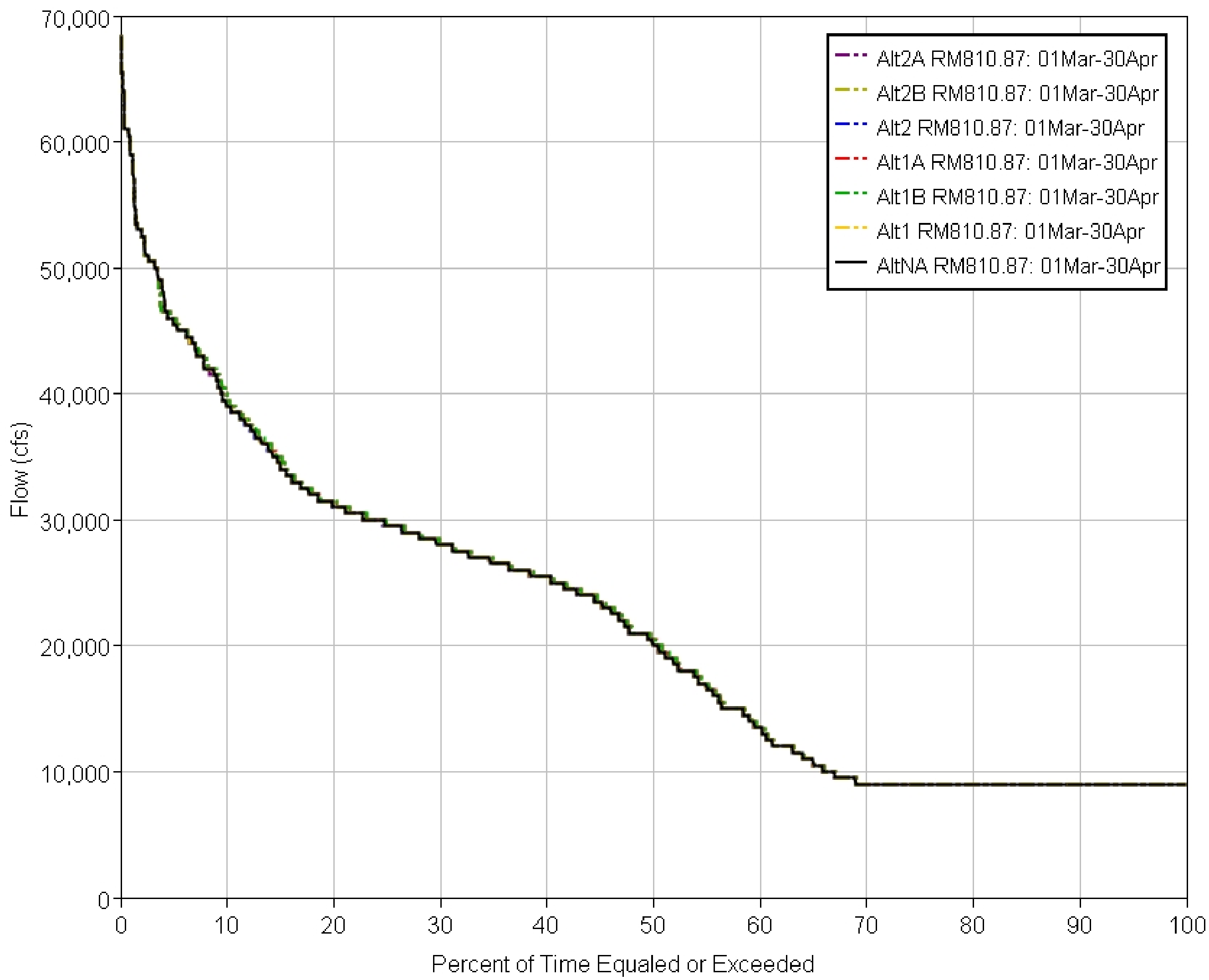


Plate 67: Gavins Point Spring Duration

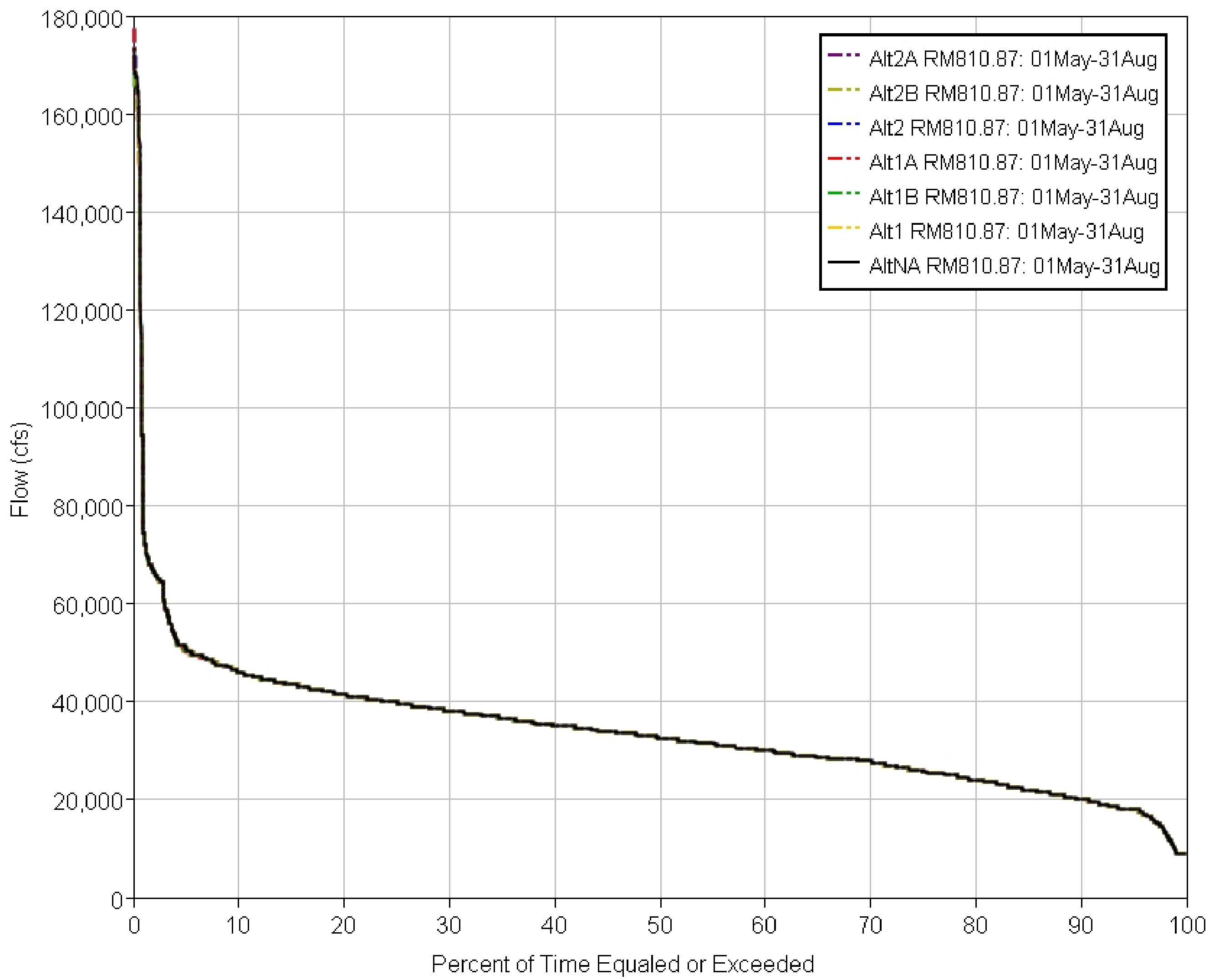


Plate 68: Gavins Point Summer Duration

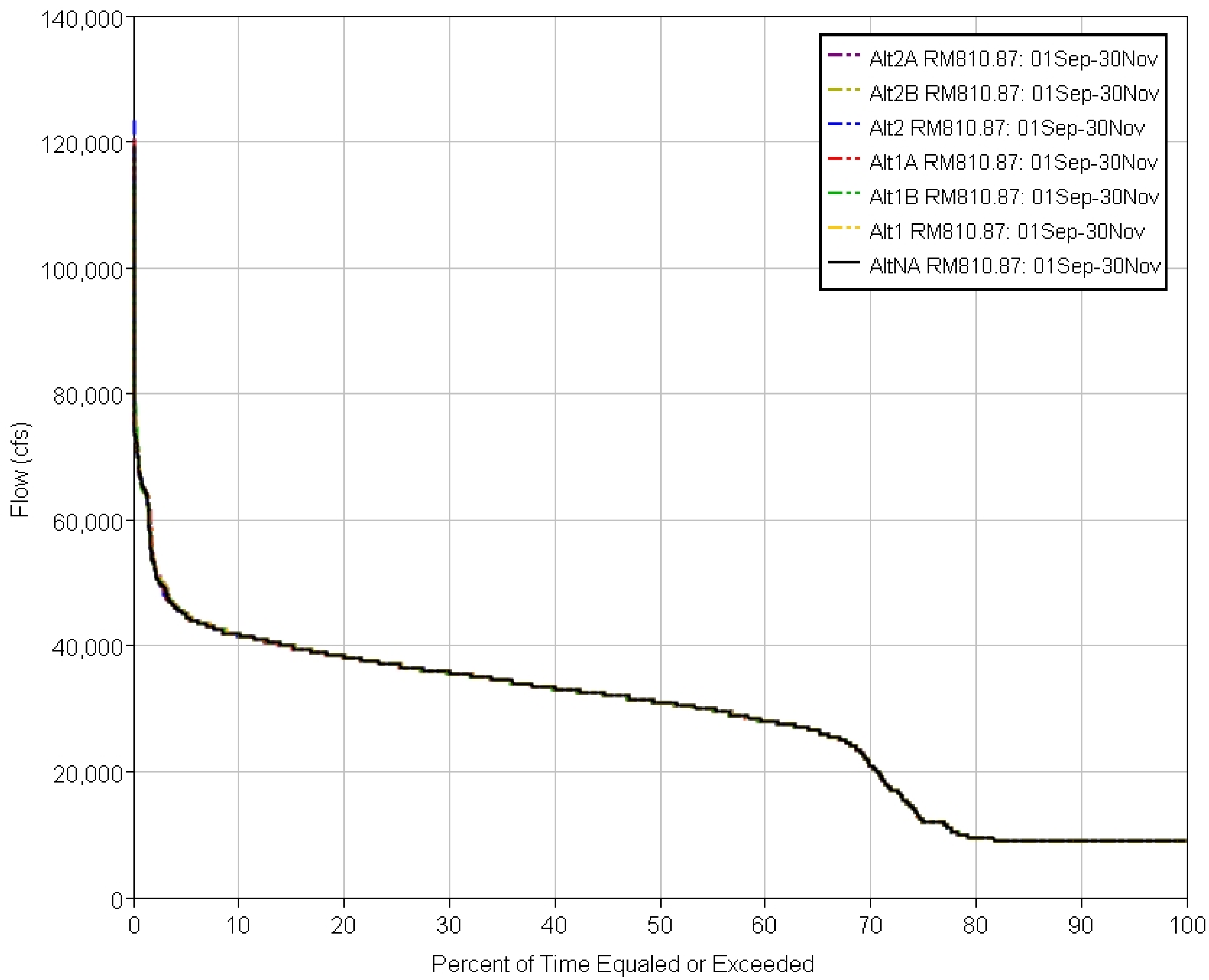


Plate 69: Gavins Point Fall Duration

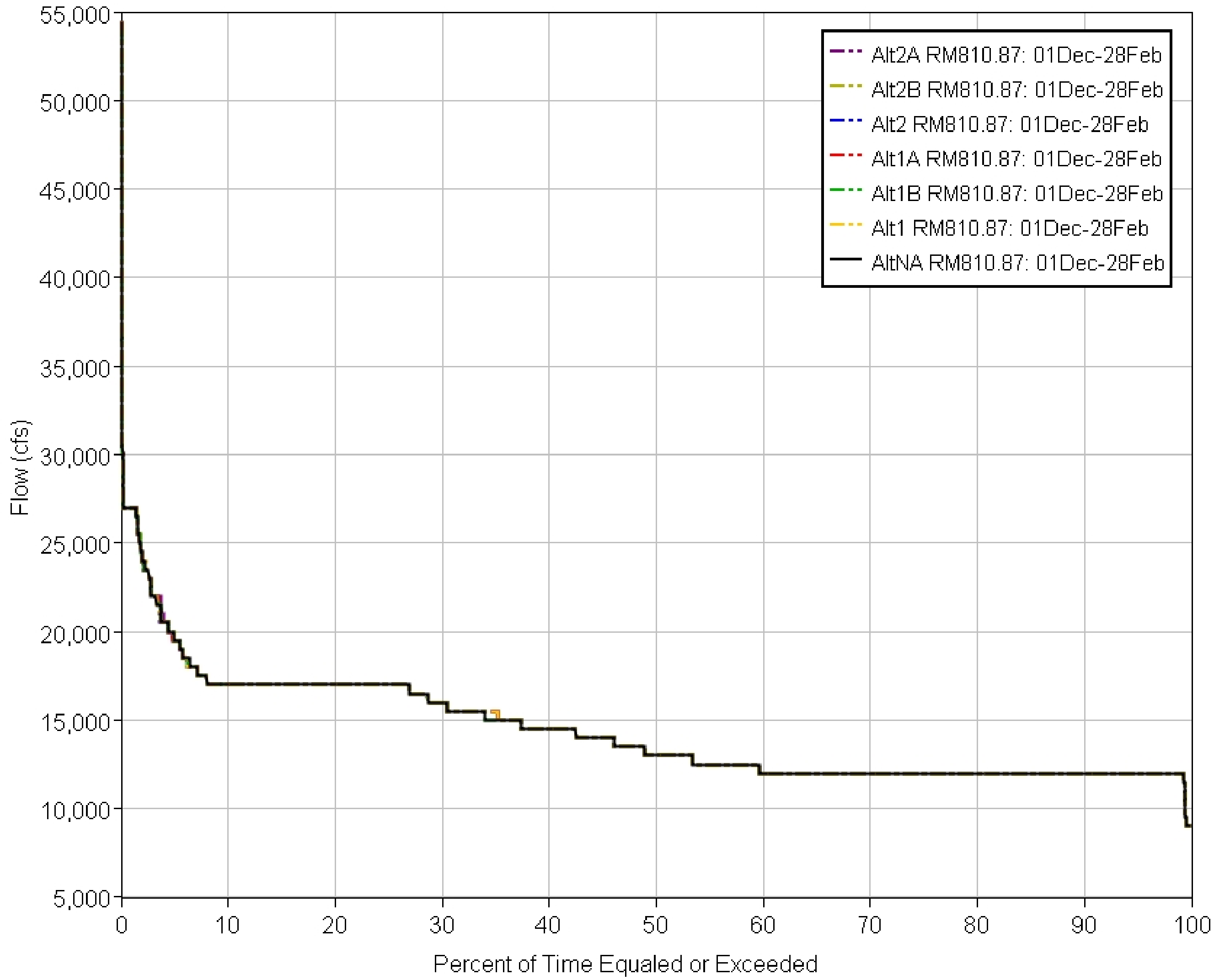


Plate 70: Gavins Point Winter Duration

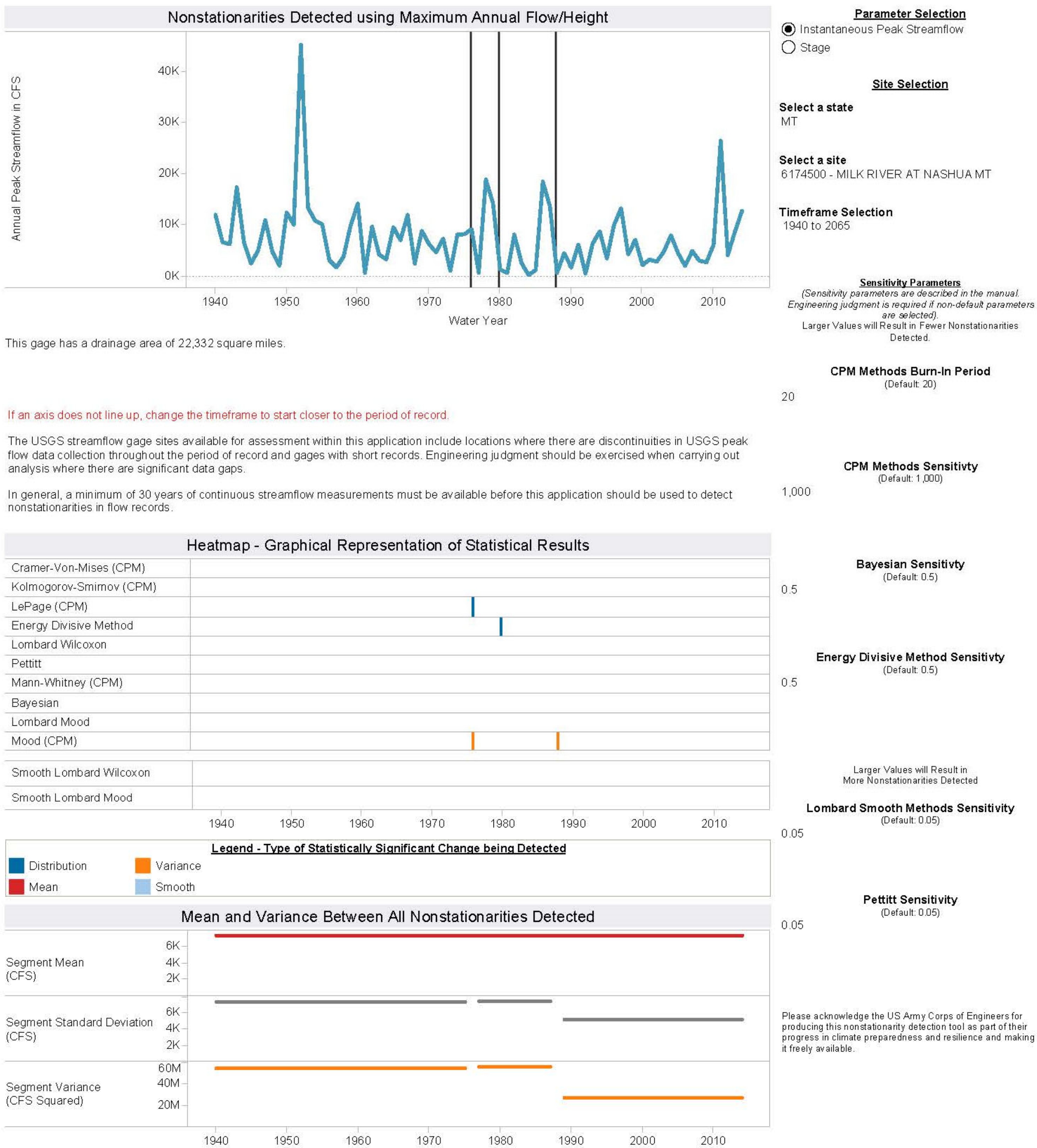
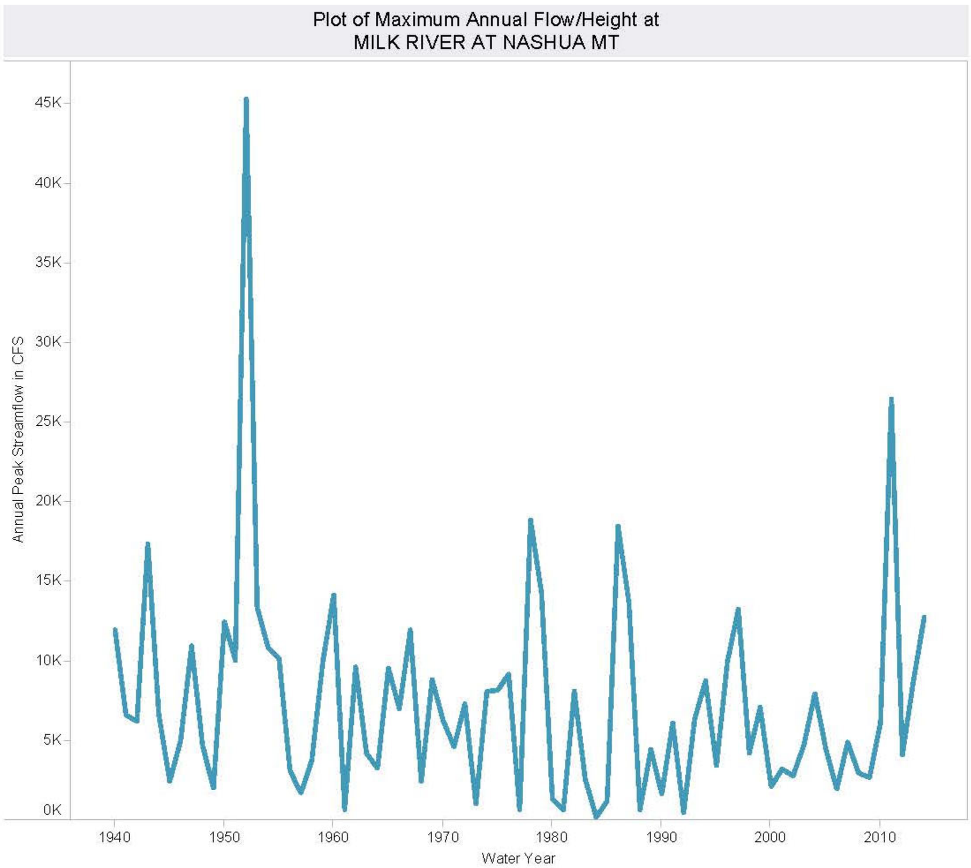


Plate 71: NSD Milk River at Nashua, MT



Timeframe Selection
1939 to 2065

Monotonic Trend Analysis

Is there a statistically significant trend?
No, using the Mann-Kendall Test at the .05 level of significance. The exact p-value for this test was 0.104.
No, using the Spearman Rank Order Test at the .05 level of significance. The exact p-value for this test was 0.105.

What type of trend was detected?
Using parametric statistical methods, **no trend** was detected.
Using robust parametric statistical methods (Sen's Slope), **no trend** was detected.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.

Plate 72: Monotonic Trend Analysis, Milk River at Nashua, MT

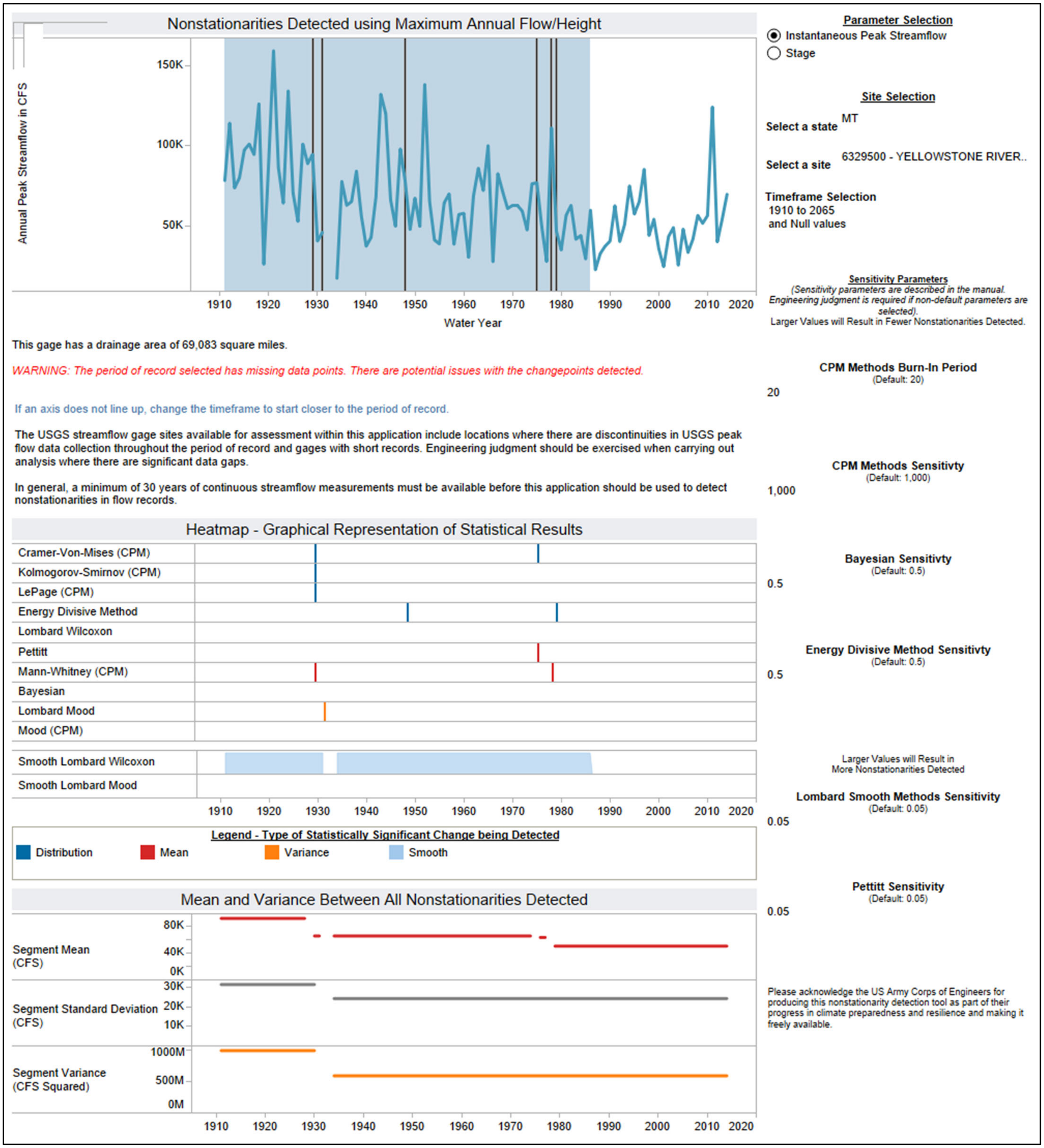
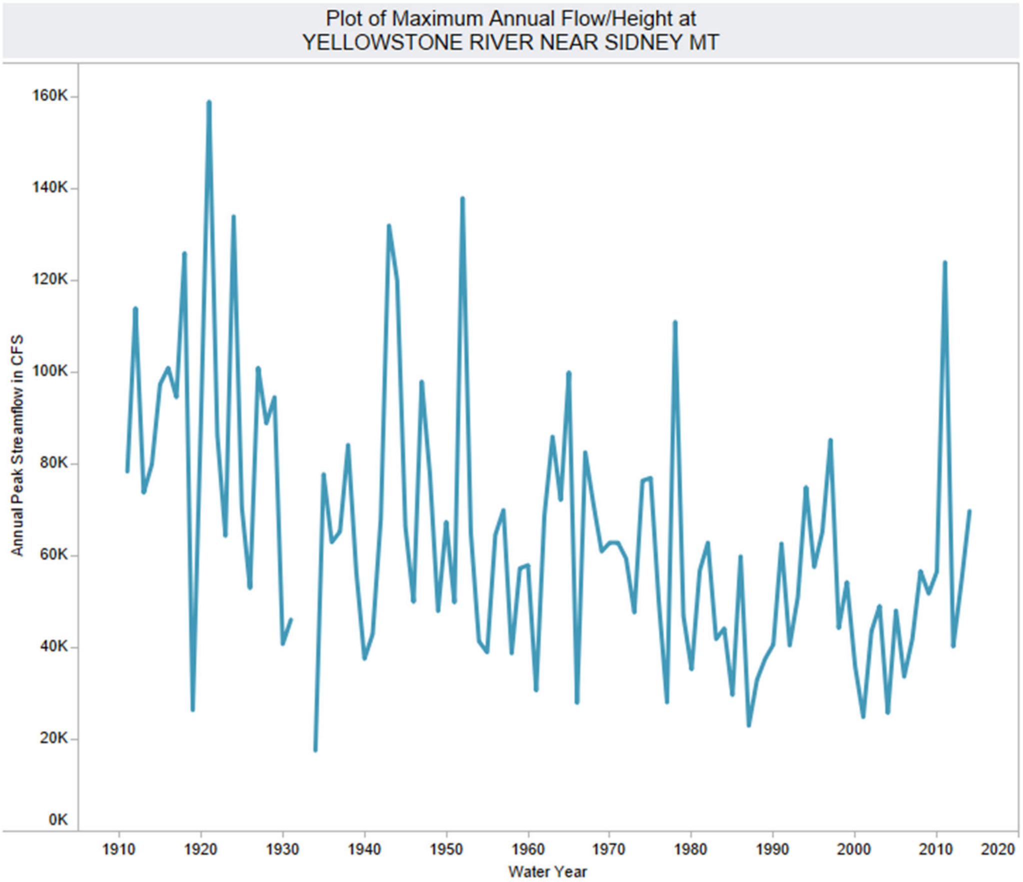


Plate 73: NSD Yellowstone River at Sidney, MT



Timeframe Selection
1883 to 2061

WARNING: The period of record selected has missing data points. There are potential issues with the trends detected.

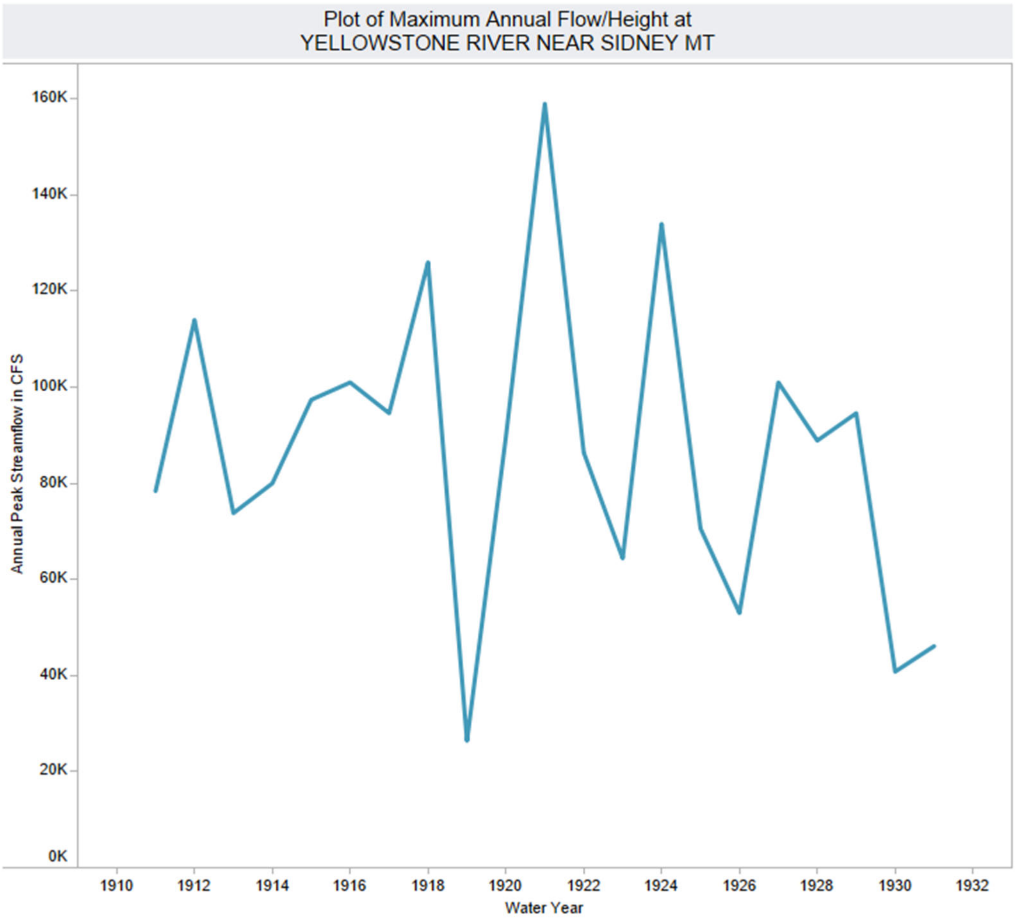
Monotonic Trend Analysis

Is there a statistically significant trend?
Yes, using the Mann-Kendall Test at the .05 level of significance. The exact p-value for this test was less than 1e-3.
Yes, using the Spearman Rank Order Test at the .05 level of significance. The exact p-value for this test was less than 1e-3.

What type of trend was detected?
Using parametric statistical methods, **a negative trend** was detected.
Using robust parametric statistical methods (Sen's Slope), **Null** was detected.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.

Plate 74: Monotonic Trend Analysis, Yellowstone River at Sidney, MT- 1911-2014



Timeframe Selection
1883 to 1932

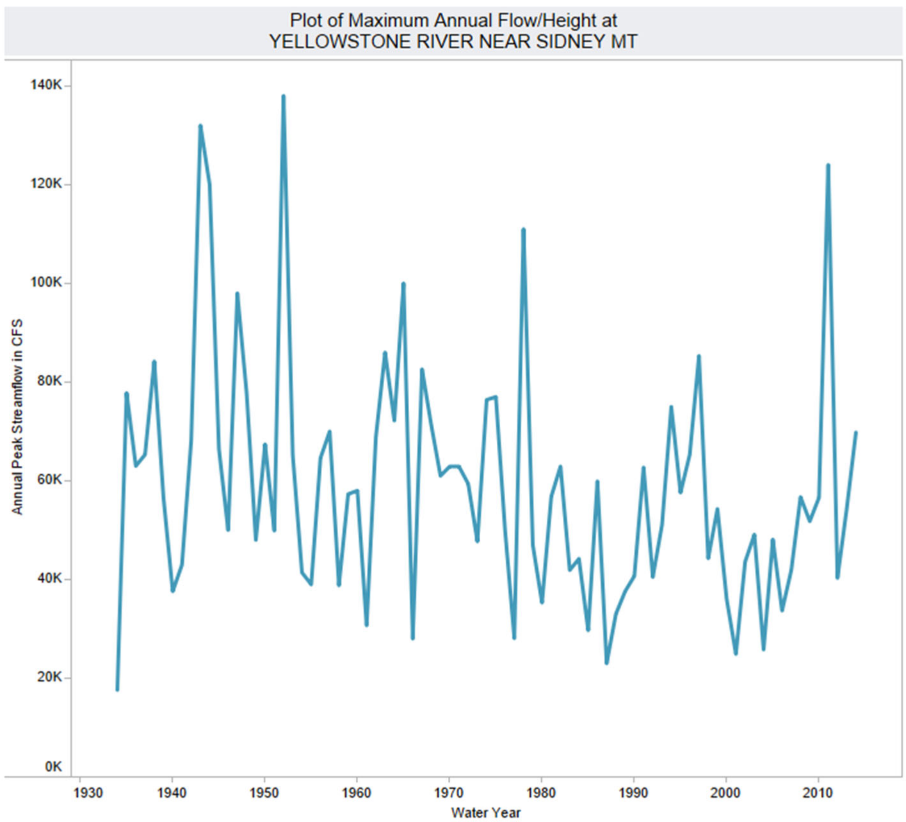
Monotonic Trend Analysis

Is there a statistically significant trend?
No, using the Mann-Kendall Test at the .05 level of significance. The exact p-value for this test was 0.290.
No, using the Spearman Rank Order Test at the .05 level of significance. The exact p-value for this test was 0.249.

What type of trend was detected?
Using parametric statistical methods, **no trend** was detected.
Using robust parametric statistical methods (Sen's Slope), **no trend** was detected.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.

Plate 75: Monotonic Trend Analysis 1911-1930, Yellowstone River at Sidney, MT



Timeframe Selection
1932 to 2061

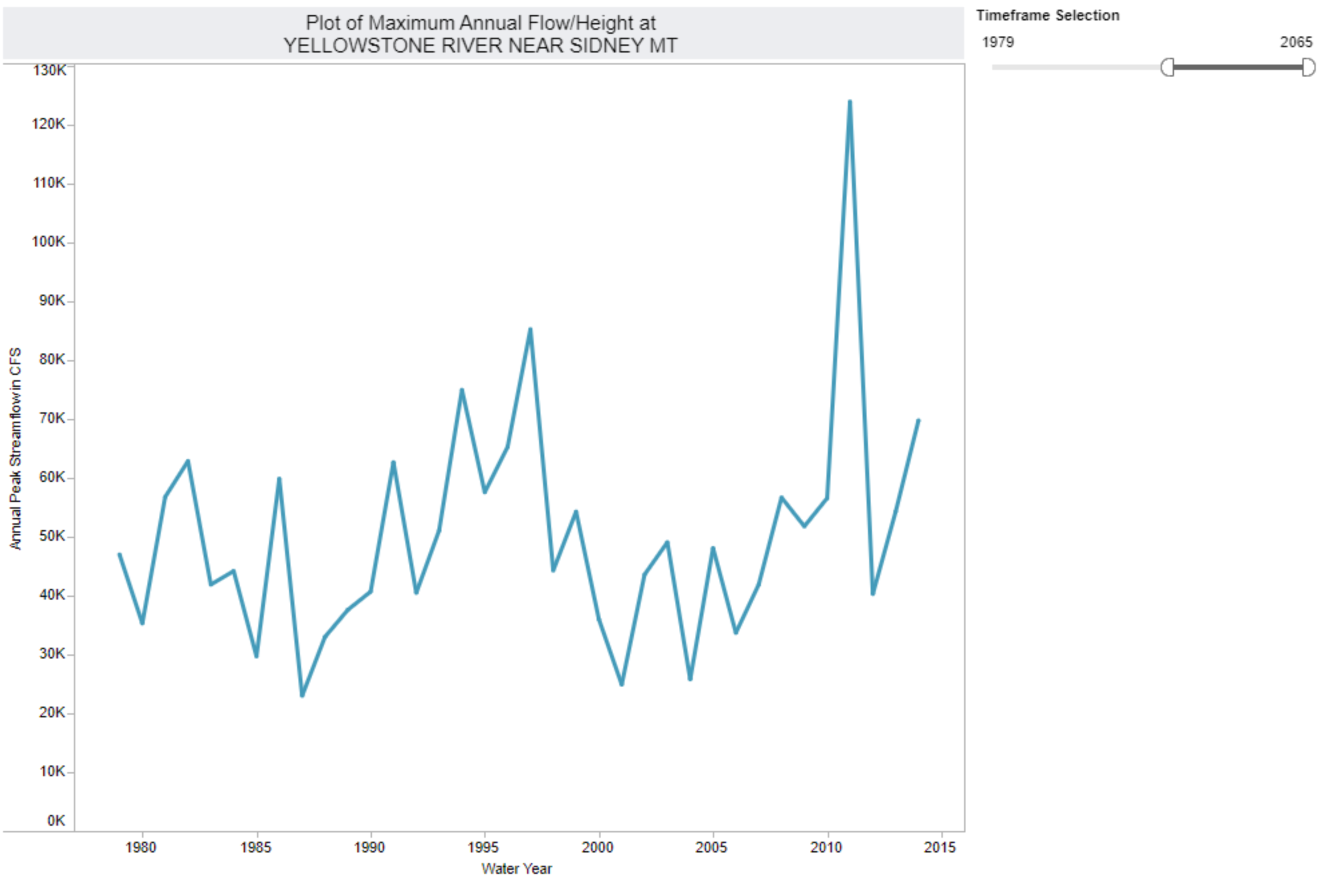
Monotonic Trend Analysis

Is there a statistically significant trend?
Yes, using the Mann-Kendall Test at the .05 level of significance. The exact p-value for this test was 0.010.
Yes, using the Spearman Rank Order Test at the .05 level of significance. The exact p-value for this test was 0.010.

What type of trend was detected?
Using parametric statistical methods, **a negative trend** was detected.
Using robust parametric statistical methods (Sen's Slope), **Null** was detected.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.

Plate 76: Monotonic Trend Analysis 1932-2014, Yellowstone River at Sidney, MT



Monotonic Trend Analysis

Is there a statistically significant trend?
No, using the Mann-Kendall Test at the .05 level of significance. The exact p-value for this test was 0.294.
No, using the Spearman Rank Order Test at the .05 level of significance. The exact p-value for this test was 0.346.

What type of trend was detected?
Using parametric statistical methods, **no trend** was detected.
Using robust parametric statistical methods (Sen's Slope), **no trend** was detected.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.

Plate 77: Monotonic Trend Analysis 1979-2014, Yellowstone River at Sidney, MT

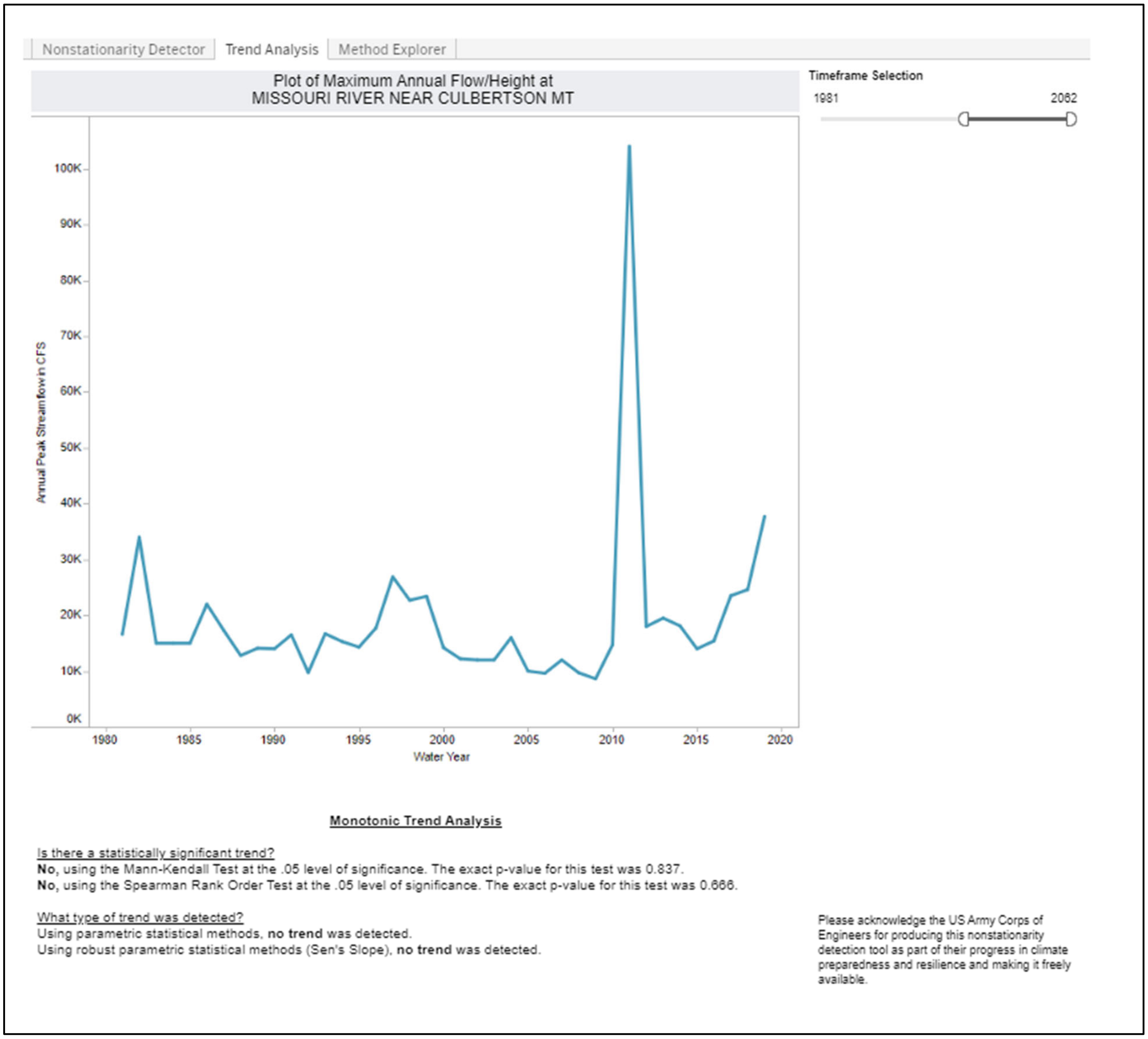


Plate 78. Monotonic Trend Analysis 1981-2020, Missouri River at Culbertson, MT

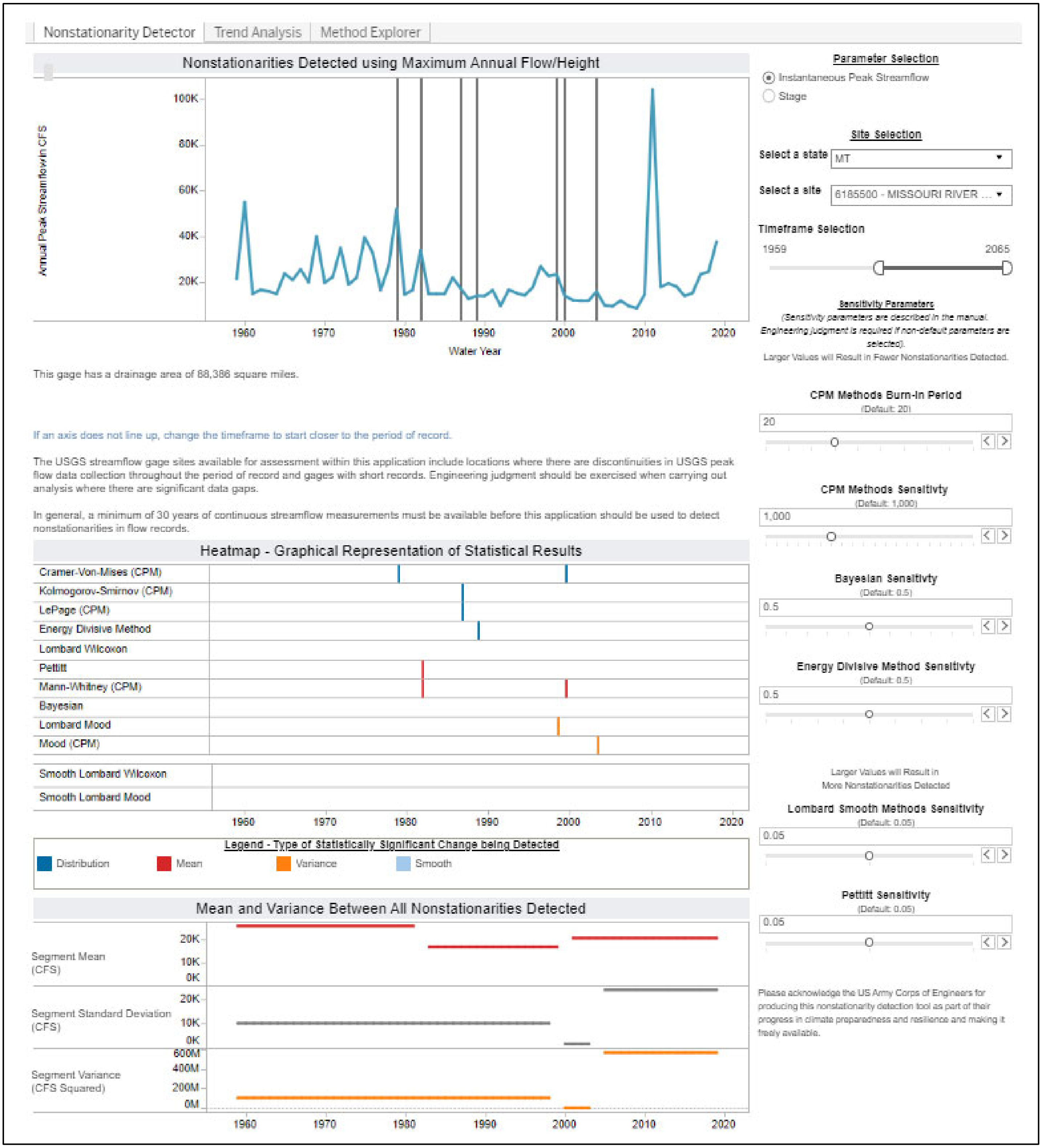
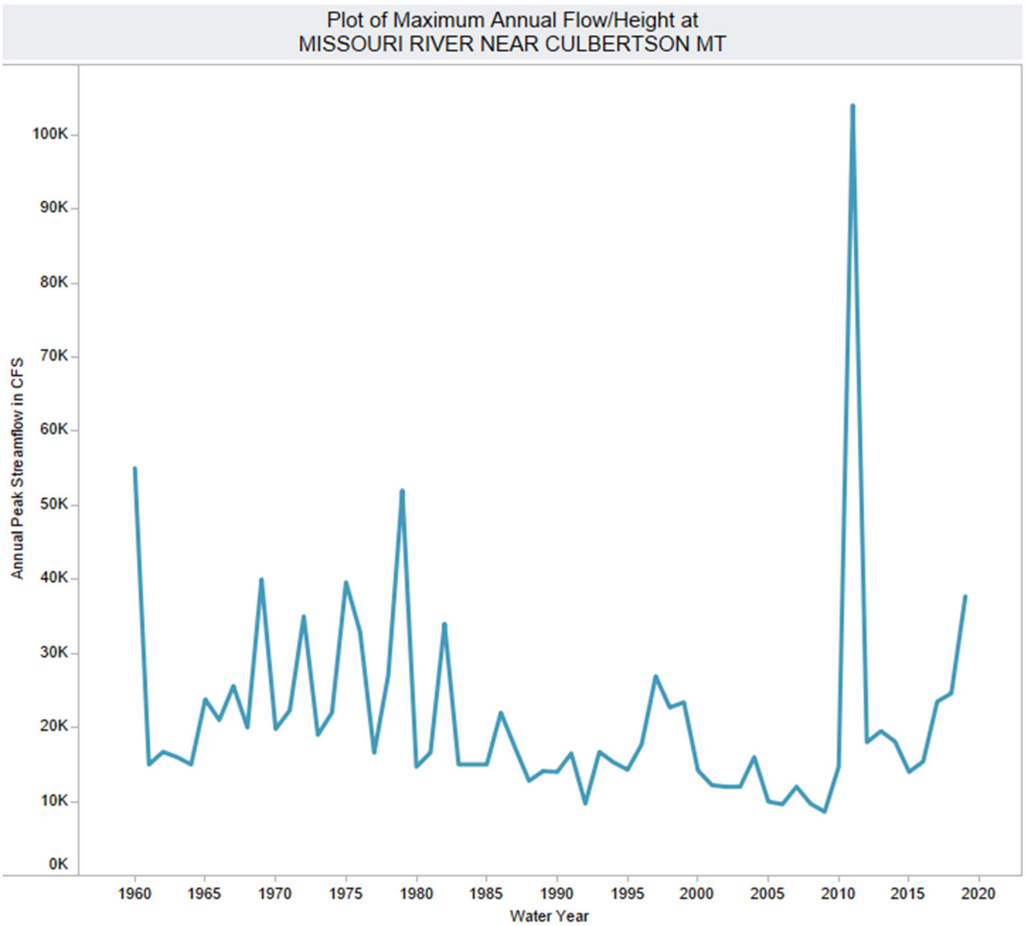


Plate 79: NSD Missouri River at Culbertson, MT-1959-2019



Timeframe Selection
1960 to 2065

Monotonic Trend Analysis

Is there a statistically significant trend?
Yes, using the Mann-Kendall Test at the .05 level of significance. The exact p-value for this test was 0.012.
Yes, using the Spearman Rank Order Test at the .05 level of significance. The exact p-value for this test was 0.017.

What type of trend was detected?
Using parametric statistical methods, **a negative trend** was detected.
Using robust parametric statistical methods (Sen's Slope), **Null** was detected.

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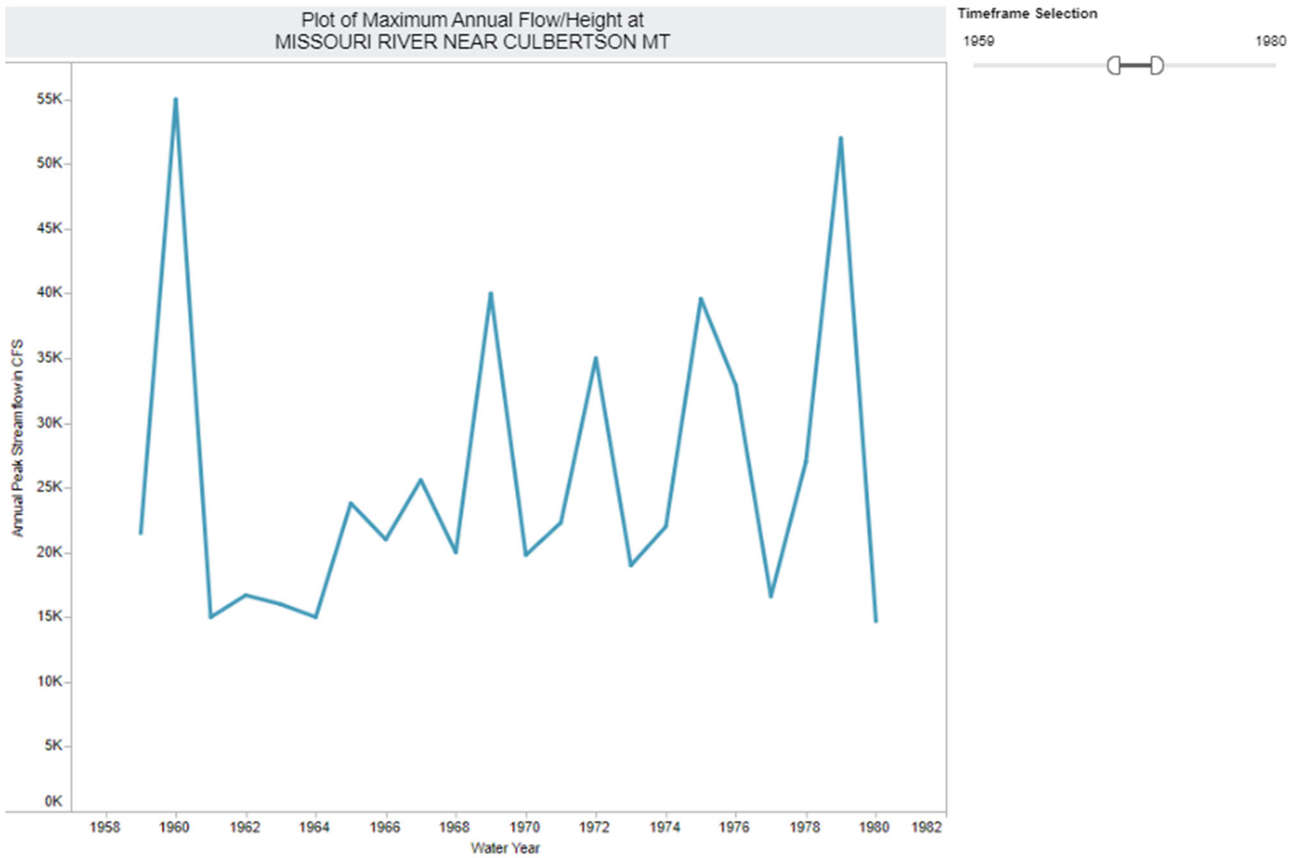
Plate 80: Monotonic Trend Analysis, Missouri River at Culbertson, MT- 1959-2019



Monotonic Trend Analysis

Is there a statistically significant trend?
No, using the Mann-Kendall Test at the .05 level of significance. The exact p-value for this test was 0.382.
No, using the Spearman Rank Order Test at the .05 level of significance. The exact p-value for this test was 0.433.

What type of trend was detected?
Using parametric statistical methods, **no trend** was detected.
Using robust parametric statistical methods (Sen's Slope), **no trend** was detected.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.

Plate 81: Monotonic Trend Analysis 1959-1980, Missouri River at Culbertson, MT

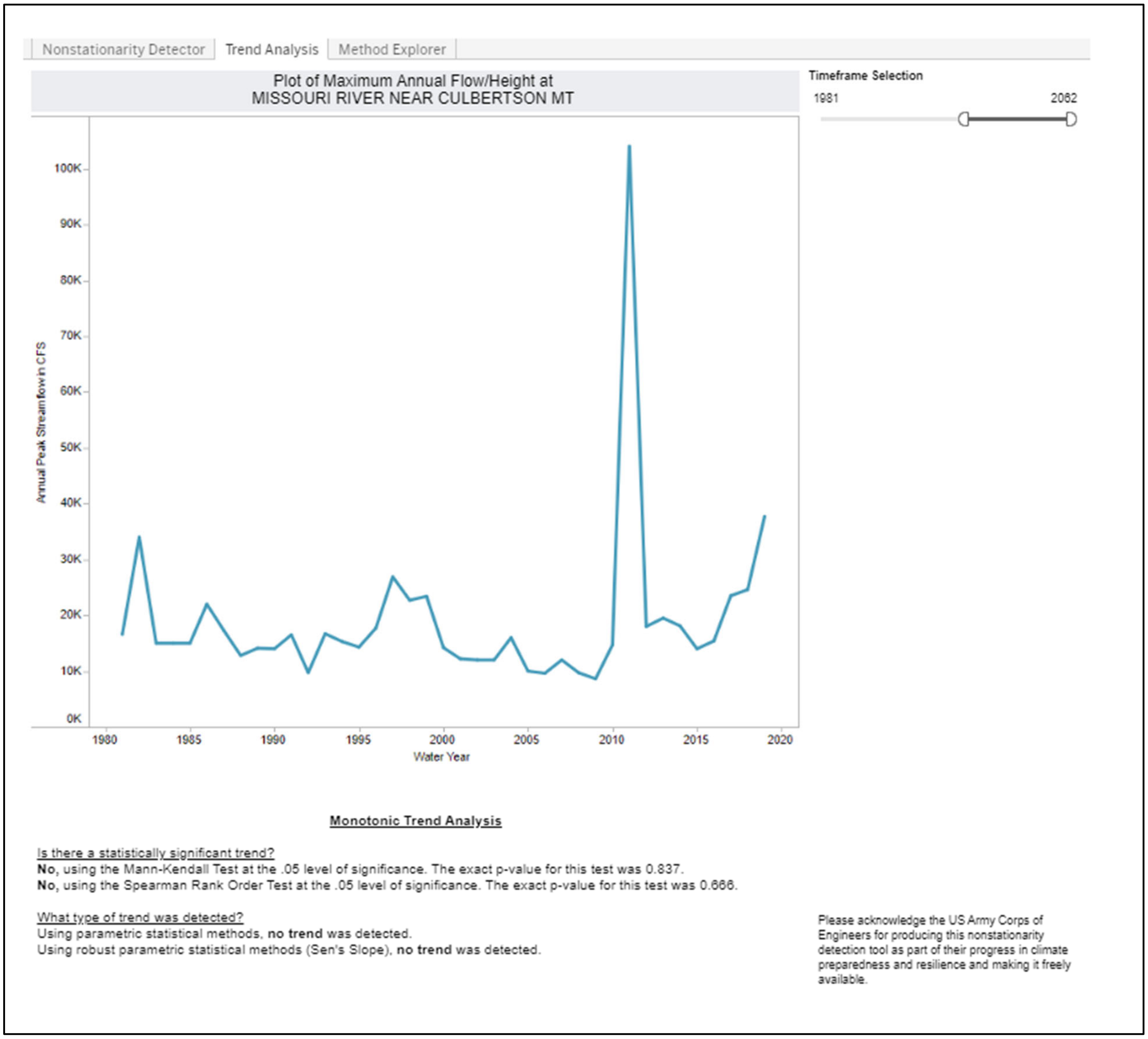


Plate 82. Monotonic Trend Analysis 1981-2020, Missouri River at Culbertson, MT

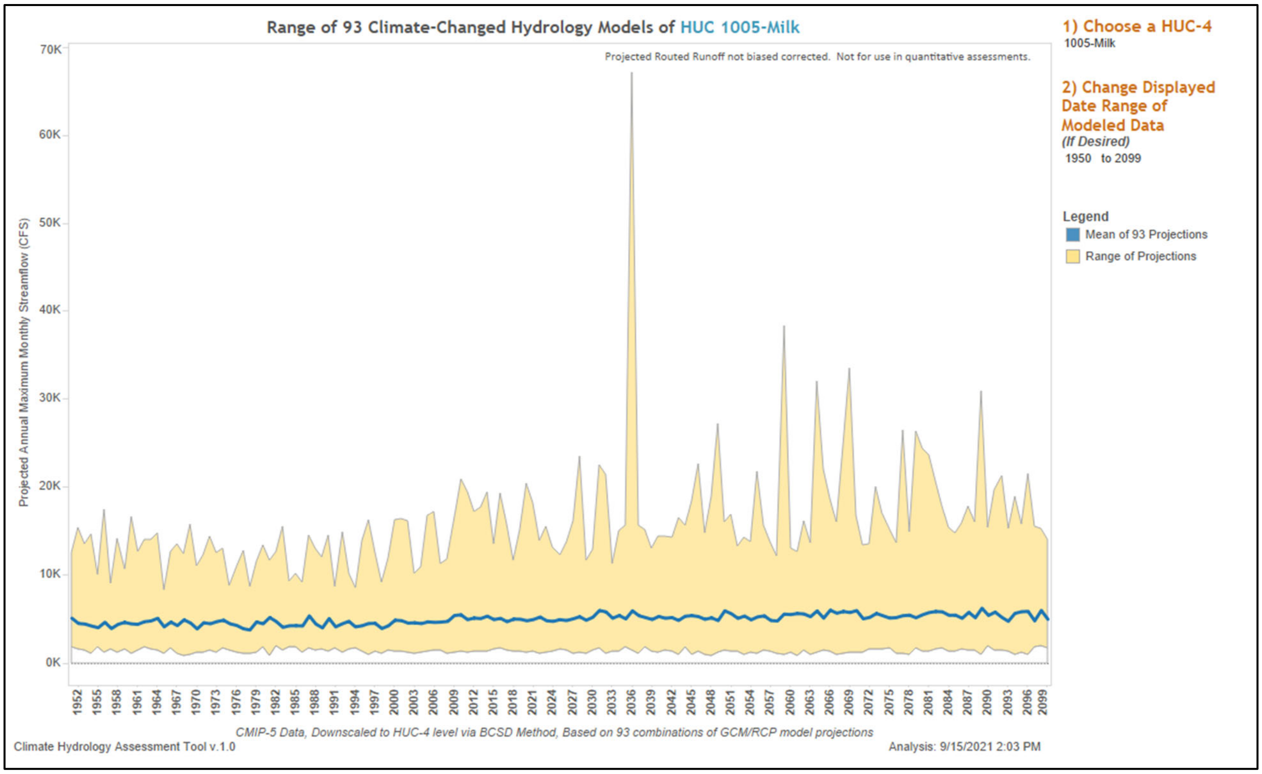


Plate 83. Milk River HUC-4 Projections and Uncertainty

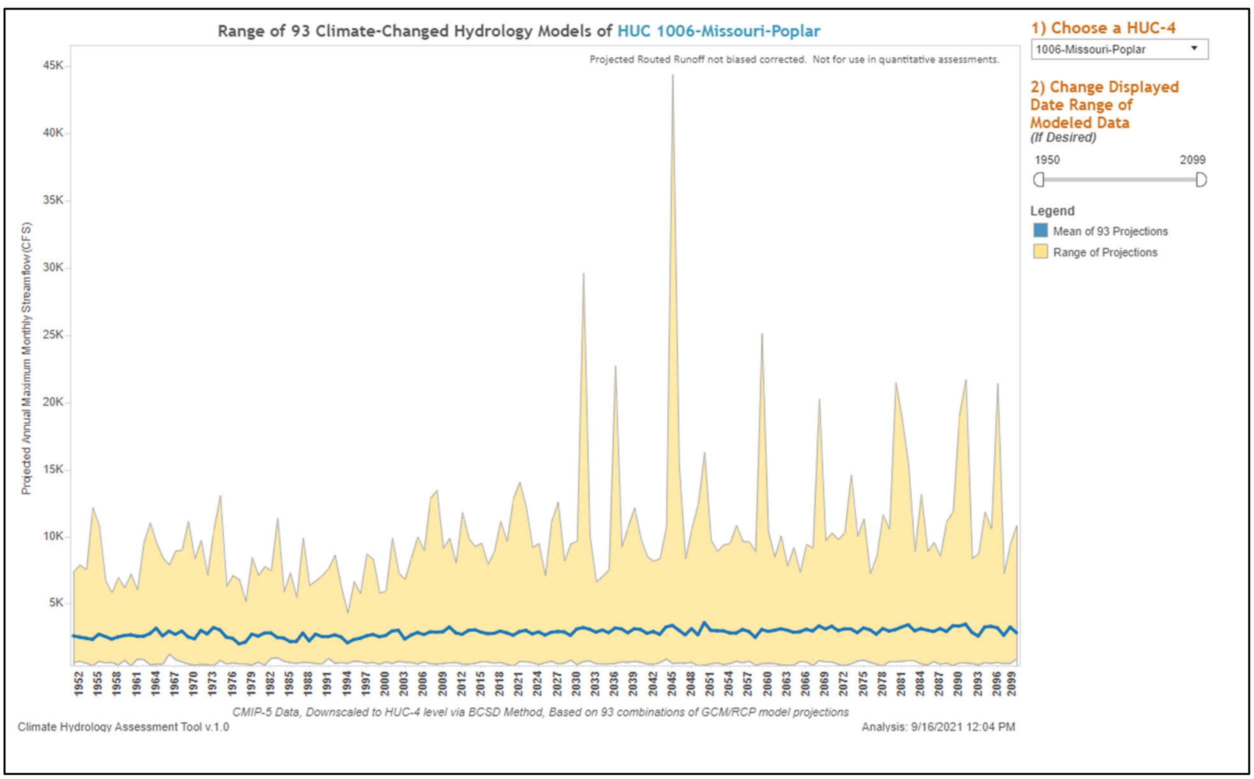


Plate 84. Missouri River-Poplar Projections and Uncertainty

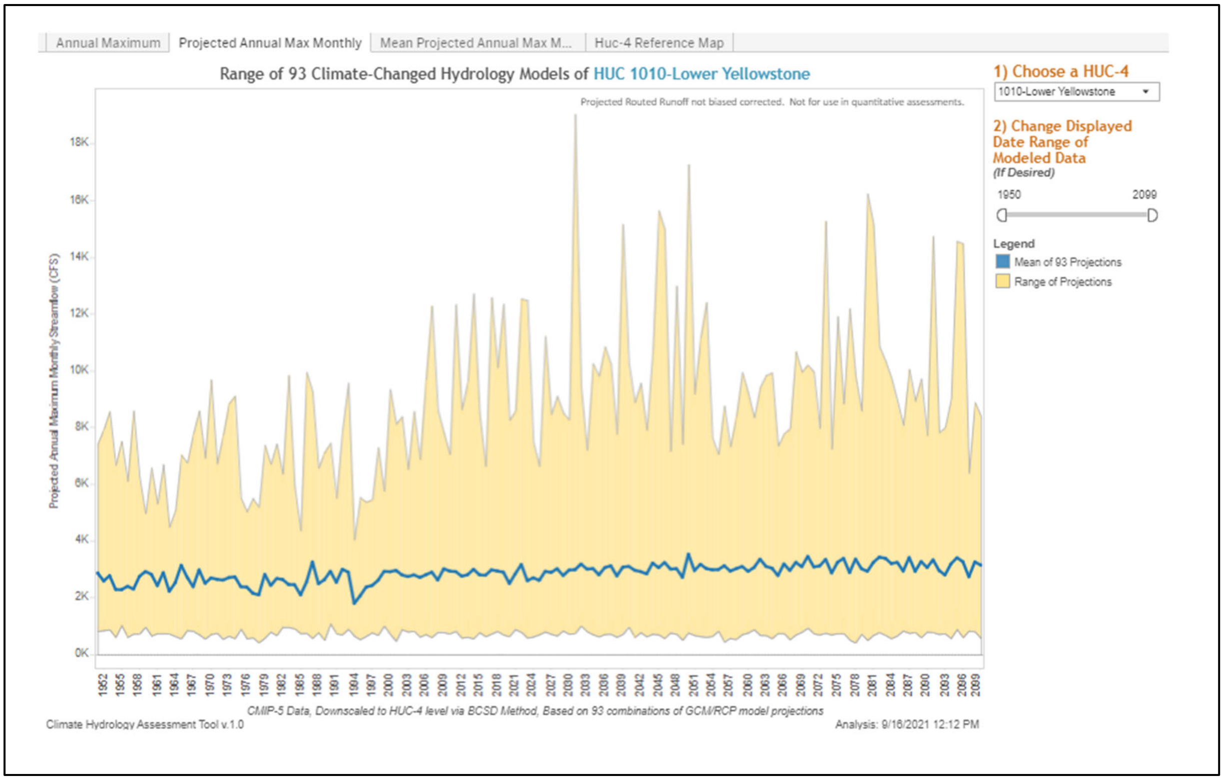


Plate 85. Lower Yellowstone Projections and Uncertainty

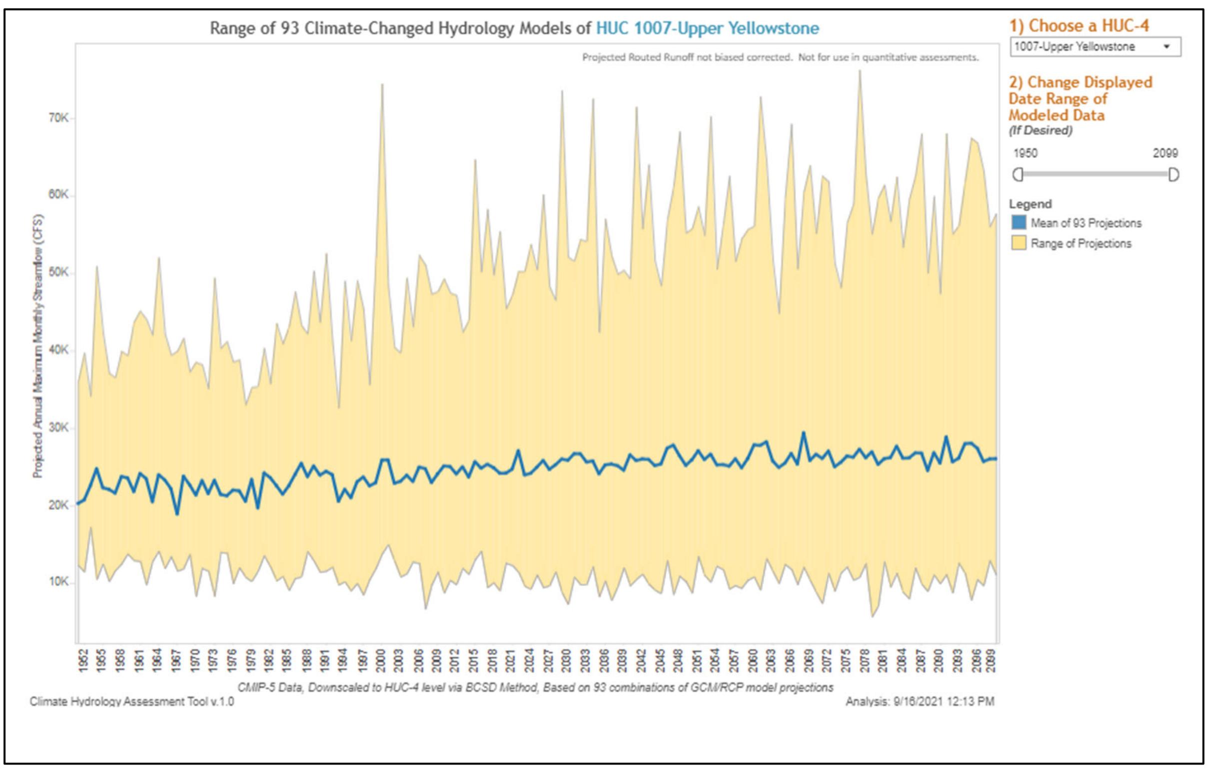


Plate 86. Upper Yellowstone Projections and Uncertainty

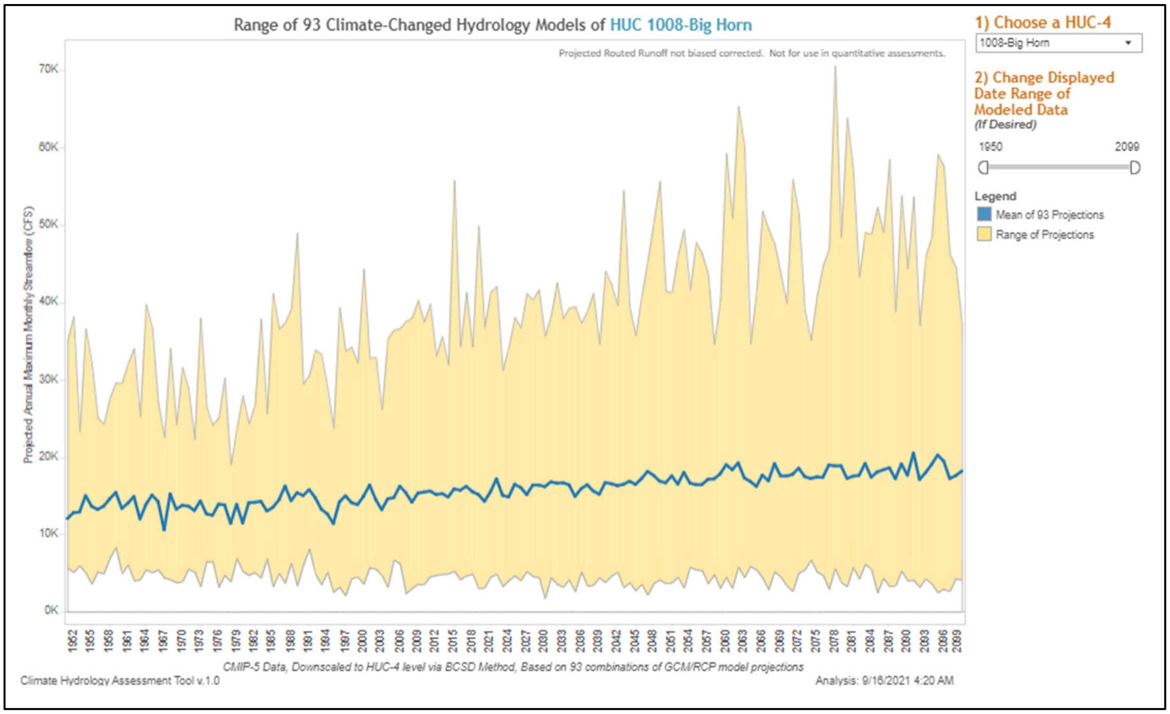


Plate 87. Bighorn Projections and Uncertainty

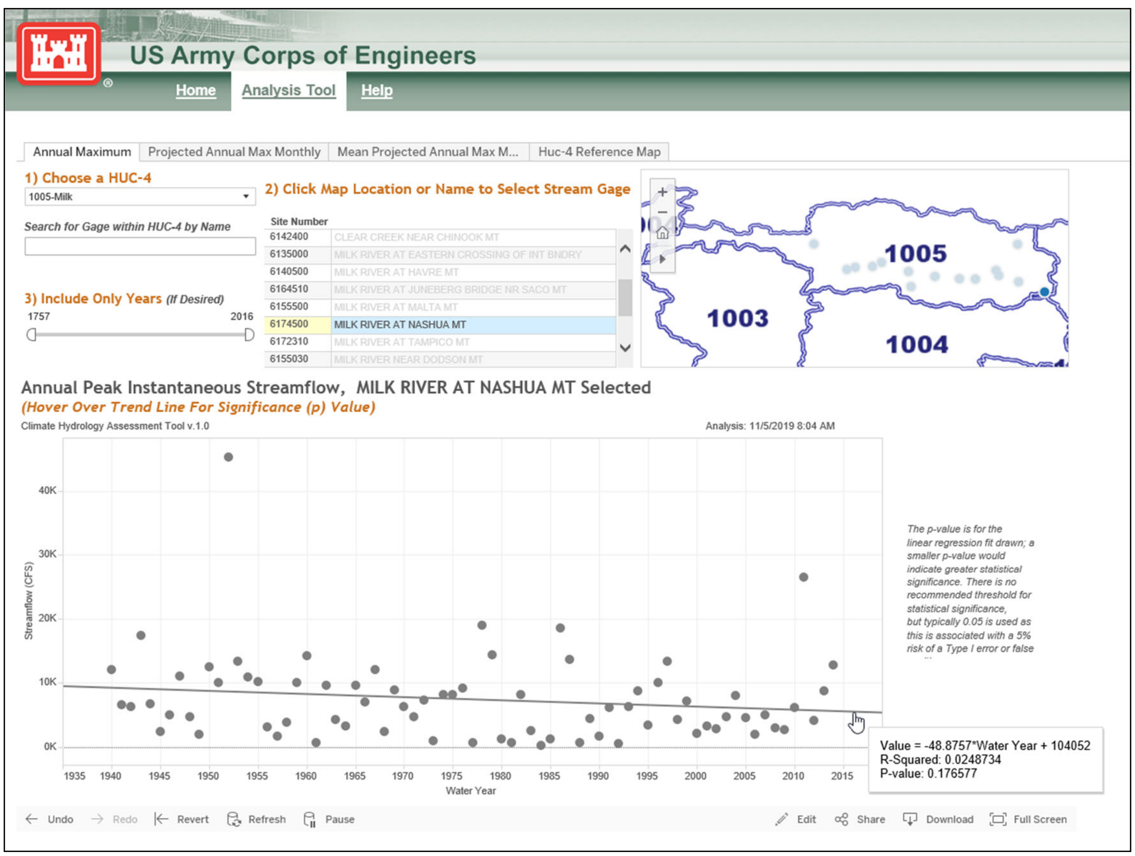


Plate 88: Milk River at Nashua MT; P-value = 0.18, not statistically significant.

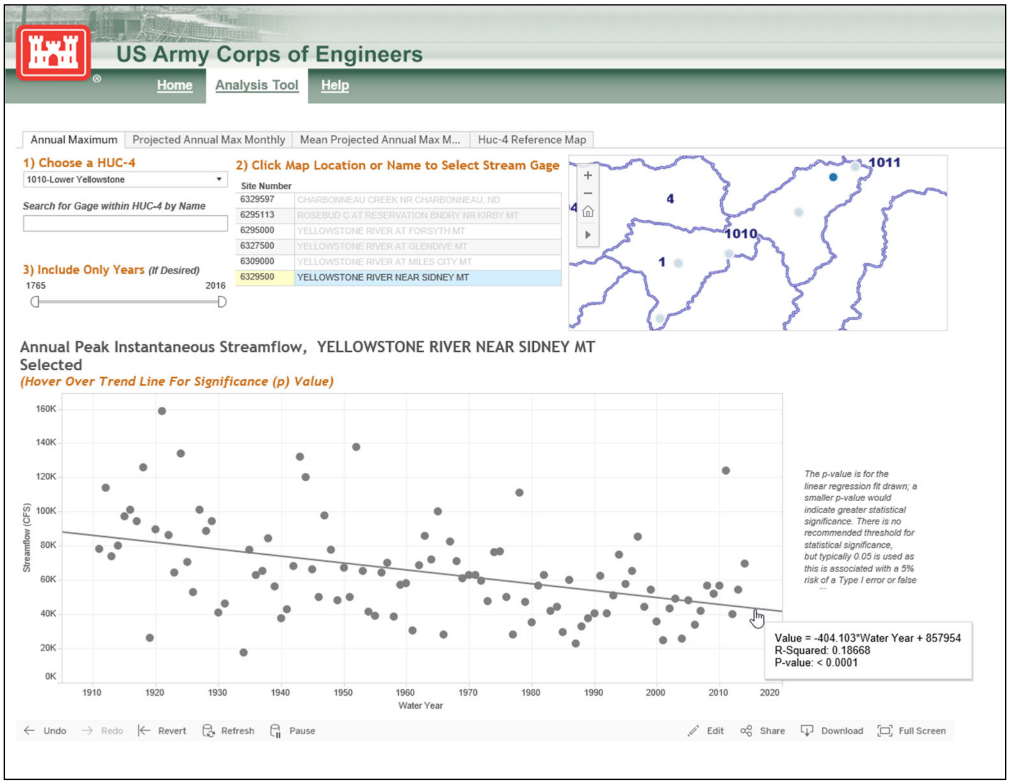


Plate 89: Yellowstone River near Sidney MT; P-value < 0.0001, statistically significant.

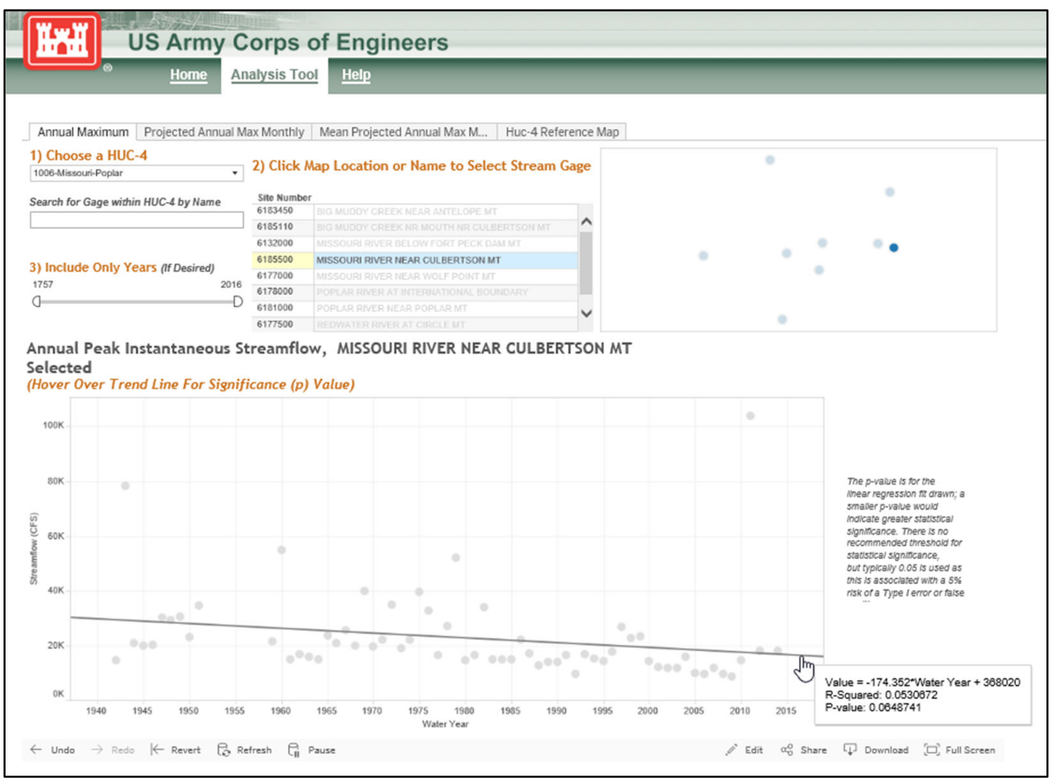


Plate 90: Missouri River at Culbertson, MT; P-value = 0.0649>0.05

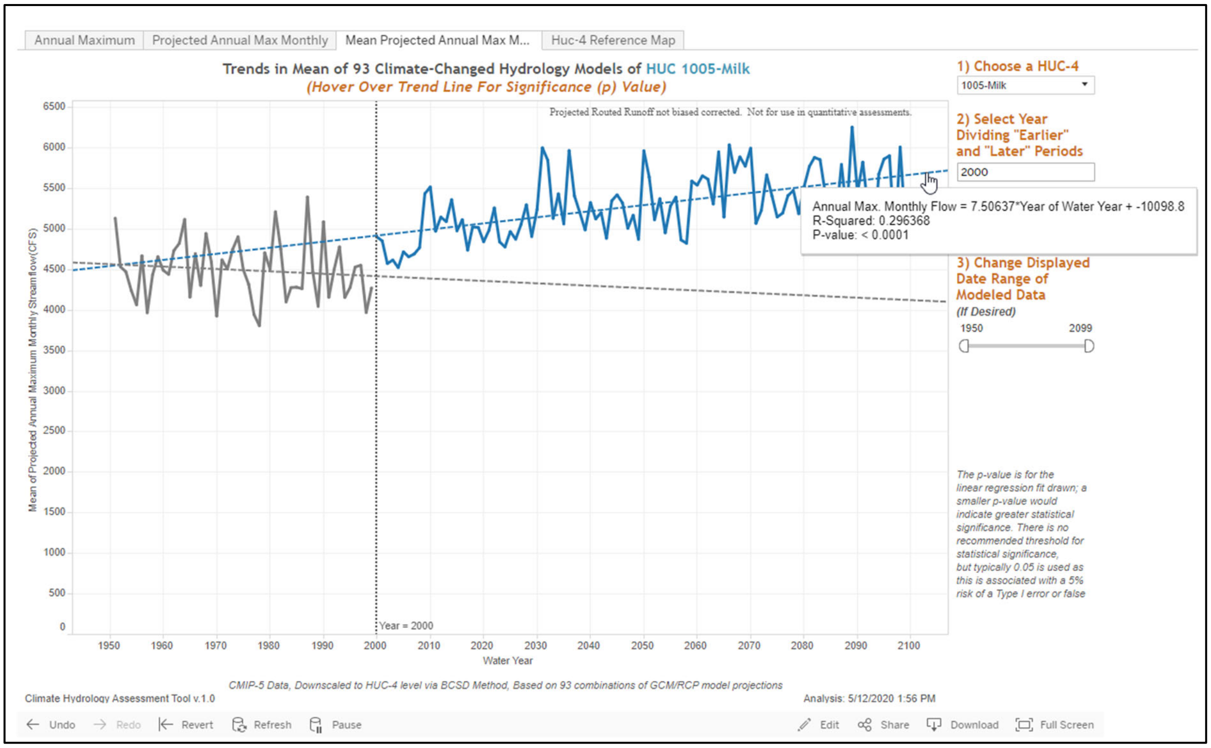


Plate 91: Milk River HUC 1005, Projected Trends

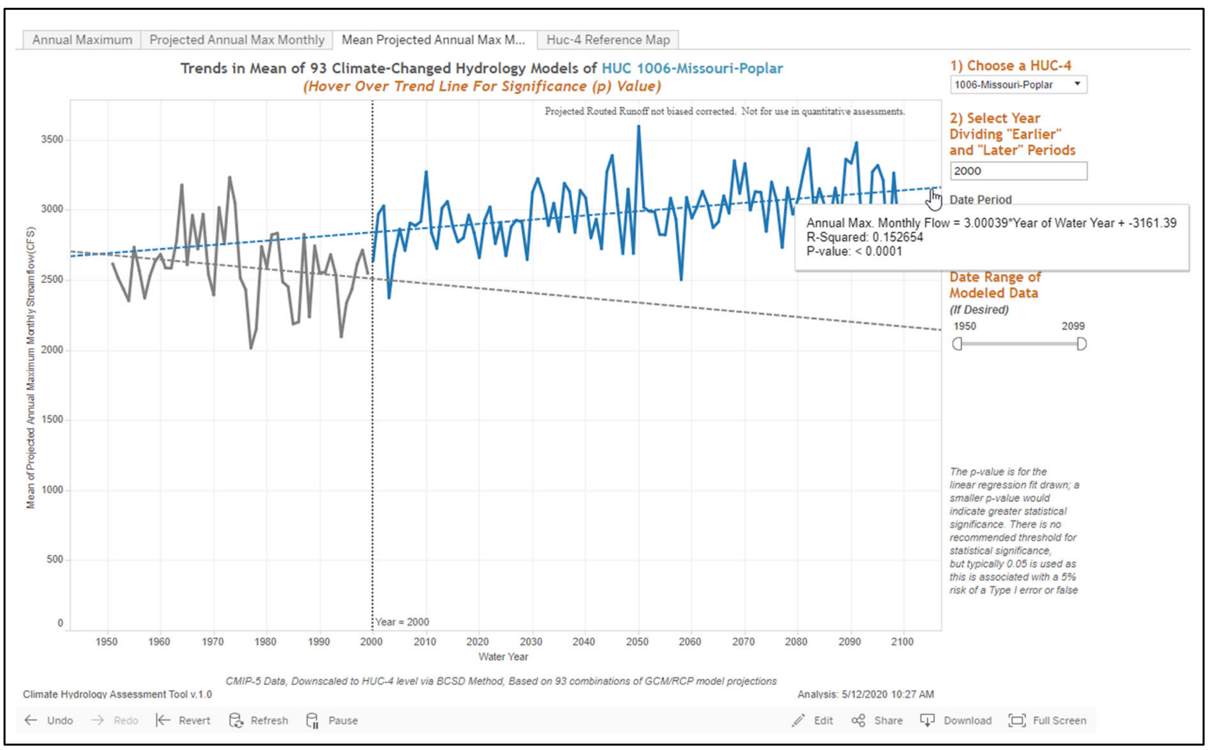


Plate 92: Missouri-Popular River HUC 1006, Projected Trends

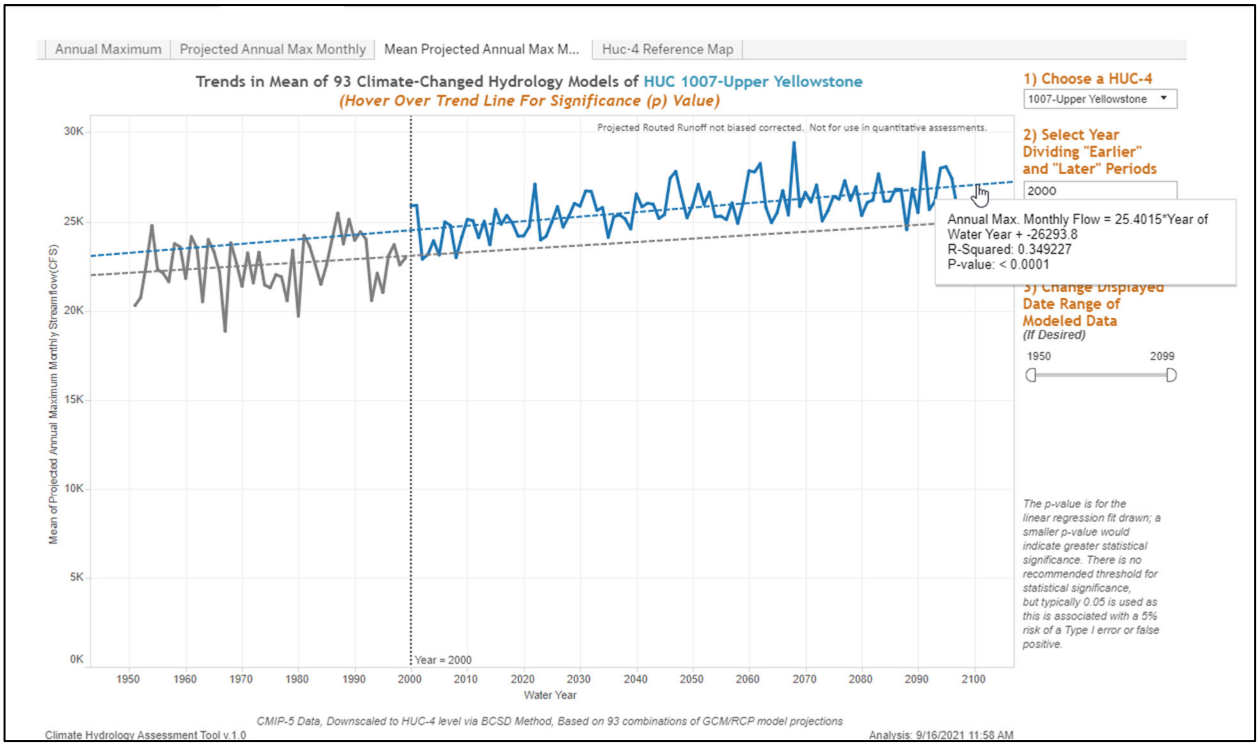


Plate 93: Upper Yellowstone HUC 1007, Projected Trends

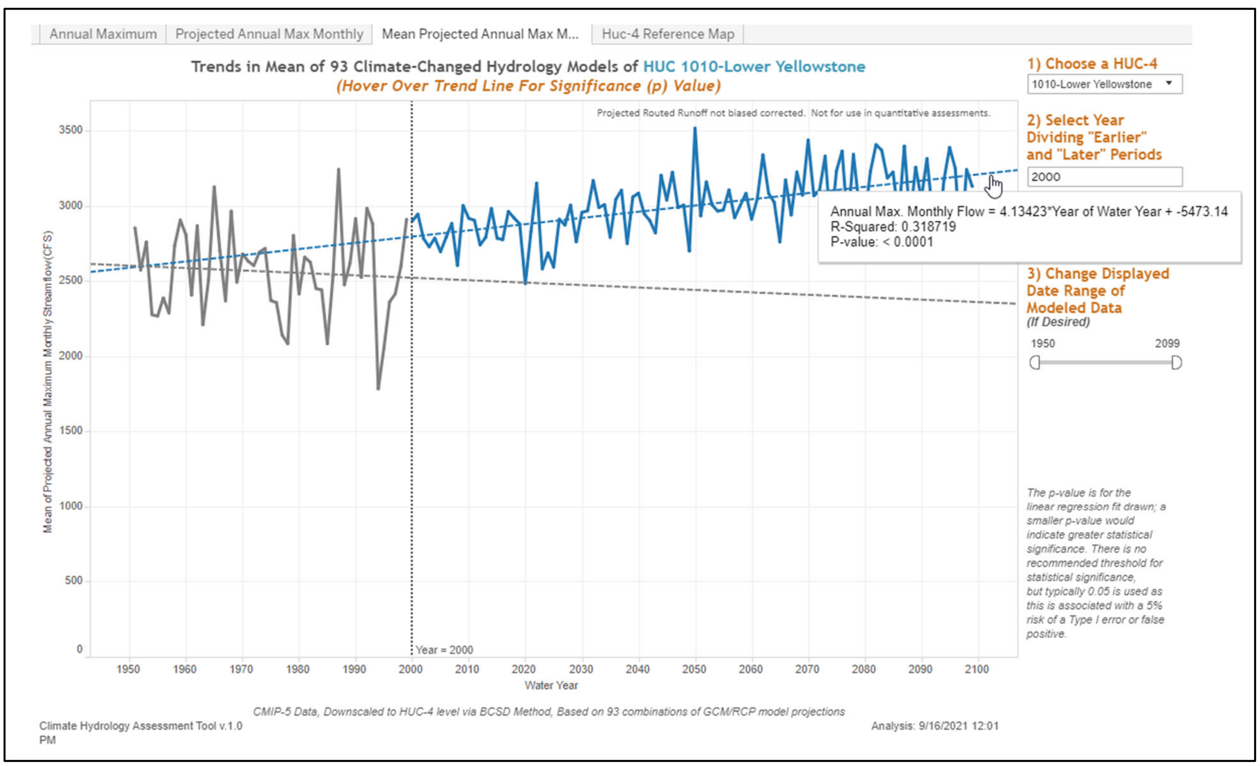


Plate 94: Lower Yellowstone River HUC 1010, Projected Trends

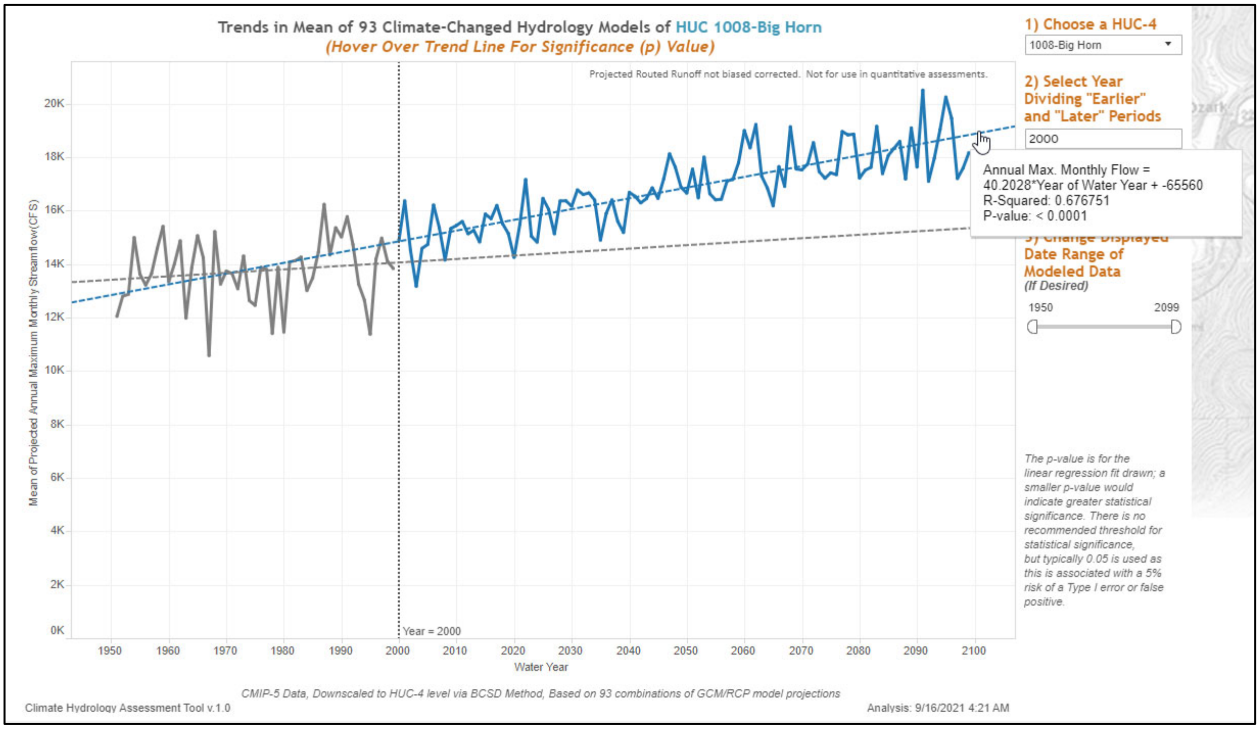


Plate 95: Bighorn River HUC 1008, Projected Trends

Attachment 1

Fort Peck HEC-RAS Re-Calibration Report

US Army Corps of Engineers ®

Omaha District

Fort Peck Flow Test Release Environmental Impact Statement

Fort Peck Reach Unsteady HEC-RAS Model Re-Calibration Report

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ACRONYMS

CFS .... Cubic Feet per Second

FTPTR-EIS .... Fort Peck Flow Test Release Environmental Impact Statement

HEC .... Hydrologic Engineering Center

LiDAR .... Light Detection and Ranging

MRRPMP-EIS .... Missouri River Recovery Program Management Plan Environmental Impact Statement

NAVD 88 .... North American Vertical Datum of 1988

RAS .... River Analysis System Software (by HEC)

RM .... 1960 River Mile

USACE .... United States Army Corps of Engineers

USGS .... United States Geological Survey

WSP .... Water Surface Profile

1 INTRODUCTION

The Hydrologic Engineering Center River Analysis System (HEC-RAS) model previously developed for the Missouri River Recovery Management Plan Environmental Impact Statement (MRRMP-EIS) was revised to include new information received during the Fort Peck Flow Test Release Environmental Impact Statement (FTPTR-EIS) study. New observed water surface profiles (WSP), gage data, and the collection of the USGS high density bathymetry in 2018 and 2019 prompted major updates to the model geometry and calibration. Only the major changes to the model geometry and calibration are documented in this report. Refer to the original calibration report from 2015 for more details and background (USACE 2015).

The Fort Peck to Lake Sakakawea RAS model was re-calibrated to 2018 and 2019 while maintaining the high flow calibration to 2011. The calibration was performed in HEC-RAS Version 5.0.6. All elevations in this report are based on the North American Vertical Datum of 1988 (NAVD88) unless otherwise noted.

Flow hydrographs were used for Fort Peck Dam's release and for the upstream boundaries of the major tributaries (Milk River, Poplar River, and Yellowstone River), and a stage hydrograph was used for Garrison Dam's Pool (Lake Sakakawea). No ungaged inflows were used for 2018 but previously calculated ungaged inflows were used to calibrate to 2011.

The MRRMP-EIS model geometry was constructed using the most recent sediment range surveys from the Omaha District, which included topographic and hydrographic data. Additional cross sections were added between the sediment ranges using LiDAR data for the overbanks and interpolation of the sediment ranges for the bathymetry where hydrographic data was unavailable. The model was updated with high resolution bathymetry collected by the USGS in 2018 and 2019 covering an approximately 20 mile reach. The model also includes the Williston, North Dakota levee. A lateral structure and storage area were used to model the levee.

The model reach includes a substantial degradation reach that extends downstream from Fort Peck Dam and a large aggradation zone in the headwaters of Lake Sakakawea. The extreme 2011 flow event significantly altered the river stage-flow relationship and model calibration to observed stages in flood years prior to 2011 is not valid in most areas. Therefore, due to impacts from the 2011 flood and long term changes within the aggradation and degradation areas, the hydraulic model is not capable of reproducing observed stage-flow relationships prior to 2011.

The model was calibrated to measured Water Surface Profiles (WSP) from 2014 and 2018 and observed stage gage data for the Missouri River. Gage data was the only source for the 2011 calibration. The computed water surface profile was within +/- 1 ft along the entire reach and in the range of +/- 0.5 ft for about 50% to 75% of the reach. These were determined to be acceptable calibration targets. Comparison to observed hydrographs indicated that the model performed acceptably on timing of flood peaks within most areas.

2 DATA SOURCES

Primary data sources for construction of the original unsteady HEC-RAS model includes terrain data, bathymetry data, and gage data. Terrain data encompasses everything from the bluffs to the riverbanks, defining the floodplain and overbanks, but does not often include data below the surface of the river. Bathymetry captures the cross section geometry below the water surface. The model geometry was updated with data collected by the USGS in 2018 and 2019. A summary of the data used in the model is provided in Table 2-1. Entries were added for the new USGS data and new water surface profiles.

Table 2-1: Summary of Data Sources with Updated USGS Data

Data Type	Data Title	Location Data Applied to Model	Collection Dates
Topographic Data			
Sediment Range Survey	Missouri River Hydrographic Surveys below Ft. Peck, Montana: River Miles 1865.7 to 1693.4	RM 1769.04 - 1597.17	Oct 2011 & Apr - May 2012
High Density Bathymetry	USGS 2019 High Density Single Beam Bathymetry	RM 1701.48 – 1692.18	July 2019
High Density Bathymetry	USGS 2018 High Density Single Beam Bathymetry	RM 1692.18 – 1679.47	June 2018
LiDAR	2018 USGS Channel Bank LiDAR	RM 1692.18 – 1679.47	September 2018
Sediment Range Survey	Lake Sakakawea and Tributaries located in west central North Dakota	RM 1594.24 - 1391.08	11-13 Sep 2011 & 1 May - 22 Aug 2012
Hydrographic Survey	Hydrographic Surveys of the Yellowstone River: Yellowstone River Miles 0 to 121.4 and Missouri River Miles 1552.6 to 1586.6	RM 1585.97 to 1552.61	Apr - Jun 2012
DEM – LiDAR	Fort Peck to Yellowstone LiDAR Mapping	Fort Peck Dam - RM 1586.74	10-12 Nov 2011
DEM – LiDAR	Yellowstone River Corridor - McKenzie County	RM 1585.28 - 1579.41	15 Oct 2007 - 2 Nov 2007
DEM – 4 m	NEXTMap	RM 1586.39 - 1585.97, RM 1578.98 - Garrison Dam	Apr - Dec 2007
Levee Profile	Williston Levee - Levee Profile (2009)	Williston Lateral Structure	2009
Land Cover			
Land Cover	National Land Cover Dataset 2006	All cross sections	2006
Flow Data			
Streamgage Data	Stage and Discharge	All cross sections	POR
Water Surface Profile			
Water Surface Elevation Data	Missouri River Water Surface Profile from Fort Peck to Lake Sakakawea	0.1 mile – Entire Reach	12-31 July 2014
Water Surface Elevation Data	Missouri River Water Surface Profile from Culbertson to Lake Sakakawea	Sediment Ranges – Culbertson to Lake Sakakawea	1 Aug 2018

2.1 GEOMETRY UPDATES

The MRRMP-EIS model geometry was updated with new data collected since it's construction. New data included high density bathymetry collected by the USGS in 2018 and 2019 for an approximately 20 mile reach. A water surface profile was also collected by the USGS in July 2019. New water surface profiles collected by USACE in 2014 and 2018 and gage data from 2014 to 2019 were all used to re-calibrate the model.

2.1.1 USGS 2018 and 2019 High-Resolution Bathymetry Geometry Update

The USGS collected high density single beam bathymetry (15 m spacing) in June 2018 over a short reach that is about 13 river miles in length. The high density reach is located just upstream from the Poplar River confluence (RM 1692.18 to 1679.47). This reach is about 80 river miles downstream of Ft Peck Dam which is located at RM 1771.5. The bathymetry was combined with September 2018 LiDAR of the channel banks and November 2011 LiDAR of the floodplain to create a DEM. A new model geometry was created using the USGS data merged into the MRRMP-EIS model.

In 2019, the USGS expanded the reach of high density data upstream about 10 additional river miles. The high density data was extended to proceed from around Wolf Point downstream to the Poplar River confluence (RM 1701.48 to 1679.47). The bathymetry was again combined with September 2018 LiDAR of the channel banks and November 2011 LiDAR of the floodplain to create a DEM (provided by the USGS). A new model geometry was created using the 2018 and 2019 USGS data merged into the MRRMP-EIS model.

A water surface profile was also collected with the 2019 data on 01 July 2019 between river miles 1701 and 1679. Daily flow from 01 July 2019 was 12,300 cfs according to the Wolf Point USGS gage record. A comparison of the observed water surface points and the model output, shown in Figure 2-1 and Figure 2-2, shows that the modified model geometry matches very well to the observed WSP.

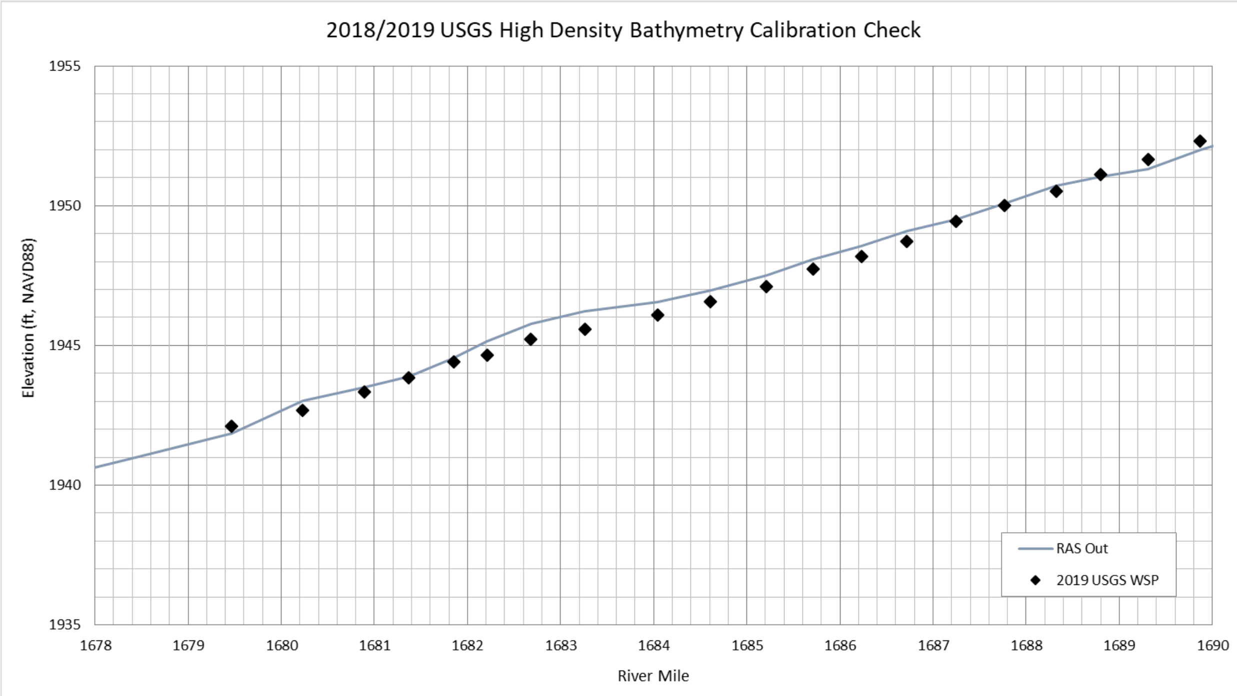


Figure 2-1. 2018/2019 High Density Bathymetry Calibration Check with 2019 Profile – RM 1690 to 1678

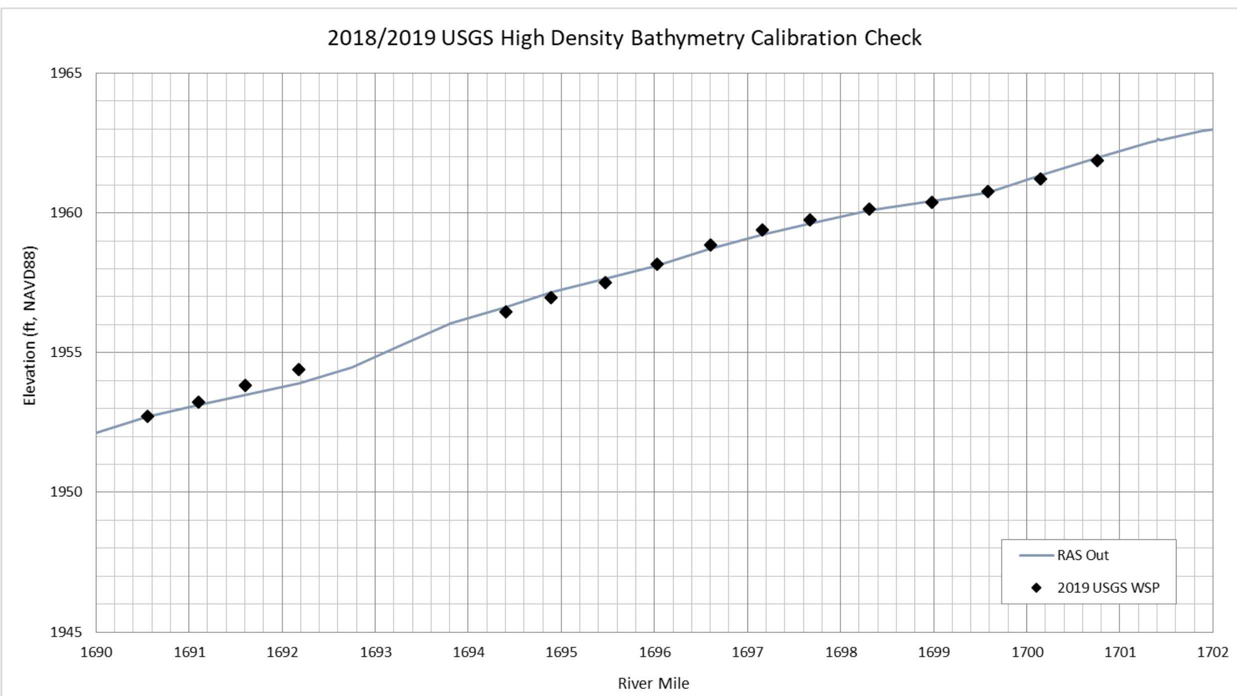


Figure 2-2. 2018/2019 High Density Bathymetry Calibration Check with 2019 Profile – RM 1702 to 1690

2.1.2 Water Surface Profile Data

Water surface profile elevation data was taken at every sediment range by USACE on August 1, 2018, and this was used as the primary source for re-calibration of the model. Another WSP was collected from 12-31 July 2014 by USACE's Engineering and Research Development Center (ERDC). The 2014 WSP data was collected at 0.1 mile intervals along the entire reach from Fort Peck Dam to Lake Sakakawea. Daily average releases from Fort Peck Dam were around 9,000 to 12,000 cfs for the July 2014 WSP and about 16,000 cfs for the August 2018 WSP.

3 MODEL INFORMATION

Unsteady computations in HEC-RAS version 5.0.6 were used for this modeling effort. A computation interval of 4 hours was used because that was determined to be a stable time-step for the model and allowed model runs to be conducted in reasonable timeframes. The vertical datum used for the model is NAVD88 (ft) and the horizontal projection is NAD 83 Montana State-Plane Coordinate System (US-Feet).

4 CALIBRATION

Model calibration was accomplished through several steps described in this section. Results as well as a discussion of level of calibration achieved and overall model performance are presented below.

4.1 MODEL CALIBRATION

Unlike previous modeling efforts on the Missouri river, a broad spectrum of flows from low flows to high flows were considered important to the project purposes. Calibration methods had to include a range of flows. The primary source of calibration data was observed stage and flow hydrographs on the main stem Missouri river gages and field measured water surface profile data from 2014 and 2018. The 2018 WSP did not cover the entire reach and only went from the Culbertson gage down to Lake Sakakawea Pool.

First, the model was re-calibrated for low flow conditions like the ones seen from 2014 to 2018. The primary data used for the low flow calibration was the 2018 partial WSP. Channel n-values were adjusted to match the model with the 2018 WSP and gage stage data. The WSP and gage data sometimes did not agree, so the modeled water surface was adjusted to be in the middle when possible. Final channel roughness values are shown in Table 4-1. Next, the flow roughness factors were re-adjusted to maintain the calibration to 2011 high flows. Previously calculated ungaged flows were included for the 2011 high flow calibration. Ineffective flow areas were double checked for consistency. The final flow roughness factors used to calibrate to the 2011 high flow event are shown in Table 4-2.

Table 4-1: Final Channel Roughness Values

Cross Section River Mile Range	Channel Manning's N-Value
1769.04 – 1760.74	0.031
1760.30 – 1752.92	0.025
1752.43 – 1742.60	0.022
1742.13 – 1732.58	0.029
1732.09 – 1720.19	0.025
1719.65 – 1701.88	0.022
1701.48 – 1671.30	0.028
1670.83 – 1638.31	0.030
1637.92 – 1620.03	0.025
1619.44 – 1608.26	0.027
1607.74 – 1597.40	0.025
1597.17 – 1587.13	0.029
1586.74 – 1575.69	0.025
1575.10 – 1554.18	0.022
1553.71 – 1391.08	0.025

Table 4-2: Flow Roughness Factors

U/S Cross Section	1761.22	1707.25	1678.5	1610.52	1594.24	1581.35	1575.1
D/S Cross Section	1707.87	1679.47	1611.04	1594.64	1582.01	1575.69	1391.08
Flow (cfs)	Roughness Factor						
0	1	1	1	1	1	1	1
20,000	1.2	1	1	1	1.1	1	1
25,000	1.3	1.2	1	0.95	1.1	1.1	1.15
30,000	1.4	1.25	1	0.95	1.15	1.2	1.25
50,000	1.4	1.25	0.95	0.95	1.15	1.25	1.3
70,000	1.4	1.1	0.9	0.95	1.1	1.3	1.3
90,000	1.4	1	0.85	0.9	1.1	1.3	1.3
110,000		1	0.85	0.9	1.1	1.25	1.3
130,000						1.25	1.3
150,000						1.25	1.3
180,000						1.25	1.3

The calibration goal was to achieve a water surface elevation within 1 ft for the entire reach and within 0.5 ft for most of the reach for both the measured water surface profiles and the observed gage data for 2011 and 2018, excluding periods of ice. The model does not account for ice. Ice causes much higher stages than would normally occur for an open water condition. Ice affected events typically occur from December to March. Plate 2 through Plate 17 show the computed profile vs the measured water surface profile. Multiple profiles are shown because due to the size of the reach, the water surface profile survey took several days to complete. Notes describing the survey schedule are included in the plots when the stage was not steady throughout the survey period.

4.2 Calibration Results

Model calibration results are within the desired range with most locations within 0.5 to 1 foot of observed stages. In general, comparison of model results to gage station hydrographs was reasonable. The measured profile calibration also provides confidence in model performance between the gage station locations. The measured profile for 2014 has many more points than we usually have and a difference with the slope of the water surface can be seen in places, especially in the upper part of the reach. Since the sediment ranges, used for the geometry, are at a set interval and it would be prohibitively costly to obtain more data between them, this was left as is in the model. The upper part of the reach was also missing WSP for 2018 so most was not re-calibrated since there was little information to compel changes. A comparison of peak stages for the 2011 flood are shown in Table 4-3.

Table 4-3: 2011 Flood Peak Stage Comparison

Location	Date	Peak Stage Difference (ft)
RM 1763.54 – blw Ft. Peck	M	M
RM 1750.99 – W Frazer Pump Plant	13Jun2011	-0.04
RM 1701.31 – Wolf Point	14Jun2011	-0.05
RM 1620.65 – Culbertson	21Jun2011	0.13
RM 1597.40 – No. 4 nr Nohly	22Jun2011	-0.13
RM 1588.95 – No. 5 nr Nohly	22Jun2011	0.02
RM 1582.01 – No. 5A at Buford	21Jun2011	0.90
RM 1577.03 – No. 6 nr Buford	M	M
RM 1552.61 – Williston	22Jun2011	-0.07
RM 1546.20 – No. 9 at Williston	22Jun2011	0.08

*M – denotes gage peak stage data is missing

*Peak stages were manually estimated due to minor timing issues and bad data points.

4.2.1 Calibration Results Affected by Ice Conditions

Ice affected conditions including ice cover, ice breakup, and ice jams occur annually within the basin. Ice formation conditions typically occur in late November to late December with iceout typically occur in the early spring, usually in the March to April time frame. No ice parameters were included in the model development or calibration. Therefore, winter condition model calibration results should be viewed with caution and recognize that results do not reflect observed conditions.

4.2.2 Stage Trend Impacts

Degradation and aggradation conditions occur through the reach due to Fort Peck Dam at the upstream model boundary and Garrison Dam at the downstream model boundary. Due to the extreme 2011 event flows and the high degree of channel adjustment that occurred during the event, accurate stage calibration prior to 2011 using the post-2011 event model geometry is not possible. Model results for the rising portion of the event in May and June demonstrate how stage-flow relationships changed during the flood and also reduce calibration accuracy through this portion of the event.

5 CONCLUSIONS

The model performs well for the 2011, 2014, and 2018 observed gage data and is calibrated to the 2014 and 2018 water surface profiles. Calibration flows for the 2014 and 2018 water surface profiles ranged from 9,000 cfs to 16,000 cfs. Significant points to consider with respect to model construction and calibration are as follows:

- Measured profile calibration in 2014 and 2018 and gage hydrograph calibration for both 2011, 2014, and 2018 indicates that the model performs satisfactorily with a stage calibration accuracy of less than 1 foot at most locations.
- Incomplete hydrographic surveys were available to construct the model. Interpolation from hydrographic sections was used combined with LiDAR data to generate cross sections at the desired spacing of about 2,500 to 3,000 feet. Consequently, the interpolated sections within the model have reduced accuracy for the below water portion of the cross section. Normal flow calibration indicated that the model performs satisfactorily which implies the interpolation method was reasonable.
- Floodplain model geometry in the reach below Williston is limited due to the use of less accurate DEMs.
- No tributary computed stage information should be used from model results without carefully assessing the purpose and considering model construction limitations.
- Aggradation and degradation that occurred during the 2011 event reduces calibration accuracy for the flood hydrograph. This also prevents calibrating to flow events prior to 2011.

6 REFERENCES

USACE (2015). *Missouri River Unsteady HEC-RAS Model Calibration Report.* Omaha, NE, U.S. Army Corps of Engineers.

Fort Peck Reach Unsteady HEC-RAS Model

Re-Calibration Report

PLATES

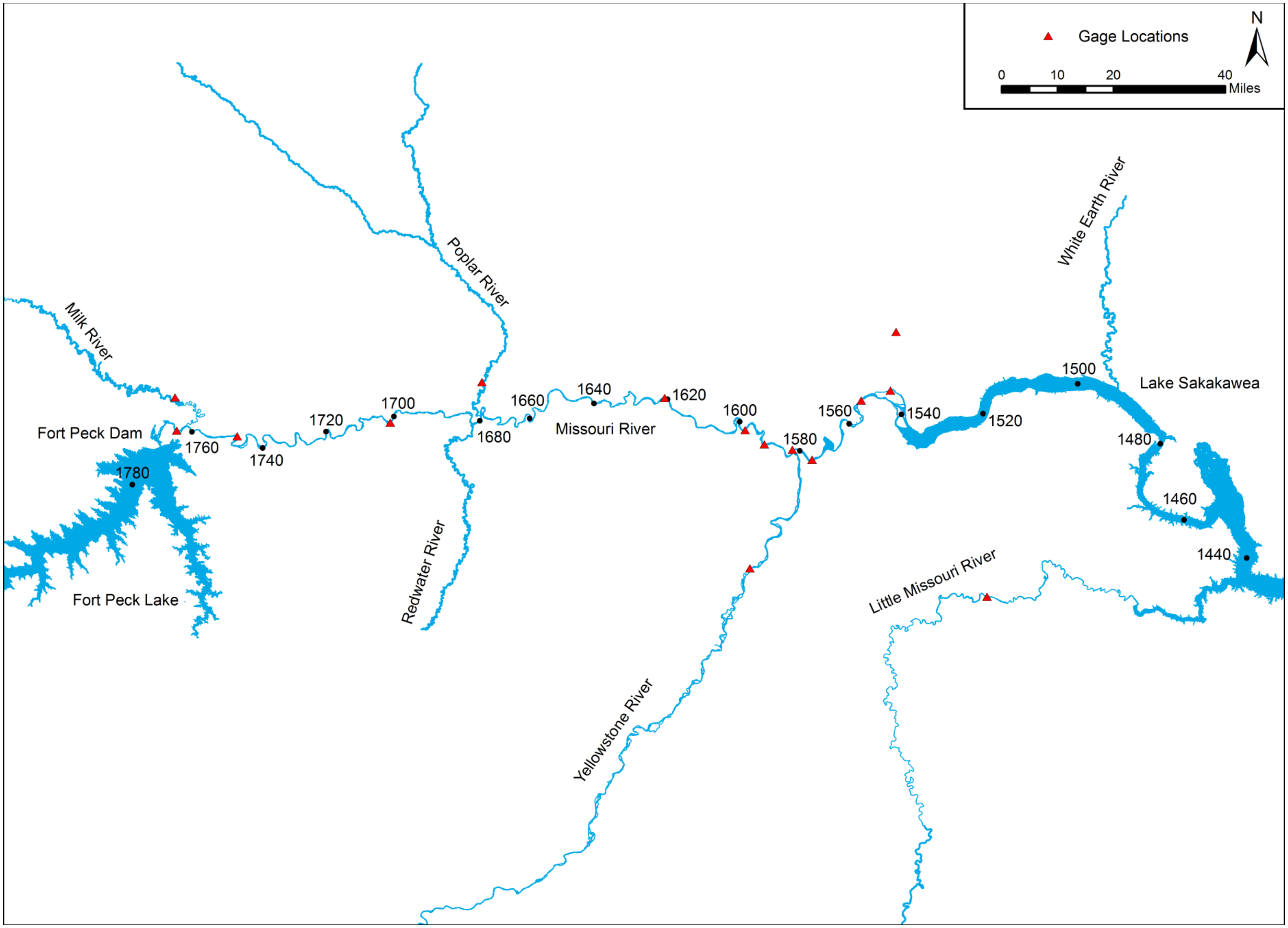


Plate 1: Overview Map

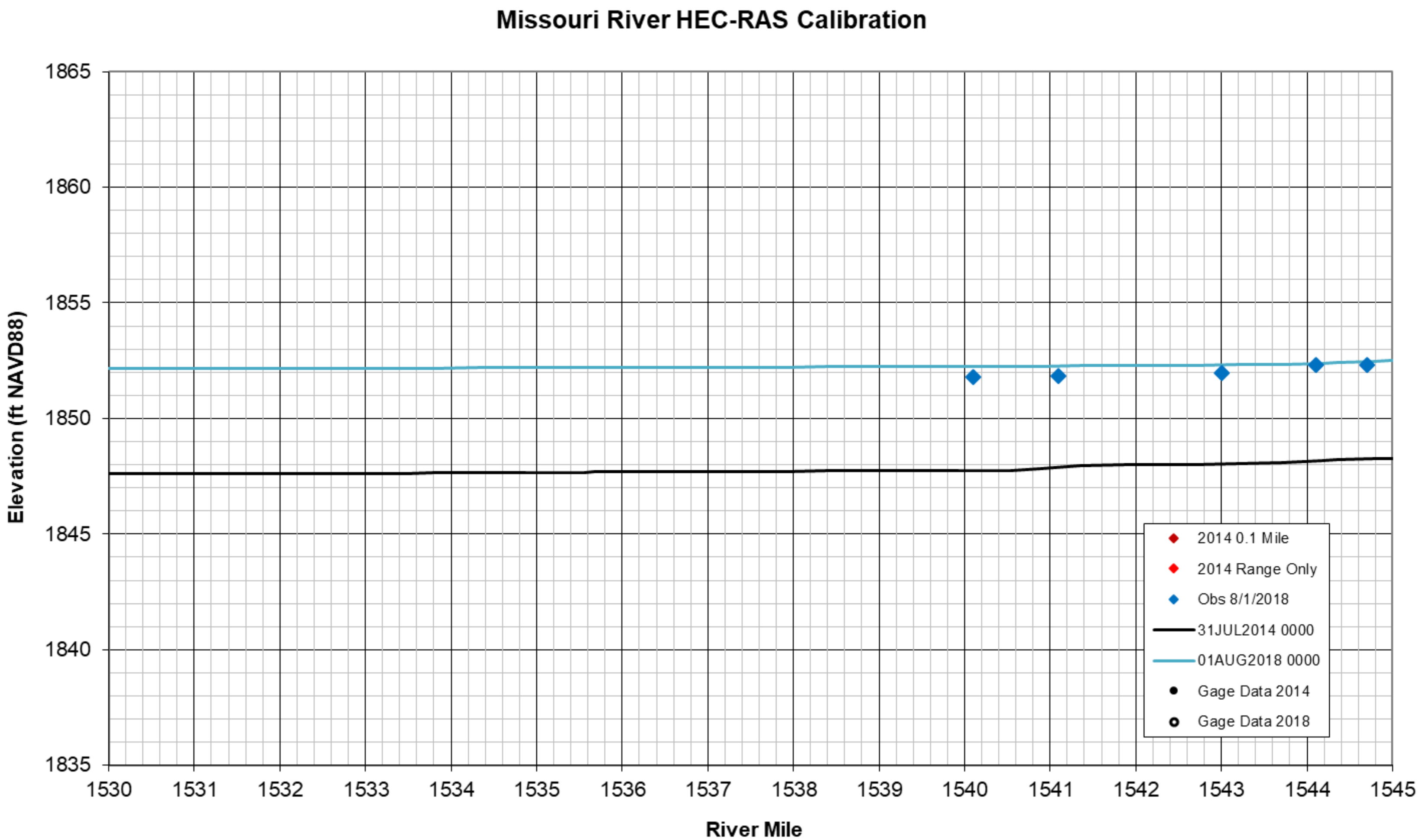


Plate 2: Measured WSP vs Computed Water Surface – RM 1530 to 1545

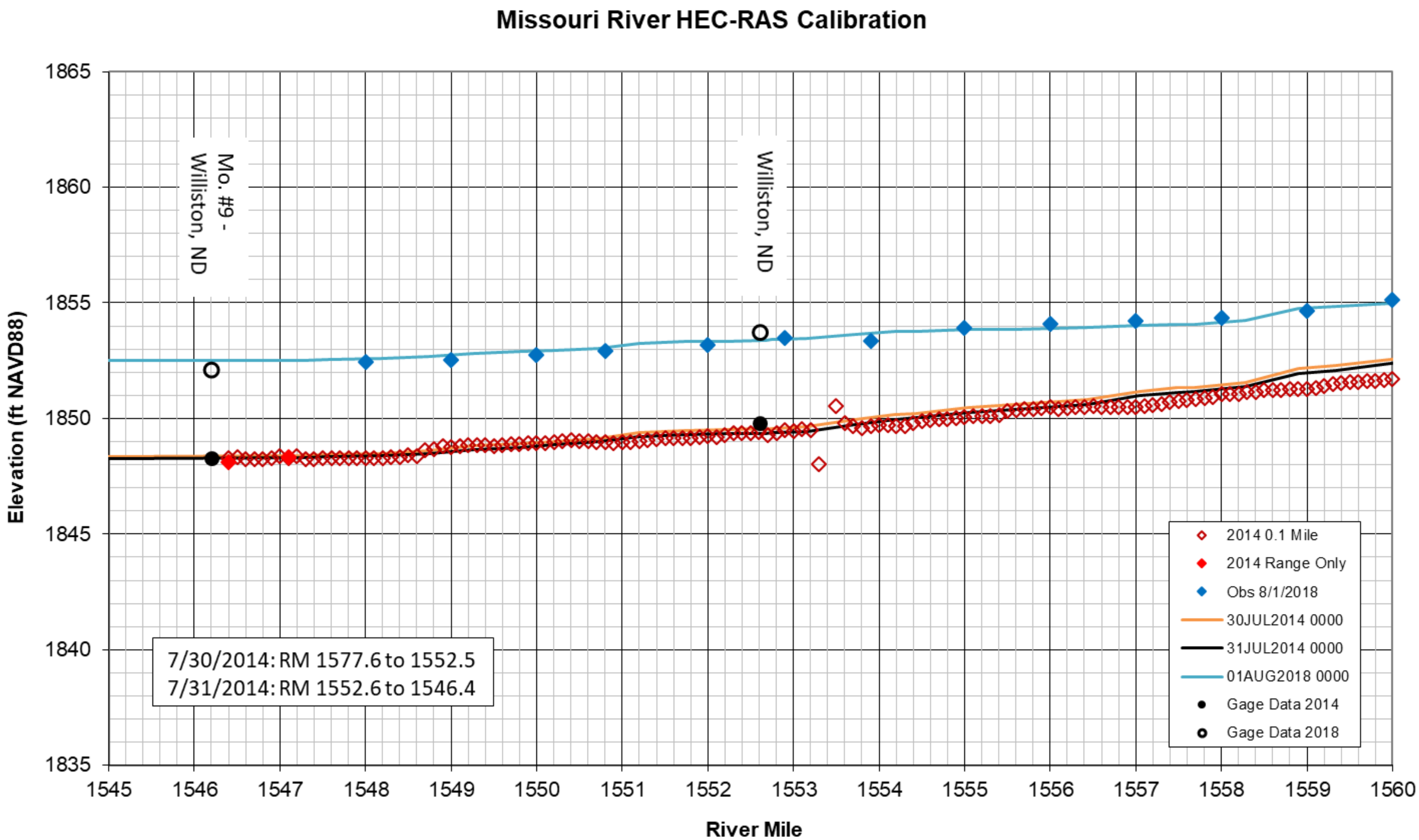


Plate 3: Measured WSP vs Computed Water Surface – RM 1545 to 1560

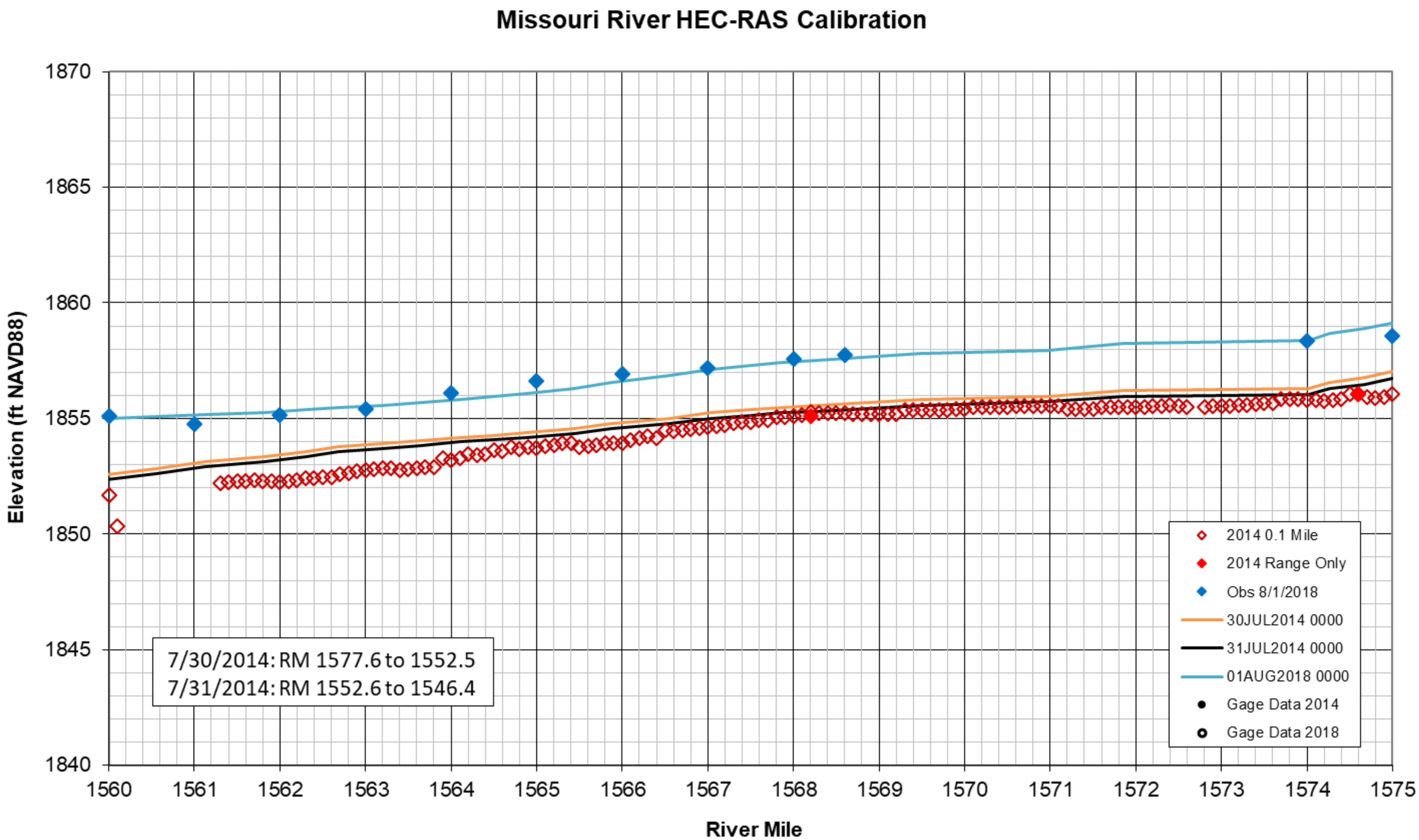


Plate 4: Measured WSP vs Computed Water Surface – RM 1560 to 1575

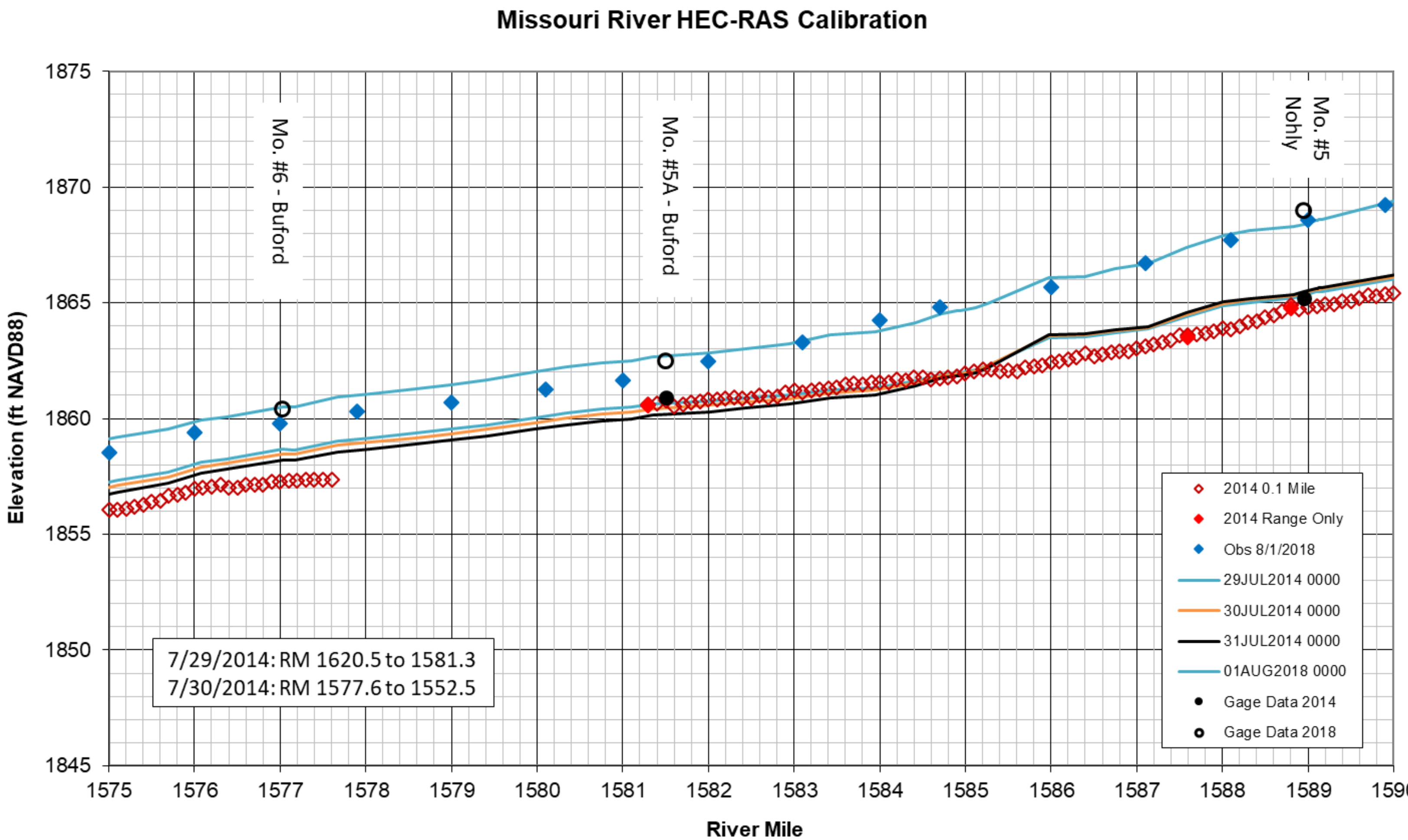


Plate 5: Measured WSP vs Computed Water Surface – RM 1575 to 1590

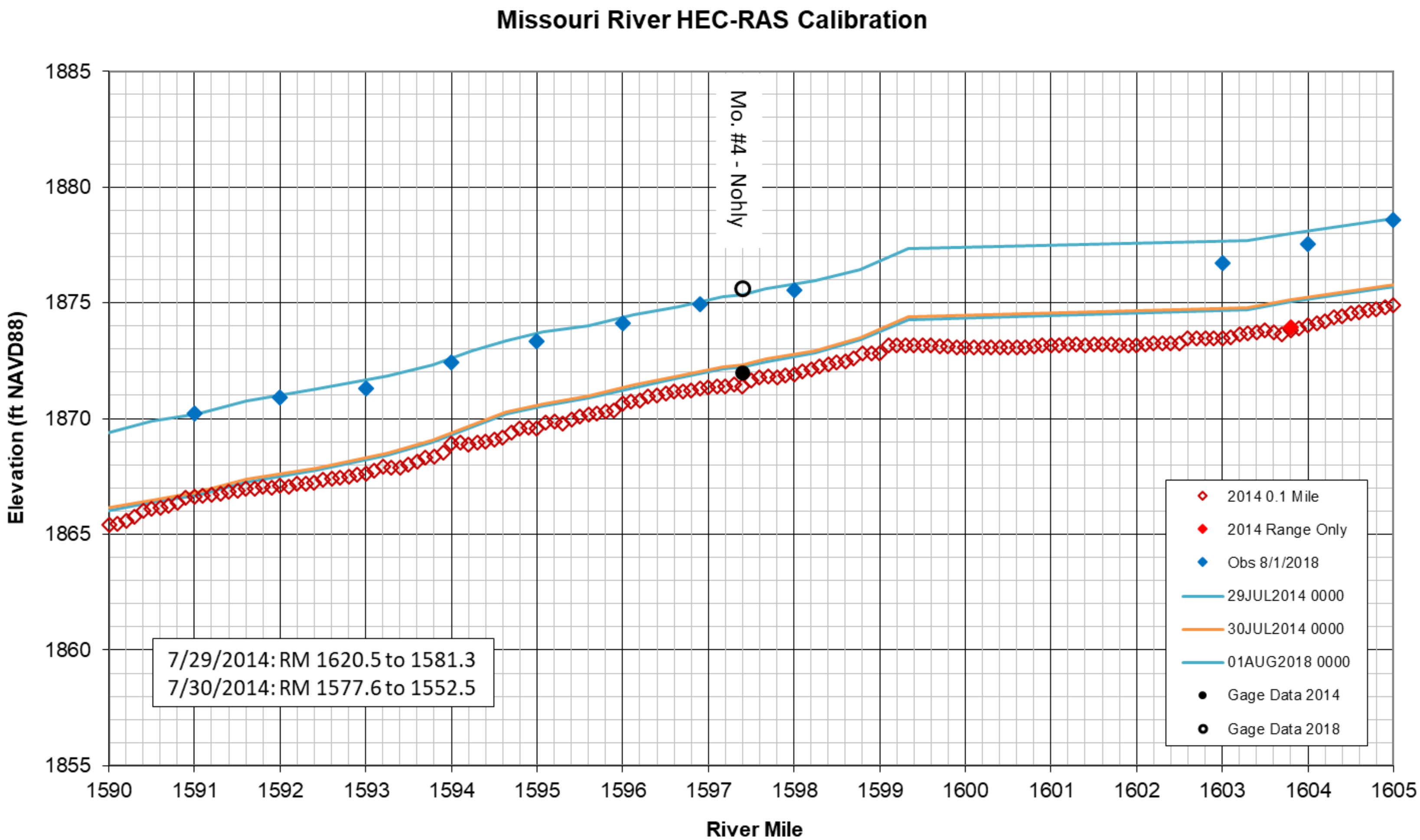


Plate 6: Measured WSP vs Computed Water Surface – RM 1590 to 1605

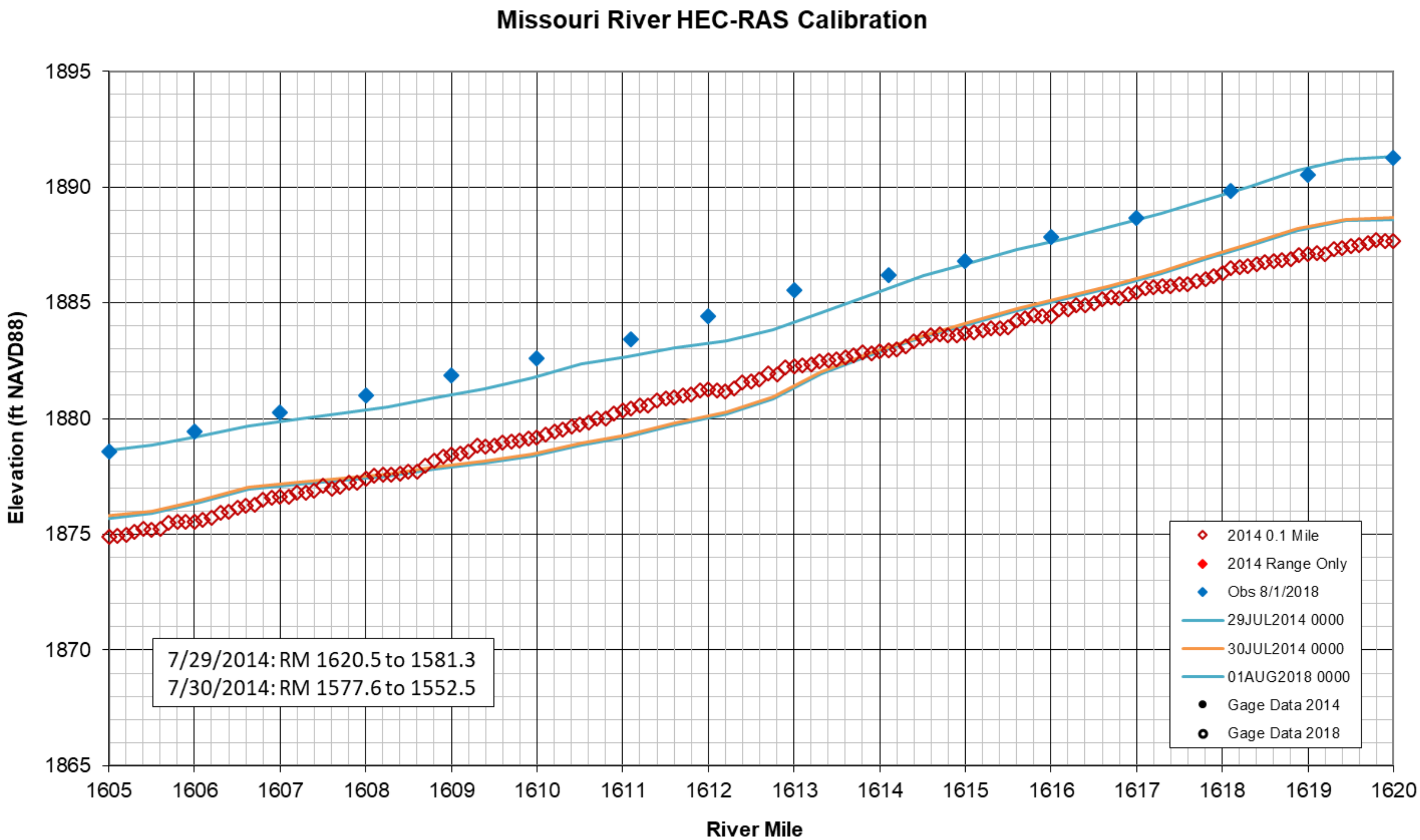


Plate 7: Measured WSP vs Computed Water Surface – RM 1605 to 1620

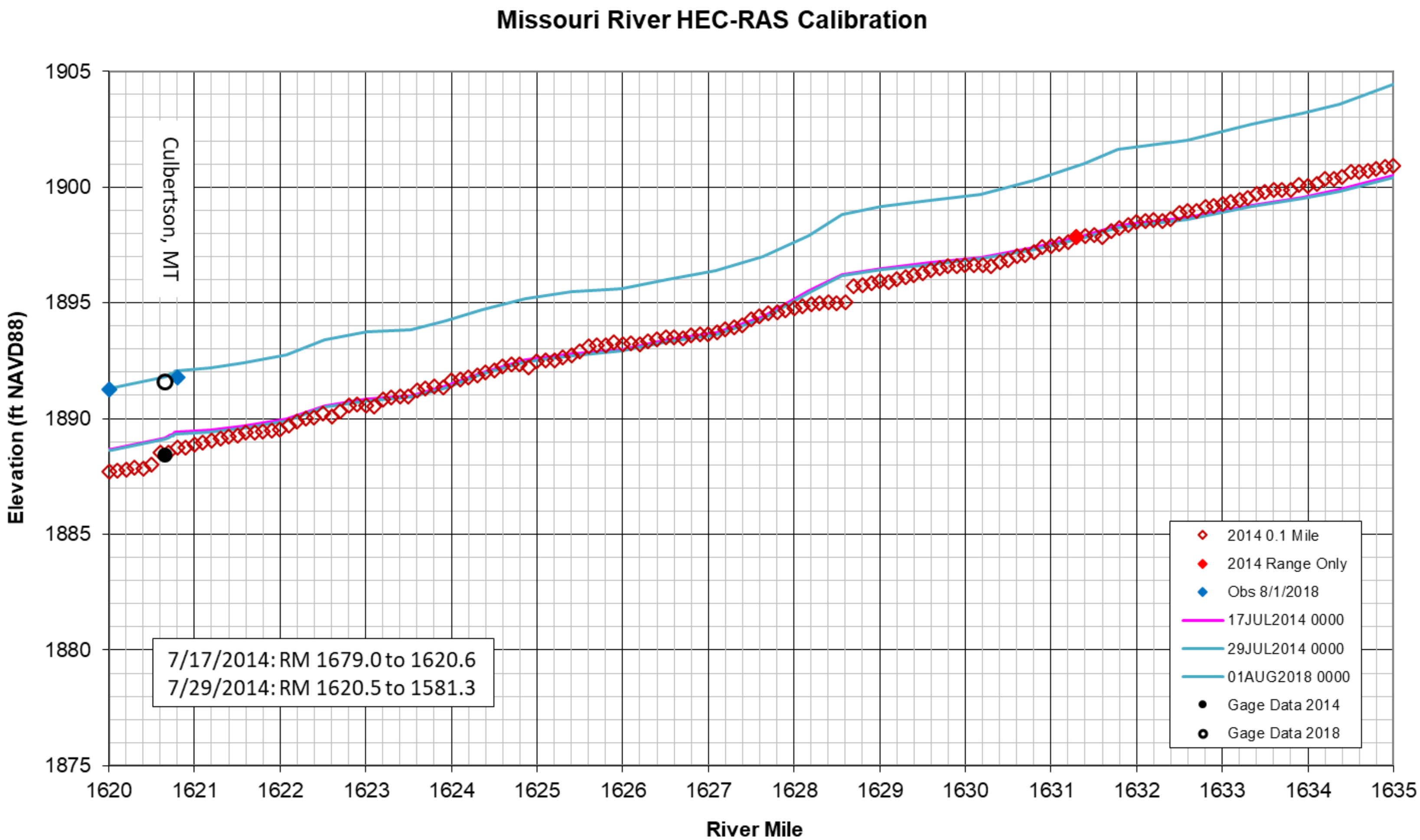


Plate 8: Measured WSP vs Computed Water Surface – RM 1620 to 1635

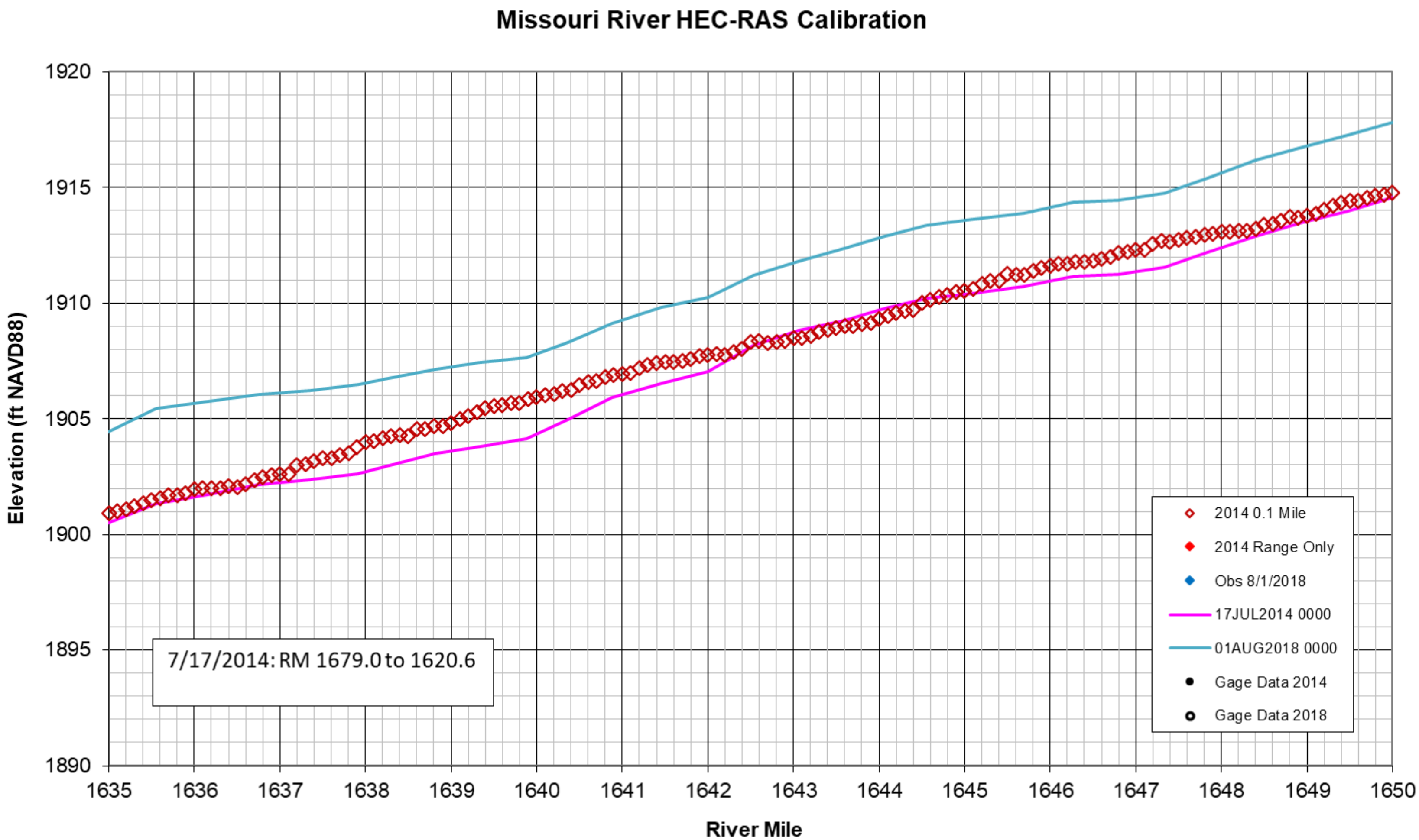


Plate 9: Measured WSP vs Computed Water Surface – RM 1635 to 1650

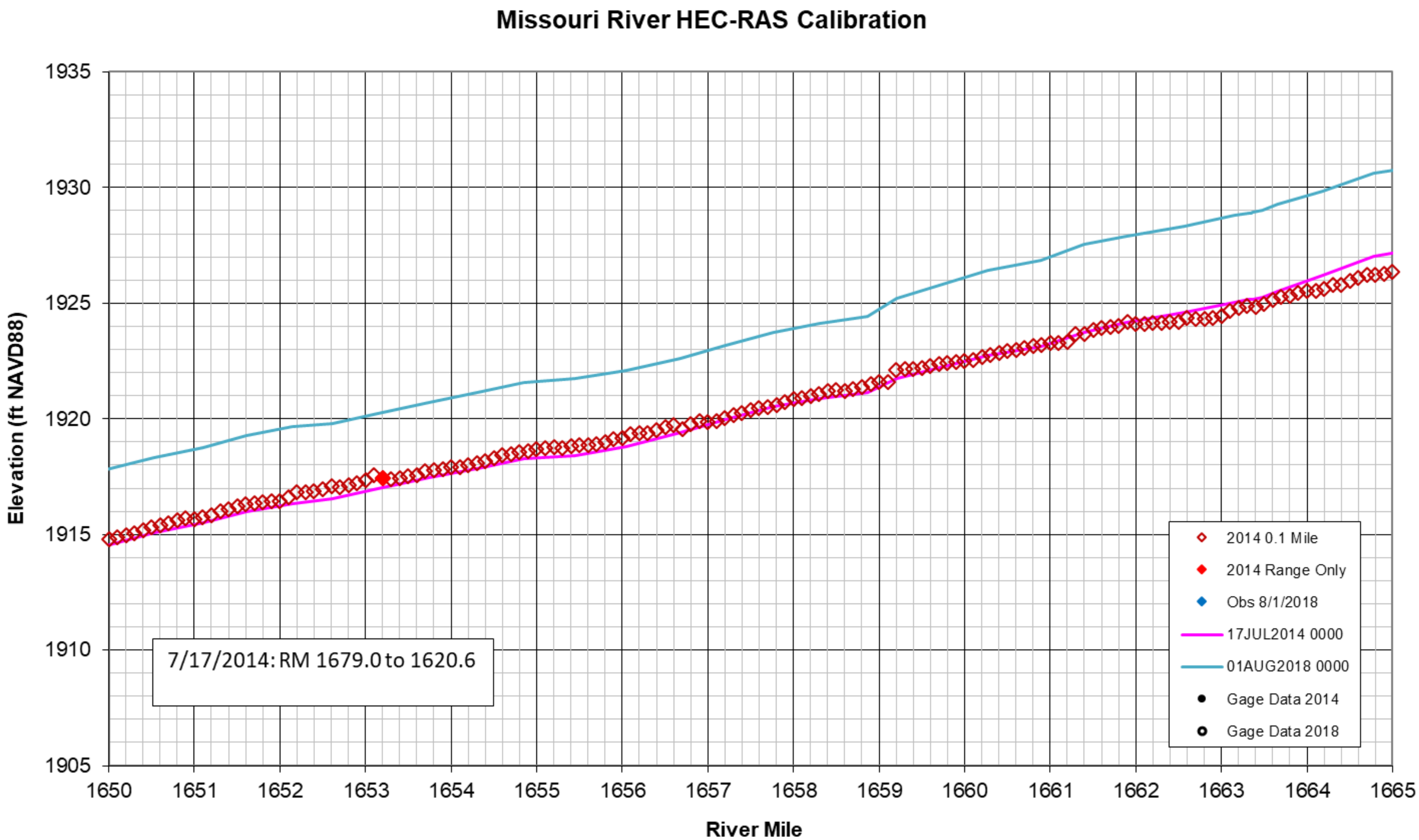


Plate 10: Measured WSP vs Computed Water Surface – RM 1650 to 1665

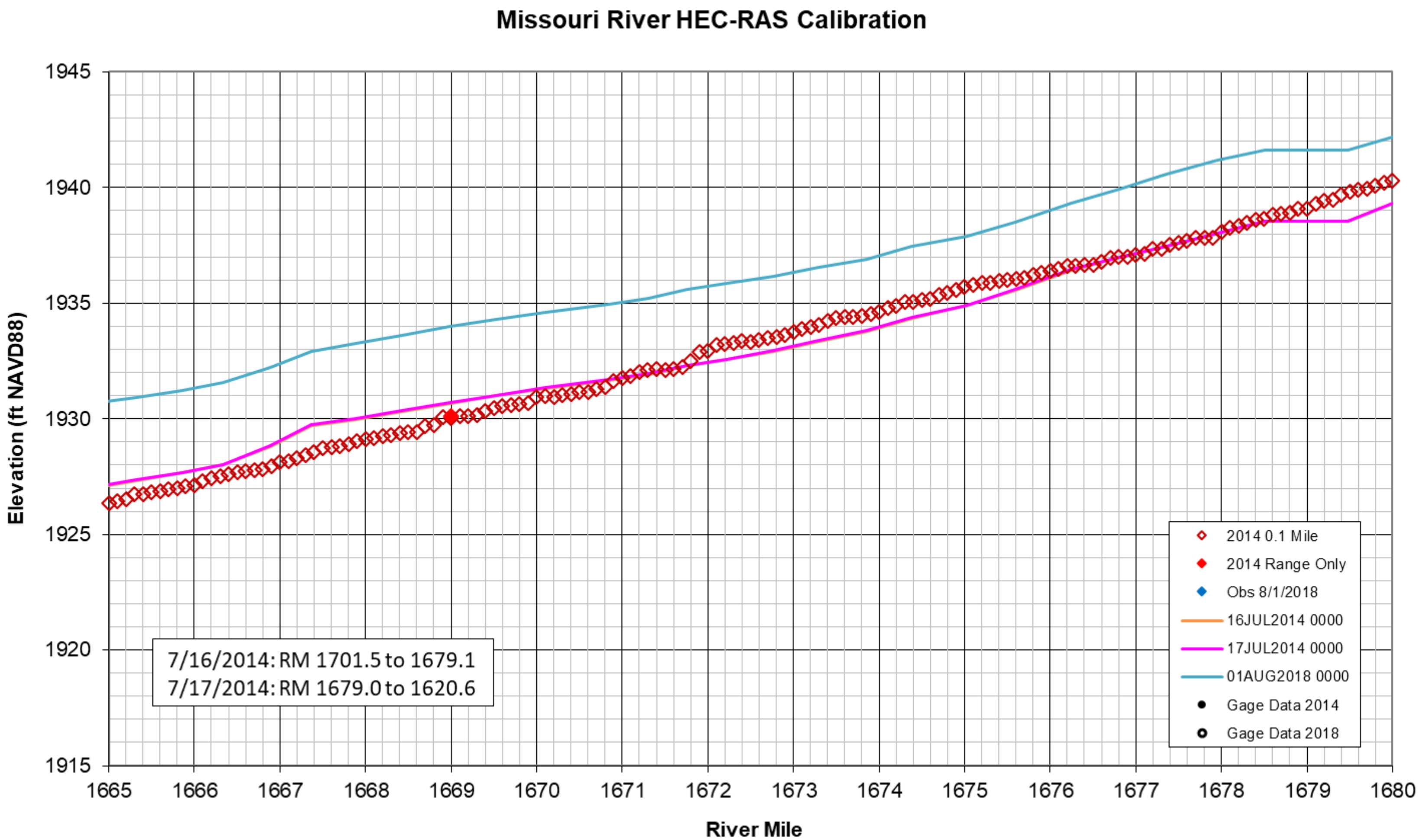


Plate 11: Measured WSP vs Computed Water Surface – RM 1665 to 1680

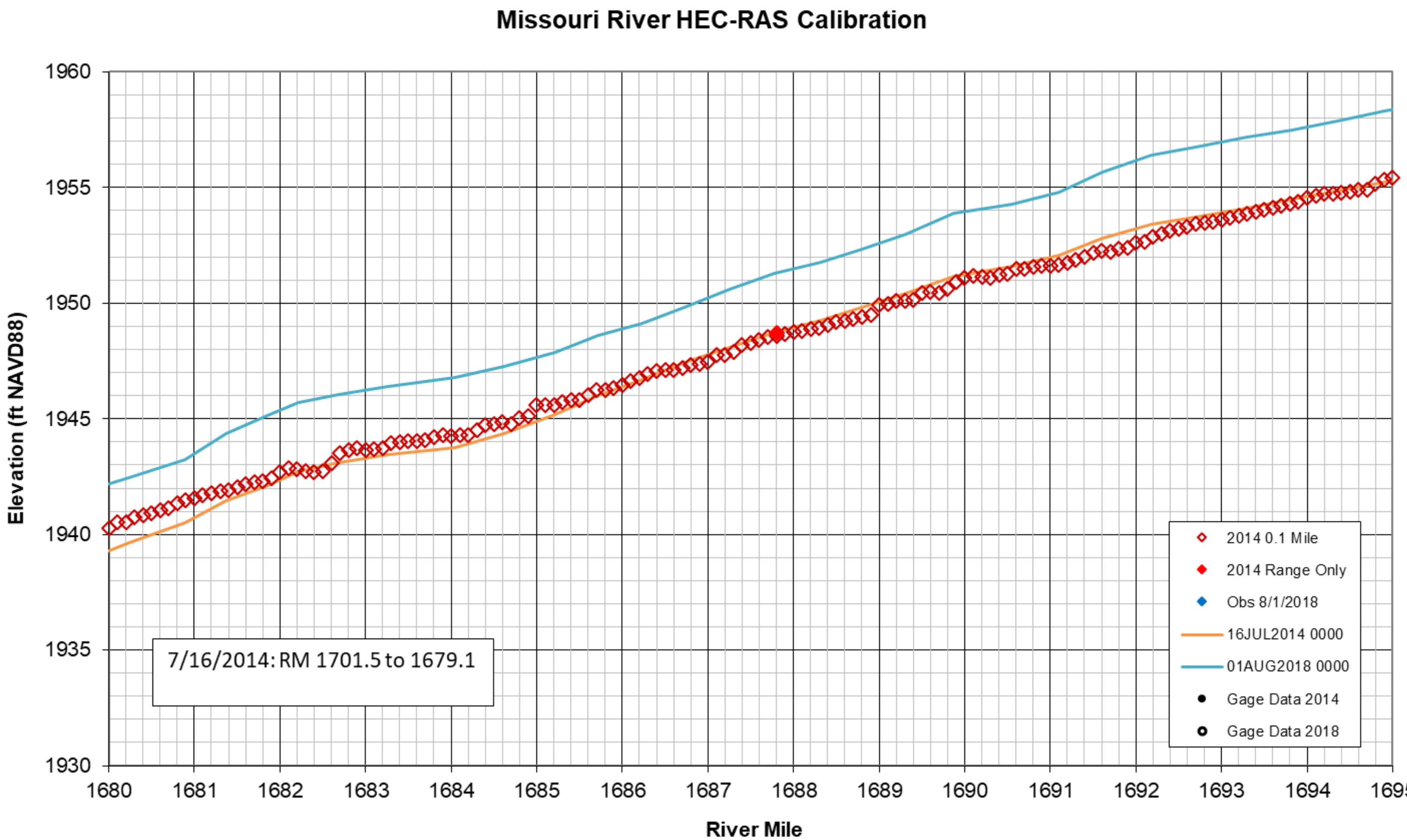


Plate 12: Measured WSP vs Computed Water Surface – RM 1680 to 1695

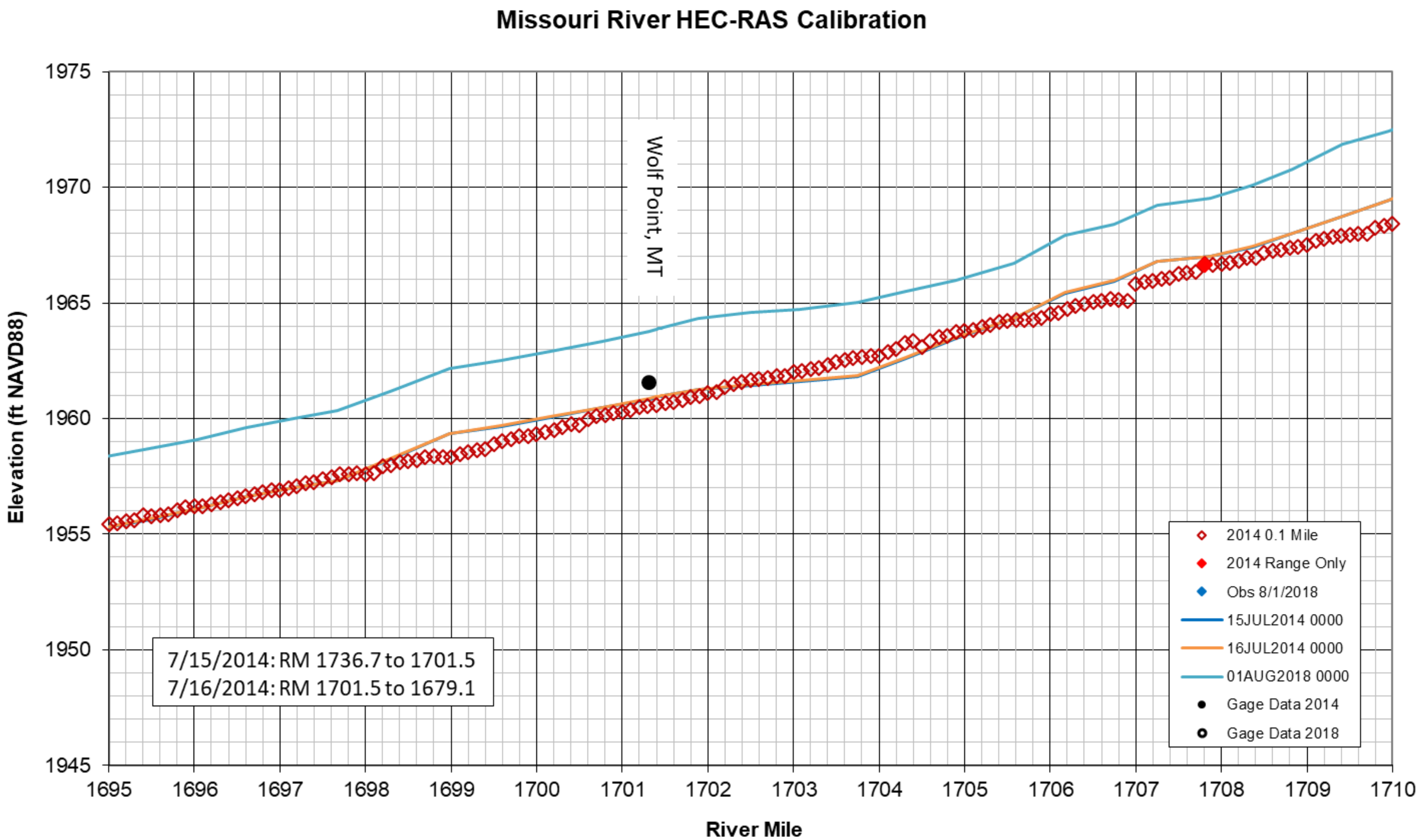


Plate 13: Measured WSP vs Computed Water Surface – RM 1695 to 1710

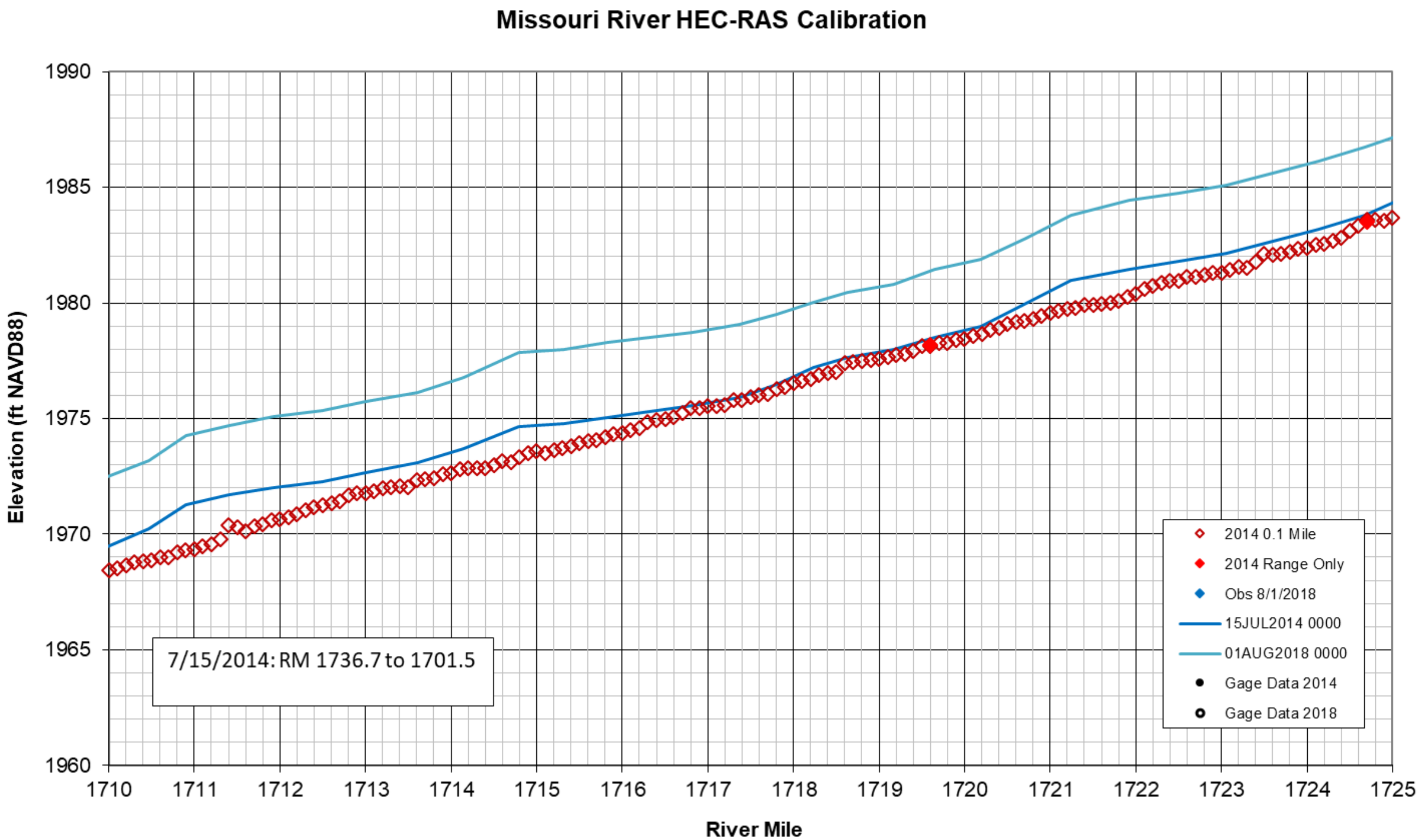


Plate 14: Measured WSP vs Computed Water Surface – RM 1710 to 1725

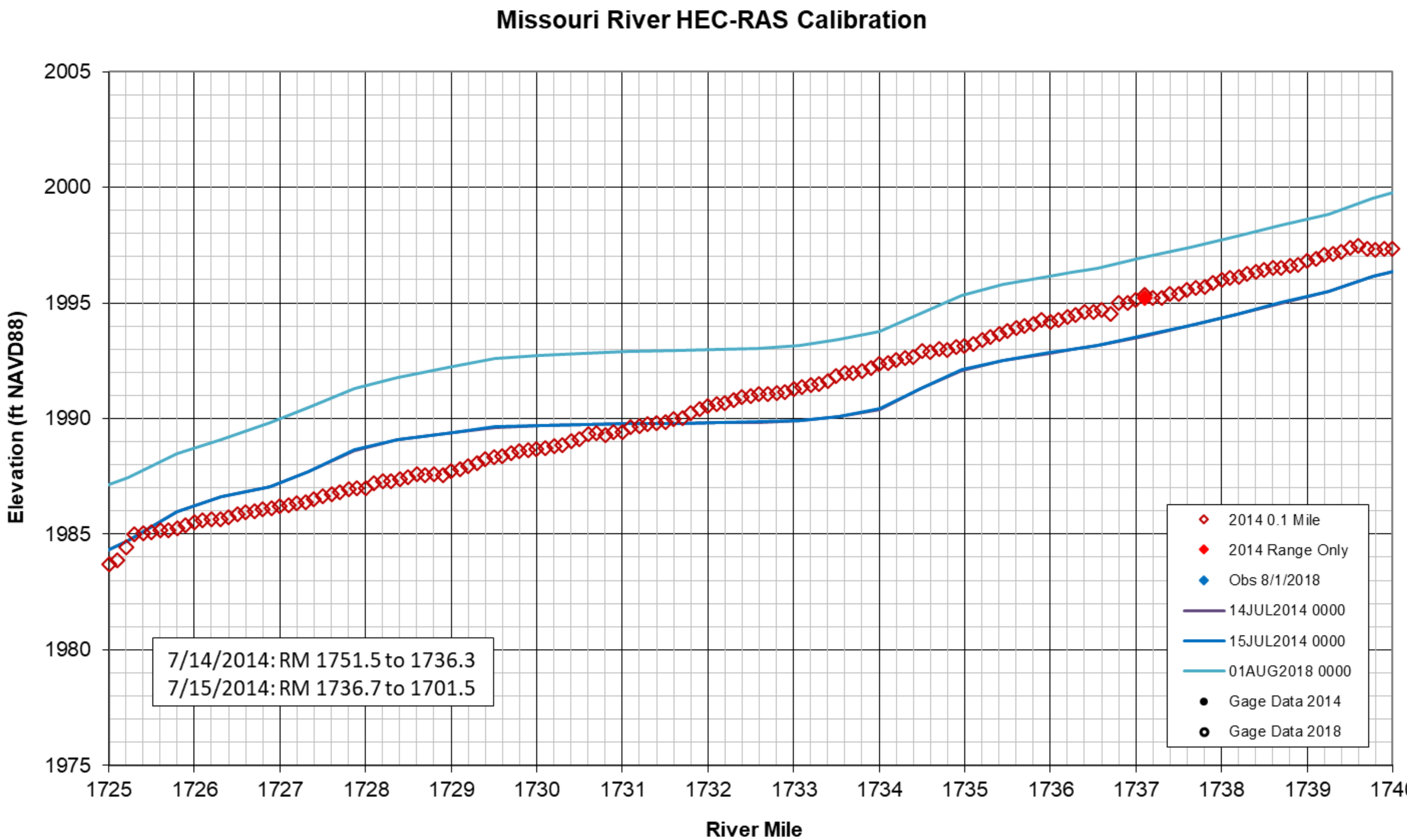


Plate 15: Measured WSP vs Computed Water Surface – RM 1725 to 1740

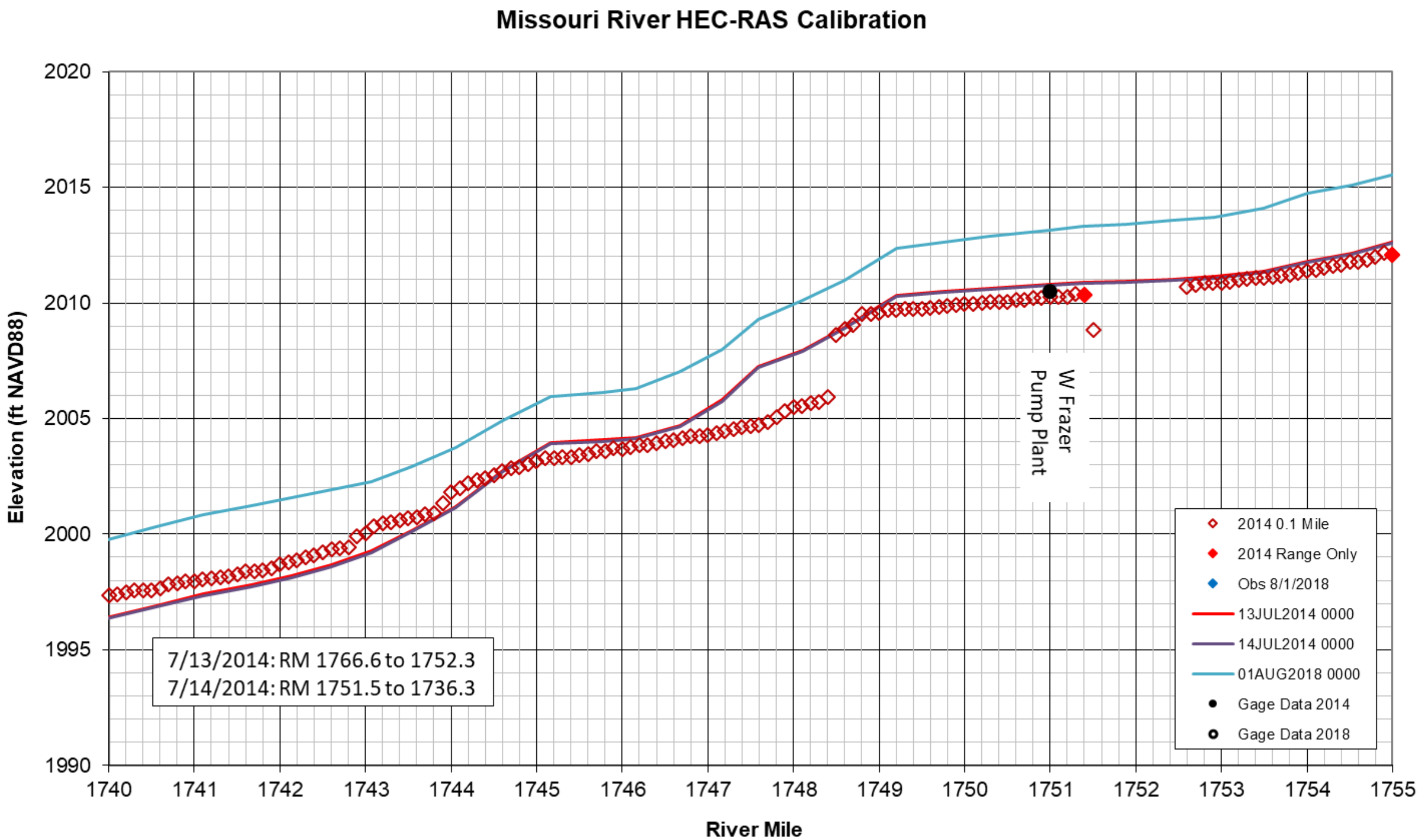


Plate 16: Measured WSP vs Computed Water Surface – RM 1740 to 1755

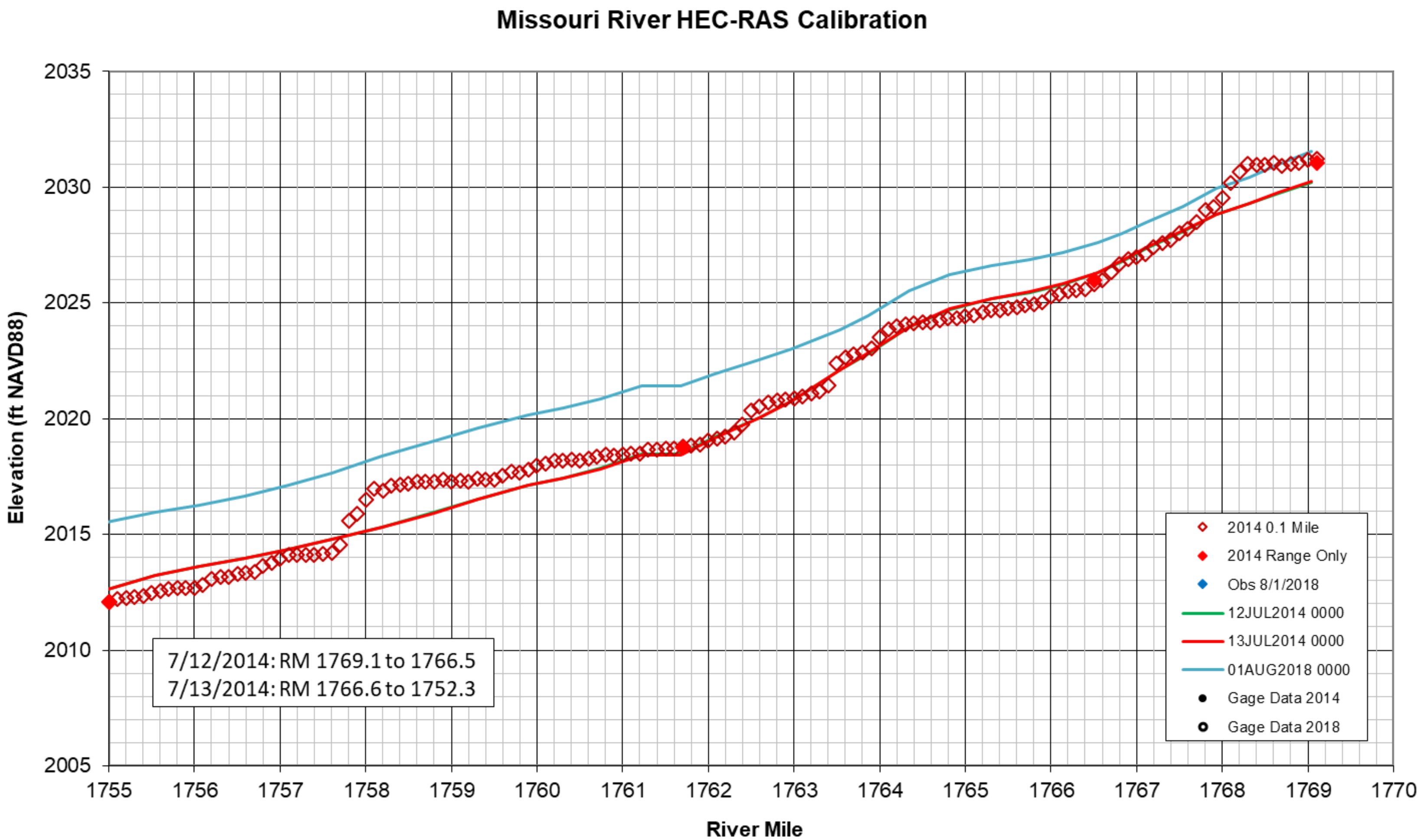


Plate 17: Measured WSP vs Computed Water Surface – RM 1755 to 1770

Attachment 2

Fort Peck Flow Alternatives Williston Area Steady RAS Flow for ResSim

Ft Peck Flow Alternatives
Williston Area Steady RAS Flows for ResSim

Introduction

Proposed Ft Peck flow alternatives will alter Ft Peck dam releases from current operations. The Williston, ND, area is located downstream of the Yellowstone River in the headwaters of Lake Sakakawea. The Williston area is protected by a federal levee that is operated by the Garrison Project Office, USACE. Flow alternative formulation includes a constraint to prevent any significant change in levee performance risk due to river levels along the levee at Williston.

An analysis was performed to determine the potential for alternatives to affect levee performance. The analysis used an HEC-RAS model to evaluate Williston levee reach river levels for various river flow and Lake Sakakwea pool combinations. The river level analysis was combined with input from Geotech regarding river elevations at which no levee deficiencies would be foreseen. The results provide constraints for use with Ft Peck flow alternatives at Williston due to levee restrictions. The Williston vicinity is shown in Figure 1.

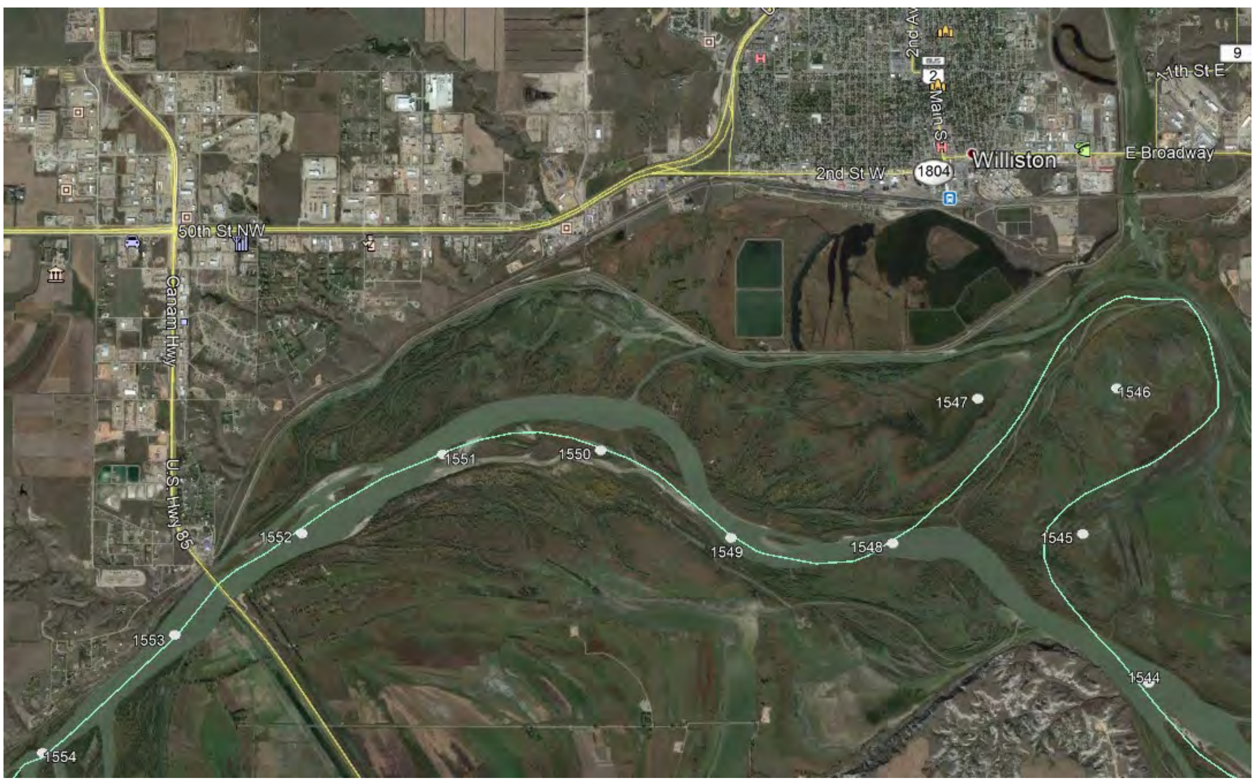


Figure 1. Williston ND Vicinity.

Analysis

An unsteady HEC-RAS model was created for the Missouri River Management Plan EIS (MRRMP-EIS, USACE 2018) for multiple reaches including the reach from Fort Peck Dam to Lake Sakakawea. The model created for the MRRMP-EIS was calibrated to 2011 - 2012 conditions. For the purposes of this study, the unsteady HEC-RAS model calibration was updated to more recent (2014 and 2018) data. The 2011 high flow calibration was also maintained. For more information on the calibration update, refer to the report *Fort Peck Flow Alternatives Analysis, Unsteady HEC-RAS Model Calibration* (March 2019).

The unsteady 2019 calibrated HEC-RAS model was converted to steady flow and the steady flow model was used to perform the analysis. The Williston area river levels are affected by river flow and downstream Lake Sakakawea pool levels. In order to evaluate alternative constraints, a series of flow and pool combinations were used to compute a series of rating curves in the Williston vicinity. Flows at Williston are the combined inflow from Ft Peck Dam releases and downstream tributaries including the Milk, Poplar, and Yellowstone Rivers. Simulations were performed for flows that ranged from 30,000 cfs to 200,000 cfs and pool elevations that ranged from the base of flood control (1837.5 ft, NGVD29 or 1838.81 ft, NAVD88) to two feet above the maximum operating pool (1856 ft, NGVD29 or 1857.31 ft, NAVD88).

Williston Levee

The HEC-RAS model includes a levee profile within the model as a lateral connection. RAS tabulates the embankment data in (Levee) Station, Elevation form. It also keeps track of the location where the cross-sections intersect the levee. A plan view of the levee and RAS model stationing is shown in Figure 2. A plot of the Williston Levee profile from the HEC-RAS model is shown in Figure 3.

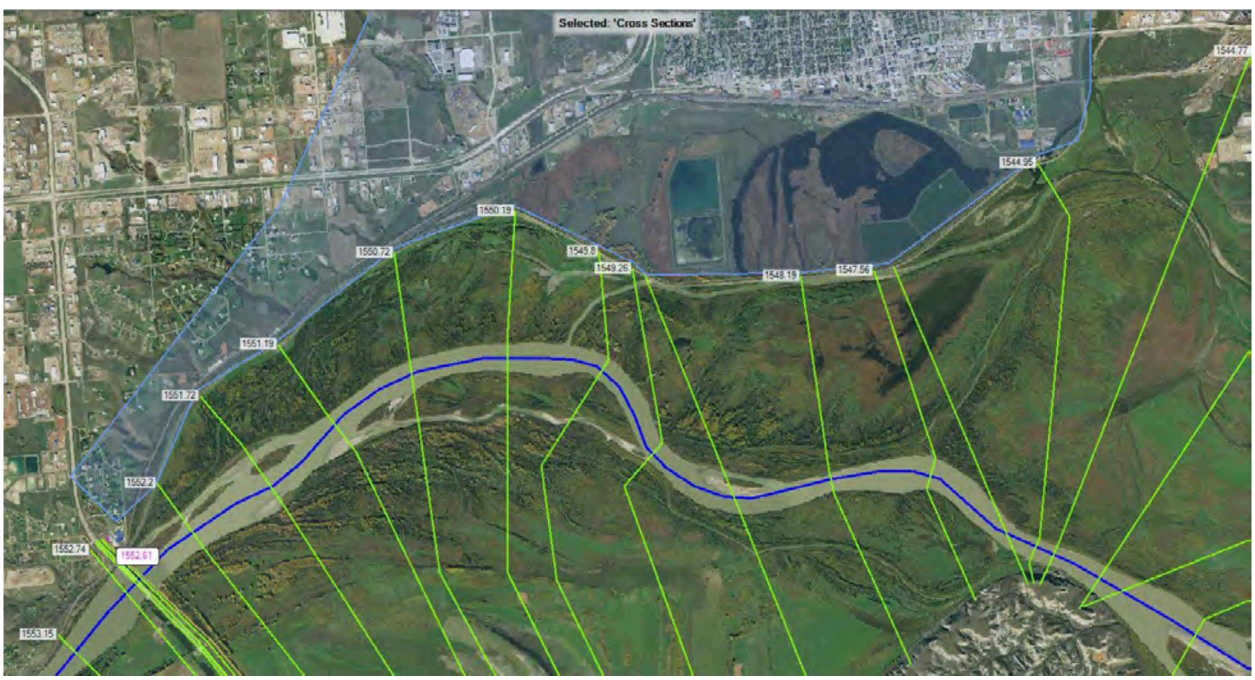


Figure 2. Williston Area RAS Model Stationing

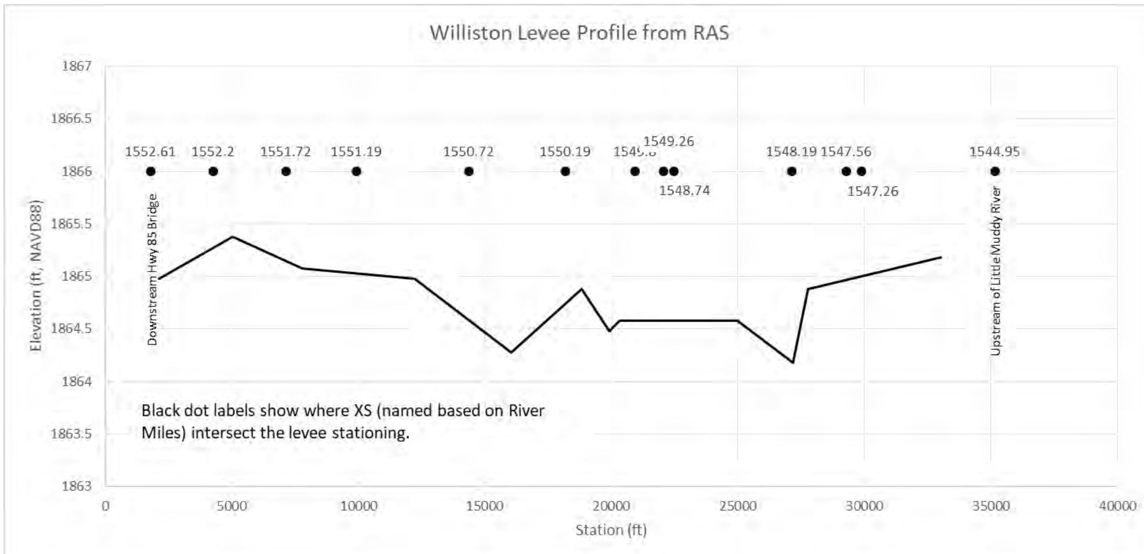


Figure 3. Williston Levee Profile from HEC-RAS

Geotech Levee Constraints

Dam Safety has identified the following performance-based risks/requirements for the Williston Levee to inform downstream flood targets for the Fort Peck Adaptive Management Framework:

a) Loading (both elevation/stage and duration) shall not appreciably increase risk.
b) Loading (including contributions from tributaries) shall not exceed the post 2011 maximum elevation set in March 2019 (1858.4 feet NGVD 29 referencing NOAA Gauge WLTN8); performance above this elevation is uncertain and therefore risks are not well characterized.
c) Under existing conditions, acceptable levee performance is expected/substantiated for loadings up to elevation 1856.0 NGVD 29 (summer 2018 flood event). However, foundation distress (boil activity) has been observed in the relief well channel at elevations approaching 1858.4 NGVD 29 (March 2019). Based on loading duration, this condition is not expected to threaten the integrity of the levee and/or its foundation but loading above elevation 1856.0 should be avoided to minimize risk.
d) Increased monitoring and surveillance of the Williston Levee is prescribed for elevations exceeding 1854.0 NGVD 29. Target elevations above 1854.0 places additional demand on already constrained Engineering Division resources (both funding and staffing) to perform surveillance activities.

Using the levee constraint criteria, the elevation of 1854 (1855.31 NAVD 88) was adopted for the maximum water surface elevation. The Geotech Dam Safety Memorandum included as attachment 1.

Water Surface Profiles

Results from the HEC-RAS model were tabulated at model cross section 1552.61 (located just downstream of the Hwy 85 bridge near the Williston Gage and at levee station 1810.75) and at model cross section 1544.95 (just upstream of the Little Muddy tributary and at levee station 35157.32). Profiles are shown in Figure 4 and Figure 5.

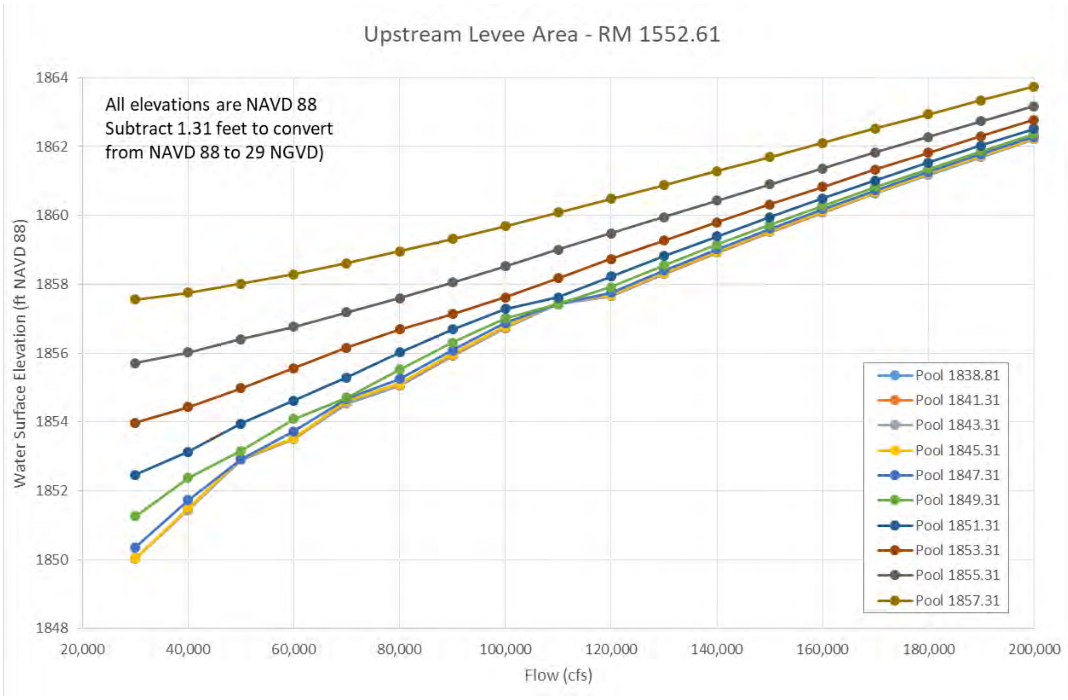


Figure 4. Cross Section 1552.61 Output

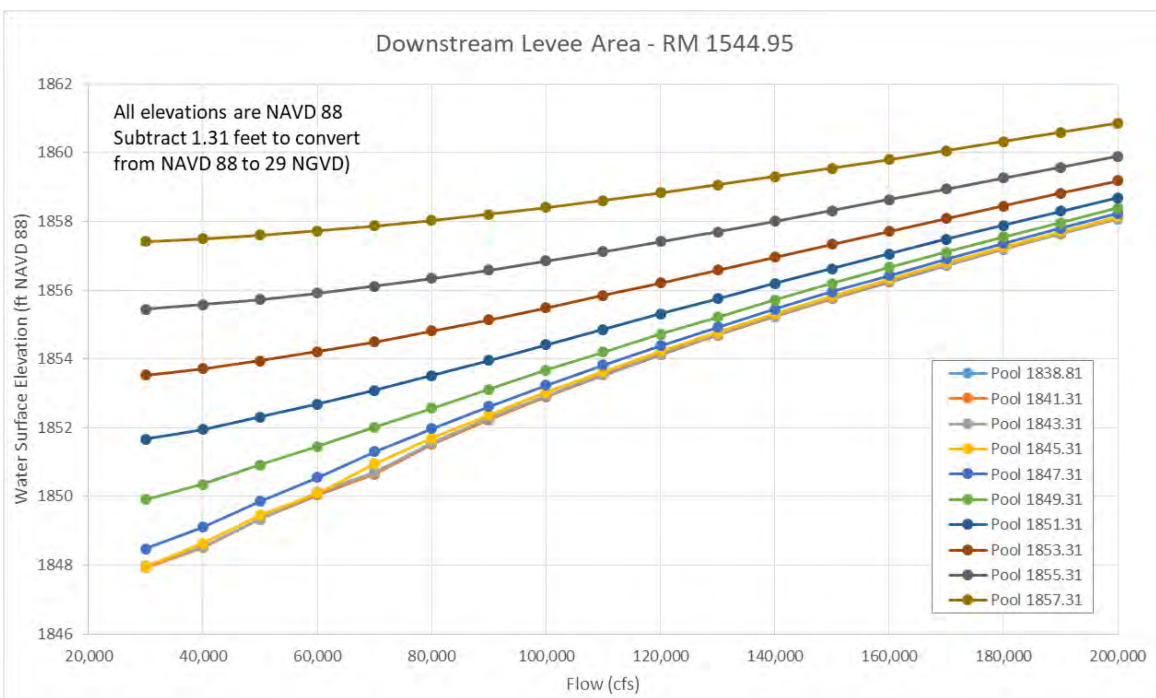


Figure 5. Cross Section 1544.95 Output

Williston Gage and Flood Impacts

The Williston gage (USGS 06330000) is at RM 1552.6, located about 100 feet downstream of the Hwy 85 bridge on the right descending (south) bank. The gage datum is 1831.84 ft, NAVD88. The NWS flood stages and impacts are shown in Table 1. Gage level flood impacts provide an additional source of information regarding alternative constraints.

Table 1. NWS Flood Stages and Impacts

Stage	Elevation (ft, NAVD88)	Flood Categories	Flood Impacts
33	1864.84		Levees surrounding Williston are likely to be topped without additional measures taken to temporarily raise the flood protection levels.
32.5	1864.34		Missouri River begins to overtop small stretch of levee near Highway 85 bridge and Williston Water Treatment Plant.
30.75	1862.59		Missouri River begins to cover Highway 85 south of Williston.
30.5	1862.34		At 30.5 ft, water is near the top of Highway 58 in areas between Fairview and Trenton.
30	1861.84		Water covers portions of 13th Avenue East and 11th Avenue East along the Little Muddy River.
28	1859.84		Water backing up into the Little Muddy River begins to cover 54th Street Northwest on the east side of Williston.
26	1857.84	Major Flood Stage	
24	1855.84	Moderate Flood Stage	Water begins to cover oil well location south of Williston. Wildlife management areas are flooded. City of Williston does not flood.
22	1853.84	Flood Stage	Low-lying farmland and access roads to oil well sites near Trenton are flooded. City of Williston does not flood.
20	1851.84	Action Stage	Ditches in the vicinity of the river will fill and wildlife management lands along the south banks will begin to flood.

Flow and Pool Constraints

The Williston gage flood levels and the Geotech levee constraints were evaluated in comparison to model computed flow levels. The resulting table provides levels at which inflows and downstream pool levels are estimated by the model to infringe on the established constraints. The results can be used as a guide for alternative screening to limit impacts. Further downstream elevations were also evaluated. However, since the constraining elevations are constant, the furthest upstream location provides the highest level of constraint. Table 2 presents results with shading to highlight combinations above the Action Stage elevation of 1851.84 NAVD 88, the Flood Stage elevation of 1853.84, and the Geotech levee constraint elevation of 1855.31 (NAVD 88).

Table 2. Water Surface Elevation Constraints

Model Computed Water Surface Elevation at RM 1552.61 Downstream of Hwy 85										
Pool Elevation										
NGVD 29	**1837.5**	**1840**	**1842**	**1844**	**1846**	**1848**	**1850**	**1852**	**1854**	**1856**
NAVD 88	**1838.81**	**1841.31**	**1843.31**	**1845.31**	**1847.31**	**1849.31**	**1851.31**	**1853.31**	**1855.31**	**1857.31**
Q Total	WSEL	WSEL	WSEL	WSEL	WSEL	WSEL	WSEL	WSEL	WSEL	WSEL
30,000	1850.05	1850.03	1850.05	1850.04	1850.35	1851.26	1852.46	1853.97	1855.71	1857.56
40,000	1851.45	1851.45	1851.46	1851.51	1851.73	1852.37	1853.13	1854.43	1856.02	1857.75
50,000	1852.9	1852.91	1852.91	1852.95	1852.92	1853.16	1853.95	1854.98	1856.4	1858.01
60,000	1853.5	1853.51	1853.54	1853.53	1853.73	1854.08	1854.62	1855.56	1856.76	1858.29
70,000	1854.53	1854.54	1854.56	1854.62	1854.67	1854.7	1855.29	1856.15	1857.19	1858.61
80,000	1855.05	1855.06	1855.08	1855.12	1855.25	1855.52	1856.02	1856.69	1857.59	1858.95
90,000	1855.92	1855.92	1855.94	1855.98	1856.08	1856.31	1856.69	1857.13	1858.05	1859.31
100,000	1856.73	1856.73	1856.74	1856.78	1856.87	1857.01	1857.28	1857.62	1858.52	1859.69
110,000	1857.43	1857.44	1857.45	1857.48	1857.42	1857.42	1857.62	1858.18	1859	1860.08
120,000	1857.65	1857.65	1857.66	1857.69	1857.76	1857.92	1858.23	1858.73	1859.48	1860.48
130,000	1858.3	1858.3	1858.31	1858.34	1858.4	1858.55	1858.82	1859.27	1859.95	1860.88
140,000	1858.92	1858.92	1858.93	1858.96	1859.02	1859.15	1859.39	1859.8	1860.43	1861.29
150,000	1859.51	1859.52	1859.53	1859.55	1859.61	1859.72	1859.95	1860.32	1860.9	1861.7
160,000	1860.09	1860.09	1860.1	1860.13	1860.18	1860.28	1860.49	1860.83	1861.36	1862.11
170,000	1860.64	1860.65	1860.66	1860.68	1860.73	1860.83	1861.01	1861.33	1861.83	1862.52
180,000	1861.18	1861.19	1861.19	1861.22	1861.26	1861.35	1861.53	1861.82	1862.28	1862.93
190,000	1861.7	1861.71	1861.72	1861.74	1861.78	1861.87	1862.03	1862.3	1862.73	1863.34
200,000	1862.21	1862.21	1862.22	1862.24	1862.28	1862.37	1862.51	1862.77	1863.17	1863.74

Q Total is the total upstream flows at Williston (cfs)
WSEL is the model computed water surface elevation NAVD 88

Attachment 1

CENWO-EDE-B 14 May 2019

MEMORANDUM FOR CENWO-PMA-C (Vanosdall)

SUBJECT: Risk-Informed Loading Determination for the Upper Missouri River Pallid Sturgeon Missouri River Recovery Program Fort Peck Adaptive Management Framework.

1. BLUF. Dam Safety recommends a target elevation of 1853.5 feet NGVD 29 for initial screening and/or modeling efforts.

2. GENERAL. In compliance with the 2018 BiOp for the Missouri River Mainstem System, Omaha District has initiated a study to evaluate changes in operational releases out of Ft Peck for the benefit of pallid sturgeon. Dam Safety has identified the following performance-based risks/requirements for the Williston Levee to inform downstream flood targets for the Fort Peck Adaptive Management Framework:

a) Loading (both elevation/stage and duration) shall not appreciably increase risk.

b) Loading (including contributions from tributaries) shall not exceed the post 2011 maximum elevation set in March 2019 (1858.4 feet NGVD 29 referencing NOAA Gauge WLTN8); performance above this elevation is uncertain and therefore risks are not well characterized.

c) Under existing conditions, acceptable levee performance is expected/substantiated for loadings up to elevation 1856.0 NGVD 29 (summer 2018 flood event). However, foundation distress (boil activity) has been observed in the relief well channel at elevations approaching 1858.4 NGVD 29 (March 2019). Based on loading duration, this condition is not expected to threaten the integrity of the levee and/or its foundation but loading above elevation 1856.0 should be avoided to minimize risk.

d) Increased monitoring and surveillance of the Williston Levee is prescribed for elevations exceeding 1854.0 NGVD 29. Target elevations above 1854.0 places additional demand on already constrained Engineering Division resources (both funding and staffing) to perform surveillance activities.

Ross Cullin, P.E.
Chief & Dam Safety Program Manager
Dam Safety Production Center, Dam Safety Section

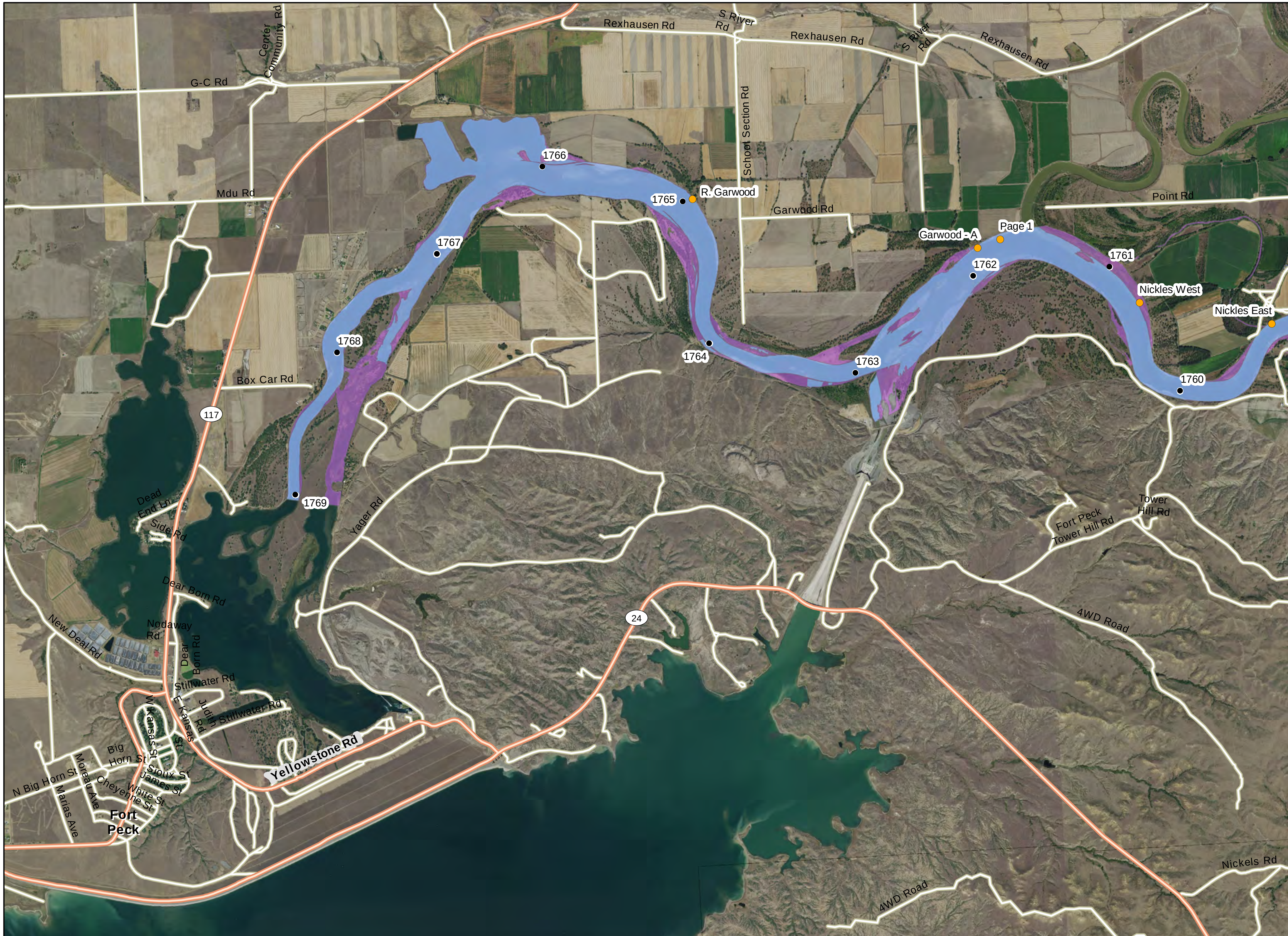
EOF FRENCH/CENWO-EDE-B/2249

RXC CULLIN/CENWO-EDE-B/2273

CF:
CENWO-EDH-F (Pridal)

Attachment 3

Cultural Resources Inundation Mapping



Missouri River
Fort Peck Dam to Williston, ND

Legend

July 2020 Surveyed Intakes
- Main Channel
- Side Channel

Aug 2020 Surveyed Intakes
- Main Channel
- Side Channel

Dec 2020 Surveyed Intakes
- Main Channel
- Side Channel
- 1960 River Miles
- Major Highways
- Highways
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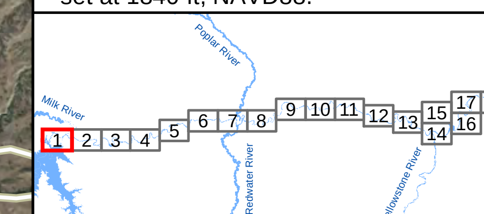
- 9,000 cfs Fort Peck Release
- 30,000 cfs Fort Peck Release

Note:
- Tributary inflows were kept constant at average June values (Milk R: 1210 cfs, Poplar R: 123 cfs, & Yellowstone R: 38, 700 cfs).
- Inundation boundaries represent the Missouri River channel only. Tributaries were not mapped.
- Lake Sakakawea pool elevation was set at 1840 ft, NAVD88.



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CENWO-EDH-F

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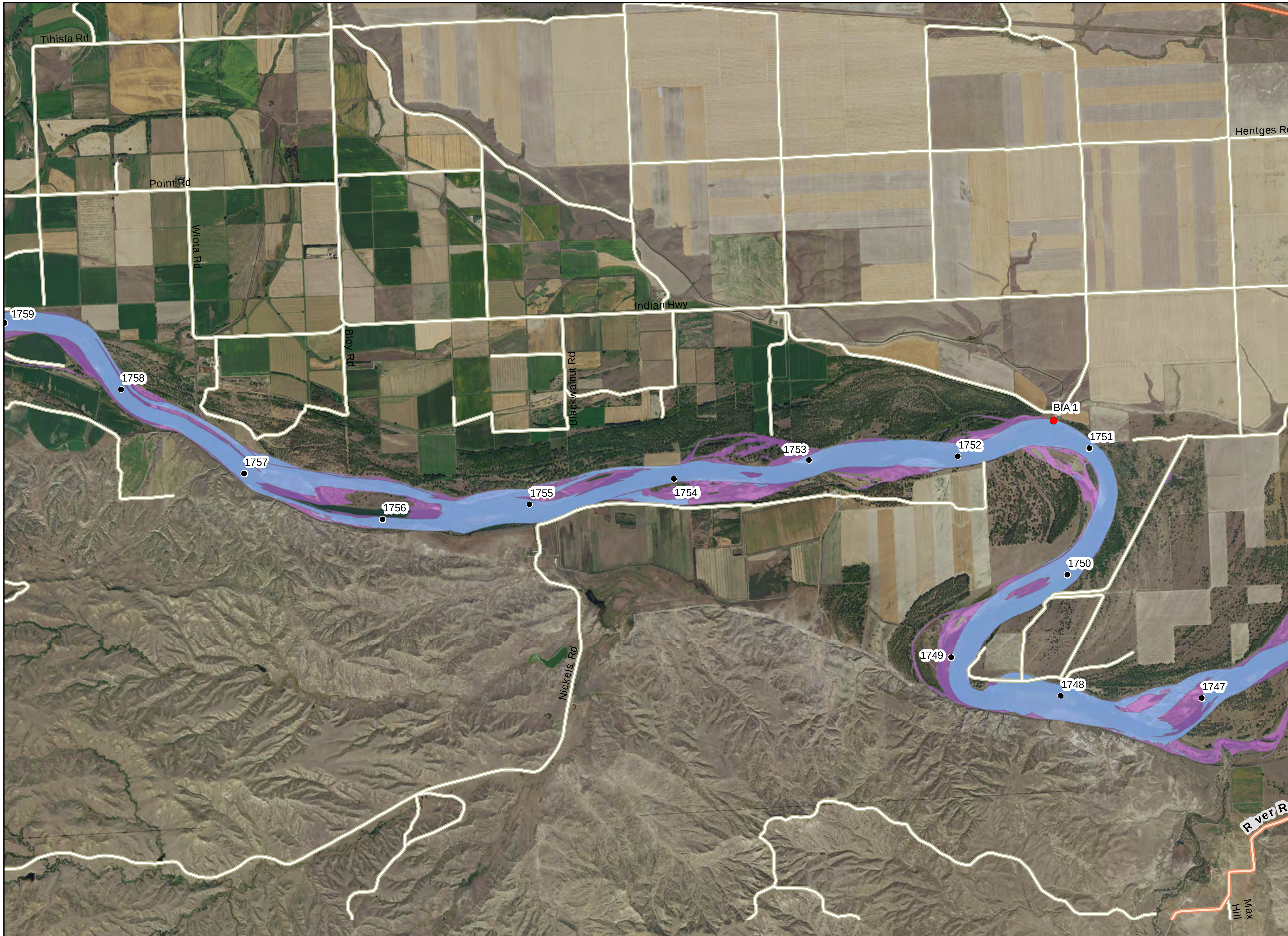

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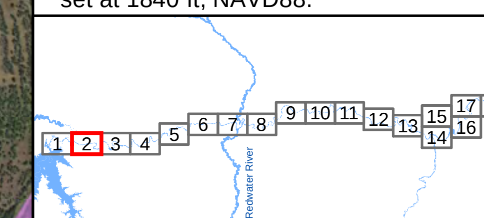

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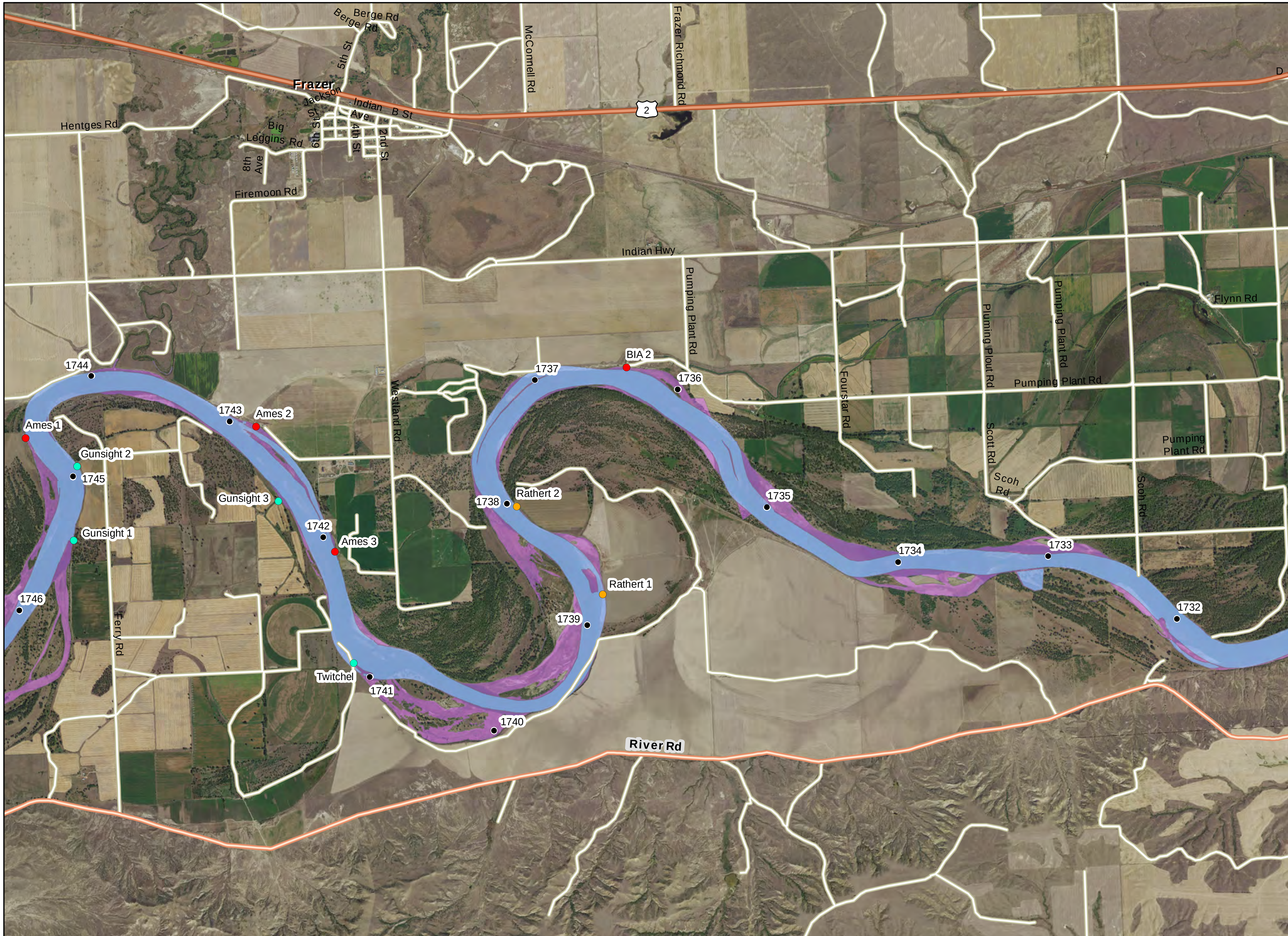

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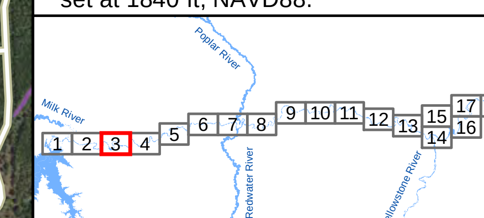

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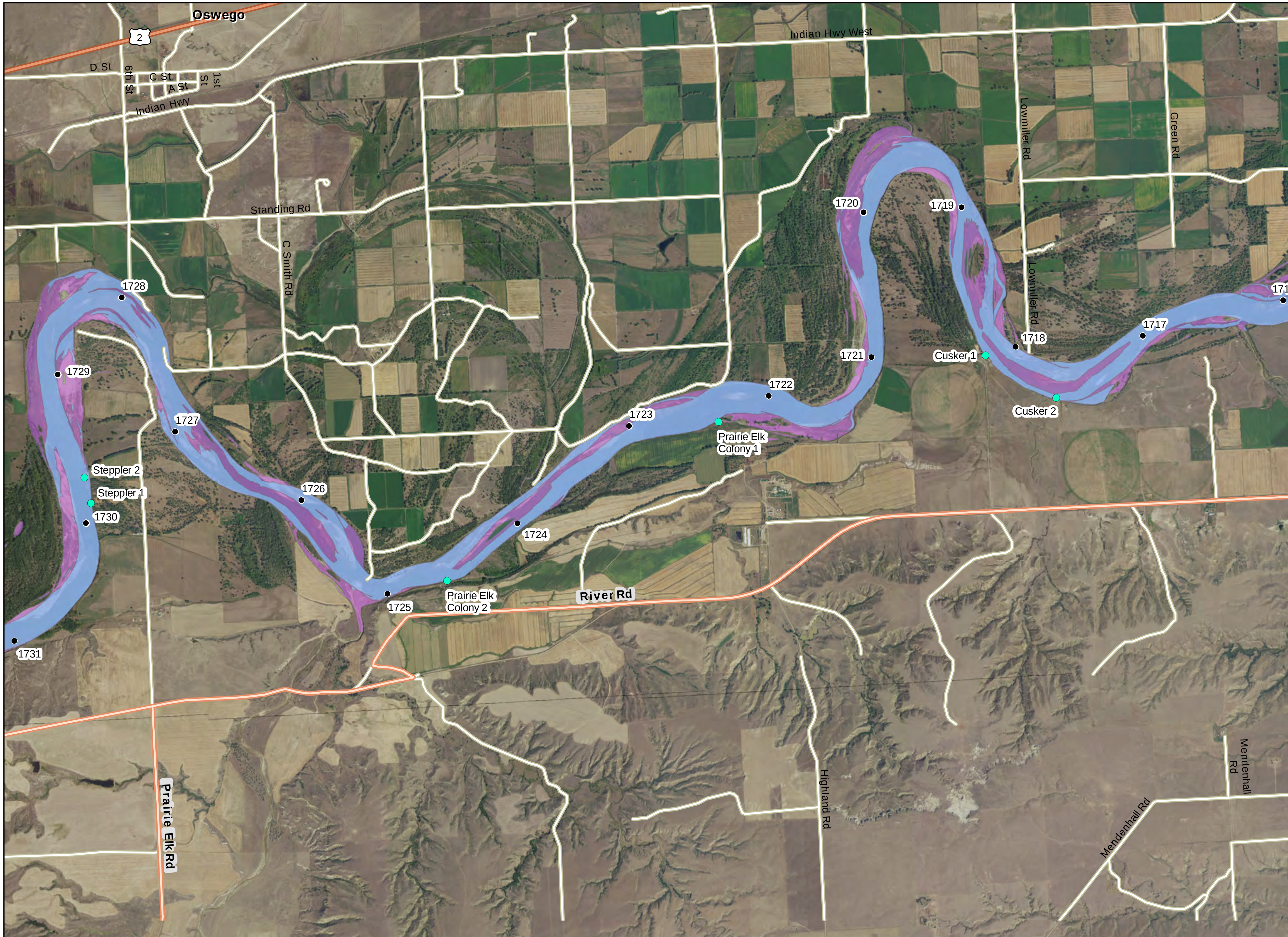

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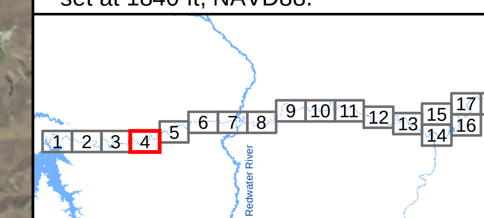

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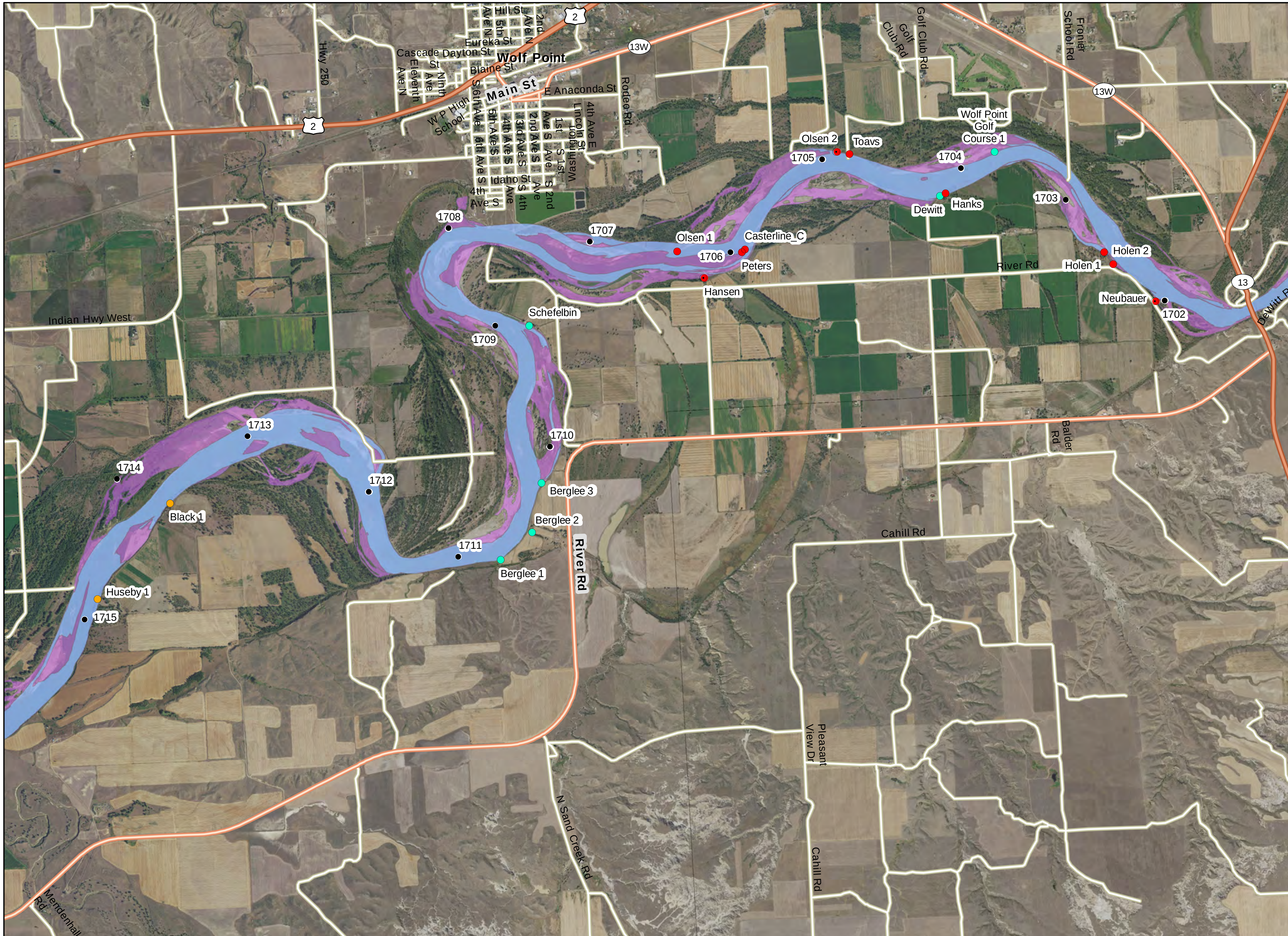

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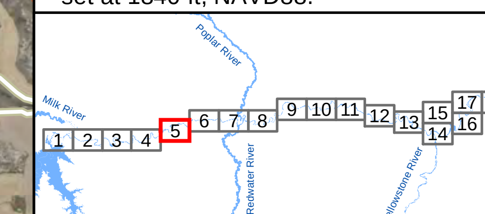

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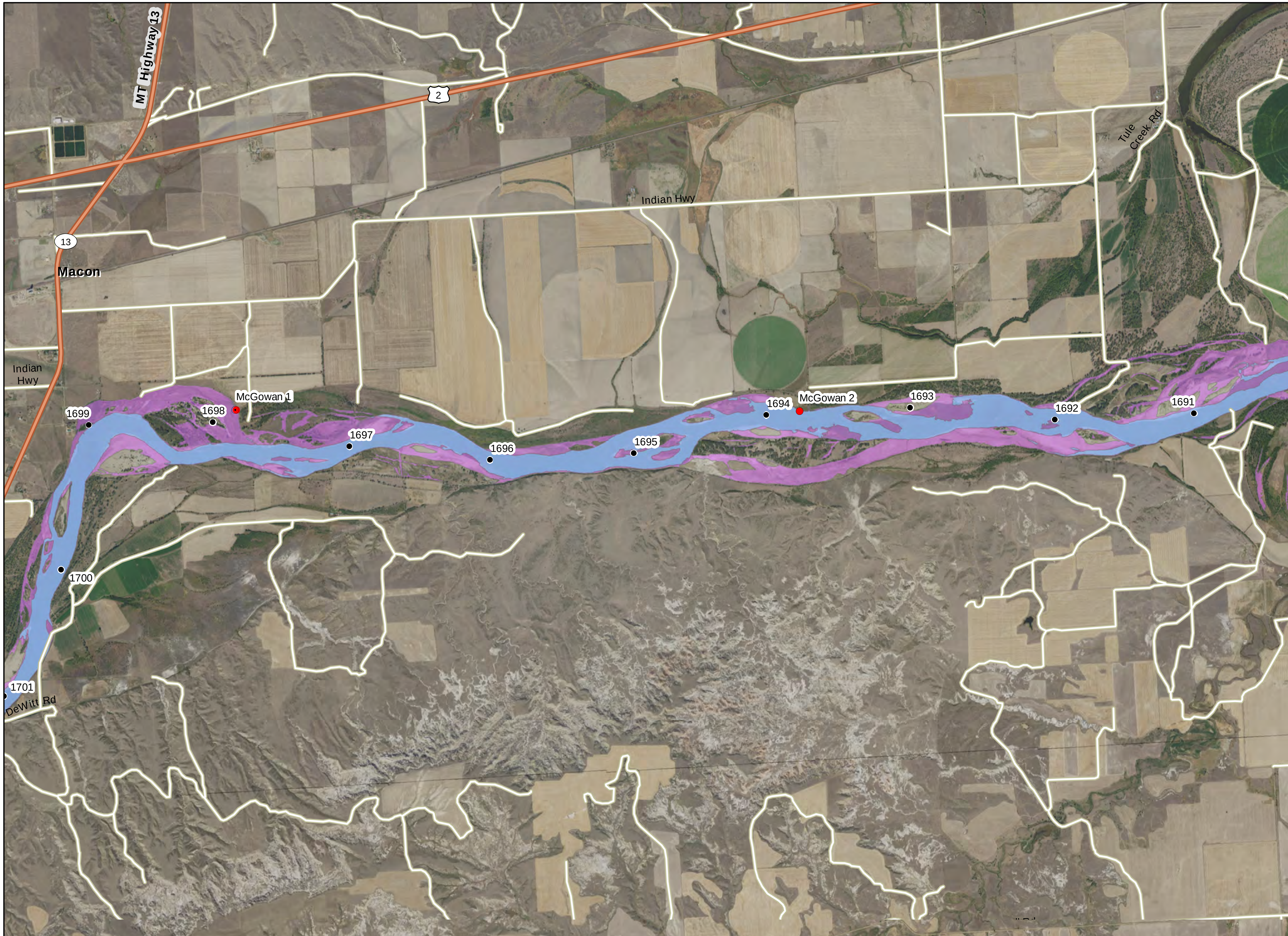

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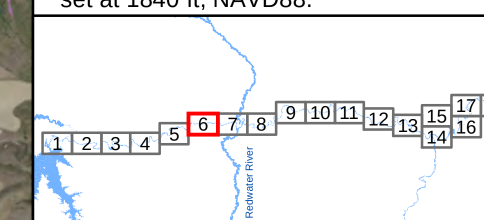

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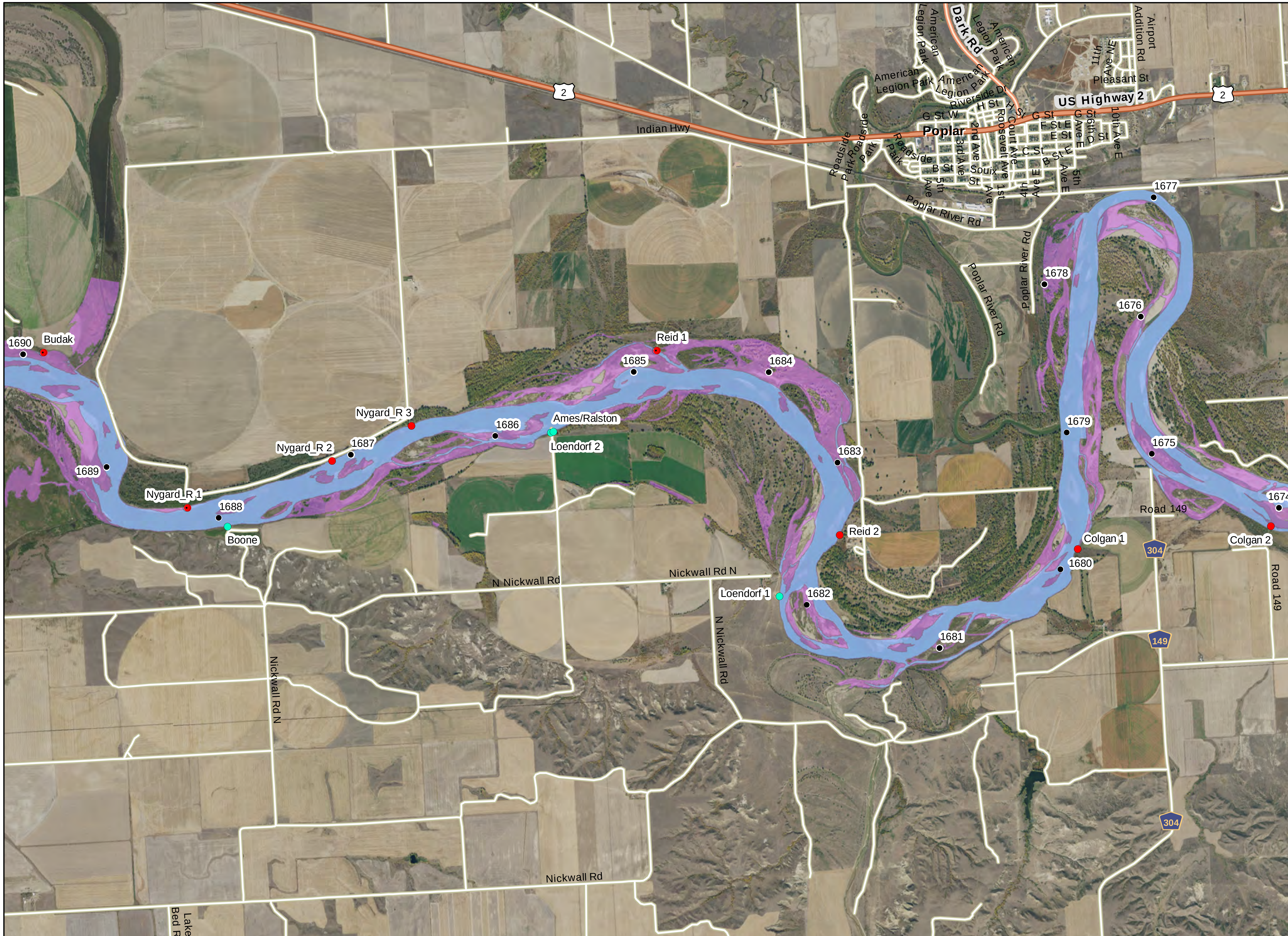

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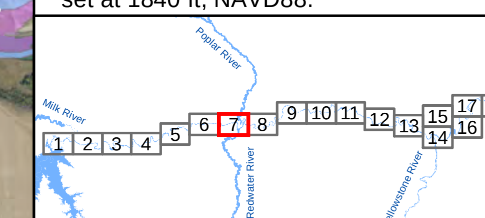

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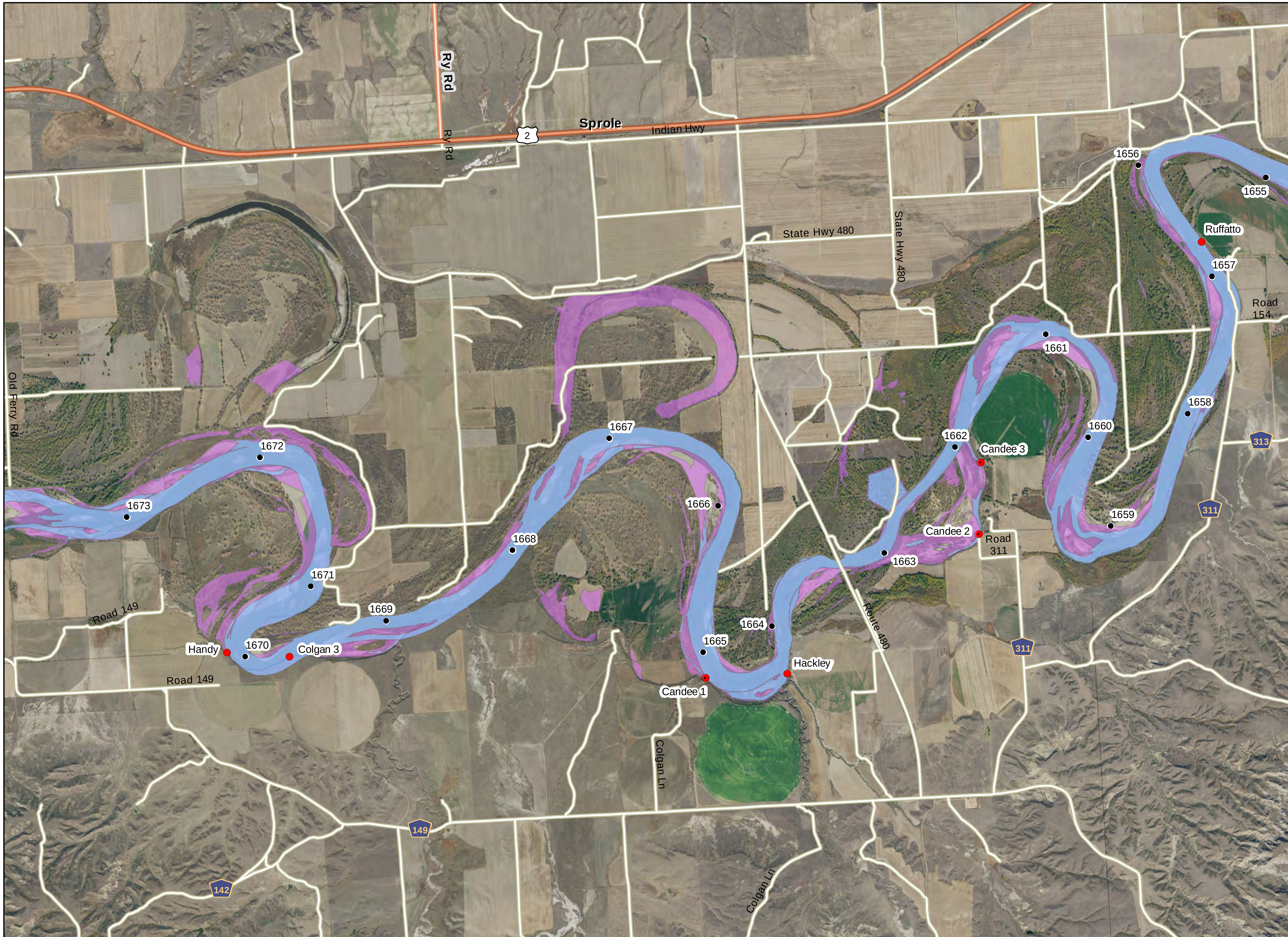

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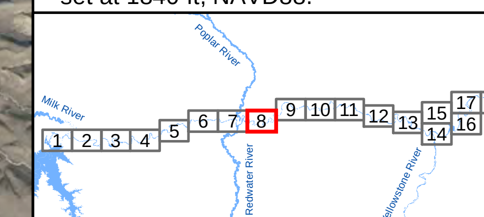

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Revision Date: 1 Mar 2021
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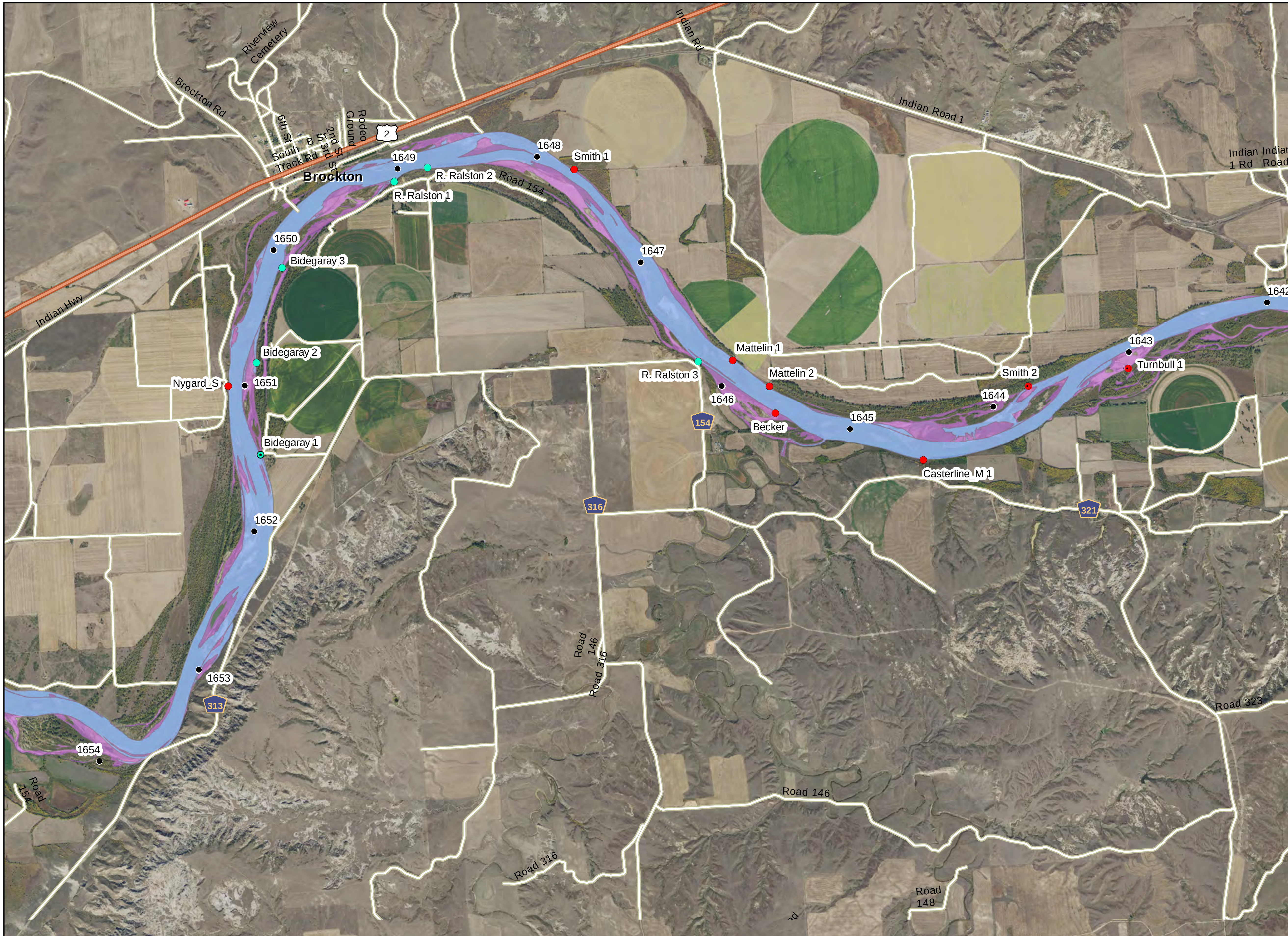

Missouri River
Fort Peck Dam to Williston, ND

Legend

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Aug 2020 Surveyed Intakes
- Main Channel
- Side Channel

Dec 2020 Surveyed Intakes
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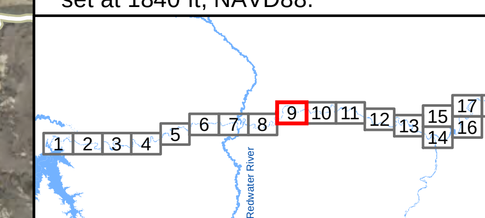

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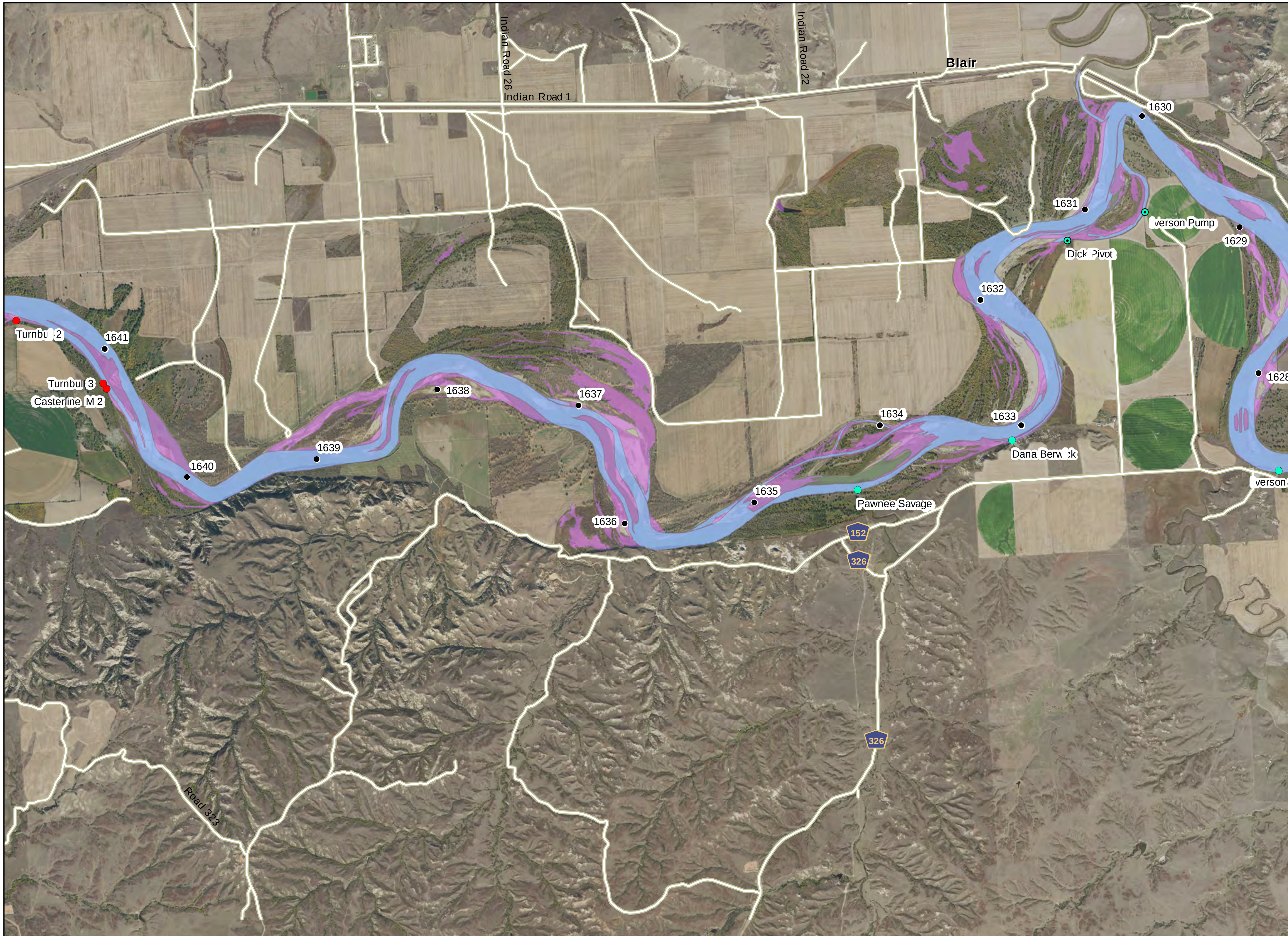

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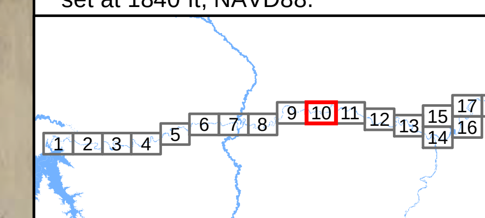

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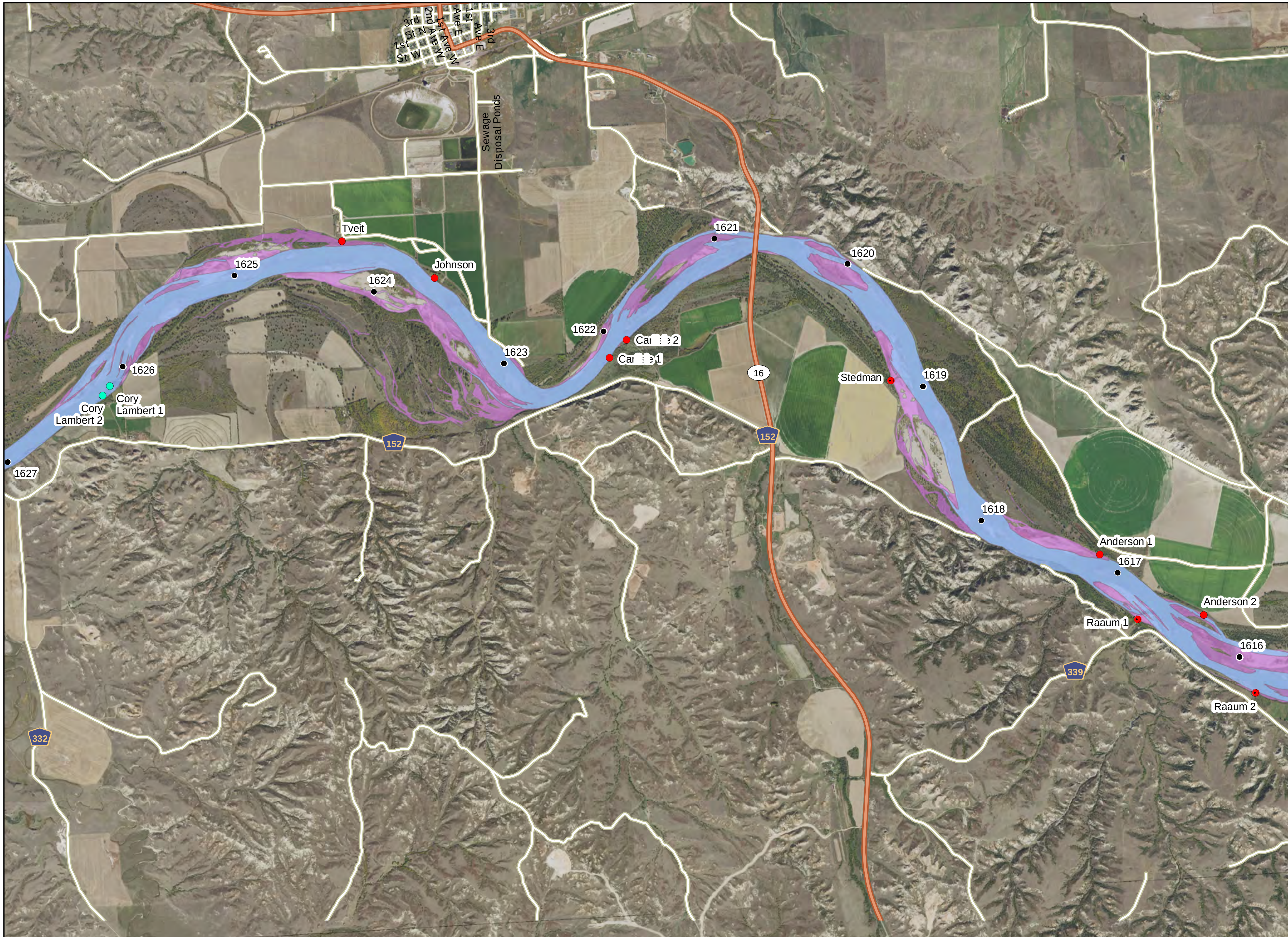

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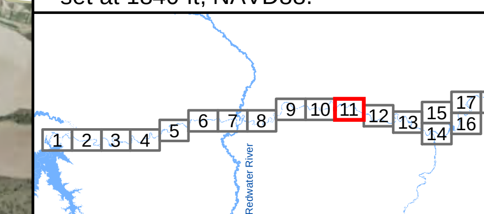

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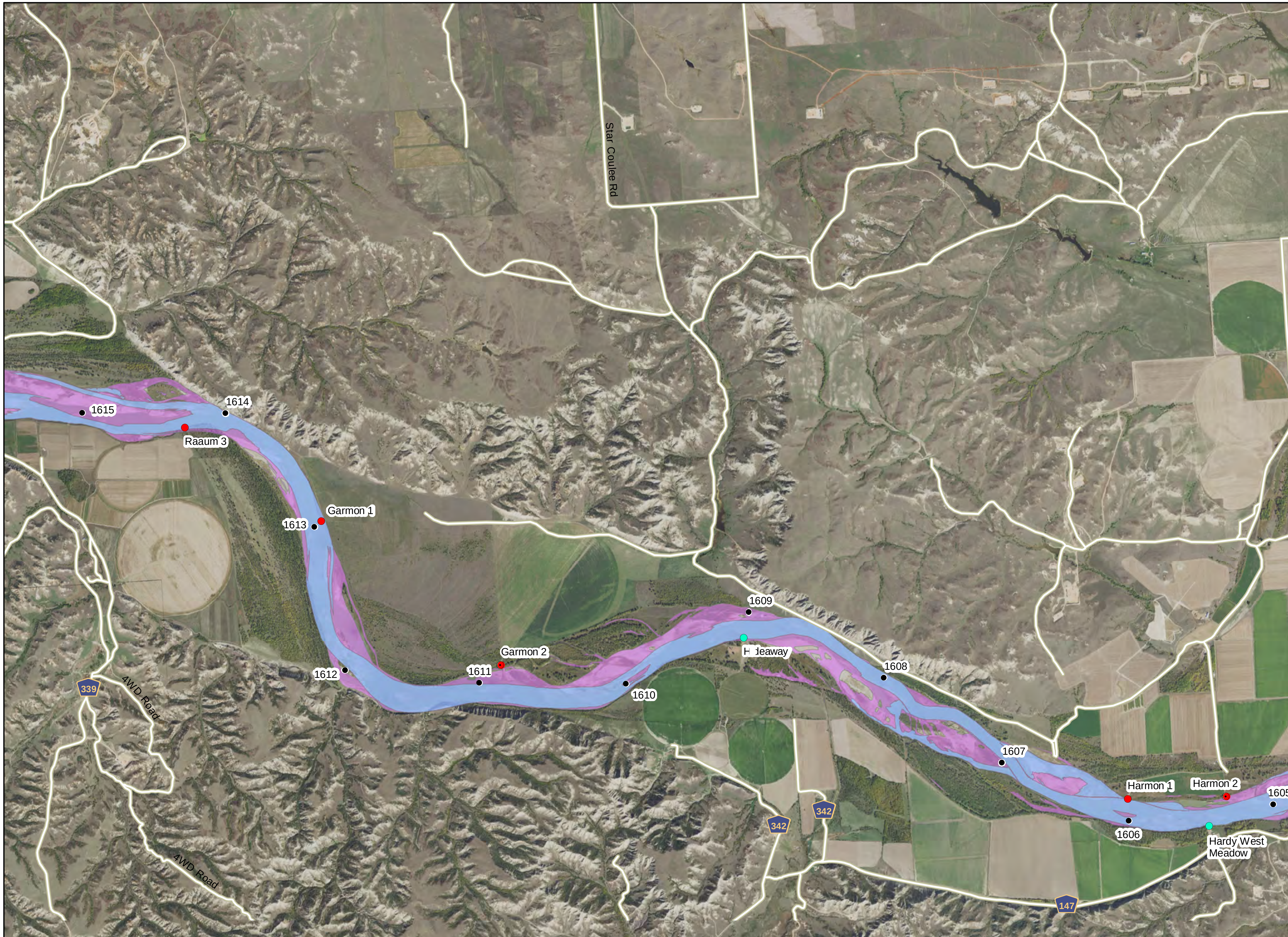
Missouri River
Fort Peck Dam to Williston, ND



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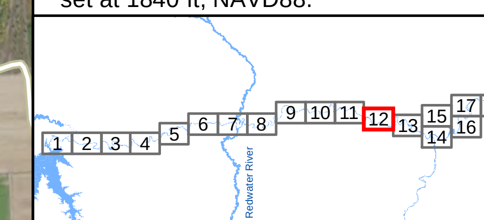

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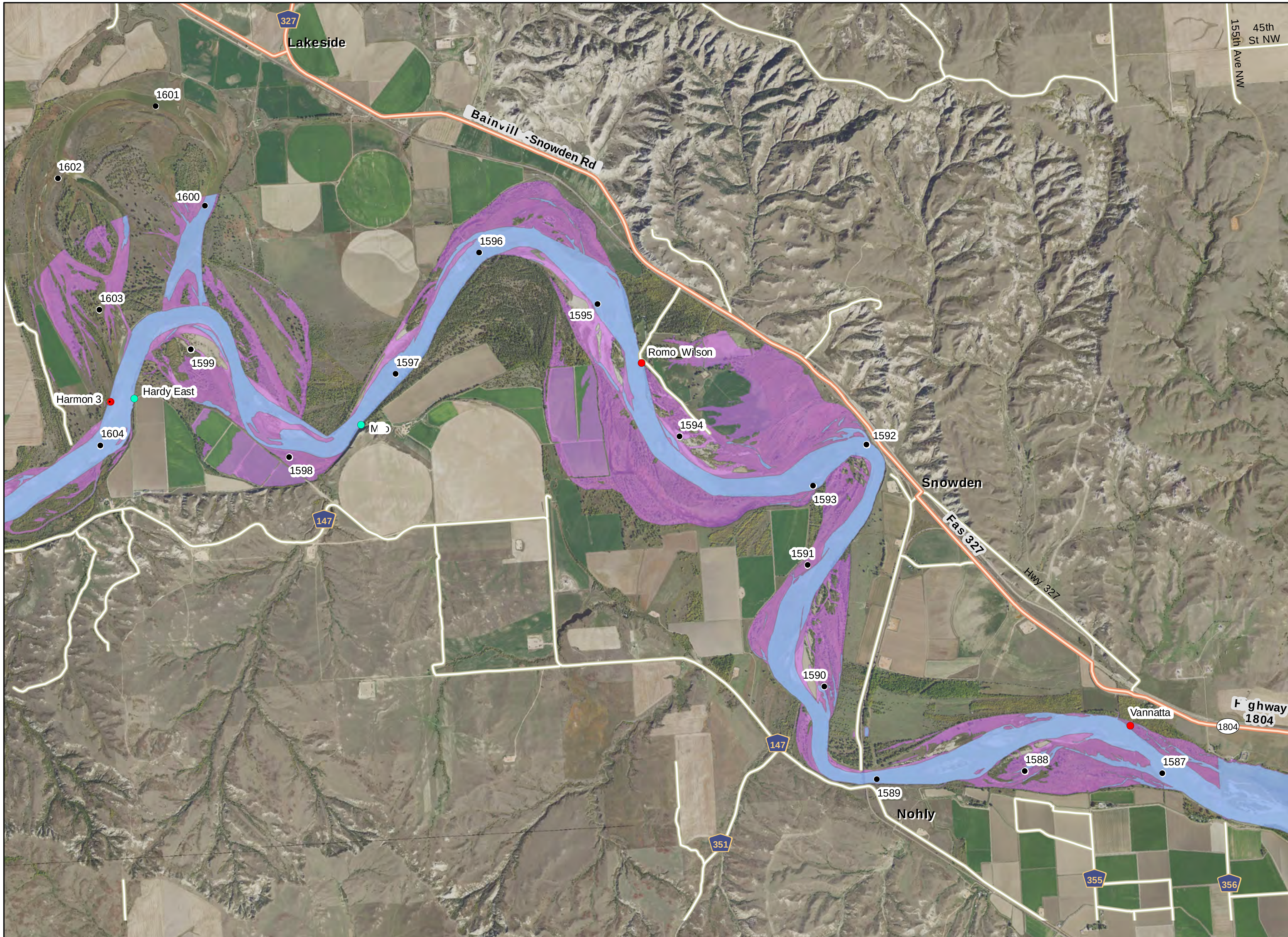

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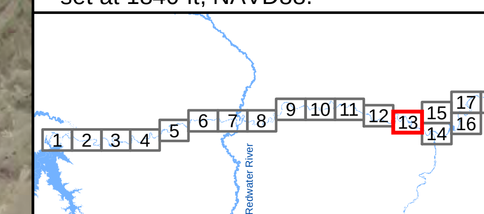

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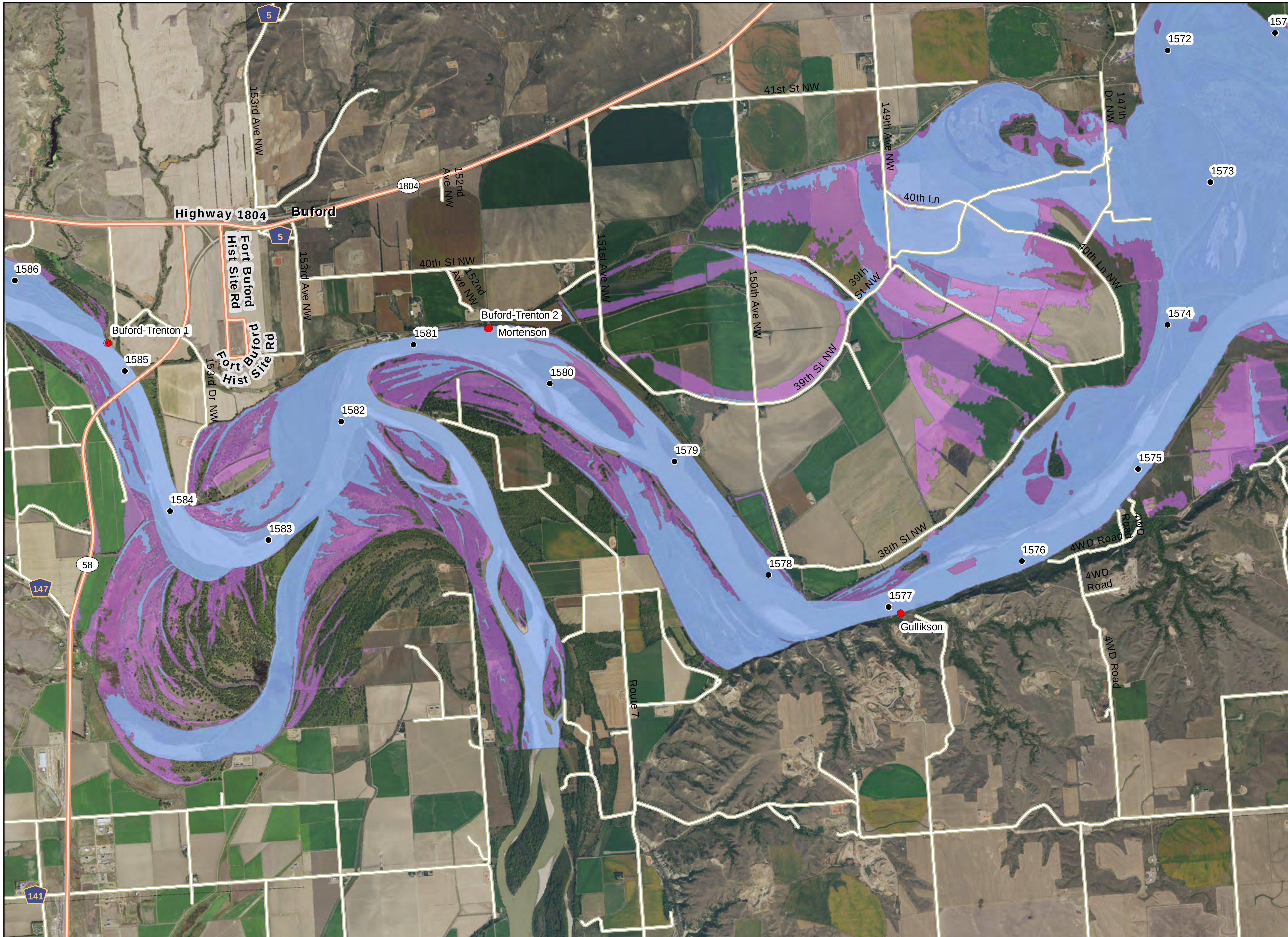

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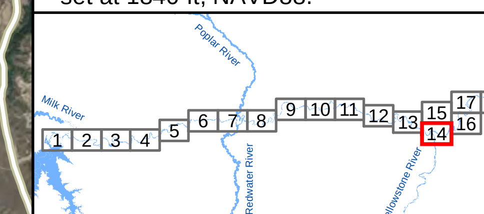

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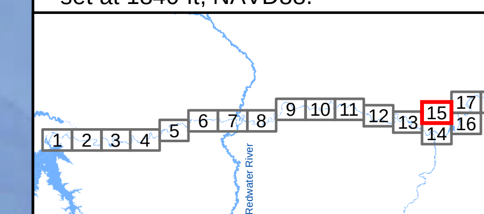

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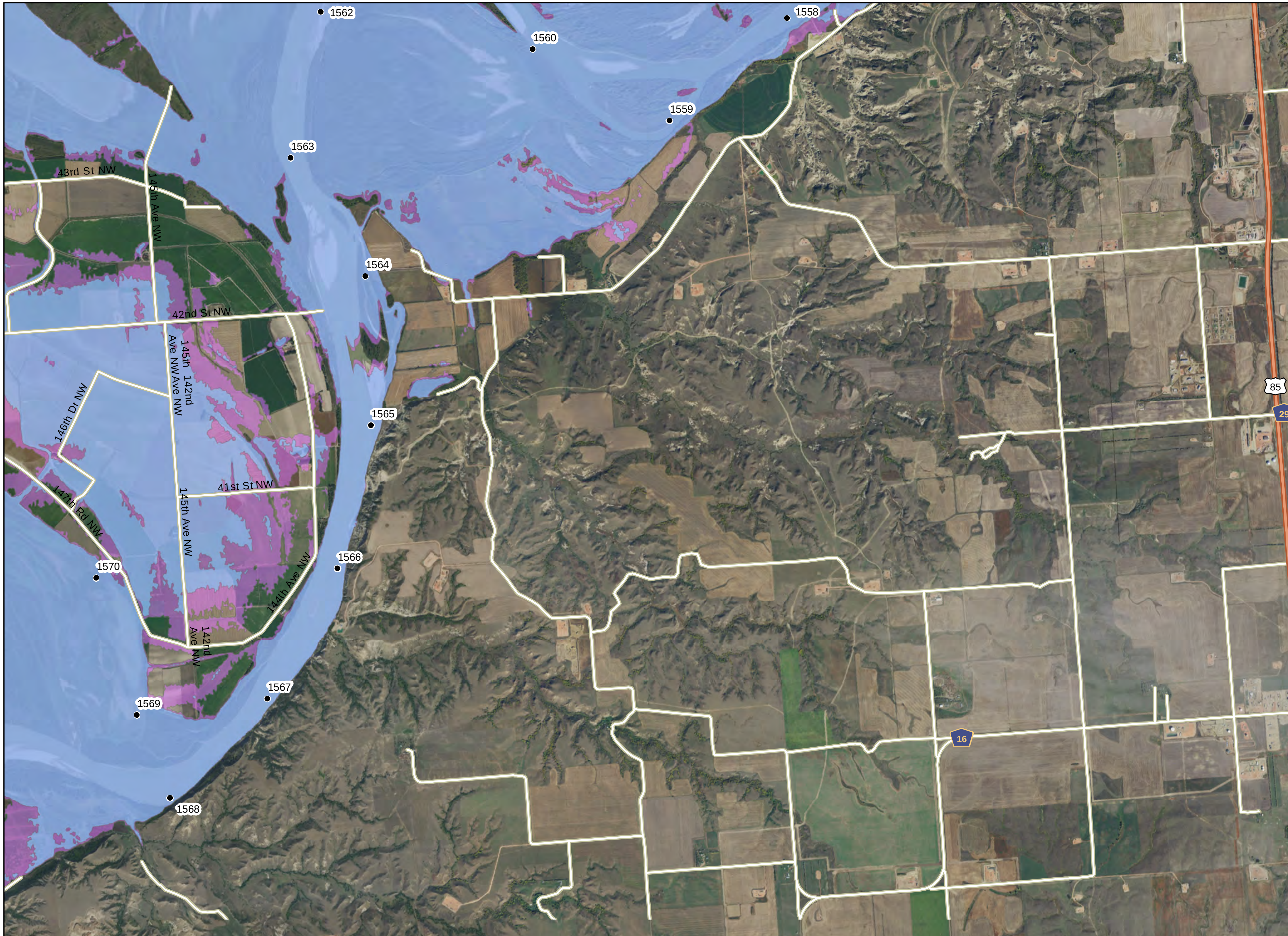

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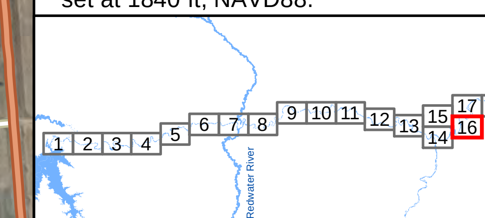

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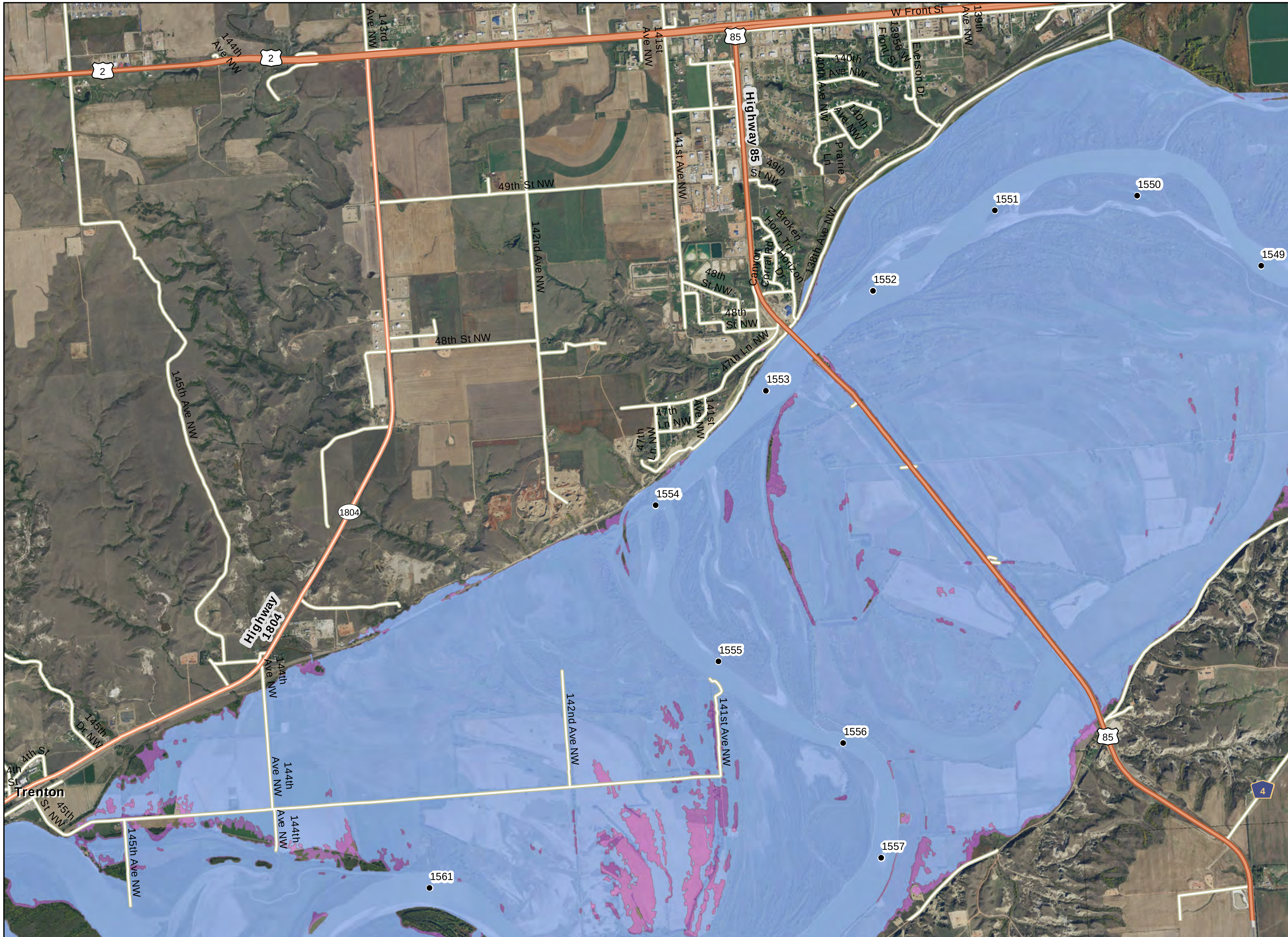

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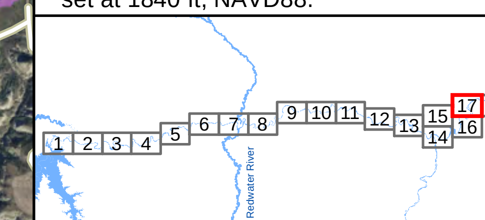

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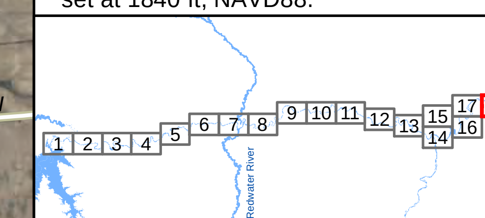

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Omaha District

Sources: 2017 NAIP

Attachment 4

Irrigation Intake Survey Data Report

Missouri River Irrigation Pump Intake Surveys
Fort Peck Dam to Williston, North Dakota
September 2021

T. Raaum Pump Site #3, RM 1614.3, Richland County, MT – 14th July 2020

Prepared by:
Engineering Division
Hydrologic Engineering Branch
River and Reservoir Engineering Section

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Missouri River Irrigation Pump Intake Surveys
Fort Peck Dam to Williston, North Dakota

1. BACKGROUND

As part of Endangered Species Act (ESA) consultation with the US Fish and Wildlife Service (USFWS) on Operation of the Missouri River Mainstem Reservoir System (System), the U.S. Army Corps of Engineers (USACE) amended its proposed action in the Biological Assessment (BA) to include formulation of test flows from the Fort Peck Dam and an adaptive management framework for their implementation to benefit pallid sturgeon recruitment. Based on the proposed action in the BA, USFWS issued a “No Jeopardy” biological opinion (BO) in April 2018. The Corps must comply with the BO in order to continue to operate the System and provide the benefits of the eight authorized purposes, including irrigation. Completion of the Fort Peck Dam Test Flows Environmental Impact Statement (Fort Peck EIS) in a timely manner is one of the requirements for compliance.

The Fort Peck EIS details two alternative hydrographs as well as a “No Action” alternative. Both of the flow alternatives include a minimum in-river flow of 8,000 cubic feet per second (cfs), as measured at the Wolf Point, Montana U.S. Geological Survey (USGS) gage, in years that a test flow could be implemented. The minimum flow would be maintained to reduce the potential risk for impacts to irrigation and municipal and industrial (M&I) water intakes from low Missouri River flows. The test flow releases would peak at approximately 28,000 to 33,000 cfs for three days in June. The selected test flow in the final Fort Peck EIS would be conducted three to five times over the course of 10 to 20 years when the hydrologic conditions are appropriate. Following the development of the two flow alternatives, USACE began analyzing the economic, cultural, and environmental impacts of the individual scenarios. USACE performed a field inventory of irrigation pump and intake sites between the Fort Peck Dam and Williston, North Dakota, for use with evaluation for the EIS.

2. SURVEY OVERVIEW

2.1 Survey Method

USACE developed a scope and methodology to collect data at a limited number of irrigation pump sites along the Missouri River between the Fort Peck Dam and Williston, North Dakota. At each site, easting, northing, and elevation (XYZ) data points were collected to determine the pump site characteristics and potential damage levels for high flow events. Participating landowners had the opportunity to identify site specific critical features such as electrical panels or pump operating levels as well as share concerns about the alternatives during the surveys. The collected survey data was then combined with river levels and hydrologic modeling to inform the economic impact analysis.

2.2 Previous 2001 Survey

Between June and August 2001, an inventory of the irrigation pumps and intakes between the Fort Peck Dam and the North Dakota border was conducted by the Roosevelt County Conservation District as contracted by USACE. The purpose of this inventory was “intended to serve as baseline data as the Army Corps of Engineers considered changes in the operation of the Fort Peck Dam, to assist in determining the potential impacts of proposed operational changes, and to serve as a baseline for monitoring conditions in the event that operational changes are effected” (Roosevelt County Conservation District 2002). A total of

143 pump sites were surveyed during the 2001 inventory, which was believed to comprise the majority of the pumps being used in the area at that time. From the results of the inventory, it was found that 101 pump sites were experiencing some bank erosion and 62 pump sites were expected to have problems operating when the flows exceeded 23,000 cfs.

2.3 July 2020 Surveys

Through coordination between USACE, the Missouri River Conservation District Council, and the Roosevelt County Conservation District, 70 sites were selected to be surveyed in 2020. This final site list covered six counties in Montana and North Dakota from the Fort Peck Dam (river mile 1771.0) to river mile (RM) 1576.5, or about 25 river miles upstream of Williston, North Dakota. Prior to the surveys, coordination was performed between local coordinators, conservation districts, and landowners to gain additional site information and to arrange access to the irrigation pump sites. This coordination resulted in the finalized schedule presented in Table 1 of Appendix A.

Site surveys were conducted from July 8th through July 15th, 2020 at the selected sites using two separate survey teams. USACE personnel for each team included one member from the Hydrologic Engineering Branch and two to three members from the Omaha District survey crew. Each team also included a state specific local coordinator. These were individuals familiar with the area that were involved with pump site landowners. The personnel on each of the two survey teams can be seen below in Table 1 and Table 2.

Table 1. Members of Survey Team 1

Organization	Name
USACE – Omaha District	Sam Manning Dave Salter Ryan King Andrew Groves
MT Local Coordinator: Agri Industries	Lee Candee
ND Local Coordinator: Buford – Trenton Irrigation District	Ken Kyos

Table 2. Members of Survey Team 2

Organization	Name
USACE – Omaha District	Adrian Saenz Michael Skiles Michael Swinford
MT Local Coordinator: Agri Industries	Neil Iversen
ND Local Coordinator: McKenzie County Water Resource District	Larry Novak

The members of each of the two survey teams had different roles and objectives during the surveys. The team member from the Hydrologic Engineering Branch was tasked with filling out a data form in collaboration with the landowner while the Omaha District survey crew members were tasked with collecting various XYZ data on key features from each site. The local coordinator served as the primary point of contact to landowners prior to the field team's arrival. They also coordinated site access and arranged a meeting time between the landowners and the survey teams.

In preparation for the site surveys, several documents were developed to aid in the identification of key survey features and collection of critical landowner information. These documents included the previously mentioned schedule of the surveys, an EIS fact sheet provided to the landowners, an example hydrograph of one of the proposed alternatives, a typical section drawing of a pump intake, and a list of the various abbreviated codes representing key features and critical elevations. These documents along with a blank survey data form can be seen in Appendix A.

2.4 Additional Surveys Performed by USFWS / MT FWP

Following the surveys in July 2020, the USFWS collaborated with Montana Fish, Wildlife & Parks (MT FWP) to perform additional surveys on approximately 50 irrigation pump sites along the Missouri River in eastern Montana. These surveys occurred from August 25th through 28th, 2020 and on December 3rd, 2020. A member from USACE Hydrologic Engineering Branch was present during the August surveys from August 25th to 27th. The MT FWP survey data and information was included primarily as a supplementary attachment to this report, and the information gathered from these additional surveys was also utilized in the analysis of the collected survey data, which can be seen in Section 5 of this report. The completed data forms have been provided to intake owners that participated in the survey.

3. MISSOURI RIVER AND SITE CONDITIONS

3.1 Missouri River Discharge and USGS Gage Heights

Releases from the Fort Peck Dam during the survey period varied from a high of 11,200 cfs on July 14th and 17th to a low of 10,800 cfs on July 15th. USGS gage discharge and heights from the Missouri River at Wolf Point and Culbertson, Montana and on the Yellowstone River at Sidney, Montana were also used to determine river flows. Detailed tables with Missouri River discharges and gage heights for each survey day can be seen in Table 1 through Table 4 of Appendix B. Tables detailing the Missouri River discharge and gage heights during the additional MT FWP surveys are also shown in Appendix B in Table 5 and Table 6.

Using the estimated flow from the gage readings, the water surface elevation was estimated at each site using an approximate rating curve for the maximum test flow release. This potential water surface rise illustrated to landowners possible site conditions during the test release and was used to identify key features that could be impacted by the test river water level rise.

3.2 Irrigation Pump and Intake Sites

The irrigation pump and intake sites were fairly well distributed within the approximately 200-mile-long survey area. The pump sites were located on both the north and south banks of the Missouri River. Key features at each site usually included a buried dogleg pipe, a power panel, and an irrigation pump (typically with floating suction). Missouri River intakes were usually placed at the bottom of the bank with a bank cut for access that often included a graded ramp. Some sites were located off the main channel on a small access canal or old channel cutoff. Several sites were larger pump intakes serving multiple irrigators. An example of a typical irrigation pump site and a larger, multi-user irrigation pump site can be seen in Figure 1 and Figure 2, and a map of the site locations surveyed by USACE can be seen in Attachment 3 of the HEC-RAS and Geomorphic Analysis Report.

Figure 1. T. Raaum Pump Floating Suction, RM 1616.7, Richland County, MT – 14th July 2020

Figure 2. Buford-Trenton Irrigation District Pump, RM 1585.2, Williams Co., ND – 15th July 2020

4. DATA COLLECTION

During the surveys of the pump sites, the two survey teams collected various types of data at each site and from the landowners. The survey data included XYZ coordinates on numerous key features at each irrigation pump site and answers to various questions regarding the operation and maintenance (O&M) costs, preferred operation elevations, and crop production. The MT FWP surveys were also conducted using the same methods of data collection as those conducted by USACE.

4.1 SITES SURVEYED

A total of 69 sites were surveyed during USACE surveys, consisting of 62 sites located in Montana and seven located in North Dakota. Of the 69 sites, 63 of the sites were listed on the initial schedule while the remaining six sites were new pump sites surveyed at the landowner's request. Additionally, 50 irrigation sites were surveyed in Montana by the MT FWP in August and December 2020, for a total of 119 pump sites surveyed.

4.2 SURVEY POINTS

As part of the surveys, the XYZ coordinates of key features at each pump site were collected. The surveyed features included the top of bank, a site high water mark, the bottom of the power panel, and the current water surface elevation. These features were surveyed in order to record their locations, to determine the characteristics of each site, and to determine the potential damage levels associated with high flow events. A schematic that was used during the surveys illustrating a typical pump site cross section and a list of the key features for an irrigation pump site can be seen in Figure 3 and Table 3 below.

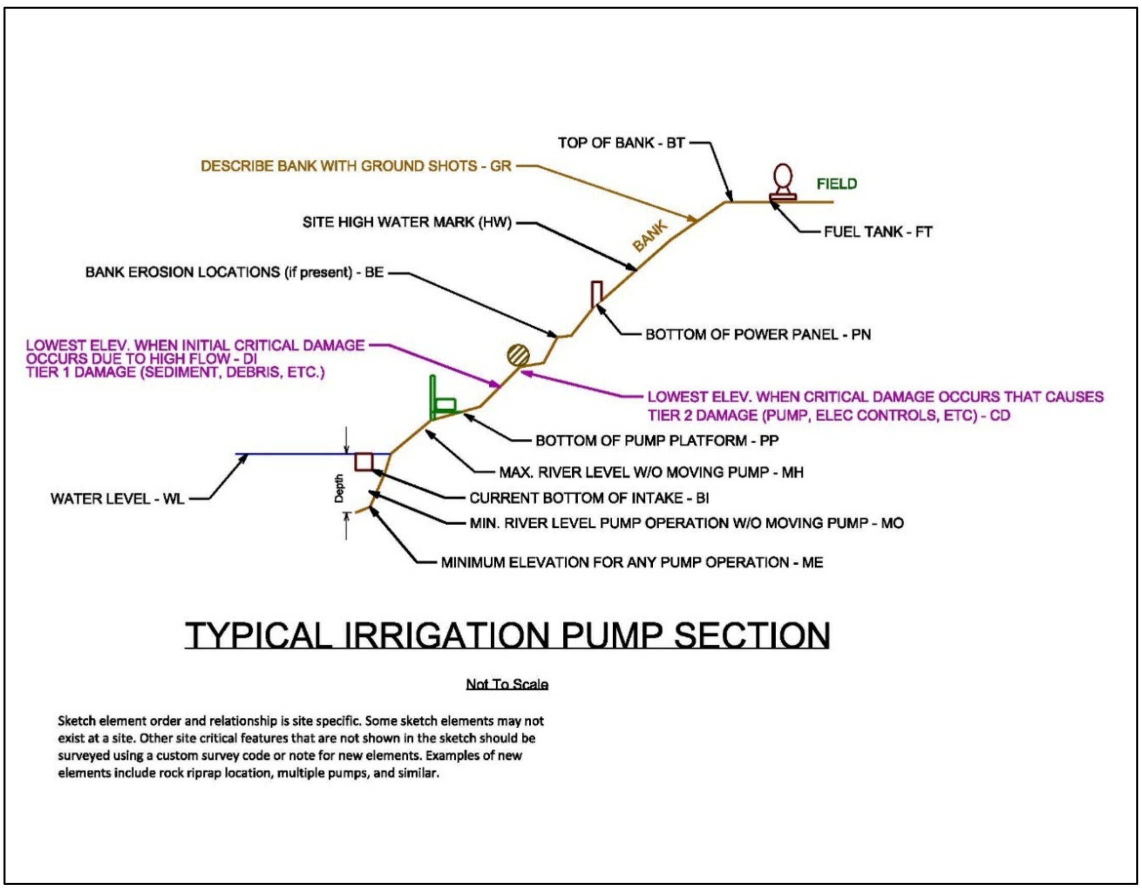

Figure 3. Typical Irrigation Pump Section with Labeled Features

Table 3. Schematic Code Definitions

Symbol	Feature
BE	Bank Erosion Locations (if present) Locations of bank erosion if present at the pump site.
BI	Current Bottom of Intake Invert of pump intake as installed at time of survey.
BT	Top of Bank Elevation Elevation of the top of bank on cross section located at the pump site.
CD	Minimum Critical Damage Elevation The lowest site elevation when critical damage occurs at the pump site to a fixed feature (pump, electrical panel, other supporting equipment). Tier 2 damage level (greater than Tier 1).
DI	Minimum Elevation Initial Critical Damage Due to High Flow Lowest river level at which debris/sediment deposition typically begins to significantly affect pump operation. (Farmer selected based on experience). Tier 1 damage level.
FT	Fuel Tank Base Elevation (if present) Base of the fuel tank utilized to operate the pump at the pump site.
GR	Ground Elevation Intermittent Ground Elevation Shots Used to Describe Bank Cross Section at Pump Site
HW	Site High Water Mark River level from previous flood event if high water mark is known.
ME	Minimum Elevation for any Pump Operation The minimum river level (after moving pump) at which any pumping is feasible to withdrawal adequate irrigation water (farmer selected based on experience)
MH	Maximum River Level Without Moving Pump Maximum river level before pump movement is required to continue operation.
MO	Minimum Pump Operation Elevation without Moving Pump The minimum river level at which the pump can withdrawal adequate irrigation water at the current location (farmer selected based on experience)
PN	Bottom of Power Panel Base of power panel utilized to operate the pump at the pump site.
PP	Bottom of Pump Platform Base of the platform to which the pump is attached at the pump site.
WL	Water Level Current river water level at pump site.

Metadata from the survey data collected by USACE can be seen below in Table 4 and Table 5.

Table 4. Montana – METADATA from 2020 Irrigation Pump and Intake Survey

Survey Date(s)	July 8 – 11 and 13 – 14, 2020
Surveyed By	USACE, Omaha District, Surveys, Mapping & GIS Section (Mr. David Salter)
Equipment	Equipment utilized in the collection and processing of the data for this project included: • TRIMBLE R10 GPS Receivers • TRIMBLE TSC3 Data Collectors • Pacific Crest HBP 450 Broadcast Radios • TRIMBLE Business Center
Horizontal Datum	NAD83, Montana (2500)
Horizontal Units	International Feet
Horizontal Accuracy	8 mm
Vertical Datum	NAVD88
Vertical Units	U.S. Survey Feet
Vertical Accuracy	15 mm

Table 5. North Dakota – METADATA from 2020 Irrigation Pump and Intake Survey

Survey Date(s)	July 15, 2020
Surveyed By	USACE, Omaha District, Surveys, Mapping & GIS Section (Mr. David Salter)
Equipment	Equipment utilized in the collection and processing of the data for this project included: • TRIMBLE R10 GPS Receivers • TRIMBLE TSC3 Data Collectors • Pacific Crest HBP 450 Broadcast Radios • TRIMBLE Business Center
Horizontal Datum	NAD83, North Dakota North (3301)
Horizontal Units	U.S. Survey Feet
Horizontal Accuracy	8 mm
Vertical Datum	NAVD88
Vertical Units	U.S. Survey Feet
Vertical Accuracy	15 mm

4.3 DATA FORM

A data form was used to collect landowner information at each site. The data form included questions regarding key pump site water levels, pump site conditions, and O&M costs in relation to the pump sites. A blank version of this survey data form is provided in Appendix A. The filled-out data forms for each pump site surveyed by USACE and USFWS have been provided to survey participants.

5. DATA EVALUATION

The compiled survey data from each of the 119 different pump sites (collected during the July 2020 USACE surveys as well as the August and December 2020 MT FWP surveys) was evaluated to determine common characteristics across the various sites as well as to develop histograms that reflect similarities between the irrigator's responses to each of the in-depth questions. Each of the histograms developed were tallied in a similar fashion and plotted to show the frequency of irrigator responses. In each of the sections below, the histograms for each question are presented and a brief explanation is provided.

5.1 Irrigator Concerns Regarding High Fort Peck Releases

The first of the in-depth questions that the irrigators were asked dealt with their concerns regarding high flow releases from the Fort Peck Dam. This question was designed to help identify the various concerns that each of the irrigators had in regard to the proposed Fort Peck releases associated with the EIS test flows. Based on the information collected, 19 similar groups or "categories" of concerns were noted from the irrigators. A histogram was developed to reflect the frequency of these 19 categories across the survey data, and this histogram can be seen in Figure 4. An accompanying table, Table 6, was also created to define the concern categories associated with the various column abbreviations of Figure 4.

Of these 19 categories, the top three concerns that were cited by the irrigators were: 1) streambank erosion and/or land loss at the pump site and throughout fields adjacent to the Missouri River ("C1"), 2) loss of pump site – high flows submerge pump site (pump site inaccessible and unable to inspect/irrigate/repair) ("C2"), and 3) flows damage/reduce life cycle of critical infrastructure (pump, intake, power panel, anchors, river dikes, etc.) and the costs associated to repair them ("C4") as well as loss of capital investment (i.e., crops, moving costs, equipment loss, land, noxious weed/insect treatment, etc.) ("C11"). It was also observed that commonly cited concerns (i.e., "C2" – "C6," "C8") dealt with and/or impacted pump sites, preparation time, worker and site safety, and potential impacts on life. Additionally, two less commonly mentioned concerns that also warrant consideration within the EIS modeling are: 1) that the proposed test occurs during critical crop irrigation periods ("C17") and 2) considerations for tribal lands and/or tribal land regulations ("C15").

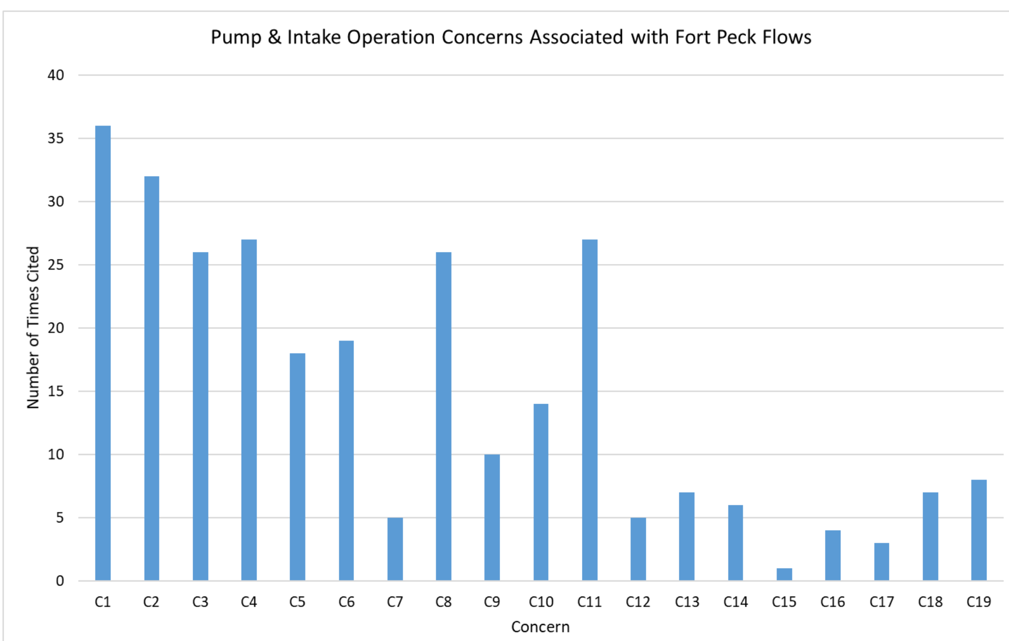

Figure 4. Irrigator Fort Peck Flow Concerns

Overall, Figure 4 illustrates the similarity of concerns between irrigators throughout the region regarding the test flows from the Fork Peck Dam while also shedding light on the various economic consideration necessary for the EIS study.

Table 6. Irrigator Fort Peck Flow Concerns

Fort Peck High Flow Concerns	
C1	Streambank erosion/land loss at pump site and throughout fields adjacent to river
C2	Loss of pump site - high flows submerge pump site (pump site inaccessible and unable to inspect/irrigate/repair)
C3	Loss of pump site - low flows make it impossible to irrigate (i.e., siltation, sediment removal, sandbars, and costs)
C4	Flows damage/reduce life cycle of critical infrastructure (pump, intake, power, anchors, river dikes, etc.) and the costs associated to repair them
C5	Flows (speed and volume) carry large debris capable of destroying pumps or injuring workers
C6	Insufficient notification necessary to make preparations, to prepare for speed of water rise, and to make adequate pump and crop management decisions
C7	Damage to infrastructure (i.e., highways, roads, power poles) that require specialist/companies
C8	Crop implications and capital costs of loss (i.e., insufficient water, submerging of fields, partial and complete loss of crops/yields)
C9	High demand/low supply of equipment, personnel, and specialists (includes people specializing in debris removal) that prolong inactivity/repairs/loss
C10	Time management conflicts (family, cattle, etc.) that impact ability to prepare for increased flows
C11	Loss of capital investment (i.e., crops, moving costs, equipment loss, land, noxious weed/insect treatment, etc.)
C12	Long term impacts of sediment aggradation downstream and increased frequency of flooding (near Lake Sakakawea)
C13	Backwater flooding of the Missouri River due to the Yellowstone River and Lake Sakakawea, which prolongs field submergence and crops
C14	Legal concerns, loss of water rights due to inability to irrigate, and other legal costs
C15	Tribal land considerations (irrigators have to abide by rules, prolongs process, and cannot react/be proactive)
C16	No financial support from agencies to help offset costs incurred during Fort Peck EIS tests
C17	Proposed test occurs during critical crop irrigation periods
C18	Inability to relocate (best pump site on property)
C19	Ecological impacts of test (wildlife displacement and loss of natural habitat)

5.2 O&M CATEGORIES

The second and third in-depth questions that the irrigators were asked dealt with the normal and "larger" O&M costs that they encountered throughout their pumping operations. The goal of these questions was to help quantify the regular costs associated with normal flow pumping operations and provide a reference to the possible expenses incurred as a result of larger flow events. Similar to the first in-depth question, histograms reflecting the type and frequency of O&M cost information provided by the landowners during the surveys were created. These histograms were separated based on size of operation and can be seen in Figure 5 and Figure 6. The specific cost information of each operation provided by the irrigator was not shown in this report, as the costs need to be verified and normalized prior to their incorporation into a model and/or report.

Of the normal O&M costs, it can be seen that the top three most cited costs by landowners were pump movement, general maintenance (which typically includes checking the pump, changing the pump's oil, and greasing the motor), and minor dredging of the pump site. On the other hand, the three least mentioned normal O&M costs were pump refueling, debris removal, and electrical costs. Of the larger O&M costs mentioned, the top three costs mentioned by the landowners were pump replacement, miscellaneous jobs (which can include riprap placement and other maintenance costs not already listed), and pump rebuild and electrical work while the three least mentioned costs were pump screen replacement, pump anchor installation, and pipe or system flush. Furthermore, while not all the listed costs were mentioned by all landowners, it is likely that several landowners have encountered similar costs pertaining to each of these categories and likely forgot to mention these costs during the surveys.

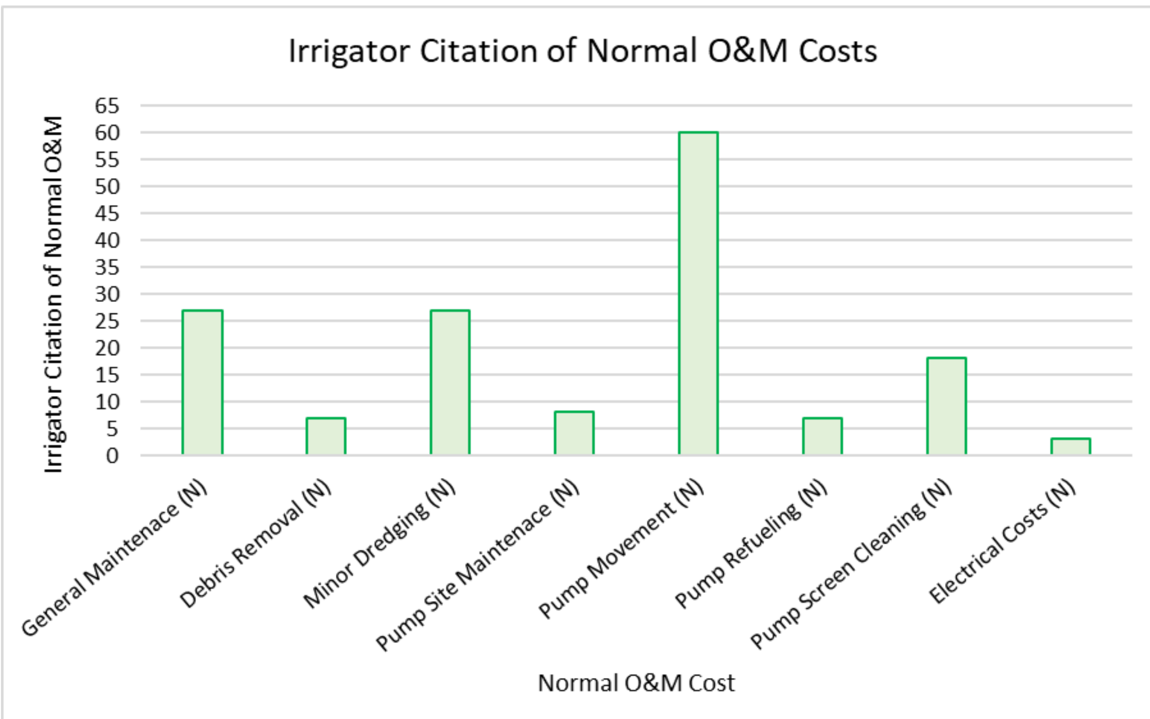

Figure 5. Normal Irrigator O&M Costs

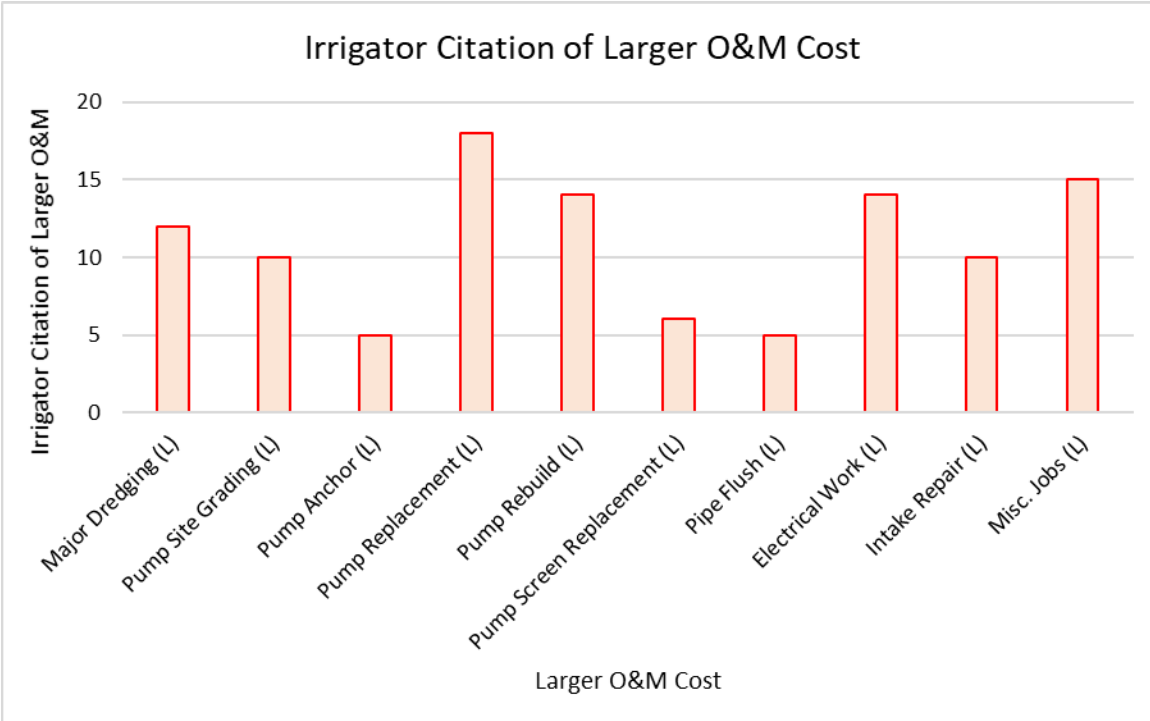

Figure 6. Larger Irrigator O&M Costs

5.3 Irrigator Crops

The last in-depth question asked to the irrigators was in regard to what crops were irrigated using the pump sites. This question was necessary to determine the types of crops grown throughout the region and to associate irrigator provided acreage size to possible crop rotation combinations and/or crop production preferences. As shown in Figure 7, the top three crops planted by the irrigators were alfalfa, corn, and wheat while the least planted crops were onions, radishes, safflower, sainfoin, and turnips. Overall, the histogram illustrates the preference by which the irrigators grow certain crops and highlights the presence of certain crops throughout the region.

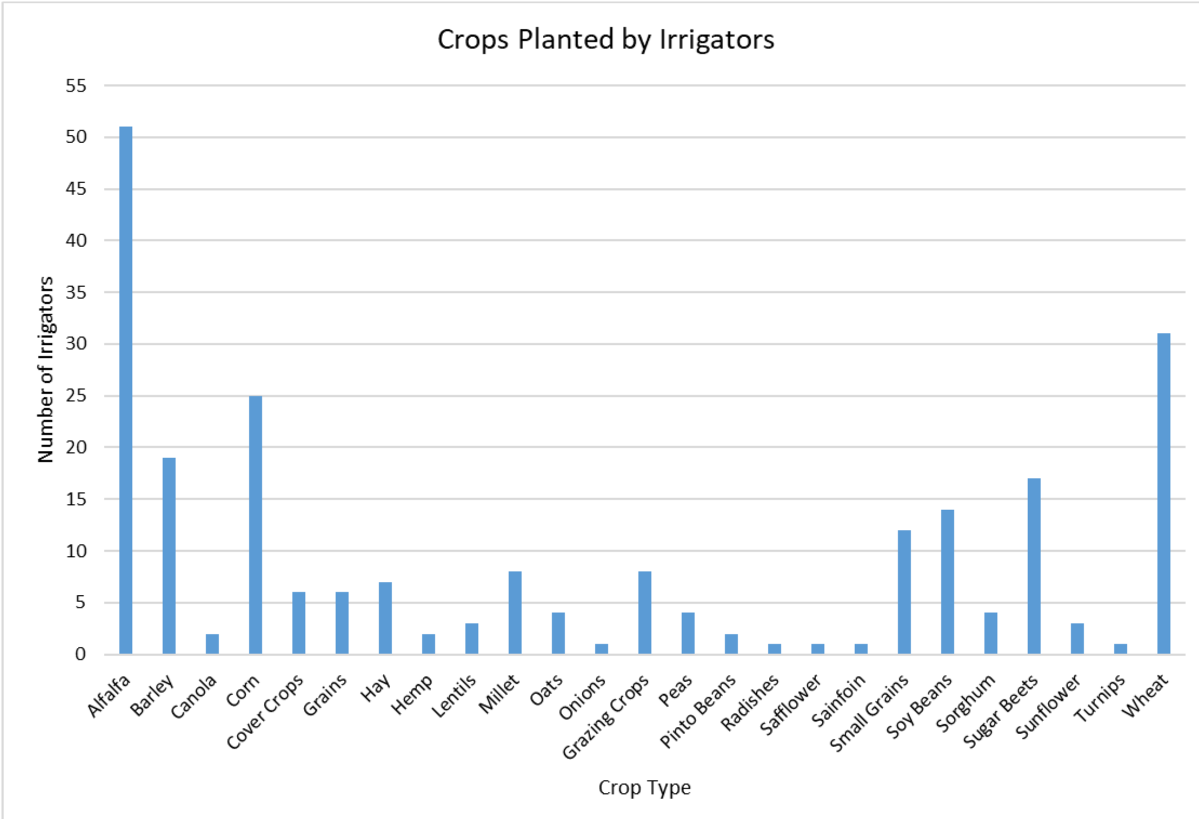

Figure 7. Crops Planted by Irrigators

5.4 Intake Site Stability Observations

After the completion of every pump site data form, the USACE hydro representative would briefly analyze the surrounding area of the pump intake to identify indicators that relayed information about the pump site's streambank stability. These indicators, such as streambank mass wasting or sandbar formation, were documented with photos and brief notes at each site. While most sites were stable enough to support reliable pumping operations, several recurring indicators spoke to the susceptibility of the sites to bank erosion and sandbar movement.

5.4.1 Overall Stability Observations

The presence of high streambanks was a common indicator throughout the surveyed river reach. Many sites also included varying degrees of streambank steepness and vegetation coverage. Pump intakes near the main channel often had more undercutting of streambank toes and prevalence of mass wasting, while pump intakes near side channels benefited from smaller flows, greater vegetation coverage, and less streambank height. However, this was not always the case. Similarly, due to the prevalence of mass wasting throughout the reach, floating debris was observed at the time of the surveys and/or documented as a concern by the landowner.

The presence of sandbars at or near the pump sites also highlighted the Missouri River's sediment movement potential. Several sites had sandbars near the pumps or visible from the site. While no exact sediment analysis was done at each site during the course of the surveys, the visual prevalence of silt and sand sediment types indicated bank vulnerability to erosion. Detailed analysis of bank erosion processes, such as rapid drawdown after pore water pressure buildup from sustained high flows, was not performed.

Figure 8 through Figure 11 highlight a few of the streambank stability indicators observed throughout the pump intake surveys.

Figure 8. W. Reid Upstream Streambank, RM 1682.5, Roosevelt County, MT, 13th July 2020

Figure 9. C. Paulson Upstream Site, Yellowstone River RM 1.7, McKenzie County, ND, 15th July 2020

Figure 10. Tveit Land & Cattle Intake Site, RM 1624.2, Roosevelt County, MT, 8th July 2020

Figure 11. S. McGowan Upstream River Reach, RM 1697.95, Roosevelt County, MT, 13th July 2020

From the above figures, several of the streambank stability indicators observed throughout the pump intake surveys can be seen. In Figure 8, a lack of vegetative cover is visible on the riverbank along with the extent of streambank height just upstream of the pump site. Figure 9 illustrates the high presence of jammed debris found upstream of the pump site, approximately 1.7 miles upstream along the Yellowstone River from its confluence with the Missouri River. In Figure 10, the formation of several sandbars adjacent to the pump's floating suction can be seen. Figure 11 shows greater vegetation coverage along the riverbank as well as a lack of high streambanks alongside the pump site, which is often found within a side channel of the Missouri River.

5.4.2 Qualitative Stability Evaluation

A qualitative stability evaluation was performed on the 119 irrigation sites collected during the July 2020 USACE surveys as well as the August and December 2020 MT FWP surveys for use in evaluating streambank stability risks that may occur as a result of the Fort Peck EIS test flows. This evaluation used a simple procedure to qualitatively rate stability at each site and by no ways should be interpreted as an absolute indicator of individual site stability. A detailed geomorphic assessment study would be required to further evaluate individual site stability and define risk into multiple factors.

Site conditions were assessed by looking for the presence of river process indicators that are often associated with stability. Site visit observations tabulated the presence of indicators consisting of high streambanks, streambank mass wasting, sandbar formation, and floating debris. These factors were the primary stability indicators that were considered for the site stability rating. Figure 12 presents the total number of visual citations of these indicators at the surveyed pump sites. For example, the presence of high streambanks (streambanks with a height of approximately 10 feet or greater from the water surface) were observed at approximately 80 of the 119 sites. The results, as shown in Figure 12, suggest that multiple instability indicators were present at each of the pump sites, and their combined contributions should be considered when evaluating site stability.

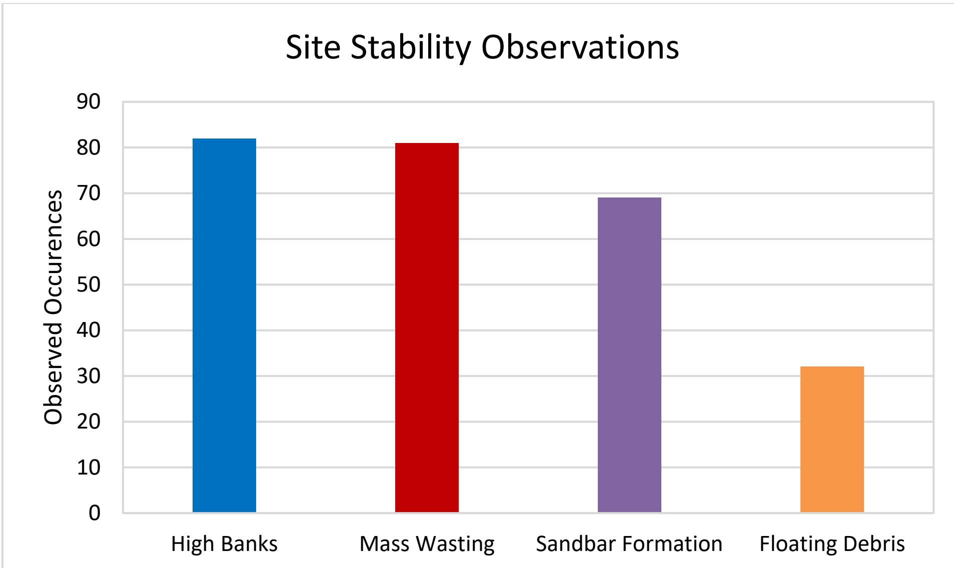

Figure 12. Presence of Streambank Stability Indicators at Surveyed Irrigation Pump Sites

The bank steepness at each site was classified as either vertical, steep, or not steep, and these three categories were determined during each site visit. Streambanks were considered to be “not steep” if the slope ranged from approximately level to approximately 1:1 (V:H) and were considered to be “steep” if the slope was approximately 1:1 to approximately 4:1. Streambanks with a slope greater than 4:1 were considered to be “vertical.” Results for the sites are shown in Figure 13, and nearly half of all sites were found to have steep banks.

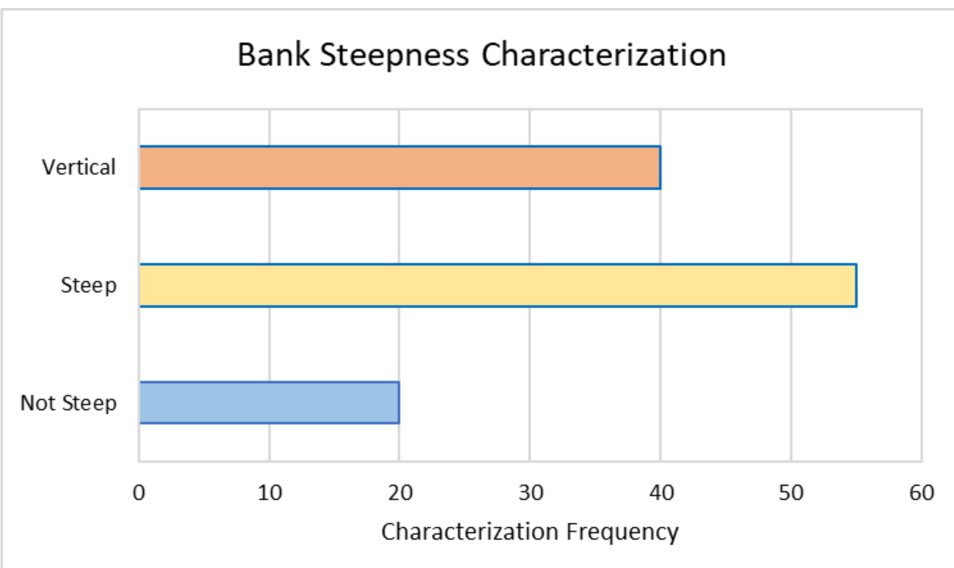

Figure 13. Histogram of Characterization Frequency of Stream Steepness

A qualitative stability rating was created to estimate stability at each site with the objective to reflect the risk of geomorphic process impacts on intake operation occurring due to a high flow event. Three categories of stability were developed consisting of stable, intermediate, and unstable. Table 7 outlines the various visual indicators used to estimate site stability within each category.

Table 7. Qualitative Streambank Stability Indices and Associated Site Observations

Stability Rating	Associated Visual Observations
Stable	-Not steep to steep streambank(s) -Little to no mass wasting present throughout visible reach -No undercut or fallen debris observed -Significant vegetative cover on streambanks -Pump site more likely to be a side channel than on the main channel
Intermediate	-Steep to vertical streambank(s) -Mass wasting observed in small to moderate segments of visible reach -Sparse undercut and fallen debris observed -Low to moderate vegetative cover on streambanks
Unstable	-Vertical streambank(s) -Mass wasting present throughout large segments of visible reach -Several undercut and fallen trees throughout area -Little to no vegetative cover on streambanks -Pump site more likely to be the main channel than on a side channel

Using the stated visual indicators, a qualitative rating was assigned to each site. Of the 119 sites, roughly 23.5% of the sites were considered stable, 53% were considered to have intermediate stability, and 23.5% were considered unstable. The intermediate sites often had one or more stability risk factors and may have moderate risk of erosion and pump site impacts during a single event. The unstable sites often had steep to vertical streambanks, little to no vegetative cover, and continuous observations of mass wasting throughout the reach, both upstream and downstream of the pump intake. The unstable sites would likely pose a higher risk of pump site and farming operation impacts during a single event.

The assigned site stability ratings reflect the results of a qualitative assessment that was based on a rapid assessment of observed site conditions during the July 2020 USACE site visits as well as the August and December MT FWP site visits. Assigned site stability ratings are suitable only for use as a qualitative indicator on a large group basis of all pump intake sites and do not reflect any type of computational or geomorphic analysis.

6. SUMMARY

Surveys of irrigation intakes on the Missouri River downstream of the Fort Peck Dam were performed in support of the Fort Peck EIS. The Fort Peck EIS details two alternative hydrographs for flow releases that include a minimum in-river flow of 8,000 cfs in years that a test flow could be implemented. The test flow releases would peak at approximately 28,000 to 33,000 cfs for three days in June, and the selected test flow for the final Fort Peck EIS would be conducted three to five times over the course of the next 10 to 20 years when hydrologic conditions are appropriate. The irrigation pump site field inventory was performed in July 2020 to assist with the analysis of the economic, cultural, and environmental impacts by

USACE. This field inventory was then followed by additional surveys conducted in August and December 2020 by the MT FWP.

In order to conduct the field inventory, USACE developed a scope and a methodology to collect data at a limited number of irrigation pump sites along the Missouri River between the Fort Peck Dam and Williston, North Dakota. At each site, XYZ data points were collected to determine the pump site characteristics and potential damage levels for high flow events. Participating landowners also had the opportunity to identify site specific critical features as well as share concerns about the flow alternatives during the surveys.

USACE site surveys were conducted from July 8th through July 15th, 2020 at the selected sites using two survey teams. The members of each of the two survey teams had different roles and objectives during the site surveys. The team member from the Hydrologic Engineering Branch was tasked with filling out a data form that addressed in-depth questions involving key pump site water levels, pump site conditions, and O&M costs related to the pump sites in collaboration with the landowner while the Omaha District survey crew members were tasked with collecting various XYZ data on key features from each site. The local coordinator served as the primary point of contact to landowners prior to the field teams' arrival, and they coordinated site access and arranged a meeting time between the landowners and the survey teams. A total of 69 sites were surveyed by USACE with 62 sites located in Montana and seven located in North Dakota. The irrigation pump and intake sites were fairly well distributed within the approximately 200-mile-long survey area. The pump sites were located on both the north and south banks of the Missouri River. Several sites were larger pump intakes serving multiple irrigators.

After completing the pump site data form at each site, the USACE hydro representative would briefly analyze the surrounding area of the pump intake to identify indicators that relayed information about the pump site's streambank stability. While most sites were stable enough to allow reliable pumping operations, several factors were observed that indicate site stability risks. The presence of high streambanks was a common indicator throughout the surveyed river reach. Many sites also included varying degrees of streambank steepness and vegetation coverage. Similarly, due to the prevalence of mass wasting, floating debris was observed at the time of the surveys and/or documented as a concern by the landowner. The presence of sandbars at or near the pump sites also highlighted the river's sediment movement potential. Site observations were used to develop a stability rating for each site.

The USFWS then collaborated with the MT FWP to perform additional surveys on approximately 50 irrigation pump sites (contributing to the 119 irrigation pump sites surveyed in total) along the Missouri River in eastern Montana, and these additional surveys occurred from August 25th through 28th, 2020 and on December 3rd, 2020. The MT FWP survey data and information was included as an attachment to this report. The information gathered from these additional surveys was also utilized in the analysis of the collected irrigation pump site survey data.

The compiled survey data from each of the different pump sites was evaluated to determine common characteristics for each site as well as to develop histograms in regard to each of the four in-depth questions that the irrigators answered. The most cited irrigation operator responses were:

Question 1 – Irrigation Operator Concerns Regarding Fort Peck Releases (top three responses):

1) Streambank erosion and/or land loss at the pump site and fields adjacent to the Missouri River
2) Loss of pump site due to high flows submerging the pump site (pump site inaccessible and unable to inspect, irrigate, or repair)
3) Flows damage or reduce the life cycle of critical infrastructure (pump, intake, power panel, anchors, river dikes, etc.) and the costs associated to repair them as well as the loss of capital

investment (i.e., crops, moving costs, equipment loss, land, noxious weed and insect treatment, etc.)

Question 2 – Irrigation Operator Normal O&M Costs (top three responses):
1) Pump movement
2) General maintenance (e.g., checking the pump, pump oil changes, and motor greasing)
3) Minor dredging of the pump site

Question 3 – Irrigation Operator Larger O&M Costs (top three responses):
1) Pump replacement
2) Miscellaneous jobs (e.g., riprap placement and other maintenance costs not already listed)
3) Pump rebuild as well as electrical work

Question 4 – Irrigation Operator Planted Crops (top three responses):
1) Alfalfa
2) Corn
3) Wheat

Collected survey data and the survey results were used to provide input to the hydrologic and economic analysis that was performed for the Fort Peck EIS.

7. REFERENCES

Roosevelt County Conservation District (2002), *Inventory of Pumps and Intakes on the Missouri River between the Fort Peck Dam and the North Dakota Border,* Prepared for the U.S. Army Corps of Engineers, Omaha District; Omaha, Nebraska.

US Army Corps of Engineers ®
Omaha District

Appendix A

Provided Survey Documents

Provided Survey Documents
Survey of Irrigation Pumps and Intakes on the Missouri River between the Fort Peck Dam and Lake Sakakawea

Table 1. Missouri River Pump Site Survey Schedule

Missouri River Pump Site Survey Schedule Summary					
		Survey Group 1	**Local Contact**	**Survey Group 2**	**Local Contact**
Tuesday	7-Jul-20	**Orientation Meeting in Sidney, MT**			
Wednesday	8-Jul-20	MT Site 12	MT Coordinator 1	MT site 9	MT Coordinator 2
Thursday	9-Jul-20	MT Site 3	MT Coordinator 1	MT Site 7	MT Coordinator 2
Friday	10-Jul-20	MT Site 5	MT Coordinator 1	MT Site 10	MT Coordinator 2
Saturday	11-Jul-20	MT Site 6	MT Coordinator 1	MT Site 11	MT Coordinator 2
Sunday	12-Jul-20	**Off**			
Monday	13-Jul-20	MT Site 1	MT Coordinator 1	MT Site 2	MT Coordinator 2
Tuesday	14-Jul-20	MT Site 8	MT Coordinator 1	MT Site 4	MT Coordinator 2
Wednesday	15-Jul-20	ND Site 1	ND Coordinator 1	ND Site 2	ND Coordinator 2
Thursday	16-Jul-20				
Friday	17-Jul-20				

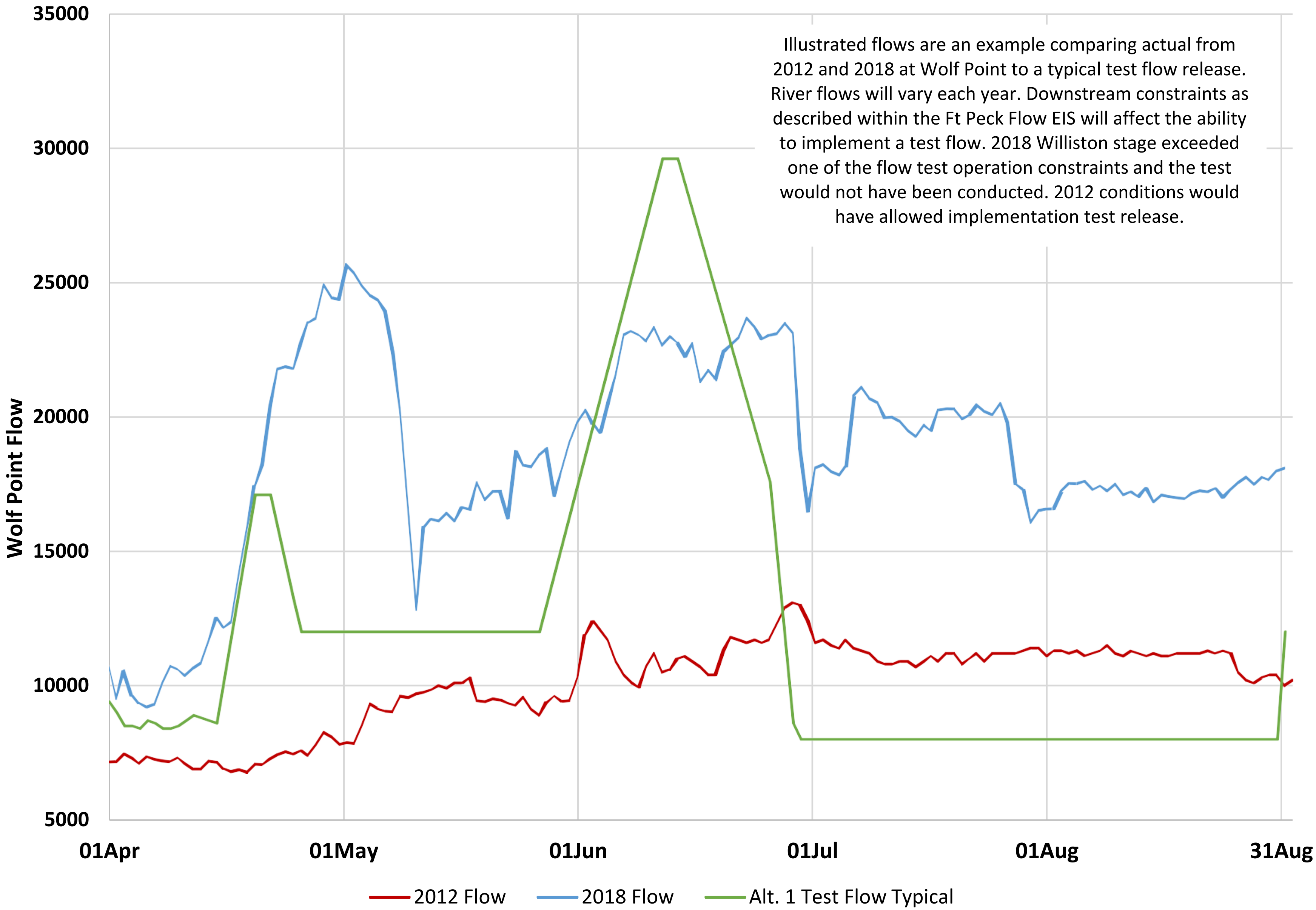

Figure 1. Example Implementation of Test Flows Compared to Actual at Wolf Point, MT

U.S. ARMY CORPS OF ENGINEERS, OMAHA DISTRICT
HYDROLOGIC ENGINEERING BRANCH
RIVER & RESERVOIR ENGINEERING SECTION

Data Sheet for Collected Pump Survey Data

Survey Crew: **Survey Date:**

PRODUCER INFO:

Owner Name:		Picture Number:	
Address:		Date/Time:	
Phone:			
Email:			
Permit #:			

LOCATION INFO:

River Mile		Min. Gage Height (GH) Feasible for Pump Operation W/O Moving		MO
River Gage Ref (e.g., Wolf Point, Culb.)		Max. GH Pump Operation W/O Moving		MH
Channel Location (main, side) Years @		Min. GH for any Intake Oper.		ME
present location		Site High Water Mark GH / Date		HW
Cost of relocation				
Min. GH Initial Critical Damage Due to High Flows		Type (sediment, debris, etc.)		DI
GH Critical Pump Impact		Impacted Feature (pump, electrical, etc.)		CD

PUMP SITE INFO:

Fixed / Portable		Avg Annual Acres Irrigated this Intake	
Type of Pump		Capacity (gpm)	
Number of Pumps		Water Depth at Pump (ft)	

Describe general river setting adjacent of pump area:

Describe the process used to move pumps. Include down times, lead-time:

Provide any additional comments concerning pump/intake operation that may be of concern relative to flow from Fort Peck:

Please describe normal operations and maintenance (O&M) costs associated with your intake and how often these costs are incurred (e.g., intake screens are cleaned twice a year and this costs about $1,000 or minor shoreline dredging occurs once per irrigation season and costs $500; include cost of farmer's labor and equipment operating expenses). Are these costs associated with high flow events?

Please describe any larger O&M costs (e.g., barge-based dredging, replacing a damaged intake, replacing site electrical controls or service panels, movement of the intake, etc.), how often these costs are incurred (e.g., twice a year, once a decade, etc.) and their relationship to high flows (i.e., are these costs generally associated with higher flow events than your normal O&M costs?).

Can you describe the type of crops you grow (e.g., sugar beets) and how many acres of each of these crops you irrigate annually using water from the Missouri River (e.g., 230 acres of sugar beets and 130 acres of potatoes are irrigated annually using water from the Missouri River)?

Would you agree access to pump site area for monitoring during test period (collect river level, observations, water sample) Yes/No:

Figure 2. Pump Site Data Form - Page 1

.PUMP SITE INFO (Additional Notes):

Please describe **normal operations and maintenance** (O&M) costs associated with your intake and **how often** these costs are incurred (e.g., intake screens are cleaned twice a year and this costs about $1,000 or minor shoreline dredging occurs once per irrigation season and costs S500; include cost of farmer's labor and equipment operating expenses). Are these **costs associated with high flow** events?

[How many people? How many hours? What type of equipment? How frequent? High flow impacts?]

Please describe any **larger O&M costs** (e.g., barge-based dredging, replacing a damaged intake, replacing site electrical controls or service panels, movement of the intake, etc.), **how often** these costs are incurred (e.g., twice a year, once a decade, etc.) and their **relationship to high flows** (i.e., are these costs generally associated with higher flow events than your normal O&M costs?).

[How many people? How many hours? What type of equipment? How frequent? High flow impacts?]

Can you describe the **type of crops** you grow (e.g., sugar beets) and **how many acres** of each of these crops you irrigate annually using water from the Missouri River (e.g., 230 acres of sugar beets and 130 acres of potatoes are irrigated annually using water from the Missouri River)?

Streambank Stability - Irrigator Responses:

What would you say is the lateral migration of the bank per year?

Is this fairly consistent throughout the year or driven mostly due to high flows?

During high flows, how much bank and/or soil movement do you see?

STREAMBANK STABLITY - Personal Observations:

Are high banks (>10 feet tall) present (Y/N):

How steep would you describe the banks (vertical, steep, not steep)?

Are there any signs of Mass Wasting (Y/N): Which bank(s):

Is there any vegetation or roots on the banks (Y/N): Which type (grass, shrub, tree):

What % of the bank is covered? Describe the channel during low flows (sand bars, soil types, etc.):

Right Bank:

Left Bank:

Is the streambank constricted upstream? If so, by what?

Personal impression of streambank stability:

Figure 3. Pump Site Data Form - Page 2

Fort Peck Dam Test Flows Environmental Impact Statement – FACT SHEET

Background: As part of Endangered Species Act (ESA) consultation with the US Fish and Wildlife Service (USFWS) on Operation of the Missouri River Mainstem Reservoir System (System), the US Army Corps of Enginners (Corps) amended its proposed action in the Biological Assessment (BA) to include formulation of test flows from Fort Peck Dam and an adaptive management framework for their implementation to benefit pallid sturgeon recruitment. Based on the proposed action in the BA, USFWS issued a "No Jeopardy" biological opinion (BO) in April 2018. The Corps must comply with the BO in order to continue to operate the System and provide the benefits of the eight authorized purposes, including irrigation. Completion of the Fort Peck Dam Test Flows Environmental Impact Statement (Ft Peck EIS) in a timely manner is one of the requirements for compliance.

Purpose: The purpose of the Ft Peck EIS is to investigate the capacity of Ft Peck Dam flow releases to test hypotheses related to the ability to attract pallid sturgeon up the Missouri River, get them to spawn in the Missouri River, and affect drift of larvae. If a test flow alternative is selected in the Final EIS, the test flow will be run 3-5 times over the course of 10-20 years when the hydrologic conditions are appropriate. This is not a permanent change to the operation of Ft Peck Dam. The Corps is currently preparing the Draft EIS with an anticipated release date for public review and comment in December 2020. The Draft EIS will be made available on the Missouri River Recovery Program webpage at https://www.nwo.usace.army.mil/MRRP/. Information on public meetings and how to submit comments will be provided along with public release of the document.

Alternatives: The Corps, through public scoping and in consultation with USFWS, has developed two alternative hydrographs and is currently analyzing the economic, cultural, and environmental impacts of those alternatives (along with a No Action Alternative) in the Ft Peck Draft EIS. Both test flow alternatives include a minimum in- river flow of 8,000 cfs measured at the Wolf Point, MT gauge in years that a test flow would be implemented to minimize impacts to M&I and irrigation water intakes from low flow. Test flow releases peak at approximately 28,000-33,000 cfs for 3 days in June. In order to analyze impacts to irrigation, the Corps and Montana Fish Wildlife and Parks (MT FWP) will be conducting surveys of irrigation intakes between Ft Peck Dam and the Lake Sakakawea upper pool. As an example, the chart below shows what Alternative 1 flows would have been in 2018 compared to no action in 2018. The shape of the hydrograph (shown below) will not change, although the timing may change slightly (i.e. one week earlier or one week later).

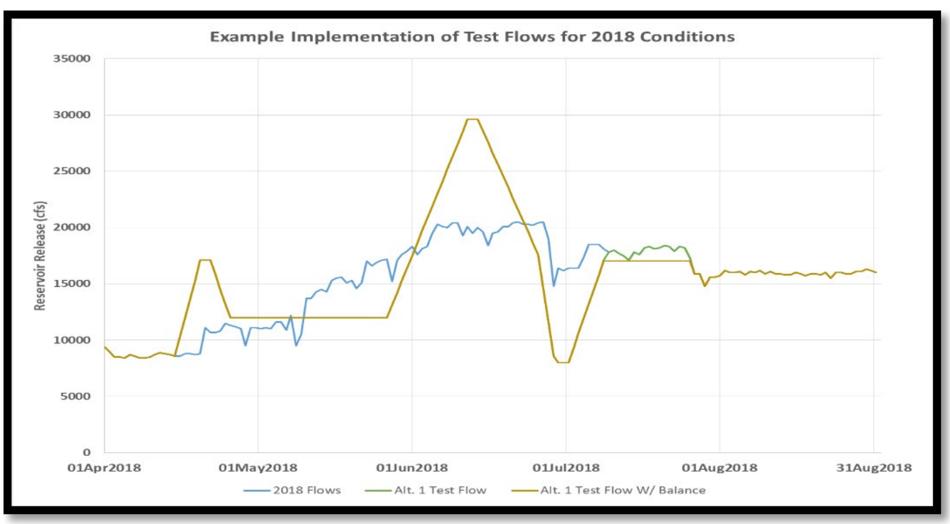

Figure 4. Fort Peck Dam Test Flows Environmental Impact Statement Fact Sheet - Page 1

Summary of the Irrigation Surveys

The intake surveys will collect data at a limited number irrigation sites along the Missouri River between Ft Peck Dam and Williston, ND. At each site, data points will be collected to determine the intake site characteristics and potential damage levels for high flow events. Participating landowners will have the opportunity to identify site specific critical features such as electrical panels and pump operating levels during the survey. Collected survey data will be combined with river levels and hydrologic modeling to inform the economic impact analysis. Data will be extrapolated for those that were not surveyed.

Summary of the High Flows Irrigation Economic Impact Analysis

The Draft EIS will include an evaluation of how changes in flows in the Missouri River from the altered hydrograph resulting from the Fort Peck Test Flows impact irrigation operations. One economic model has already been developed to evaluate low flow impacts. A second model, will evaluate the impacts from increased high flow conditions. A key to developing the high flow model will be the collection of data and information that is the focus of the irrigation survey discussed above.

The planned approach for evaluating irrigation impacts from high flows includes determining two tiered high flow thresholds. The first threshold (called "tier 1") considers a high flow that would result in maintenance to clear minor debris from clogged intakes including the cleaning of screens or the use of a shore-side backhoe to remove sediment buildup around the intake. A second tiered threshold (called "tier 2") considers a high flow that would cause significant damage to the intake and infrastructure (e.g. electrical subpanels or the intake itself) or require a water-based dredging operation to bring the intake back online. The analysis will estimate the instances when high flows would reach or exceed the thresholds from the hydrologic and hydraulic model. The economic analysis also includes gathering information and data from irrigators or other industry experts to estimate the potential costs [costs of maintenance (tier 1) and intake repairs and replacement (tier 2)] given the number of high flow incidences associated with each type of flow to estimate a change in costs from No Action for each alternative.

Ft Peck EIS Schedule

- July/August 2020: Irrigation surveys completed
- December 2020: Draft EIS released for 60 day public review
- January/February 2020: Public Meetings
- August 2021: Final EIS posted
- October 2021: Record of Decision signed

Figure 5. Fort Peck Dam Test Flows Environmental Impact Statement Fact Sheet - Page 2

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Omaha District

Appendix B
USGS Gage Readings Data Summaries

USGS Gage Readings Data Summaries
Survey of Irrigation Pumps and Intakes on the Missouri River between the Fort Peck Dam and Lake Sakakawea

Table 1. Missouri River Pump Site Gage Readings Summary - Montana - Survey Group 1

USGS Gage Readings Data Summary During Survey - Montana Pump Intake Sites							
Day	Date	Survey Group 1					
		Group	Site ID	Time (MDT)	USGS Gage	Gage Height (ft)	Discharge (cfs)
Tuesday	7-Jul-20	Orientation Meeting in Sidney at 1400 MT					
Wednesday	8-Jul-20	Group 9	Turnbull 1	0845	Wolf Point, MT (USGS 06177000)	12.69	12,300
			Turnbull 2	1010		12.61	12,000
			Turnbull 3	1055		12.63	12,100
			Casterline_M 2	1115		12.62	12,100
			Casterline_M 1	1245		12.59	12,000
			Becker	1345		12.62	12,100
		Group 6	Ruffatto	----		----	----
			Candee 2	----		----	----
			Candee 3	1635		12.54	11,900
Thursday	9-Jul-20	Group 3	Hanks	0900		12.24	11,100
			Holen 2	1015		12.29	11,200
			Holen 1	1015		12.29	11,200
			Neubauer	1115		12.30	11,300
			Peters	1155		12.34	11,400
			Casterline_C	1155		12.34	11,400
			Hansen	1300		12.37	11,400
Friday	10-Jul-20	Group 5	Colgan 1	0920		12.49	11,700
			Colgan 2	1000		12.46	11,700
			Colgan 3	1030		12.51	11,800
			Candee 1	1130		12.49	11,700
			Hackley	1100		----	----
		Group 2	Handy	1100		----	----
Saturday	11-Jul-20	Off					
Sunday	12-Jul-20						
Monday	13-Jul-20	Group 1	Ames 3	1015	Fort Peck (MRBWM Daily River Bulletin)	3.25	11,100
			Ames 2	1100		3.26	
			Ames 1	1150		3.27	
			BIA 2	1400		3.27	
			BIA 1	1450		3.27	
Tuesday	14-Jul-20	Group 4 (con.)	Carlisle 2	0830	Culbertson, MT (USGS 06185500)	4.86	12,100
			Carlisle 1	0900		4.83	12,000
			Stedman	0930		4.87	12,100
			Raaum 1	1020		4.87	12,100
			Raaum 2	1045		4.86	12,100
			Raaum 3	1120		4.88	12,200

Table 2. Missouri River Pump Site Gage Readings Summary - Montana - Survey Group 2

USGS Gage Readings Data Summary During Survey - Montana Pump Intake Sites							
Day	Date	Survey Group 2					
		Group	Site ID	Time (MDT)	USGS Gage	Gage Height (ft)	Discharge (cfs)
Tuesday	7-Jul-20	Orientation Meeting in Sidney at 1400 MT					
Wednesday	8-Jul-20	Group 9	Johnson	0800	Culbertson, MT (USGS 06185500)	5.07	12,600
			Tveit	1000		5.03	12,500
			Culbertson	1100		5.05	12,600
		Group 11	Romo_Wilson	1400		5.08 @ 1200	12,600 @ 1200
			Vannatta	1700		5.05 @ 1400	12,600 @ 1400
Thursday	9-Jul-20	Group 7	Smith 1	0800	Wolf Point, MT (USGS 06177000)	12.23	11,100
			Smith 2	0800		12.23	11,100
			Mattelin 1	1000		12.30	11,300
			Mattelin 2	1000		12.30	11,300
			Nygard_S	1400		12.42	11,600
Friday	10-Jul-20	Group 10	Garmon 1	1430	Culbertson, MT (USGS 06185500)	4.75 @ 0800	11,900 @ 0800
			Garmon 2	1330		4.74 @ 1000	11,800 @ 1000
			Harmon 1	1100		4.72 @ 1200	11,800 @ 1200
			Harmon 2	1000		4.66@ 1400	11,600 @ 1400
			Harmon 3	1200		4.68 @ 1600	11,700 @ 1600
			Harmon 4	1230		4.70 @ 1800	11,700 @ 1800
Saturday	11-Jul-20	Group 9	Anderson 2	0900		4.76	11,900
			Anderson 1	1000		4.76	11,900
Sunday	12-Jul-20	Off					
Monday	13-Jul-20	Group 2	McGowan 1	0800	Wolf Point, MT (USGS 06177000)	12.68	12,200
			McGowan 2	0900		12.56 @ 1000	11,900 @ 1000
			Olsen 1	1200		12.60 @ 1200	12,000 @ 1200
			Olsen 2	1300		12.58 @ 1400	12,000 @ 1400
			Toavs	1400		12.55 @ 1600	11,900 @ 1600
		Group 4	Reid 1	1700		12.54 @ 1800	11,900 @ 1800
			Reid 2	1800		----	----
			Budak	1530		----	----
Tuesday	14-Jul-20	Group 4 (con.)	Nygard_R 1	0900		12.65 @ 0800	12,200 @ 0800
			Nygard_R 2	1045		12.64 @ 1200	12,100 @ 1200
			Nygard_R 3	1115		12.64 @ 1400	12,100 @ 1400

Table 3. Missouri River Pump Site Gage Readings Summary - North Dakota - Survey Group 1

USGS Gage Readings Data Summary During Survey - North Dakota Pump Intake Sites							
Day	Date	Survey Group 1					
		Group	Site ID	Time (MDT)	USGS Gage	Gage Height (ft)	Discharge (cfs)
Wednesday	15-Jul-20	Group 1	Buford-Trenton 1	0750	Culbertson, MT (USGS 06185500)	4.80	12,000
			Buford-Trenton 2	0840	Culbertson, MT (USGS 06185500) and Sidney, MT (USGS 06329500)	4.80 / 6.34	12,000 (USGS 06185500) + 14,200 (USGS 06329500) = 26,200
			Mortenson	0900		4.77 / 6.33	11,900 (USGS 06185500) + 14,200 (USGS 06329500) = 26,100

Table 4. Missouri River Pump Site Gage Readings Summary - North Dakota - Survey Group 2

USGS Gage Readings Data Summary During Survey - North Dakota Pump Intake Sites							
Day	Date	Survey Group 2					
		Group	Site ID	Time (MDT)	USGS Gage	Gage Height (ft)	Discharge (cfs)
Wednesday	15-Jul-20	Group 2	Gullikson	0900	Culbertson, MT (USGS 06185500) and Sidney, MT (USGS 06329500)	4.80 / 6.28 @ 1400	12,000 (USGS 06185500) + 14,000 (USGS 06329500) = 26,000 @ 1400
			Paulson 1	1100		4.79 / 6.30 @ 1200	11,900 (USGS 06185500) + 14,100 (USGS 06329500) = 26,000 @ 1200
			Paulson 2	1200	Sidney, MT (USGS 06329500)	6.32 @ 1000	14,100 @ 1000
			Tjelde	1300		6.33 @ 0800	14,200 @ 0800

Table 5. Missouri River Pump Site Gage Readings Summary – MT FWP – August 2020 Survey

Missouri River Pump Site Gage Readings Summary - MT FWP						
Day	**Date**	**Site**	**Time (MDT)**	**USGS Gage**	**Gage Height (ft)**	**Discharge (cfs)**
Monday	24-Aug-20	**Orientation Meeting in Fairview**				
Tuesday	25-Aug-20	Remi Bidegaray #1	0735	Wolf Point, MT (USGS 06177000)	12.33	11,000
		Remi Bidegaray #2	----		----	----
		Remi Bidegaray #3	0910		12.29	10,900
		Rex Ralston #1	1130		12.24	10,800
		Rex Ralston #2	1140		12.23	10,800
		Rex Ralston #3	1222		12.18	10,700
		Dick Iverson #1	1430		12.12	10,500
		Dick Iverson #	----		----	----
		Dana Berwick	----		----	----
		Dick Iverson #3	----		----	----
		Dick Iverson #4	----		----	----
		Dick Iverson #5	1800		12.14	10,600
		Cory Lambert #1	1912		12.13	10,520
		Cory Lambert #2	1930		12.15	10,600
Wednesday	26-Aug-20	Lee Loendorf #1	0900	Wolf Point, MT (USGS 06177000)	12.36	11,100
		Lee Loendorf #2	0945		12.36	11,100
		Mike Ames and Rex Ralston	1000		12.36	11,100
		Boone Whitmer	1147		12.37	11,100
Thursday	27-Aug-20	Jim Dewitt	0800	Fort Peck (MRBWM Daily River Bulletin and USGS 06132000)	3.08	11,100
		Airport Golf Club	0900		3.09	
		Verlin and Cody Steppler #1	----		----	----
		Verlin and Cody Steppler #2	1040		3.10	11,100
		Prairie Elk Colony #1	1141		3.10	
		Prairie Elk Colony #2	----		----	----
		Gunsight #1	----		----	----
		Gunsight #2	----		----	----
		Gunsight #3	----		----	----
		Burt Twitchel	----		----	----
		Duane Blevins	1630		3.13	11,100
Friday	28-Aug-20	David Hardy #1	1213	Culbertson, MT (USGS 06185500)	4.55	10,913
		David Hardy #2	1249		4.59	11,000
		David Hardy #3	----		----	----
		David Hardy #4	----		----	----
		Schefelbine	1730	Fort Peck (MRBWM Daily River Bulletin and USGS 06132000)	3.08	11,300
		Cusker Inc. #1	1800		3.06	
		Cusker Inc.#2	1818		3.06	
		Trenton Berglee #4	----		----	----
		Trenton Berglee #3	----		----	----
		Trenton Berglee #2	----		----	----
		Trenton Berglee #1	----		----	----

Table 6. Missouri River Pump Site Gage Readings Summary – MT FWP – December 2020 Survey

Missouri River Pump Site Gage Readings Summary - MT FWP						
Day	**Date**	**Site**	**Time (MDT)**	**USGS Gage**	**Gage Height (ft)**	**Discharge (cfs)**
Thursday	3-Dec-20	Matt Page	0820	Fort Peck (MRBWM Daily River Bulletin and USGS 06132000)	----	8,100
		Ron Garwood #1	0957		----	
		Bill and Irene Rathert #2	1435		----	
		Bill and Irene Rathert #1	----		----	----
		Mark Black	----		----	----
		Huseby Farms Inc.	----		----	----
		David Anderson	----		----	----
		Ron Garwood #2	----		----	----
		Les Nickles #1	----		----	----
		Les Nickles #2	----		----	----