North Platte Chokepoint Investigation
Final Report

January 2023

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1 Introduction

River Design Group, Inc. (RDG) was retained by the Crane Trust and Audubon Nebraska, in partnership with Ducks Unlimited, The Nature Conservancy and Nebraska Game and Parks Commission to investigate causes and potential solutions for the North Platte Chokepoint Reach located in North Platte, Nebraska (Figure 1-1). The Chokepoint Reach is a section of the North Platte River upstream of its confluence with the South Platte River where channel capacity has decreased over time due to channel aggradation from sand deposition (Turner 2021). Changes in channel capacity limit the ability of water managers to deliver water to downstream users and to replicate natural ecological dynamics for the benefit of species of concern without increasing flood risk to the City of North Platte. Previous studies of the Chokepoint Reach have been limited in scope and recommendations have mostly disregarded reach-scale effects and natural river processes. As such, the purpose of this study is to use available data to evaluate the root causes of decreased channel capacity and identify potential solutions to increase conveyance through the North Platte Chokepoint while providing opportunities for conservation actions.

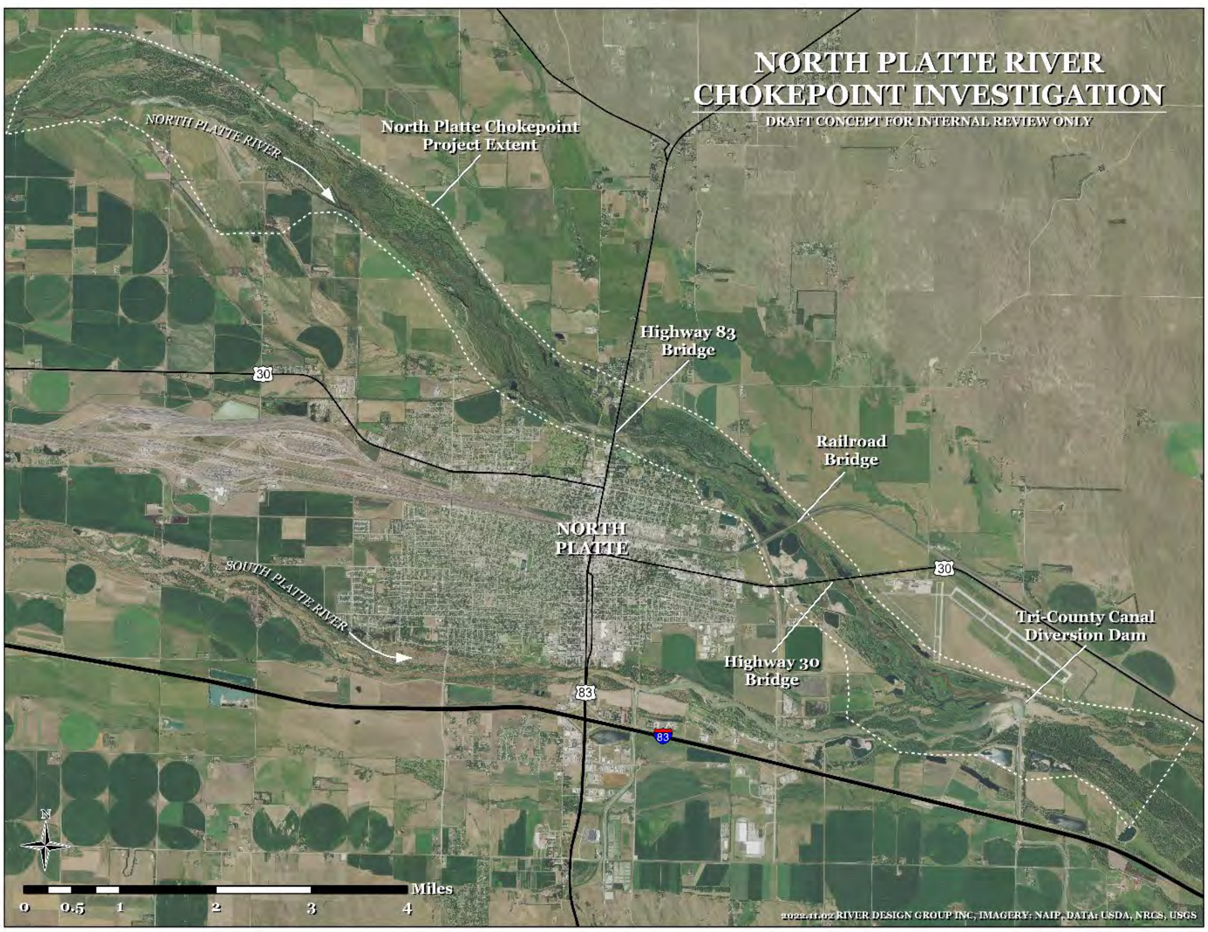

Figure 1-1. Vicinity map for the North Platte Chokepoint Investigation near North Platte, Nebraska.

1.1 Study Objectives

The North Platte Chokepoint Investigation is one of several efforts being completed to support the broader goal of increasing flow and sediment delivery to the Central Platte River Valley. The Crane Trust and Audubon Nebraska collaborated with multiple stakeholders to identify objectives to guide this study. The project stakeholder group, Vision for an Ecologically Sound Platte River (VESPR), includes representatives of the Crane Trust, Audubon Nebraska, Ducks Unlimited, The Nature Conservancy, U.S. Fish and Wildlife Service (USFWS), Playa Lakes Joint Venture, Nebraska Game and Parks Commission and University of Nebraska. The stakeholders acknowledge that the North Platte River has many uses and the study objectives must accommodate a broad audience to achieve solutions to the problem. VESPR identified the following objectives to guide the recommended solutions to increase capacity in the Chokepoint Reach:

- Reduce flood risk including basement seepage from groundwater;
- Maintain irrigation canal operations;
- Improve habitat for native species;
- Decrease infrastructure maintenance; and
- Promote opportunities for recreation.

1.2 Study Scope

The purpose of the study is to investigate the factors contributing to the loss of capacity in the Chokepoint Reach and provide recommendations that address the project objectives. The study scope was developed by VESPR in the form of several key questions for which technical responses were requested. It is acknowledged that it may not be possible to answer all of these questions using available information and that critical uncertainties will need to be addressed by future work. The questions addressed in this study are:

1. ***What are the major factors contributing to a loss of channel capacity at the North Platte Chokepoint Reach?***

   a) *What is the impact of the Tri-County Dam on flow capacity?*

   b) *What impact do highway and railroad bridges have on flow capacity?*

   c) *What is the impact of woody species establishment on flow capacity? What is the impact of exotic-invasive species?*

2. ***What is the flooding risk to the city of North Platte under various high flow conditions?***

    a) *What would be the spatial extent of flooding in the city of North Platte and adjacent communities considering a range of high flows including 3,000, 6,000, 9,000, and 12,000 cfs under current and projected future streamflow capacities?*

    b) *In the absence of releases from Kingsley Dam, what is the probability that these flows will occur downstream of Lake McConaughy and upstream of the city of North Platte?*

    c) *What level of rainfall needs to be observed locally for such flows to occur?*

    d) *How do climate projections influence the probability of large rainfall events and therefore flooding risk from peak river flows?*

3. ***What is the projected future capacity at the North Platte Chokepoint under various management conditions?***

    a) *If nothing is done, at what rate will flow capacity in the North Platte River change?*

    b) *What would be the projected change in capacity under various management scenarios (e.g., regular sediment removal, installation of a sediment bypass system at the Tri-County Canal Diversion Dam, regular in-channel vegetation control, etc.)?*

4. ***What potential actions could increase capacity through the North Platte Chokepoint?***

2 Chokepoint Reach Background and Past Studies

2.1 Reach Overview

The North Platte Chokepoint represents one of the few areas of consistent bed aggradation in the North Platte and Central Platte River valleys (Chen et al. 1999). The North Platte Chokepoint Reach (Chokepoint Reach) stretches west of the City of North Platte along the North Platte River for approximately 7 miles upstream of the confluence with the South Platte River, and flow capacity in this reach has declined from approximately 10,000 cfs in 1938 to about 1,600 cfs today (Turner 2021). Flow through the Chokepoint Reach is ostensibly limited by reach-scale bed aggradation, channel constrictions, and vegetation encroachment. This reduced conveyance capacity restricts the ability of water managers to provide flows to the biologically important mainstem of the Platte River for the benefit of wildlife and their habitats without flooding communities in the North Platte area (Simon and Associates 2000, NRC 2005, Murphy et al. 2006, NeDNR 2013). The Central Platte River is an important waterway that sustains three federally listed species and 11 state listed species, as well as robust agricultural production. Periods of high flow in the Central Platte River Valley are necessary to maintain the basin's ecological structure, function, and groundwater recharge (Caven et al. 2019). Sufficient flow is also important for river-related recreation such as kayaking which helps sustain the economic vitality of the region.

Flow to the North Platte Chokepoint is controlled primarily by releases from Kingsley Dam (Lake McConaughy) located 50 miles upstream with additional flow contributions from tributaries located downstream of Kingsley Dam including Birdwood Creek. The flow regime is regulated for irrigation use and exhibits a significantly altered annual hydrograph relative to pre-dam conditions. Most of the combined flow of the North and South Platte Rivers is diverted at the Tri-County Canal Diversion Dam (TCCDD), essentially drying up the bed of the Platte River from the confluence downstream to Overton during the irrigation season. In addition to the TCCDD, the Chokepoint Reach includes several infrastructure elements that either constrict or encroach upon the historical floodplain including three bridges, several levees, residential and commercial developments, and numerous sand and gravel extraction pits.

2.2 Bridges

Three bridges cross the North Platte River in the Chokepoint Reach including the U.S. Highway 83 Bridge, Union Pacific Railroad Bridge, and U.S. Highway 30 Bridge. The bridge configurations vary, but in general the openings span only the active river channel thereby constricting the width of the floodplain by more than 85%. Bridge attributes are summarized in Table 2-1.

Table 2-1. Summary of bridge attributes in the North Platte Chokepoint Reach.

Attribute	Highway 83	Union Pacific Railroad	Highway 30
Distance from confluence	5.1 miles	3.0 miles	2.3 miles
Width of opening	320 feet	250 feet	560 feet
Floodplain width	2,700 feet	2,700 feet	4,000 feet
Piers in active channel	5	5 (of 17 total)	4

2.3 Tri-County Canal Diversion Dam

Built in 1940, the Tri-County Canal Diversion Dam (TCCDD) is located immediately downstream of the confluence of the North Platte and South Platte Rivers. Operated by the Platte River Public Power and Irrigation District (PRPPID) (Formerly Central Nebraska Public Power and Irrigation District (CNPPID)), the TCCDD provides irrigation water to numerous downstream users and generates electricity via three hydropower facilities (CNPPID 2022a). The TCCDD is a 10.7-foot high, 874-foot long channel-spanning concrete structure (USACE 2022). Water flows through a 195-foot-long headgate structure on the south abutment of the diversion dam into the supply canal which has a capacity of 2,170 cfs. TCCDD operations follow protocols outlined in the facility license issued by the Federal Energy Regulatory Commission (FERC 1998).

During a site visit to the North Platte Chokepoint in June 2022, sediment mobility was observed in the North Platte River at flows of approximately 1,000 cfs, which is a typical flow during the irrigation season. Per TCCDD operators, dredging operations occur approximately 10 months per year and more than 100,000 tons of sediment are dredged per year to maintain flow into the supply canal. Based on this information, it can be presumed that the sandy bed material in North Platte is frequently mobile and being supplied to the TCCDD on a nearly continuous basis.

Figure 2-1. View along the crest of the Tri-County Canal Diversion Dam with active dredging operations.

2.4 Canal Operations

An Environmental Account was required by the FERC relicensing of the CNPPID and NPPD in 1998 to address threatened and endangered species issues related to CNPPID and NPPD operations.

The Environmental Account is a “block of water” set aside in Lake McConaughy to supplement flows in the Platte River. Water is added to the Environmental Account and stored in Lake McConaughy until the water is needed. A volume of water equal to 10% of Storable Natural Inflows into Lake McConaughy are contributed to an Environmental Account (with some exceptions) with total contributions not to exceed 100,000 acre-feet in any year. Total stored Environmental Account water is limited to a volume of 200,000 acre-feet.

The Environmental Account is a part of the Platte River Cooperative Agreement signed by the governors of Nebraska, Wyoming and Colorado and the Secretary of the Interior to address the needs of four threatened and endangered species using the Platte River by developing the Platte River Recovery Implementation Program (PRRIP). One of the goals of the PRRIP is to improve habitat for endangered species along the central Platte River by re-timing or adding 130,000 to 150,000 acre-feet of water per year (Program water). The Environmental Account in Nebraska, along with a Pathfinder Dam modification project in Wyoming and the Tamarack groundwater recharge project in Colorado, are expected to provide 70,000 to 80,000 acre-feet per year with the remaining water coming from other water supply projects and conservation programs.

One of the benefits of the Environmental Account is the ability to store and release Program water from other sources. For example, Program water can be released from Pathfinder Reservoir on the North Platte River in Wyoming and recaptured in the Environmental Account in Lake McConaughy, which is closer to important habitat along the central Platte River. The water can then be released from McConaughy when needed.

The U.S. Fish and Wildlife Service (USFWS) is responsible for requesting releases of water from the Environmental Account. There are certain conditions that apply to the use of Environmental Account water. The most significant rule is that the Environmental Account Manager may not request releases of Environmental Account water that will cause or add to out-of-bank flooding along the river. Another condition is that Environmental Account water may be diverted through hydropower facilities, as long as the water is returned to the river.

Agricultural and environmental flows are routed both through the Chokepoint Reach and around it using an extensive network of diversions and canals. Water released from Lake McConaughy flows through Lake Ogallala to the Nebraska Public Power District’s (NPPD) Keystone Diversion Dam. At the Keystone Diversion Dam water can be released to the North Platte River or diverted into the Sutherland Canal via a siphon located near Paxton. Water that flows through the Sutherland Canal is returned to the South Platte River 3 miles upstream of the TCCDD. Water diverted at the TCCDD flows down the Supply Canal and can be returned to the Central Platte River near Brady or Overton. Six additional diversions are located between Kingsley Dam and North Platte (Figure 2-2).

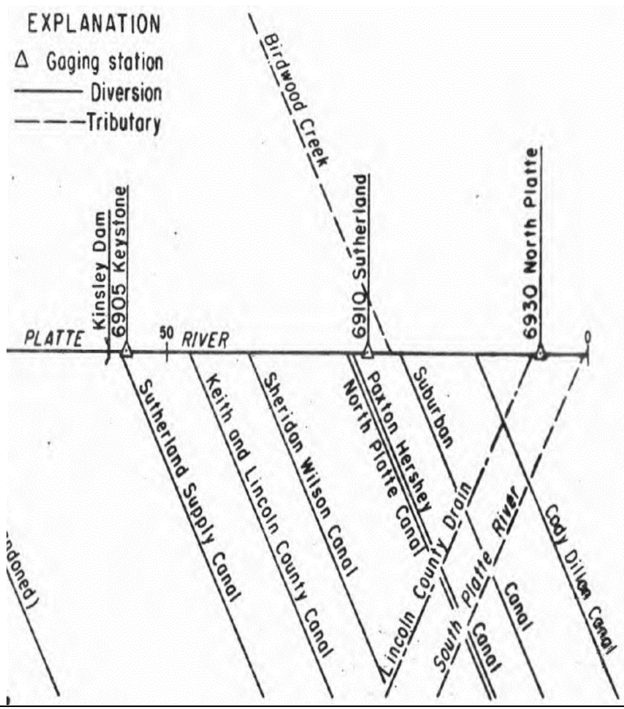

Figure 2-2. North Platte River gaging stations and locations of tributaries and diversions (USGS 1976).

As water travels through the Supply Canal, it produces power at the Jeffrey, Johnson No. 1 (J-1) and Johnson No. 2 (J-2) hydropower plants, each with a capacity of about 20,000 kilowatts. With the 50,000-kilowatt Kingsley Hydro plant, water flowing through CNPPID's system can generate up to 113,000 kilowatts of electricity (CNPPID 2022b). Other benefits of the canal system include the creation of lakes for recreation, wetlands and other fish and wildlife habitat, and groundwater recharge.

The E65 and Phelps canal rehabilitation projects were designed to provide groundwater recharge for areas served by irrigation wells. A lined system or pipelines were specified where irrigation comes mainly from surface water. The result has been a generally stable water table beneath and adjacent to CNPPID's service area. Data from USGS and the Conservation and Survey Division of the University of Nebraska-Lincoln show that the water table beneath Central's service area has risen by 10 to 50 feet (UNL 2022). Similar data from counties just outside Central's service area show declines in the groundwater table of 5 to 30 feet over the last 60 years.

An economic analysis of cost and benefits provided by the CNPPID project was completed at the time of FERC relicensing in 1998. Under terms and conditions of the original license, the project would have had an annual cost of about $12.9 million and produced about 374 gigawatt-hours of energy annually, with a total power value of about $11.6 million annually. Operational changes and enhancement measures required by the new license increased the project's cost and reduced the value of the project's power by about $1 million annually, and therefore the project was estimated to have an annual cost of about $2.4 million more than the value of the power in 1998 (FERC 1998).

2.5 Flood Risk

Flood stage for the City of North Platte is monitored at the gage located at the Highway 83 Bridge, North Platte River at North Platte (#06693000). Since installation of the gage, streambed aggradation has triggered several shifts in the rating curve and the flow corresponding to flood stage has decreased due to loss of channel capacity (Figure 2-3). When the gage was installed, the flow corresponding to the current flood stage was three feet lower. It should be noted that elevations in this figure reference the NGVD29 and do not correspond directly to elevations in the hydraulic modeling completed for this study which reference NAVD88.

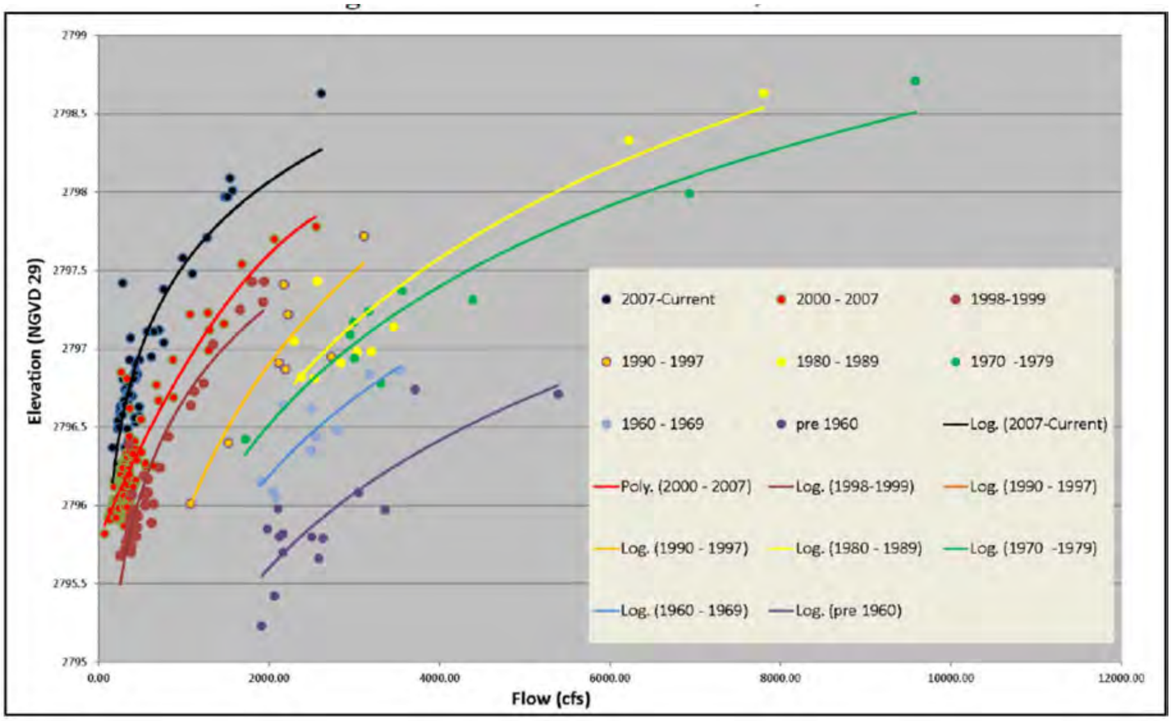

Figure 2-3. Rating curve shifts at the North Platte gage site (plot from presentation by Turner 2021 and data provided by Nebraska Silver Jackets 2012).

2.6 Past Chokepoint Studies

The Executive Director's office of the Platte River Recovery Implementation Program (PRRIP) has examined a number of potential mitigation actions to address capacity in the Chokepoint Reach and determined most of them insufficient to increase channel capacity to 3,000 cfs and/or prohibitively costly (PRRIP 2021). Recent studies conclude that capacity of the Chokepoint reach is 1,500 cfs to 2,000 cfs based on the flood stage at the Highway 83 gage. Limited evaluations of the root causes of this problem have been conducted and most solutions evaluated by the PRRIP have focused on the temporary removal of sediment and/or increasing flow capacity via control structures (e.g., berms). Solutions to increase the natural outflow of sediment from the Chokepoint Reach that could improve ecosystem resilience have not been thoroughly evaluated. In addition, the TCCDD has received minimal attention in past studies for its impact on the Chokepoint Reach and no studies have accounted for impacts to habitat, recreation, and local economies.

2.7 Literature Review and Research

This study builds upon prior research completed on the Platte River system and recent hydraulic modeling studies completed for the North Platte River. A brief synopsis of relevant research is provided below by topic.

2.7.1 Hydrology

USGS (1976) presented historical and geographical data pertinent to streamflow and summarized water-resources data that are representative of hydrologic conditions for the North Platte River and South Platte River based on 80 years of data. Williams (1978) showed that the Platte River's natural hydrograph was characterized by robust spring flows followed by a natural decline in the summer.

Mean flows, median flows, and the 1.5-year flood peaks of the North Platte and Platte Rivers in Nebraska have significantly decreased over the 20th century in response to reservoir storage, river flow diversions, and periods of drought (USBR 2003). The trend in the mean river flows and the 1.5-year flood peaks are both very similar with flows being the highest during the 1895 to 1909 period, a wetter climatic period, declining somewhat during the 1910 to 1935 period when reservoirs began to come on line, and declining to their lowest values of the 20th century during the 1936 to 1969 period. During the 1936 to 1969 period, several reservoirs and irrigation diversions came on line as part of the Tri-County canal, and two periods of drought in the 1930s and the 1950s occurred. Mean flows and the 1.5-year flood peaks increased somewhat over the 1970 to 1999 period, but were still significantly less than the 1895 to 1935 period.

2.7.2 Geomorphology and Vegetation

O'Brien and Currier (1987) report that the Platte River system is young relative to most large rivers as identified by its braided planform. Reductions in peak discharge and sediment supply have caused changes in pattern, shape, bed material size, and slope. The active channel has narrowed, and woody vegetation has formed over much of the former floodplain. Currier and Davis (2000) provide photographic and historical evidence in support of the prairie river concept, suggesting that the channels of the Platte were predominantly open and largely absent of trees. The shift towards woodland habitat in the North Platte River between Overton and the City of North Platte has resulted in a shift in sandhill crane and whooping crane distribution to the east where more non-woodland habitat remains (Caven et al. 2019).

Kinzel, et. al. (2005a) monitored the reach downstream of a riparian vegetation removal project on the Platte River. It was hypothesized that the removal of riparian vegetation and disking could stimulate channel widening by increasing the potential of these surfaces to erode under natural fluvial action. It also was hypothesized that a local increase in sediment supply might occur resulting in geomorphic change downstream. The effects of the management activities were monitored from 2001 to 2004. Although statistically significant differences were detected in some of the variables, increases in mean bed elevation did not occur in a greater percentage of the monitoring sections measured downstream compared to upstream. This result suggests that vegetation removal and disking did not have a substantial effect on the downstream river channel morphology and sediment transport. It is important to note, however, that river flows following the management activities were at historical low rates, and the potential to affect geomorphic change within and downstream from the managed reach were limited.

2.7.3 Sediment Supply and Transport

Annual sediment yields from the geologic formations in the North Platte River watershed are substantially larger than those from the South Platte, indicating that historically the North Platte was the dominant contributor of sediment to the Platte (O'Brien and Currier 1987). Reductions in river flow and construction of large storage reservoirs have caused a substantial reduction in the sediment transport rates over the 20th century. All indicators of channel forming discharge evaluated for the North Platte River, include the 1.5-year peak flood, effective discharge (computed by two different methods), and the median sediment transporting discharge have declined over the 20th century (USBR 2003). Reductions in river flow and sediment load would be expected to result in a narrower Platte River channel.

Beginning in 1941, Platte River flows decreased substantially through the 70-mile reach between the TCCDD and the Johnson-2 return channel a few miles upstream from Overton, Nebraska. Sediment is still transported past the TCCDD (either by natural transport or hydraulic dredging), but the transport capacity of the downstream river flows to keep this sediment moving has reduced over time along the 70-mile reach. This causes sediment to deposit and aggrade portions of the downstream river channel (USBR 2003).

2.7.4 Habitat Modeling

Kinzel, Nelson and Parker (2005) related observed crane roosting sites to river morphology and hydraulics in the central Platte River. Crane roost maps defined from infrared video were superimposed on the hydraulic modeling results to identify the ranges in depth and velocity preferred by roosting cranes. They found that cranes generally prefer to roost in water depths less than 0.40 meters with velocities less than 0.70 meters per second.

2.7.5 Climate Change

Evidence strongly suggests that snowpack in the Rocky Mountains is declining as a result of climate change, reducing snowmelt feeding the Platte River, and further limiting future water resources in Nebraska (Caven et al. 2019).

2.8 Vision for an Ecologically Sound Platte River

A desired future condition for the Platte River is described in *A Long-Term Vision for an Ecologically Sound Platte River* (Caven, et. al. 2022). In this comprehensive planning document, the authors outline a detailed strategy to accomplish conservation objectives in the Platte River Basin. In addition to providing a thorough summary of existing conditions and the ecological context, the document identifies needed actions and provides quantitative goals to achieve the desired future conditions for the Platte River.

3 Methods

3.1 Overview

The approach for the North Platte Chokepoint Investigation focused on remote sensing, field observations, hydrologic analysis, and hydraulic modeling. Methods relied entirely on utilizing existing information and no additional data collection was undertaken to support the study. With assistance from VESPR, existing information was researched, and requests were submitted to acquire available data.

3.2 Remote Sensing

Remote sensing analyses utilized historical aerial imagery and LiDAR data were used to prepare relative elevation maps and perform a geomorphic change detection analysis. The relative elevation mapping utilized 2017 topo-bathy LiDAR and imagery (Quantum Spatial 2018) to compare river and floodplain elevations to a longitudinal profile of the top of exposed sand bars. Relative elevation mapping is useful for illustrating geomorphic characteristics, floodplain connection and floodplain encroachment from infrastructure and development. Relative elevation maps for the Chokepoint Reach are provided in Appendix A. An example relative elevation map for the TCCDD site at the confluence of the North Platte and South Platte Rivers is provided in Figure 3-1.

The geomorphic change detection analysis utilized 2011 LiDAR and 2017 topo-bathymetric LiDAR to compare changes in floodplain elevations over a six-year period. Geomorphic change detection analysis is useful for illustrating changes in river alignment, scour and deposition patterns and human-caused landscape changes. Because the 2011 LiDAR did not include channel bathymetry, the analysis does not reflect changes in the bed elevation of the North Platte River. Geomorphic change detection maps for the Chokepoint Reach are provided in Appendix C. An example geomorphic change detection map for the river segment between the Highway 83 Bridge and Union Pacific Railroad Bridge near the City of North Platte is provided in Figure 3-2.

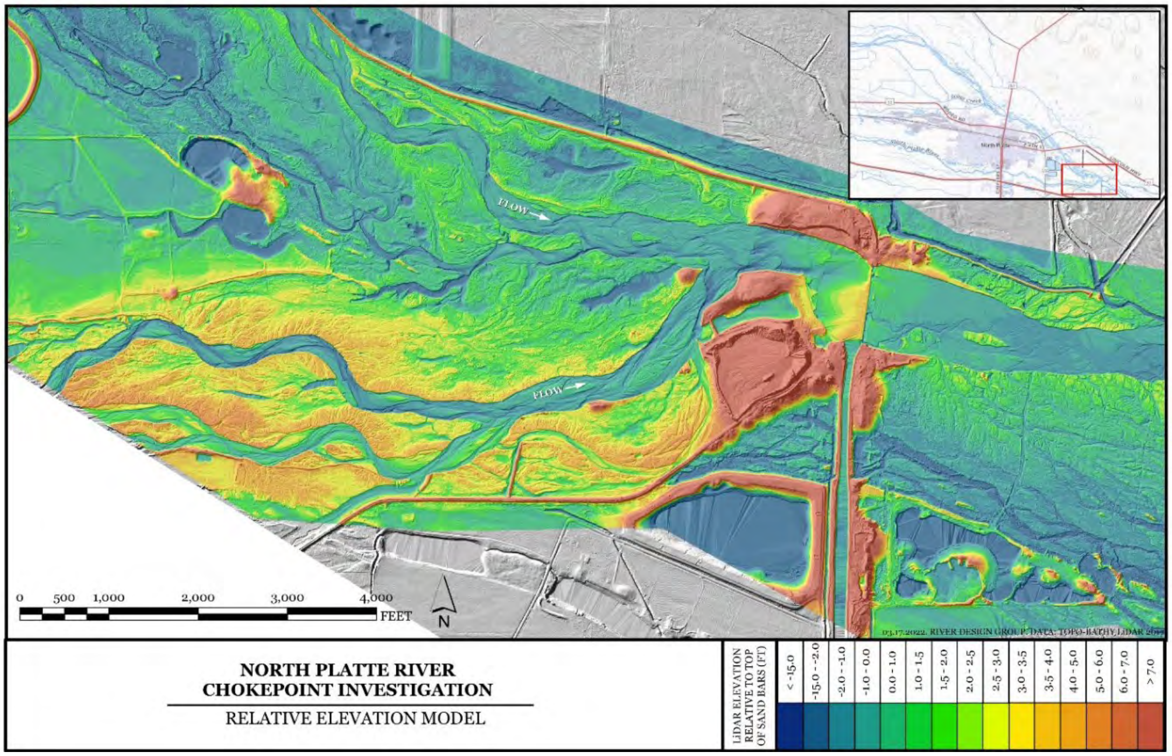

Figure 3-1. Relative elevation map for the TCCDD site at the confluence of the North Platte and South Platte Rivers.

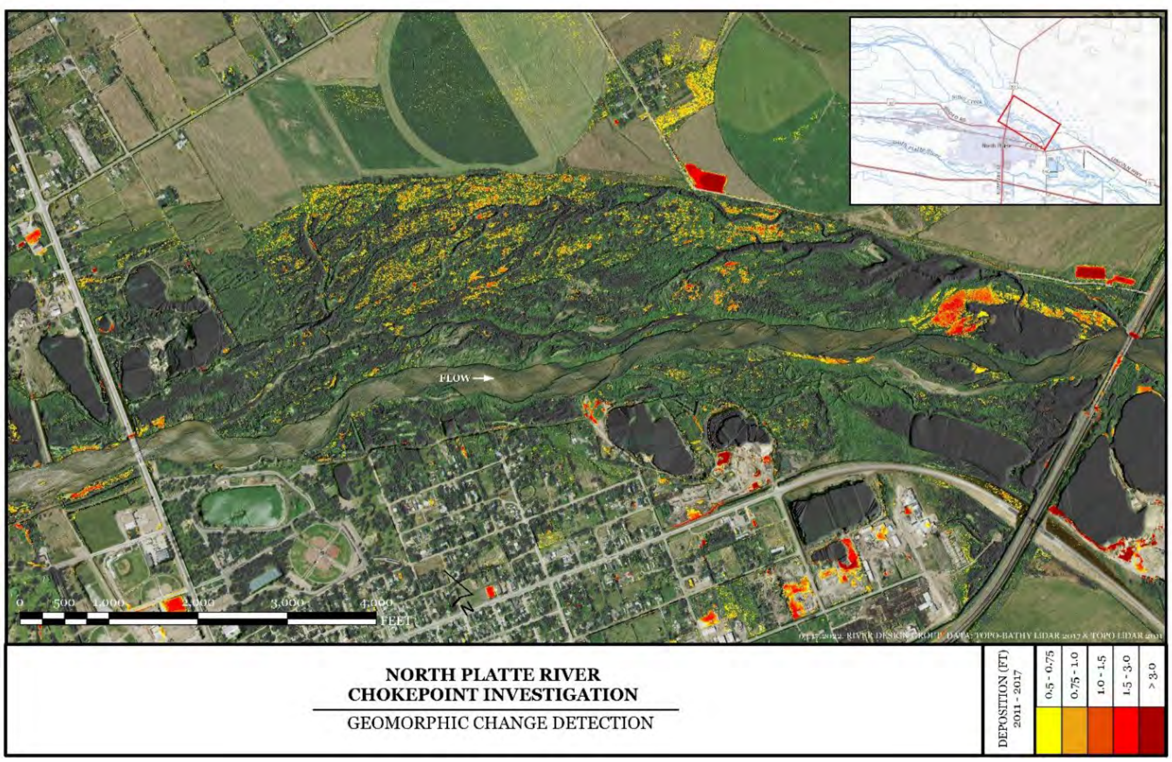

Figure 3-2. Geomorphic change detection map for the river segment between the Highway 83 Bridge and Union Pacific Railroad Bridge near the City of North Platte. Changes in the river channel are not shown due to lack of 2011 bathymetry data.

3.3 Field Visit

A field visit to the Chokepoint Reach was conducted on June 5th through June 7th, 2022. Sites visited included:

- Kingsley Dam (Lake McConaughy);
- Bridges and other river access points downstream of Kingsley Dam;
- Birdwood Creek gage site;
- River excursion via kayak from Hershey State Park to the U.S. Highway 30 Bridge; and
- Tri-County Canal Diversion Dam.

Site visits were useful for observing site-specific conditions related to vegetation communities, sediment transport characteristics, river stability, riparian habitat, and infrastructure elements. Observations were documented with photographs.

Figure 3-3. Sand transport observed in Birdwood Creek at the USGS gage site (left). Phragmites monoculture commonly found along the North Platte Chokepoint Reach (right).

3.4 Hydrologic Analysis

This section provides an overview of the hydrologic analysis completed for this study. A detailed summary of the hydrologic methods and results is provided in Appendix B. The hydrologic analysis included an evaluation of available gage data for the North Platte River and tributaries downstream of Kingsley Dam. The analysis focused on the North Platte River at North Platte (USGS #06693000) for the pre-dam era (1895-1931) and post-dam era (1941-2022). The tributary analysis focused on Birdwood Creek near Hershey (USGS #0669200) for two hydroperiods including 1933 to 1978 and 1979 to 2022. Analyses completed included:

- Annual hydrograph and flow duration for the North Platte River;
- Monthly flow statistics for the North Platte River;
- Flood frequency analysis for North Platte River;
- Flood frequency analysis for Birdwood Creek;

- Flood frequency for un-gaged tributaries using scaled contributing area for Birdwood Creek; and
- Rainfall-runoff correlation between North Platte airport weather station and Birdwood Creek.

Climate model projections for the region were also reviewed to assess the potential effect of climate change on the frequency and magnitude of flood events on the North Platte River and flows from the tributaries between Kingsley Dam and the City of North Platte. Climate projections suggest that the probability of large rainfall events and the flooding risk from peak river flows could increase or decrease. Given the uncertainty of climate model predictions, a range of possible outcomes is possible given the climate model's wide band of confidence limits.

The flood frequency analysis provides discharge estimates for use in modeling higher discharge events and project stability thresholds. The flow duration analysis provides criteria for designing the floodplain elevations suitable for riparian vegetation. Mean monthly flow estimates provide flow criteria for biological periods of interest (e.g. crane migration) and in water work conditions during construction. Total annual flow estimates provide information for long-term trend assessments of river morphology, vegetation, and aquatic species. This portion of the investigation followed standard USGS hydrologic analysis methodologies.

3.4.1 North Platte River Hydrologic Analysis

Selected results from the hydrologic analysis portion of Appendix B are presented here. A summary hydrograph and mean monthly flows for the lower North Platte River are presented in Figure 3-4 and Figure 3-5. Selected design discharges are provided in Table 3-1.

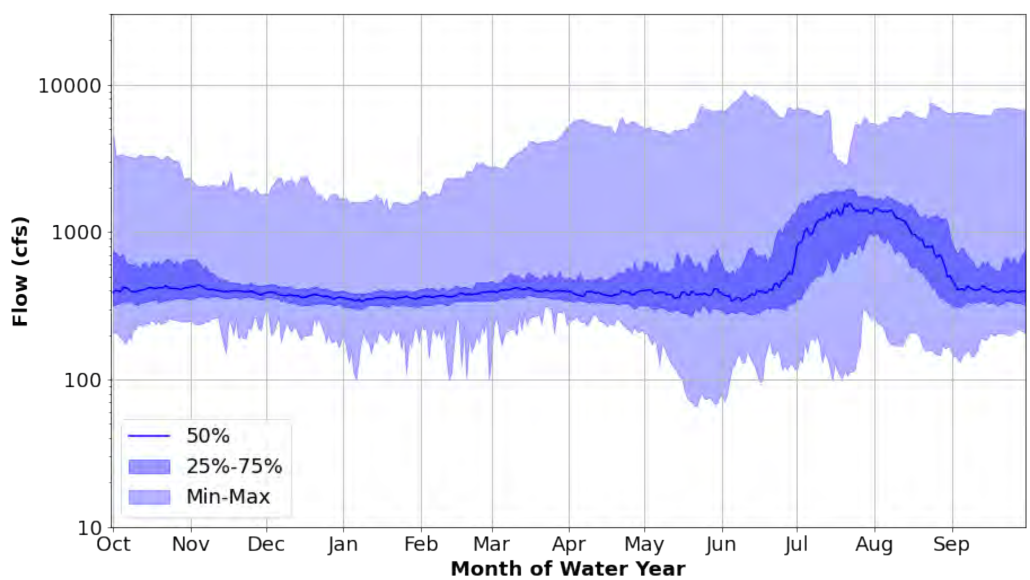

Figure 3-4. Post-dam (WY 1941 – 2022) summary hydrograph for the North Platte River at North Platte (#06693000).

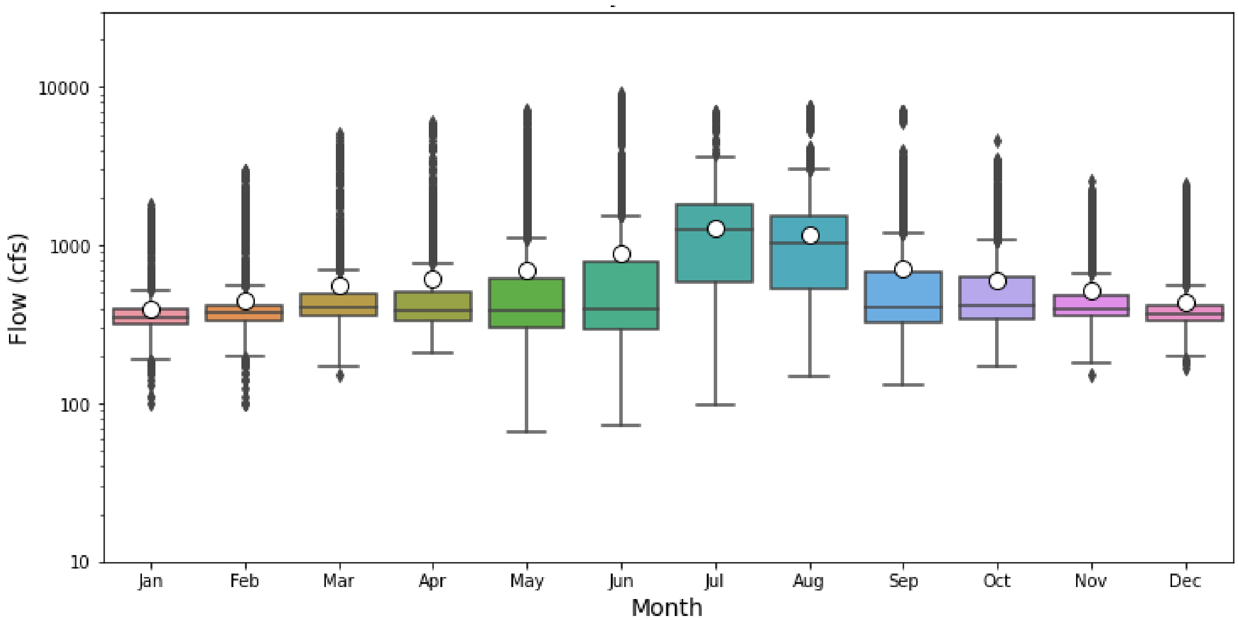

Figure 3-5. Post-dam (WY 1941 – 2022) monthly flows for the North Platte River at North Platte (#06693000).

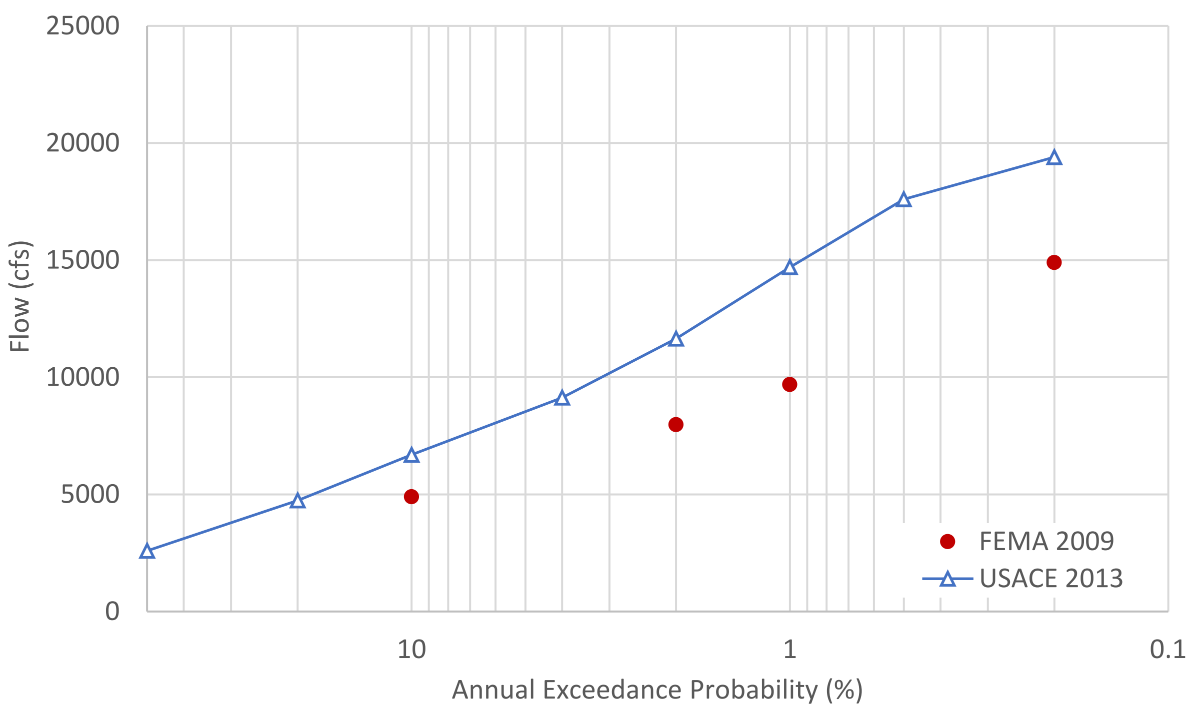

Figure 3-6. Peak flow quantiles developed by FEMA (2009) and USACE (2013) for the North Platte River near North Platte (#06693000).

Table 3-1. Selected flow statistics for the North Platte River at North Platte.

Metric or Recurrence Interval (years)	Annual Exceedance Probability[1]	Flow (cfs)
Baseflow	N/A	400
Bankfull	N/A	1,200
2	0.5	2,590
5	0.2	4,740
10	0.1	6,690
25	0.04	9,130
50	0.02	11,650
100	0.01	14,700
200	0.005	17,600
500	0.002	19,400

[1] Flow statistics developed by USACE (2013).

3.5 Hydraulic Modeling

This section provides an overview of the hydraulic modeling approach used for this study. A detailed summary of the hydraulic modeling methods and results is provided in Appendix B. HEC-RAS version 6.2 (USACE 2022) was used to perform simulations of one-dimensional steady-flow hydraulics for existing conditions and scenarios designed to determine the effects of bridges, the Tri-County Canal Diversion Dam and vegetation on flow through the reach. The model was also used to evaluate potential modifications to the channel, floodplain and infrastructure to support development of recommendations.

3.5.1 Adaptation of Existing Models

The hydraulic model used for this study is the product of three prior modeling efforts. The first iteration of the model was the Platte River Recovery Implementation Program (PRRIP) one-dimensional steady model from North Platte to Keystone (HDR, Tetra Tech and The Flatwater Group 2011). This model was developed for non-flood flows and the calibration efforts targeted flows below 2,000 cfs. The model was modified by USACE to allow for modeling of higher flows as part of the North Platte River Flood Risk Impacts Assessment and Communication study (USACE 2013) and for use in design and permitting for the State Channel Berm (USACE 2018). The State Channel Berm model was used as the starting point for this study.

The study model is a single-reach model that extends from the TCCDD at the confluence to a point approximately 5.5 miles upstream of Highway 83. The model domain was extended approximately 1,000 feet downstream of the TCCDD to enable a comparison of water surface elevations through the dam and confluence area. Model stationing was adjusted to accommodate this change. The existing conditions model geometry was updated to include 2017 topo-bathymetric LiDAR (Quantum Spatial 2018). A total of 50 cross sections were used to represent the channel and floodplain geometry for the existing conditions model. The existing conditions model geometry includes three structures representing the Highway 30 Bridge, Highway 83 Bridge and Union Pacific Railroad (UPRR) Bridge. Hydraulic modeling parameters are summarized in Table 3-2. The model schematic is provided in Figure 3-7.

Table 3-2. Parameters for North Platte Chokepoint hydraulic model.	
Software	HEC-RAS Version 6.2
Geometry	2017 topo-bathymetric LiDAR
Flows	1,000 to 12,000 cfs
Roughness	0.020 (channel) to 0.160 (floodplain)
Cross Sections	50
Calibration	Unchanged from USACE model
Infrastructure	Bridges, Tri-County Canal Diversion Dam, Levees
Ineffective Flow Areas	Bridges, borrow pits, vegetated islands

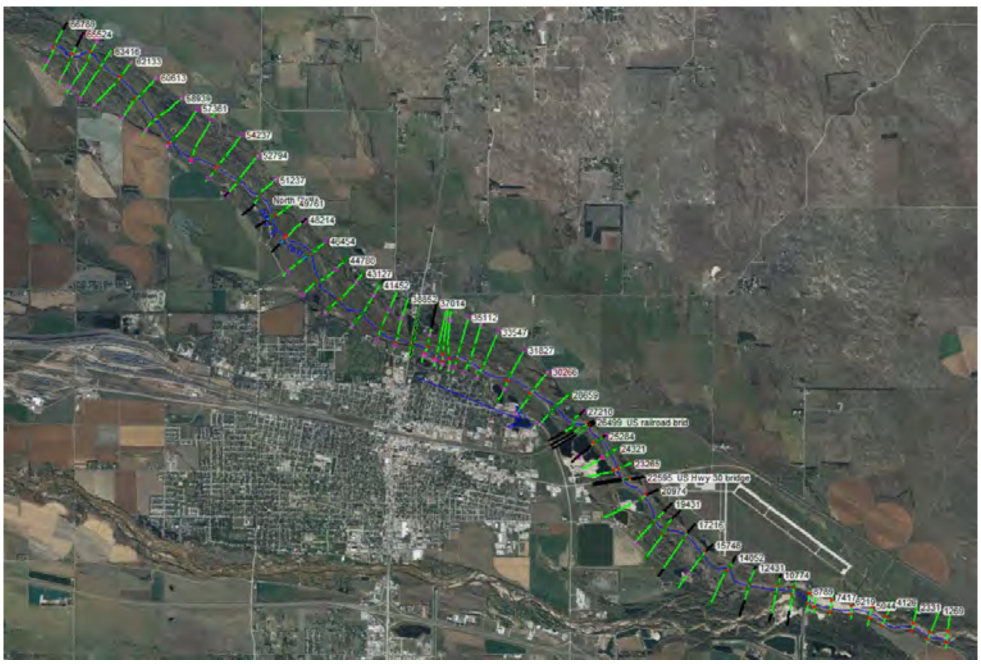

Figure 3-7. HEC-RAS 1D model schematic for the North Platte Chokepoint Reach.

3.5.2 Modeling Scenarios

Ten hydraulic modeling scenarios were developed to address the key questions outlined in the scope of work. Modeling scenarios were aimed at evaluating the sensitivity of channel capacity to the individual effects of bridge constrictions, the TCCDD, sediment aggradation and vegetation encroachment. Modifications to model geometry were made to simulate each scenario. Vegetation removal was simulated by reducing the channel roughness to represent non-vegetated floodplain conditions. Hydraulic modeling scenarios are summarized in Table 3-3.

Table 3-3. Hydraulic modeling scenarios for the North Platte Chokepoint Investigation.

Scenario	Condition Modeled	Question Addressed
1	Existing conditions	Current channel capacity
2	Removal of bridge structure	Effect of bridge on capacity
3	Increase bridge openings to 500 ft	Effect of constrictions on capacity
4	Increase bridge openings to 1,000 ft	Effect of constrictions on capacity
5	Remove Tri-County Canal Diversion Dam	Effect of dam on capacity
6	Bypass dam and dredge 200-ft width through reach	Effect of aggradation on capacity
7	Bypass dam and dredge 500-ft width through reach	Effect of aggradation on capacity
8	Bypass dam and dredge 1000-ft width through reach	Effect of aggradation on capacity
9	Remove vegetation to 500-ft width	Effects of vegetation on capacity
10	Remove vegetation to 1000-ft width	Effects of vegetation on capacity

An illustration of model geometry modifications for selected scenarios is presented in Figure 3-8 and Figure 3-9. For dredging scenarios, the channel was widened, and the thalweg was lowered to match the historical channel profile represented by a linear interpolation of the upstream and downstream reach slopes of 0.12% through the accumulated sediment in the Chokepoint Reach. For bridge constriction scenarios, the channel was widened only, and no channel lowering was included. For this analysis, it was assumed that the interpolated slope through the TCCDD corresponds to the invert elevations of the gates and no disruption of the profile is caused by the TCCDD. This assumption must be validated with a survey of elevations at the TCCDD outlet gates.

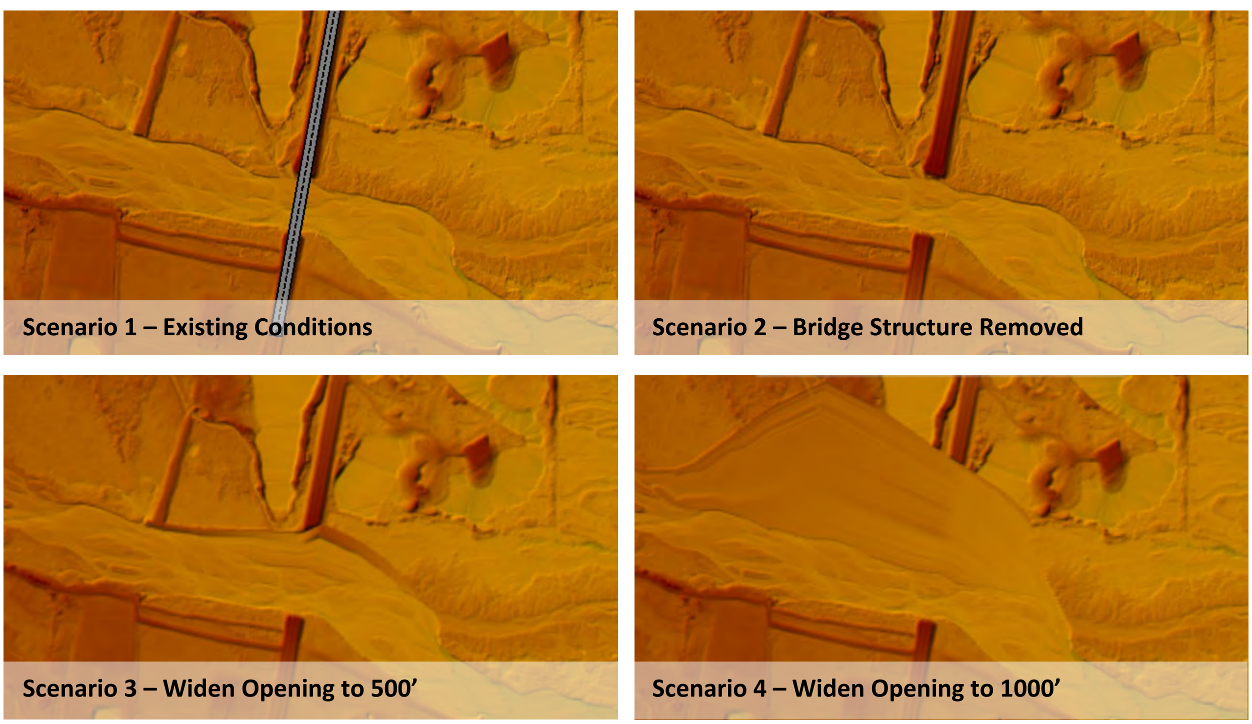

Figure 3-8. Illustration of model geometry modifications for scenarios representing bridge constrictions.

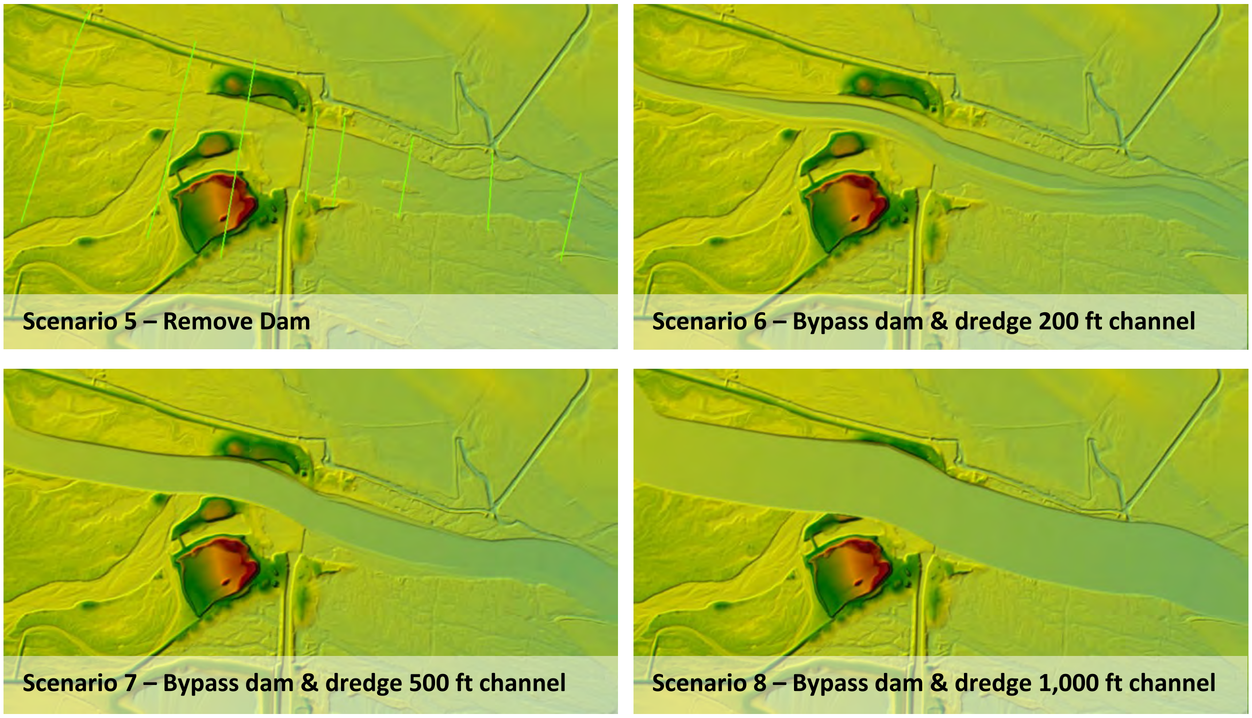

Figure 3-9. Illustration of model geometry modifications for scenarios representing sediment removal and flow bypass around the TCCDD.

3.5.3 Model Accuracy and Limitations

The existing conditions model was validated by comparing modeled water surface elevations with gage data and elevations sampled from 2017 LiDAR data. Overall accuracy of the model was good with differences of less than 0.5 feet through the Chokepoint Reach.

The model used in this study does not account for flows that escape the main channel or are attenuated by bank storage. Running unsteady-flow simulations to account for flow splits was beyond the scope of this study and was not necessary to ascertain the primary effects of the bridges, TCCDD and vegetation on water surface elevations through the reach. The USACE report (2014) notes that flows splits may account for 33% - 45% of the total flow for flows ranging from about 4,500 cfs to 5,900 cfs. Water escapes the main channel upstream of the Union Pacific Railroad Bridge and is routed through White Horse Creek and the airport. In addition, flows may be routed through the City of North Platte. It appears that water begins to flow into the Whitehorse Creek area at about 2,000 cfs and flow may overtop the levee protecting the airport at about 7,000 cfs. Once flows exit the North Platte River and begin flowing through the city, airport, or White Horse Creek, conveyance areas are generally shallow with little to no defined drainage path. As flows increase, flow paths through these areas could be significantly different from those predicted by the 1D model. Two-dimensional and/or unsteady-flow modeling would be required to accurately define inundation areas and flow paths for flows greater than approximately 2,000 cfs.

4 Results and Conclusions

This section presents the results of the analyses completed to address the key questions outlined in the scope of work.

4.1 Effects of Bridge Constrictions on Channel Capacity

Bridges were evaluated in three hydraulic modeling scenarios aimed at testing the sensitivity of water surface elevations and channel capacity to the width of the bridge openings. Effects on water surface elevations were evaluated at the model cross sections upstream of each bridge. Changes in water surface elevation were summarized to determine the maximum change and maximum distance that the change extended upstream of each bridge. Effects on channel capacity were more challenging to evaluate because capacity differs at each cross section due to variation in the size and shape of the channel. As such, changes to channel capacity were computed at the cross section immediately upstream of each bridge. This was typically, but not always, the location of the greatest change in water surface elevation in the vicinity of the bridge.

The flood stage monitoring location at the Highway 83 Bridge was only affected by the constriction at the Highway 83 Bridge. Constrictions at the Union Pacific Railroad Bridge and Highway 30 Bridge had no effect on channel capacity at the flood stage monitoring location. Increasing the width of bridge openings has marginal effects on water elevations at Highway 83 (less than 0.5 foot for a discharge of 2,000 cfs). Increasing the width of the Highway 83 Bridge opening would increase localized capacity by less than 551 cfs (20%) for a discharge of 2,773 cfs. Modeling indicates that the Railroad Bridge causes the greatest constriction and localized increases in capacity of 18% to 41% could be gained by increasing the width. Modeling indicates that the Highway 30 Bridge is not a significant constriction likely due to effects of adjacent levees. Based on model results, it appears that bridges may contribute to localized aggradation within one-half mile upstream of each bridge. Effects of bridge constrictions on channel capacity are presented in Table 4-1. Effects on water surface elevation are presented in Figure 4-1, Figure 4-2 and Figure 4-3.

Table 4-1. Increase in channel capacity at bridge locations for widening the openings to 1,000 feet.

Increase in capacity at Highway 83	Increase in capacity at Union Pacific Railroad	Increase in capacity at Highway 30
+ 96 (7%) at 1,334 cfs	+ 443 (30%) at 1,473 cfs	
+ 551 (20%) at 2,773 cfs	+ 930 (33%) at 2,786 cfs	
+ 1,189 (24%) at 4,906 cfs	+ 1,886 (41%) at 4,626 cfs	No increase
+ 2,042 (24%) at 8,362 cfs	+ 1,434 (18%) at 8,125 cfs	
Existing width = 320 feet	Existing width = 250 feet	Existing width = 560 feet

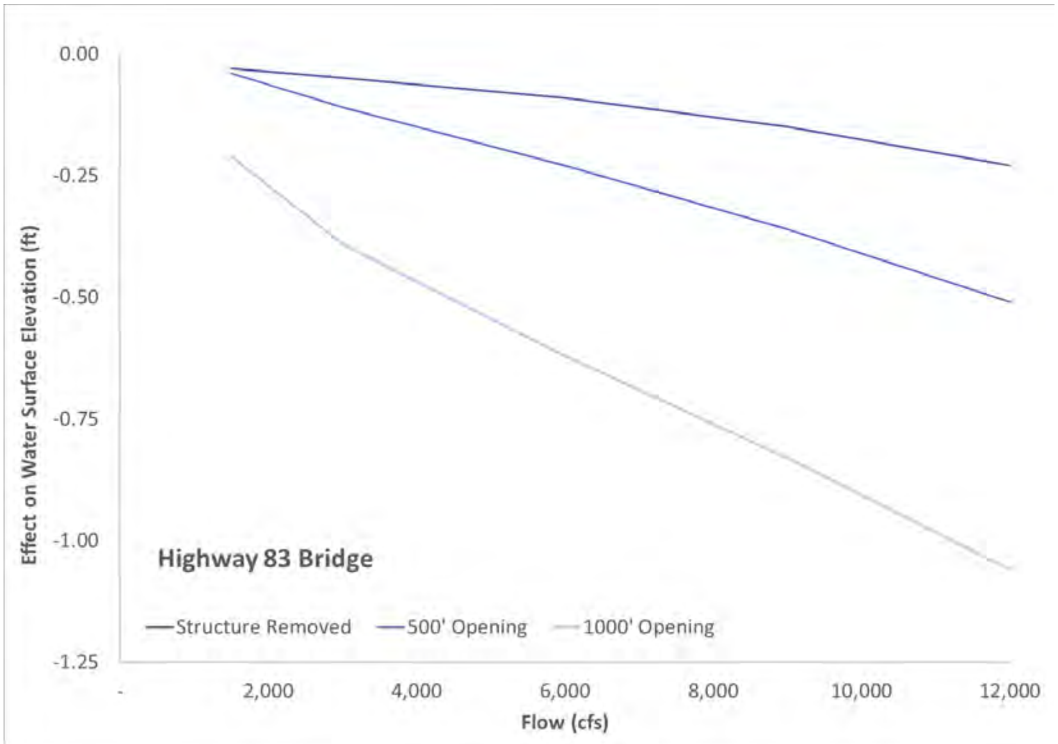

Figure 4-1. Hydraulic model results summarizing the effects of bridge constriction scenarios on water surface elevations at the Highway 83 Bridge.

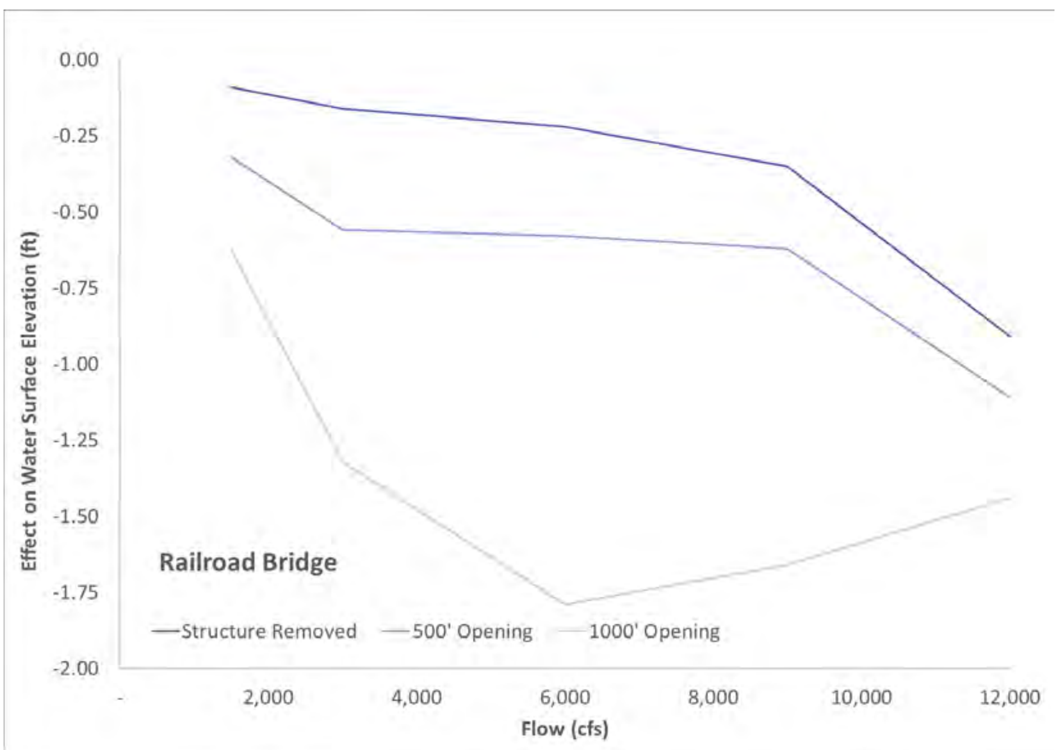

Figure 4-2. Hydraulic model results summarizing the effects of bridge constriction scenarios on water surface elevations at the Union Pacific Railroad Bridge.

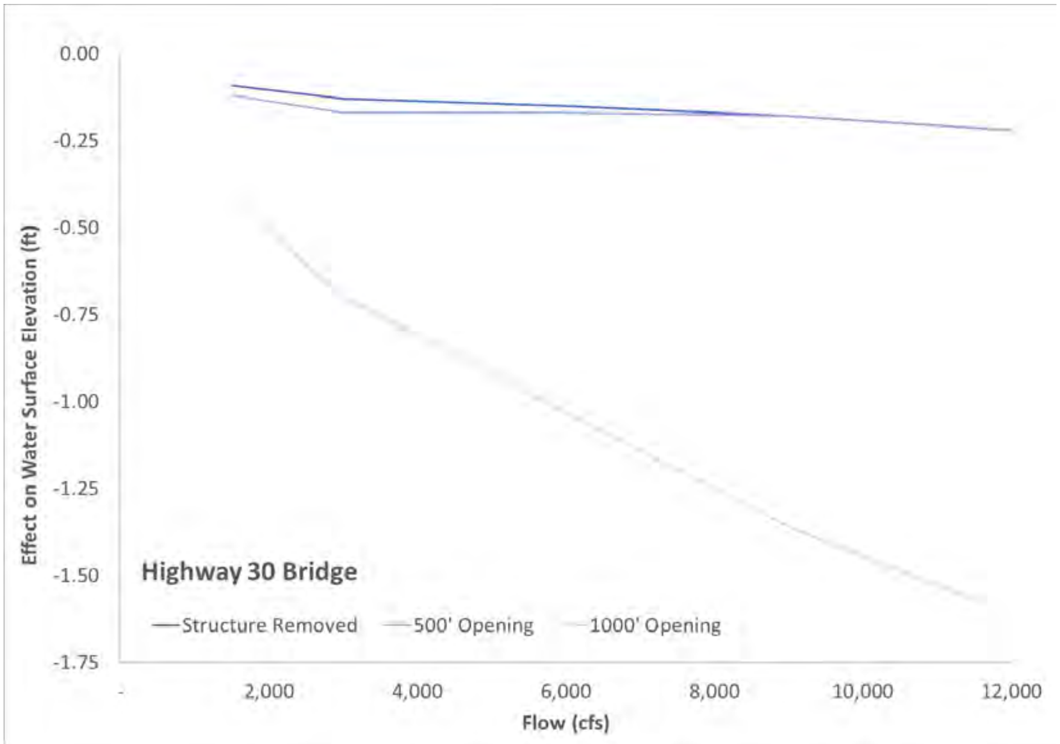

Figure 4-3. Hydraulic model results summarizing the effects of various bridge constriction scenarios on water surface elevations at the Highway 30 Bridge.

4.2 Effects of Vegetation Encroachment on Channel Capacity

Vegetation removal was evaluated in two hydraulic modeling scenarios aimed at evaluating the sensitivity of water surface elevations and channel capacity to the effects of vegetation encroachment on the channel. Vegetation establishment in the Chokepoint Reach is enhanced by altered magnitude and timing of flows. In addition, the lack of natural disturbance from floods and fire supports vegetation growth and maturity.

Results indicate that vegetation likely contributes to reach-scale deposition but has only minor effects on capacity at the bridges of less than 10%. Removal of vegetation in the model had marginal effect on water elevations at all flows. Effects of vegetation removal on channel capacity are presented in Table 4-2. Effects on water surface elevation are presented in Figure 4-4.

Table 4-2. Increase in channel capacity at bridge locations for vegetation removal within 1,000 feet of the active channel.

Increase in capacity at Highway 83	Increase in capacity at Union Pacific Railroad	Increase in capacity at Highway 30
+ 119 (10%) at 1,143 cfs	+ 106 (7%) at 1,473 cfs	+ 119 (10%) at 1,143 cfs
+ 153 (6%) at 2,576 cfs	+ 186 (7%) at 2,786 cfs	+ 153 (6%) at 2,576 cfs
+ 183 (4%) at 4,573 cfs	No increase	+ 183 (4%) at 4,573 cfs
+ 654 (9%) at 7,080 cfs	No increase	+ 654 (9%) at 7,080 cfs

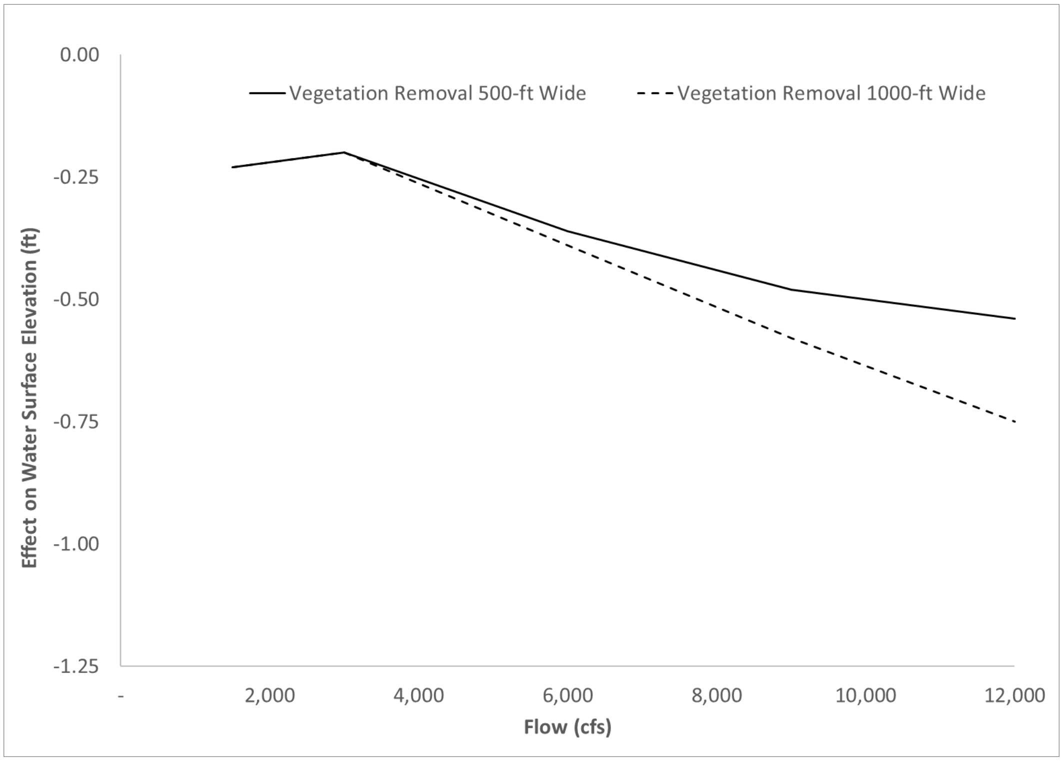

Figure 4-4. Hydraulic model results summarizing the effects of vegetation removal scenarios on water surface elevations.

4.3 Effects of the Tri-County Canal Diversion Dam

Analysis of the 2017 topo-bathymetric LiDAR illuminates the extent of sediment deposition in the Chokepoint Reach. The average reach gradient above and below the Chokepoint Reach is 0.12% with a noticeable wedge of sediment present in the study reach. A linear interpolation of the upstream and downstream gradients through the Chokepoint Reach was completed to define an equilibrium channel profile and illustrate the reach-scale aggradation that has occurred upstream of the TCCDD. The estimated equilibrium channel and extent of sediment deposition is presented in Figure 4-5.

Based on the LiDAR analysis, the TCCDD appears to be the primary cause of reach-scale aggradation in the Chokepoint Reach. Sedimentation extends over six miles upstream of the dam with a maximum depth of approximately six feet as measured from the bottom of the equilibrium channel profile. Deposition in the floodplain is much greater than six feet in places and deposition extends one mile below the dam likely due to periodic overtopping. The volume of the sediment wedge upstream of the dam is estimated to be approximately 5 million cubic yards.

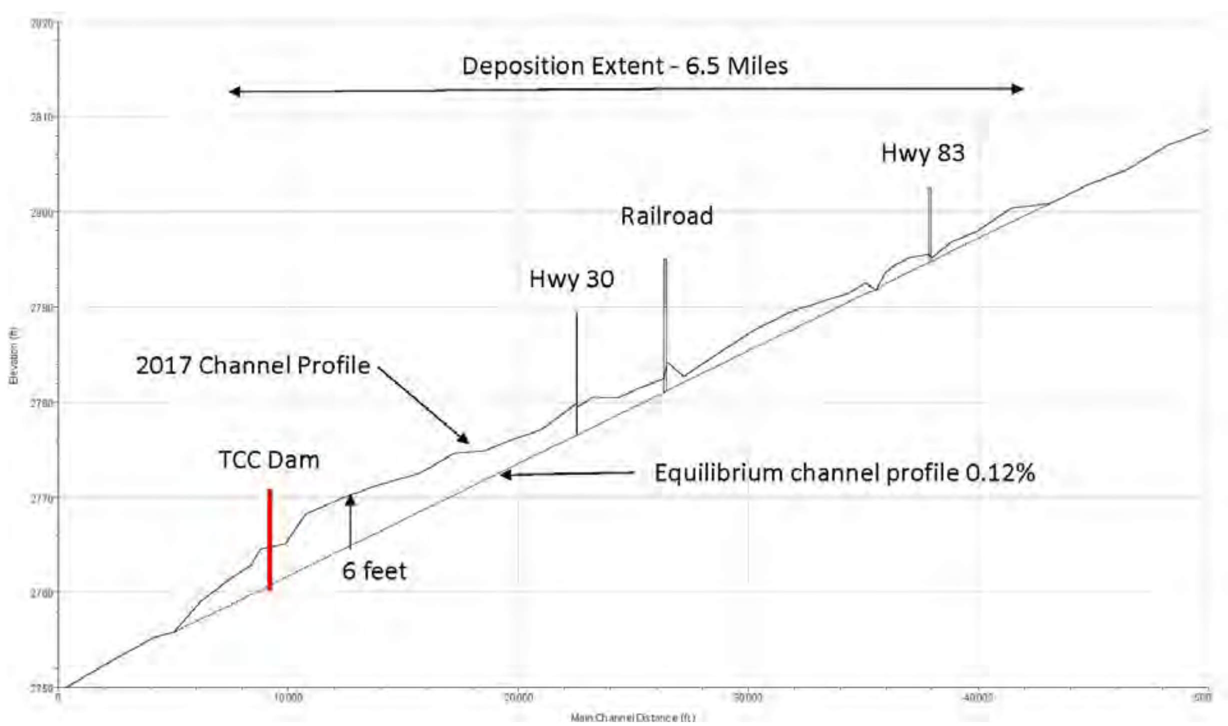

Figure 4-5. Analysis of 2017 topo-bathymetric LiDAR depicting the estimated North Platte River equilibrium channel profile and extent of sediment deposition in the Chokepoint Reach.

4.4 Flow Contributions from Tributaries

The tributary flow analysis was completed to determine the probability of flows ranging from 3,000 cfs to 12,000 cfs occurring downstream of Lake McConaughy in the absence of releases from Kingsley Dam. Direct contributions to flow in the North Platte River in this area are limited due to basin characteristics (i.e. closed basins, highly permeable soils, and irrigation withdrawals). The only gaged tributary is Birdwood Creek with a reported contributing area of 80 square miles. Contributing flows were extrapolated from Birdwood Creek to the entire sub-watershed between Kingsley and North Platte. Birdwood Creek represents approximately 25 percent of this area. Based on the USGS period of record for Birdwood Creek (1932 – 1993) adjusted for tributary area, flows of 3,000 cfs have an annual exceedance probability of approximately 8% (return interval of approximately 12 years) with 5% confidence limits on the annual exceedance probability of 4% to 15% (return interval ranging from 7 to 24 years). Estimated flows for lower North Platte River tributaries are presented in Figure 4-6.

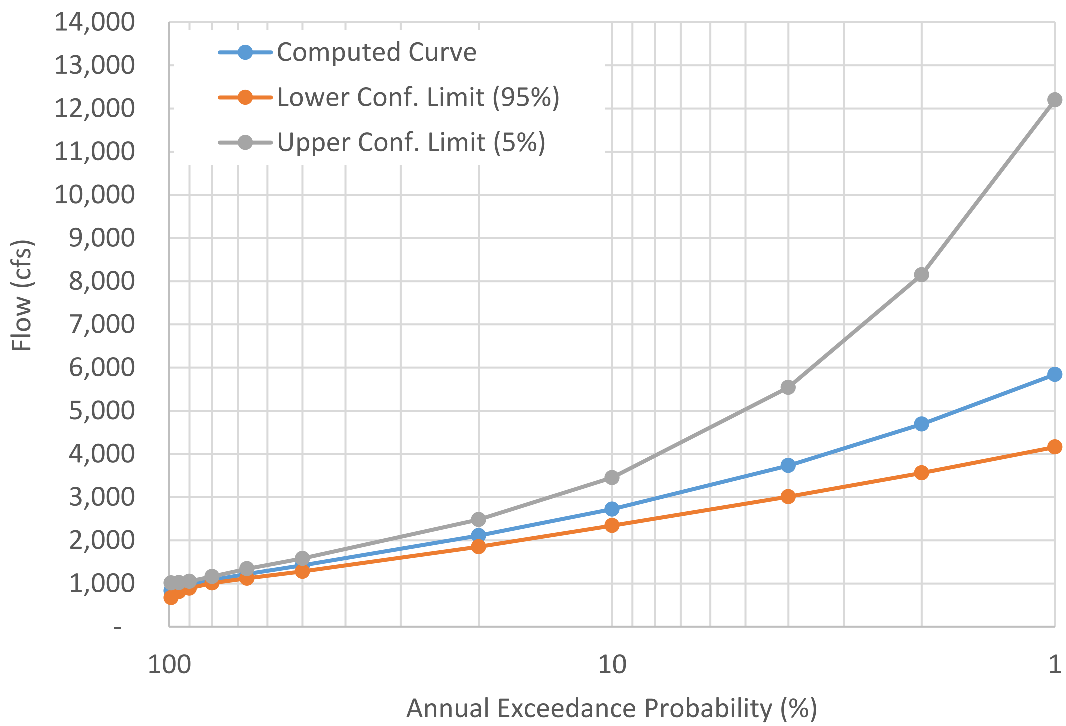

Figure 4-6. Area-adjusted peak flows for lower North Platte River tributaries based on Birdwood Creek peak flows (1932 – 1993).

Rainfall data recorded at the North Platte airport was correlated with flow data from the gage on Birdwood Creek to determine how much rainfall needs to be observed for flows of 3,000 cfs to 12,000 cfs to occur at North Platte (Figure 4-7). The correlation was poor, likely due to spatial variations in precipitation and basin characteristics. Results are consistent with other studies completed by USGS (1976) and NeDNR (2013). Climate projections suggest that the probability of large rainfall events and the flooding risk from peak river flows could increase or decrease. Given the uncertainty of climate model predictions, a range of possible outcomes is possible given the climate model's wide band of confidence limits.

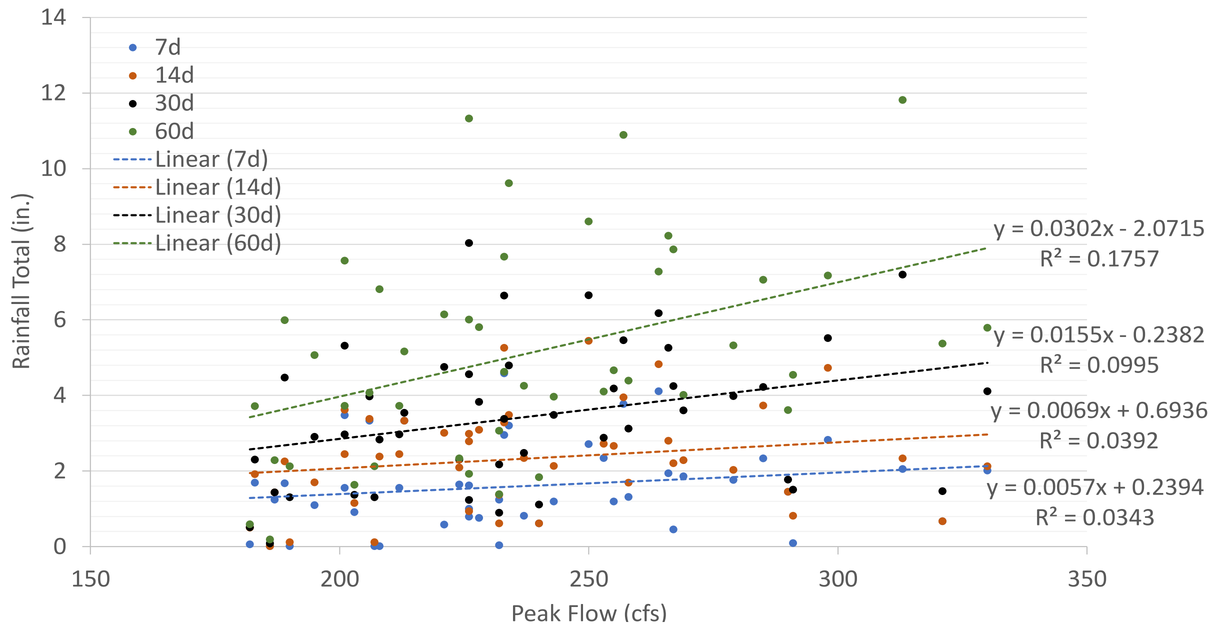

Figure 4-7. Rainfall-runoff correlation between the North Platte airport weather station and Birdwood Creek.

4.5 Chokepoint Trends and Future Capacity

Trends in chokepoint capacity have been evaluated by PRRIP (Turner 2021). The analysis included a summary of rating curve shifts at the North Platte gage and plots of stage-discharge relationships from 1940 through 2012 (Figure 4-8) corresponding to the time period since the TCCDD has been in operation (1940 to present). The analysis found that stage at the gage has increased three feet for a flow of 2,000 cfs and capacity at flood stage has decreased from approximately 10,000 cfs to less than 2,000 cfs (Figure 4-9). The analysis also showed that flows exceeding 3,000 cfs occurred only three times over the 72-year period. Based on this analysis, capacity has decreased approximately 85% in 80 years corresponding to an average annual decrease in capacity of 2.2% based on an exponential regression model and both observed and interpolated flow capacity values (Figure 4-10). This model projects that flow capacity could decrease to less than 300 cfs by the year 2100 given no intervention.

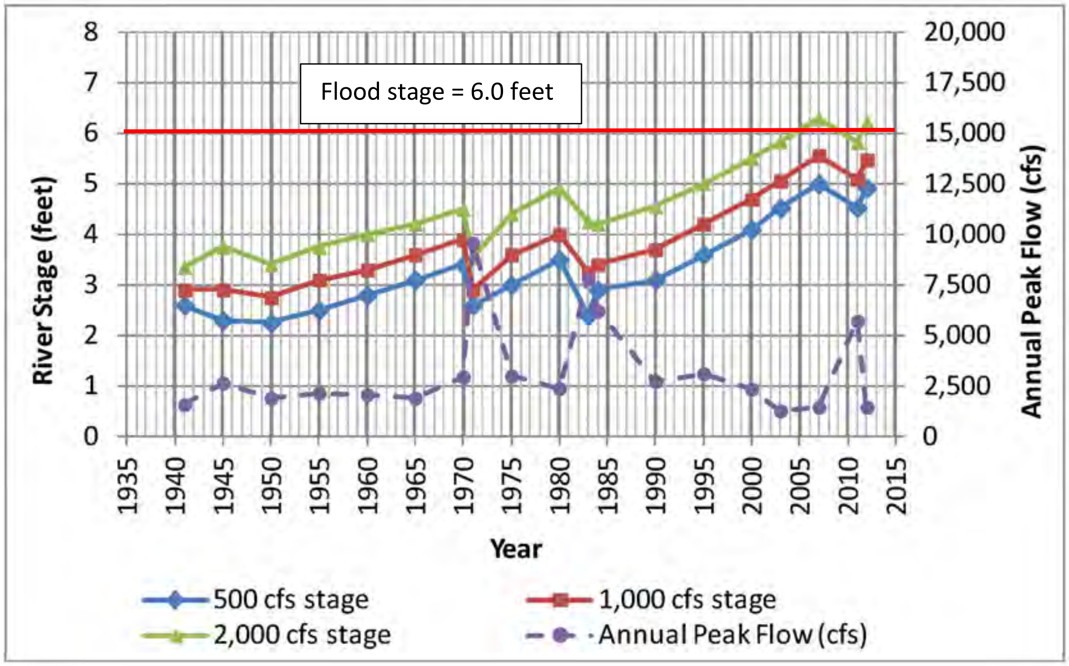

Figure 4-8. Plot showing the increase in river stage for selected flows at the North Platte gage site since operation of the Tri-County Canal Diversion Dam in 1940 (Turner 2021). Current flood stage is 6.0 and stage has increased 3 feet for a flow of 2,000 cfs.

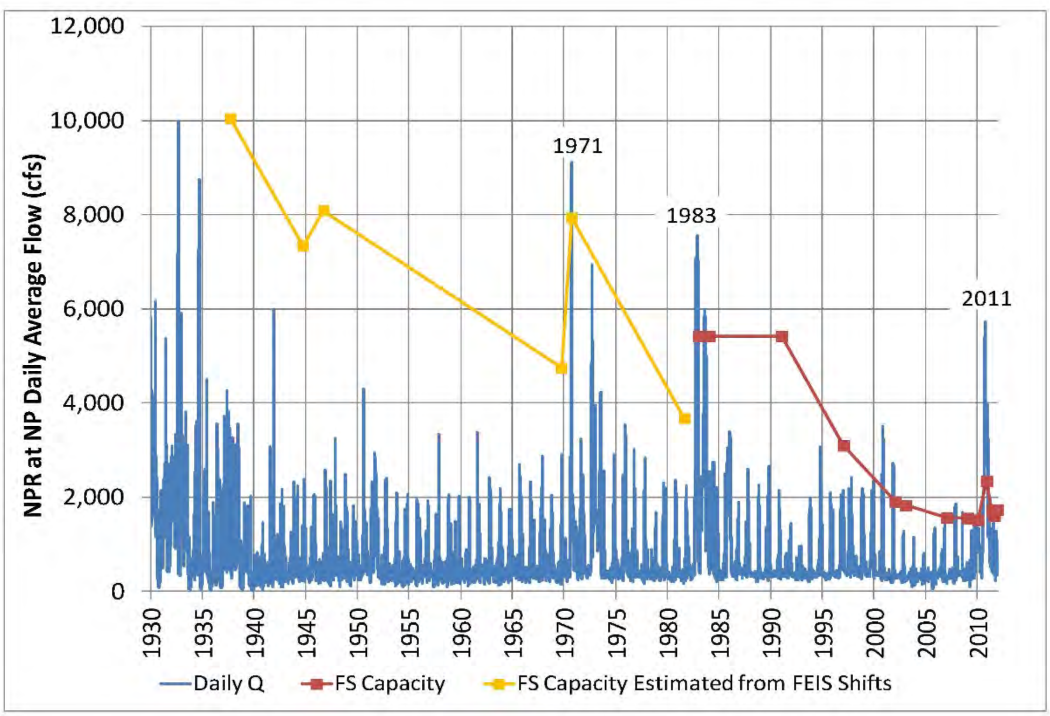

Figure 4-9. Plot showing the decrease in flood stage capacity at the North Platte gage site since operation of the Tri-County Canal Diversion Dam in 1940 (Turner 2021). Flood stage capacity has decreased from approximately 10,000 cfs in 1940 to less than 2,000 cfs in 2012.

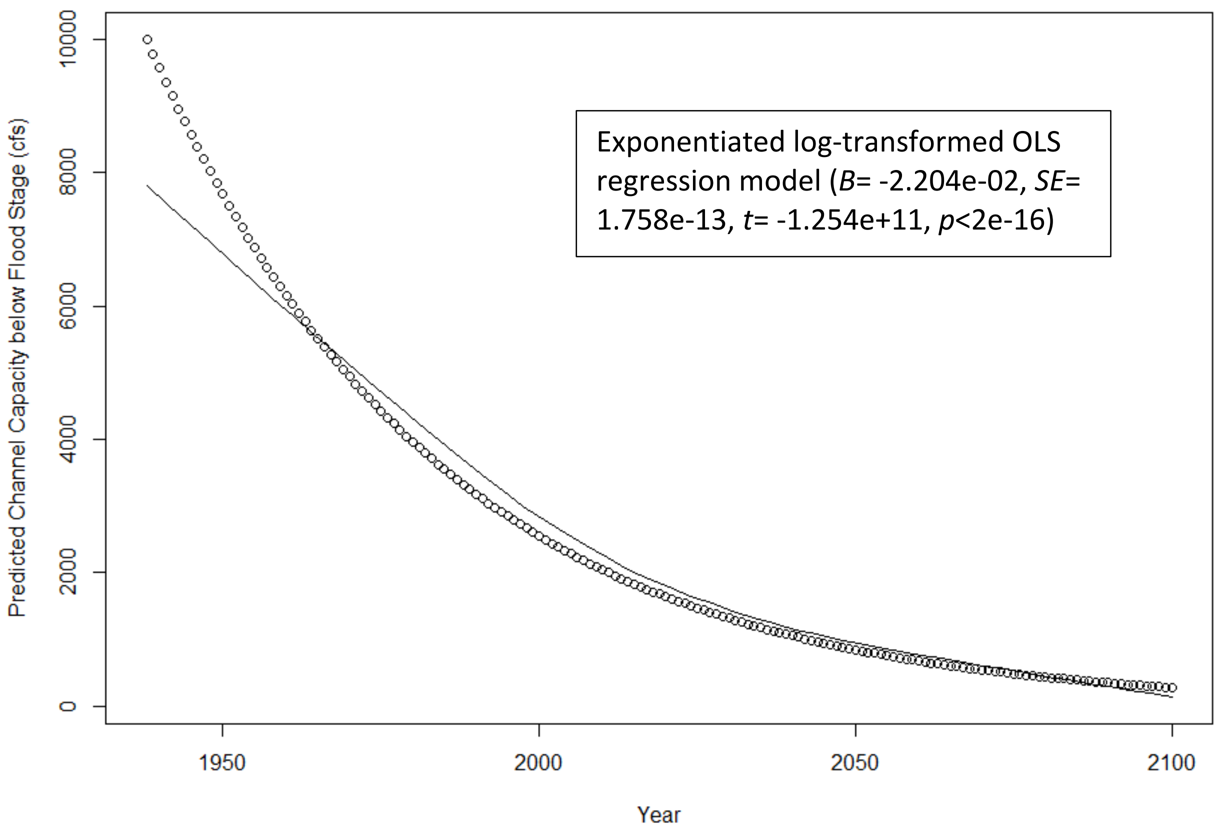

Figure 4-10. Predicted capacity through the North Platte Chokepoint Reach from 1938 to 2100 based on an exponential regression model and both observed and interpolated flow capacity values.

4.6 Chokepoint Capacity for Selected Dredging Scenarios

Three dredging scenarios were simulated using the hydraulic model. Scenarios included dredging a channel seven miles through the Chokepoint Reach at the estimated equilibrium channel slope (Figure 4-5) for widths of 200 feet, 500 feet and 1000 feet (Figure 3-9). Changes in channel capacity for the three dredging scenarios are presented in Table 4-3.

Table 4-3. Modeled flood stage capacity at the Highway 83 Bridge for dredging scenarios.

Scenario	Flood Stage Capacity (cfs)	Dredge volume (cubic yards)
Existing Conditions	1,775	N/A
Dredge 200 feet wide	4,678	1,500,000
Dredge 500 feet wide	7,868	3,700,000
Dredge 1,000 feet wide	> 12,000	7,400,000

4.7 Conclusions and Responses to Key Questions

Responses to the key questions are provided below.

1. ***What are the major factors contributing to a loss of channel capacity at the North Platte Chokepoint Reach?***

   a) *What is the impact of the Tri-County Dam on flow capacity?*

   Response: The TCCDD is the primary cause of reach-scale aggradation in the Chokepoint Reach. By blocking the entire channel and creating a backwater, the equilibrium slope of the Chokepoint reach has been reduced thus causing extensive deposition and channel aggradation. Analysis of 2017 topo-bathymetric LiDAR found that sedimentation extends over six miles upstream of the dam with a maximum depth of approximately six feet as measured from the bottom of the equilibrium channel profile. Analysis methods are described in Section 3.5 and results are presented in Section 4.3.

   b) *What impact do highway and railroad bridges have on flow capacity?*

   Response: The bridges constrict the North Platte floodplain by as much as 85%. Modeling found that bridge constrictions contribute to localized effects on channel capacity and effects are relatively minor for moderate flows up to 3,000 cfs. Sedimentation effects from the TCCDD extend upstream through the three bridges. Increasing the width of the bridge openings is not a sustainable solution without addressing TCCDD operations and reach-scale aggradation. Analysis methods are described in Section 3.5 and results are presented in Section 4.1.

   c) *What is the impact of woody species establishment on flow capacity? What is the impact of exotic-invasive species?*

   Response: The current hydrologic regime supports vegetation establishment and vegetation encroachment on the channel contributes to reach-scale deposition. If vegetation was removed on a reach scale, channel capacity would increase by less than 10% for flows up to 7,000 cfs. Reach-scale vegetation removal may provide short-term benefits for habitat and capacity, but benefits would be temporary due to the lack of historical disturbance regimes such as floods and fires. Vegetation removal is not a sustainable solution without addressing TCCDD operations, reach-scale aggradation, and Kingsley Dam operations. Analysis methods are described in Section 3.5 and results are presented in Section 4.2.

2. ***What is the flooding risk to the city of North Platte under various high flow conditions?***

   a) *What would be the spatial extent of flooding in the city of North Platte and adjacent communities considering a range of high flows including 3,000, 6,000, 9,000, and 12,000 cfs under current and projected future streamflow capacities?*

Response: Existing hydraulic models have limitations for producing accurate inundation maps. For moderate flows of 2,000 to 6,000, the models depict flow escaping from the channel and beyond the floodplain into areas not included in the model geometry. It is possible to modify the model geometry and examine flow splits to evaluate inundation extents more accurately; however, this level of analysis was beyond the scope of this study. Moreover, such an analysis would need to consider the context of existing flood studies completed by USACE and FEMA. Hydraulic model accuracy and limitations are described in Section 3.5.3.

b) *In the absence of releases from Kingsley Dam, what is the probability that these flows will occur downstream of Lake McConaughey and upstream of the city of North Platte?*

Response: Without releases from Kingsley Dam, flows of 3,000 cfs have an annual exceedance probability of ~8% (return interval of ~12 years) based on the USGS period of record for Birdwood Creek (1932 – 1993) adjusted for tributary area. Analysis methods are described in Section 3.4 and results are presented in Section 4.4.

c) *What level of rainfall needs to be observed locally for such flows to occur?*

Response: The correlation between rainfall at the North Platte Airport and observed flow at the Birdwood Creek gage was poor with a regression analysis statistical fit measure (R^2) less than 0.2. The poor correlation is likely attributed to spatial variations in precipitation, availability of precipitation data in tributary watersheds and diverse basin runoff characteristics. Results are consistent with other studies completed by USGS (1976) and NeDNR (2013). Analysis methods are described in Section 3.4 and results are presented in Section 4.4.

d) *How do climate projections influence the probability of large rainfall events and therefore flooding risk from peak river flows?*

Response: Climate model projections for the region were reviewed to assess the potential effect of climate change on the frequency and magnitude of flood events on the North Platte River and flows from the tributaries between Kingsley Dam and the City of North Platte. Climate projections suggest that the probability of large rainfall events and the flooding risk from peak river flows could increase or decrease. Given the uncertainty of climate model predictions, a range of possible outcomes is possible given the climate model's wide band of confidence limits.

3. ***What is the projected future capacity at the North Platte Chokepoint under various management conditions?***

a) *If nothing is done, at what rate will flow capacity in the North Platte River change?*

Response: Based on analyses completed by PRRIP (Turner 2021), capacity of the Chokepoint Reach has decreased from approximately 10,000 cfs in 1940 to less than 2,000 cfs in 2012. Based on this analysis, capacity has decreased approximately 85% in 80 years corresponding to an average annual decrease in capacity of 2.2%. Results are described in Section 4.5.

b) *What would be the projected change in capacity under various management scenarios (e.g., regular sediment removal, installation of a sediment bypass system at the Tri-County Canal Diversion Dam, regular in-channel vegetation control, etc.)?*

Response: Three dredging scenarios were simulated using the hydraulic model. Scenarios included dredging a channel seven miles through the Chokepoint Reach at the estimated equilibrium channel slope (Figure 4-5) for widths of 200 feet, 500 feet and 1,000 feet (Figure 3-9). Dredging a channel 200 feet wide could increase flood stage capacity from approximately 1,500 cfs to 4,000 cfs. Analysis methods are described in Section 3.5 and results are presented in Section 4.6.

5 Recommendations

This study builds upon previous work by utilizing 2017 topo-bathymetric LiDAR data and hydraulic modeling to improve the understanding of factors contributing to deposition and streambed aggradation in the North Platte Chokepoint Reach. The findings of this study explain the loss of channel capacity in the Chokepoint Reach and provide a basis for developing solutions to increase flow and sediment delivery to the Central Platte River Valley. It is acknowledged that the North Platte River has many uses and recommendations must accommodate a broad audience to achieve solutions to the problem. VESPR provided criteria to guide the recommendations of this study including reduce flood risk, maintain irrigation canal operations, improve habitat for native species, decrease infrastructure maintenance, and promote opportunities for recreation. Moreover, recommendations that address the root causes of the problem are sought. As such, recommendations provided herein focus on TCCDD operations and sediment removal from the Chokepoint Reach. The following recommendations are conceptual and numerous questions exist regarding feasibility. Additional analysis and discussion with stakeholders will be required to refine the concepts and validate feasibility.

5.1 Sediment Removal

Removal of accumulated sediment from the Chokepoint Reach will require a combination of dredging and modifications to TCCDD operations to allow sediment to bypass the dam. For this concept, dredging would be employed to excavate a pilot channel down to the estimated pre-dam profile that would allow river flows to perform additional sediment removal via lateral scour. The amount of energy available for flow to remove sediment would depend on how much flow can bypass the TCCDD. A sediment transport model would be needed to evaluate potential combinations of dredging and flow releases that would be feasible. A plan and profile exhibit illustrating the sediment removal concept is provided in Figure 5-1. A conceptual cross section exhibit is provided in Figure 5-2.

5.1.1 Sediment Removal Benefits

Pros and cons for the sediment removal concept are presented as benefits and feasibility considerations. Concept benefits include:

- Primary cause of sedimentation addressed by restoring equilibrium channel slope to the reach;
- Increase in flood stage capacity from 1,800 cfs to 4,600 cfs at Highway 83 (North Platte Gage);
- Reduced flood risk;
- Reduced dredging operations at TCCDD;
- Lower water table limits vegetation establishment on the channel margins;
- Continued channel erosion by river flow removes existing vegetation;
- Sediment delivery to downstream reaches; and
- Formation of new sand bars creates habitat for focal species.

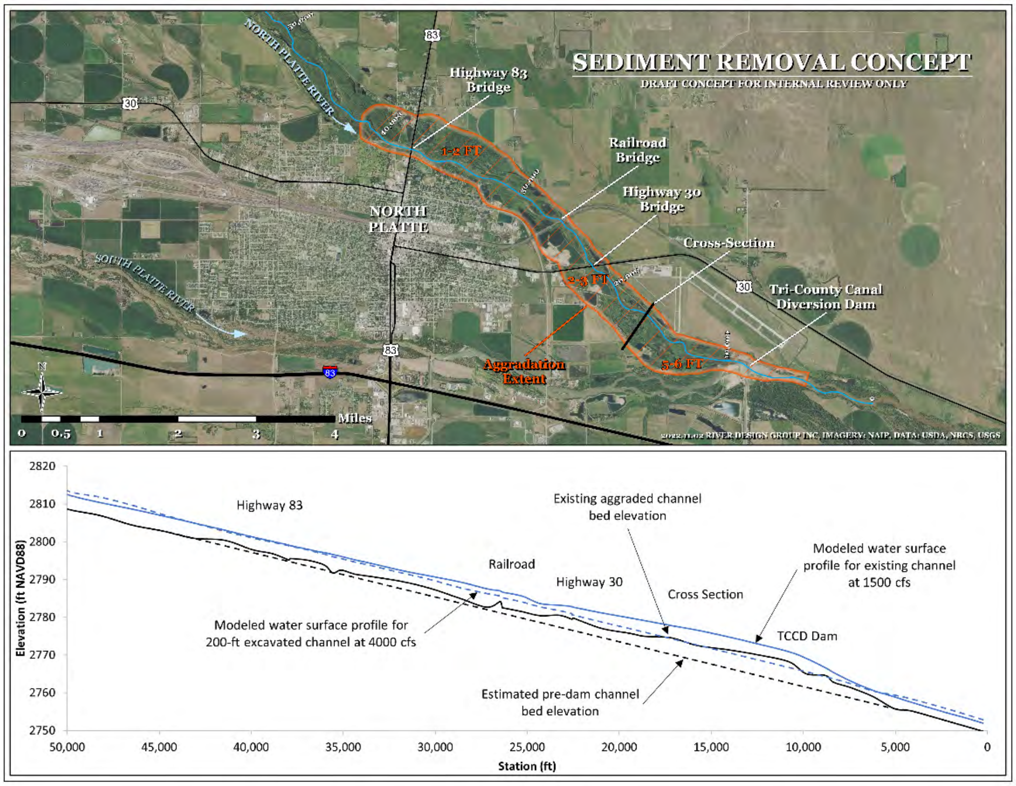

Figure 5-1. Plan and profile exhibit illustrating a sediment removal concept for the Chokepoint Reach.

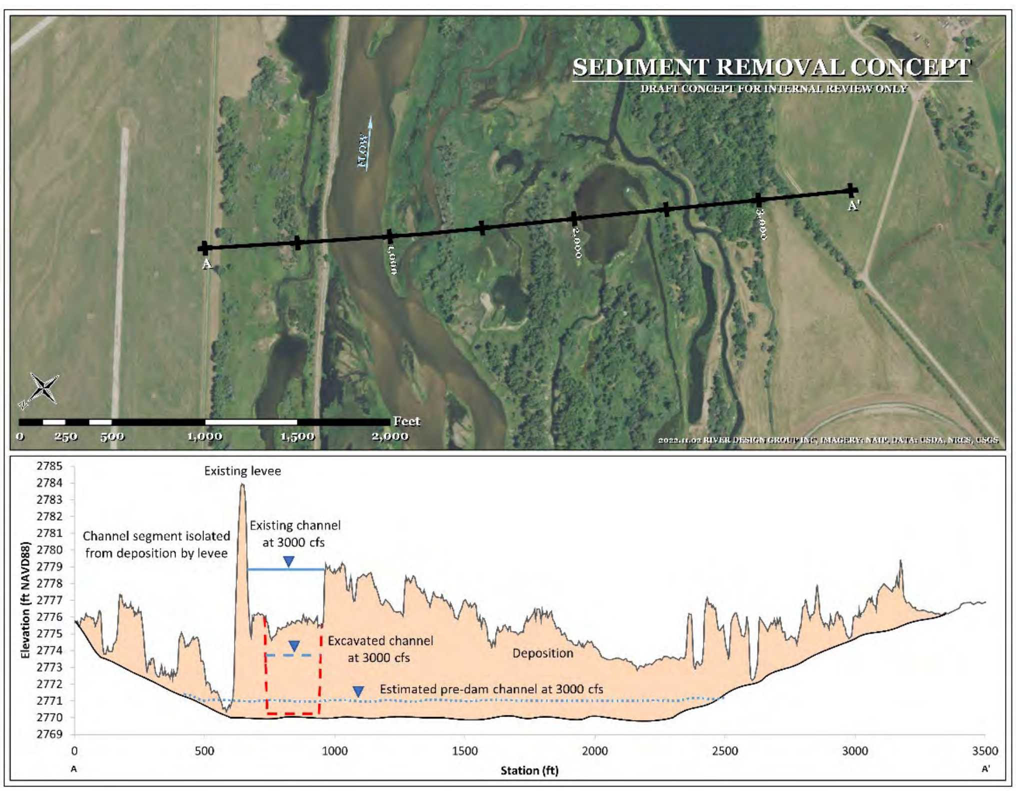

Figure 5-2. Cross section exhibit illustrating a sediment removal concept for the Chokepoint Reach. Cross section location noted on plan and profile exhibit.

5.1.2 Sediment Removal Feasibility Considerations

Feasibility considerations for the sediment removal concept include:

- Modifications to TCCDD and irrigation/hydropower operations;
- Extent of channel erosion in response to dredging and river flows;
- Impacts of channel erosion on private property and infrastructure;
- Impacts of sediment delivery to downstream reaches;
- Sustainability of dredged channel;
- Ability to manage flows from Kingsley Dam to sustain channel capacity;
- Vegetation re-establishment at lower elevations;
- Permitting, outreach and coordination with stakeholders; and
- Cost.

5.1.3 Sediment Removal Data Gaps

Many of the feasibility questions related to sediment removal could be addressed with a sediment transport model. The model would be utilized to evaluate morpho-dynamic change in the Chokepoint Reach in response to dredging and changes in TCCDD operations. Preliminary questions to be addressed by the model include:

- How much dredging is required to allow the river to do the remaining work (i.e., amount of active versus passive sediment removal)?
- What magnitude and duration of flows are needed to move the desired amount of sediment?
- How much lateral erosion could occur in response to dredging?
- Which areas could be affected by erosion?
- How much flow and sediment can bypass the TCCDD via the existing spillway and radial gates?
- Where does the sediment go that bypasses the TCCDD?

Also, there is potential to address sediment removal feasibility with experimental flow releases from the TCCDD. Much like the previous flow test conducted to evaluate the effectiveness of flood mitigation measures, another flow test could be conducted to determine how much flow and sediment can be evacuated passively from the Chokepoint Reach by opening the TCCDD gates at a prescribed flow rate.

5.2 Canal Modifications

Canal modifications would include consolidation of CNPPID diversions and construction of canal connections to allow for more flow and sediment to bypass the TCCDD. While many potential canal modifications could be considered, this concept presents a four-mile canal connection between the NPPD canal and TCCDD canal. This concept would eliminate NPPD return flows to the South Platte River and convey flow directly to the TCCDD canal, thus reducing TCCDD diversion needs. An exhibit for the conceptual canal connection is provided in Figure 5-3.

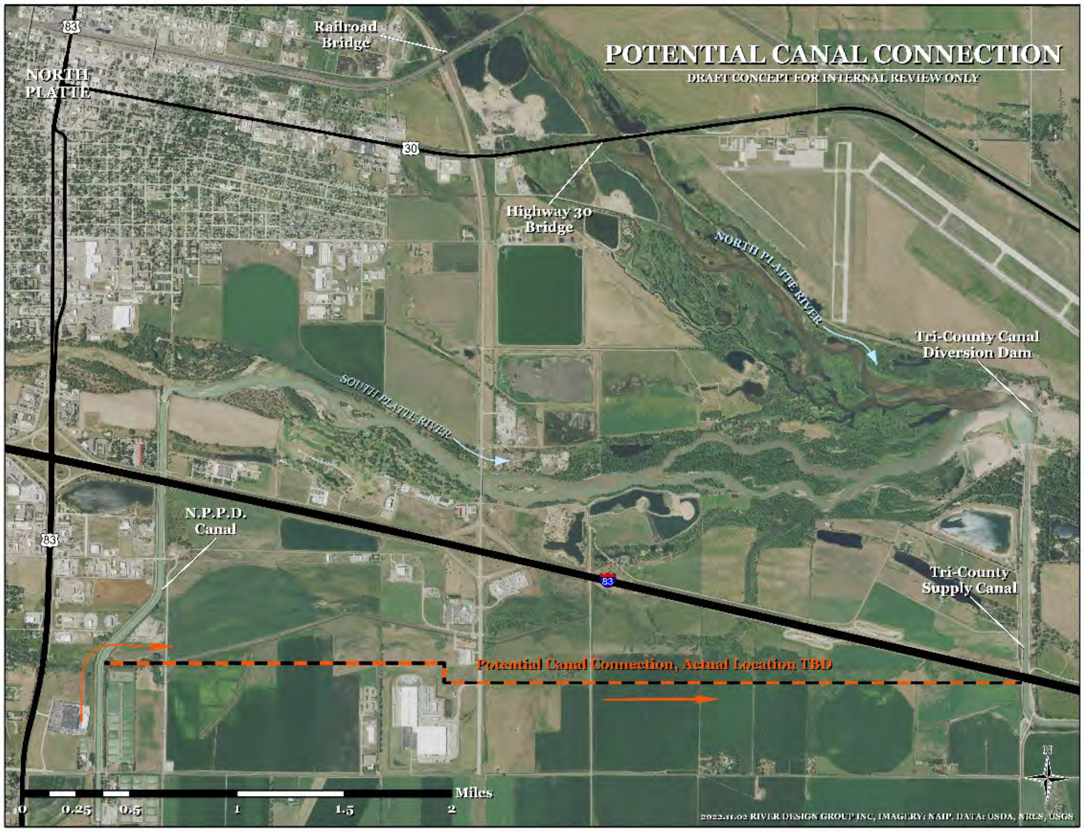

Figure 5-3. Exhibit illustrating a potential canal connection concept between the NPPD canal and TCCDD canal.

5.2.1 Canal Modification Benefits

Pros and cons for the canal modification concept are presented as benefits and feasibility considerations. Benefits are similar to those listed for the sediment removal concept. Listed benefits are contingent upon modifying operations at the TCCDD to allow sediment to evacuate and pass through the Chokepoint Reach. Concept benefits include:

- Reduces or eliminates the need for the TCCDD;
- Dam modification could allow for passive sediment evacuation;
- Reduced dredging operations at TCCDD;
- Primary cause of sedimentation addressed by restoring equilibrium channel slope to the reach;
- Increase in channel capacity and reduced flood risk;
- Lower water table limits vegetation establishment;
- Continued channel erosion removes existing vegetation;
- Sediment delivery to downstream reaches; and
- Formation of new sand bars creates habitat for focal species.

5.2.2 Canal Modification Feasibility Considerations

Feasibility considerations for the canal modification concept include:

- Land acquisition for new canal;
- Modifications to irrigation/hydropower operations;
- Instream flow requirements and water rights for the lower South Platte River;
- Ecological, hydrologic and geomorphic impacts to the lower South Platte River;
- Extent of channel erosion in response to passive sediment removal;
- Impacts of channel erosion on private property and infrastructure;
- Impacts of sediment delivery to downstream reaches;
- Sustainability of new channel;
- Permitting, outreach and coordination with stakeholders; and
- Cost.

5.2.3 FERC Relicensing

There are numerous operational and regulatory issues to address with potential canal modifications. Perhaps the best opportunity to propose changes to CNPPID operations is during the FERC relicensing process. The current license was issued in 1998 for a term of 40 years and the next renewal is scheduled for 2038 (FERC 1998). Feasibility assessments related to the recommended Chokepoint solutions would need to be completed during the timeframe prior to the FERC license renewal.

6 References

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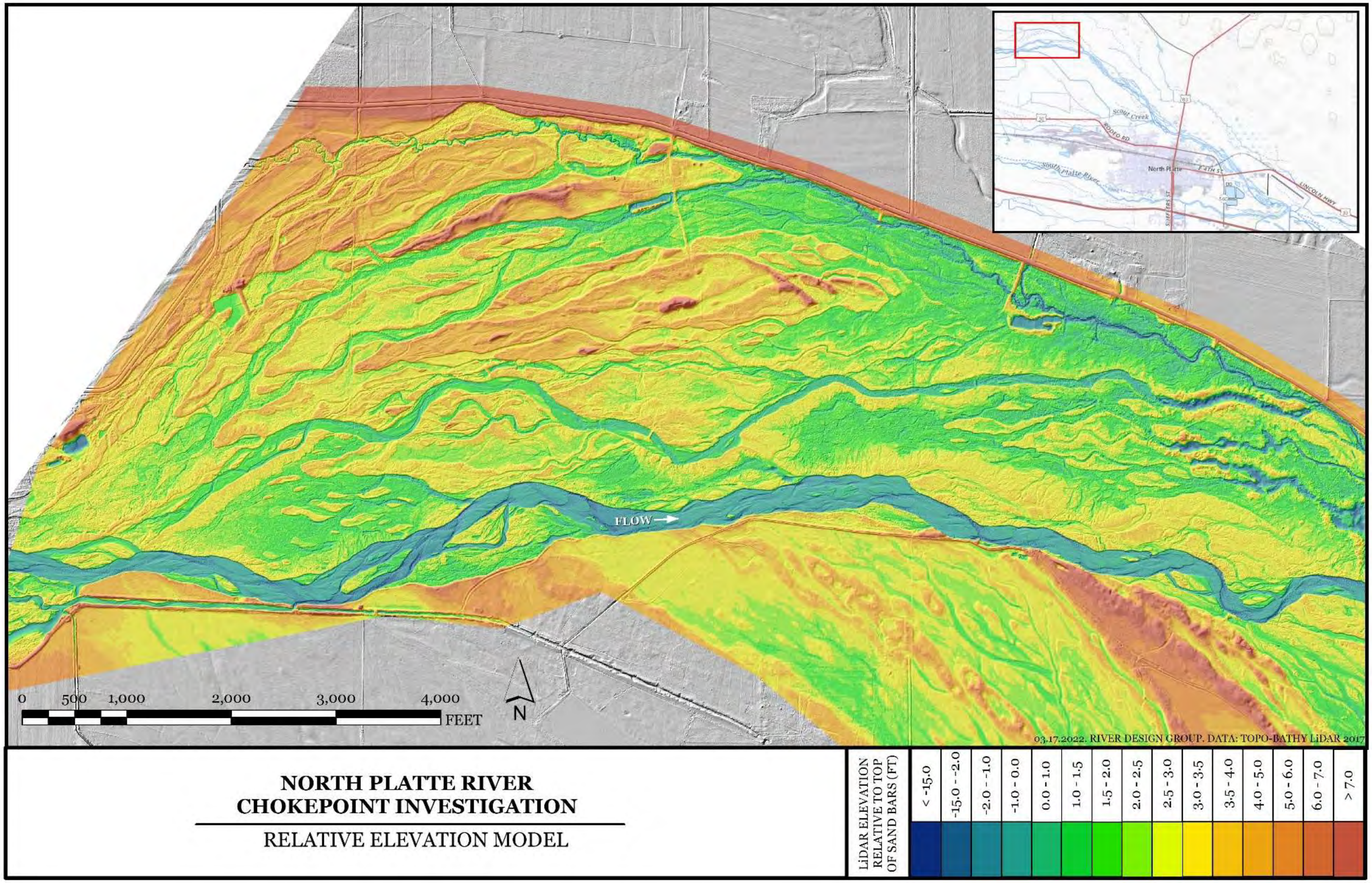
APPENDIX A

RELATIVE ELEVATION MAPS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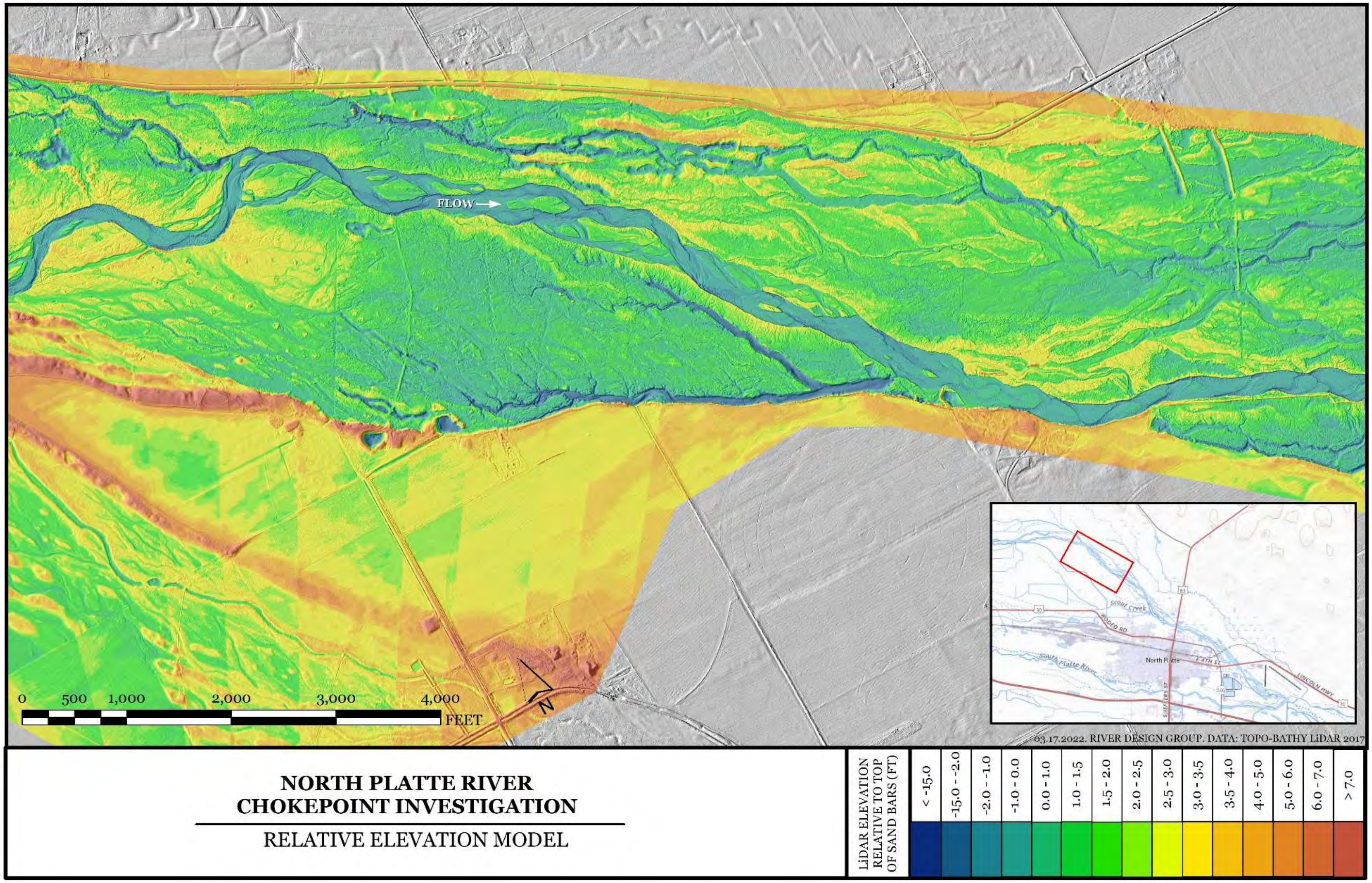
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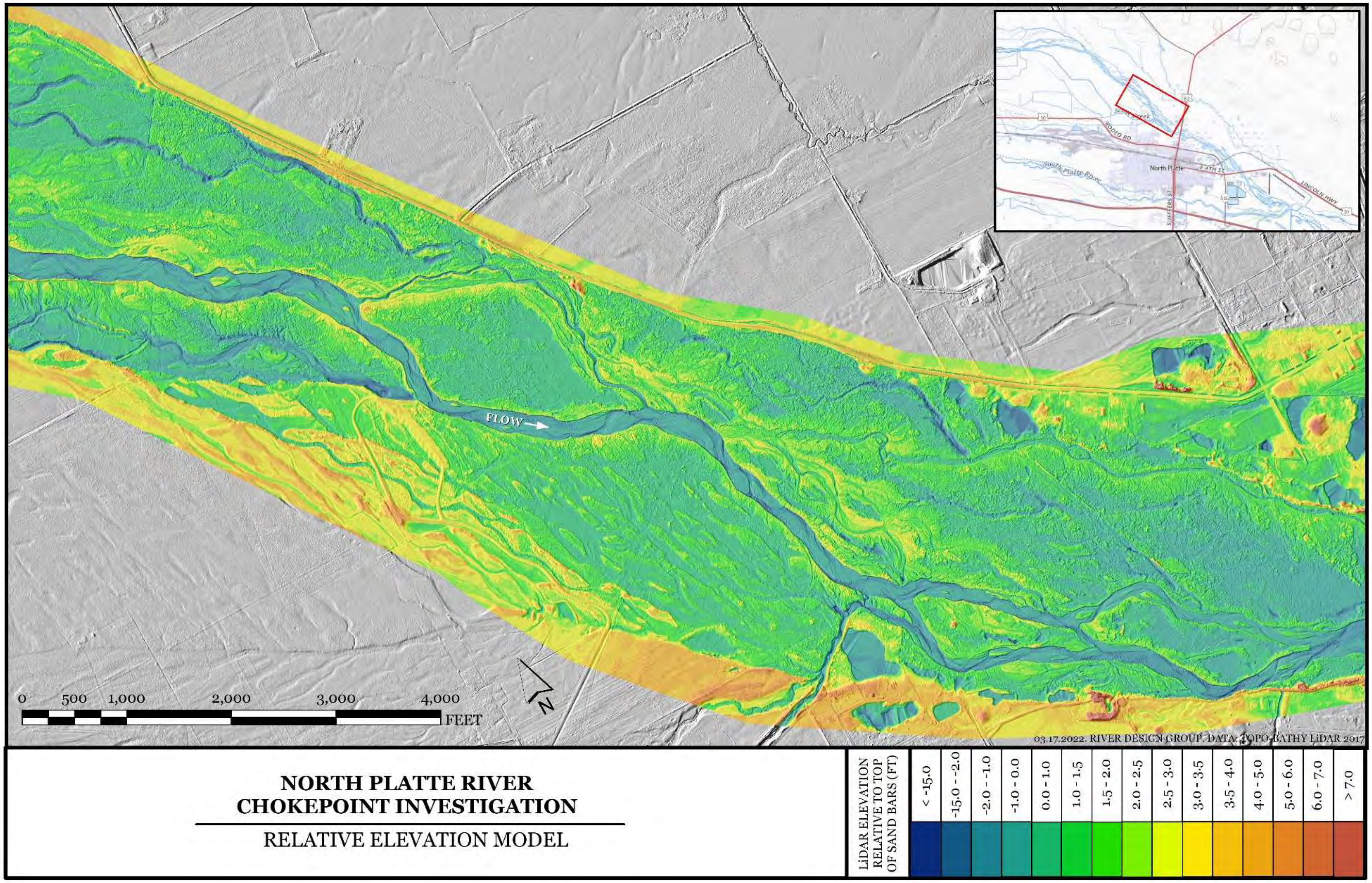
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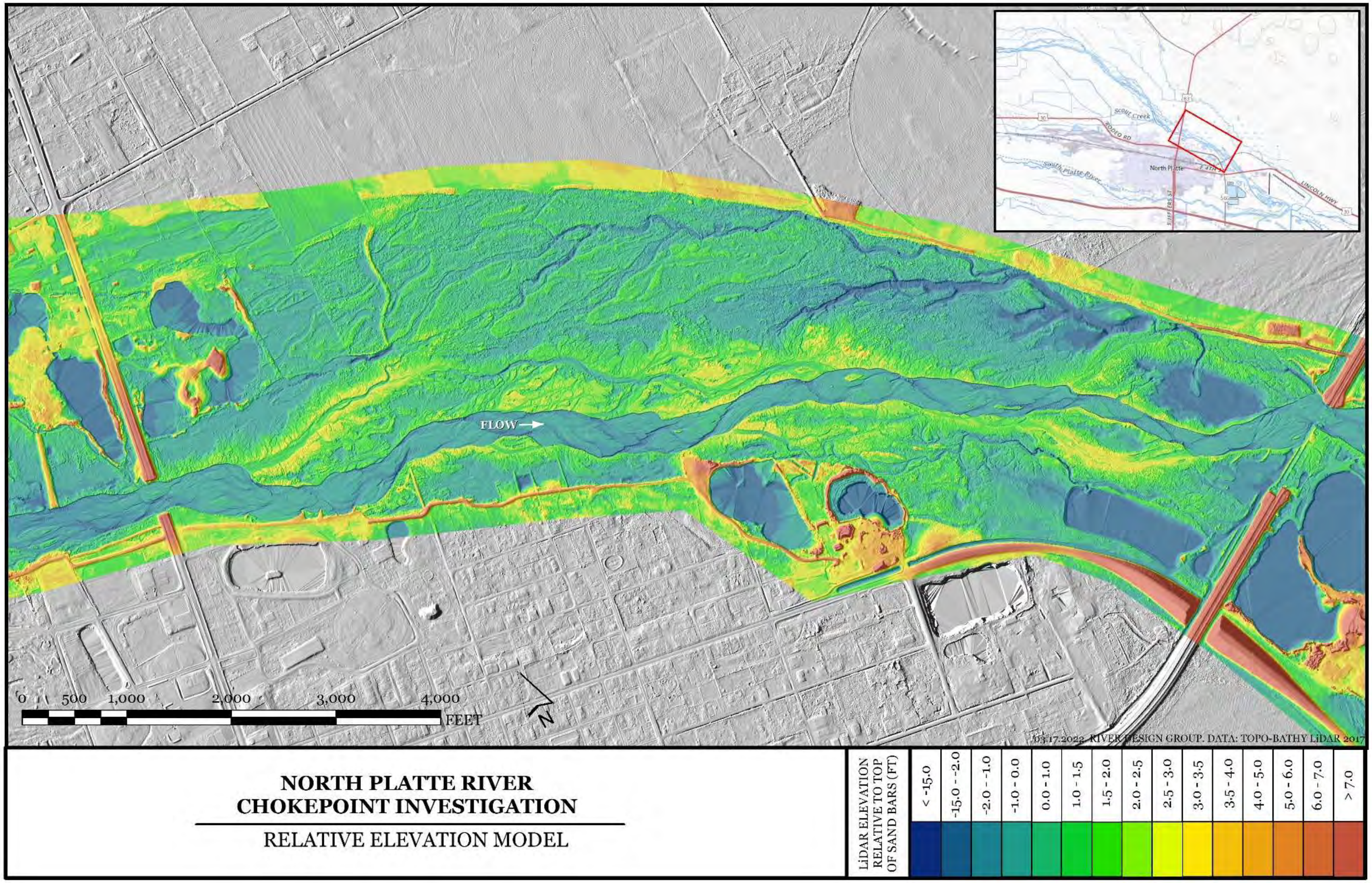
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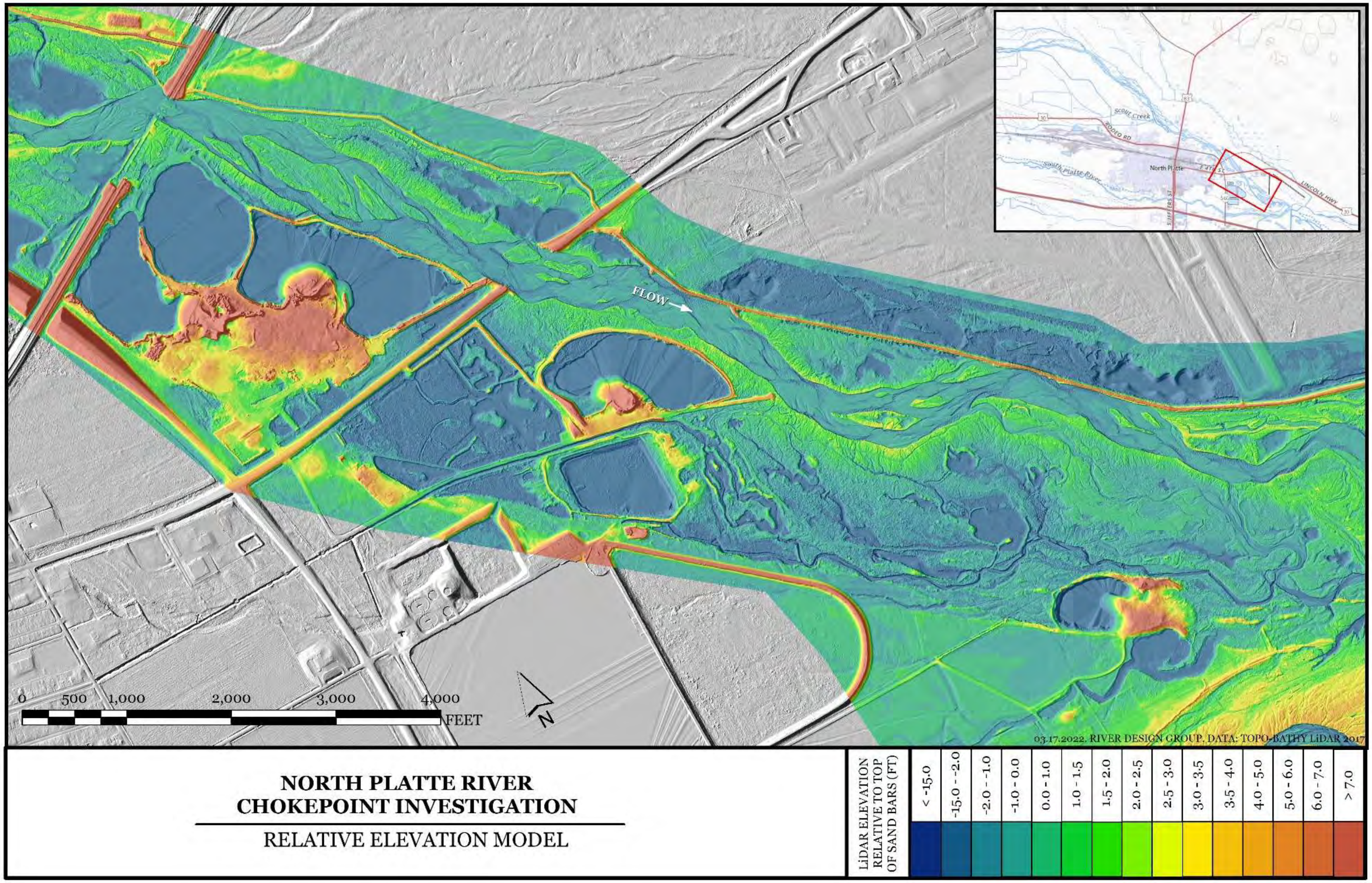
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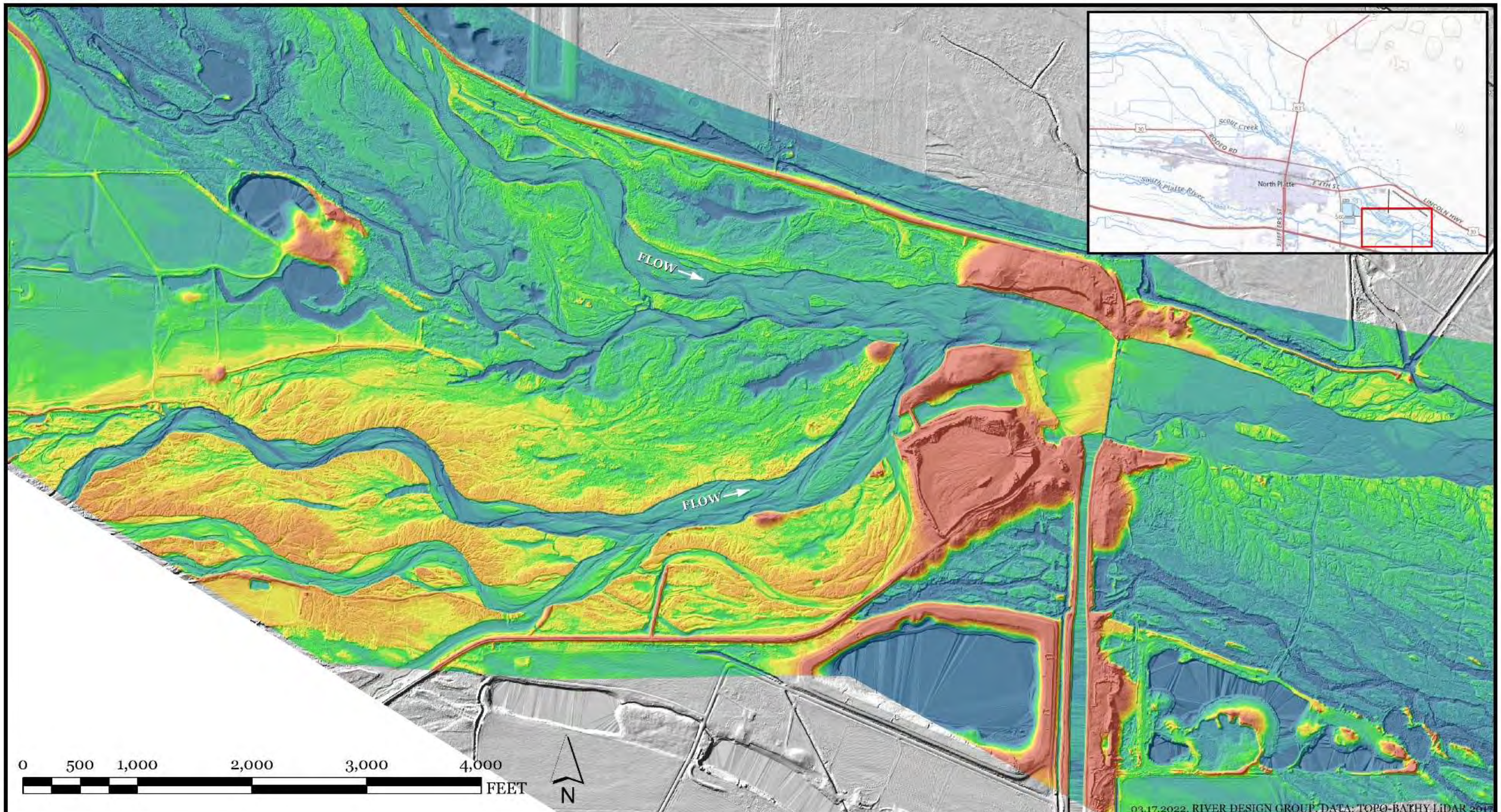

NORTH PLATTE RIVER
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RELATIVE ELEVATION MODEL

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APPENDIX B

HYDROLOGIC ANALYSIS

AND HYDRAULIC MODELING DATA

Table of Contents

B-1. Introduction

This appendix presents results of the hydrologic analysis and hydraulic modeling completed for the North Platte Chokepoint Investigation. This analysis supports the identification of root causes of sediment aggradation and flow restriction in the Chokepoint Reach of the North Platte River. The Chokepoint Reach begins at the confluence of the North and South Platte Rivers two miles east of the City of North Platte and ends approximately 5 miles to the west of North Platte (Figure B-2-1).

An initial review of available hydrologic data and hydraulic modeling data was completed to inform the need for additional information necessary to answer the questions posed in the RFP. Flow statistics and hydraulic models were developed for the Chokepoint Reach for use in analysis of existing conditions and preliminary evaluation of potential restoration actions. Hydrologic analysis and hydraulic modeling methods, results and limitations are described in the following sections.

B-2. Hydrology

This section presents the data, methods and results of hydrologic analysis of the Chokepoint Reach. Watershed characteristics are summarized based on available data and prior studies. Contemporary hydrology was investigated using analysis of available flow data. River stage trends are reported for select locations to inform questions regarding loss of channel capacity. Climate change trends and indicators are summarized from available literature to inform the potential for future flooding.

B-2.1 Watershed

The North Platte River begins near Walden, Colorado and flows north to Casper, Wyoming before turning southeast and flowing to North Platte, Nebraska where it joins the South Platte River (Figure B-2-2). The North Platte River is impounded by six major dams. The downstream most dam is Kingsley Dam which impounds Lake McConaughy and is located about 50 miles upstream of the confluence of the North and South Platte Rivers. North Platte River watershed elevations range from over 12,000 feet at the headwaters to 2,770 feet at the confluence.

The contributing drainage area for the Chokepoint Reach is approximately 26,300 square miles which is 85 percent of the North Platte River's total drainage area of 30,900 square miles at the North Platte at North Platte gage (USGS 2022). Contributing drainage area is defined as the area from which water drains to a single point along a stream. Total drainage area includes noncontributing drainage areas, such as sinks and potholes. The contributing drainage area between Kingsley Dam and the City of North Platte is approximately 326 square miles (Figure B-2-3). Contributing drainage area of tributaries to the North Platte River in this reach are limited by closed basins, highly permeable soils and irrigation withdrawals. Birdwood Creek is the largest tributary to the Lower North Platte Subbasin with a contributing drainage area of approximately 80 square miles.

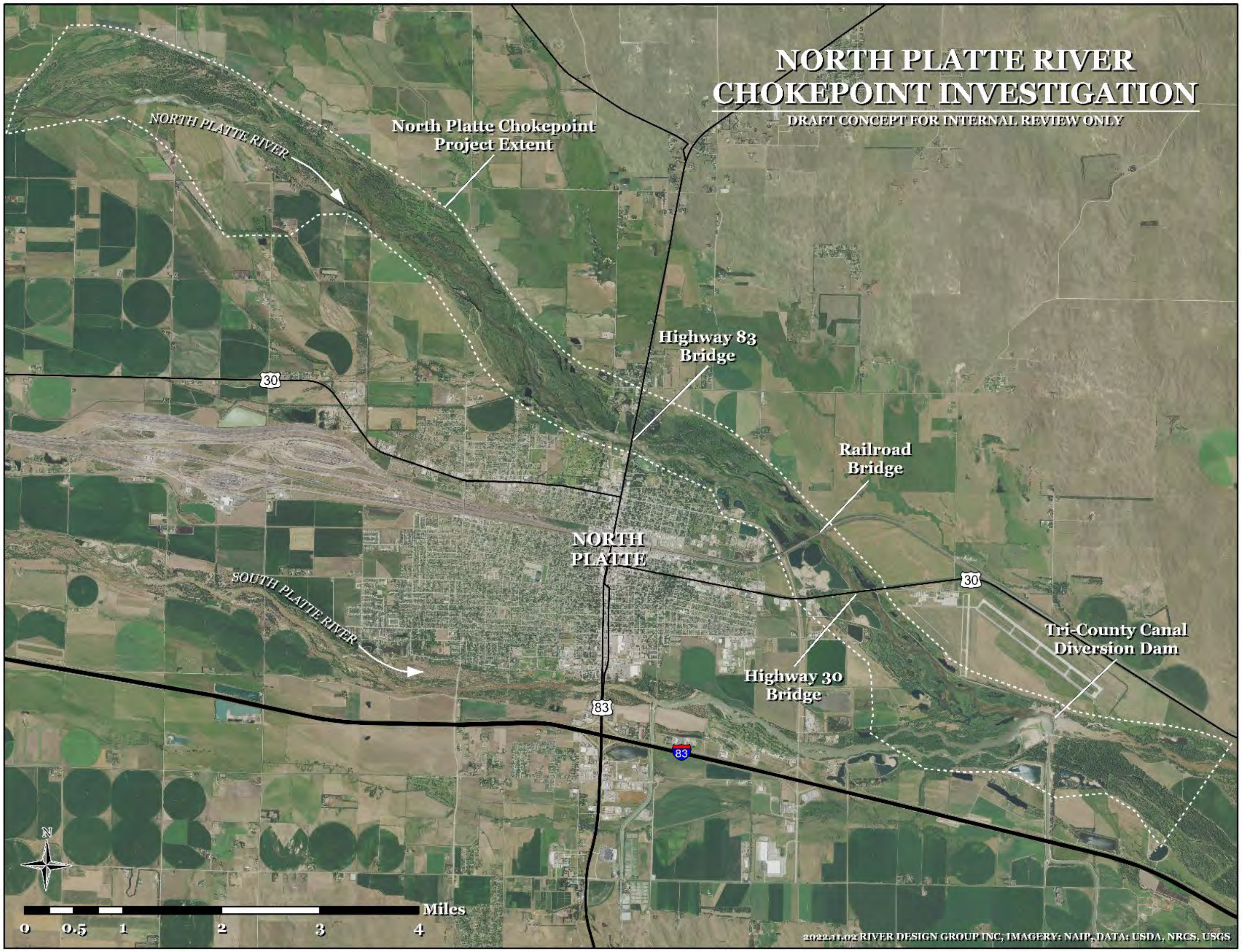


Figure B-2-1. North Platte River Chokepoint Reach map.

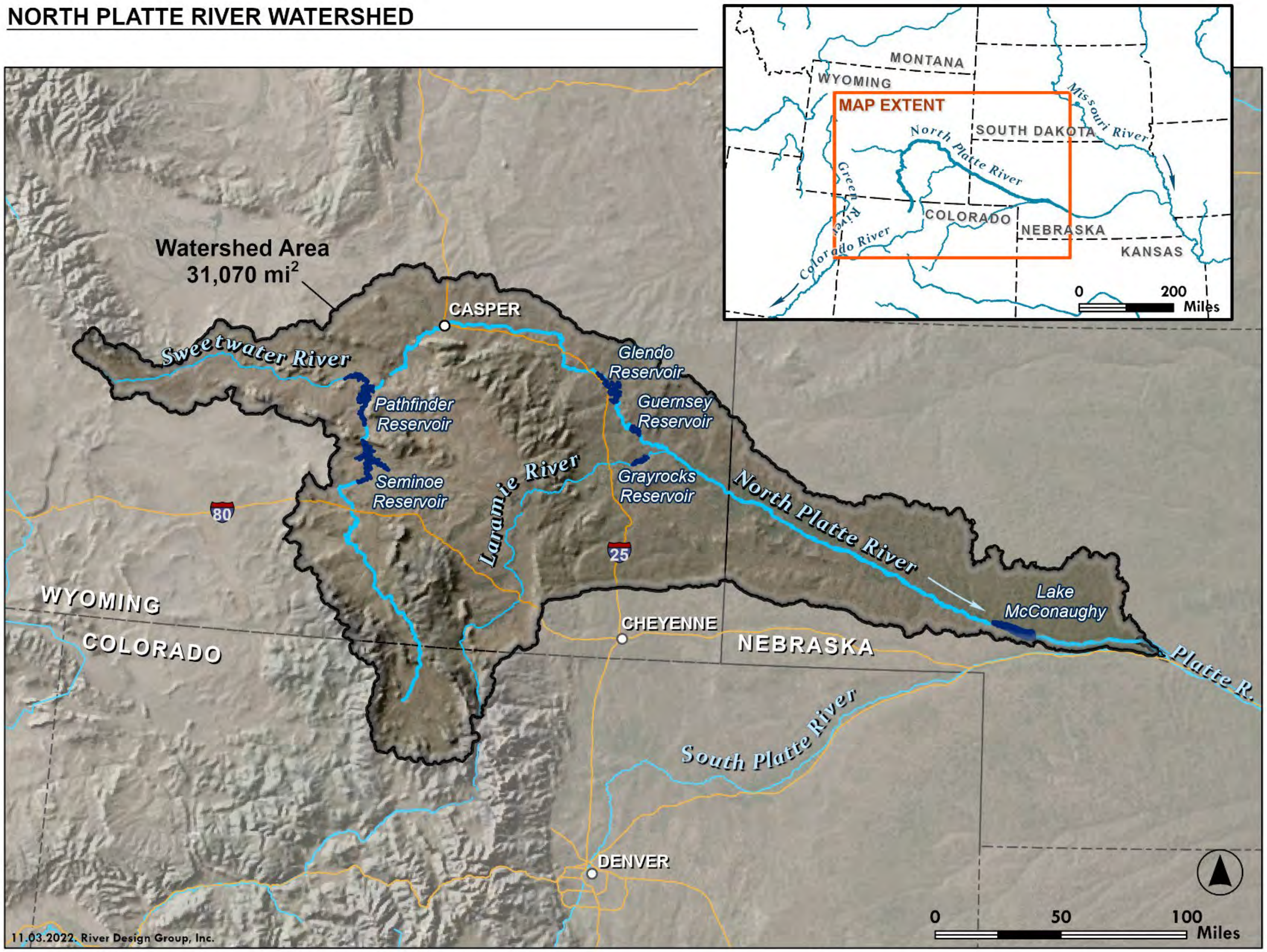


Figure B-2-2. North Platte River watershed map.

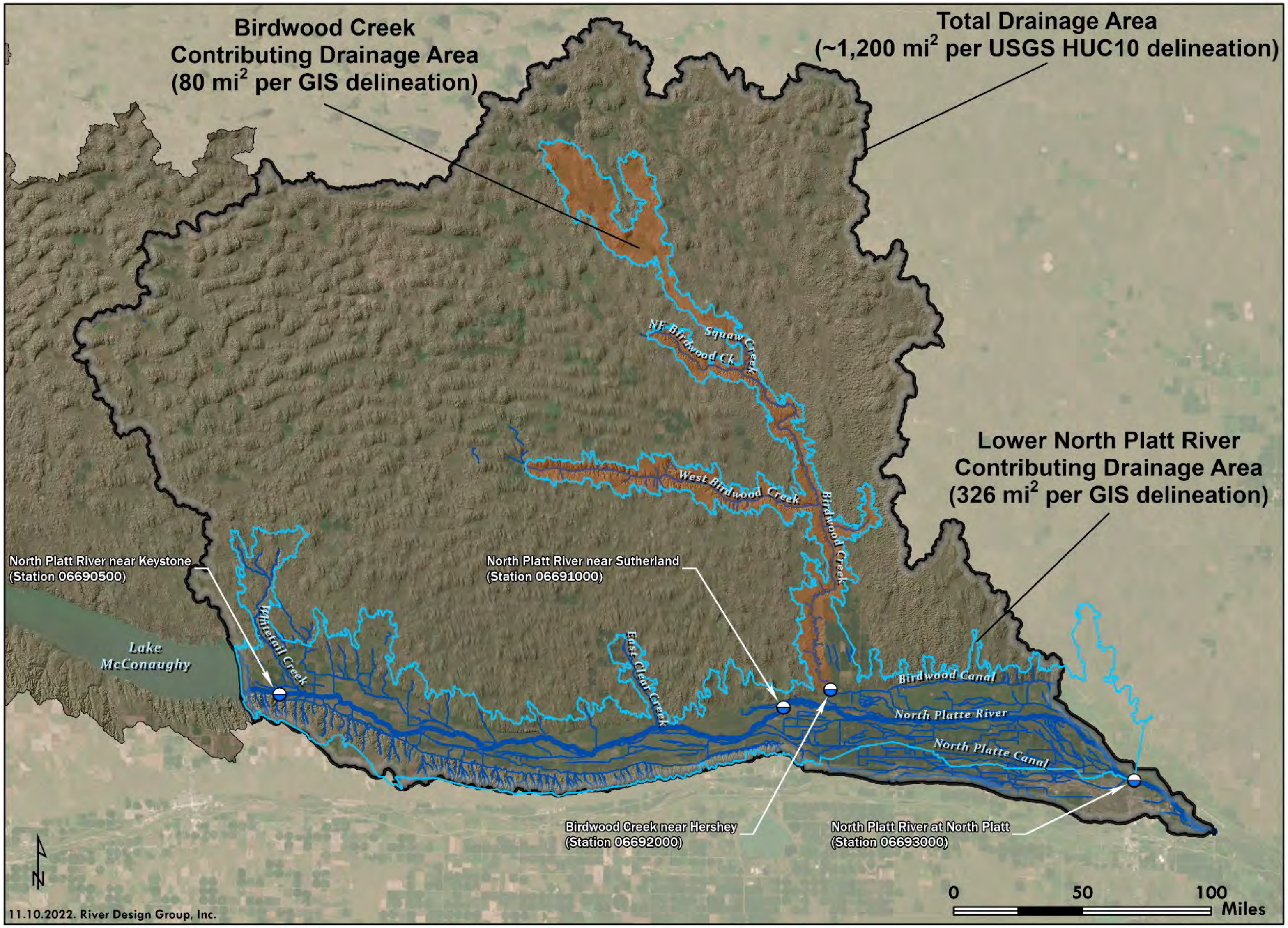


Figure B-2-3. Lower North Platte River contributing drainage area map.

B-2.2 Climate

Monthly average precipitation and air temperature for the Lower North Platte sub-basin that extends from the upstream end of Lake McConaughy to the City of North Platte are plotted in Figure B-2-4 (Stroud Water Research Center. 2023). Monthly average air temperatures range from 25 degrees Fahrenheit (F) in January to 74 F in July. Monthly average precipitation ranges from 0.4 inches in December and January to 3.3 inches in June.

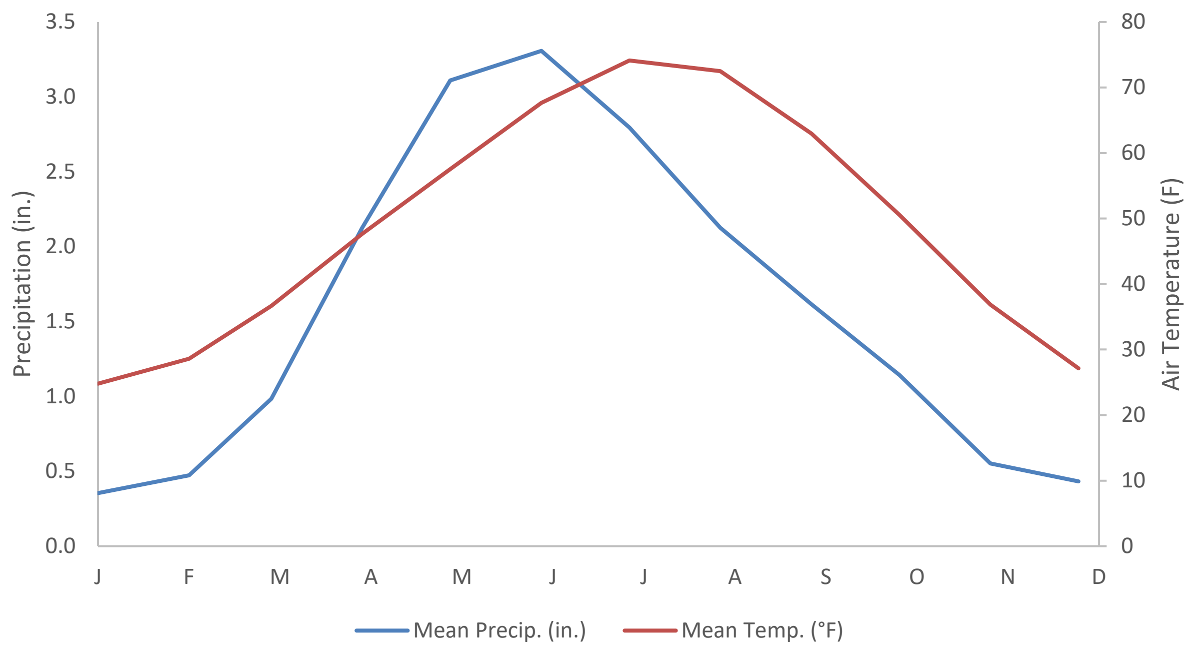


Figure B-2-4. Chart of mean monthly precipitation and air temperature for the Lower North Platte River.

B-2.3 Streamflow Data

Flows have been measured on the North Platte River for more than 128 years under a variety of State and Federal programs. The programs were sporadic from 1894 to 1931 and have been nearly continuous since 1931. Flow data are available from USGS for the period from 1895 through 1994 (USGS 2022). Flow data are available through the Nebraska Department of Natural Resources (NDNR) for the period from 1994 through present (NDNR 2022). Four streamflow gaging stations have operated for various periods in the Chokepoint Reach (Table B-2-1).

Hydrographs showing the time periods for which data are available are presented for the North Platte River at Keystone, Sutherland and North Platte as well as for Birdwood Creek near Hershey in Figure B-2-5. Total drainage area and contributing drainage area reported by USGS for each gage are tabulated in Table B-2-1. The North Platte River at North Platte has the longest period of record of any gage in the basin and clearly shows long-term trends in flow through the Chokepoint Reach. Data for the North Platte River at Keystone and Sutherland, and Birdwood Creek are limited prior to the early to mid-1990’s with some data generally available for 1917 and the early 1930’s.

Table B-2-1. Summary of streamflow-gaging station characteristics.

USGS / NDNR Station #	Station Name	Period of Record		Total Drainage Area	Contributing Drainage Area	Contributing Area as % Station Drainage Area	Contributing Area as % Contributing Area at North Platte (#06693000)
		Range	Yrs	(mi²)	(mi²)		
06690500	North Platte River near Keystone	1917 - 2022	82	29,300	25,800	88%	98%
06691000	North Platte River near Sutherland	1908 - 2022	91	29,800	26,120	88%	99%
06692000	Birdwood Creek near Hershey	1932 - 2022	91	940	80	9%	0.3%
06693000	North Platte River at North Platte	1895 - 2022	128	30,900	26,300	85%	100%

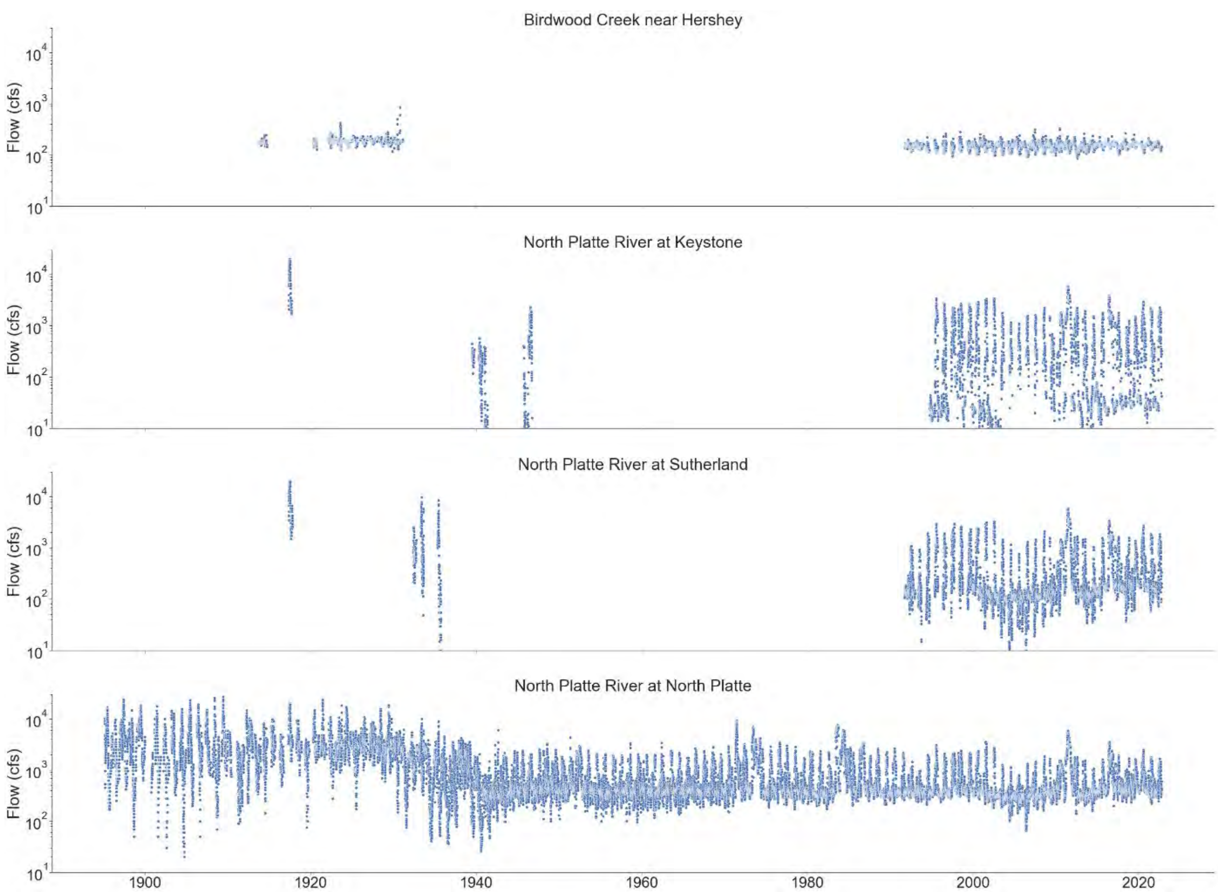


Figure B-2-5. Hydrographs of mean daily flow for the Chokepoint Reach gages.

B-2.4 Mean Daily Flow

The primary station used in this analysis, North Platte River at North Platte (#06693000), has been in operation since 1895. The station was operated by USGS through 1994 and then by NDNR (Figure B-2-6). Recorded flows from USGS (2022) and NDNR (2022) overlap for the period from 1904 to 1905. These records were combined with USGS records taking precedence. Flow records for the period of 1895 through 1922 were partial-duration, with flows typically missing during the winter months, except for 1900 which is missing data from January through September. Flows for missing periods were interpolated from available records to enable computation of total annual flow as described in the following section.

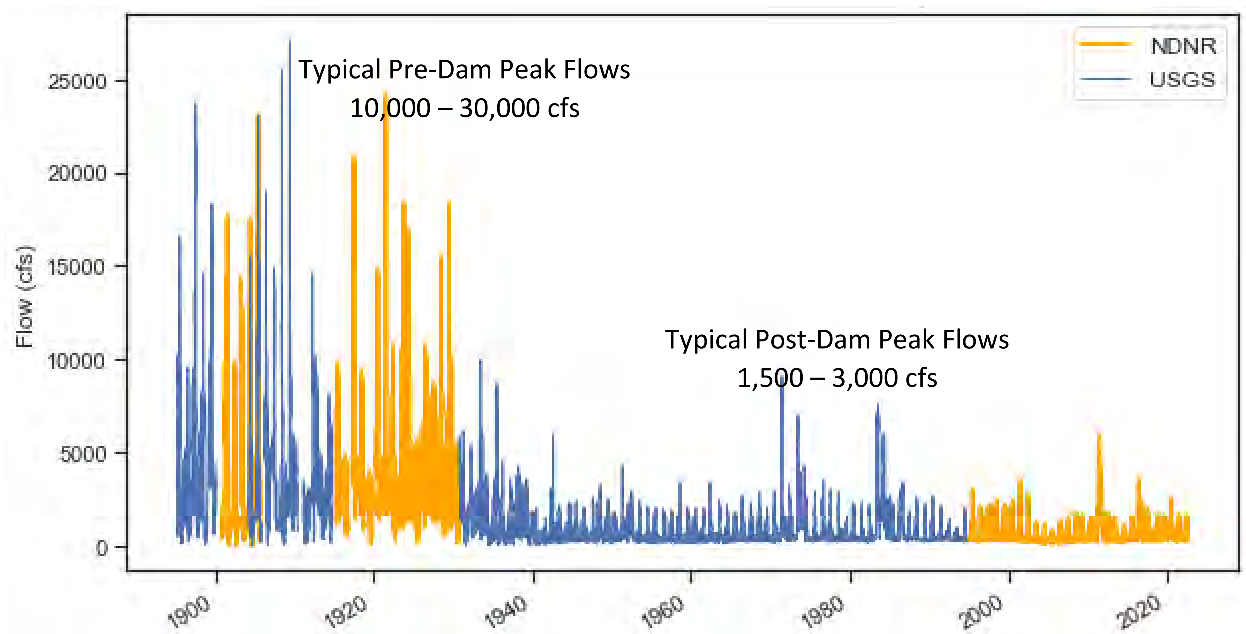


Figure B-2-6. Hydrograph of mean daily flow for the North Platte River at North Platte (#06693000).

B-2.5 Total Annual Flow

Total annual flow in million acre-feet (MAF) for the North Platte River at North Platte (#06693000) was computed for the period from 1901 to 2022 (Figure B-2-7). Partial-duration records were interpolated for the period from 1901 to 1922. Interpolated flow for these periods accounted for up to four percent of total annual flow, however, the actual volume of missing flow is unknown. For the period from 1901 through 1931, prior to significant development of water resources, total annual flow ranged from 1.0 MAF to 3.7 MAF with an average of 2.4 MAF. Between 1930 and 1940 the total annual flow declined to about 0.5 MAF. After 1940, total annual flow ranged from about 0.2 MAF to 1.8 MAF with an average of 0.5 MAF. The period of sustained low flow between 1940 and 1970 can be attributed to a combination of several factors including major droughts of the 1930's and the 1950's and water resources development including the construction of several large reservoirs, diversions, and groundwater pumping (Simons and Associates 2000).

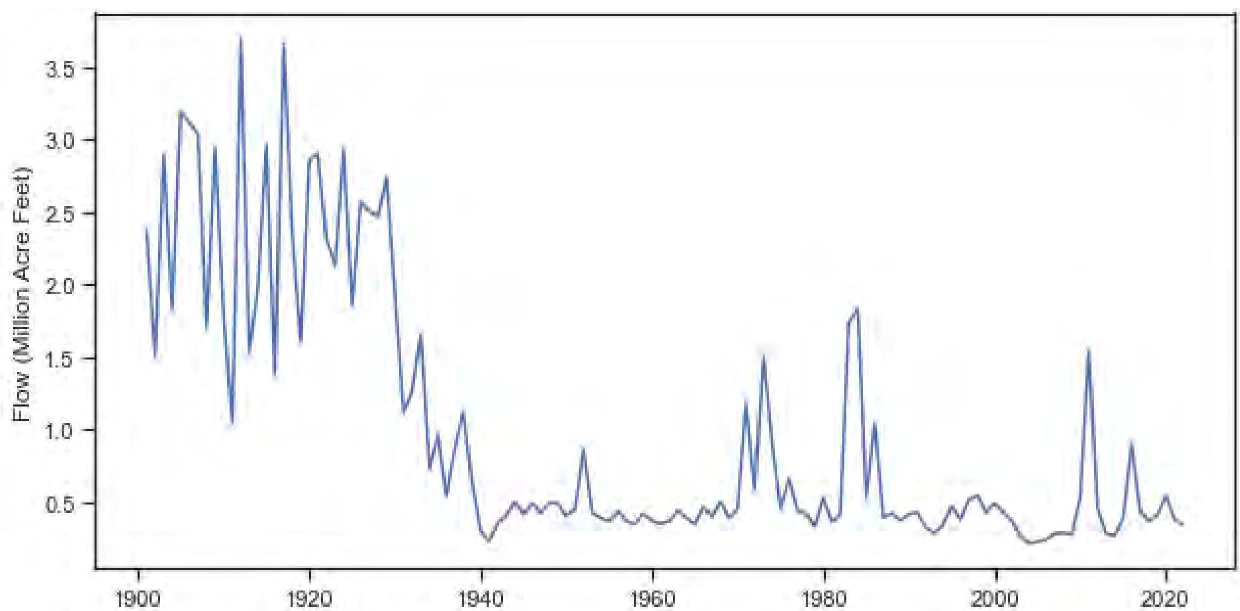


Figure B-2-7. Total annual flow hydrograph for North Platte River at North Platte (#06693000).

B-2.6 Seasonality of Daily Flow

Summary flow hydrographs for the North Platte River at North Platte for pre- and post-Kingsley Dam conditions are plotted by month of water year in Figure B-2-8. The water year begins in October and runs through September of the following year. Flows remain relatively low during the winter months. As spring approaches there is a general rise in flow culminating in peak flows that typically occur in late May or June. After the peak, flow recedes to the lowest levels of the year during the late summer.

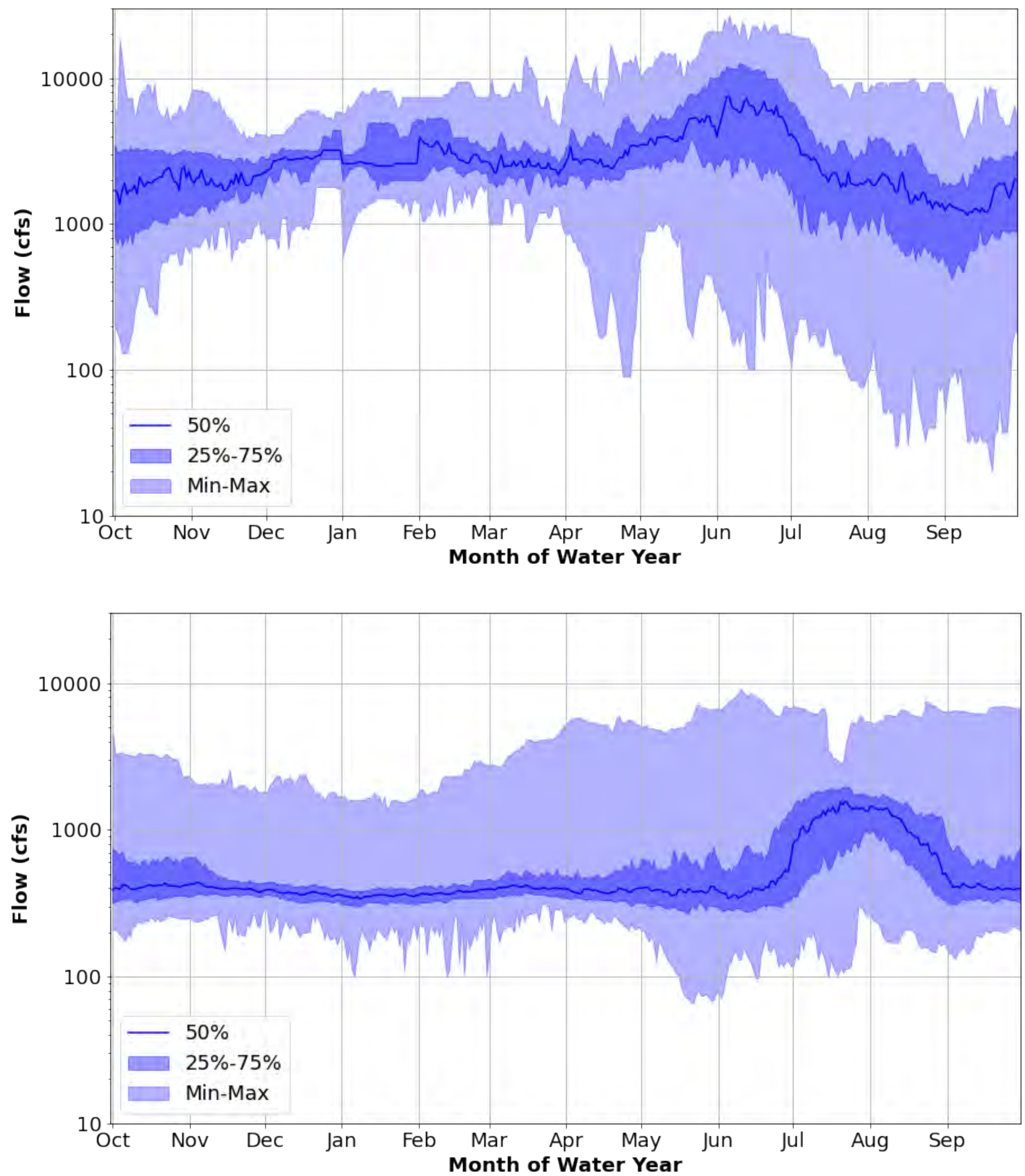
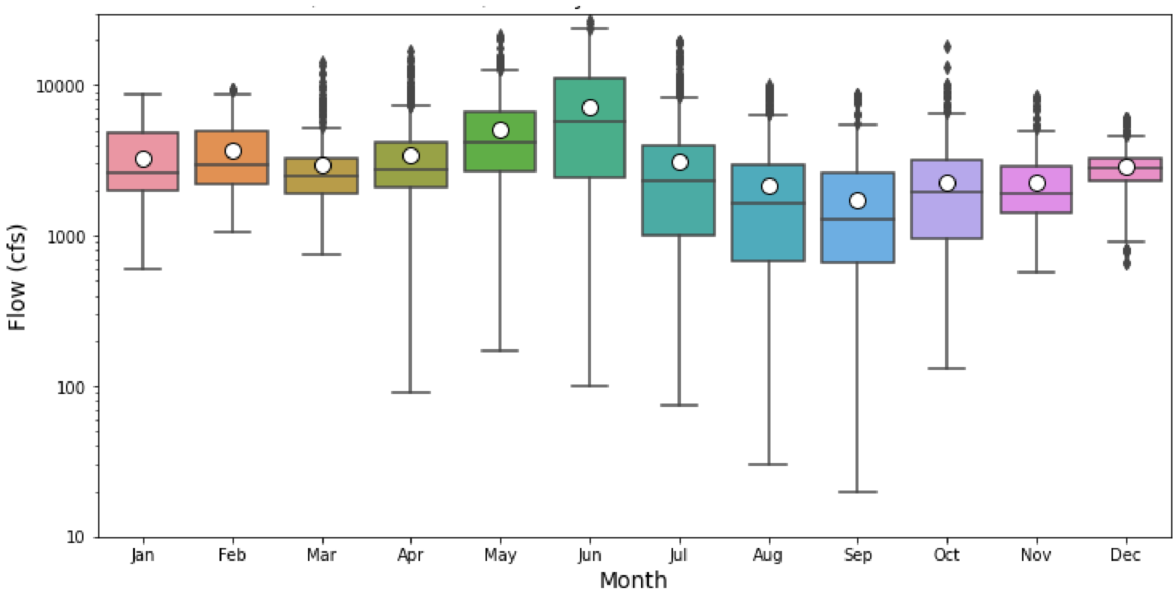


Figure B-2-8. Pre-dam (WY 1895 – 1931, top) and post-dam (WY 1941 – 2022, bottom) summary hydrographs for North Platte River at North Platte (#06693000).

B-2.7 Mean Monthly Flow

To better understand the flows likely to occur on a more frequent basis, mean monthly flow was computed using mean daily flow data adjusted for contributing drainage area at the project site. In addition, the minimum and maximum for each month were computed (Table B-2-2). Historically, high flows were most common in June. For the post-dam period from 1942 to 2022 the timing of high flows has shifted and the highest flows now occur in July (Figure B-2-9). Mean monthly flow has declined by 76%, on average, with a range of -46% to -88% (Table B-2-3).



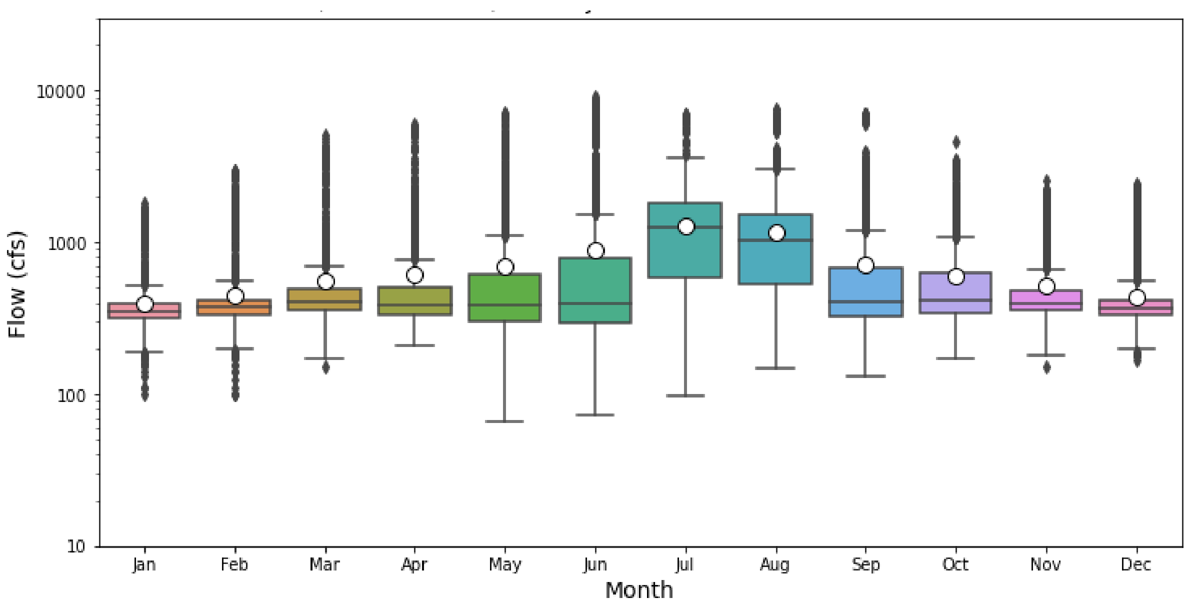


Figure B-2-9. Pre-dam (WY 1896 – 1931, top) and post-dam (WY 1942 – 2022, bottom) summary hydrographs for North Platte River at North Platte (#06693000).

Table B-2-2. Monthly flow statistics for the North Platte River.

Month	Flow (cfs)			
	Pre-dam		Post-dam	
	Average	Median	Average	Median
January	3,303	2,600	393	350
February	3,694	2,975	451	373
March	2,959	2,490	563	401
April	3,446	2,750	608	384
May	5,066	4,150	702	383
June	7,105	5,800	893	394
July	3,146	2,300	1,298	1,250
August	2,162	1,650	1,161	1,020
September	1,736	1,280	710	406
October	2,259	1,950	598	411
November	2,232	1,900	516	399
December	2,892	2,800	439	370

Table B-2-3. Change in monthly flow statistics for the North Platte River.

Month	Post-dam vs. Pre-dam			
	Δ Flow (cfs)		% Difference	
	Average	Median	Average	Median
January	-2,910	-2,250	-88%	-87%
February	-3,243	-2,602	-88%	-87%
March	-2,396	-2,089	-81%	-84%
April	-2,838	-2,366	-82%	-86%
May	-4,364	-3,767	-86%	-91%
June	-6,212	-5,406	-87%	-93%
July	-1,848	-1,050	-59%	-46%
August	-1,002	-630	-46%	-38%
September	-1,026	-874	-59%	-68%
October	-1,661	-1,539	-74%	-79%
November	-1,717	-1,501	-77%	-79%
December	-2,453	-2,430	-85%	-87%

B-2.8 Flow Duration

Low flow frequency statistics are useful to estimate the water available under extreme conditions as well as to evaluate the risk of channel dewatering. Flow duration statistics were calculated from mean daily flow data for the North Platte River at North Platte (#06693000). Annual flow duration statistics for the pre-dam and post-dam periods are compared in Figure B-2-10 and Table B-2-4.

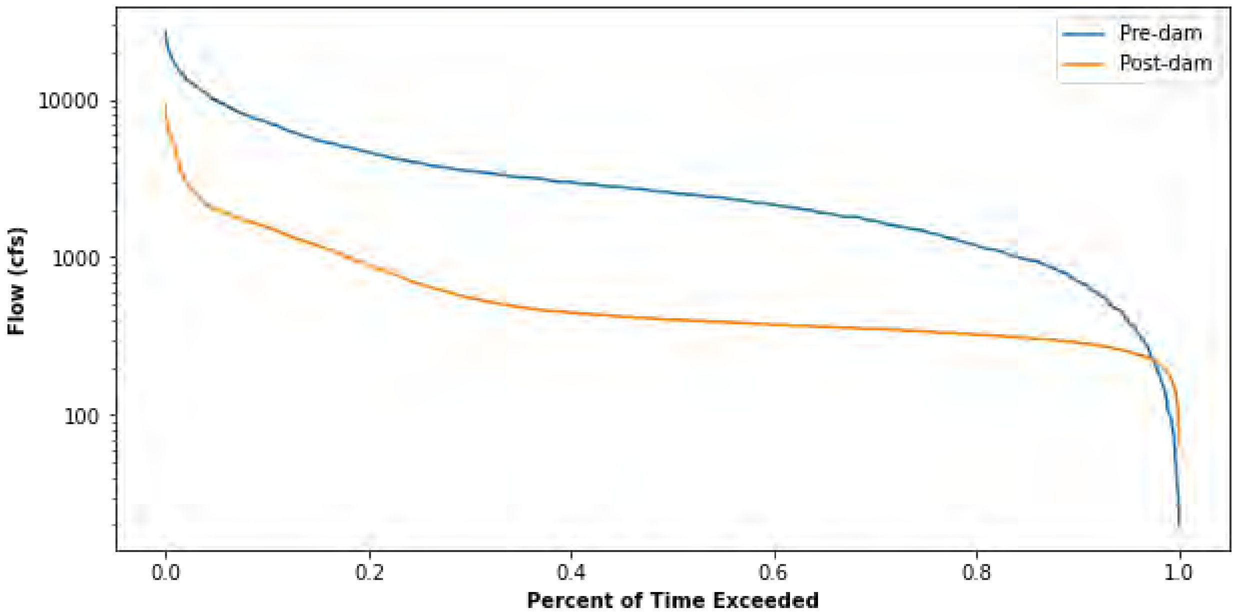


Figure B-2-10. Pre-dam (WY 1896 – 1931) and post-dam (WY 1942 – 2022) flow duration for North Platte River at North Platte (#06693000).

Table B-2-4. Annual flow duration statistics.

Percent of Time Exceeded	Flow (cfs)			Percent Diff.
	Pre-dam	Post-dam	Difference	
1%	102	180	79	77%
5%	395	251	-144	-37%
10%	699	287	-412	-59%
20%	1,190	322	-868	-73%
30%	1,691	350	-1,341	-79%
40%	2,150	374	-1,776	-83%
50%	2,550	401	-2,150	-84%
60%	2,991	444	-2,547	-85%
70%	3,511	551	-2,959	-84%
80%	4,618	893	-3,725	-81%
90%	7,167	1,544	-5,623	-78%
95%	9,865	2,002	-7,863	-80%
99%	16,559	4,558	-12,001	-72%

B-2.9 Annual Peak Flow

The magnitude of peak flows has declined since development of Lake McConaughy and other impoundments in the North Platte basin (Figure B-2-11). Simons and Associates (2000) summarizes the broad changes in peak flow for the North Platte River at North Platte as follows:

"… peak flows in the late 1800's and early 1900's often exceeded 20,000 cfs and reached almost 30,000 cfs on one occasion. Peak flows dropped to a lower level after the initial construction of mainstem reservoirs on the North Platte River averaging about 10,000 to 15,000 cfs with a maximum of about 24,000 cfs in the time period from about 1908 to 1930. After the completion of several additional reservoirs in the 1930's - 1940's time frame, the peak flow on the North Platte River was dramatically reduced, rarely exceeding 5,000 cfs after 1940."

Peak flow discharge-probability relationships were developed by FEMA for the 1978 FIS and republished without update for the 2009 FIS. Updated peak flow quantiles were developed by USACE (2013) using methods described below:

"Due to the complex nature of reservoir regulations and their impact on flow frequency for the North Platte River, hydrology cannot rely on straight forward 17b analysis. Instead, a basin modeling approach is necessary to determine unregulated flow frequency and to convert this into regulated flow frequency values. This effort was completed by Riverside Technology, inc. under contract with the USACE (Contract W9128F-13-T-0011). This effort expanded upon the previously existing National Weather Service (NWS) Missouri Basin River Forecast Center (MBRFC) modeling to develop this data. Key updates to the modeling include HEC-Reservoir Simulation for numerous reservoirs, updated reservoir operation rules based upon discussions with USBR and CNPPID, and incorporated the recent flood information…"

Peak flows developed by FEMA and USACE are compared in Table B-2-2 and Figure B-2-12. Peak flows developed by USACE in 2013 are 30 percent to 52 percent higher than those published by FEMA in 2009.

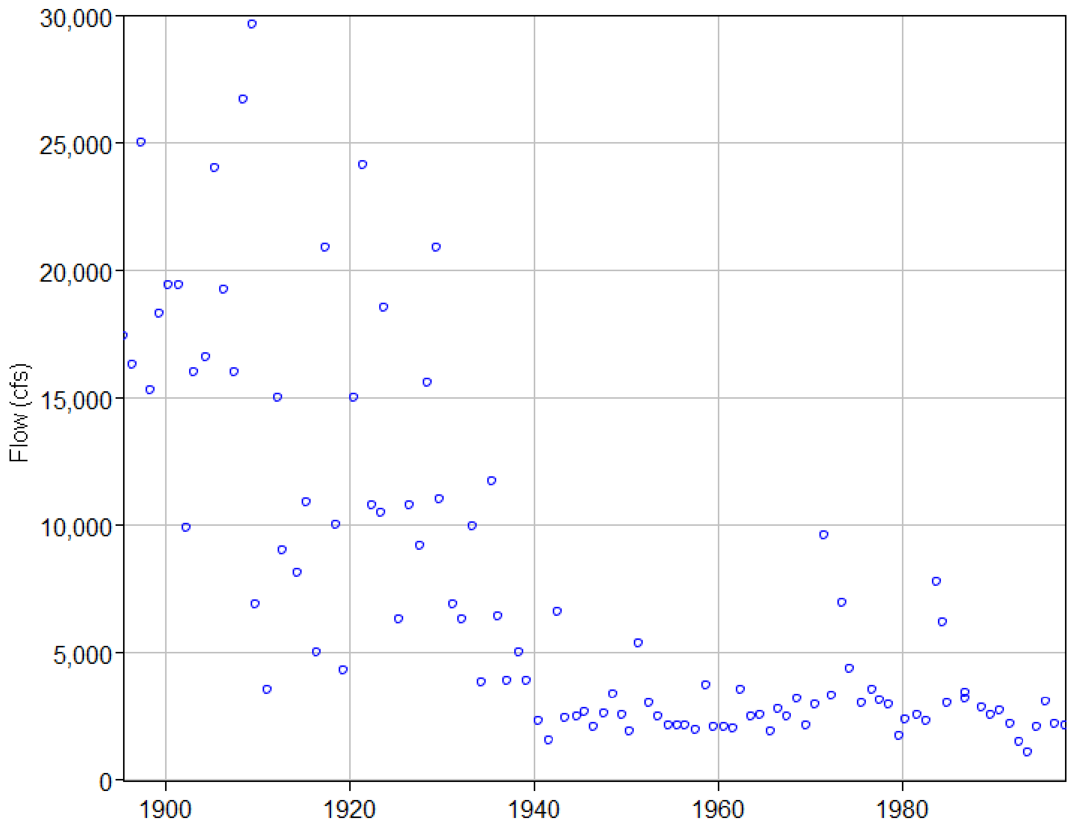


Figure B-2-11. USGS published peak flows for the North Platte River near North Platte (#06693000).

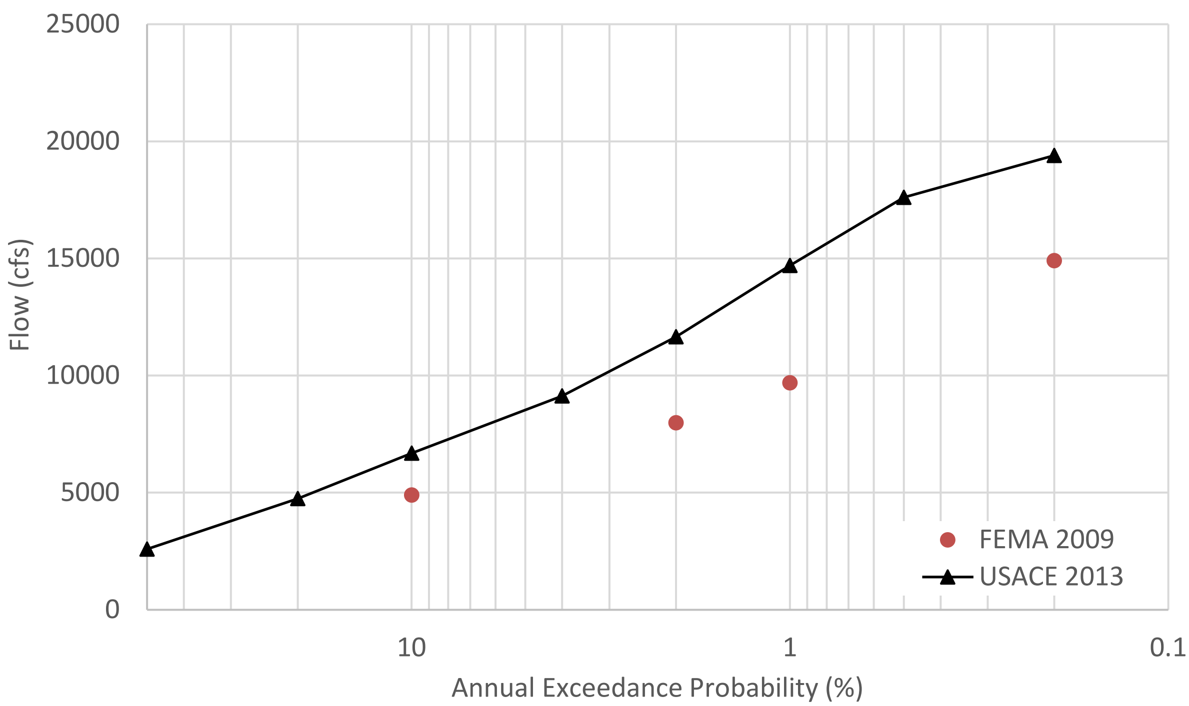


Figure B-2-12. Peak flow quantiles developed by FEMA (2009) and USACE (2013) for the North Platte River near North Platte (#06693000).

Table B-2-5. Comparison of flood frequency estimates for the North Platte River near North Platte.

Prob. (%)	Return Interval (yrs)	Peak Flow (cfs)			
		FEMA 2009	USACE 2013	Difference	Percent Difference
50	2		2,590	2,590	
20	5		4,740	4,740	
10	10	4,900	6,690	1,790	37%
4	25		9,130	9,130	
2	50	7,980	11,650	3,670	46%
1	**100**	**9,690**	**14,700**	**5,010**	**52%**
0.5	200		17,600	17,600	
0.2	500	14,900	19,400	4,500	30%

Flood frequency estimates are often correlated with geomorphic indicators such as bankfull channel forming flow, channel maintenance flow or the threshold of floodplain activation; however, because they are developed by fitting a Log Pearson III extreme event probability distribution to instantaneous peaks, they are more appropriate for ascertaining flood risk, and do not necessarily correlate well with hydraulic geometry below the 10-year recurrence interval.

B-2.10 Tributary Flows

Peak flow quantiles were calculated for Birdwood Creek using available gage data Figure B-2-13. Quantiles for Birdwood Creek were adjusted to account for the contributing drainage from all tributaries to the North Platte River between Kingsley Dam and the North Platte at North Platte gage (#092000) in order to estimate the probability of flows ranging from 1,000 cfs to 12,000 cfs occurring in the project reach without contributions from Kingsley Dam (Figure B-2-14 and Table B-2-6). Geographic information system analyses were used to calculate contributing drainage area for Birdwood Creek and for the ungagged area between Kingsley Dam and the North Platte at North Platte gage. Watershed boundaries were calculated using automated methods and a manual quality control review was conducted. Data were adjusted where deemed in error.

Contributing drainage area for Birdwood Creek and the North Platte at North Platte gage were used to compute an area adjustment factor for estimating tributary flows. Ungaged contributing tributary area was estimated at 246 square miles. Birdwood Creek contributing area was estimated at 80 square miles. The contributing drainage area ratio of 3.1 was applied to Birdwood Creek peak flows to estimate total flow for the ungagged contributing area. Based on the USGS period of record for Birdwood Creek (1932 – 1993) adjusted for tributary area, flows of 3,000 cfs have an annual exceedance probability of approximately 8% (return interval of approximately 12 years) with 5% confidence limits on the annual exceedance probability of 4% to 15% (return interval ranging from 7 to 24 years).

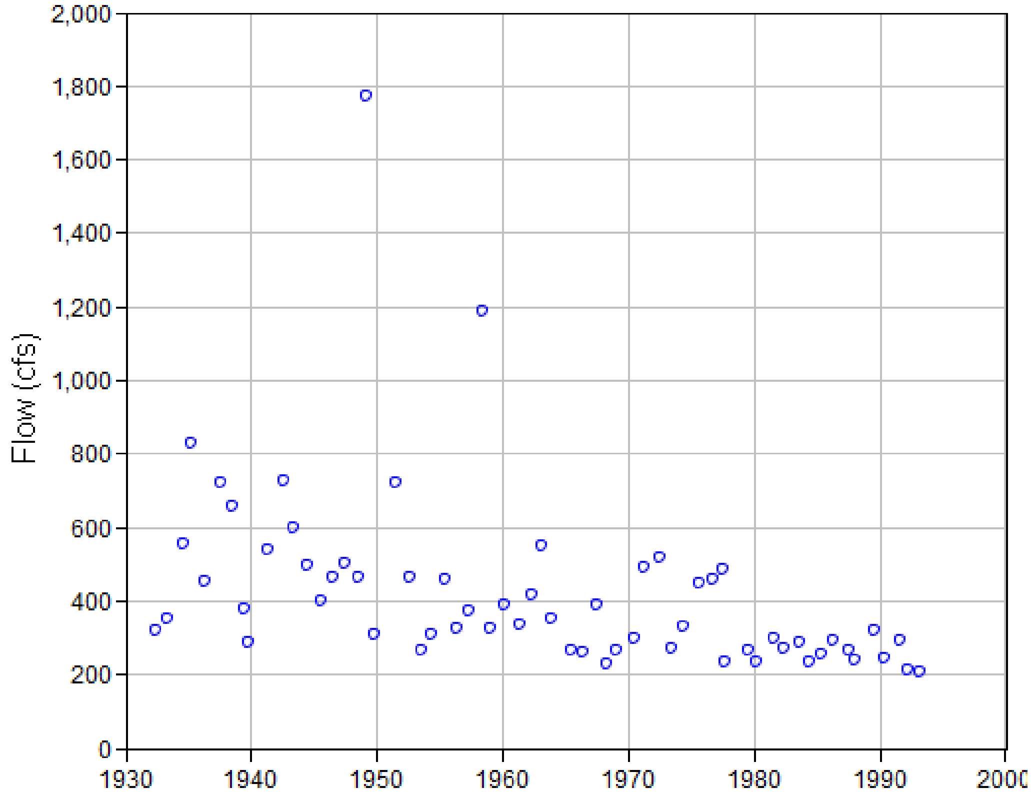


Figure B-2-13. Peak flows for Birdwood Creek (#06692000).

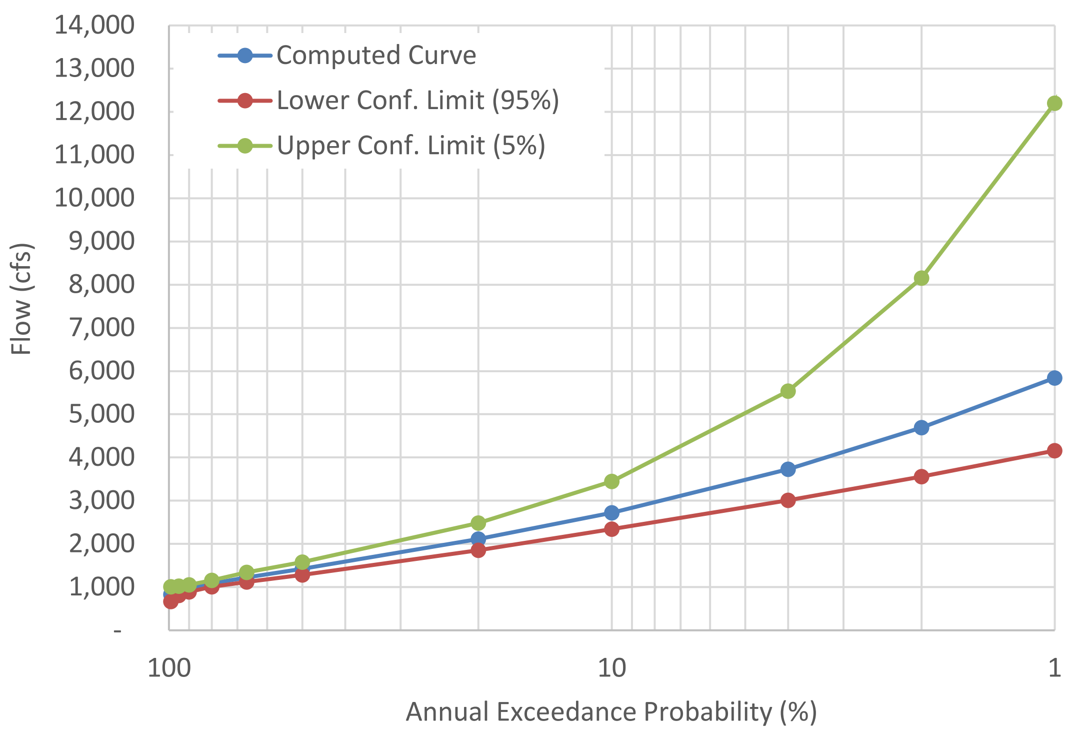


Figure B-2-14. Area-adjusted peak flows for lower North Platte River tributaries.

Table B-2-6. Area-adjusted peak flows for Lower North Platte River tributaries based on annual peak flows in Birdwood Creek from 1979 to 2022.

Annual Exceedance Probability (%)	Return Interval (yrs)	Birdwood Creek (cfs)	Computed Curve	Upper Conf. Limit (5%)	Lower Conf. Limit (95%)
0.2	500	2,400	7,180	24,530	4,350
0.5	200	1,800	5,440	13,900	3,620
1	100	1,400	4,380	9,160	3,120
2	50	1,200	3,520	6,110	2,670
4	25	920	2,800	4,160	2,260
10	10	670	2,040	2,590	1,750
20	5	520	1,580	1,860	1,390
50	2	350	1,070	1,190	960
67	1.50	300	910	1,000	840
80	1.25	270	810	870	750
90	1.11	240	730	790	670
95	1.05	220	680	760	610
99	1.01	200	620	760	510

Rainfall data recorded at the North Platte airport was correlated with flow data from the gage on Birdwood Creek to determine how much rainfall needs to be observed for flows of 3,000 cfs to 12,000 cfs to occur (B-2-15). The correlation was poor, likely due to spatial variations in precipitation and basin characteristics.

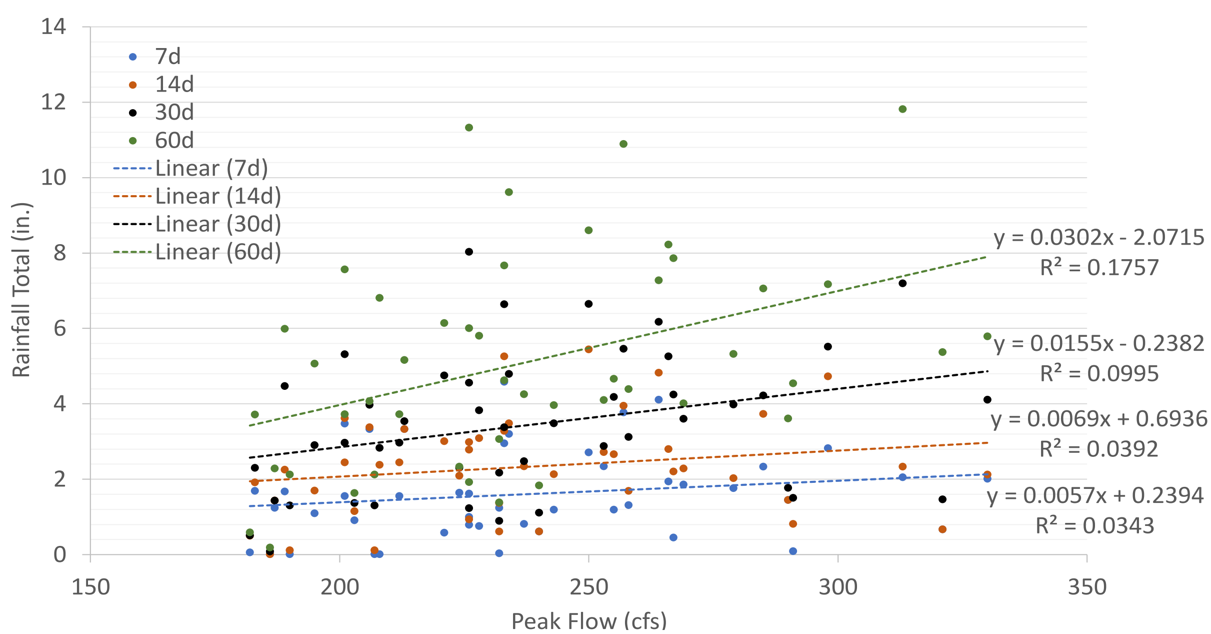


Figure B-2-15. Rainfall runoff correlations the North Platte airport weather station and Birdwood Creek.

B-2.11 River Stage Trends

Trends in river stage were investigated by Chen, Rus, and Stanton (1999) using available flow and stage data. No significant trend in bed elevation was noted for the period from 1945 to 1987 at the gage downstream of Keystone Dam. Birdwood Creek has experienced a downward trend in stage of 0.091 meters per decade, which translates to an approximate base level change of 2.4 feet in the eight decades since installation of Keystone Dam. No trends were reported for the Sutherland or North Platte gages.

B-2.12 Climate Change

Climate model projections for the region were also reviewed to assess the potential effect of climate change on the frequency and magnitude of flood events on the North Platte River and flows from the tributaries between Kingsley Dam and the City of North Platte. Climate projections suggest that the probability of large rainfall events and the flooding risk from peak river flows could increase or decrease. Given the uncertainty of climate model predictions, a range of possible outcomes is possible given the climate model's wide band of confidence limits.

B-3. Hydraulics

This section describes the hydraulic modeling completed to evaluate existing conditions and identify major factors contributing to the loss of channel capacity in the Chokepoint Reach of the North Platte River. One-dimensional steady-flow simulations of existing conditions and nine scenarios representing potential future conditions were completed to characterize hydraulic conditions in the channel and floodplain over a range of flows from 100 cfs to 12,000 cfs. Modeling scenarios were designed to determine the effects of bridges, the Tri-County Canal Diversion Dam and vegetation on flow through the reach. The model output was used to characterize existing channel and floodplain hydraulics and to investigate the effects that modifications to the channel, floodplain and infrastructure would have on flow through the reach. The following sections discuss methods and results for each simulation.

B-3.1 Model Development

Hydraulic performance was simulated using HEC-RAS version 6.2 (USACE 2022). The model used for this study is the product of three prior modeling efforts. The first iteration of the model was the Platte River Recovery Implementation Program (PRRIP) 1-dimensional steady flow model of the reach extending from North Platte to Keystone (HDR, Tetra Tech and The Flatwater Group 2011). This model was developed for in-channel flows and calibration efforts targeted flows below 2000 cfs. The PRRIP model was modified by USACE to allow for modeling of higher flows as part of the North Platte River Flood Risk Impacts Assessment and Communication study (USACE 2013) and for use in design and permitting for the State Channel Berm (USACE 2018). The State Channel Berm model was used as the starting point for this study. The existing conditions model geometry was updated to reflect bathymetric data collected in 2017 and modified as necessary to evaluate the effects of bridge constrictions, the Tri-County Canal Diversion, and vegetation removal scenarios.

B-3.2 Model Domain

The existing conditions model is a single-reach model that extends from the Tri-County Canal Diversion just downstream of the confluence of the North Platte River with the South Platte River to a point approximately 5.5 miles (8.8 km) upstream of Highway 83. The model domain was extended approximately 1,000 feet downstream of the Tri-County Canal Diversion to enable a comparison of water surface elevations through the dam and confluence area. Model stationing was adjusted to accommodate this change and a cross reference listing HEC-RAS river station (RS) for this model and the USACE North Platte model (2018) is provided in Table B-3-1.

B-3.3 Spatial Reference and Vertical Datum

The horizontal coordinate system used for the model is “NAD83(2011) / Nebraska (ftUS)” (EPSG #6880). Unless otherwise noted, all elevations referenced in this memorandum are relative to the North American Vertical Datum of 1988 (NAVD88).

B-3.4 Existing Conditions Geometry

The existing conditions geometry file was developed for evaluation of the State Channel Berm project (USACE 2018) and modified for use in this analysis. The cross sections were re-sampled from a topo-bathymetric Light Detection and Ranging (LiDAR) digital elevation model (DEM) developed using data collected in 2017 (Quantum Spatial). A total of 50 cross sections were used to represent the channel and floodplain geometry for the existing conditions model. Cross section spacing ranges from 89 feet to 1,795 feet with an average of 1,151 feet. The cross sections are oriented perpendicular to the expected flow lines for both small to moderate (1- to 50-yr) events and larger magnitude (100-yr to 500-yr) flood events.

The existing conditions model geometry includes three bridge nodes representing the Highway 30 bridge, Highway 83 bridge and Union Pacific Railroad (UPRR) bridge. Bridge data were developed by USACE (2013). The geometry for the bridges was developed from as-built plans obtained from the Nebraska Department of Roads and from the UPRR. Steady-flow contraction and expansion coefficients for the bounding cross sections to each of the highway bridges were set at 0.3 and 0.5, respectively. For the UPRR bridge they were set at 0.6 and 0.8. It was noted in the draft 2013 USACE report provided with the 2013 model that bridge skew was used at the UPRR Bridge, however, the State Channel Berm model provided does not use bridge skew. The higher expansion and contraction coefficients may have been used in lieu of bridge skew in the final State Channel Berm model. The contraction and expansion coefficients were not adjusted for this study.

Ineffective flow areas, blocked obstructions, and levees were used in the State Channel Berm model to prevent the model from computing flow in areas that are either hydraulically disconnected from the river or which would not contribute to the conveyance. Permanent ineffective flow areas and blocked obstructions were used throughout the model for model calibration. This approach was applied in both the PRRIP model (2011) and the USACE models (2013 and 2018). Ineffective flow area and levee data were updated for the current modeling effort to reflect changes evident in the 2017 LiDAR. The existing conditions 1D model schematic is shown in Figure B-3-1.

Table B-3-1. Stationing cross reference.

CAD Station	RAS Station
66789	889202.5
65524	887938.1
64373	886787.3
63416	885830.1
62133	884546.7
60613	883026.5
58939	881352.5
57361	879774.5
55816	878229.7
54237	876651.3
52794	875207.8
51237	873651.0
49761	872175.1
48214	870628.0
46454	868867.8
44780	867193.5
43127	865541.4
41452	863865.6
39941	862355.3
38852	861265.6
37976	860390.0
37909	860316.0
37854	860268.1
37014	859428.4
36357	858771.4
35946	858359.7
35554	857967.8
35112	857526.0
34365	856779.1
33547	855960.5
31827	854241.2
30266	852679.8
28659	851072.7
27210	849624.5
26499	848912.5
26397	848800.0
26321	848735.3
25284	847698.4
24321	846735.3
23265	845678.8
22595	845009.0
22547	844958.0
22506	844919.5
20974	843388.0
19431	841844.6
18590	841004.1
17216	839630.0
15748	838161.5
14052	836466.0
12431	834844.5
10774	833188.0
9846	832260.0
8946	831359.8

B-3.5 Modeling Scenario Geometries

Geometry files were created for each of the nine modeling scenarios representing potential future conditions. Cross sections were maintained in the same locations as the existing conditions model to facilitate comparison of water surface elevations. Geometry files for the bridge modification scenarios (#s 2 – 4) were developed by modifying the bridge structures and cross sections upstream and downstream of each bridge. Geometry files for the dam and sediment removal scenarios (#s 5 – 8) were developed by creating channel surfaces and merging them with the existing conditions surface to create a seamless digital elevation model for each of the scenarios. Geometry files for the vegetation removal scenarios (#s 9 – 10) were developed by modifying floodplain roughness values to represent channel roughness (0.028) rather than floodplain roughness. The modeling scenario schematic is shown in Figure B-3-2.

B-3.6 Model Boundary Conditions

The downstream boundary water surface elevation for the existing condition model was taken from the State Channel Berm model developed by USACE (2018). The existing condition model uses a known water surface elevation of 2770.04 feet (NAVD88) for all flow profiles. This elevation represents the water surface elevation at the Tri-County Canal Diversion Dam. A normal depth approximation with a slope of 0.0014 was used for the modeling scenarios where the model was extended downstream of the dam.

The model uses horizontally varied roughness (Manning's n) values that were assigned based on discretized vegetation data as described in the PRRIP model documentation by HDR and TetraTech (2011). The existing conditions model was recalibrated for moderate flow conditions of approximately 4,000 to 5,000 cfs by USACE (2013) using observed water surface elevations from a high flow event in 2011. Roughness values used for this study were not adjusted from those used in the 2018 USACE model. Roughness values range from 0.020 to 0.160. The higher roughness values (> 0.1) were assigned to be representative of existing floodplain conditions that include tall, dense grasses and shrubs. Conveyance-weighted channel roughness values range from 0.028 to 0.060.

B-3.7 Model Limitations

The steady-state model used in this study does not account for flows that escape the main channel or are attenuated by bank storage. Running unsteady-flow simulations to account for flow splits was beyond the scope of this study and was not necessary to ascertain the primary effects of the bridges, the diversion dam and vegetation on water surface elevations through the reach.

The USACE report (2014) notes that flows splits may account for 33% - 45% of the total flow for flows ranging from about 4,500 cfs to 5,900 cfs. Water escapes the main channel upstream of the UPRR Bridge and is routed through Whitehorse Creek and the airport. In addition, flows may be routed through the City of North Platte. It appears that water begins to flow into the Whitehorse Creek area at about 2,000 cfs and flow may overtop the levee protecting the airport at about 7,000 cfs. Once flows exit the North Platte River and begin flowing through the city, airport, or White Horse Creek, conveyance areas are generally shallow with little to no defined drainage path. As flows increase, flow paths could through these areas could be significantly different from those predicted by the 1D model. Two-dimensional and/or unsteady-flow modeling would be required to accurately define inundation areas and flow paths for flows greater than approximately 2000 cfs.

HDR and TetraTech (2011) report that short-duration high flow (SDHF) releases that occur with dry antecedent soil-moisture conditions are strongly affected by gains and losses associated with bank storage. The unsteady-flow model developed for use in evaluating the effectiveness of SDHF releases incorporated a bank storage model to account for these effects under specific conditions. Unsteady-flow modeling was beyond the scope of this study and the current model does not account for bank storage.

B-3.8 Sediment Mobility

The bed of the North Platte River and South Platte River in the vicinity of the confluence consists primarily of sand. Historical accounts of sediment in the Platte River system taken from Eschner et al. (1983) are provided in Simons and Associates (2000): "Fremont (1845) described the southern channel of the South Platte River near the confluence with the Platte River as being 'generally quicksands.'" Bed material in the North Platte River measured by USACE in 1931 had a median grain size diameter of about 0.5 mm and D_{84} of 2.0 mm (Simons and Associates 2012).

Sediment mobility was evaluated by comparing channel-average velocity and shear stress for each scenario at a flow of 2,000 cfs. This flow is near the 1.5-year peak flow of 2,380 cfs reported in USBR 2003 for the period of 1970 to 1999. It also coincides with the middle of the range of bankfull flows computed by USBR (2003) using the equal discharge interval method (~600 cfs to 3,800 cfs), effective discharge computed using the probability method (~1,500 cfs – 2,100 cfs), and median sediment transporting discharge (~1,200 cfs – 4,100 cfs).

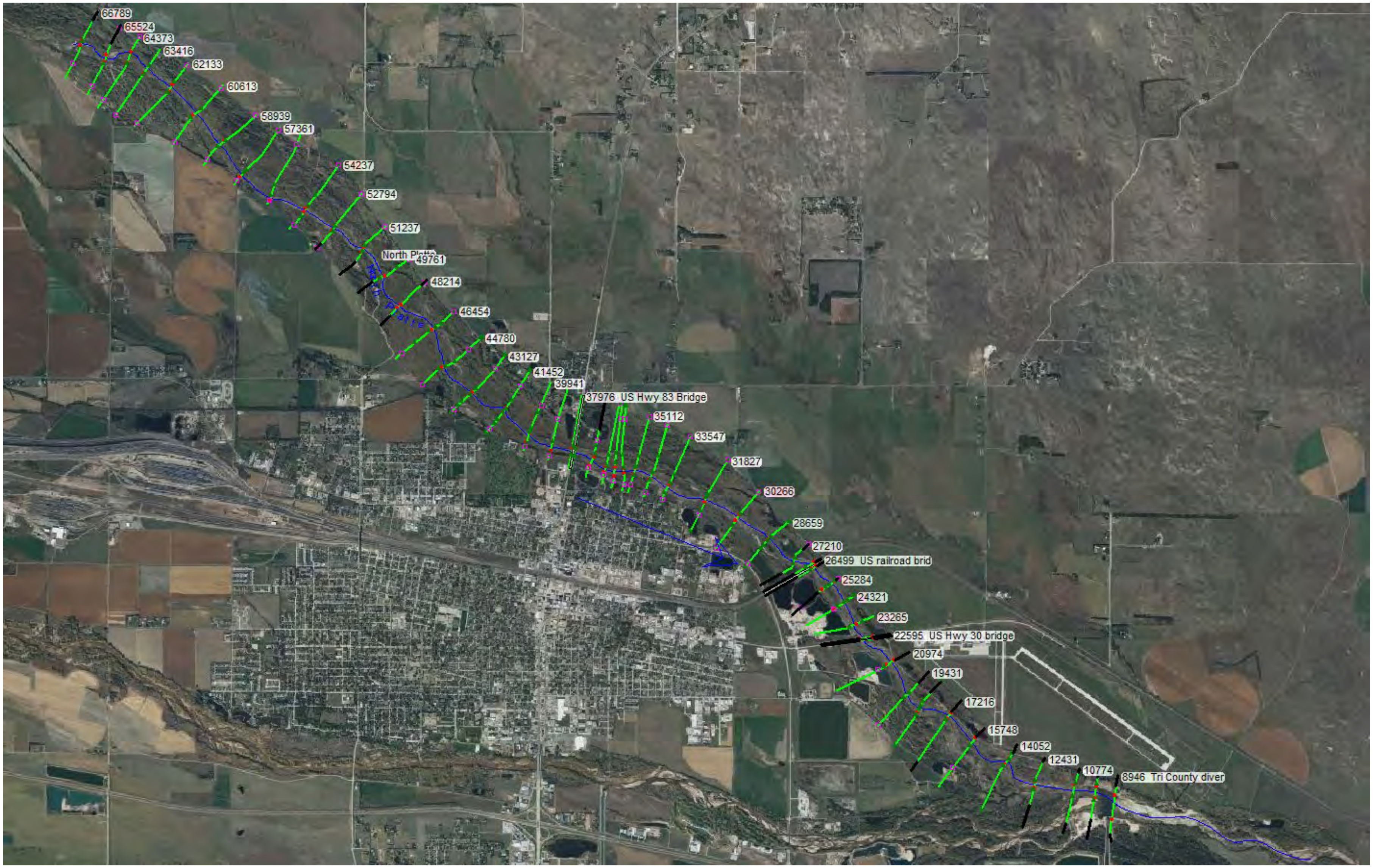


Figure B-3-1. Existing conditions HEC-RAS 1D model schematic.

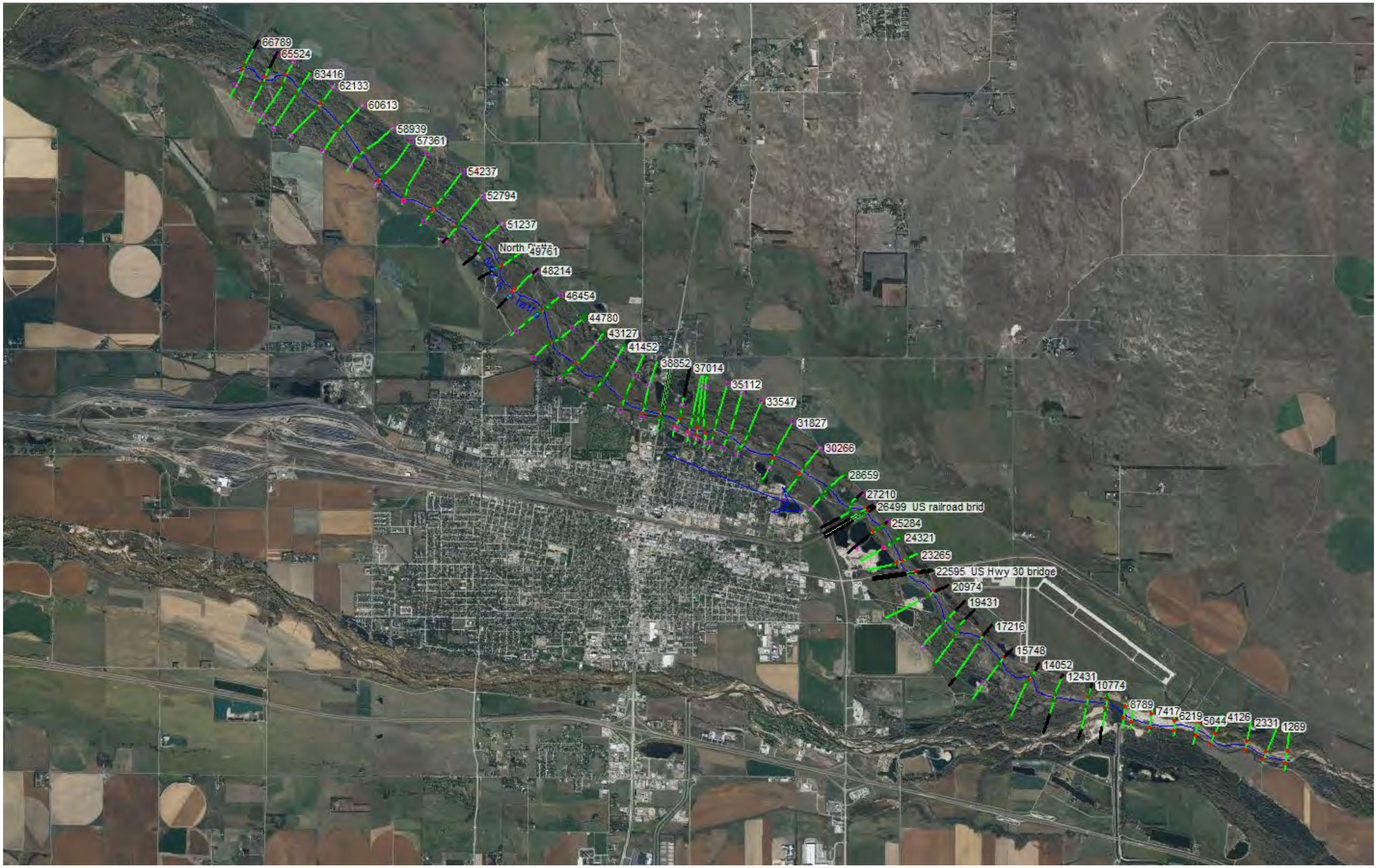


Figure B-3-2. Modeling scenarios HEC-RAS model schematic (note: nine cross sections added at downstream end of model).

B-3.9 Existing Conditions Model Validation

The existing conditions model run was validated using the stage-discharge rating table (# 27a) for the North Platte River near North Platte gage (NDNR #06693000) that was in effect at the time that the 2017 Lidar was acquired. Vertical shifts are applied to these rating curves to improve the accuracy of flow estimates as the base level of the river changes over time. In order to develop a rating curve to use for model validation, the historical shifts since the development of the effective rating curve were plotted for flows above and below 1000 cfs. A piecewise logarithmic regression analysis was used to approximate the relationship of shift to flow and this shift relationship was applied to the base rating curve to develop a validation rating curve (Figure B-3-3 and Figure B-3-4).

Seasonal variation in vegetation and dune morphology may account for the large variation in stage at flows below 400 cfs. The rating table is compared with predicted water surface elevations from the hydraulic model upstream and downstream of the bridge in Figure B-3-5. The location of the gage has changed several times, most recently from the upstream side of the bridge to the downstream side. Based on gage notes, it appears that the datum of the gage is still associated with the upstream gage location.

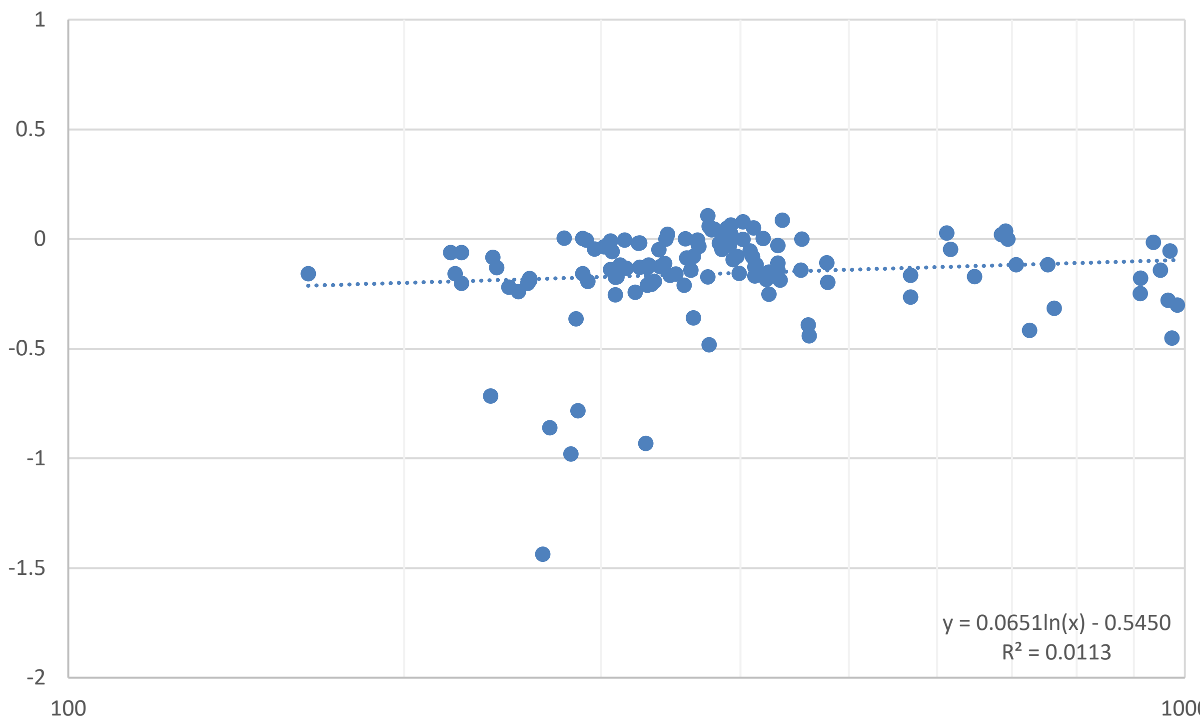


Figure B-3-3. North Platte River at North Platte (NDNR #06693000) shift for flows less than 1000 cfs.

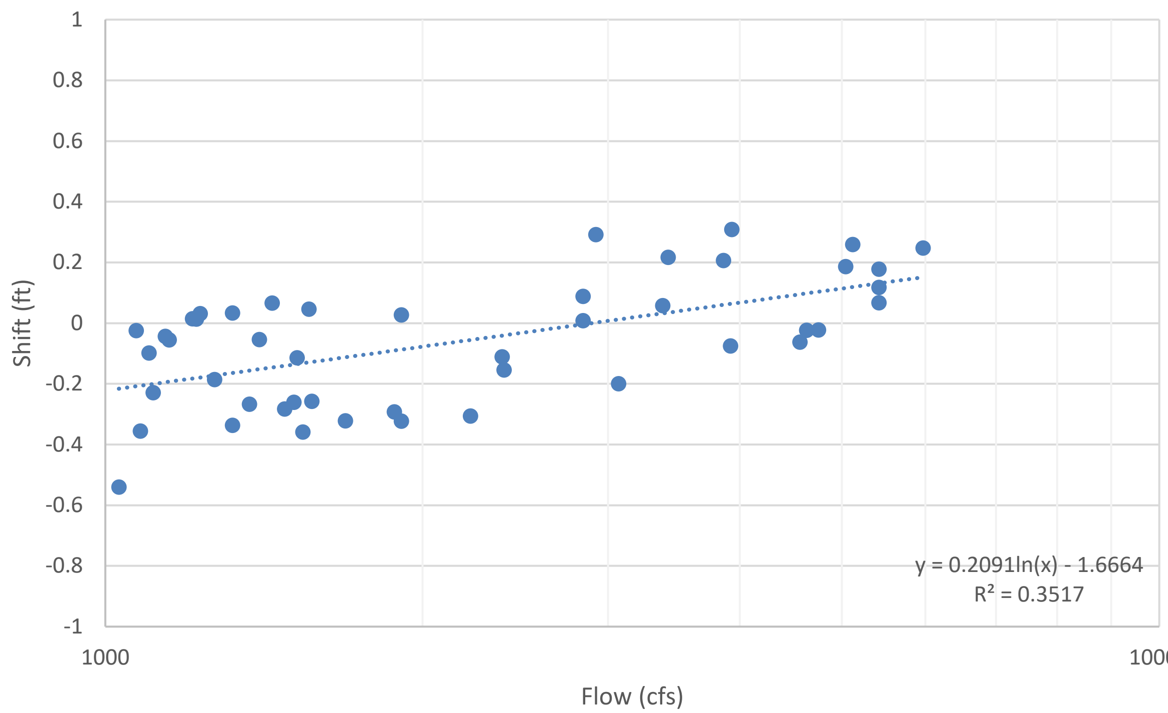


Figure B-3-4. North Platte River at North Platte (NDNR #06693000) shift for flows greater than 1000 cfs.

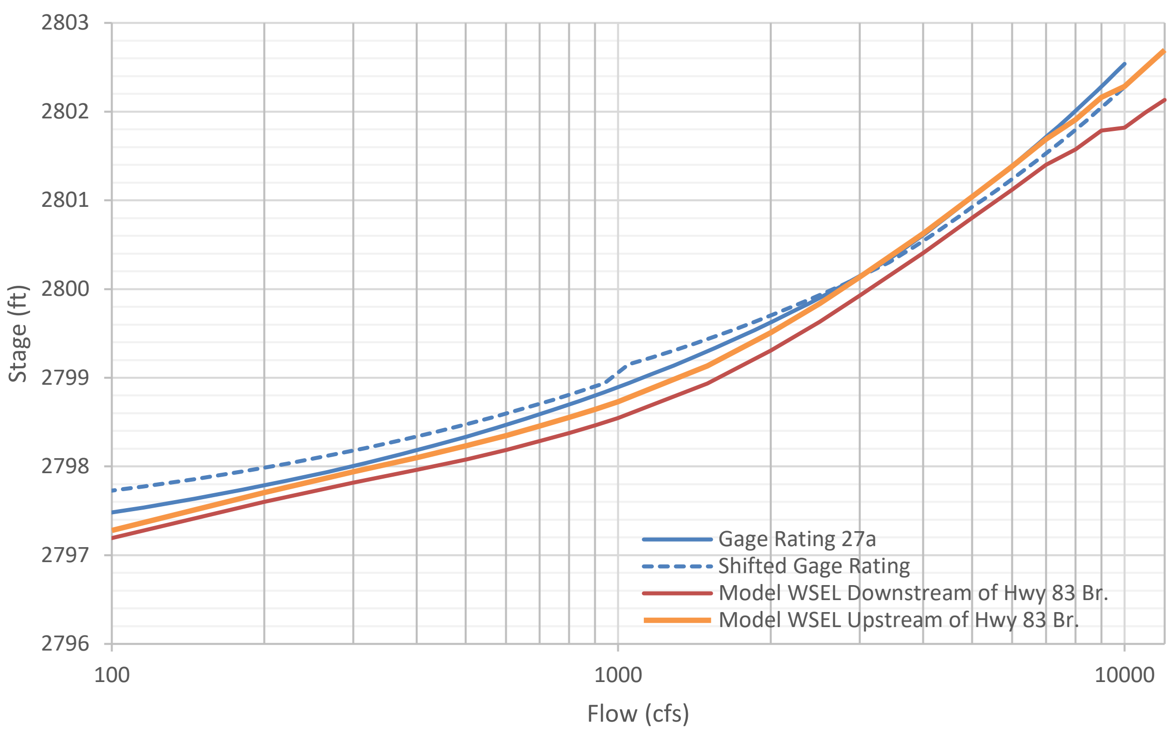


Figure B-3-5. HEC-RAS 1D model predicted WSEL compared with North Platte River at North Platte (NDNR #06693000) rating curve 27a. Blue line is gage rating curve, dashed blue line is shifted rating curve, red line is model WSEL downstream of Highway 83 and orange line is model WSEL upstream of Highway 83.

In order to validate model results throughout the reach, modeled water surface elevations were compared with elevations sampled from the hydro-flattened DEM supplied with the 2017 Lidar data. Water surface elevations were extracted from the hydro-flattened DEM for each cross section in the model. Points within the water's edge breakline polygon were selected and averaged for each cross section (Figure B-3-6). The standard deviation in water surface elevation for the 50 cross sections ranged from 0.05 feet to 0.16 feet with an average of 0.09 feet. These water surface elevations were compared with the existing condition model water surface elevations for a flow of 400 cfs, the average flow for the day of the Lidar acquisition. Differences in water surface elevation are plotted in Figure B-3-7.

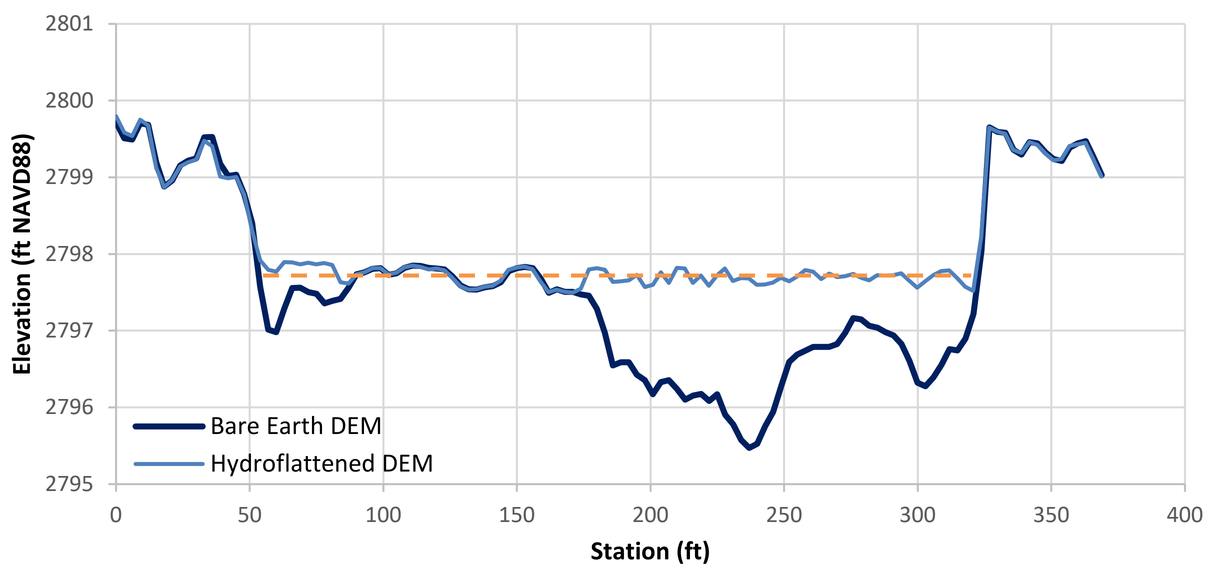


Figure B-3-6. Cross section showing variation in water surface elevation from 2017 LiDAR.

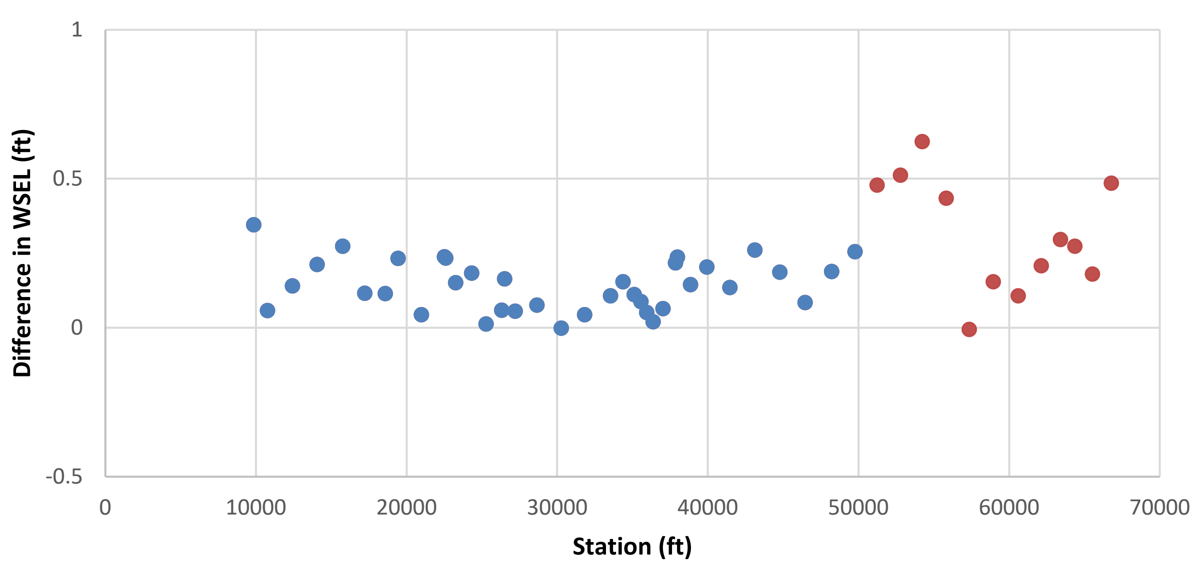


Figure B-3-7. Difference in water surface elevation between hydraulic model and 2017 LiDAR for flow of 400 cfs.

Overall accuracy of the model was good with differences of less than 0.5 feet. The average difference between the rating curve and the model water surface elevations upstream of the Highway 83 bridge was -0.13 feet with an RMS value of 0.23 feet. The differences between the modeled water surface elevation and the Lidar water surface were generally less than 0.3 feet through the Chokepoint Reach. These results are consistent with previous modeling efforts. The PRRIP model report indicates that computed and observed water surface elevations agreed at most cross sections within 0.3 feet with maximum differences of less than 1.0 feet. USACE (2013) reports average differences ranging from 0.02 feet to 0.47 feet with absolute differences ranging from -0.06 feet to 0.60 feet.

B-3.10 Existing Conditions Model Results

The primary purpose of the existing conditions model was to generate estimates of water surface elevations through the project area for flows ranging from 100 cfs to 12,000 cfs for comparison with various modeling scenarios. Selected water surface elevation profiles for the existing condition model representing flows ranging from 400 cfs to 12,000 cfs are presented in Figure B-3-8.

Under existing conditions at a flow of 2,000 cfs, channel-average simulated velocities ranged from about 2 to 4 feet per second (fps) (Figure B-3-9). Channel-average shear stresses ranged from about 2 to 4 pounds (force) per square foot (lb/sqft) (Figure B-3-10). The spike in shear stress at station 26321 is associated with a relatively steep water surface profile slope exiting the UPRR bridge.

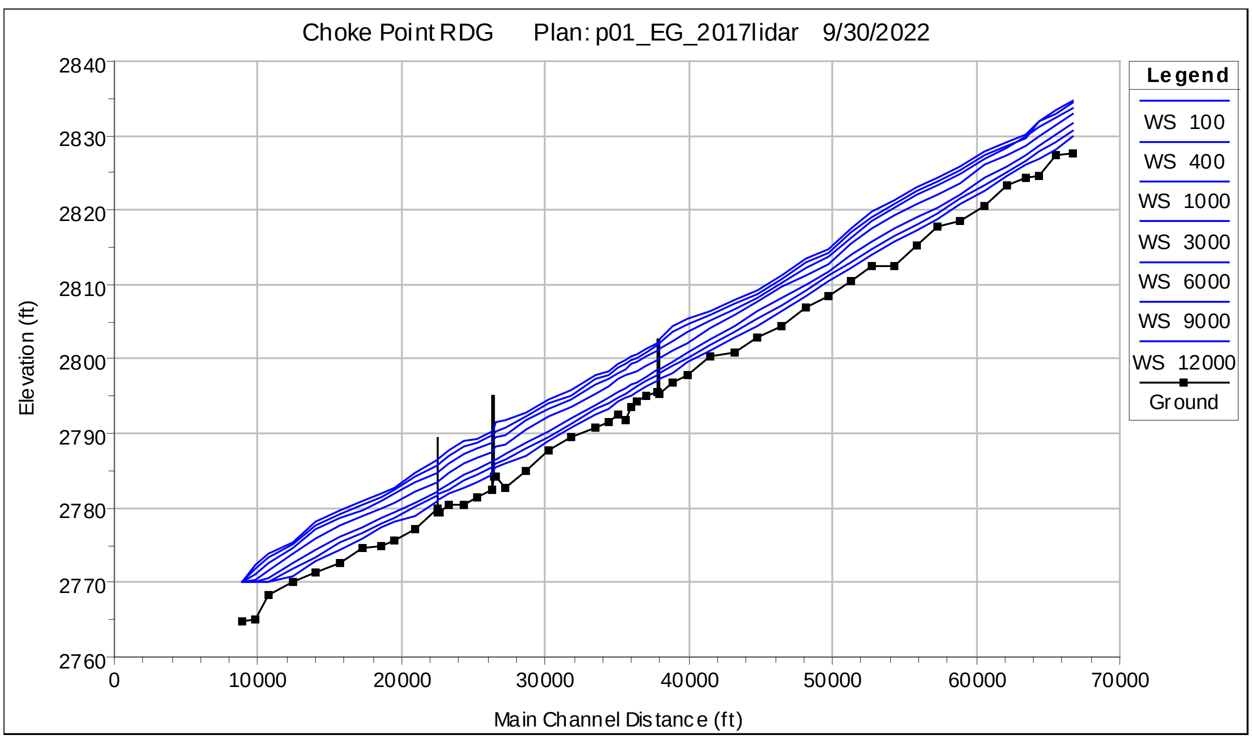


Figure B-3-8. Select existing condition water surface profiles for flows ranging from 100 cfs to 12,000 cfs.

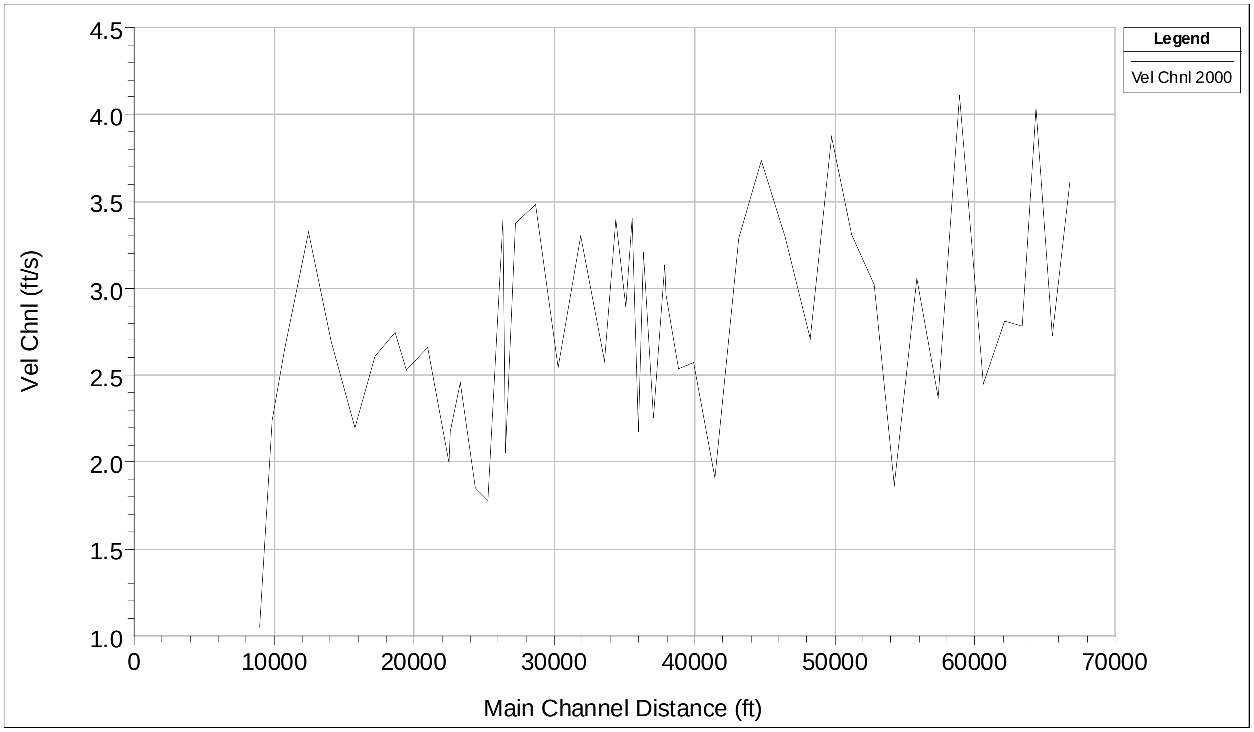


Figure B-3-9. Channel-average velocity profile for 2,000 cfs.

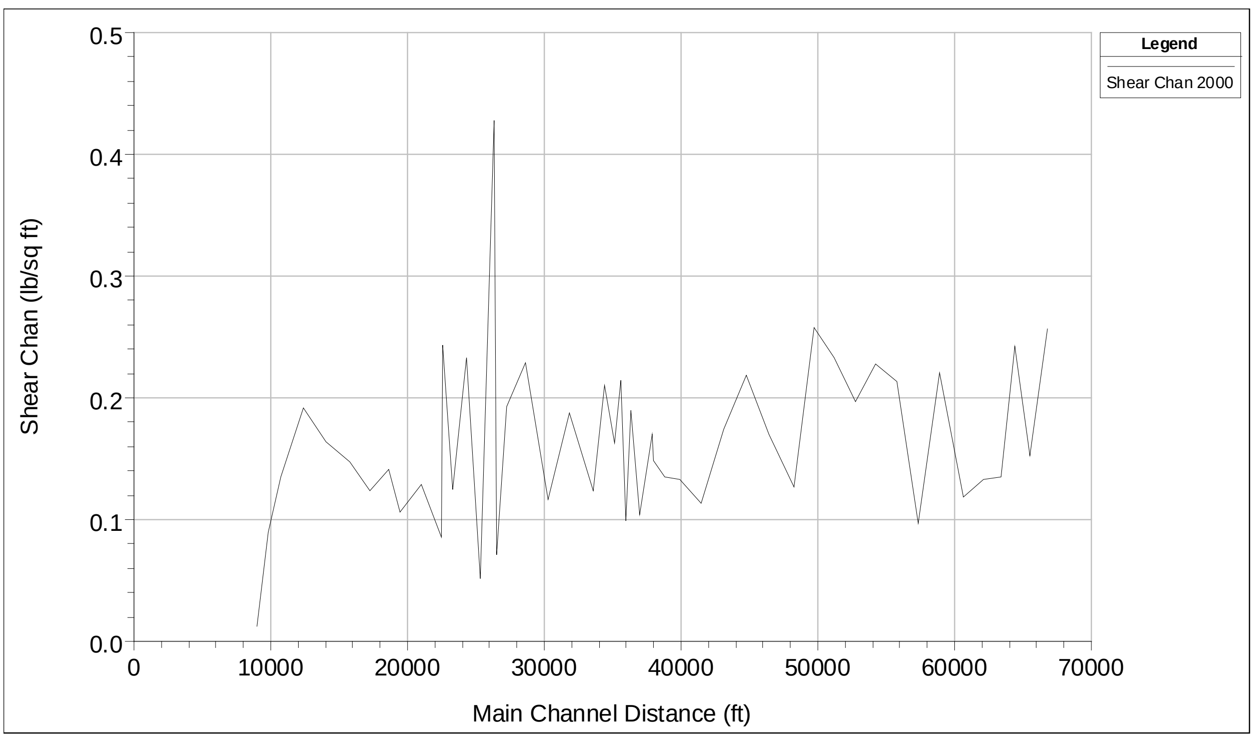


Figure B-3-10. Channel-average shear stress profile for 2,000 cfs.

B-3.11 Modeling Scenario Results

Nine modeling scenarios were developed to evaluate the effects of bridge constrictions, the Tri-County Canal Diversion, and vegetation removal. Hydraulic model output was used to compare water surface elevations, velocities, and shear stress through the reach for each scenario.

B-3.11.1 Bridge Modification (Scenarios 2 – 4)

Scenarios 2, 3 and 4 address the influence of bridges in the reach. The three bridges in the existing conditions model were modified to simulate removal of bridge piers and determine what effect increasing the cross-sectional area through the bridge openings would have (Figure B-3-11). For Scenario 2, the bridge structures were removed to evaluate the effect of the piers. For Scenario 3, the bridge openings and channel through the bridge were increased to a width of approximately 500 feet. For Scenario 4, the bridge openings and channel through the bridge were increased to a width of approximately 1,000 feet. The results from these simulations were compared with the existing conditions model to determine the effects of the three bridges on water surface elevations, velocities, and sediment mobility for flows ranging from 1,000 cfs to 12,000 cfs. Water surface elevation profiles for each scenario are compared with existing conditions in Figures B-3-12 through B-3-14.

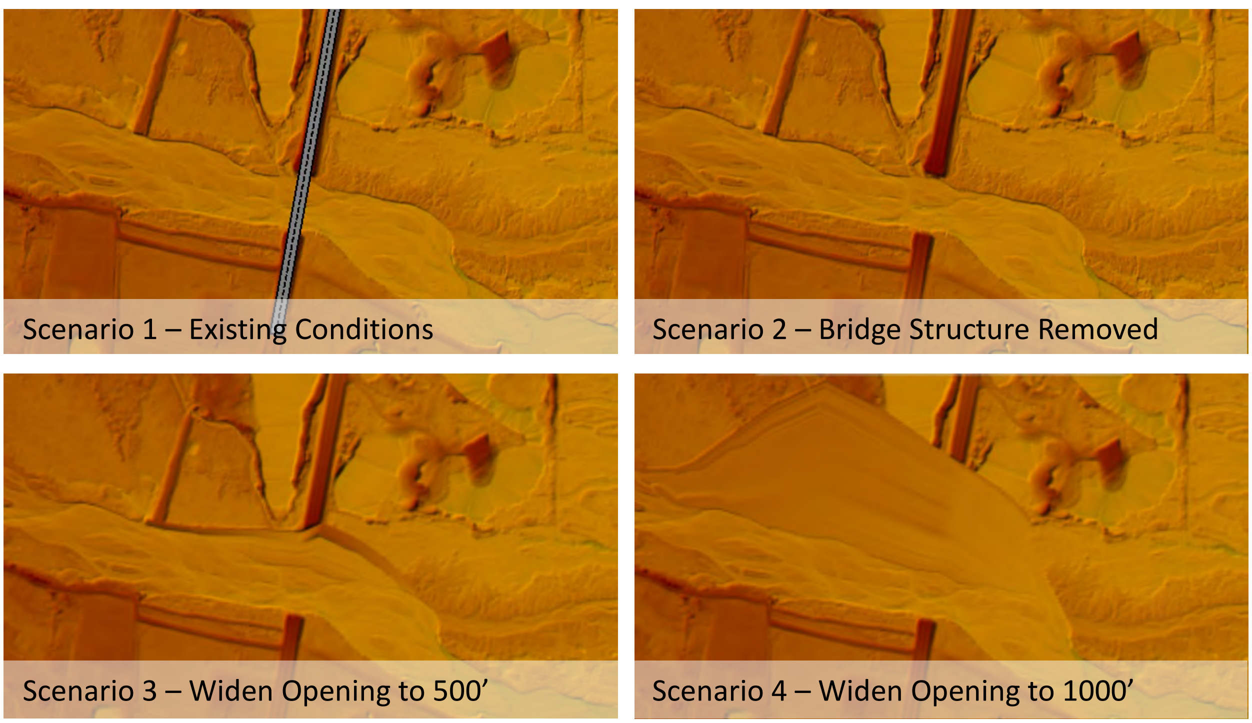


Figure B-3-11. Example terrain data for bridge modification scenarios at Highway 83.

Removing the bridge structures from the model to simulate the effect of converting the bridges to free-span structures and widening the bridge openings resulted in relatively localized changes in water surface elevations with effects extending 3,500 feet upstream for flows of less than

6,000 cfs in Scenarios 2 and 3. For flows greater than 6,000 cfs, the effects extended about one mile upstream of the Highway 83 bridge. The combination of removing the bridge structures and widening the channel to 1000 feet in Scenario 3 resulted in effects extending from the Highway 30 bridge upstream of the Highway 83 bridge 0.5 to 1.3 miles. Maximum change in water surface elevations ranged from -0.09 feet to -1.61 feet across all scenarios and flows. At the Highway 30 bridge, changes ranged from -0.03 feet to -1.06 feet (Figure B-3-18). Changes in water surface elevations resulting from modification of the railroad bridge, in conjunction with the Highway 30 bridge ranged from -0.09 feet to -1.79 feet (Figure B-3-19). Changes in water surface elevations ranged from -0.03 feet to -1.06 feet at the Highway 83 bridge (Figure B-3-20). Average-channel velocity and shear stress profiles are plotted for each scenario at a flow of 2,000 cfs in Figures B-3-21 through B-3-26.

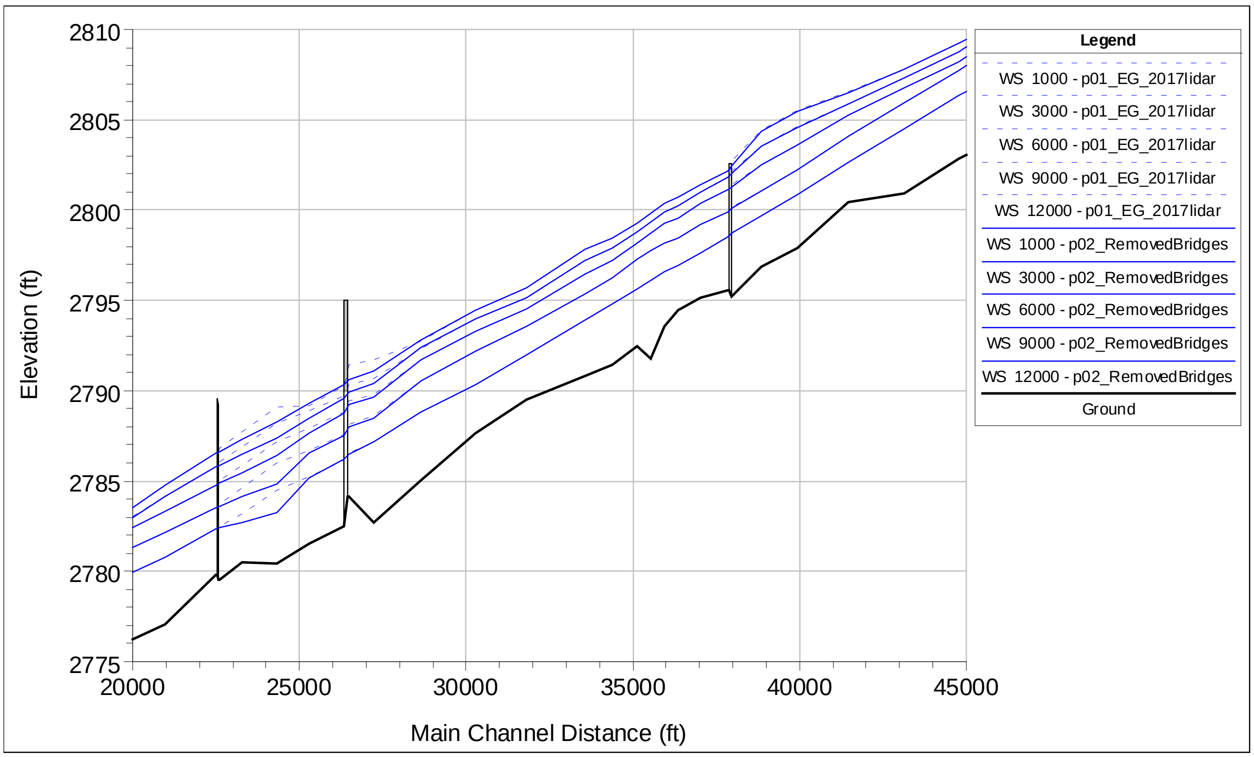


Figure B-3-12. Water surface elevation profiles for bridge modification Scenario 2 – bridge structures removed (solid blue lines) compared with existing condition (dashed blue lines).

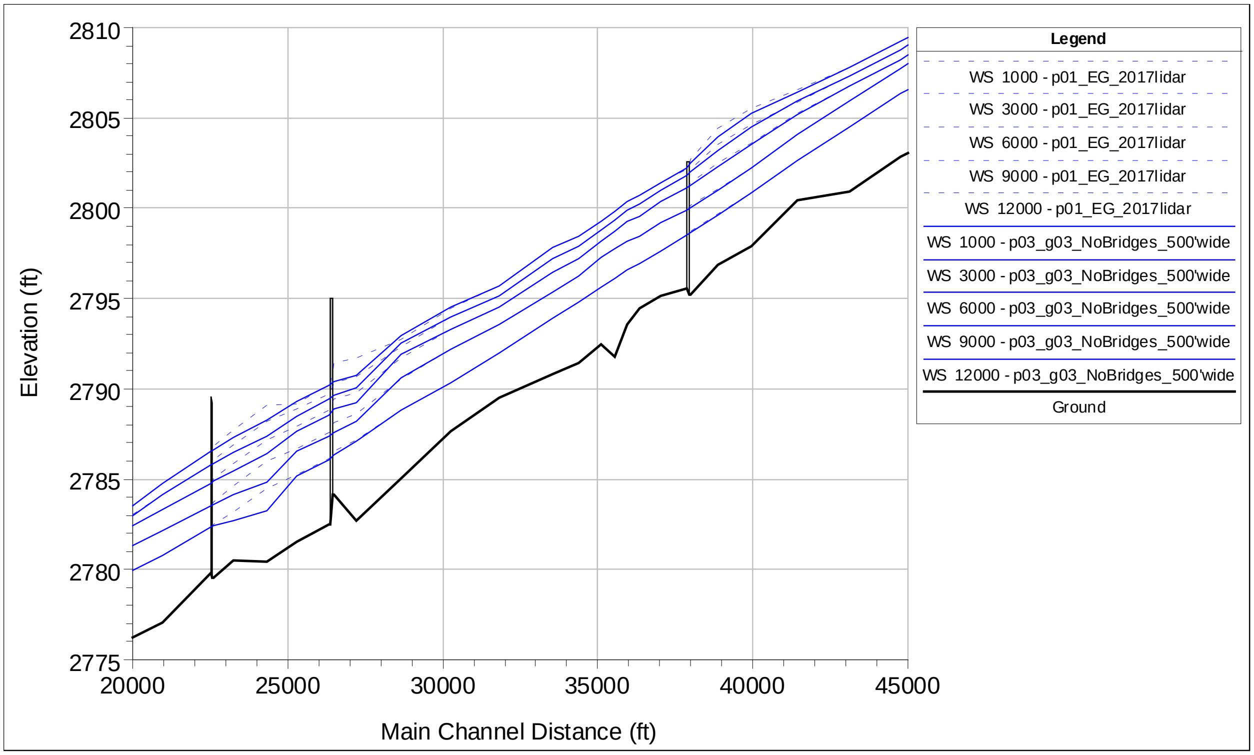


Figure B-3-13. Water surface elevation profiles for bridge modification Scenario 3 – openings widened to 500 feet (solid blue lines) compared with existing condition (dashed blue lines).

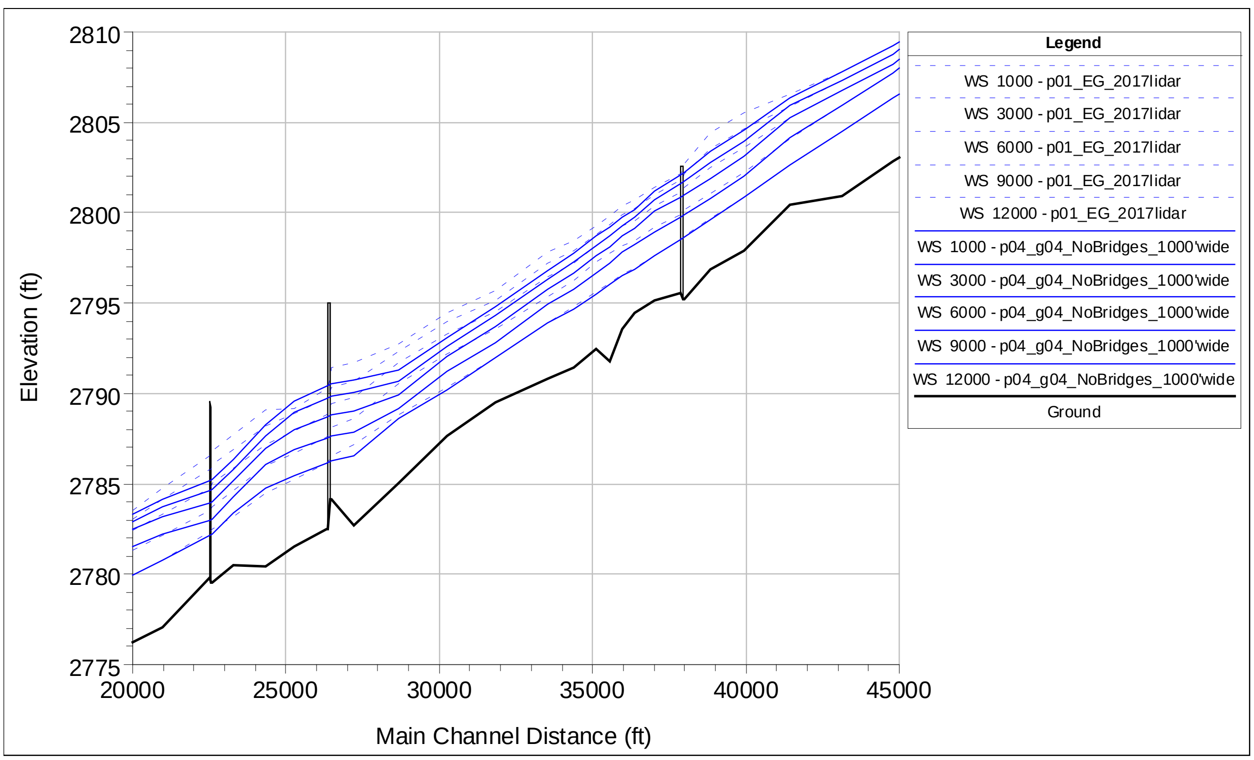


Figure B-3-14. Water surface elevation profiles for bridge modification Scenario 4 – openings widened to 1000 feet (solid blue lines) compared with existing condition (dashed blue lines).

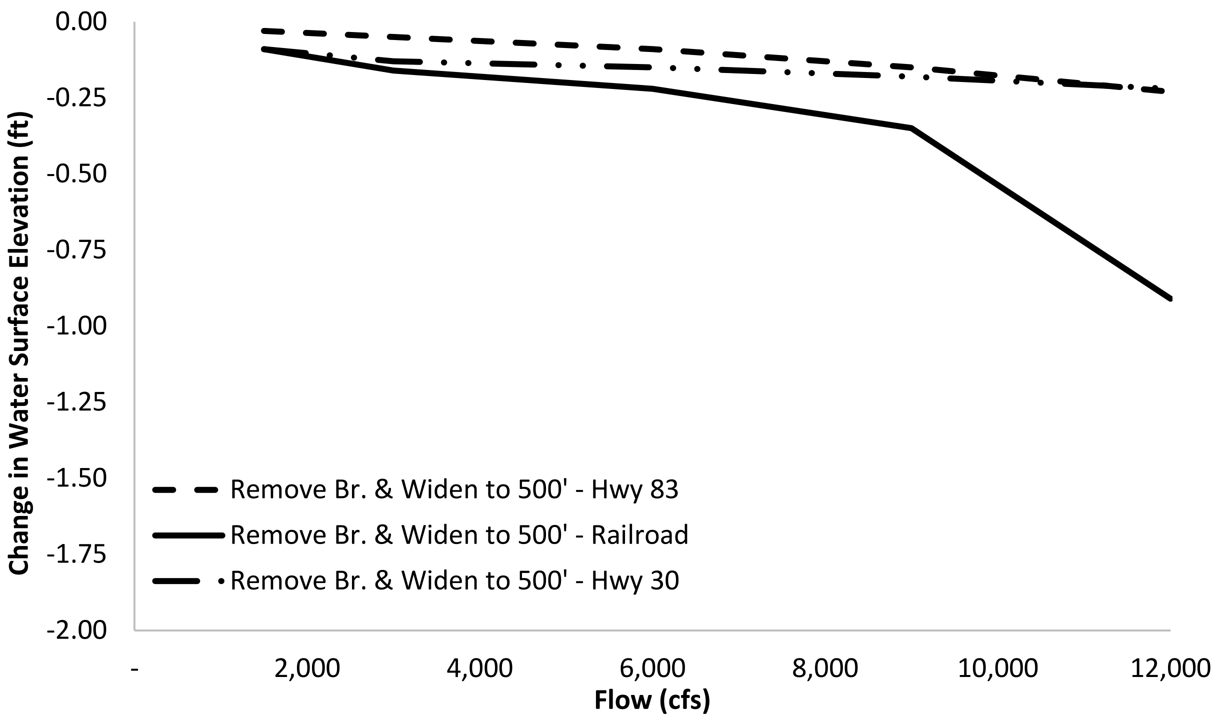


Figure B-3-15. Change in water surface upstream of each bridge for bridge modification Scenario 2 – bridge structures removed.

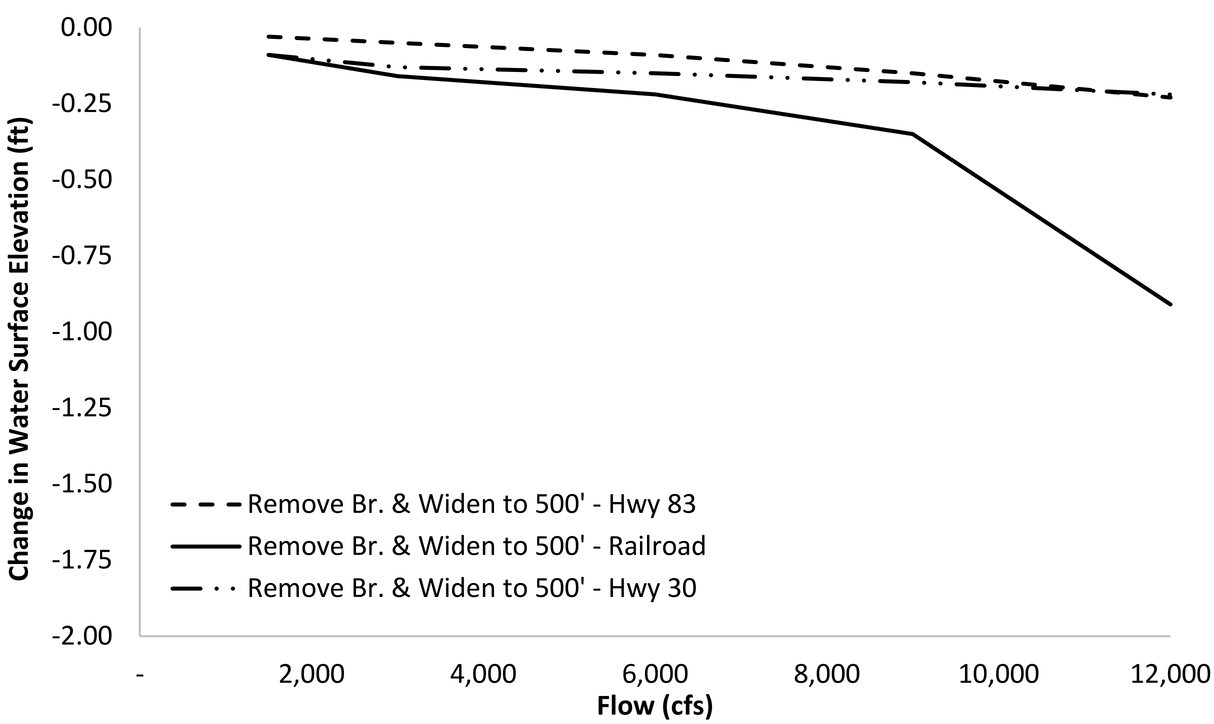


Figure B-3-16. Change in water surface elevation upstream of each bridge for bridge modification Scenario 3 – openings widened to 500 feet.

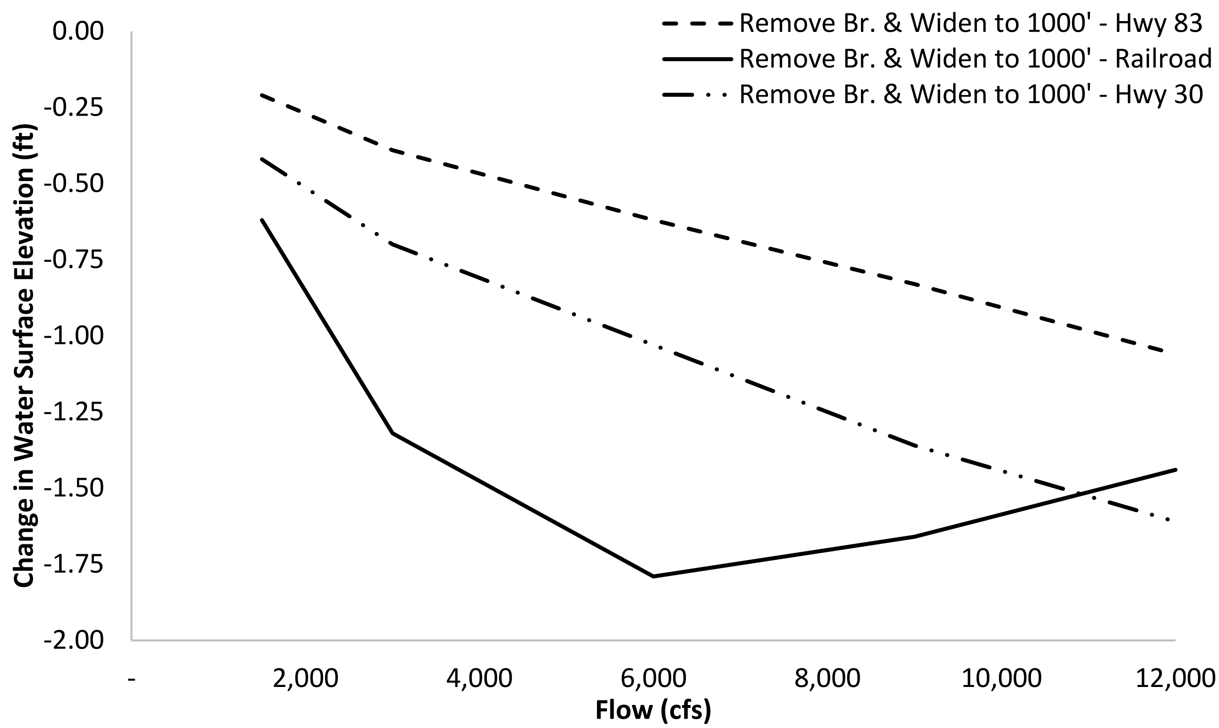


Figure B-3-17. Change in water surface elevation upstream of each bridge for bridge modification Scenario 4 – openings widened to 1000 feet.

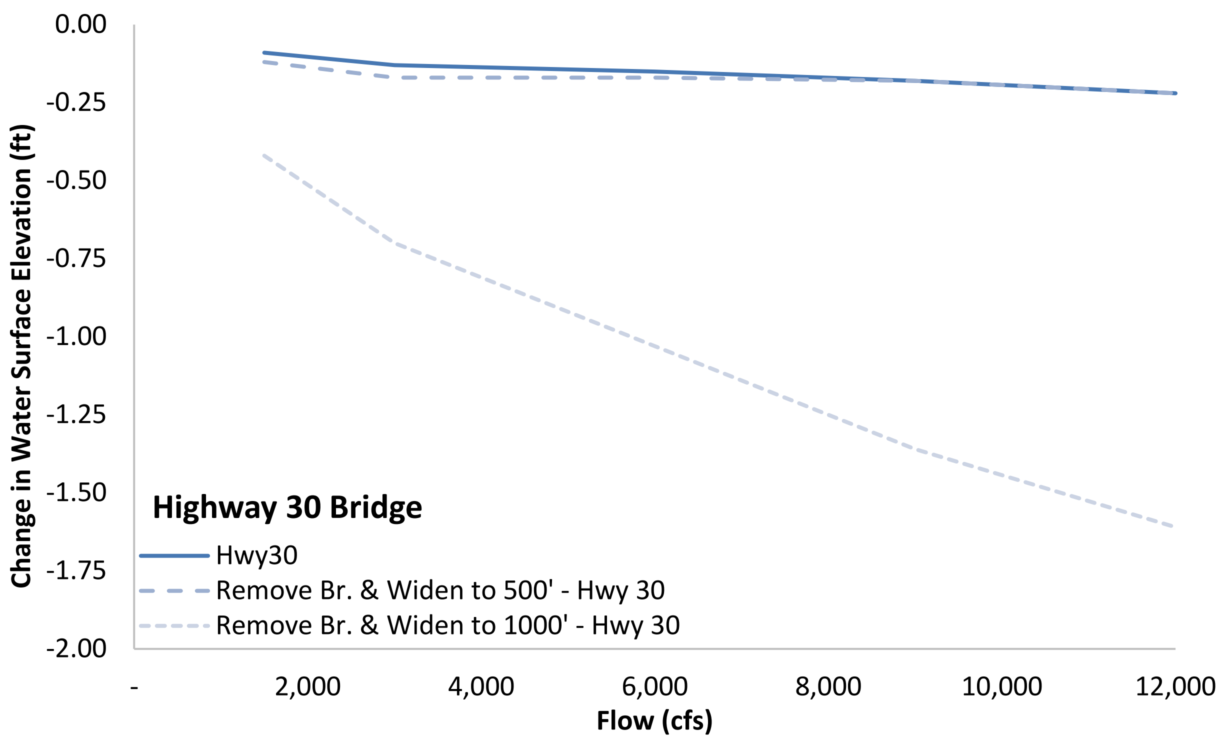


Figure B-3-18. Change in water surface elevation for bridge modifications at Highway 30.

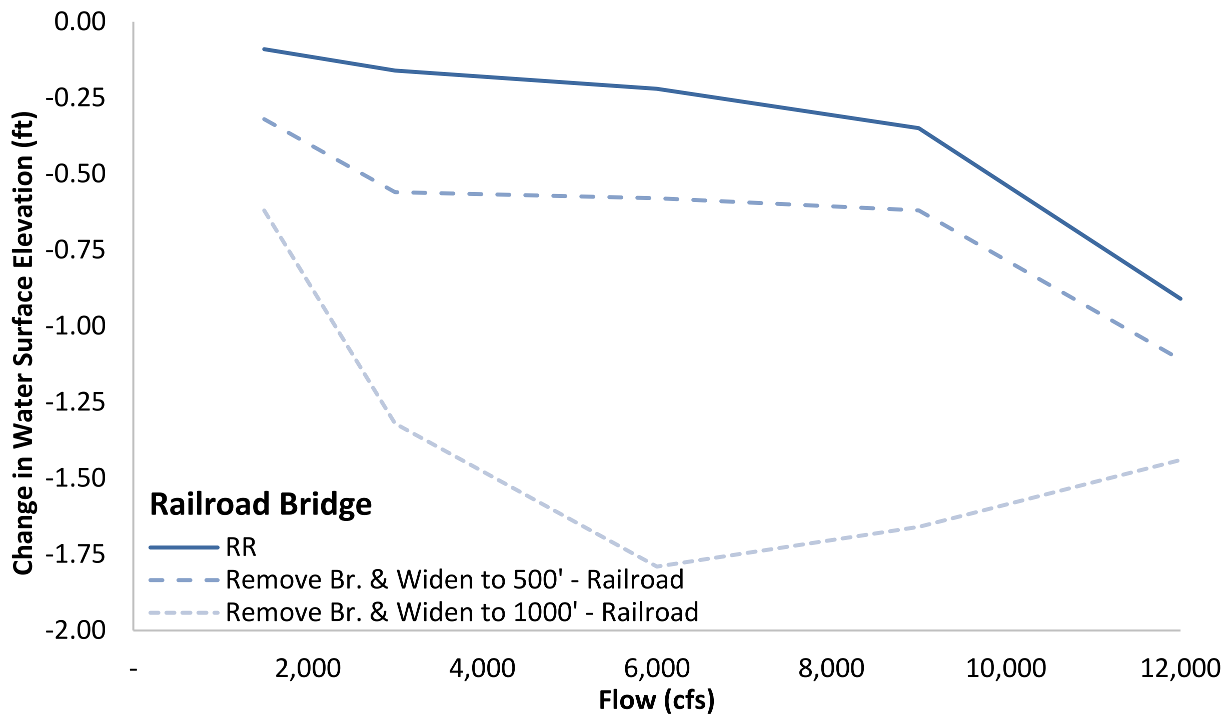


Figure B-3-19. Change in water surface elevation for bridge modifications at Railroad Bridge.

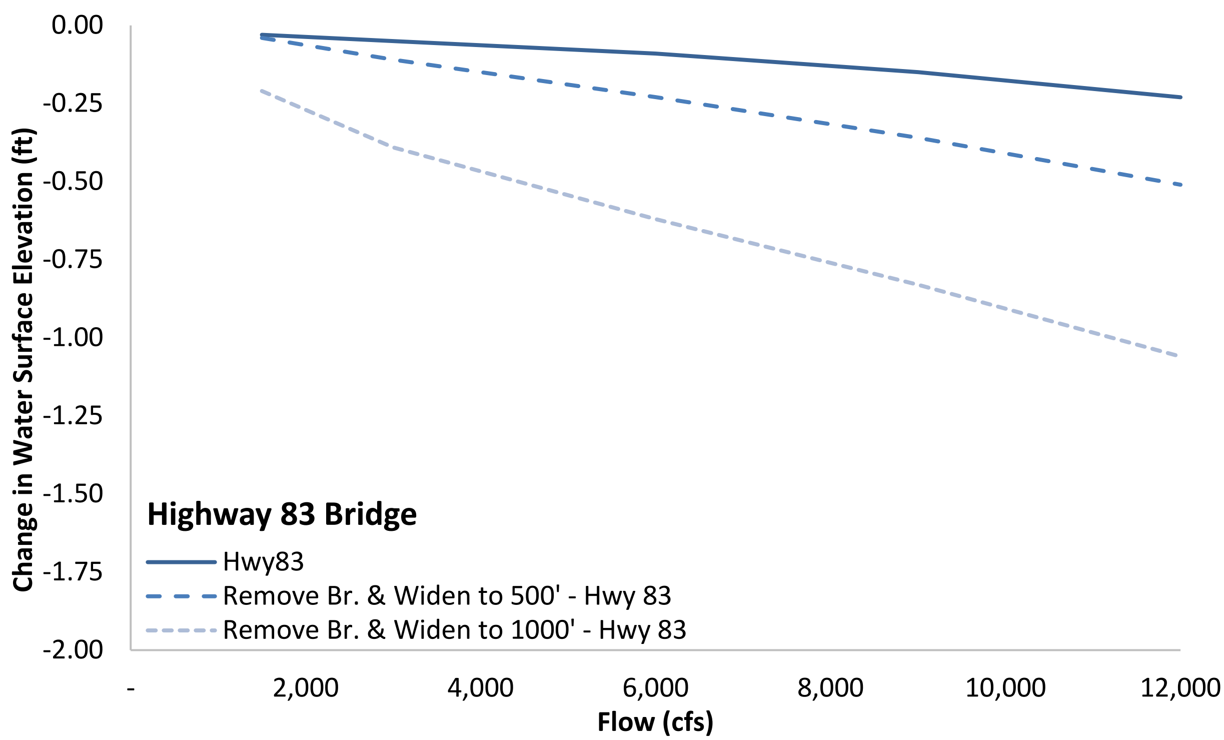


Figure B-3-20. Change in water surface elevation for bridge modifications at Highway 83.

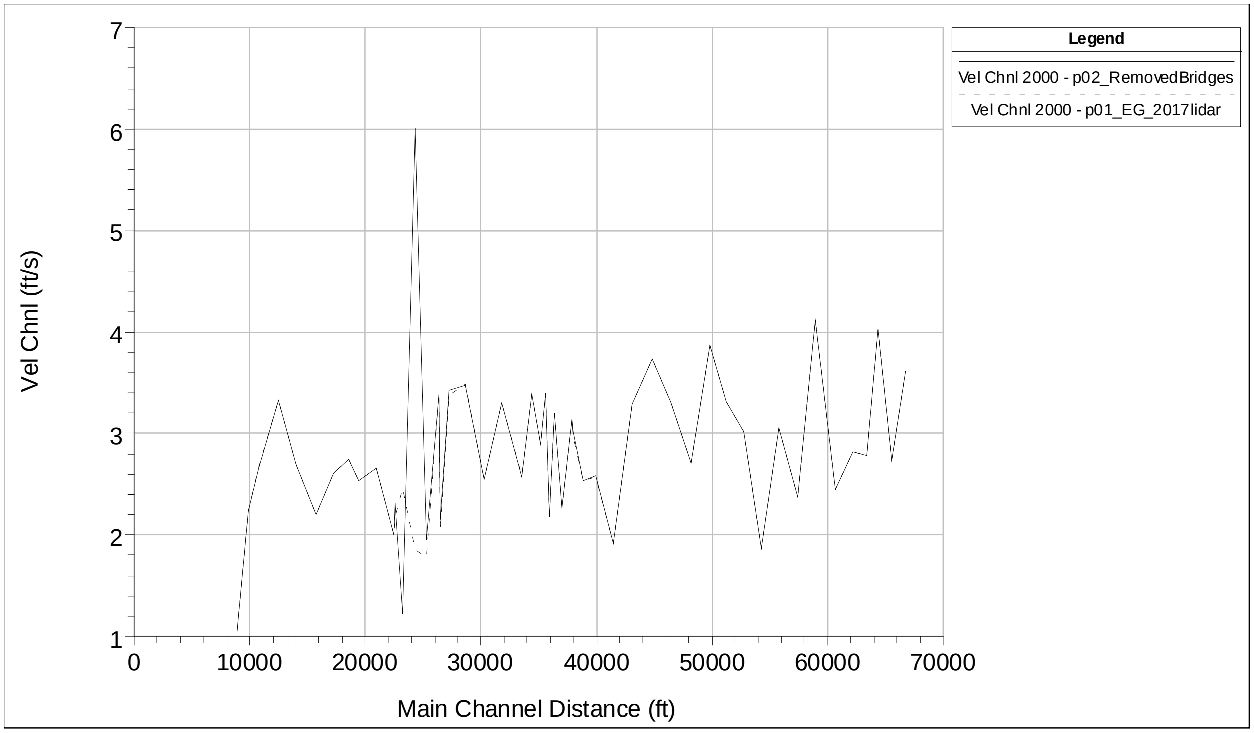


Figure B-3-21. Velocity profiles for bridge modification Scenario 2 – bridge structures removed (solid line) compared with existing condition (dashed line).

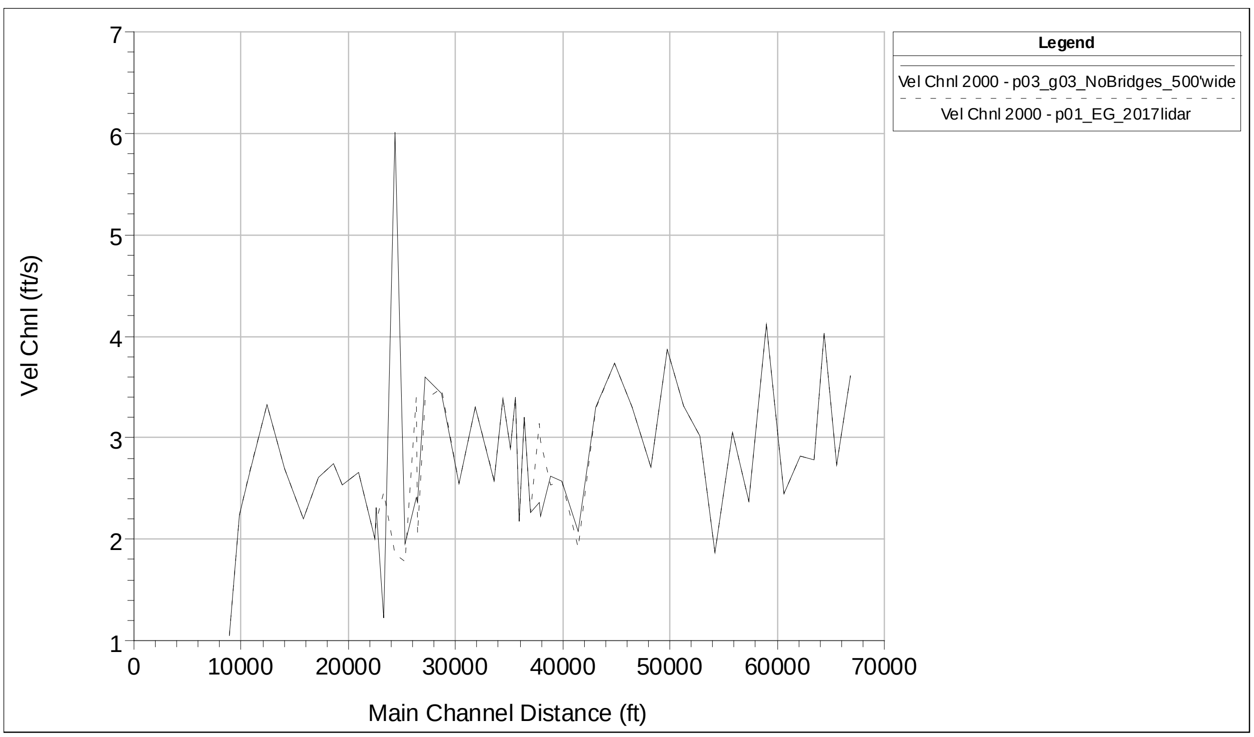


Figure B-3-22. Velocity profiles for bridge modification Scenario 3 – openings widened to 500 feet (solid line) compared with existing condition (dashed line).

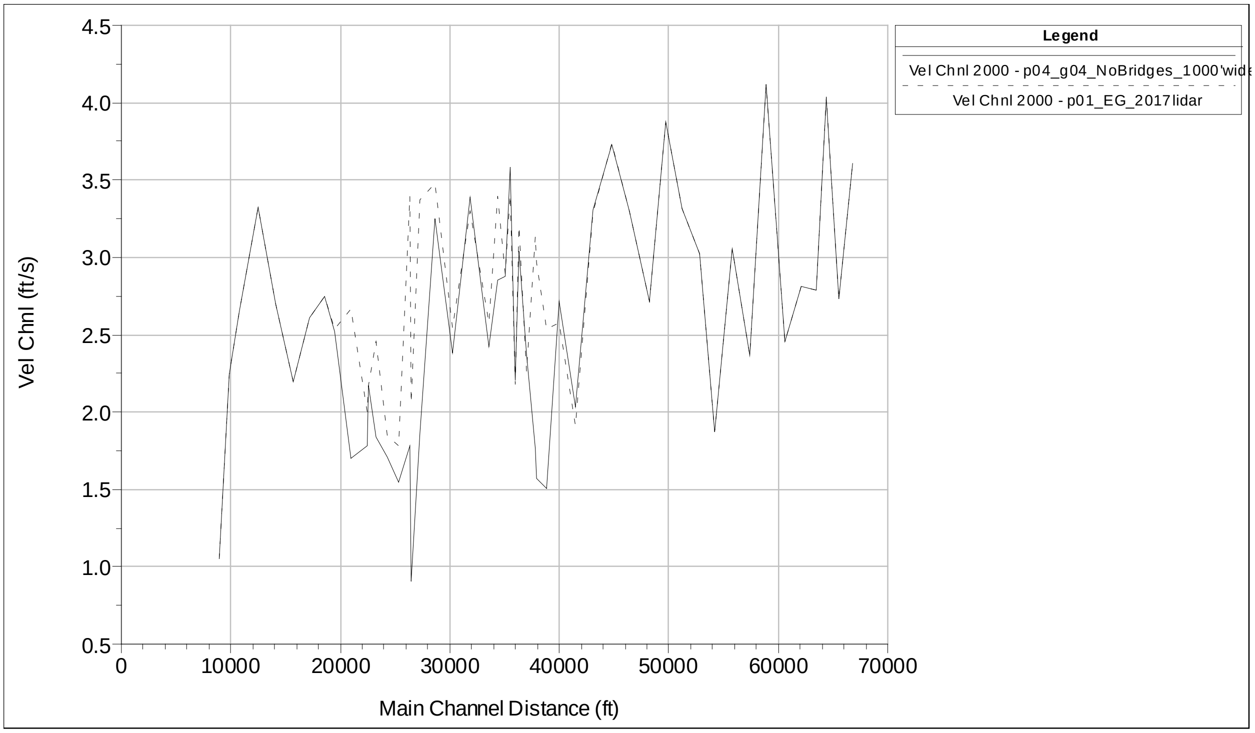


Figure B-3-23. Velocity profiles for bridge modification Scenario 4 – openings widened to 1000 feet (solid line) compared with existing condition (dashed line).

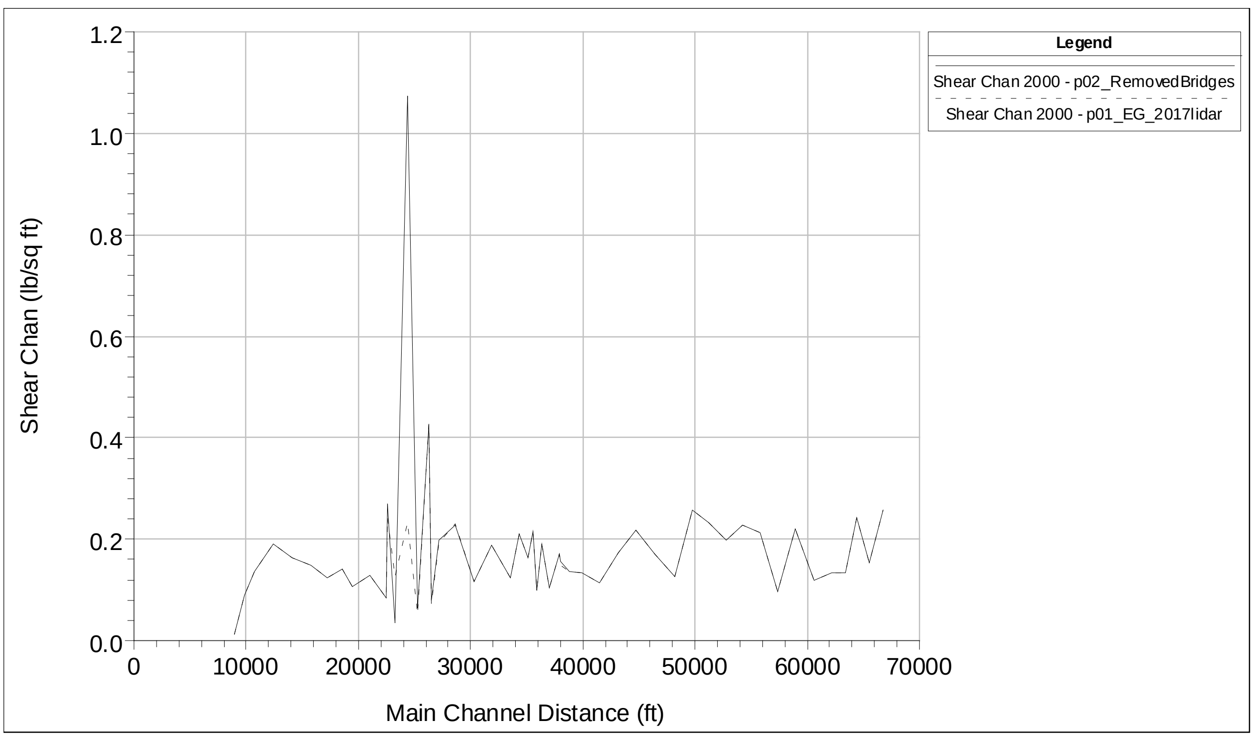


Figure B-3-24. Channel-average shear stress profiles for bridge modification Scenario 2 – bridge structures removed (solid line) compared with existing condition (dashed line).

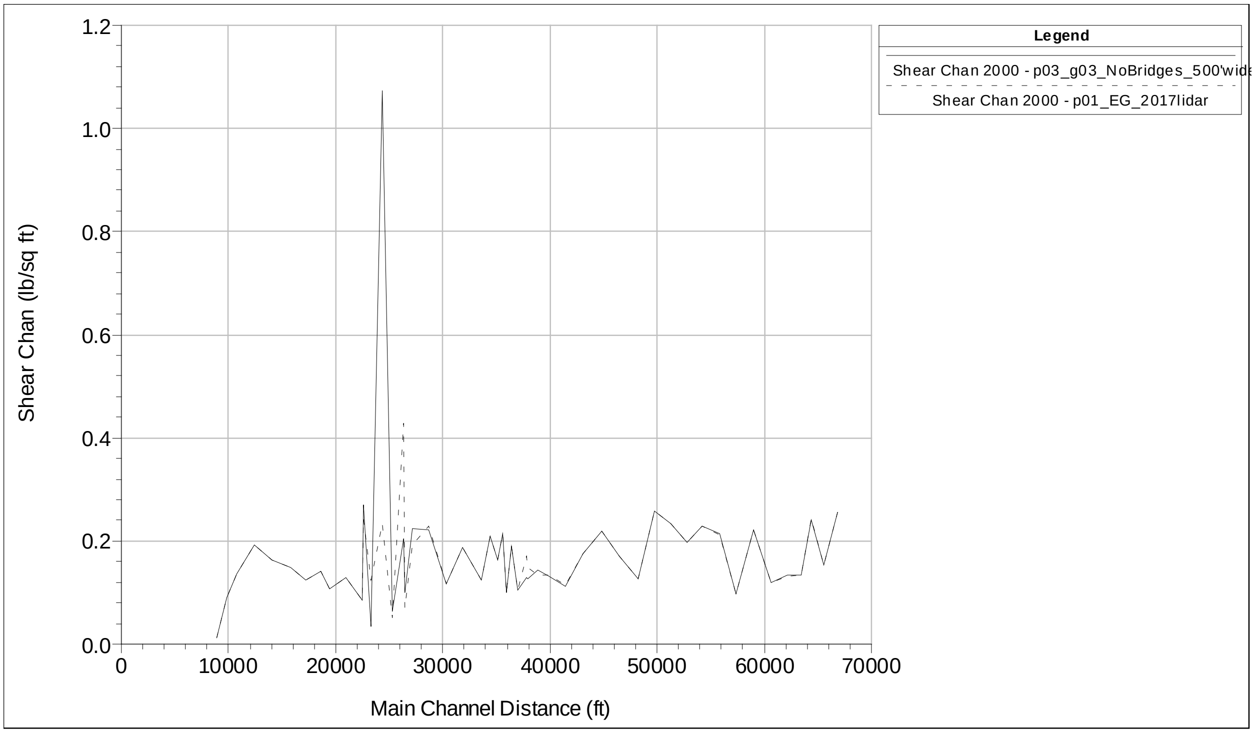


Figure B-3-25. Channel-average shear stress profiles for bridge modification Scenario 3 – openings widened to 500 feet (solid line) compared with existing condition (dashed line).

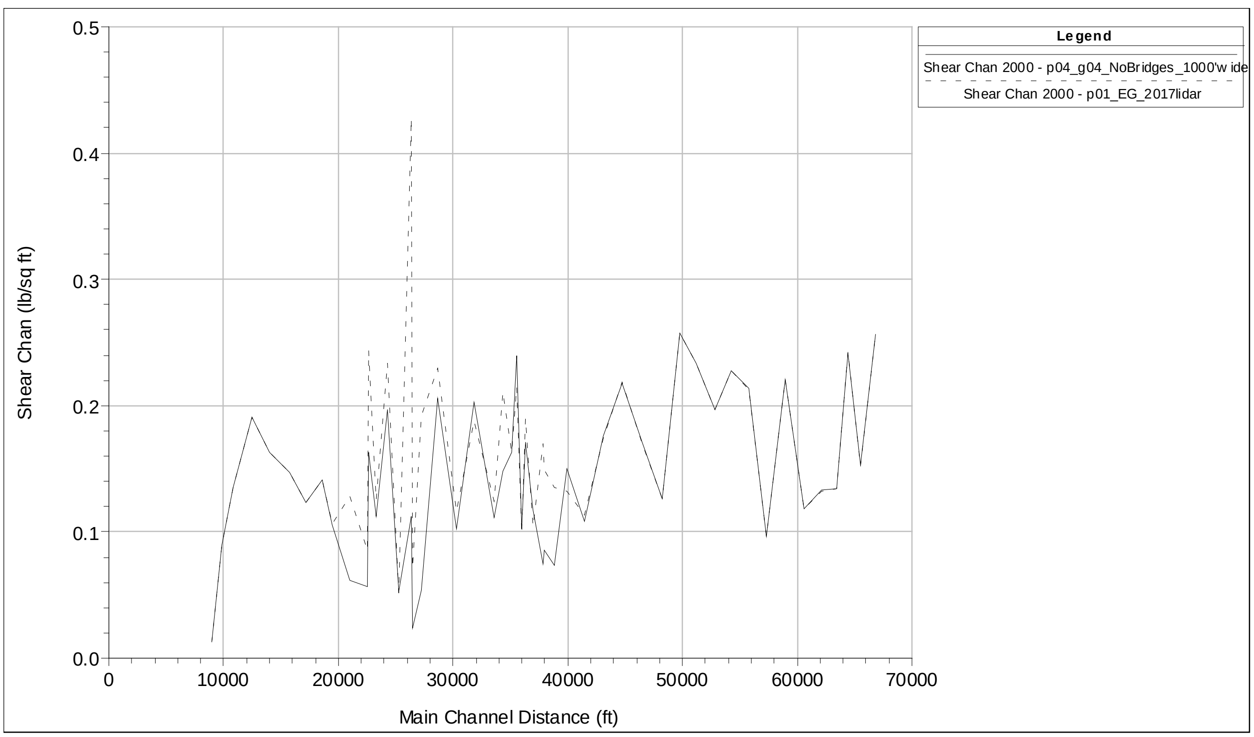


Figure B-3-26. Channel-average shear stress profiles for bridge modification Scenario 4 – openings widened to 1000 feet (solid line) compared with existing condition (dashed line).

B-3.11.2 Tri-County Canal Diversion and Sediment Removal (Scenarios 5 – 8)

The effects of the Tri-County Canal Diversion Dam were analyzed by modifying the model geometry to simulate removal of the dam and removal of the accumulated sediment wedge in the reach upstream of the dam (Figure B-3-27). The model geometry was extended approximately one mile downstream of the dam to enable analysis of these effects. For Scenario 5, the cross section representing the dam was removed to simulate the effect of dam removal. For Scenarios 6, 7 and 8, in addition to removing the dam, the channel upstream of the diversion was lowered to match the approximate pre-dam reach slope of 0.0012 ft/ft. This slope is similar to the historical slope of the lower portion of the North Platte River of 0.00126 ft/ft reported in Simons and Associates (2012). The channel width was modeled as 200 feet for Scenario 6, 500 feet for Scenario 7, and 1,000 feet for Scenario 8.

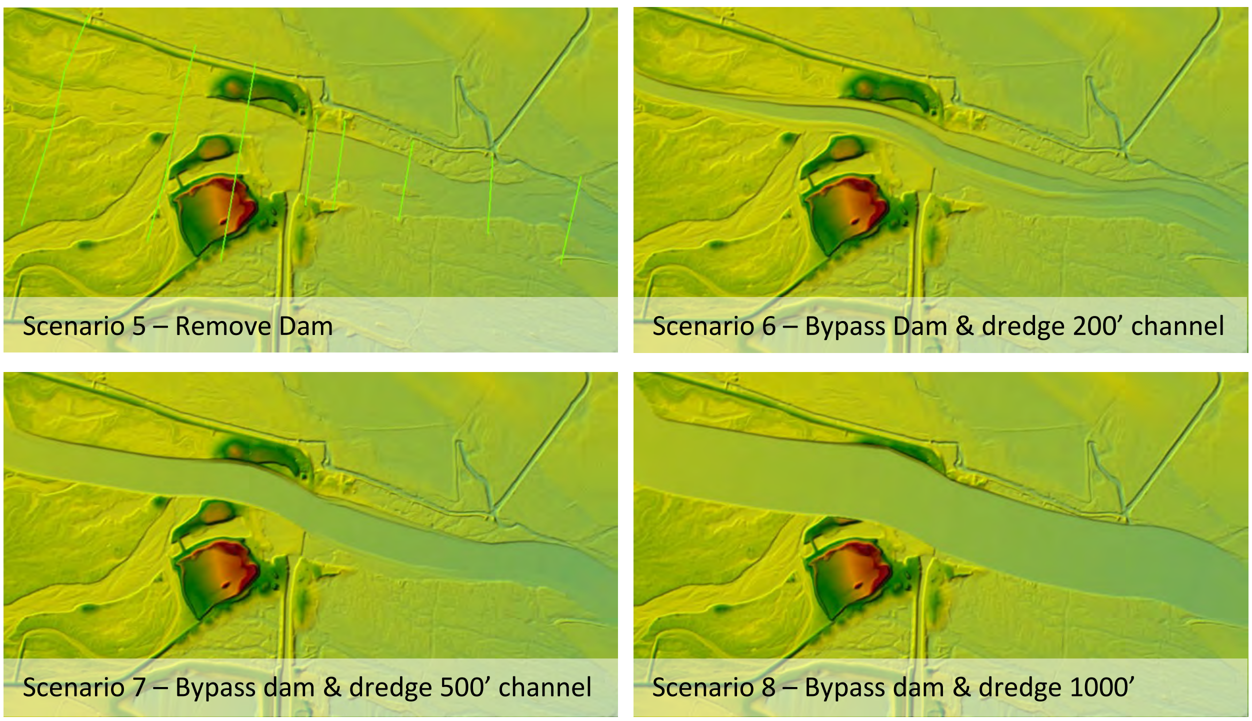


Figure B-3-27. Example terrain data for Tri-County Canal Diversion and sediment removal scenarios.

The dam removal and sediment removal scenario results were compared to determine the effect of the dam on water surface elevations, velocities, and shear stress through the reach. Water surface elevation profiles for the sediment removal scenarios (6 – 8) are compared with the dam removal scenario (Scenario 5) in Figures B-3-28 through B-3-30. The dam removal scenario is the same as existing conditions with the exception that the model has been extended downstream and the cross section immediately upstream of the dam was removed which resulted in only localized effects on water surface elevations.

Removing the dam resulted in maximum changes in water surface elevation of -1.3 to -3.4 feet with effects extending between 1.0 and 1.3 miles upstream of the dam. Removing the accumulated sediment wedge resulted in changes in water surface elevations, velocities and shear stress with effects beginning downstream of the dam about one mile and extending about two miles upstream of the Highway 83 bridge, for a total distance of between 7.4 and 8.6 miles. The combination of removing the dam and lowering the channel resulted in changes in water surface elevations ranging from -4.0 feet to -8.6 feet across all scenarios and flows (Figure B-3-31). Channel-average velocity and shear stress profiles are plotted for each scenario at a flow of 2,000 cfs in Figures B-3-32 through B-3-37.

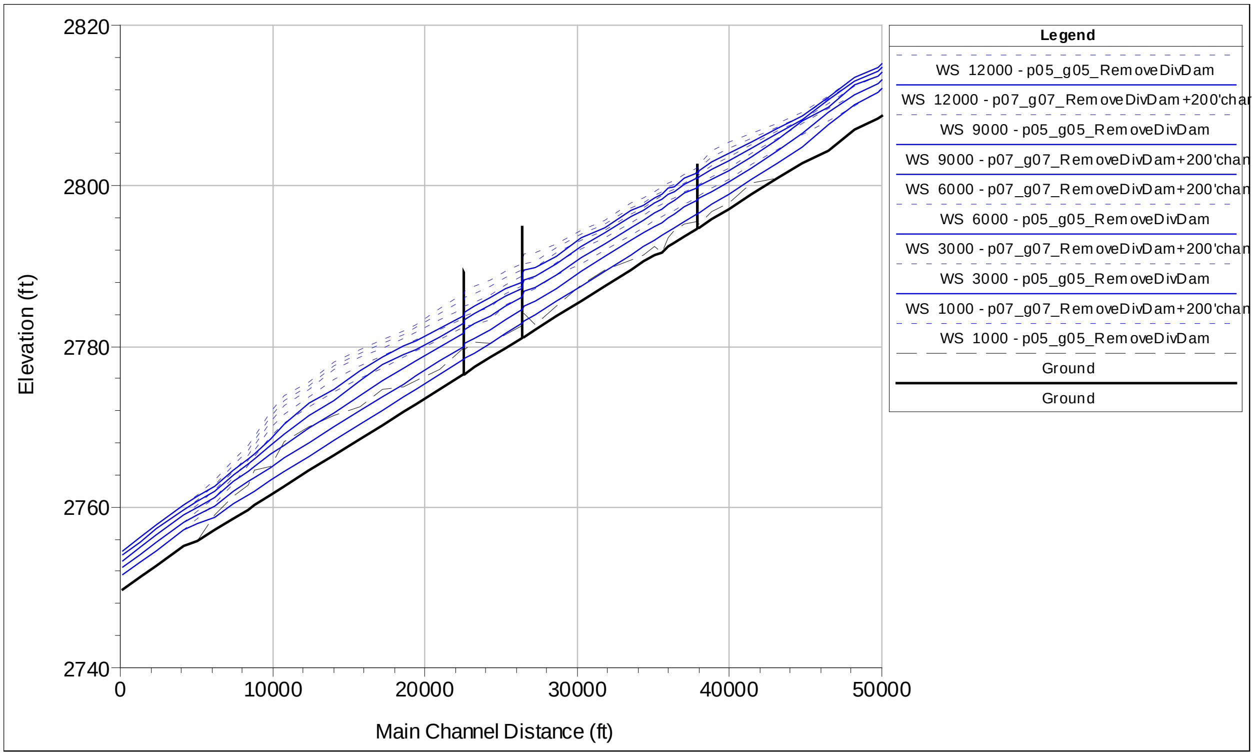


Figure B-3-28. Water surface elevation profiles for sediment removal Scenario 6 – 200' wide channel (solid lines) compared with Scenario 5 – diversion removed (dashed lines).

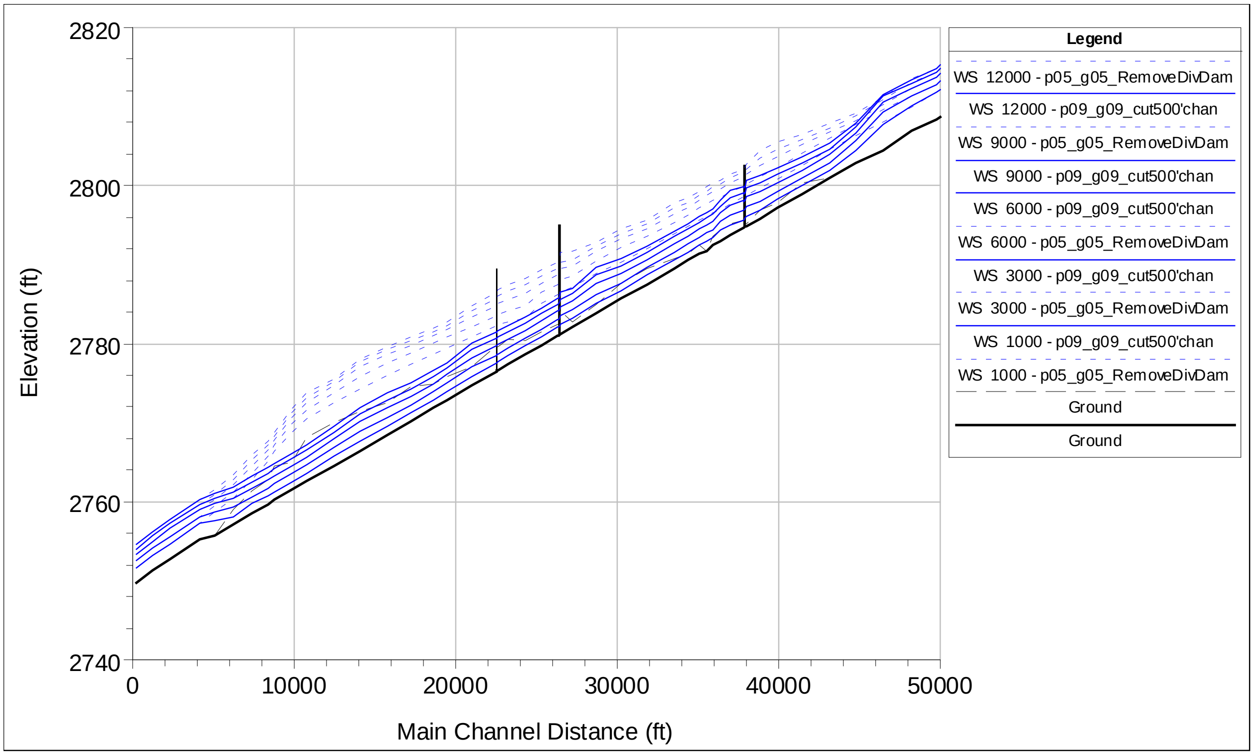


Figure B-3-29. Water surface elevation profiles for sediment removal Scenario 7 – 500' wide channel (solid lines) compared with Scenario 5 – diversion removed (dashed lines).

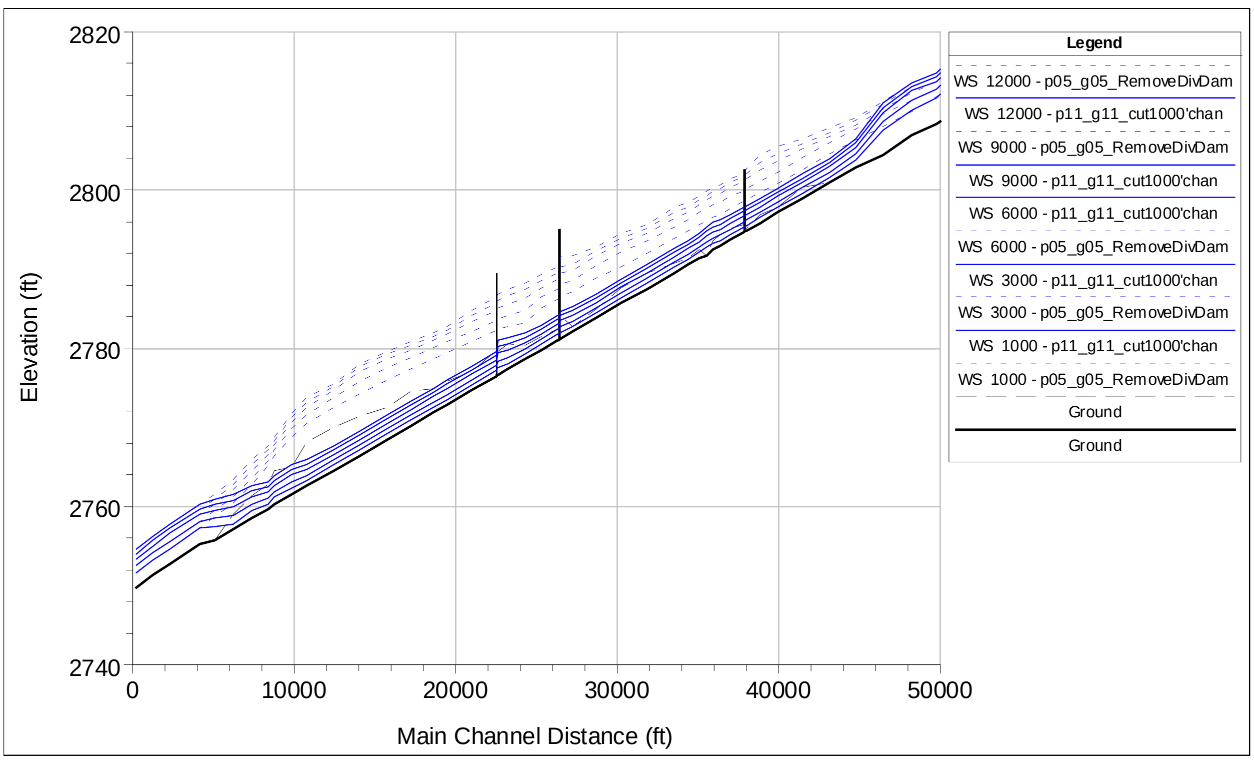


Figure B-3-30. Water surface elevation profiles for sediment removal Scenario 8 – 1000' wide channel (solid lines) compared with Scenario 5 – diversion removed (dashed lines).

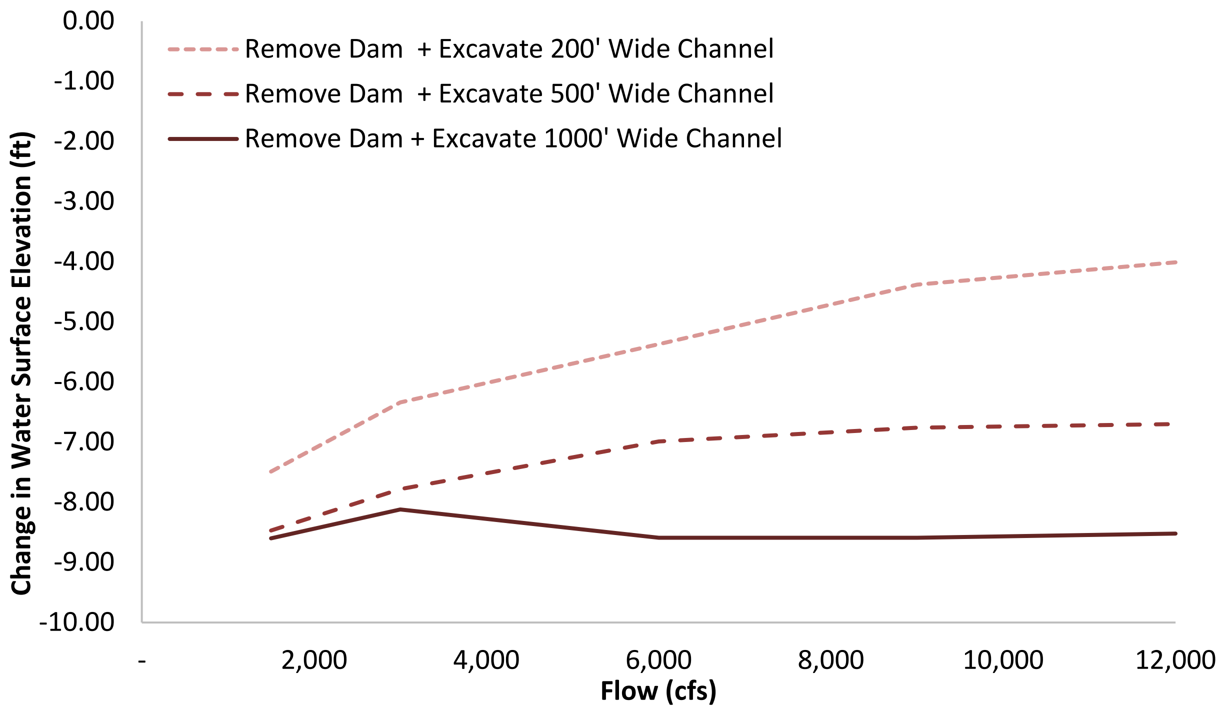


Figure B-3-31. Change in water surface elevation for sediment removal scenarios.

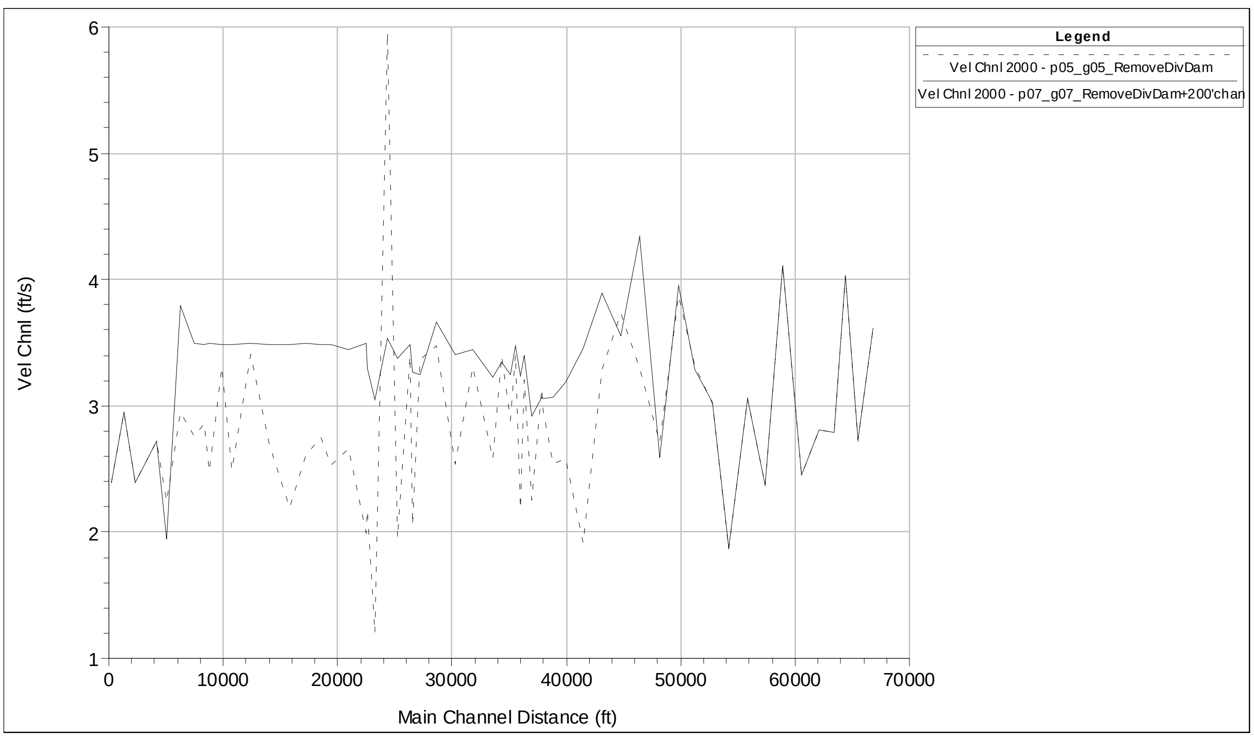


Figure B-3-32. Velocity profiles for sediment removal Scenario 6 – 200' wide channel (solid line) compared with Scenario 5 – diversion removed (dashed line).

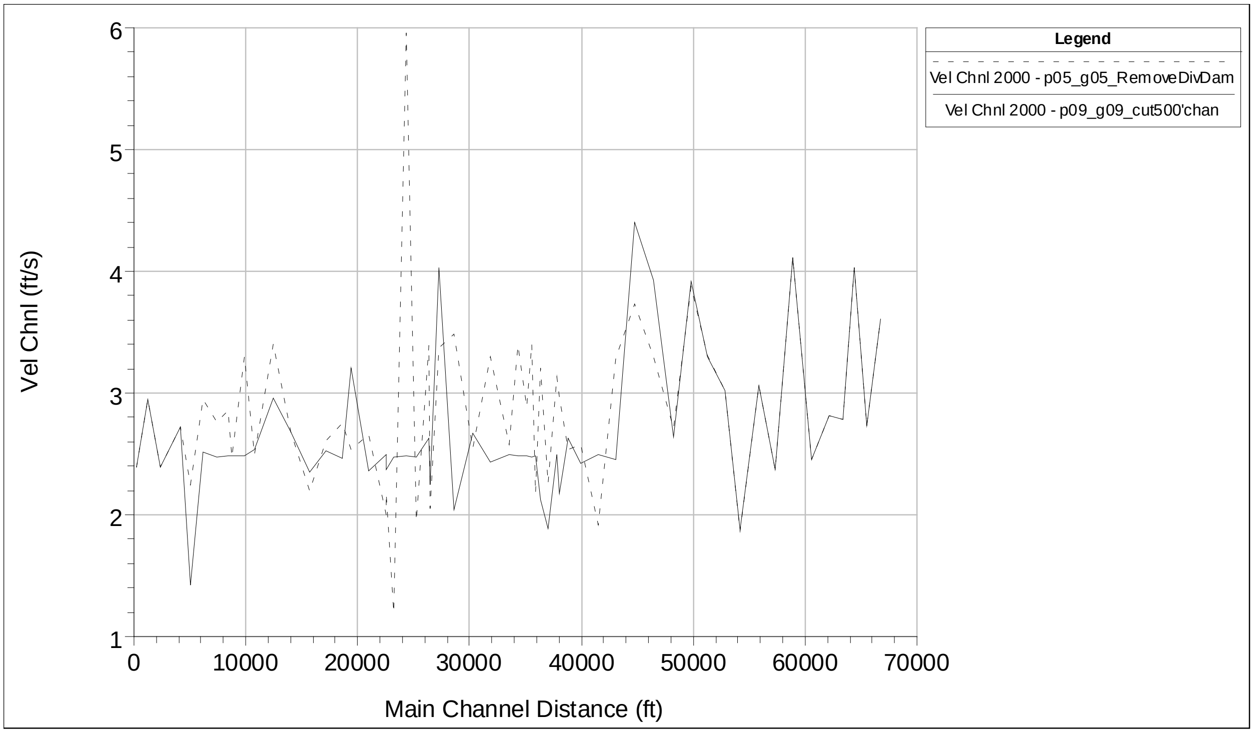


Figure B-3-33. Velocity profiles for sediment removal Scenario 7 – 500' wide channel (solid line) compared with Scenario 5 – diversion removed (dashed line).

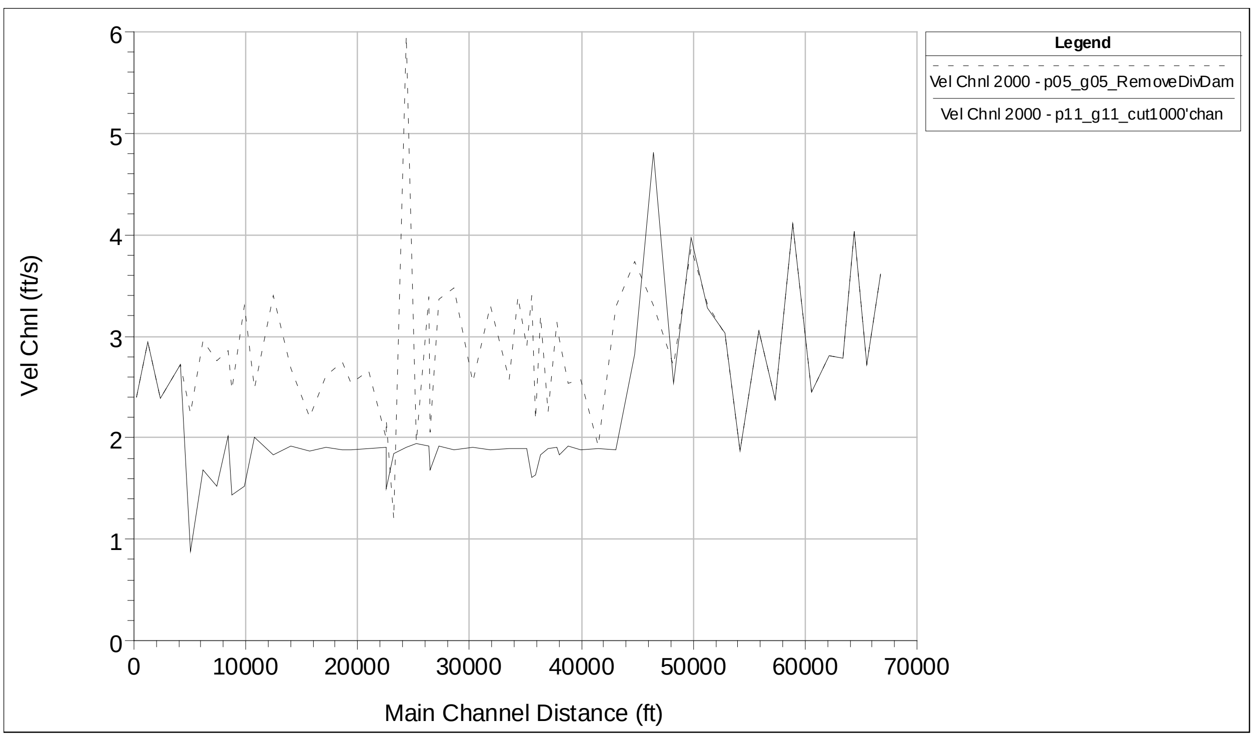


Figure B-3-34. Velocity profiles for sediment removal Scenario 8 – 1000' wide channel (solid line) compared with Scenario 5 – diversion removed (dashed line).

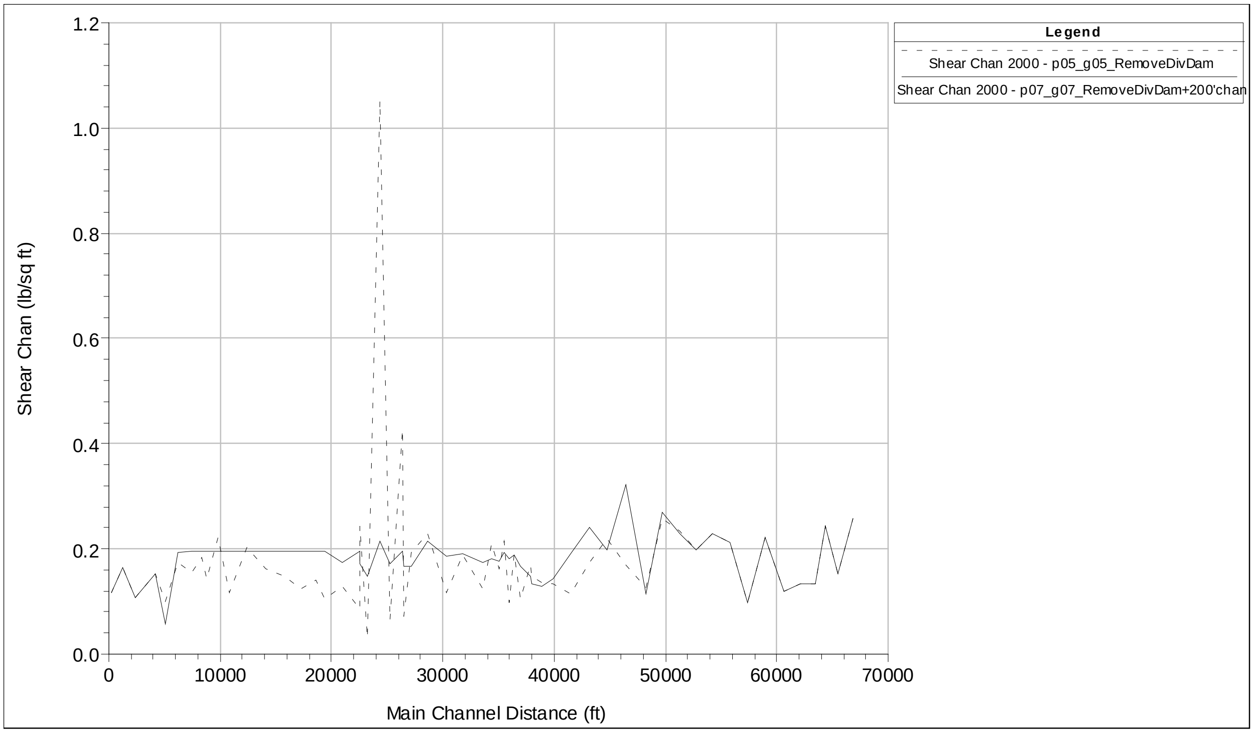


Figure B-3-35. Channel-average shear stress profiles for sediment removal Scenario 6 – 200' wide channel (solid line) compared with Scenario 5 – diversion removed (dashed line).

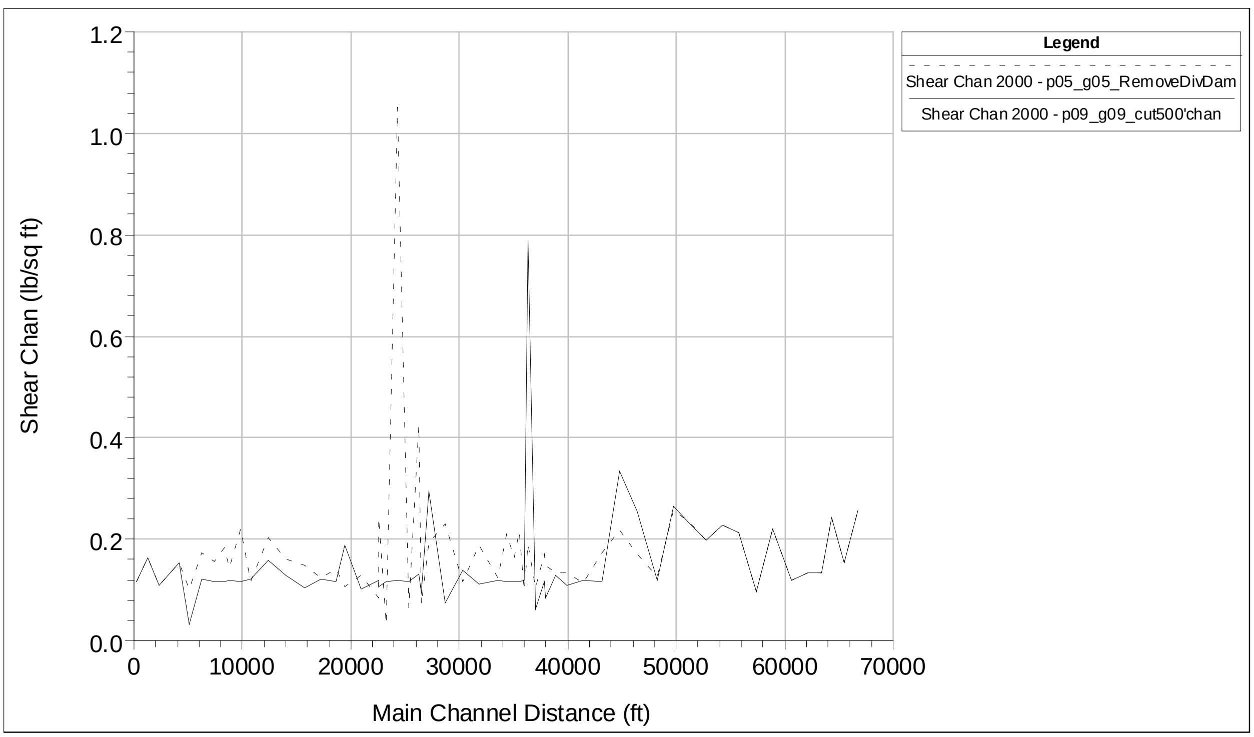


Figure B-3-36. Channel-average shear stress profiles for Scenario 7 – 500' wide channel (solid line) compared with Scenario 5 – diversion removed (dashed line).

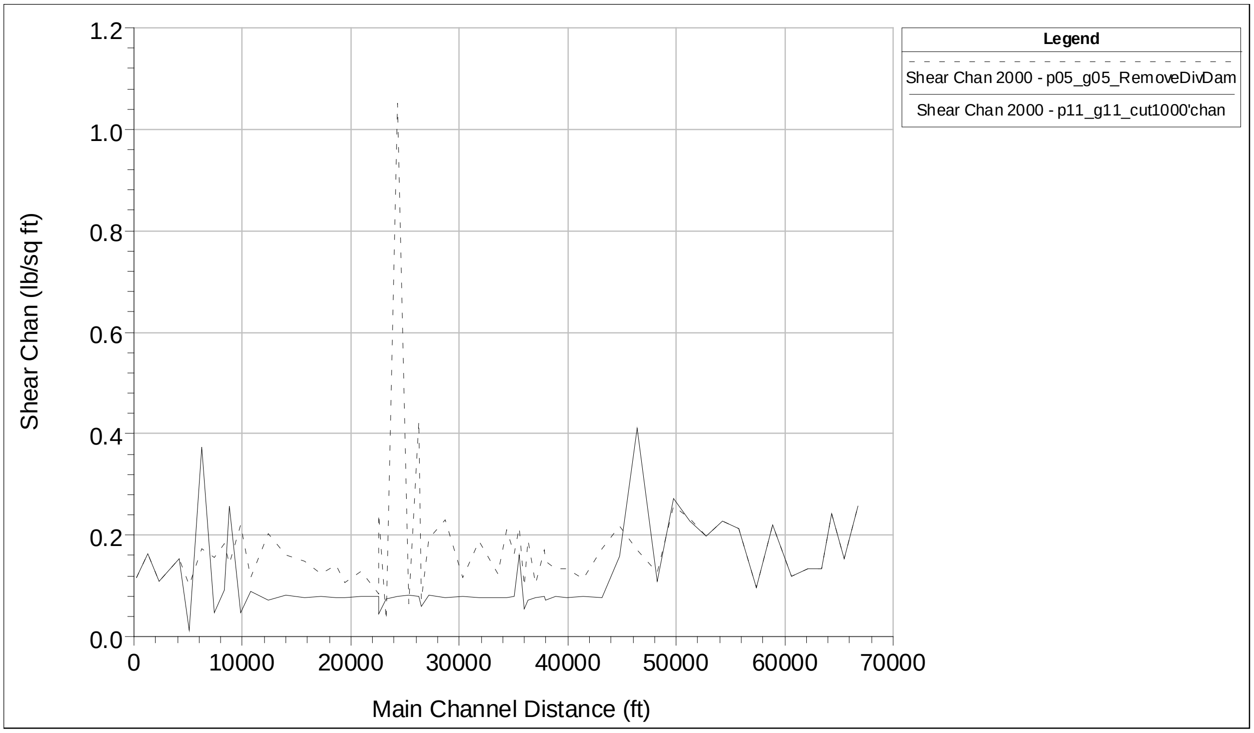


Figure B-3-37. Channel-average shear stress profiles sediment removal Scenario 8 – 1000' wide channel (solid line) compared with Scenario 5 – diversion removed (dashed line).

B-3.11.3 Vegetation Removal (Scenarios 9 – 10)

Given the documented impacts of vegetation on sediment transport on the main stem Platte River, the effects of continued vegetation removal on channel capacity and sediment transport in the Chokepoint reach were evaluated. Incremental changes in roughness were made in the model geometry to evaluate the effect of vegetation removal (Figure B-3-38). Results were compared to existing conditions to measure the effect of vegetation removal.

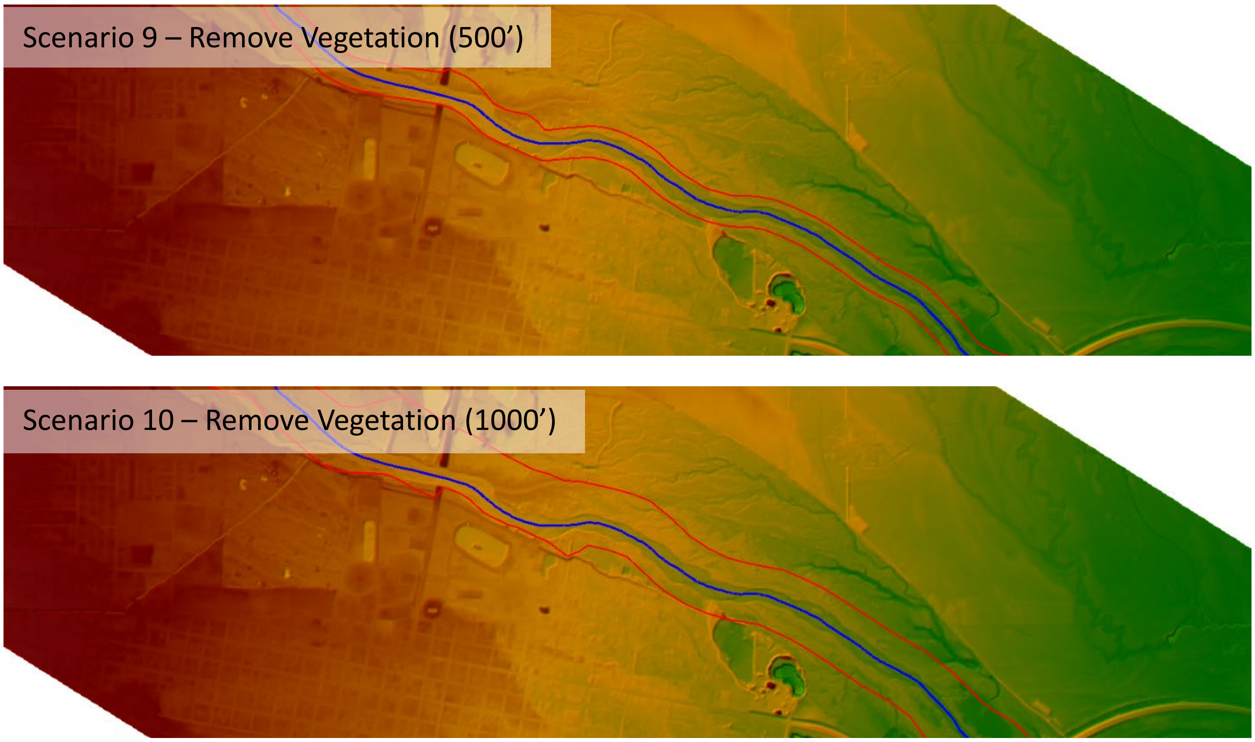


Figure B-3-38. Example geometry data for vegetation removal scenarios. Red lines indicate extent of roughness adjusted to simulate vegetation removal.

The results were compared with the existing conditions model to determine the effect of the vegetation removal on water surface elevations, velocities, and shear stress through the reach. Water surface elevation profiles for the vegetation removal scenarios (9 – 10) are compared with the existing conditions in Figures B-3-39 and B-3-40. Vegetation removal resulted in maximum changes in water surface elevation of -0.20 to -0.75 feet (Figure B-3-41) with effects extending through the entire reach. Channel-average velocity and shear stress profiles are plotted for each scenario at a flow of 2,000 cfs in Figures B-3-42 through B-3-45.

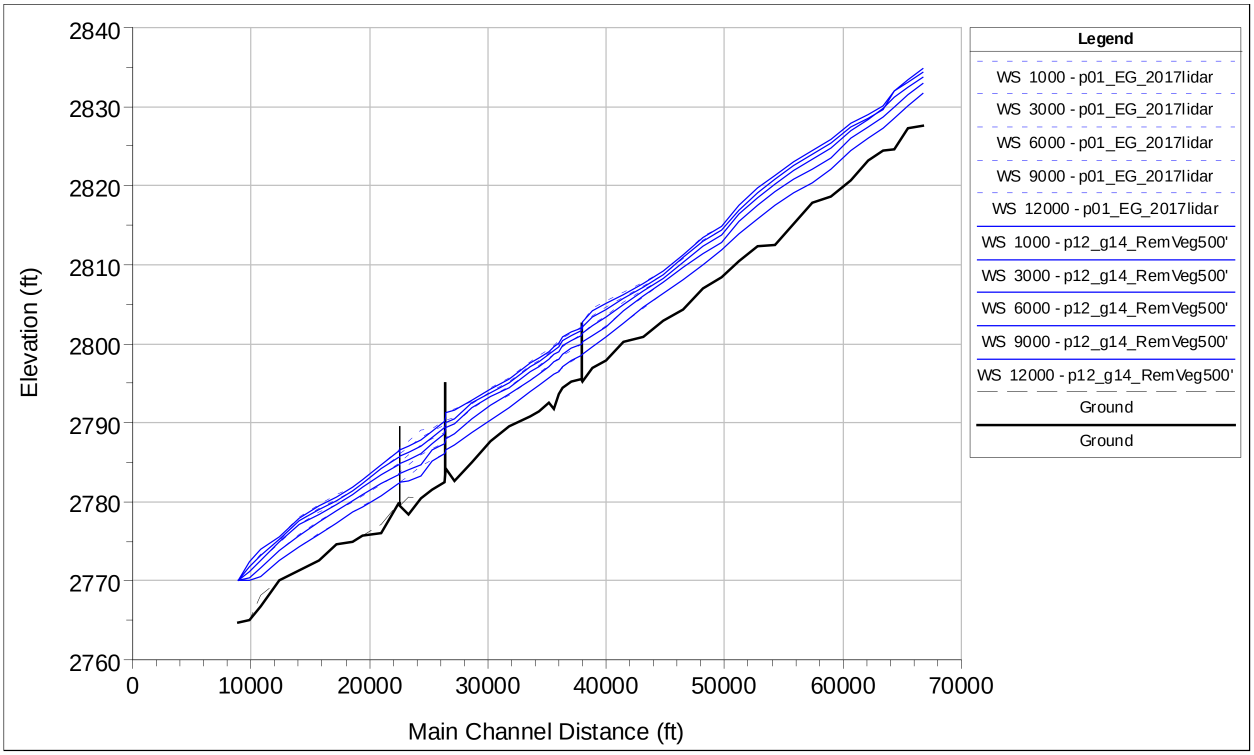


Figure B-3-39. Water surface elevation profiles for vegetation removal Scenario 9 – 500' wide (solid lines) compared with existing condition (dashed lines).

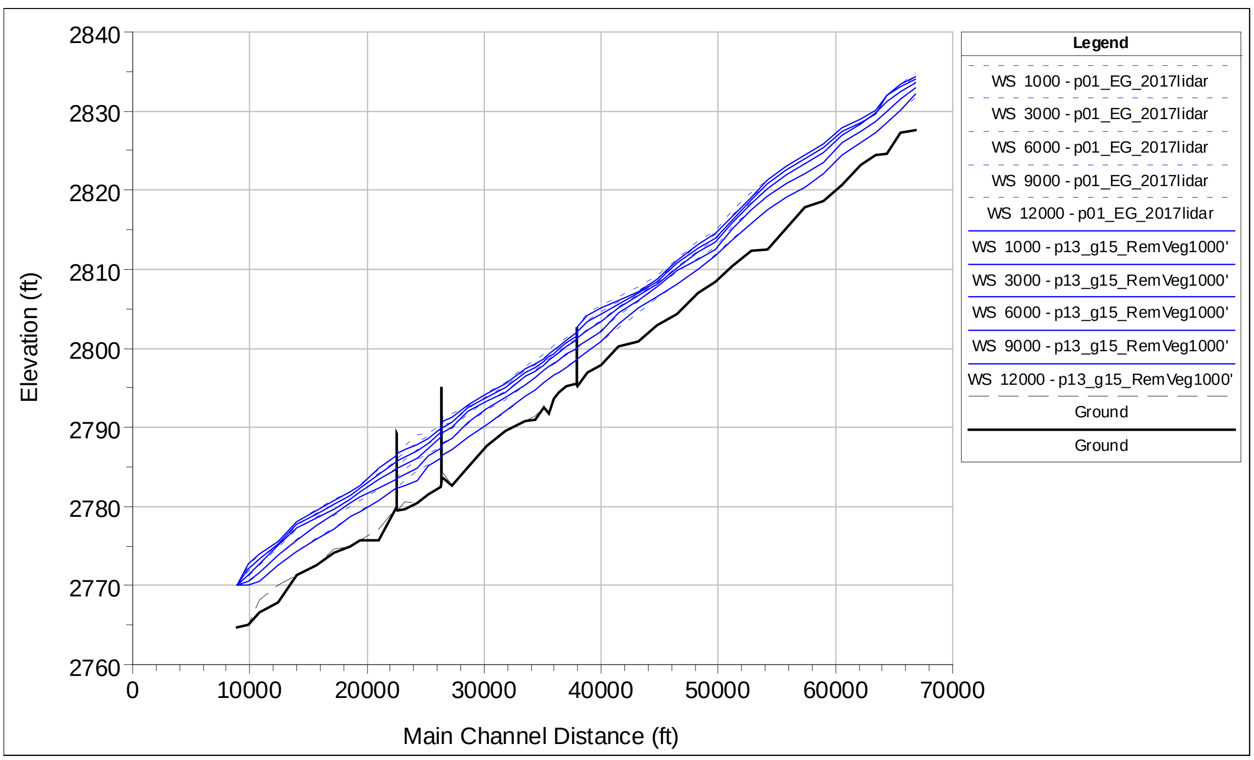


Figure B-3-40. Water surface elevation profiles for vegetation removal Scenario 10 – 1000' wide (solid lines) compared with existing condition (dashed lines).

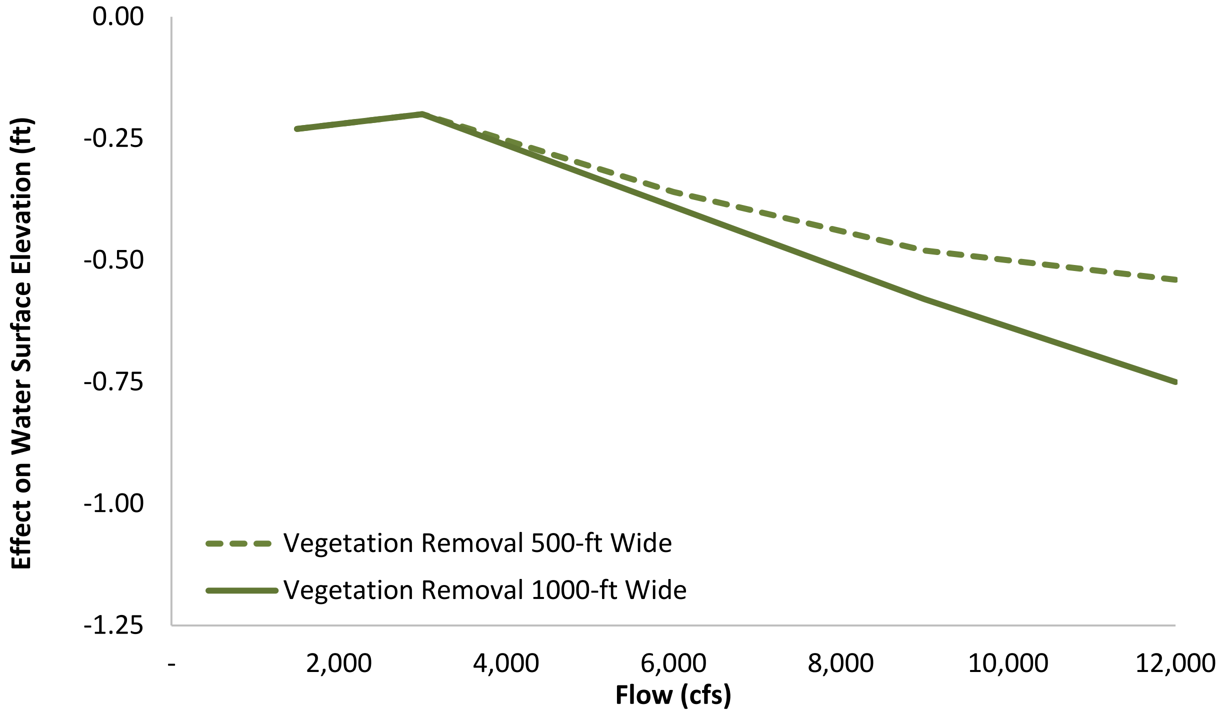


Figure B-3-41. Change in water surface elevation for vegetation removal scenarios.

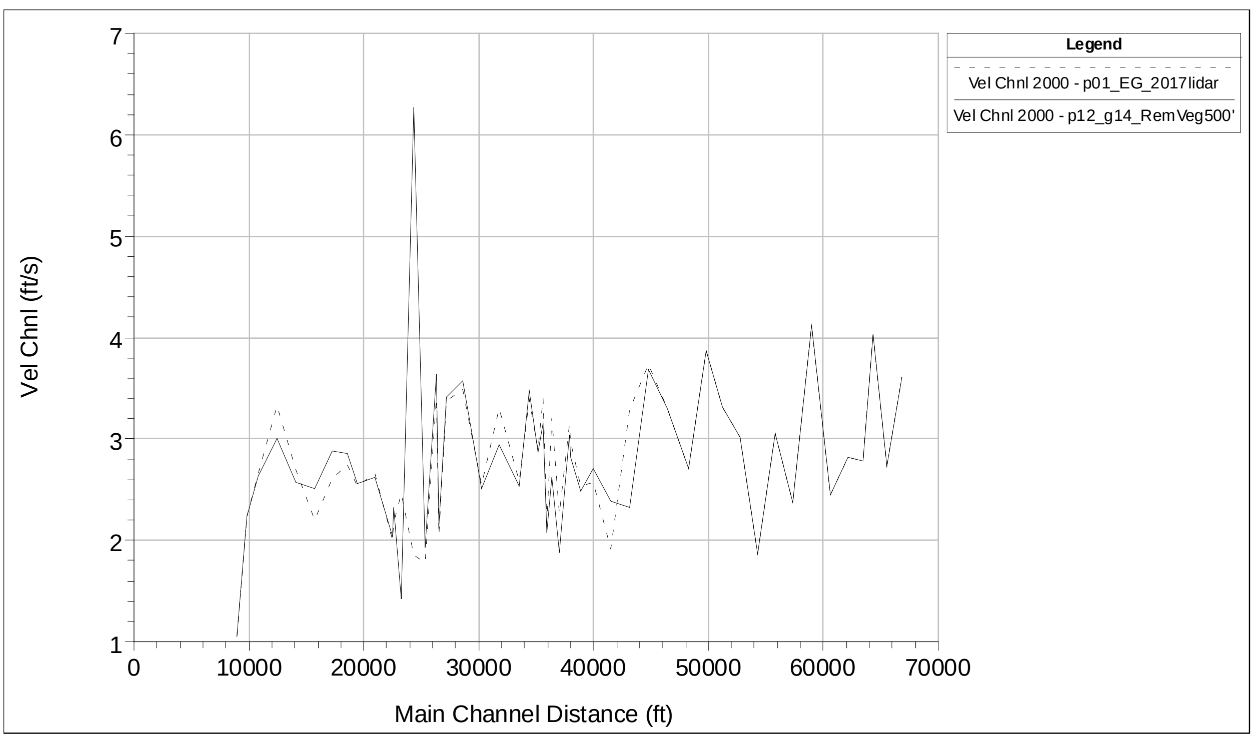


Figure B-3-42. Velocity profiles for vegetation removal Scenario 9 – 500’ wide (solid line) compared with existing condition (dashed line).

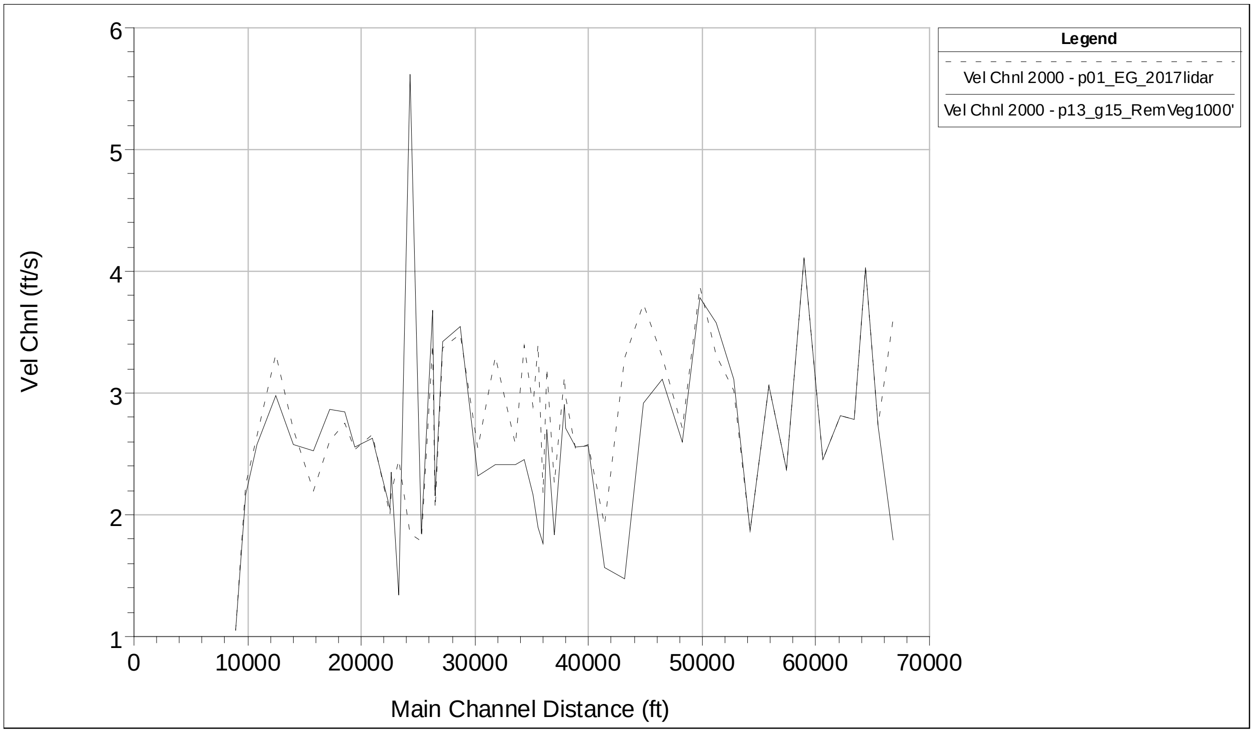


Figure B-3-43. Velocity profiles for vegetation removal Scenario 10 – 1000' wide (solid line) compared with existing condition (dashed line).

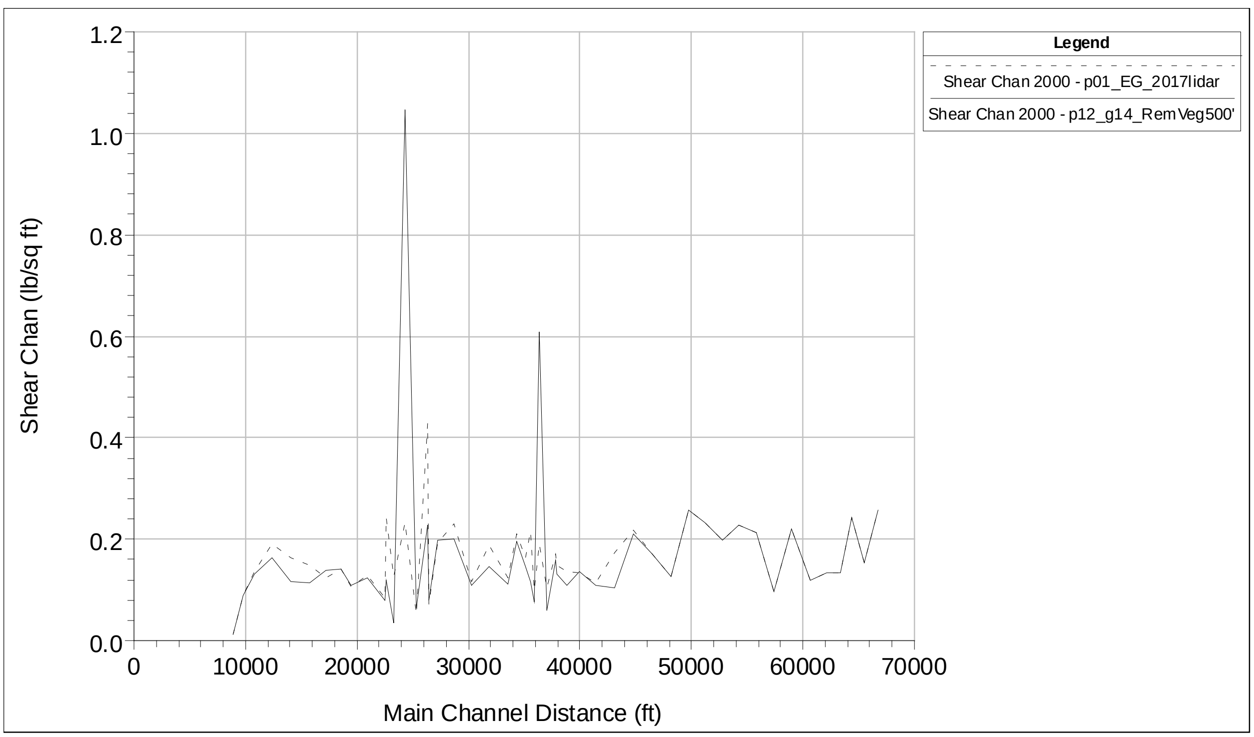


Figure B-3-44. Channel-average shear stress profiles for vegetation removal Scenario 9 – 500' wide (solid line) compared with existing condition (dashed line).

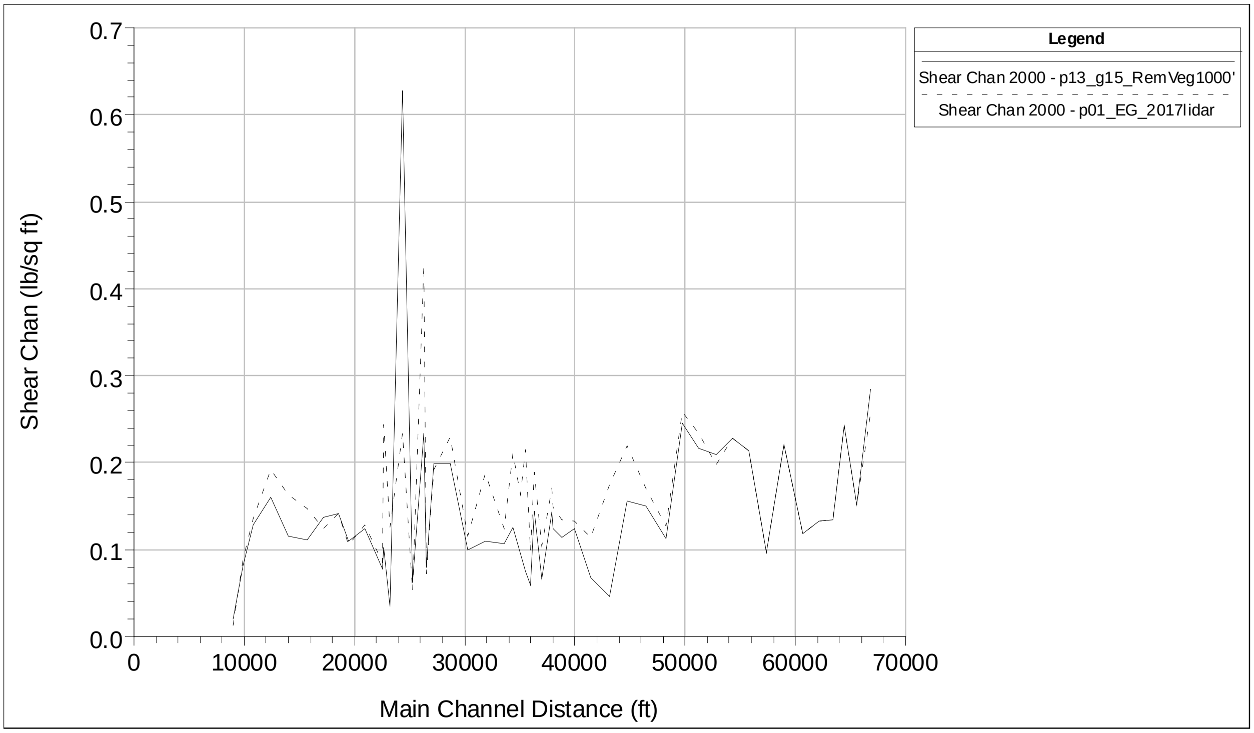


Figure B-3-45. Channel-average shear stress profiles for vegetation removal Scenario 10 – 1000' wide (solid line) compared with existing condition (dashed line).

B-4. References

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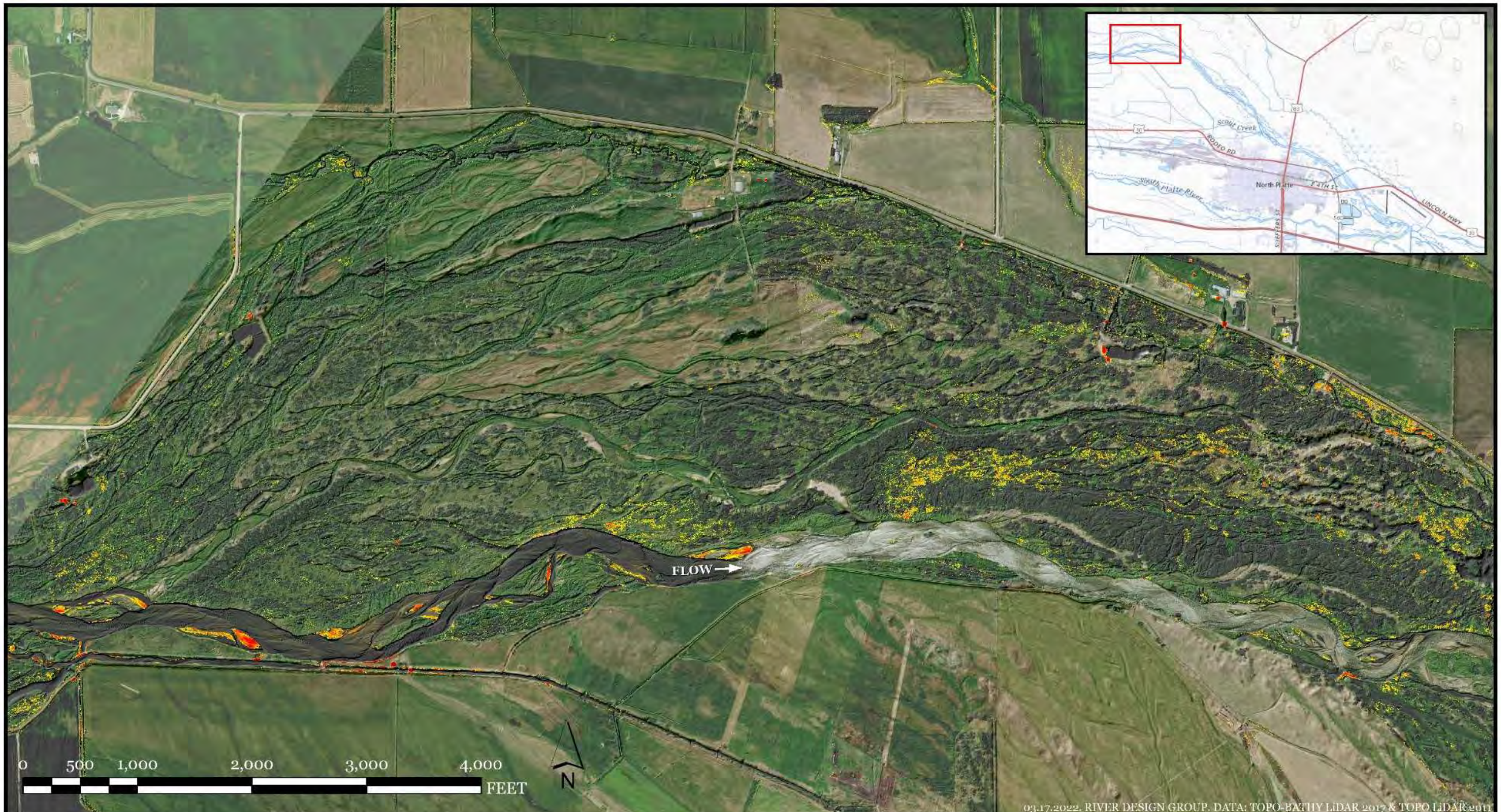
APPENDIX C

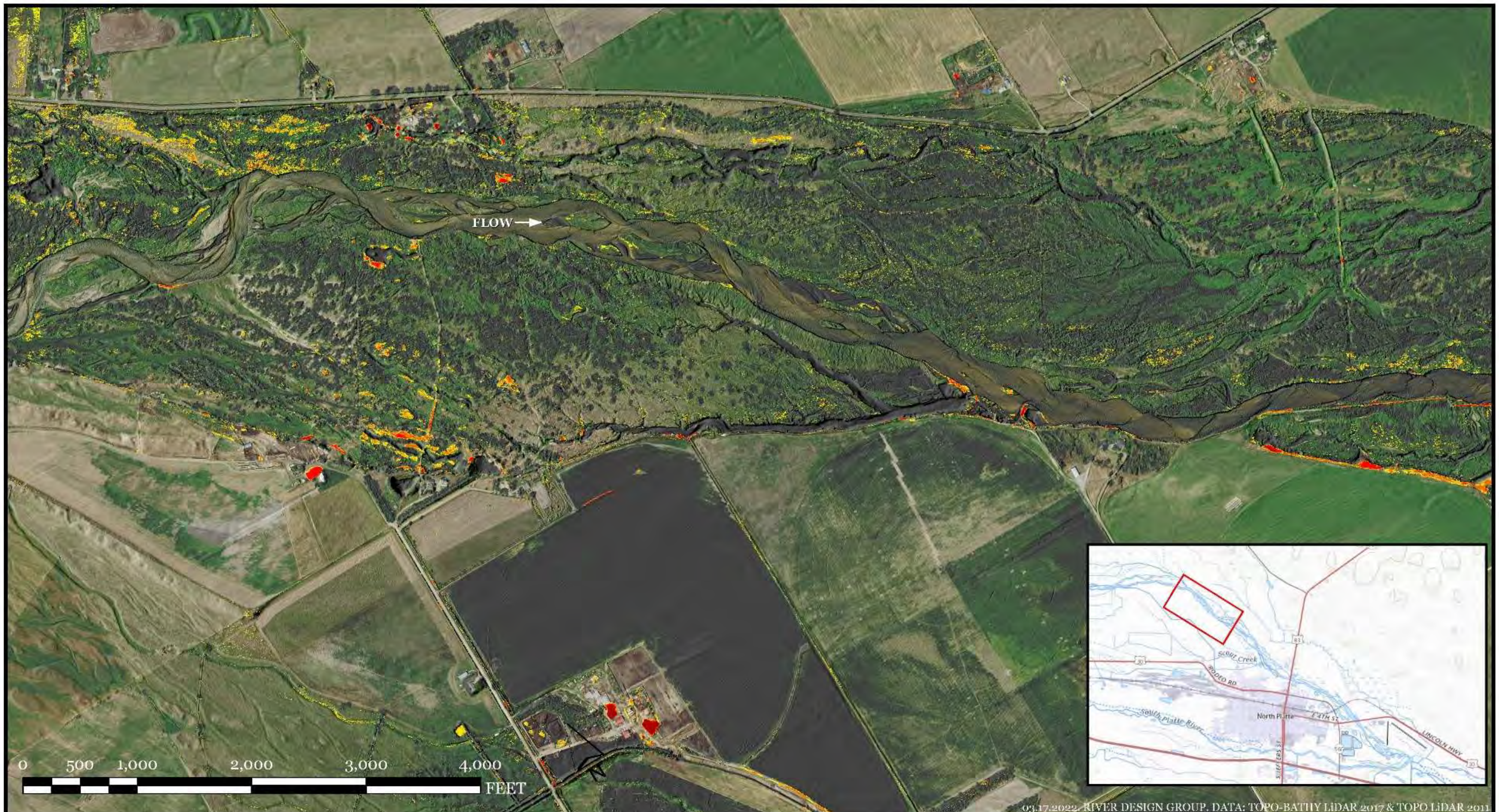
GEOMORPHIC CHANGE DETECTION MAPS



NORTH PLATTE RIVER
CHOKEPOINT INVESTIGATION

GEOMORPHIC CHANGE DETECTION

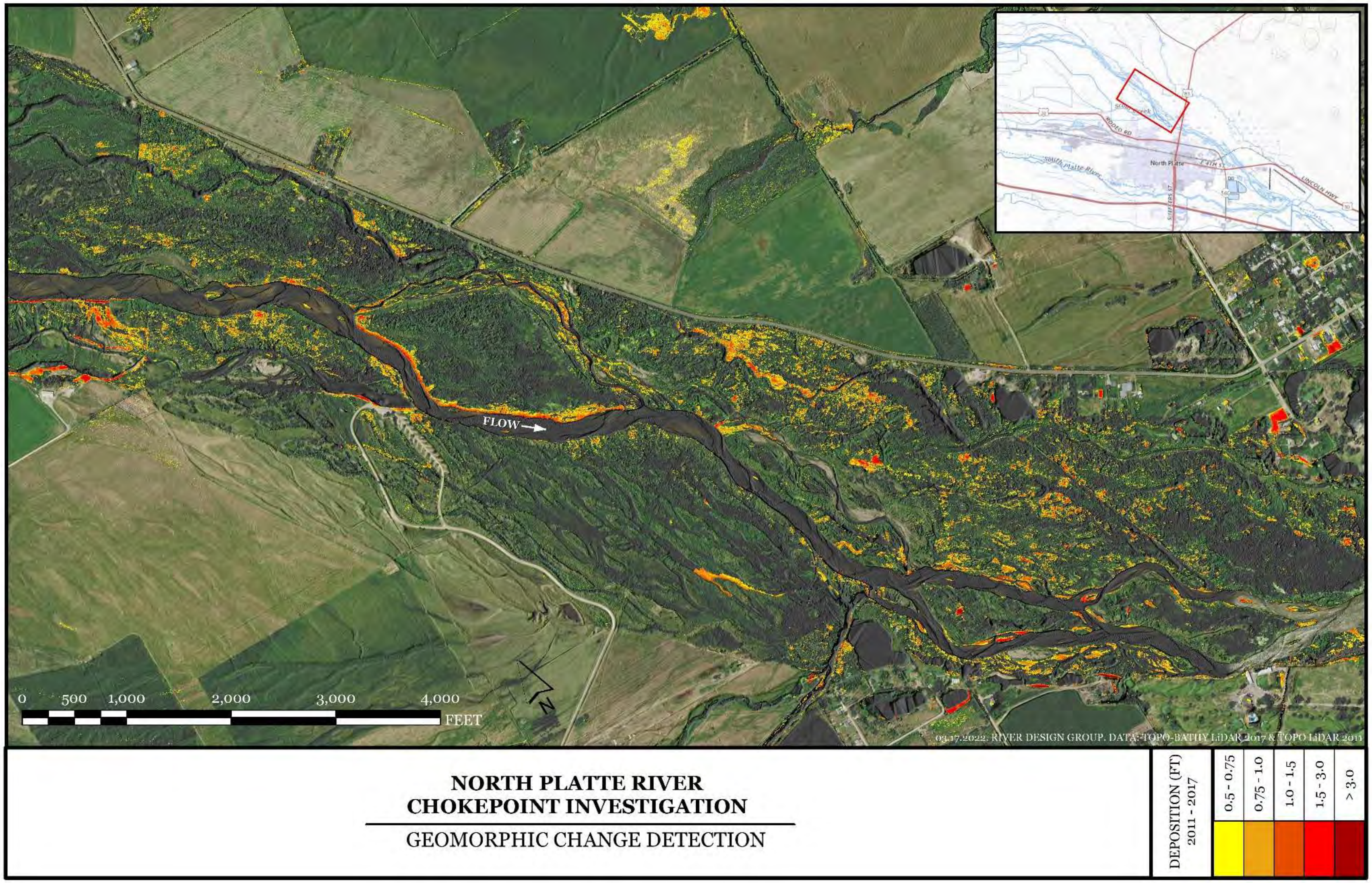
DEPOSITION (FT) 2011 - 2017	0.5 - 0.75	0.75 - 1.0	1.0 - 1.5	1.5 - 3.0	> 3.0

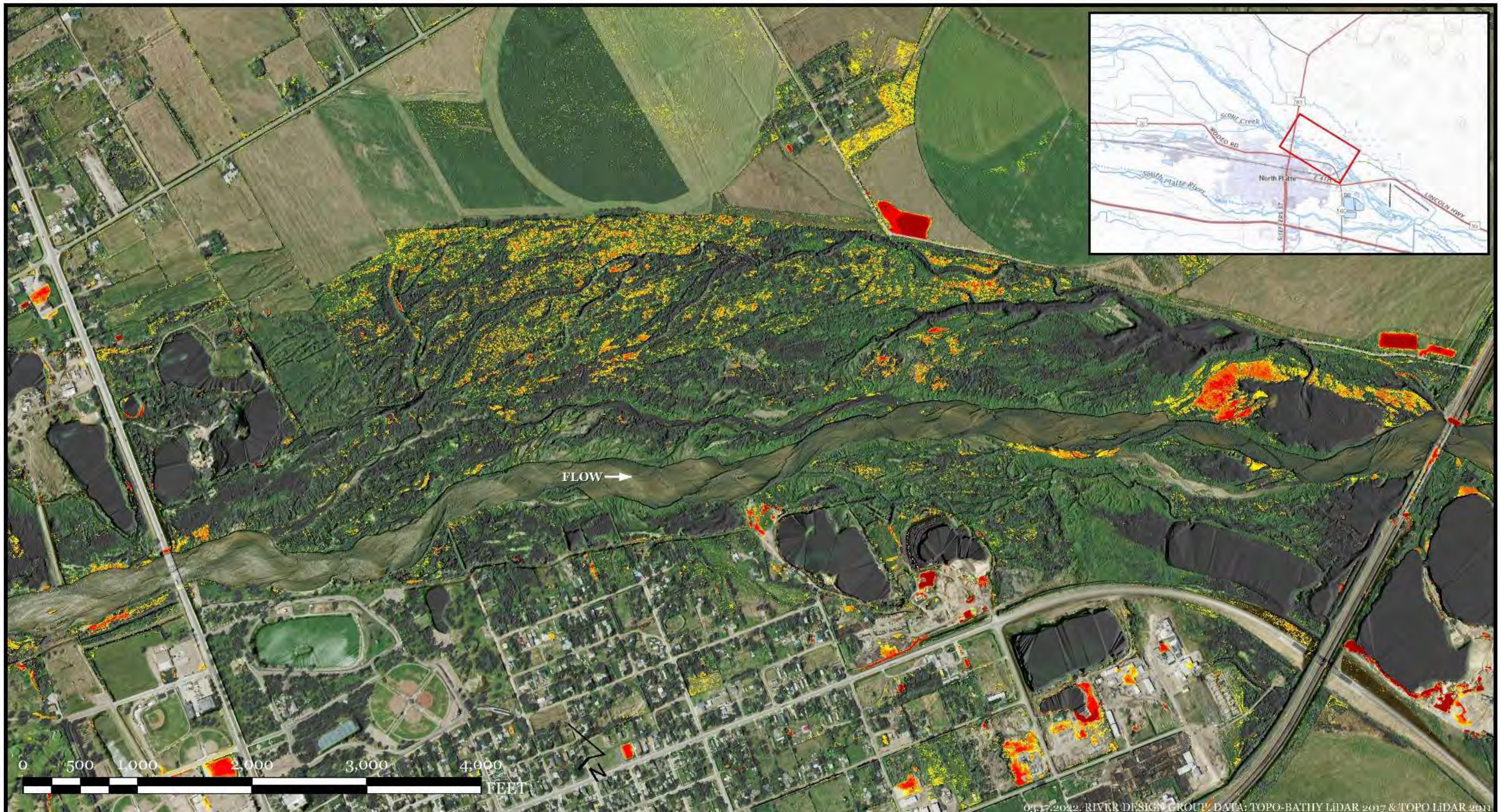


NORTH PLATTE RIVER
CHOKEPOINT INVESTIGATION

GEOMORPHIC CHANGE DETECTION

DEPOSITION (FT) 2011 - 2017	0.5 - 0.75	0.75 - 1.0	1.0 - 1.5	1.5 - 3.0	> 3.0

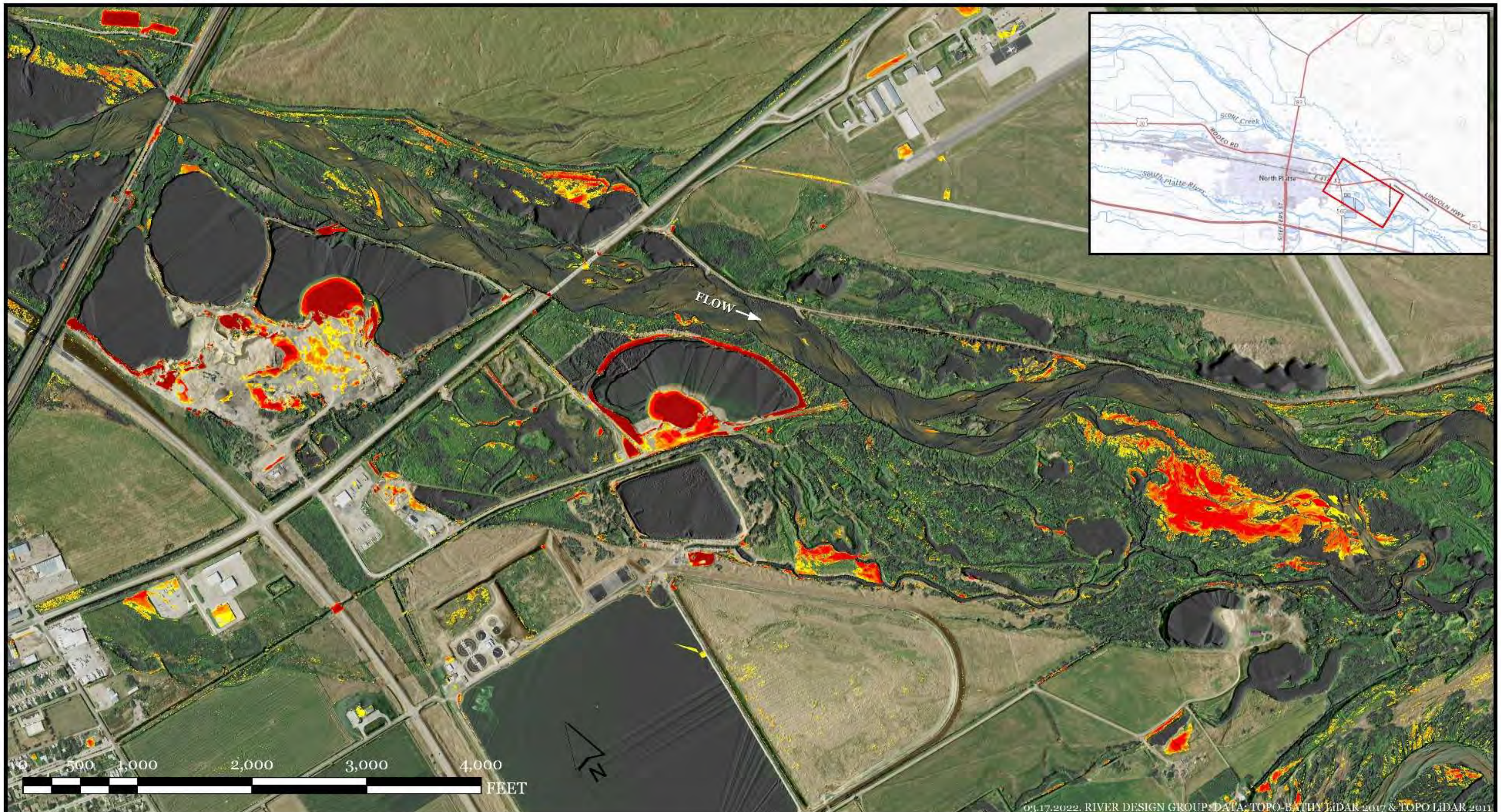

FLOW
0
500
1,000
2,000
3,000
4,000
FEET
N
03.17.2022: RIVER DESIGN GROUP. DATA: TOPO-BATHY LiDAR 2017 & TOPO LiDAR 2011
NORTH PLATTE RIVER
CHOKEPOINT INVESTIGATION
GEOMORPHIC CHANGE DETECTION
DEPOSITION (FT)
2011 - 2017
0.5 - 0.75
0.75 - 1.0
1.0 - 1.5
1.5 - 3.0
> 3.0



NORTH PLATTE RIVER
CHOKEPOINT INVESTIGATION

GEOMORPHIC CHANGE DETECTION

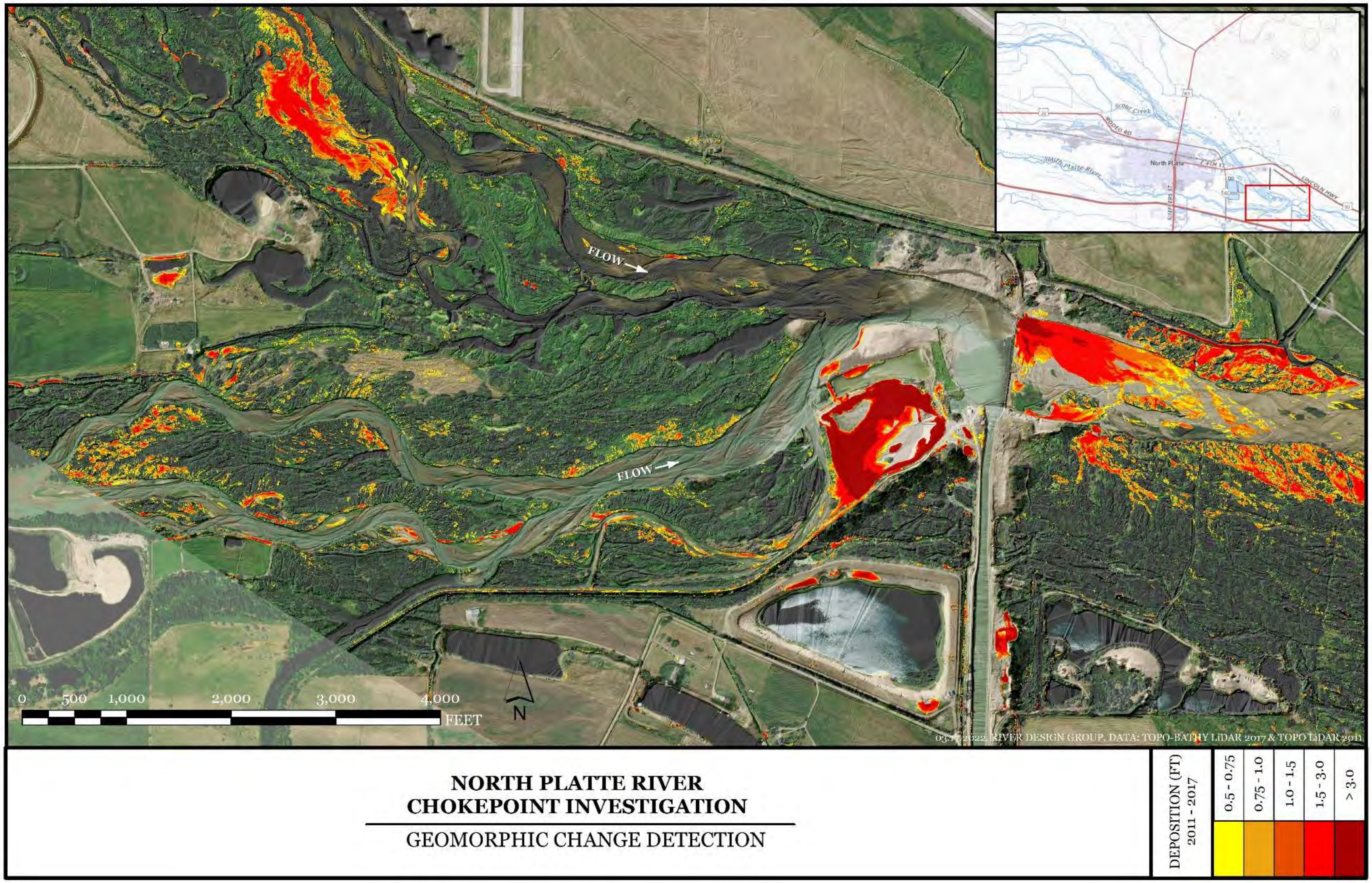
DEPOSITION (FT) 2011 - 2017	
0.5 - 0.75	yellow
0.75 - 1.0	orange
1.0 - 1.5	dark orange
1.5 - 3.0	red
> 3.0	dark red



NORTH PLATTE RIVER
CHOKEPOINT INVESTIGATION

GEOMORPHIC CHANGE DETECTION

DEPOSITION (FT) 2011 - 2017	0.5 - 0.75	0.75 - 1.0	1.0 - 1.5	1.5 - 3.0	> 3.0


FLOW
FLOW
Scout Creek
RODEO RD
South Platte River
North Platte
E 4TH ST
STEFFERS ST
LINCOLN HWY
83
30
0
500
1,000
2,000
3,000
4,000
FEET
N
03.17.2022, RIVER DESIGN GROUP, DATA: TOPO-BATHY LiDAR 2017 & TOPO LiDAR 2011
NORTH PLATTE RIVER
CHOKEPOINT INVESTIGATION
GEOMORPHIC CHANGE DETECTION
DEPOSITION (FT)
2011 - 2017
0.5 - 0.75
0.75 - 1.0
1.0 - 1.5
1.5 - 3.0
> 3.0

RDG
RIVER DESIGN GROUP

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