Platte River Recovery Implementation Program (PRRIP)

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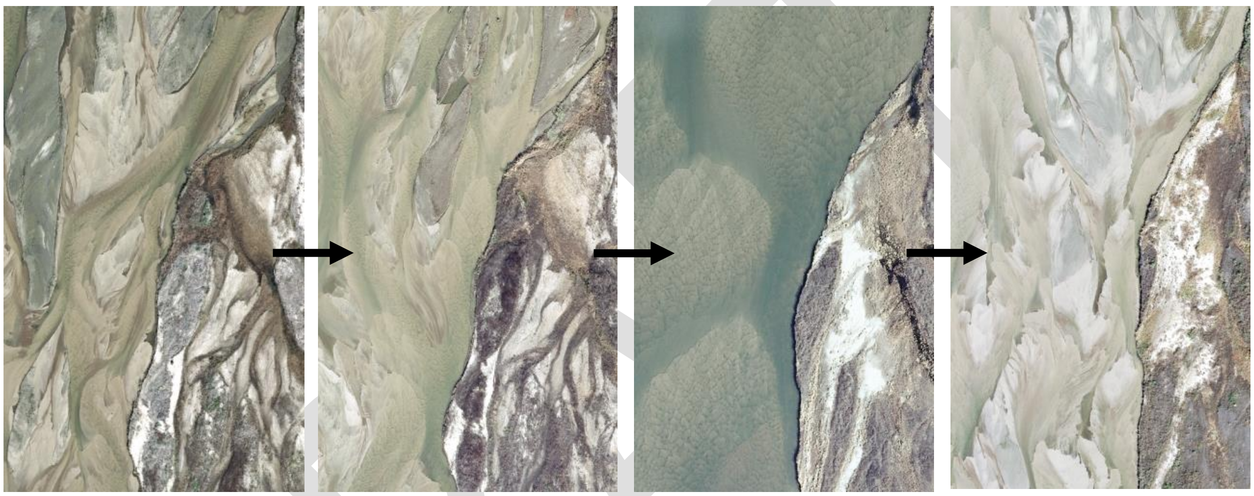
SYSTEM-SCALE GEOMORPHOLOGY AND VEGETATION MONITORING REPORT

2017 - 2020



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Executive Summary

This report documents the first implementation of the PRRIP System-Scale Geomorphology and Vegetation Monitoring effort utilizing remote sensing methods. The goal of the project is to track long-term trends in morphology and in-channel vegetation in the Associated Habitat Reach (AHR) of the Central Platte River, with a focus on changes that may affect habitat for the PRRIP target species. A variety of metrics associated with target species habitat are presented in this report, including trends in wetted width and depth of the channel, width of channel that is unobstructed by tall vegetation, sediment volume differencing, and channel area suitable for whooping crane roosting. Aerial imagery and topobathymetric LiDAR data from annual flights over the Central Platte are analyzed to estimate these metrics. Additionally, data are presented concerning the primary factors that drive habitat change—hydrology and management. This report includes simple comparisons of mean habitat metric values of channel areas managed by PRRIP and other conservation groups vs. unmanaged channel, which allows for a preliminary assessment of the impact of in-channel management. The data may be used in the future to address PRRIP Big Questions, including those concerning the impact of sediment augmentation and germination suppression flow releases on channel conditions. All analyses in this report generally indicate that the AHR remained relatively stable from 2017-2020, with no dramatic shift in channel conditions, despite minor impacts from the 2019 high flow events.

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1. Introduction

The Platte River Recovery Implementation Program (PRRIP or Program) is responsible for implementing aspects of the recovery plan for the endangered whooping crane (*Grus americana*). The Program's Adaptive Management Plan (AMP) management objective is to contribute to the survival of whooping cranes (WC) during migration. Performance indicators include increasing the area of suitable WC roosting and foraging habitat. Research and monitoring conducted during the First Increment (2007-2019) suggest width of channel unobstructed by dense vegetation and the distance to nearest forest are the best indicators of roosting habitat suitability (PRRIP, 2017; Baasch et al., 2019). System-scale geomorphology and vegetation monitoring documents trends in channel morphology, vegetation, and WC habitat suitability metrics in relation to natural hydrology, flow releases, and in-channel mechanical management actions. This information is used by the Program to assess our ability to create and maintain suitable whooping crane habitat under a broad range of environmental conditions.

From 2009 – 2016 the Program implemented a field-based monitoring protocol that included topographic transect surveys, vegetation plot surveys, and sediment size/transport sampling (Tetra Tech, 2017). That approach was abandoned after 2016 due to low spatial coverage, increasing cost and the recognition that much of the vegetation and sediment data was not useful for addressing priority uncertainties. In 2017 the Program pivoted to a remote-sensing approach based around collection and analysis of high-resolution aerial imagery and bathymetric LiDAR. To our knowledge, this is the first-time collection of aerial bathymetric LiDAR has been conducted at this scale, frequency, and resolution. Consequently, the Executive Director's Office (EDO) spent much of 2017-2020 collaborating with the Program's remote sensing contractor, Quantum Spatial Inc. (QSI), and working internally to develop and refine analysis methods that could be applied annually at a system scale.

The newly updated remote-sensing data collection and analysis protocol is attached as Appendix A. Protocol implementation includes the following analyses: 1) quantification of management metrics and hydrologic metrics, 2) two-dimensional hydrodynamic modeling to characterize channel hydraulics across a range of discharges, 3) object-based classification of in-channel land cover to characterize changes in in-channel vegetation, 4) topographic differencing to calculate bed volume change, and 5) estimation of suitable whooping crane roosting area. The results of each of these analyses are interpreted relative to Extension Science Plan[1] learning priorities.

1.1 Scope of Analysis and Reporting Scales

The Platte River is a major tributary to the Missouri River with a contributing drainage area of approximately 71,000 square miles (Figure 1). The headwaters of the North and South Platte Rivers are located in the Rocky Mountains and flow eastward to their confluence near North Platte, NE. The central Platte River extends downstream from that point to the Loup River confluence near Columbus, NE. The 90-mile stretch of the Big Bend reach of the central Platte River from Lexington, NE to Chapman, NE is the focus area for Program implementation and is referred to as the Associated Habitat Reach (AHR).

[1] The First Increment AMP has been updated and renamed Extension Science Plan.

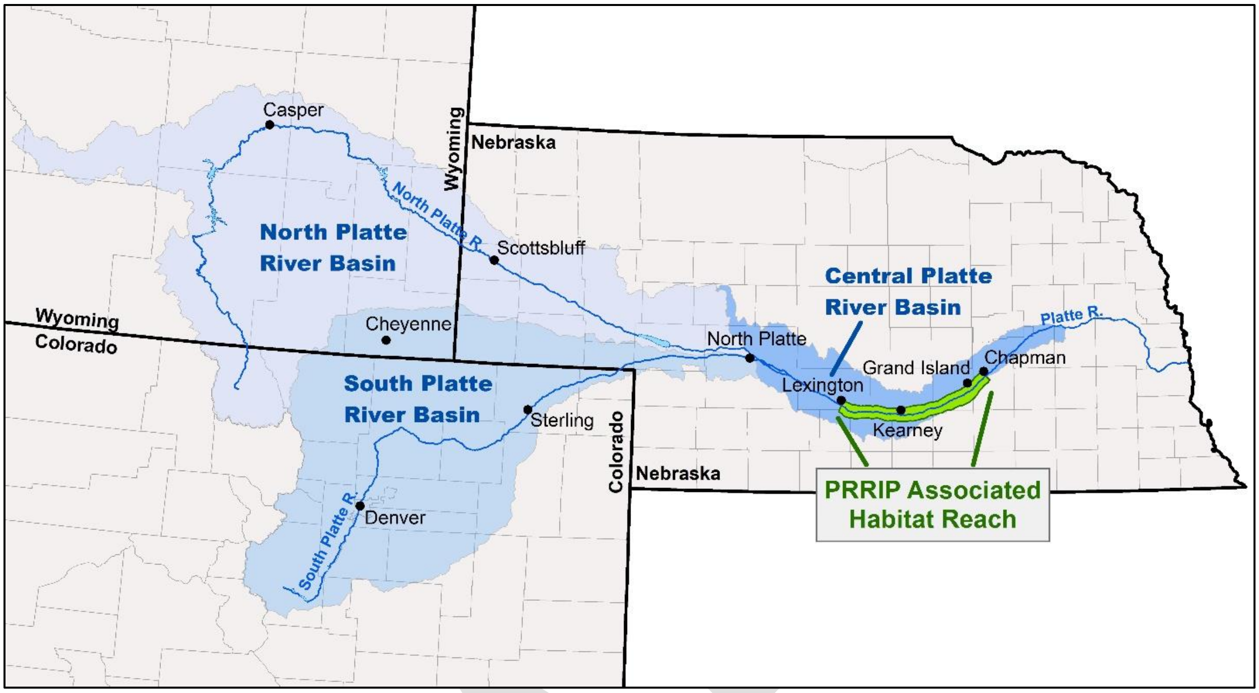


Figure 1. Map of the central and upper Platte River basin including the Program's Associated Habitat Reach (AHR) where management actions are implemented to benefit target species.

Analyses were conducted for the entire AHR and are generally reported at three spatial scales: the entire AHR, by geomorphic reach, and by management type. AHR-scale metrics are reported as means to capture reach-wide annual trends and exclude the two segments (north and south channel) upstream of Overton because they are typically hydrologically disconnected from each other, and the CNPPID J2 Return exerts a controlling influence on reach hydrology.

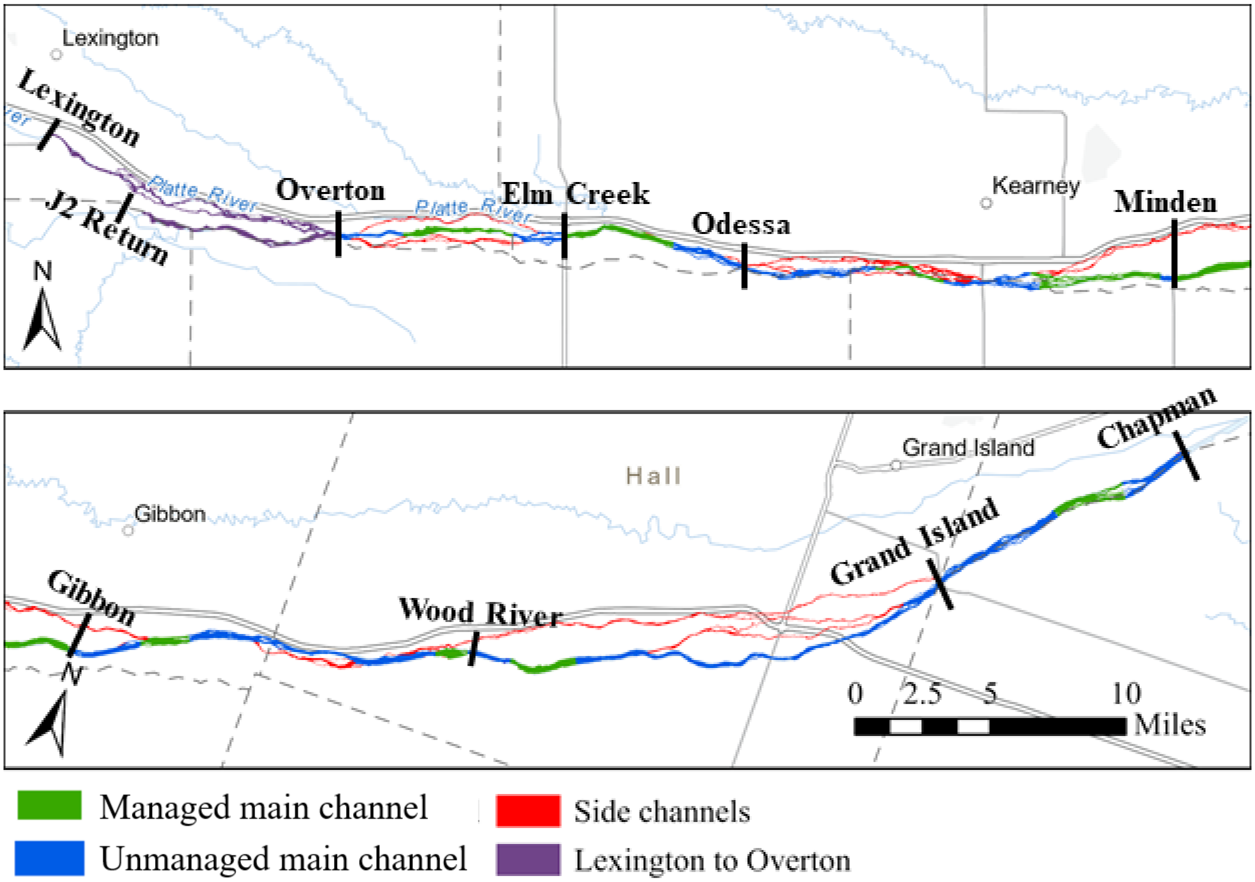
Geomorphic reaches are based on delineations by Fotherby (2009), grouping segments with similar hydrology and channel morphology into nine (9) reaches (Table 1 and Figure 2). Five of the geomorphic reaches have major flow splits. In those reaches, results are reported for all channels together and the main channel individually[2]. Two additional reaches (Elm Creek to Odessa and Grand Island to Chapman) also have minor flow splits, but no side channels of enough size to be separated in analyses.

Management-scale analyses compare channel characteristics of "managed" and "unmanaged" areas of the main channel. Managed areas include sections of channel managed by PRRIP or other groups that are consistently managed to reduce in-channel vegetation coverage. This includes The Crane Trust, The Audubon Society, The Nature Conservancy, Central Nebraska Public Power and Irrigation District (CNPPID), and the Nebraska Public Power District (NPPD). These areas were delineated using the PRRIP management database, which is described in detail in Section 2.

[2] Suitable whooping crane habitat rarely occurs in side channels due to inadequate width.

Table 1. Geomorphic Reach designations of the AHR, based on Fotherby (2009).

Reach Name	**Reach Code**	**Reach Length (mi)**	**Geomorphic Description**	**% Flow in Main Channel**
North channel from Lexington Bridge to Overton Bridge	N-lexington_overton	11.3	Wandering: Unconsolidated and heavily vegetated overbank.	25%
South channel J2 Return to Overton Bridge	J2_overton	7.5	Meandering: Incised as much as 25 feet and void of incoming bedload.	75%
Overton Bridge to Elm Creek Bridge	overton_elmcreek	8.7	Unconsolidated: Main channel braided and anastomosed.	75%
Elm Creek Bridge to Odessa Bridge	elmcreek_odessa	7	Consolidated: Braided and anastomosed.	100%
Odessa Bridge to Minden Bridge	odessa_minden	16.7	Unconsolidated: Main channel mostly anastomosed.	55%
Minden Bridge to Gibbon Bridge	minden_gibbon	5.9	Unconsolidated: Main channel braided.	60%
Gibbon Bridge to Wood River Bridge	gibbon_woodriver	15.2	Consolidated: Braided and island braided.	80%
Wood River Bridge to Grand Island (Hwy 34)	woodriver_gi	18.8	Unconsolidated: Main channel mostly braided.	55%
Grand Island (Hwy 34) to Chapman Bridge	gi_chapman	11	Consolidated: Alternating braided and anastomosed.	100%



Nebraska Game & Parks Commission, Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS

Figure 2. Map of the Associated Habitat Reach (AHR) including geomorphic reaches, main and side channels, main channel areas that are managed to reduce in-channel vegetation (managed), and other main channel areas (unmanaged).

1.2 Merging Field and Remote Sensing Data and Analyses

The Program has collected and analyzed both field and remote sensing data since 2009. In many cases, the field- and remote-sensing based protocols involve quantification of similar or identical metrics. However, the underlying spatial coverage, data collection methods, and analyses are quite different. It is important that the Program be able to visualize and assess trends since the inception of monitoring. It is also important to identify and avoid situations where changes in methodology could lead to interpretive errors. As such, this report generally presents annual data for the entire system-scale monitoring period of 2009-2020 with the data separated by protocol. In cases where the metrics and results are not comparable, pre-2017 data has been omitted.

1.3 Big Questions and Priority Hypotheses

The Program is currently updating its Adaptive Management Plan (renamed Science Plan) for the First Increment Extension. Draft Science Plan Big Questions and associated hypotheses relevant to geomorphology and vegetation monitoring include:

Big Question 1: How effective is it to use Program water to maintain suitable[3] whooping crane roosting habitat?

- **Management Hypothesis WC1:** During drought periods, 30-day minimum germination suppression releases (2,000 cfs target between June 1-July 15) will slow vegetation expansion into the channel and increase the percent of AHR channel that remains highly suitable for whooping crane roosting.

Big Question 2: How effective is Program management of *Phragmites* for maintaining suitable whooping crane roosting habitat?

- **Management Hypothesis WC2:** During drought periods, 30-day minimum germination suppression releases (2,000 cfs target between June 1-July 15) in combination with continued herbicide spraying and channel disking will slow *Phragmites* rhizome/stolon expansion into the channel and increase the percent of AHR channel that remains highly suitable for whooping crane roosting.

Assumes ongoing phragmites spraying. Program science strongly indicates that natural peak flow events exceeding 13,000 cfs or mechanical vegetation clearing are necessary to remove vegetation and increase maximum unobstructed channel width (MUCW). Channel-inundating flow releases are only hypothesized to maintain unvegetated width.

Big Question 3: Is sediment augmentation necessary to create and/or maintain suitable whooping crane habitat?

- **Management Hypothesis WC6:** Sediment augmentation is necessary to halt the narrowing and incision in the south channel downstream of the J2 Return.

System-scale geomorphology and vegetation monitoring will focus on tracking trends in metrics that are relevant to these Big Questions and associated hypotheses including trends in physical habitat metrics like MUCW as well as potential hydrologic and management drivers. Analyses of management action performance (answering Big Questions) will occur periodically using (in part) physical habitat metric data generated as part of system-scale monitoring.

[3] Channels with ≥ 650 ft maximum width unobstructed by dense vegetation (MUCW) are highly suitable for whooping crane roosting (PRRIP, 2017, Baasch et al., 2019)

2. Mechanical Management

The Program and other organizations mechanically manage in-channel vegetation on both a site and system scale to maintain channel width and provide suitable WC roosting habitat.

- System-scale management actions include helicopter application of herbicide to control invasive vegetation (principally *Phragmites*) and sediment augmentation downstream of the J2 Return to halt channel incision and narrowing in the upper portion of the AHR.
- Site-scale management actions include clearing of trees from in-channel islands and disking of herbaceous vegetation on sandbars and along bank edges. These actions are taken to increase unvegetated channel width and promote channel widening through lateral erosion.[4]

It is important to track these actions to 1) assess their effectiveness, and 2) account for them in analyses of the relationship between natural drivers (such as hydrology) and channel response. Specific management metrics include the spatial extent of annual spraying, woody vegetation clearing and disking as well as the volume of sediment (cubic yards and tons) augmented each year.

2.1 Mechanical Management Analysis Methods

The Program maintains a Geographic Information System (GIS) geodatabase of the spatial extent of vegetation management actions. Table 2 provides the source of GIS data used to document annual management actions in that database. Aerial herbicide application is accomplished by helicopter with boom-mounted global positioning system (GPS) that records the spatial extent of application. Tree clearing and disking areas are recorded via GPS field surveys and track-logs and are then validated with orthorectified imagery collected twice annually. Sediment augmentation area and volumes for each year are calculated using pre- and post-augmentation Light Detection and Ranging (LiDAR) data collected by the Program. Augmentation quantities are validated using RTK-GPS, and area (acres) and volumes (cubic yards/tons) are calculated using a cut-fill routine in GIS for reporting.

Table 2. Data source for documentation of annual system- and site-scale management actions.

Management Action	Data Source
Aerial Herbicide Application	Helicopter applicators equipped with boom-mounted GPS
Tree Clearing	GPS field surveys validated with Program imagery
Disking	GPS track-logs validated with Program imagery
Sediment Augmentation	Pre- and post-augmentation topo-bathy LiDAR surveys

[4] Removing vegetation from bars and bank edges reduces tensile strength of the soil, increasing erodibility (Bankhead, 2012)

Some mechanical management activities occur outside of the active channel. Accordingly, vegetation clearing polygons were clipped to the channel extent using an analysis mask developed for the object-based land cover classification, as described in Section 5.

2.2 Mechanical Management Results

Most mechanical management during the period of 2006 - 2020 was comprised of aerial herbicide application and disking with tree clearing occurring on a much smaller scale (Figure 3). The period of 2006 – 2009 coincided with the end of a historic drought in the basin and the associated proliferation of *Phragmites* into the river channel. Aerial herbicide application to control *Phragmites* began in 2007, peaked in 2009, and has been relatively constant since 2016 at approximately 500 acres per year. We hypothesize that this is the baseline level of treatment that is necessary to prevent *Phragmites* from reinfesting the channel. It is not certain whether baseline effort will need to increase during dry periods or if the continual annual control effort has normalized the amount of treatment for all year types.

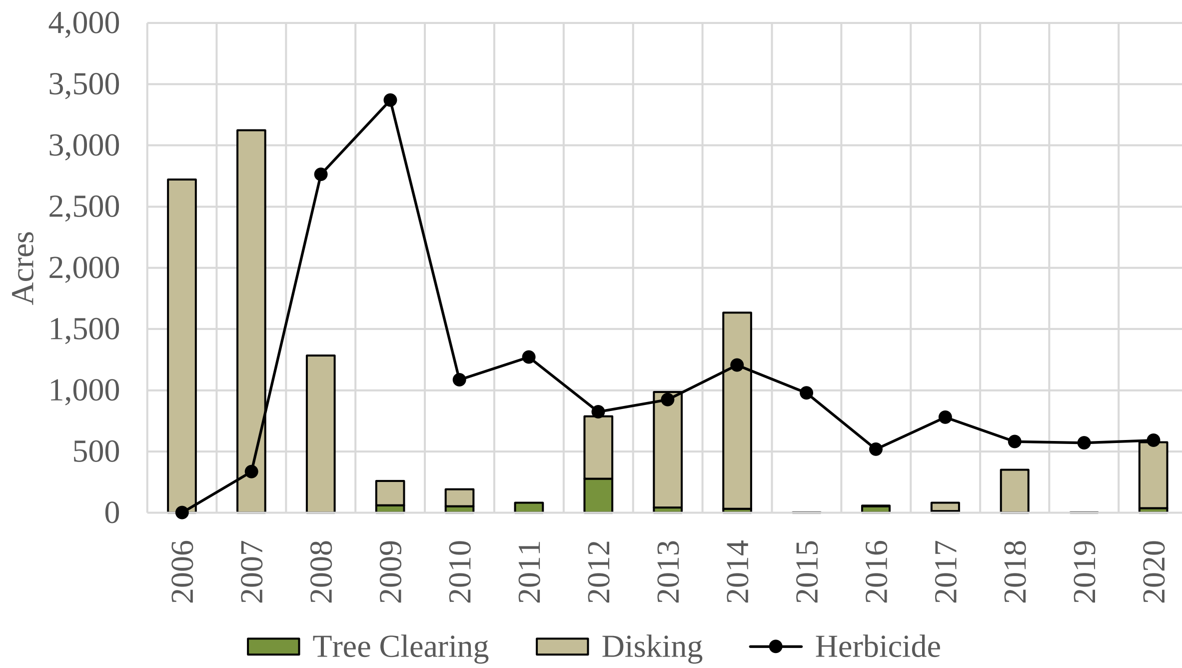


Figure 3. Total area of in-channel tree clearing, river channel disking and aerial herbicide application by year for the AHR.

See Appendix Section B for complete mechanical management results.

3. Hydrologic Analysis

Flow is a primary driver of annual changes in channel characteristics on the Platte (Murphy et al., 2004, Farnsworth et al., 2018). The magnitude, timing, and duration of flows drive complex relationships with in-channel vegetation and sediment transport. For example, high peak flows in any season can scour vegetated sandbars and collapse banks. Lower flows sustained over a long period in the growing season can suppress seed germination. Both types of flow suppress vegetation and support unvegetated channel width, though through different physical processes. The hydrologic metrics included in this report have all been hypothesized to have distinct spatiotemporal effects on in-channel habitat.

3.1 Hydrologic Metrics

Priority hydrologic metrics are presented in Table 3 and a larger suite of hydrologic metrics, including flow duration curves and exceedance percentiles for germination and WC migration seasons are reported in Appendix C. Priority metrics including mean annual discharge (Q_{AVG}), annual flow volume (V_{af}) and peak flow discharge/return interval (Q_{P}/Q_{Py}) are indicators of general hydrologic conditions in the reach. The Annual 40-day maximum flow ($Q_{Max\ 40}$) has been found to be a good predictor of increases in unvegetated channel width (PRRIP, 2017) and mean June flow (Q_{June}) is hypothesized to be a good predictor of channel width maintenance in years absent large peak flow events. Flow distribution curves are also provided as a general indicator of the distribution of mean daily discharge within each year (Appendix C).

Table 3. Priority hydrologic metrics, symbols and importance.

Metric	Metric Symbol	Utility
Mean Annual Discharge (cfs)	Q_{AVG}	Indicator of general hydrologic conditions
Annual Flow Volume (AFY)	V_{af}	Indicator of general hydrologic conditions
Annual Mean Daily Peak Discharge (cfs)	Q_{P}	This is the annual peak flow discharge. Mean daily flow is used because it occurs for a sufficient duration to do work within the channel.
Annual Peak Flow Return Interval (years)	Q_{Py}	Indicator of how frequently peak flow magnitudes occur
Annual 40-Day Maximum Flow (cfs)	$Q_{Max\ 40}$	Indicator of peak flow magnitude-duration relationship; good predictor of unvegetated channel width increases
Mean June Flow (cfs)	Q_{June}	Hypothesized to be good predictor of unvegetated channel width maintenance in absence of peak flow events
Flow Distribution Curves	NA	Distribution of mean daily discharge within the year

3.2 Hydrologic Analysis Methods

Mean daily discharge records were obtained for two United States Geological Survey (USGS) stream gages located at Overton (06768000) and Grand Island (06770500) for the period of 2009-2020. Metric values were calculated for each gage location. Annual peak flow return interval was calculated using the methodology from USGS Bulletin #17B (Interagency Advisory Committee on Water Data, 1982). We used a period of record of 1958-2020 for return interval calculations as the last major reservoir on the North Platte River was completed in 1957.

3.3 Hydrologic Analysis Results

Mean daily discharge at the Grand Island gage (06770500) for the period of geomorphology and vegetation monitoring (2009-2020) is plotted in Figure 4. During this period, mean annual discharge ranged from a low of 942 cfs at Overton in 2009 to a high of 4,214 cfs at Grand Island in 2011 (Table 4 and Table 5).

Mean daily peak discharge since initiation of system-scale monitoring ranged from a low of 2,960 cfs at Overton in 2018 to a high of 18,200 cfs at Grand Island in 2019 (Table 4 and 5). The 2019 Grand Island peak had a 24-year return interval. Other notable peaks included a long-duration peak in 2011 with an approximately 5-year return interval and 2013 and 2015 peaks with 15-year return intervals. Notably, all large peaks occurred in late spring except for the 2013 event which occurred in the fall due to a historic precipitation event in the upper South Platte basin. The median of the mean daily peak discharge for the reporting period is approximately 8,700 cfs.

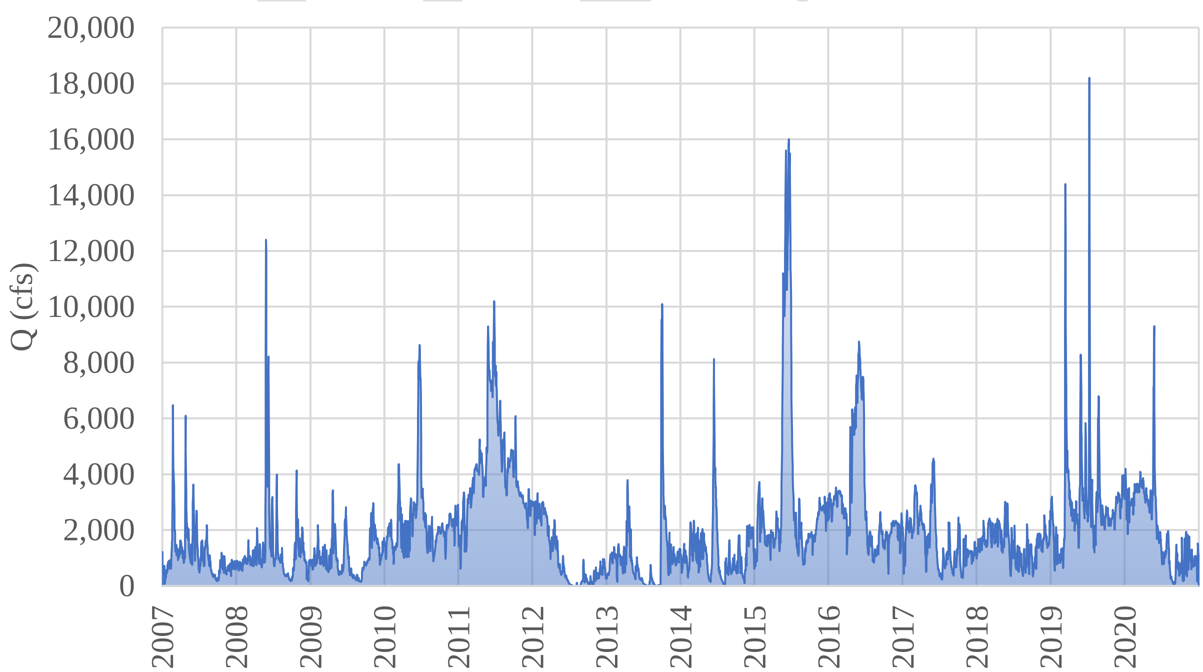


Figure 4. Mean daily discharge at the USGS Grand Island (06770500) gage.

Table 4. Summary of flow metrics at the USGS Overton (06768000) gage from 2009 to 2020. Years of remote monitoring are shown in green.

Water Year	Mean Annual Discharge	Annual Volume (ac-ft)	Mean Daily Peak Discharge	Return Interval (Years)	40-Day Max Discharge	Mean June flow (germination)
Mean 1958-2020	1,706	1,235,039	6,401	4.2	3,775	2,711
2009	942	681,929	3,600	1.5	1,811	1,282
2010	2,157	1,561,636	7,370	3.4	4,108	4,536
2011	3,877	2,807,021	8,720	4.6	7,503	7,675
2012	1,114	806,776	3,430	1.4	2,796	319
2013	1,140	824,993	12,400	9.9	4,129	303
2014	1,249	904,099	7,360	3.4	3,150	3,822
2015	3,506	2,538,110	15,300	16.6	12,708	12,920
2016	2,950	2,137,701	8,600	4.5	7,364	6,433
2017	1,550	1,122,462	4,440	1.8	2,768	2,069
2018	1,415	1,024,113	2,960	1.3	1,834	1,343
2019	2,274	1,646,137	9,750	5.6	3,089	2,822
2020	1,802	1,305,700	3,820	1.5	2,977	1,966

Table 5. Summary of flow metrics at the USGS Grand Island (06770500) gage from 2009 to 2020. Years of remote monitoring are shown in green.

Water Year	Mean Annual Discharge	Annual Volume (ac-ft)	Mean Daily Peak Discharge	Return Interval (Years)	40-Day Max Discharge	Germination (June)
Mean 1958-2020	1,749	1,266,672	7,370	4.5	3,977	2,841
2009	1,039	752,027	3,430	1.2	2,011	845
2010	2,289	1,657,360	8,630	3.3	4,960	3,126
2011	4,214	3,050,549	10,200	4.6	7,982	6,216
2012	978	709,145	3,320	1.2	2,857	630
2013	1,024	741,203	10,100	4.5	3,524	575
2014	1,199	867,918	8,120	3	2,778	1,474
2015	3,341	2,418,834	16,000	14.9	12,636	9,116
2016	2,993	2,168,546	8,750	3.4	7,390	7,057
2017	1,585	1,147,310	4,560	1.5	2,943	2,752
2018	1,502	1,084,571	3,010	1.2	2,036	1,888
2019	3,008	2,176,267	18,200	24	4,615	3,609
2020	2,005	1,453,271	9,310	3.8	3,755	3,471

See Appendix Section C for complete hydrologic results.

4. Hydrodynamic Modeling

Two-dimensional hydrodynamic modeling is used to estimate water surface elevation, velocity and other hydraulic metrics at a variety of flows based on bathymetric LiDAR-derived channel topography. Modeled hydraulic metrics are used to estimate changes in width, depth, and area of shallow water, all of which are important elements of in-channel WC habitat.

4.1 Hydrodynamic Modeling Methods

Two dimensional (2-D) hydrodynamic models compute water-surface elevation and other hydraulic metrics from an elevation surface derived from annual topobathymetric LiDAR surfaces. Modeling was performed using the Bureau of Reclamation (BOR) SRH-2D Version 2.2 (BOR, 2008) solver with Version 13.1 of the Aquaveo Surface Water Modeling System (SMS) graphical user interface (Aquaveo, 2010). SRH-2D provides a significant advantage over most 2-D models because the density of the computational points can be increased in complex active channels areas and decreased in others to maintain reasonable model size and computational efficiency. The AHR was subdivided into six sub-models (Figure 5), rather than the nine geomorphic reaches, to reduce processing and computation time. Topobathymetric LiDAR surfaces were processed into a computational mesh with model node spacing of approximately 20 feet, in accordance with the BOR SRH-2D guidelines (BOR, 2008).

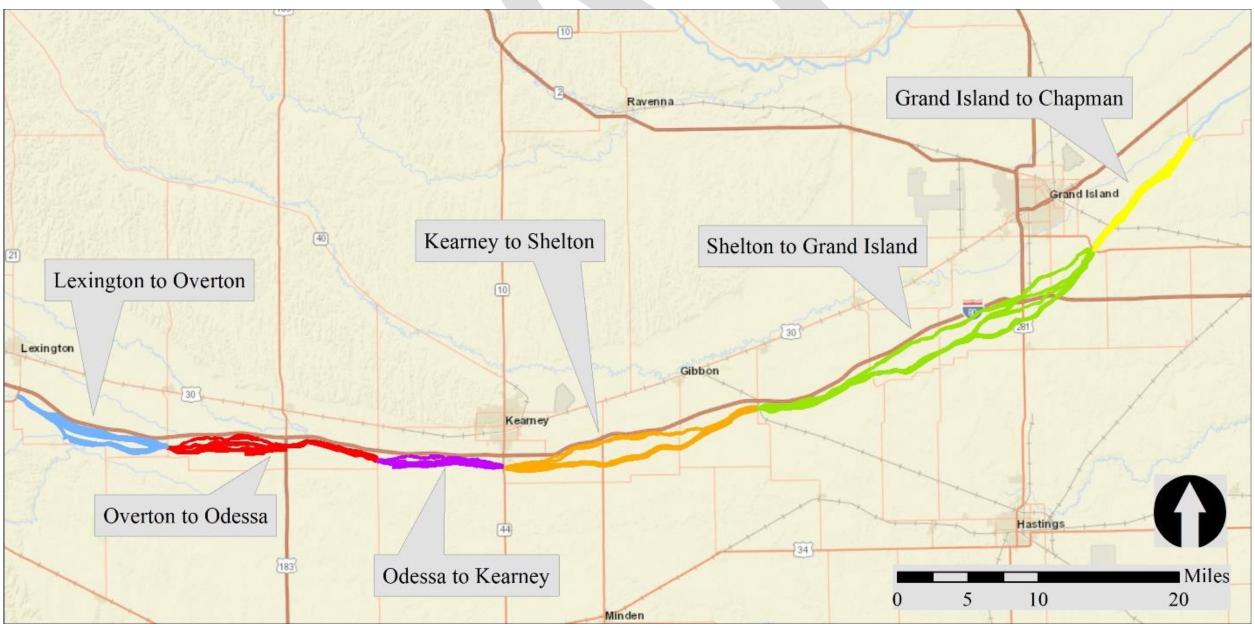


Figure 5. Hydrodynamic sub-models within the AHR.

The SRH-2D model utilizes Manning's roughness coefficients to represent channel roughness. Since all flow is confined to the active channel at discharges of interest (for this analysis), a single roughness coefficient was used for each reach model. The coefficient was calibrated by iteratively adjusting the value until modeled stage converged to field measurements. The calibrated model was then validated to a second discharge and measured water surface elevation. A comparison of modeled and LiDAR-measured water surface elevations (Table 6) indicates all but one modeled water surface elevation fall within +/- 0.2 ft of measured values. Values of NA in the table represent areas without validation points. Since the modeling effort began, we have worked to develop access to a series of stable channel locations to measure validation points that cover all sub-model reaches.

Table 6. Predicted water-surface elevations minus LiDAR-measured water-surface elevations (ft) for all models 2017-2020.

Sub-Reach	2017	2018	2019	2020
Lexington to Overton	NA	0.14	-0.06	-0.02
Overton to Odessa	NA	-0.15	-0.11	0.1
Odessa to Kearney	0.23	-0.07	0.13	-0.06
Kearney to Shelton	0.17	-0.04	-0.1	-0.06
Shelton to Grand Island	-0.07	-0.09	0.09	-0.01
Grand Island to Kearney	NA	NA	0.18	-0.07

SRH-2D model output was processed with both R (R Core Team, 2017) and GIS to calculate hydraulic metrics of interest (Table 7). Wetted width was calculated by sampling the model area extent with transect lines spaced at 500 ft. intervals. Other metrics were calculated through tabular manipulation in R. More detail on these methods can be found in Appendix A1.

Table 7. Subset of useful hydrodynamic metrics parameterized from the reach-wide hydrodynamic modeling results.

Metric	Utility
Percent flow consolidated in main channel at 2,000 cfs	Important for assessing relationship between flow and channel width metrics in split flow reaches.
Mean depth at 2,000 cfs	Important reference for incision
Mean wetted width at 2,000 cfs	Important for assessing relationship between wetted width and vegetation germination
Width:depth ratio at 2,000 cfs	Higher values reflect higher degree of braiding
Wetted area at 5,000 cfs	Used to mask in-channel area for clipping total unobstructed channel width (TUCW)
Area with Depth < 1ft	Important whooping crane habitat metric

4.2 Hydrodynamic Modeling Results

A plot of the 2020 modeled wetted width of all channels at 2,000 cfs (Figure 6) indicates that width is highly variable throughout the AHR but generally increases in a downstream direction. A plot of the 2020 modeled wetted width of the main channel (Figure 7) does not show the same increasing downstream trend, in part because wetted with of the main channel is strongly influenced by the proportion of flow that is consolidated into the main channel at any given location.

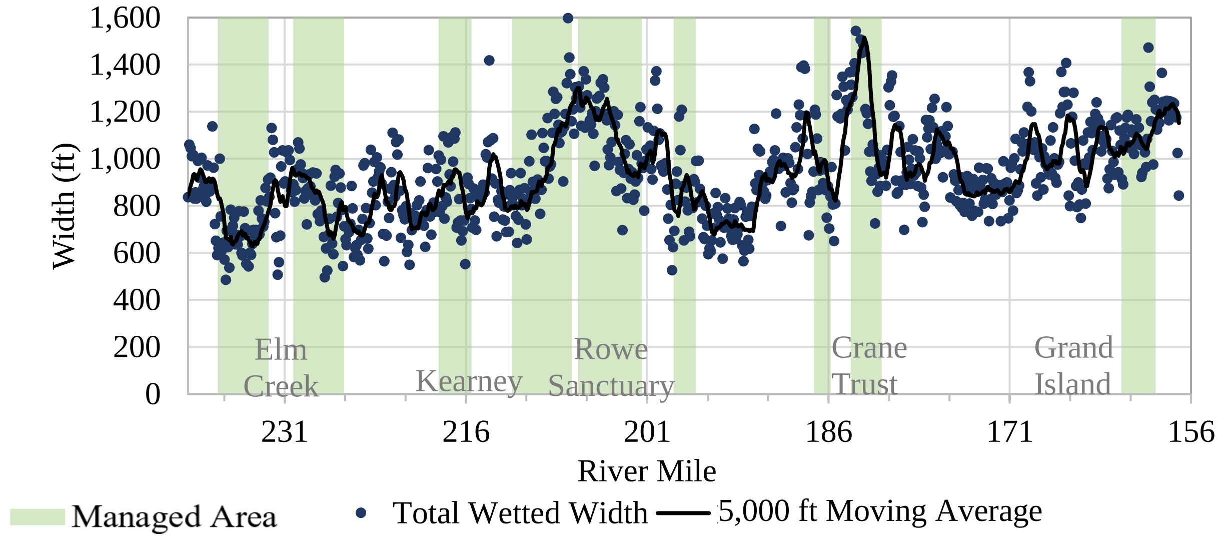


Figure 6. All channels wetted width, as sampled at 500 ft transect intervals from the 2000 cfs 2020 hydrodynamic model.

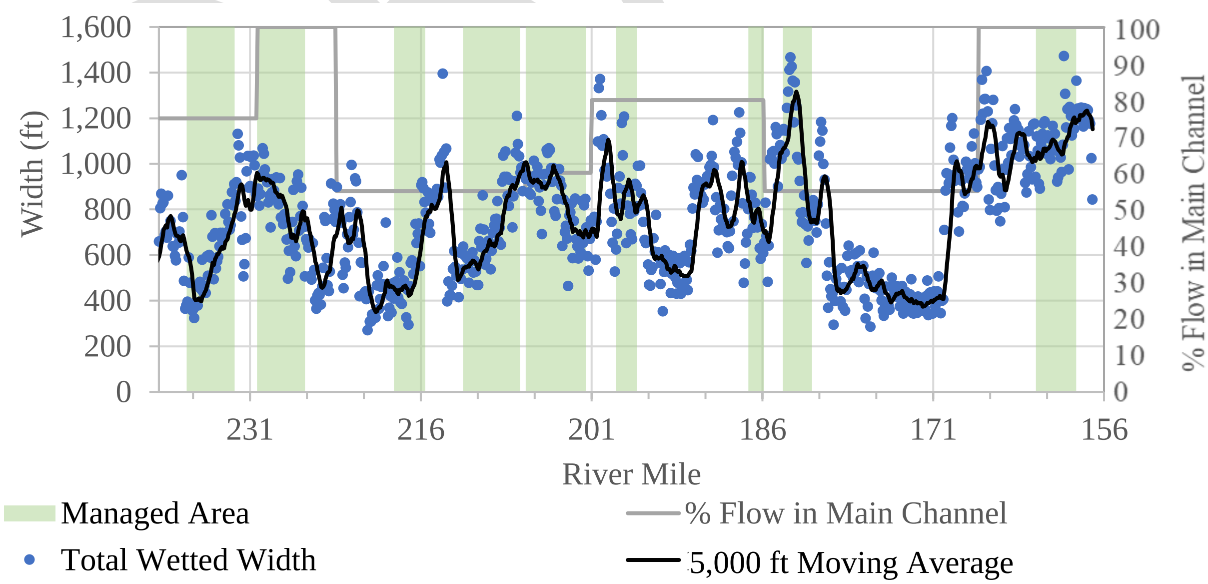


Figure 7. Main channel wetted width, as sampled at 500 ft transect intervals from the 2000 cfs 2020 hydrodynamic model.

Comparing managed areas to other areas of the main channel provides a cursory indication of the effect of management on morphology. Managed areas have, on average, slightly higher width, lower depth, and a higher width:depth ratio than other areas. However, the differences are small. The differences in wetted width are well within the bounds of the standard error of the distribution (Figure 7). The 2019 floods did not appear to substantially change channel hydraulics. However, in 2019, managed areas did experience a small increase in average depth and corresponding decrease in the width:depth ratio. Overall, year-to-year differences are small and indicate that the morphology of the AHR did not change substantially from 2017-2020.

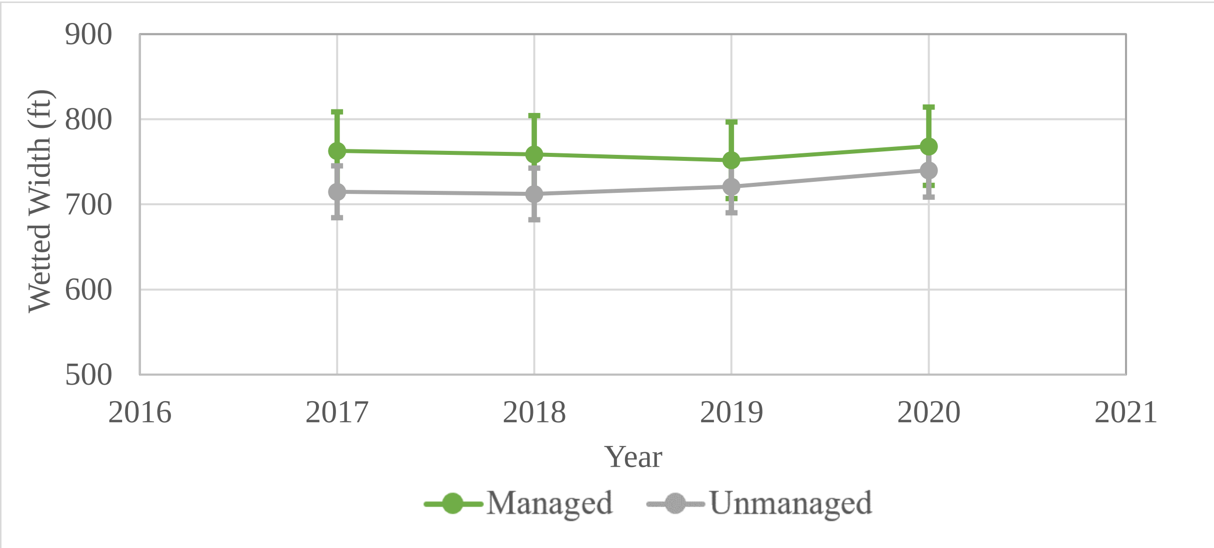


Figure 8. Mean (points) and standard error (bars) of wetted width over time from Overton to Chapman in areas of the main channel managed to reduce in-channel vegetation (managed) and other main channel areas (unmanaged). Data are sampled at 500 ft transect intervals from the 2000 cfs 2020 hydrodynamic model.

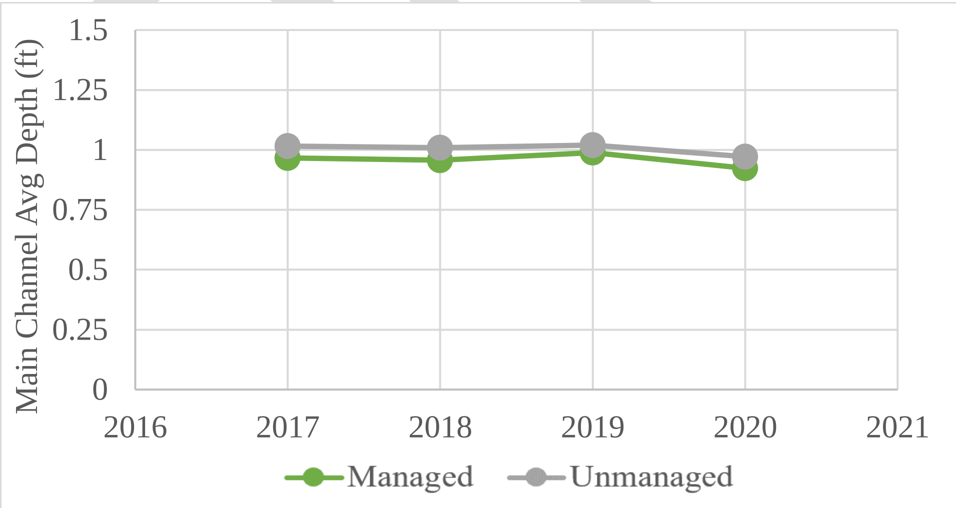


Figure 9. Mean depth over time from Overton to Chapman, from the 2000 cfs 2020 hydrodynamic model in areas of the main channel managed to reduce in-channel vegetation (managed) and other main channel areas (unmanaged).

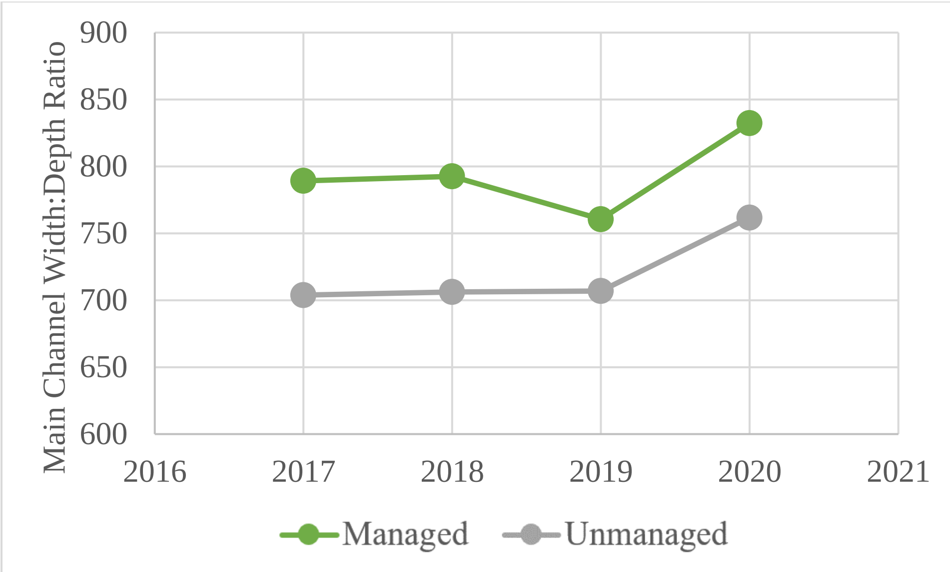


Figure 10. Width:depth ratio over time from Overton to Chapman, from the 2000 cfs 2020 hydrodynamic model in areas of the main channel managed to reduce in-channel vegetation (managed) and other main channel areas (unmanaged).

The modeling results also allow for the examination of the area of channel with depth less than 1 ft, which is an important component of WC roosting habitat. Results indicate that the area of shallow channel is maximized at a flow of 750 cfs (Figure 11). At 2,000 cfs, the percentage of the total channel area < 1 ft deep was slightly higher in managed areas (Figure 12). Shallow channel area increased every year in managed areas and did not appear to be strongly influenced by the 2019 floods. Shallow channel area did not increase as much in unmanaged areas.

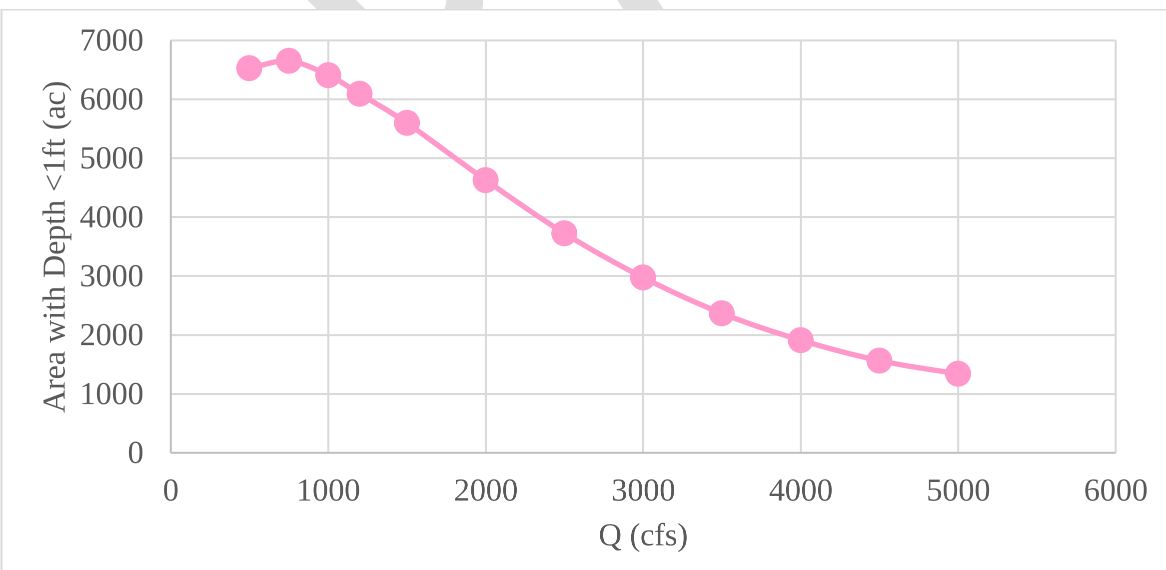


Figure 11. Total channel area from Overton to Chapman with depth less than 1 ft, as estimated with the 2020 hydrodynamic model.

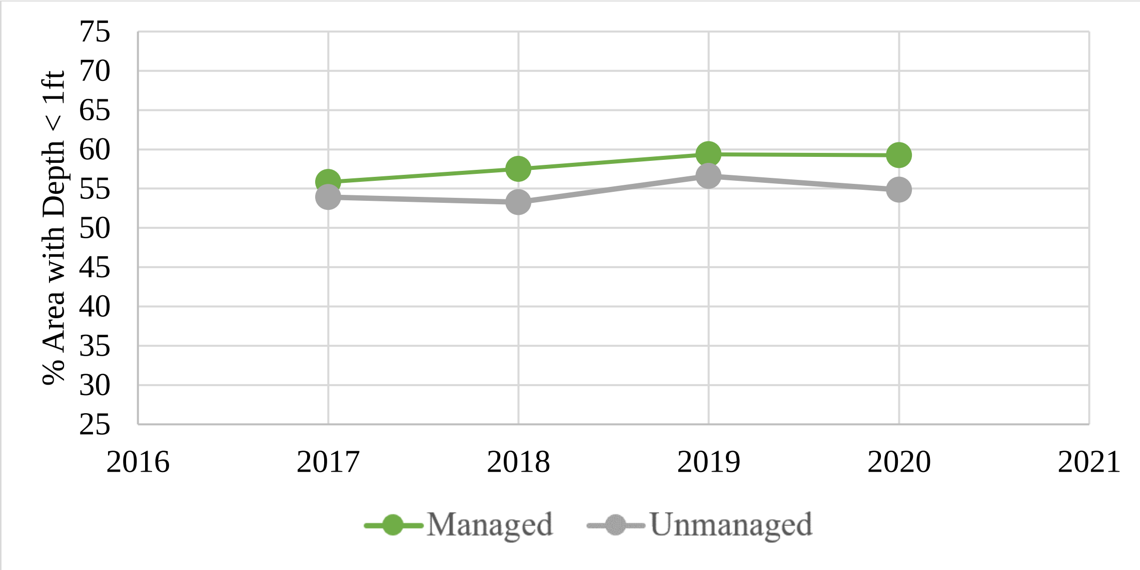


Figure 12. Percentage of channel area with depth less than 1 ft at 2000 cfs in areas of the main channel managed to reduce in-channel vegetation (managed) and other main channel areas (unmanaged) as estimated from 2017-2020.

See Appendix Section D for complete hydrodynamic modeling results.

5. Land Cover Classification

Quantifying land cover change over time is critical for understanding changes in PRRIP target species habitat and measuring the success of management. The land cover classes included in this protocol are water, sand, and vegetation of various height classes. Analyzing trends in coverage of each class can provide important information about vegetation dynamics in the AHR. From a WC habitat perspective, the most important aspect of classification is defining areas of the channel that are unobstructed (water, sand, or vegetation less than 2 ft in height) or are obstructed by vegetation greater than or equal to 2 ft in height.

Channel width that is unobstructed by tall vegetation is evaluated in two different ways. Maximum unobstructed channel width (MUCW) represents the maximum continuous channel width that is unobstructed by vegetation ≥ 2 ft in height. It is a good predictor of whooping crane roost location (Baasch et al., 2019). Total unobstructed channel width (TUCW) represents the total of all segments of channel width unobstructed by vegetation ≥ 2 ft in height. TUCW is an important physical process metric (Farnsworth et al., 2018) as it is less impacted by the orientation of vegetated obstructions within the active channel.

5.1 Land Cover Classification Methods

From 2009-2016, field crews estimated MUCW and TUCW in the field at anchor point locations via field surveys. PRRIP researchers have also estimated MUCW and TUCW from annual aerial imagery by visually identifying unvegetated channel segments at predetermined transect locations (Farnsworth et al., 2018).

From 2017 forward, object-based classification of land cover class from annual aerial imagery will be used as a replacement for visual classification. Object-based classification is an automated algorithmic method that can interpret remote sensing data, categorizing it into predefined land cover classes. It offers several advantages over visual classification by removing the potential for observer bias, simultaneously incorporating both elevation and imagery data, and improving repeatability among years.

The remote sensing data used for classifications was collected via airplane by Quantum Spatial, Inc. (QSI) in either October or November from 2017-2020. Processed coverages include 4-band (red, green, blue, and near-infrared) imagery (Figure 13a) and LiDAR elevation surfaces representing both the bare earth and the top of vegetation used to derive vegetation height (Figure 13b). QSI assessed accuracy for each year of data collection using ground control check points (QSI, 2016; QSI, 2017; QSI, 2018; QSI, 2019; QSI, 2020). The elevation vertical accuracy, presented here as a 95% confidence interval for elevation estimates, varied from 0.1 to 0.2 ft between years on dry, unvegetated surfaces (Table 16).

Land cover classification was accomplished using Trimble eCognition object-based classification software (Trimble, 2021). In object-based classification, pixels are grouped into spectrally homogenous objects, and then the objects are classified utilizing user-defined criteria. This method differs from the more traditional pixel-based classification, in which all pixels are classified by their individual spectra (Burnett & Blaschke, 2003). Object-based classification has been demonstrated to be more effective than pixel-based classification in a wide variety of environments (Blaschke, 2010), and a powerful tool for specifically classifying patches of in-channel vegetation on sandbars (Demarchi et al., 2016).

The land cover classification schema incorporated 6 classes as defined in Table 8. Both the imagery and elevation data were classified at 3 ft spatial resolution. Water and sand were differentiated from vegetation using the Normalized Difference Water Index (NDWI) and Normalized Difference Vegetation Index (NDVI). NDWI and NDVI are indices combining reflectance in the green and near-infrared bands (McFeeters, 1996), and the red and near-infrared bands (Rouse et al., 1973), respectively. NDVI values range from -1 to 1 and are positively correlated with leaf density and health (Rouse et al., 1973). NDWI values also range from -1 to 1, with positive values representing water (McFeeters, 1996).

Water was differentiated from land using the NDWI and sand was differentiated from short vegetation using NDVI. The cutoff values for both indexes were visually calibrated for each year—values are presented in Table E1 in Appendix E. Annual NDVI calibration is necessary due to the impact of climactic variations on vegetation health. Vegetation was then differentiated into height classes using the LiDAR vegetation height surface (Figure 13b). This process generated a reach-wide map of land cover classes as shown in Figure 13c. In-channel land cover classes less than 2ft in height were considered unobstructed, that is, they were not considered as presenting a visual obstruction to whooping cranes utilizing the channel. Typical vegetation included in each vegetation height class can be found in Table 8.

Table 8. Land cover classes derived from object-based classification, obstructed or unobstructed classification, and typical vegetation type.

Land Cover Class	Obstructed/ Unobstructed	Typical Vegetation Class
Area of Sand and Water	Unobstructed	Unvegetated
Area of Vegetation < 2 ft	Unobstructed	Sparse or dense short herbaceous
Area of Vegetation 2 – 6 ft	Obstructed	Tall herbaceous or *Phragmites*
Area of Vegetation 6 – 15 ft	Obstructed	*Phragmites* or woody vegetation
Area of Vegetation > 15 ft	Obstructed	Woody vegetation

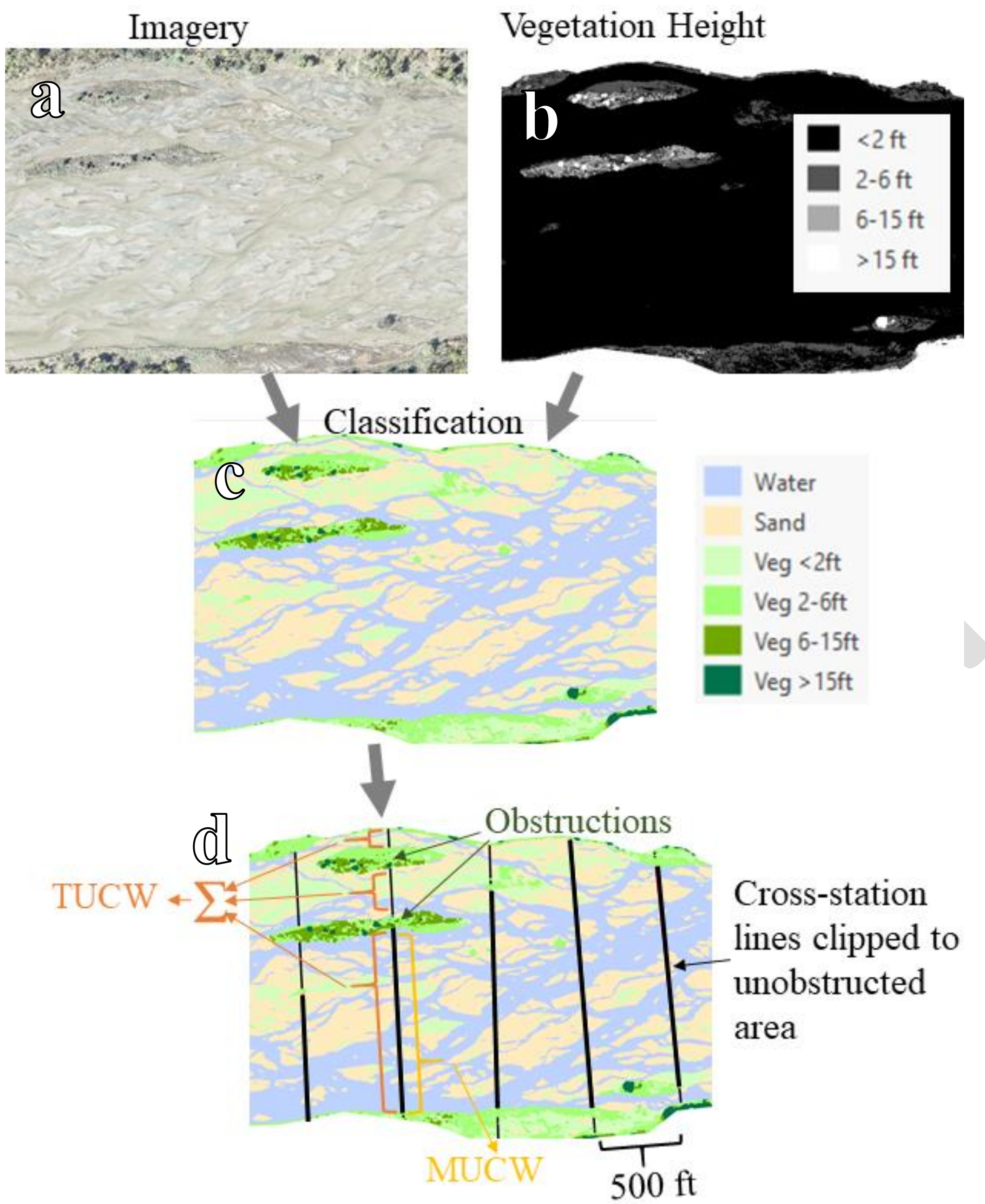


Figure 13. Conceptual diagram illustrating the combination of (a) imagery and (b) LiDAR-derived vegetation height data to (c) classify land cover surface. The land cover surface is then used to (d) clip cross-station lines to unobstructed area, calculate MUCW as maximum continuous channel width that is unobstructed by vegetation ≥ 2 ft in height, and calculate TUCW as the total of all segments of channel width unobstructed by vegetation ≥ 2 ft in height.

Classification analyses were validated by comparing object-based classification results to field data. For best comparison, field validation points were collected within a week of the data collection flight. A total of 440, 157, and 124 validation points were collected by the EDO in 2018, 2019, and 2020, respectively. Field data were also collected in 2017, but according to a preliminary classification schema that was not ultimately used, the data from that year were unsuitable for a validation analysis. Complete confusion matrices presenting comparisons between object-based classifications and field classifications are presented in Tables E2, E3, and E4 in Appendix Section E.

The comparison analysis indicated obstructed /unobstructed area agreement exceeded 80% in all years and 90% in two out of three years (Table 9). The most common error was classification of points identified in the field as tall vegetation (> 2 ft) as some shorter class of vegetation. This error is likely a result of the spatial scale of the remote sensing data. The vegetation height rasters used in analysis represent the average elevation of the LiDAR point cloud within each 3 ft x 3 ft cell. If a vegetation patch is small or sparse, the highest points may be averaged out to a lower value at the point of conversion from LiDAR point cloud to raster. A cell that contains a sparse or partial patch of vegetation 6-15 ft in height, for example, may have an average elevation value lower than 6 ft.

Table 9. Result of comparisons between object-based land cover classification and field classification by year.

Year	**Total Classification Agreement (among all classes)**	**Percent of Disagreement Attributable to Vegetation Height Underestimate**	**Obstructed/ Unobstructed Agreement**
2017	N/A	N/A	N/A
2018	86%	89%	91%
2019	82%	90%	82%
2020	94%	57%	98%

Land cover classification maps were used to identify the total area of each class and to calculate MUCW and TUCW (Figure 13d and Table 10). MUCW and TUCW were extracted by spatially clipping cross-station lines spaced at 500 ft intervals throughout the AHR to the area of unobstructed classes—water, sand, and vegetation less than 2 ft in height (Figure 13d). TUCW was additionally clipped to the 5,000 cfs flow extent to prevent unvegetated line segments from extending overbank. MUCW was then measured at each of the clipped cross-station lines as the maximum continuous channel width that is unobstructed by vegetation ≥ 2 ft in height. TUCW was measured at each of the clipped cross-station lines as the total of all segments of channel width unobstructed by vegetation ≥ 2 ft in height. Mean values of each metric were then calculated at various spatial scales to examine larger-scale trends.

Table 10. Habitat metrics derived from land cover classifications that are important for whooping cranes.

Metric	Metric Symbol	Definitions
Maximum Unobstructed Channel Width	MUCW	The longest continuous channel width unobstructed by vegetation ≥ 2 ft in height
Total Unobstructed Channel Width	TUCW	Sum of all segments of channel width unobstructed by vegetation ≥ 2 ft in height
Percent Unobstructed Area		Percent area of the channel unobstructed by vegetation ≥ 2ft in height

Mean MUCW and TUCW were calculated for all channels together and the main channel individually. Past PRRIP analyses have focused on MUCW of all channels—which is almost exclusively located in the main channel— and TUCW of the main channel as being most relevant to WC.

5.2 Continuity With Older Data

While object-based classification will serve as the principal method for measurement of in-channel vegetation from 2017 onward, either the pre-2017 visual remote sensing classification or field-surveyed data must be used in tandem with the newer data to capture longer-term changes. Large-scale differences in most years are evident when results from field surveys and visual remote sensing classification are compared for both MUCW (Figure 14) and TUCW (Figure 15). In many years, the difference in the mean values is as much as 200-300 ft.

These discrepancies can be ascribed to several differences between methods including the field survey extending MUCW past the edge of channel into the overbank; the remote sensing visual classification of vegetation height without elevation data; differing delineation of the channel bank location; as well as the limited sample size of the field survey transects compared to the remote sensing transects. Because visual classification is most like the object-based classification in terms of both measurement methods, spatial coverage, and sample size, the visual classification will be used going forward to report channel widths prior to 2017.

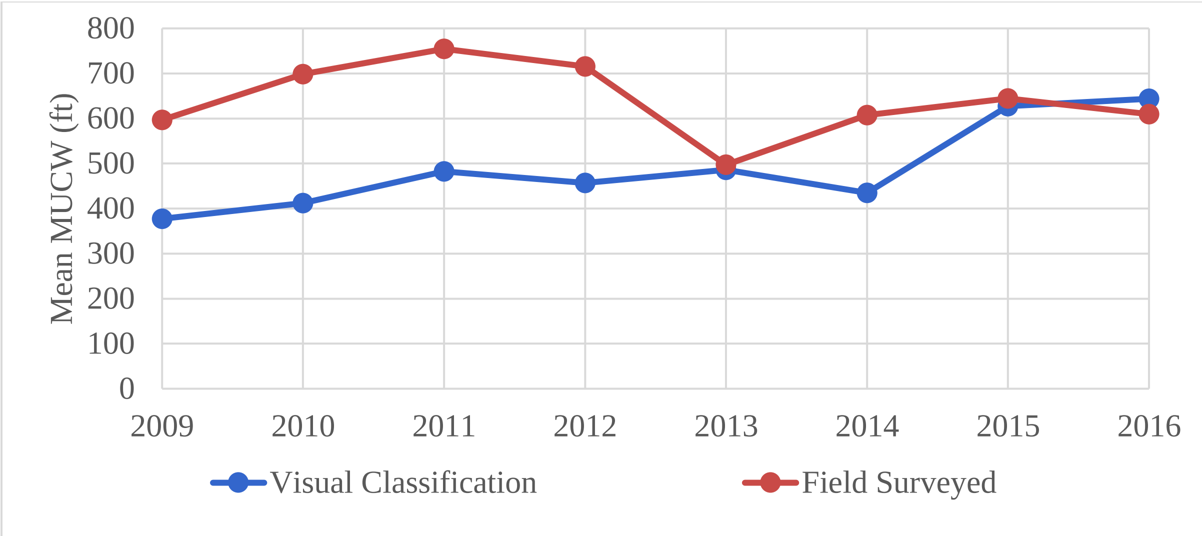


Figure 14. Comparison of the mean MUCW over all channels as measured with visual classification and field surveys from 2009-2016.

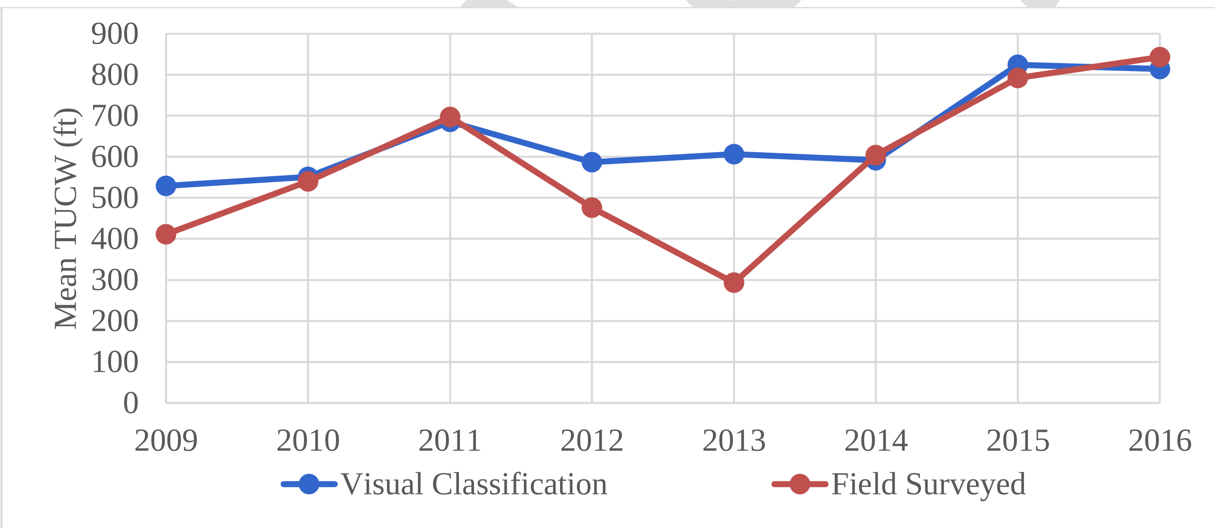
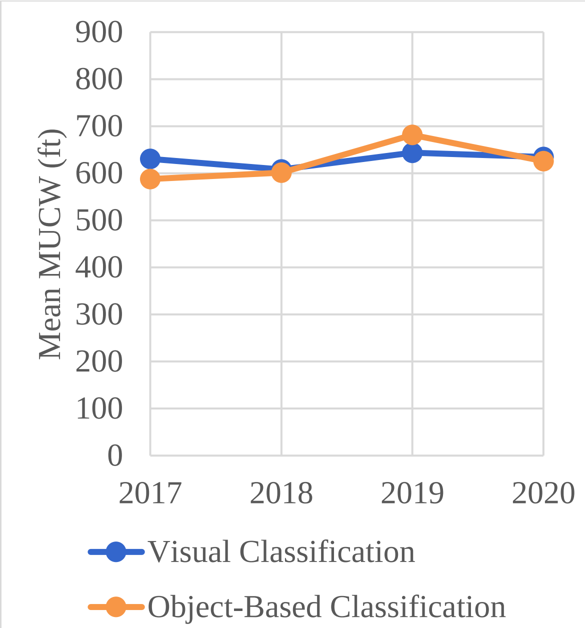


Figure 15. Comparison of the mean TUCW of the main channel as measured with visual classification and field surveys from 2009-2016.

Object-based and visual classification results for MUCW and TUCW were compared for the period of 2017-2020 (Figure 16) to evaluate the similarity of estimates from the two methodologies. Paired t-tests were used to compare results from the two methods using the same subset of originally sampled transects at 5,000 ft spacing to reduce spatial autocorrelation.



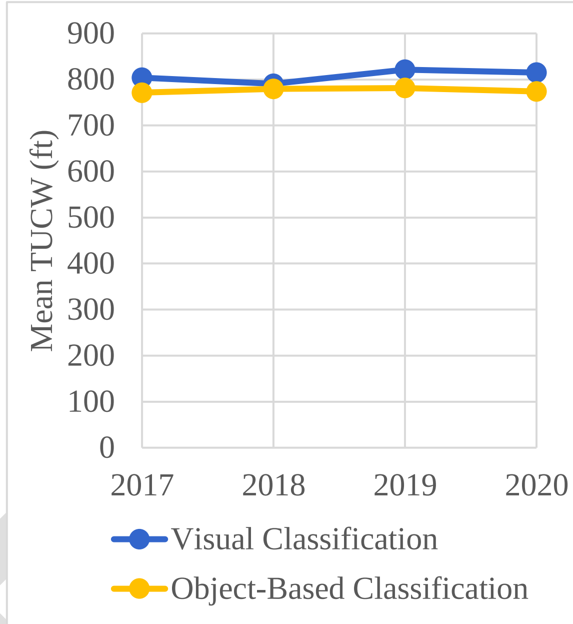


Figure 16. Mean MUCW (all channels) values (left) and TUCW (main channel) values (right), as measured with visual classification and object-based classification for the years 2017-2020.

Object-based classification unobstructed channel widths were typically narrower than visually classified channel widths from 2017-2020, but differences constituted a small percentage of widths. Mean estimates of object-based classification MUCW were significantly narrower in 3 of 4 compared years, with the largest average difference of 52 ft, or 9% of the average, occurring in 2017 (Table 11). Mean estimates of object-based classification TUCW were also significantly narrower in 3 of 4 compared years, with the largest average difference of 33 ft, or 4% of the average, occurring in 2017 (Table 12). Overall, the limited, predictable channel width measurement differences between object-based and visual classifications will allow for effective analysis of large-scale, long-term trends using visual classifications prior to 2017 and object-based classification starting in 2017.

Table 11. Comparing object-based and visual classification estimates of MUCW estimates along the same transects. P values were calculated using paired t-tests within each year.

Year	Est. Mean Diff. Ecog-Visual (ft)	Diff. % of Mean	Difference 95% Confidence Interval (ft)	p value
2017	-52	9	-83 : -22	<0.01
2018	-22	4	-52 : 7	0.13
2019	39	6	5 : 72	0.03
2020	-21	3	-40 : -2	0.03

Table 12. Comparing object-based and visual classification estimates of MUCW and TUCW estimates along the same transects. P values were calculated using paired t-tests within each year.

Year	Est. Mean Diff. Ecog-Visual (ft)	Diff. % of Mean	Diff. Confidence Interval (ft)	p value
2017	-33	4	-49 : -18	<0.01
2018	-2	0	-20 : 16	0.82
2019	-29	4	-43 : -14	<0.01
2020	-28	3	-46 : -9	<0.01

The systematic difference between visual and object-based classification may in part due to the lack of elevation or vegetation height data in the visual classification methods. Visual observers rely primarily on vegetation density to interpret vegetation height. One land cover that exemplifies potential problems with this method is grass. In-channel grasses on the Platte may range from 0-6 ft tall and at any height may be highly variable in color and density (Figure 17). Determining whether each patch is greater or less than 2 ft based on visual interpretation of aerial imagery alone is inherently subjective.

Figure 17. Three patches of in-channel grass observed on the Platte in November of 2021 with variable height, density, and color. Researcher is 6 ft tall.

There are other factors that may explain the systematic difference between the visual and object-based classification results, including the subjective nature of bank delineation by visual observers, and the scale of visual observation. Visual observers typically draw out unobstructed width lines at a scale of 1:2,400. At that scale, visual observers may miss small patches of obstructing vegetation, resulting in overextension of unobstructed width lines. Whatever its cause, the systematic difference between the two methods is small, which indicates that large-magnitude trends in MUCW and TUCW are detectable when incorporating results from the two methods together.

5.3 Land Cover Classification Results

Total classified areas are displayed in Figure 18 and Tables 13 and 14. The total area of unobstructed channel —water, sand, and vegetation less than 2 ft in height increased in both 2018 and 2019 and returned to 2017 levels in 2020. Unvegetated channel area (water and sand) increased slightly in 2018, corresponding with losses in coverage of all vegetation classes, though primarily vegetation less than 2 ft in height. Unvegetated channel increased more substantially in 2019, likely due to the high flow events that occurred that year. Most of that increase was due to a reduction in the area of vegetation 2-6 ft in height, which decreased by approximately 50%. We infer that the increase in unobstructed area in 2019 was driven by disturbance of higher islands and near-overbank areas with tall, established vegetation.

In 2020, the coverage of vegetation 2-6 ft in height increased by over 150%, to encompass more area than was observed in 2017-2019. Water, sand, and vegetation less than 2 ft in height simultaneously decreased in coverage, suggesting that vegetation on islands and near-overbank areas recovered quickly from the 2019 flood disturbance.

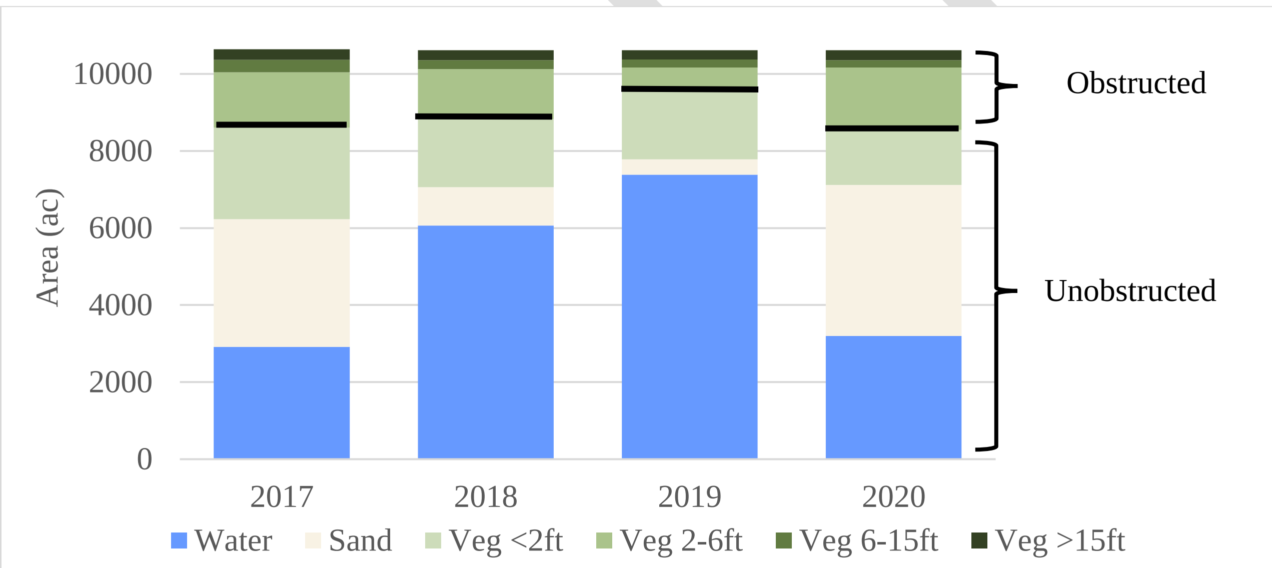


Figure 18. Total area of land cover classes in the main channel. Brackets on the right indicate classes that are grouped as obstructed or unobstructed.

Table 13. Area and % change of all classes as measured in each year in the main channel from Overton to Chapman from 2017 - 2020.

	Area (ac)				% Change		
Class	2017	2018	2019	2020	2017 - 2018	2018 - 2019	2019 - 2020
Water & Sand	6231	7060	7784	7122	13	10	-9
Veg <2ft	2373	1768	1779	1426	-26	1	-20
Veg 2-6ft	1441	1300	608	1617	-10	-53	166
Veg 6-15ft	321	232	200	192	-28	-14	-4
Veg >15ft	275	255	245	258	-7	-4	5

Table 14. Area and % change of obstructed and unobstructed main channel area in each year from Overton to Chapman from 2017 - 2020.

Class	Area (ac)				% Change		
	2017	2018	2019	2020	2017 - 2018	2018 - 2019	2019 - 2020
Unobstructed	8604	8828	9563	8548	3	8	-11
Obstructed	2037	1787	1053	2067	-12	-41	96

When plotted by river mile, MUCW (all channels) and TUCW (main channel) (Figures 19 and 20) exhibit a high degree of variability. MUCW is more variable than TUCW due to its higher sensitivity to the location of obstruction within the channel. Small in-channel obstructions can reduce MUCW by hundreds of feet, cutting it in half or more, while impacting TUCW only minimally.

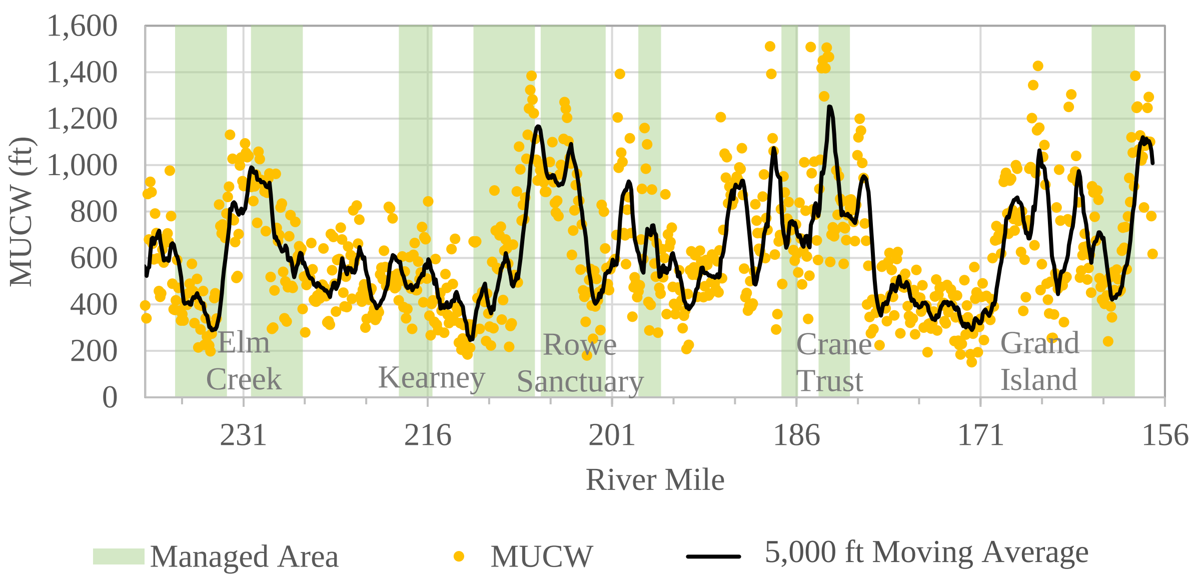


Figure 19. All channels maximum unobstructed width (MUCW), as sampled at transects spaced at 500 ft intervals, with a 5,000 ft moving average. Channel areas managed to reduce in-channel vegetation are shaded green.

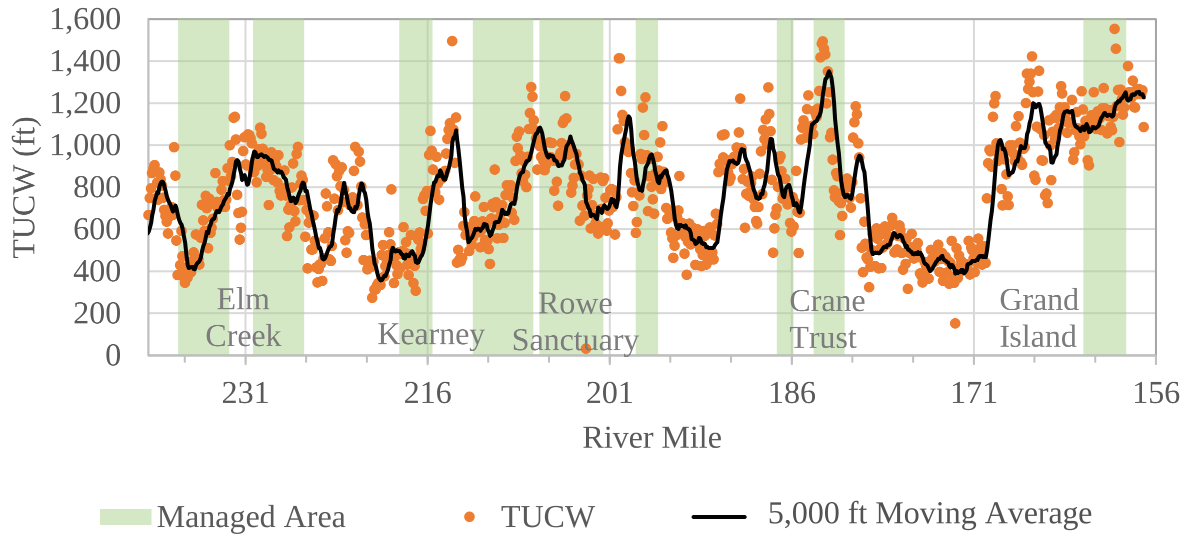


Figure 20. Main channel total unobstructed width (TUCW), as sampled at 500 ft transects, with a 5,000 ft moving average. Channel areas managed to reduce in-channel vegetation are shaded green.

When compared to the historical record of mean MUCW (all channels) and TUCW (main channel) values from visual classification (Figures 21 and 22), the period of 2017-2020 was relatively stable. The modest increase in MUCW and TUCW following the 2019 floods (<50 ft) was substantially less than the approximately 200 ft increases in both metrics that occurred in 2015.

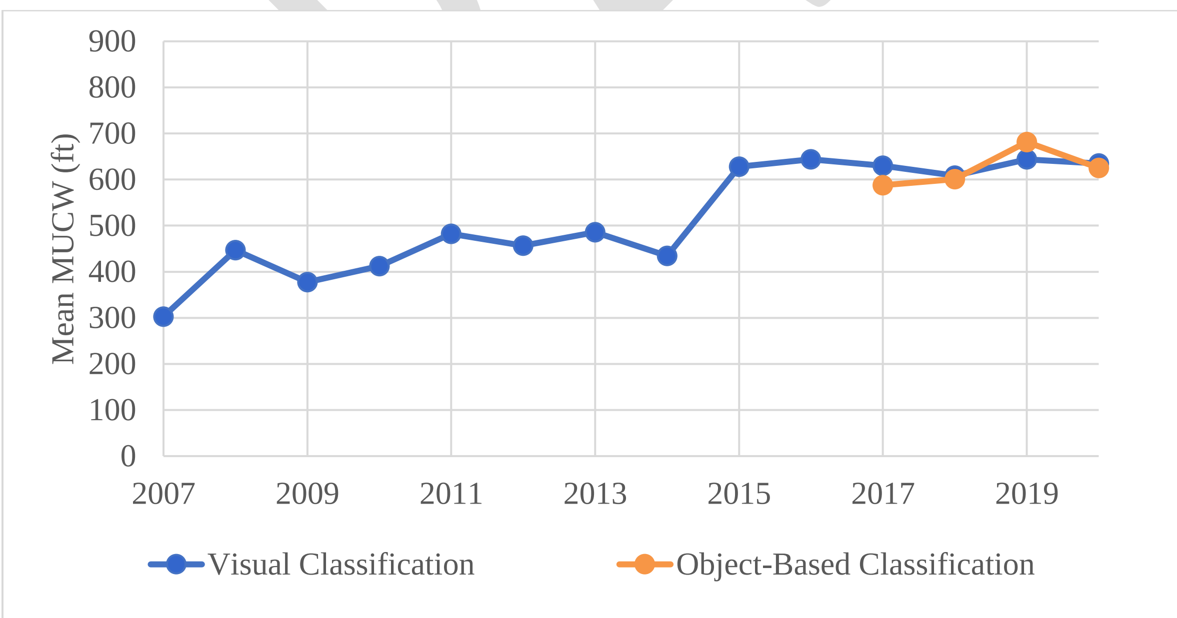


Figure 21. Mean MUCW over all channels by year from visual classification of aerial imagery and object-based classification.

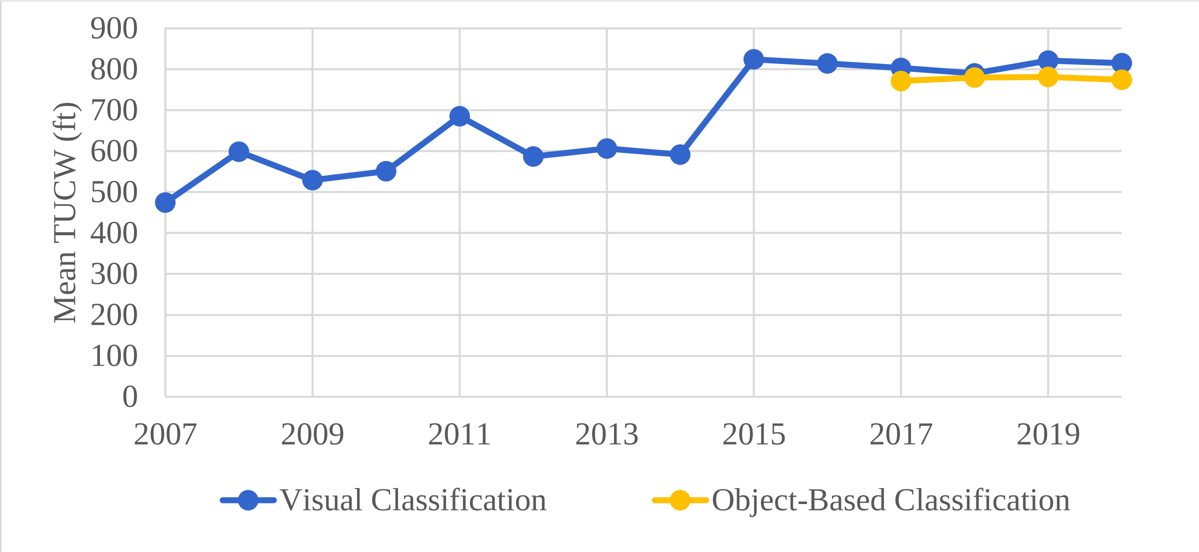


Figure 22. Mean main channel TUCW by year from visual classification of aerial imagery and object-based classification.

Prior PRRIP research indicated that mean daily peak (Q_P), 40-Day Max ($Q_{MAX\ 40}$), and mean discharge during the seed germination period in June (Q_{June}) may influence the occurrence and distribution of in-channel vegetation in the AHR (citation). These metrics are plotted together in Figure 23 with TUCW estimated from visual remote sensing from 2007-2016 and object-based classification from 2017-2020. As demonstrated in the figure, TUCW increased substantially in 2015, following a peak flow event with both high magnitude (Q_P) and duration ($Q_{MAX\ 40}$). Less substantial width responses occurred following 2008, 2011 and 2019 peak flow events. TUCW remained stable during the period of 2017-2020 despite years with no substantial peak flow. During those years, germination season flow was higher than during prior drought years (2012-2014) indicating that channel inundation during the germination season may be preventing vegetation from establishing in the channel.

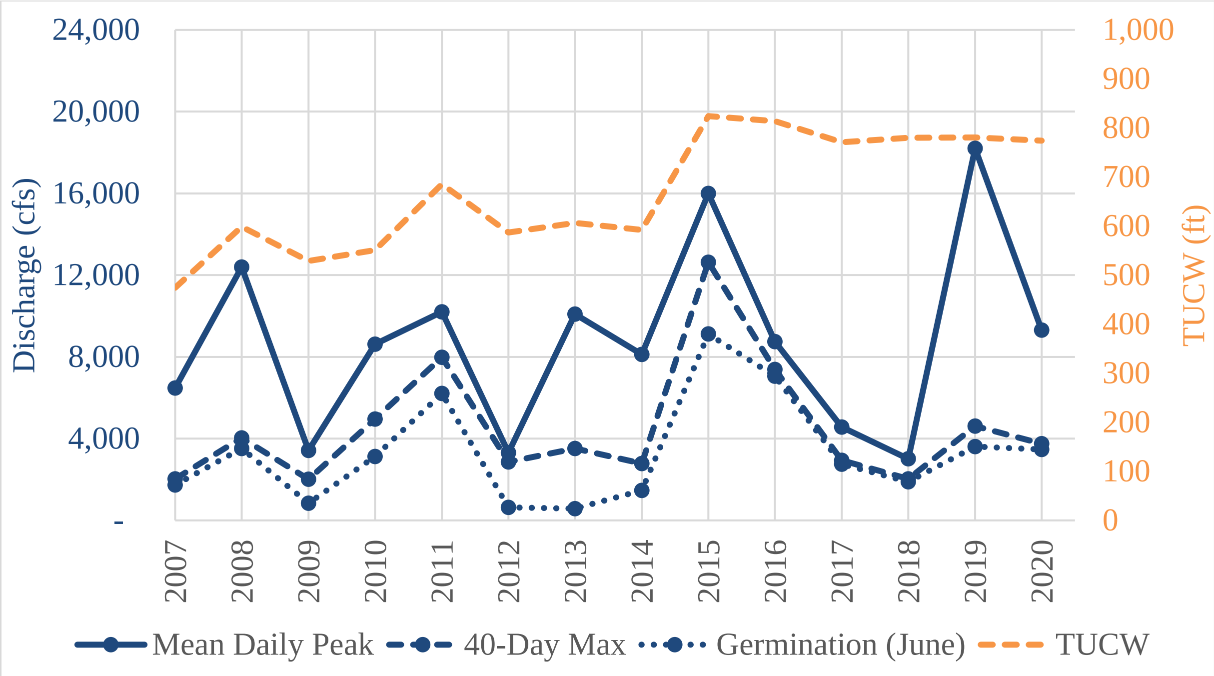


Figure 23. Hydrologic metrics and corresponding main channel TUCW as measured with visual classification from 2007 to 2020. Displayed TUCW values were estimated with visual remote sensing from 2007-2016 and object-based classification from 2017-2020.

For all years, the percent unobstructed area, MUCW (all channels), and TUCW (main channel) are all higher in areas managed by PRRIP than other areas (Figures 24- 26). Both percent channel area unobstructed and MUCW increased in both areas as a response to the 2019 floods and then returned to similar 2017-2018 levels in 2020 (Figures 24 and 25). TUCW was not evidently affected by the 2019 floods in either area (Figure 26).

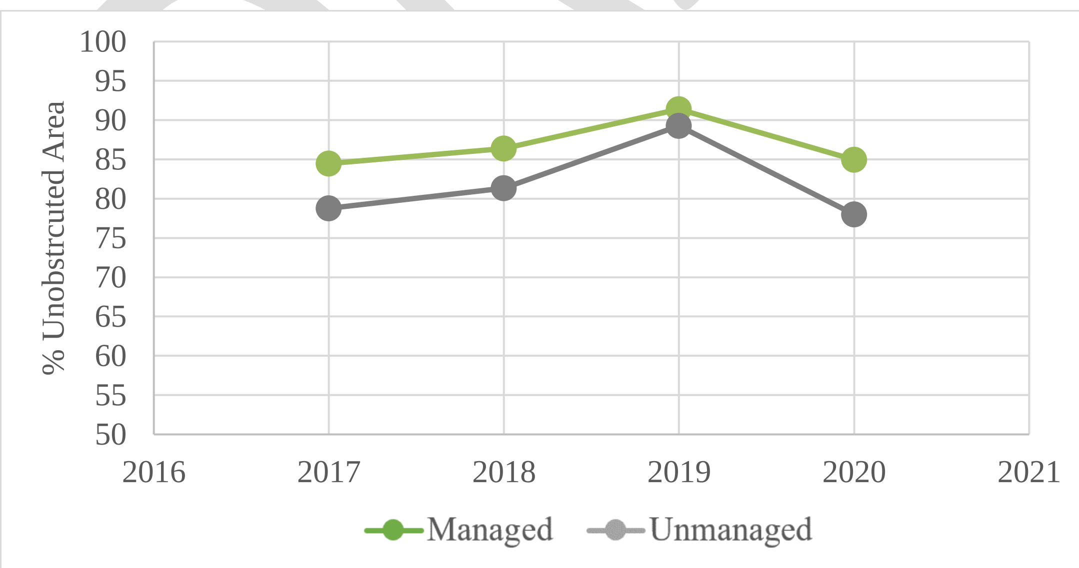


Figure 24. Percent unobstructed area in main channel areas managed to reduce in-channel vegetation (managed) and other areas (unmanaged).

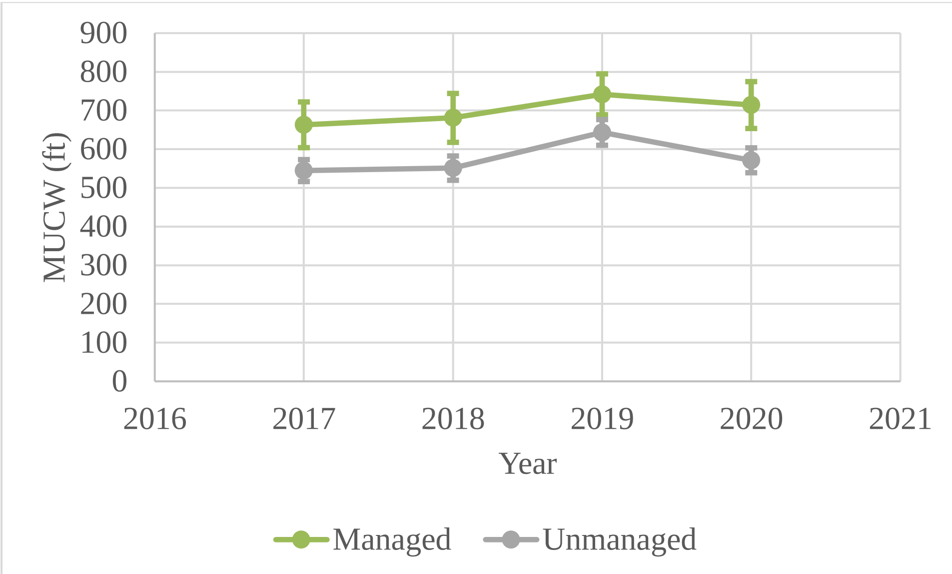


Figure 25. MUCW means (points) and standard errors (bars) of in main channel areas managed to reduce in-channel vegetation (managed) and other areas (unmanaged).

Figure 26. TUCW means (points) and standard errors (bars) in main channel areas managed to reduce in-channel vegetation (managed) and other areas (unmanaged).

A 2-sample t-test was used to understand if MUCW and TUCW of the main channel were different in managed and unmanaged areas (Table 15). A subset of transects (5,000 ft spacing) was used for comparisons to reduce spatial autocorrelation. MUCW was on average wider in managed areas, with the mean difference as much as 127 ft in 2018; however, due to high width variability between transects, the differences were not statistically significant. TUCW values were very similar on managed and unmanaged areas, with the mean difference in all years estimated to be 10 ft or less and not statistically significant.

Table 15. Two-sample t-test results comparing main channel MUCW and TUCW values on managed vs unmanaged areas.

Year	MUCW			TUCW		
	Est. Mean Diff. Managed - Unmanaged (ft)	Diff. 95% Conf. Int.	p-value	Est. Mean Diff. Managed - Unmanaged (ft)	Diff. 95% Conf. Int.	p-value
2017	104	-28 : 237	0.12	10	-119 : 139	0.88
2018	127	-15 : 270	0.08	-8	-138 : 122	0.91
2019	94	-31 : 219	0.14	-10	-142 : 122	0.88
2020	123	-15 : 262	0.08	-4	-136 : 129	0.96

See Appendix Section E for complete land cover classification results.

6. Volume Change Analysis

Quantifying annual variation in sediment volume is critical for understanding changes in channel morphology and habitat in the AHR and for evaluating the success of management actions. A negative sediment balance resulting in a degradational channel has been identified as one of the primary drivers of historic habitat loss for the PRRIP target species (DOI, 2006).

6.1 Volume Change Methods

The 2009-2016 PRRIP field reach-wide monitoring (RWM) team collected two types of data to estimate annual sediment transport: repeat cross-section elevation surveys and repeat bed and suspended sediment load samples at five bridges. Sediment load samples were used to develop sediment transport rating curves, which were applied to annual flow data to estimate differences in sediment transport throughout the AHR. Over time, the RWM team concluded that the limited spatiotemporal coverage of samples (Tetra Tech, 2017), as well as the chaotic, episodic, and threshold-dependent nature of sediment transport (Wohl et al., 2015) limited ability to make inferences about AHR sediment dynamics based on the field-based RWM protocol.

An alternative to collecting field-based data is to use LiDAR or other remote sensing tools to create digital elevation models (DEMs) of the complete region of interest. The newer DEM elevation values are subtracted from the older values, yielding a DEM of Difference (DoD). The DoD values can be summed together to directly estimate the net bed volume change. DoD values can also be analyzed spatially to determine where aggradation or degradation occurs within a reach, and at what magnitude. The updated RWM protocol utilizes this method based on topobathymetric LiDAR data. Due to the fundamental differences in sampling method and spatial coverage between the field and remote sensing methods, the PRRIP Independent Science Advisory Committee

(ISAC) recommended that field-based volume change estimates not be used in tandem with the remote sensing-based estimates in this or future analyses (PRRIP, 2022).

The LiDAR elevation data were collected from an airplane by QSI in either October or November of the years 2016-2020. The rasters have 3 ft spatial resolution and vertical error of less than 3 inches for dry areas and less than or equal to 9 inches for wet areas (QSI, 2016; QSI, 2017; QSI, 2018; QSI, 2019; QSI, 2020). All accuracy values are presented in Table 16. Accuracy was assessed by QSI at the time of data collection, and is based on comparison of field RTK GPS ground control check points to the LiDAR DEM. The accuracy values represent the 95% confidence interval, as derived from the population of differences between field-measured and DEM values. QSI's accuracy assessments are designed to meet the guidelines of the Federal Geographic Data Committee National Standard for Spatial Data Accuracy (FGDC, 1998). The accuracy assessment data indicate elevation values in wet areas had consistently higher uncertainty than dry areas across all years. As a result of deeper and more turbid water during the period of data collection, wet areas in 2019 had a higher uncertainty value at 9 inches (Table 16).

Table 16. Accuracy estimates for the LiDAR DEM surfaces from each year for wet and dry areas. Accuracy values represent 95% confidence in the estimate.

Year	Dry Accuracy (in)	Wet Accuracy (in)
2016	1.7	3.1
2017	2.2	4.6
2018	1.2	4.2
2019	1.2	9.0
2020	2.2	3.1

The software Geomorphic Change Detection 7.5 (GCD) from the Riverscapes Consortium (Riverscapes Consortium, 2020) was used for most components of the volume change analysis. GCD is a GIS-based software designed to estimate sediment budgets via the morphological method and quantify associated error. A conceptual model representing the processing is given in Figure 27.

Estimating error is a critical component of volume change analysis. Each DEM has its own error which is then propagated through to the DoD. Several methods exist in the literature for quantifying error from DoD-derived sediment budgets. Recent research (e.g. Wheaton et al., 2010; Bangen et al., 2016) has suggested that for many rivers, error is not spatially uniform, but varies considerably with conditions of the surface like roughness, slope, and vegetation. In this case, fuzzy inference systems (FIS) may serve as a good framework to quantify spatially variable error (Wheaton et al., 2010). Examining the elevation distribution of coincident points, or LiDAR points that are within a negligible XY distance from each other, has been proposed as a method to examine the spatial distribution of error and develop boundaries for FIS groups (Hensleigh, 2014).

A preliminary analysis of coincident points in a sample reach for one analysis year was completed to examine the effect of slope, water depth, and vegetation height on the elevation difference of coincident points (serving as a proxy for error). None of the factors were found to have a significant effect on proxy error. This is likely due to the consistently low values of slope, water depth, and grain size on the Central Platte. Therefore, a FIS-based spatially variable error model was not used for this analysis.

Instead, error was assumed to be spatially constant within wet and dry areas, but different between them, based on the QSI accuracy estimates presented in Table 16. Following differencing of the elevation values to produce a DoD, each difference value was assigned a probability that the change was real, rather than a result of measurement error, based on a combination of the difference magnitude and uncertainty associated with the two differenced DEMs. The difference values were then thresholded probabilistically at 95%, consistent with the Lane et al. (2003) method. The result of this method was that elevation differences falling below the confidence limit were excluded from the volume change calculation. Significant elevation differences (exceeding the confidence limit) were summed to yield the net volume change for each reach and analysis year.

For each area of interest over which difference values were summed to yield volume change, the error of the volume change estimate was calculated as the sum of the propagated elevation uncertainty values across the DoD surface, multiplied by area, consistent with Lane et al. (2003). These error values were used to evaluate the significance of volume change estimates. If volume change confidence interval was below 0, the area was determined to be significantly degradational, meaning that it experienced a net loss of sediment during the time period. If the confidence interval was above 0, the area was determined to be significantly aggradational. If the confidence interval crossed 0, it was not possible to determine with confidence whether the area was aggradational or degradational.

This remote sensing method also allows for the elevation differences of each cell to be classified, and both the area and volume change separated by class. The elevation difference (ΔZ) classifications used in this analysis are as follows:

1. Aggradation
2. Bed degradation
3. Lateral Erosion

Aggradation and bed degradation represent low-magnitude positive and negative elevation differences typically associated with the migration of sandbars. An area with bed degradation that outpaces aggradation may be incising. Lateral erosion represents large-scale negative elevation changes near the channel banks and on the margins of established islands. High levels of lateral erosion are an indication of channel widening. For this analysis, lateral erosion areas were classified as areas along channel/bar/island margins (within 20 ft of the modeled 5,000 cfs flow extent) with an elevation difference less than or equal to -2 ft. Areas of bed degradation were classified as all remaining significantly negative areas.

Net bed volume change was subsequently calculated by subtracting the magnitude of bed degradation from aggradation. Lateral erosion is not included in the net bed volume change calculation, because it is a measure of channel bank change rather than channel bed change.

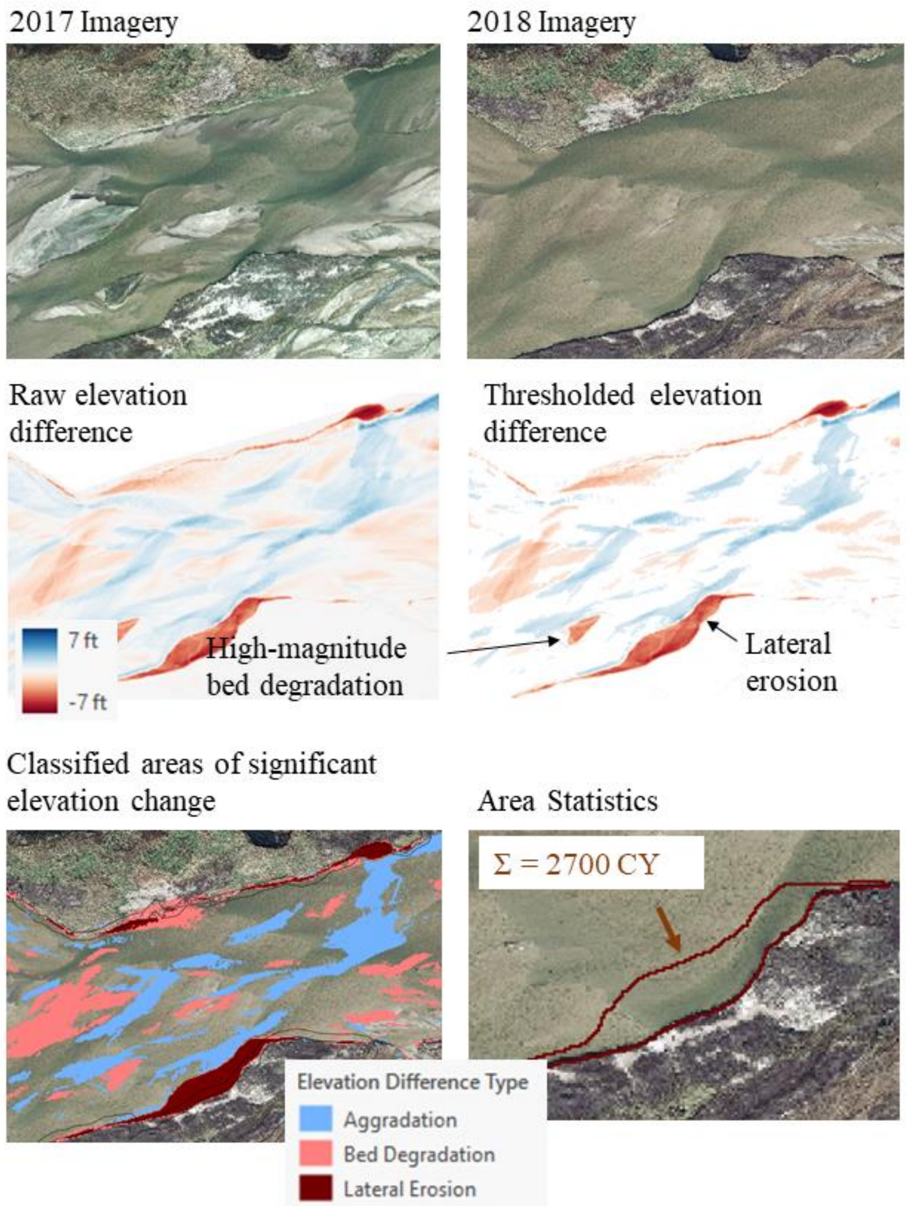


Figure 27. Conceptual diagram outlining how elevation values of two years are differenced, thresholded based on probability, classified by difference type, and analyzed spatially.

The lateral erosion estimate was adjusted for the J2 Return to Overton reach to account for sediment augmentation activities in the reach. The analysis mask included the area excavated for the purposes of sediment augmentation, and the classification algorithm automatically classified the excavation area as lateral erosion. The volume of excavated material is quantified annually for sediment augmentation monitoring and is reported to the U.S. Army Corps of Engineers. Excavation volume is quantified by differencing the fall and summer LiDAR elevations for the excavation area within the same year. Lateral erosion and sediment augmentation volume are presented separately for the J2 Return to Overton reach.

6.3 Volume Change Results

The AHR net sediment balance analysis indicates that 2017-2020 was a period of relative stability (Figure 28). The net volume change estimates were negative for all analysis years except 2019-2018, though the confidence interval for all years crossed 0, indicating that no year in this period was either significantly net aggradational or degradational.

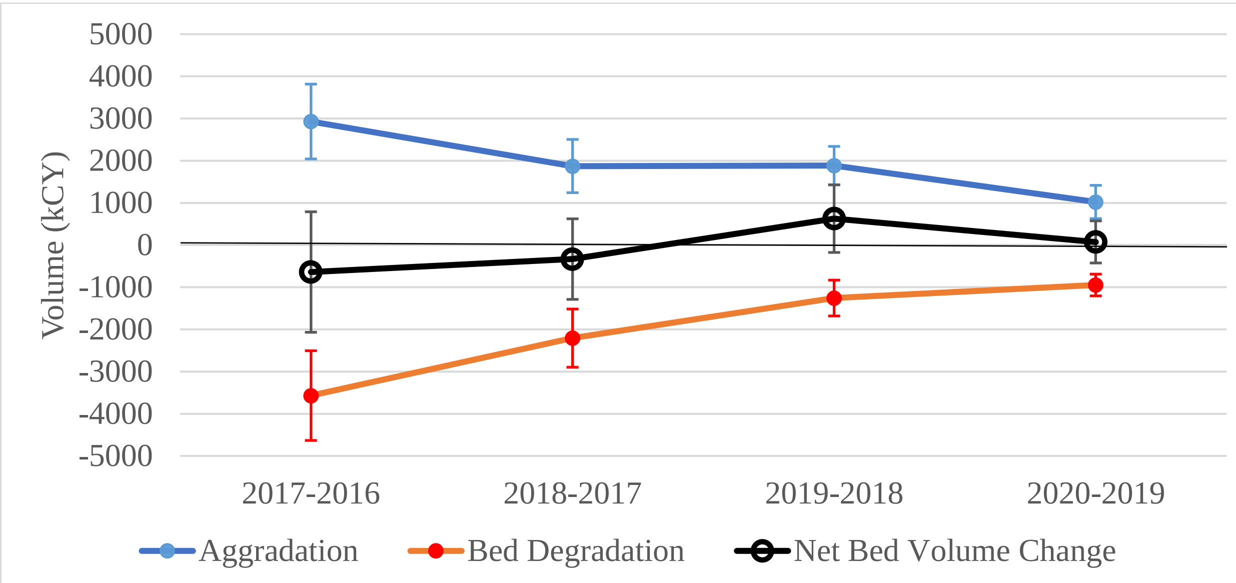


Figure 28. Total volumes of significant elevation change (points), and error (bars), classified as either aggradation or bed degradation, with net bed volume change, for all channels from Overton to Chapman.

When making sediment balance comparisons between years, it is important to note that the higher uncertainty values in wet areas in 2019 reduced the total area that met the significance threshold necessary for inclusion in the analysis. Nevertheless, a signature from the 2019 floods is evident when significant elevation differences are classified (Figures 28 - 30). 2019 saw an increase in both the area of aggradation (Figure 29) and the volume of lateral erosion (Figure 30). Bed degradation did not increase in 2019 in correspondence with the rate of aggradation. This indicates that the dominant sediment dynamic during the floods was lateral erosion and subsequent deposition of eroded material, rather than general bed erosion. The elevated magnitude of lateral erosion volume in 2019 (Figure 30) suggests that certain areas of the channel experienced widening. This is reflected in a slight (non-significant) increase in wetted width at the AHR-scale (Figure 8).

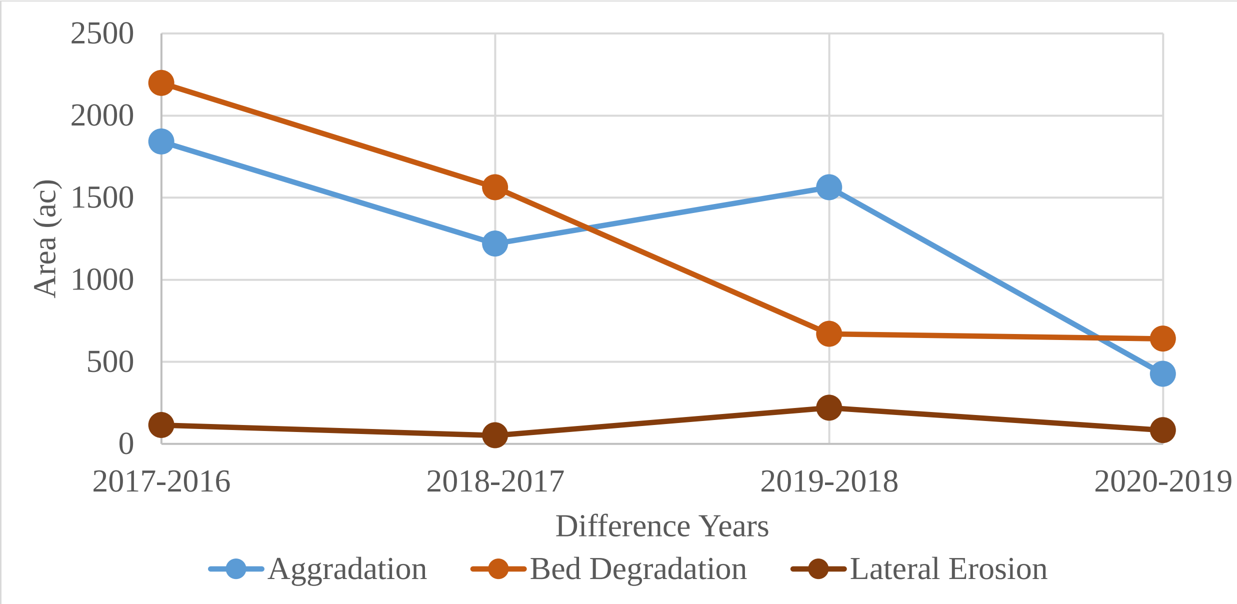


Figure 29. Total area of significant elevation change classified as either aggradation, bed degradation, or lateral erosion between years. These values represent all channels from Overton to Chapman.

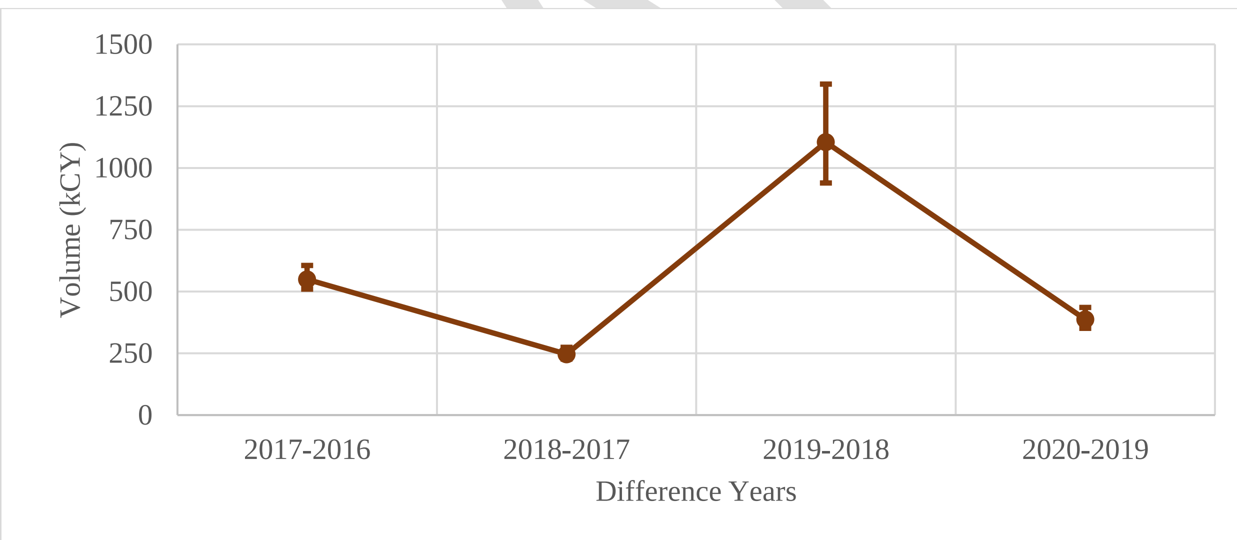


Figure 30. Total volume of lateral erosion (points) with estimated error (bars) by year. These values represent all channels from Overton to Chapman.

While the net bed volume change estimate for all reaches from Overton to Chapman was positive, but not significantly positive for the 2019-2018 analysis (Figure 28), many individual reaches were significantly aggradational during that time period (Figure 31). The 5 reaches from Odessa to Chapman, as well as the north channel from Lexington to Overton, all experienced a net gain in channel bed volume. The aggradation may reflect material that was laterally eroded during the 2019 floods and subsequently deposited in the channel bed.

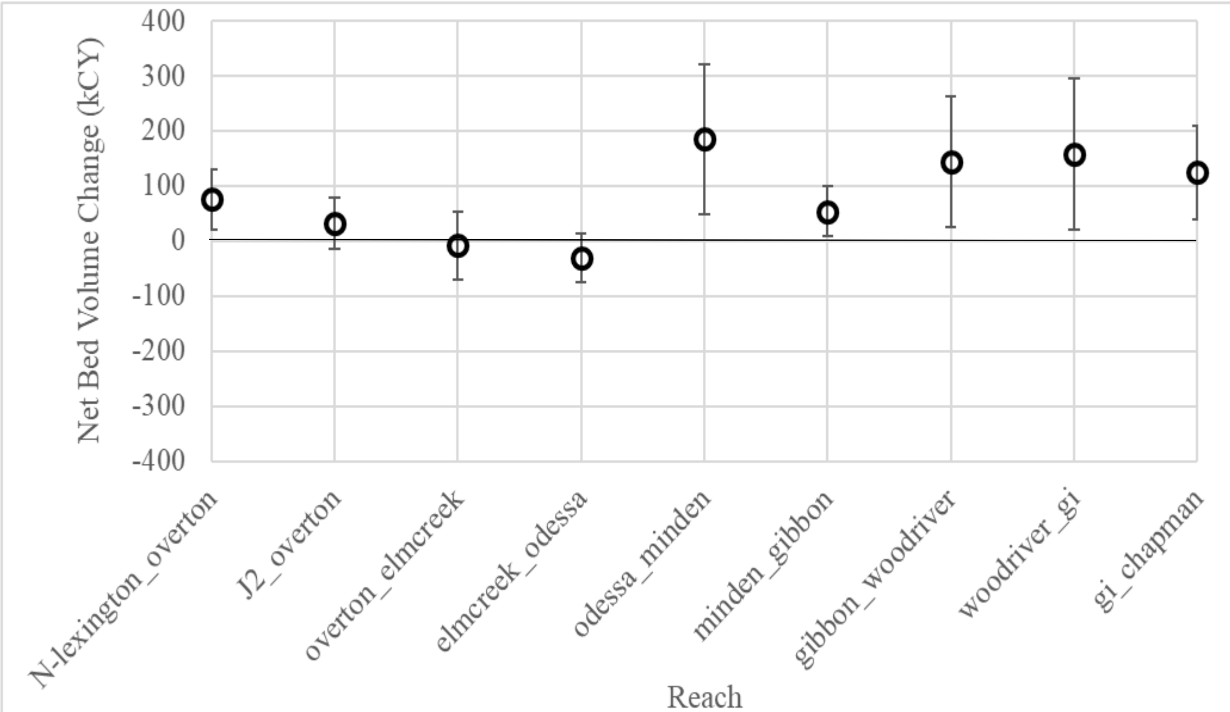


Figure 31. Net channel bed volume change estimates (points) and estimated error (bars) for all channels by reach, 2019-2018.

The geomorphic reaches from Overton to Chapman have similar rates of lateral erosion when averaged by river mile (Figure 32). However, the north channel from Lexington to Overton has notably lower values of lateral erosion than the other reaches, while the J2 Return to Overton reach experienced significantly higher rates of lateral erosion than all other reaches. The data represented in Figure 32 are only for one difference surface—2019-2018—however, the pattern was consistent across all years examined. The north channel from Lexington to Overton likely has lower rates of lateral erosion because of consistently lower flow in that channel relative to others below the J2 Return, as well as the dominance of tall, woody vegetation in that reach, which stabilizes banks.

Sediment augmentation volume is included in addition to lateral erosion for the J2 Return to Overton reach in Figure 32. Lateral erosion and sediment augmentation may play similar roles in channel sediment dynamics by introducing material to the channel bed.

The high rate of lateral erosion in the J2 Return to Overton reach is likely due to a combination of reach slope and hydrology, which is dominated by the clearwater hydropower return flows from the J2 Canal. Sediment-starved water entering the channel at the J2 Return has resulted in high rates of bed degradation in the reach, which has in turn reduced channel slope. Much of the upper portion of the reach with reduced slope has transitioned from a braided planform to a single-thread wandering planform that meanders back and forth across the incised channel section, laterally eroding floodplain terraces along the outside of bends.

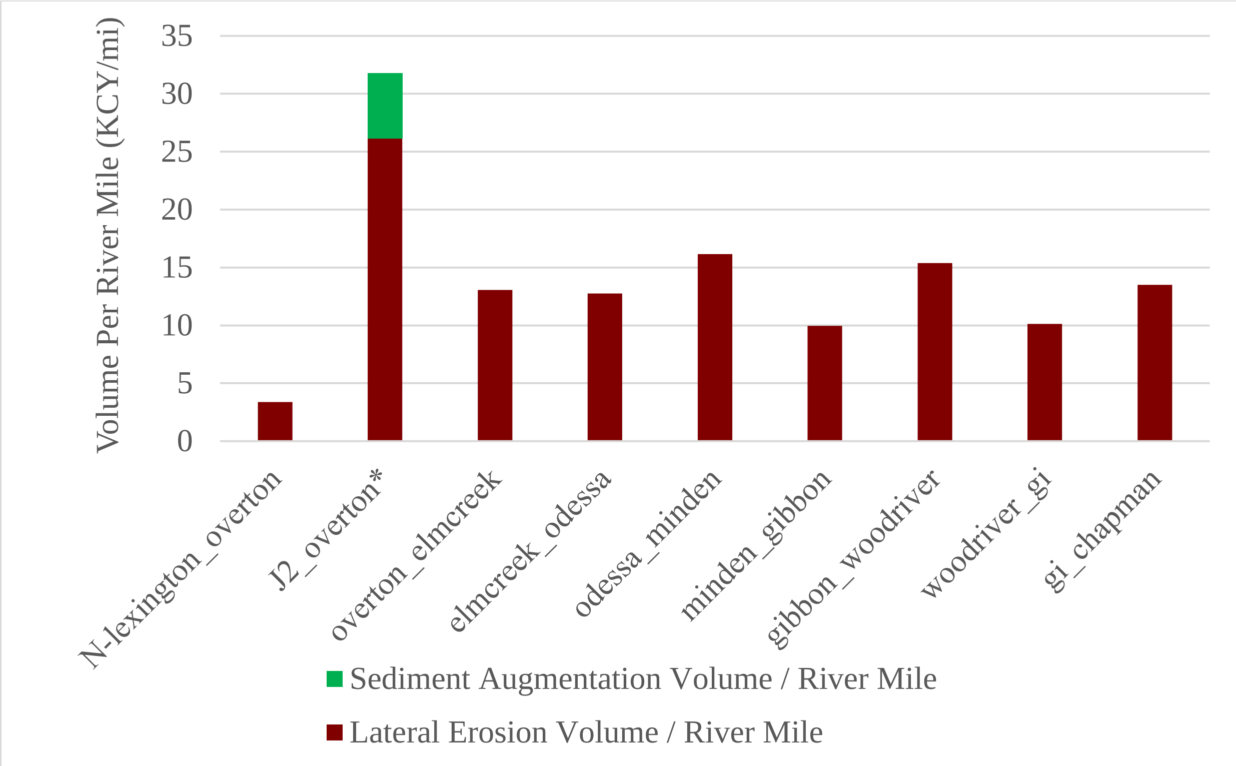


Figure 32. Lateral erosion volume by geomorphic reach for all channels for the analysis period 2019-2018. **Sediment augmentation in the J2 Return to Overton reach is subtracted from the classified lateral erosion volume, and reported separately.*

The sediment balance of the J2 Return to Overton reach is of particular interest to PRRIP. The reach has a history of incision and narrowing because of the sediment-starved water entering the river at the return. PRRIP sediment augmentation efforts have been focused on this reach since 2017 to halt the downstream progression of incision and narrowing. 6 KCY / river mile of sediment was mechanically augmented to the J2 Return to Overton reach in 2019 (Fig. 32). Additionally, 26 KCY / river mile of sediment was laterally eroded within the reach (Fig. 32). Lateral erosion may act as a natural sediment augmentation by adding sediment to the channel bed within the reach and downstream.

Volume change and net sediment balance of the J2 Return to Overton reach are presented in Figure 33. The reach had a positive, though not significant, net channel bed volume difference for 3 out of 4 analysis years (Figure 33). The sediment balance within the reach is not an adequate measure of success of sediment augmentation efforts, which are targeted primarily to address habitat areas downstream like Cottonwood Ranch. To address this question directly, volume differencing data such as these will be incorporated into a systematic and streamlined approach to measure the success of sediment augmentation by the EDO in 2022.

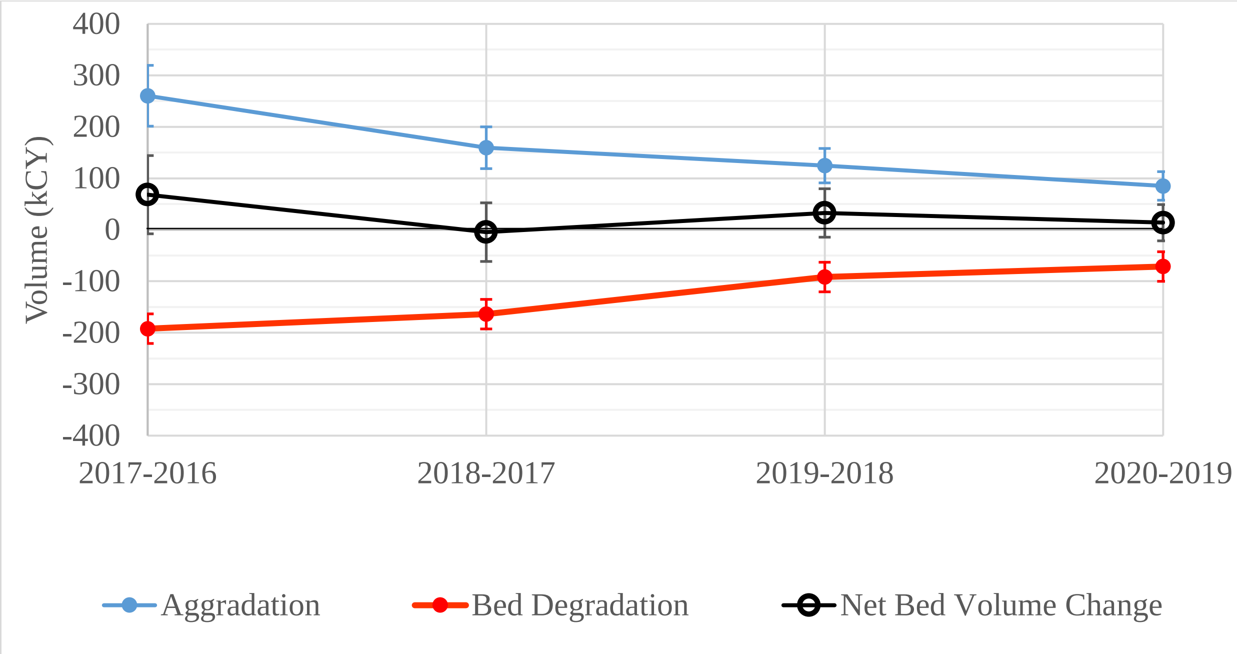


Figure 33. Total volumes of significant elevation change (points), and error (bars), classified as either aggradation or bed degradation, with net bed volume change, for the J2 Return to Overton reach.

See Appendix Section E for complete volume change analysis results.

7. Suitable Whooping Crane Roosting Habitat

7.1 Suitable Whooping Crane Roosting Habitat Methods

Suitable WC roosting area is defined here as an area of channel with unobstructed width wider than 650 ft and depth shallower than 1 ft. These criteria were determined through analysis of whooping crane telemetry data by Pearse et al. (2016) and Baasch et al. (2019). The area of suitable roosting habitat has been evaluated by intersecting unobstructed width results from the land cover classification and depth results from the hydrodynamic modeling (Figure 34).

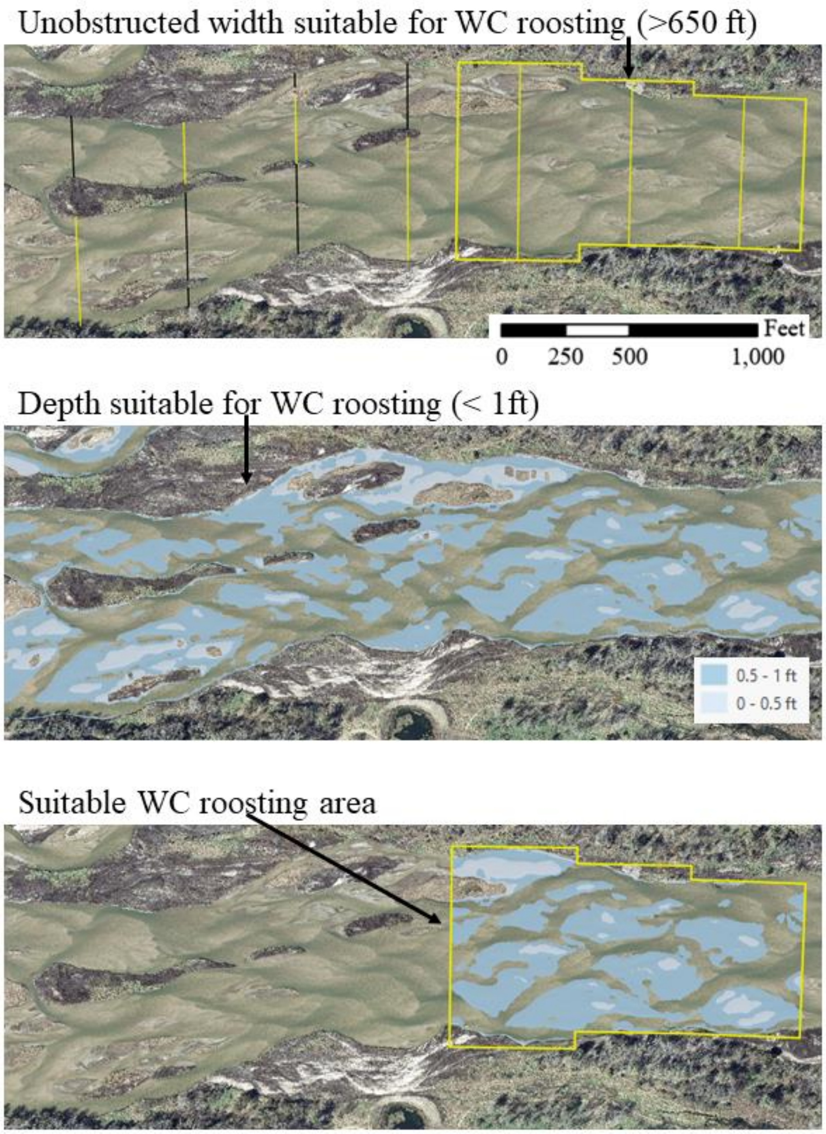


Figure 34. Conceptual diagram illustrating the classification of suitable WC roosting area by intersecting unobstructed width and modeled depth results.

7.2 Suitable Whooping Crane Roosting Habitat Results

Due to its dependence on the availability of suitably shallow water, the area of suitable roosting habitat in the AHR is maximized at a flow of approximately 750 cfs (Figure 35). The area of suitable roosting habitat on the main channel is considerably greater in the geomorphic segments from Minden to Chapman due in part to longer reach length (Figure 36). When considered as an area percentage, the reaches Elm Creek to Odessa, Gibbon to Wood River, Wood River to Grand Island, and Grand Island to Chapman have similar values for percent suitable roosting area, ranging from 21-31%. Overton to Elm Creek and Odessa to Minden have lower values, at 10 and 7%, respectively. The Minden to Gibbon reach stands out with 73% suitable whooping crane roosting area at 2000 cfs.

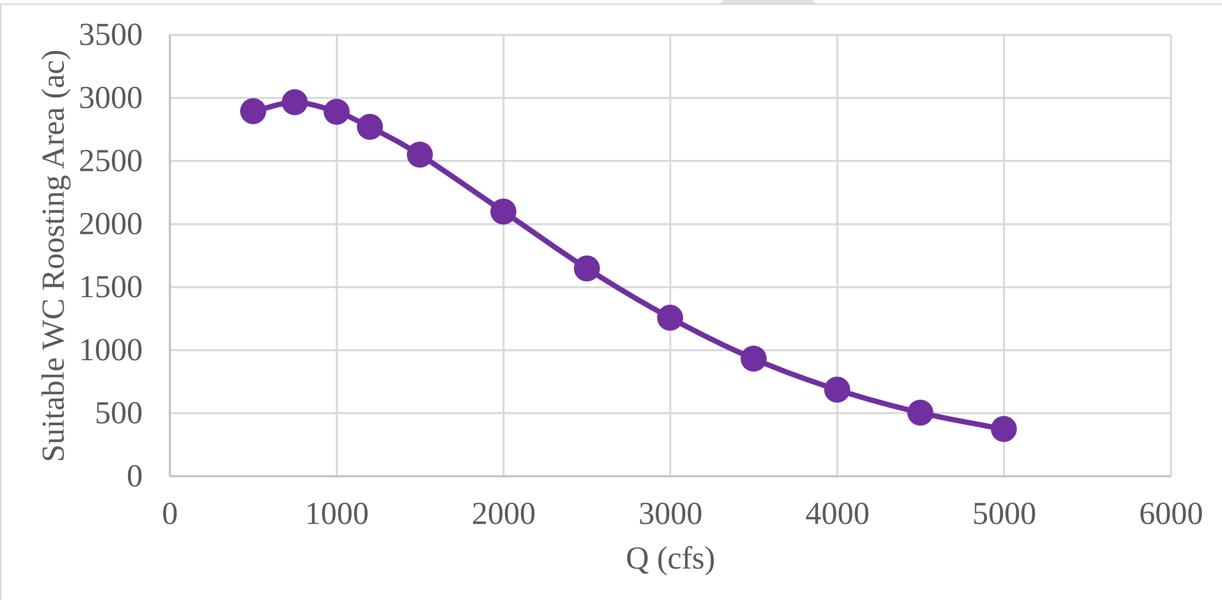


Figure 35. Suitable whooping crane roosting area in the AHR by modeled flow, for all channels in 2020.

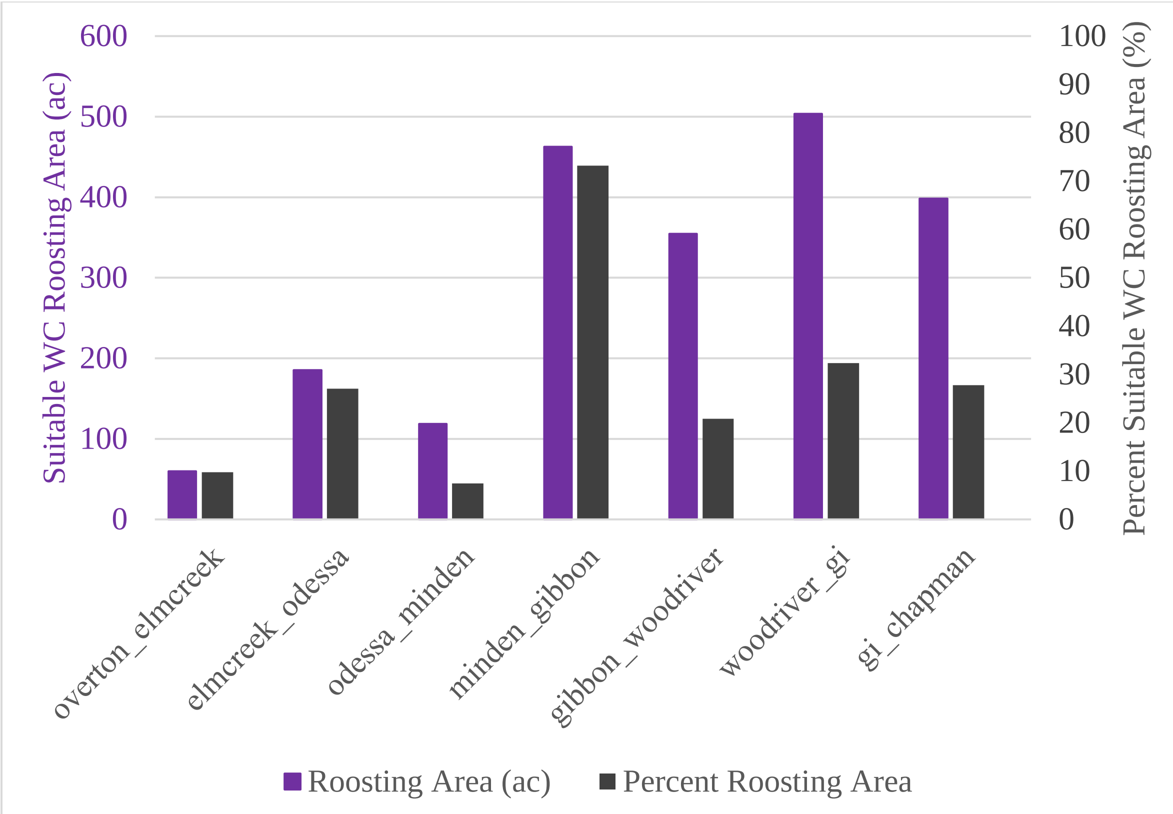


Figure 36. Absolute and percent suitable roosting area by geomorphic reach for the main channel, modeled at 2000 cfs with 2020 data.

Managed lands have consistently higher percent whooping crane roosting area values than other main channel areas across all years (Figure 37). Both areas experienced an increase in the availability of suitable roosting habitat in 2019, likely as a response to the floods. Both areas also saw a return to similar 2017-2018 levels in 2020. The temporal trend more closely mirrors the trend in MUCW (Figure 21) than the area with depth less than 1 ft (Figure 12), suggesting that the 2019 flood impacts of roosting habitat availability were driven by change in vegetation cover rather than change in depth.

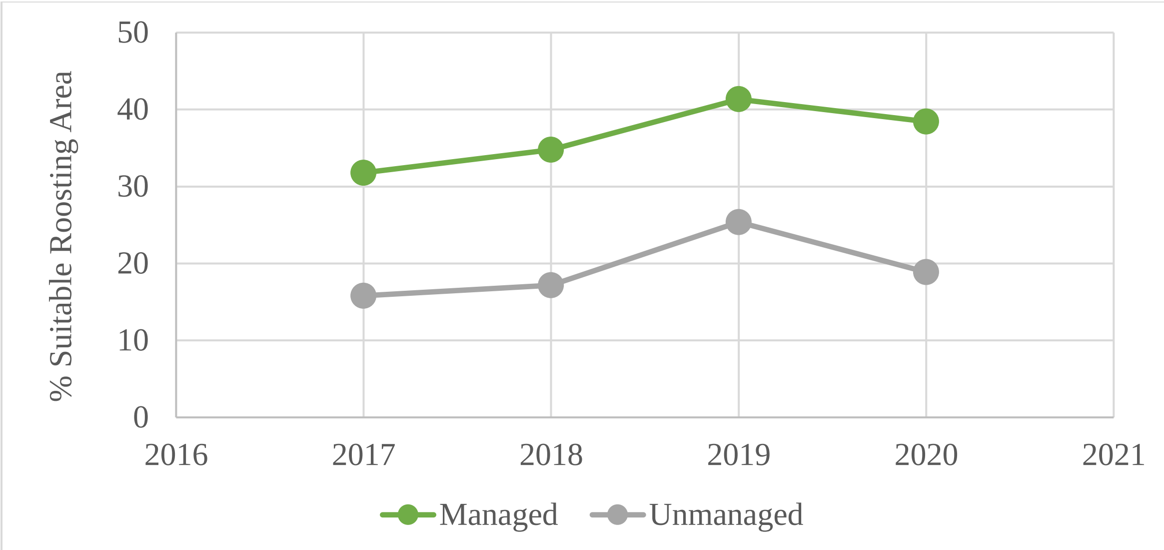


Figure 37. Percent suitable roosting area at 2000 cfs over time for managed areas vs. unmanaged areas of the main channel.

See Appendix Section G for complete suitable whooping crane roosting area results.

8. Emerging Issues

Over the course of the last several years, the EDO noted that the main channel along the southern edge of Mormon Island (Wood River to Grand Island reach) was becoming increasingly vegetated and the middle channel through the island was simultaneously widening. A review of aerial imagery indicates a substantial shift in the flow split at that location through time (Figure 38). In 2001, south (main) channel width at the split was 460 ft and middle channel width at the split was 265 ft. By 2020, the middle channel was wider (350 ft) than the south channel (340 ft).

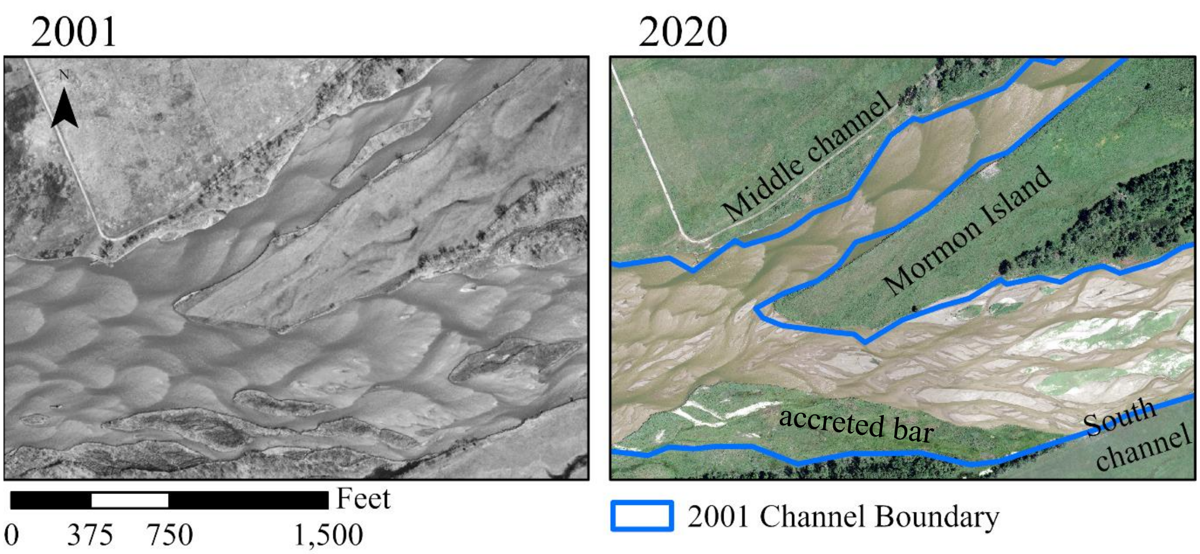


Figure 38. Aerial imagery from 2001 and 2020 in the vicinity of Mormon Island. A polygon representing the 2001 channel extent is overlain on the 2020 imagery.

We utilized the 2017-2020 hydrodynamic models to evaluate split flow at that location at 500 and 2,000 cfs (Table 17). Figure 39 presents the modeled distribution of depths at 2,000 cfs. As demonstrated in the table and figure, more than half of the flow is now conveyed by the middle channel with substantially less flow and correspondingly shallower flow depth occurring in the south channel. In 2020, an estimated 25% of main channel flow was conveyed by the south channel at 2,000 cfs.

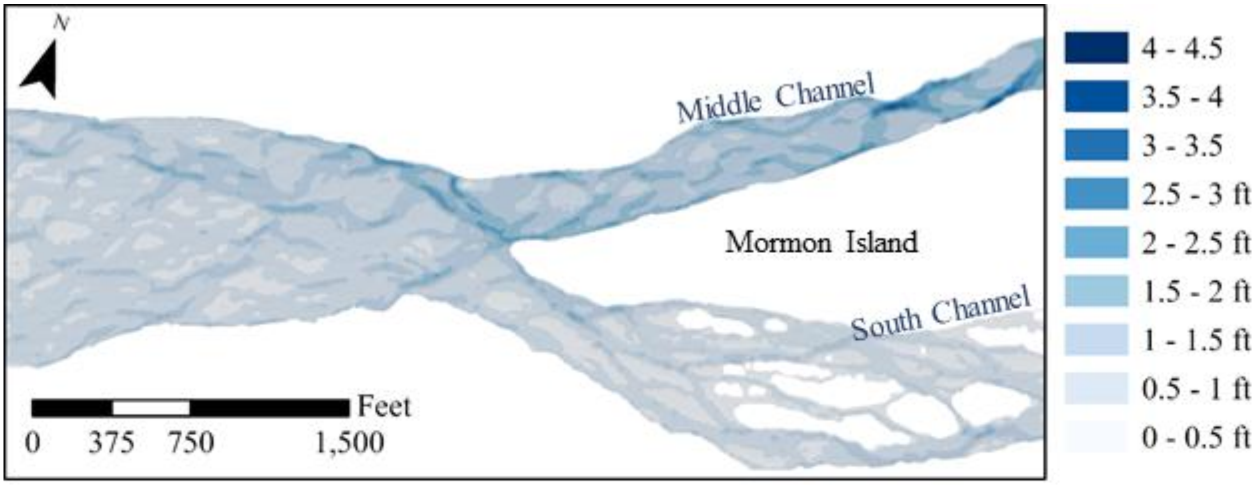


Figure 39. Model flow depths (2020) at 2,000 cfs. Flow is substantially deeper in the middle channel than the south channel, which historically carried the majority of flow around the south side of Mormon Island.

Table 17. Mormon Island flow split (2020 model) at 500 and 2000 cfs.

Q (cfs)	% Flow in South Channel			
	2017	2018	2019	2020
500	17	14	24	12
2000	30	29	33	25

This shift in flow distribution has likely been caused by the accretion of a large bar along the south bank at the upstream end of the south channel (Figure 38). This flow obstruction directs flow toward the middle channel at low and moderate discharges. Over time, we expect WC habitat suitability to decline in the 11-mile segment of the south channel downstream of the flow split as the previously highly suitable channel vegetates and narrows. At the same time, middle channel suitability is expected to increase as that channel widens, although at 350 ft, it is much narrower than the 650 ft MUCW that the Program considers to be highly suitable for WC roosting. Mechanical vegetation control in the south channel will slow the rate of decline in suitability but will requiring increasing effort over time.

9. Big Questions

The Program's First Increment Extension Science Plan will be finalized in early 2022. The 2022 System-scale Geomorphology and Vegetation Monitoring Report will include a section relating monitoring results to Extension big questions.

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11. Appendices

A. Revised Draft Monitoring Protocol

A1. Hydrodynamic Modeling

A2. Land Cover Classification

A3. Volume Change

B. Hydrologic Results

C. Hydrodynamic Modeling Results

D. Land Cover Results

E. Volume Change Results

APPENDIX TO SYSTEM-SCALE GEOMORPHOLOGY AND VEGETATION MONITORING REPORT: 2017-2020

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Appendix A1. Hydrodynamic Modeling Protocol

1. Utilize SRH – 2D software to create models at 12 flows (500, 750, 1000, 1200, 1500, 2000, 2500, 3000, 3500, 4000, 4500, 5000) at 5 bridge segments (Lexington to Overton, Overton to Kearney, Kearney to Shelton, Shelton to Grand Island, Grand Island to Chapman) with each year's topobathymetric LiDAR elevations. SR-2D output is stored as a .dat text file which can be 1 GB or more in size for one model run. Each text file is stored with that reach's model node numbers, the XYZ coordinates of the model nodes, and an array of outputs for each node, including depth and velocity.

2. Compile stock shapefiles used in analysis
   a. Bank Hull—shapefile representing all channels in the AHR extending 50-100 ft overbank. Excludes bridges and powerline footprints
   b. Geomorphic reaches – the Bank Hull clipped at bridges dividing the reaches
   c. Main Channel and Side Channel, stored as separate shapefiles – the Bank Hull clipped to channel type
   d. Cross-station lines, labeled with Cross Station ID value in Attribute Table. Oriented approximately perpendicular to the main channel
   e. Polygons representing managed and unmanaged areas of the main channel. managed areas are under any ownership

3. Prepare bridge segment node database for processing results. An important component of processing model results is relating the output text files to a node database. Each bridge segment model result output file includes information on all nodes in that bridge segment, whether or not they are inundated at that flow. Each node in the model results output is stored with its Node ID and that node's X, Y, and Z coordinate. A stock node database for each bridge segment is joined to the model output text files in order to make area measurements and analyze results at various spatial scales. In order to spatially manipulate the node data, the XYZ coordinates can be opened in ArcGIS as points. The node database should include a field for the node area in square feet
   a. The node databases should already include a binary field representing the main channel. To edit this field, select the nodes by location within the main channel polygon. Create an MC field, and populate selected nodes with 1.
   b. The node databases should already include representing geomorphic reach. To edit this field, select the nodes by location within the geomorphic reach masks and calculate field for each geomorphic reach
   c. Each year, the node database should be updated with results from the Land Cover Classification in order to estimate suitable whooping crane roosting area.
      i. Open the model nodes as points and create a new field like WC_XXXX, such as WC_2017, which denotes suitable unobstructed width for whooping crane roosting habitat for that year
      ii. Open unobstructed width lines from the Land Cover Classification
      iii. Select unobstructed width lines that are greater than or equal to 650 ft

        iv. Use the Graphic Buffer tool to buffer the selected with lines with Butt cap type to create regions of the channel with suitable width for whooping crane roosting
        v. Select by Location for the model nodes within the areas with suitable width
        vi. Populate the WC_XXXX field for selected nodes with 1
    d. Export the attribute table of the node database as a .csv for use in processing model results

4. Process SRH-2D output to analyze results. Note: This workflow is best implemented with R. A script that accomplishes this workflow will be stored on the Headwaters server to be utilized for future analyses
    a. For each model run, subset the results to reduce data size and processing time. Subset rows to those with depth greater than 0. Cut off all columns besides Node ID, water depth, and X velocity
    b. Join the node database to the model run results, using Node ID as the key. Now the data should include Node ID, water depth, X velocity, Node area, the geomorphic reach, a binary main channel field, and a binary field representing suitable unobstructed width for whooping crane roosting habitat for each year
    c. Subset the bridge segment model results into geomorphic reaches. This is a messy process and it is different for each bridge segment. Each geomorphic reach is extracted from the bridge segments in Table A1. Most geomorphic reaches are subsetted from one bridge segment run. For two geomorphic reaches – Odessa to Minden and Gibbon to Wood River – two bridge segments must be joined together first and then subsequently subsetted to the geomorphic reach.

Table A1. Relationships between geomorphic reaches and bridge segments

Geomorphic Reach	Bridge Segments
N-lexington_overton	lexington_overton
J2_overton	lexington_overton
overton_elmcreek	overton_odessa
elmcreek_odessa	overton_odessa
odessa_minden	odessa_kearney, kearney_shelton
minden_gibbon	kearney_shelton
gibbon_woodriver	kearney_shelton, shelton_gi
woodriver_gi	shelton_gi
gi_chapman	gi_chapman

    d. Subset the geomorphic reach data to the main channel by selecting the rows where MC is equal to 1
    e. Subset the geomorphic reach data to the side channels by selecting the rows where MC is not equal to 1

f. Populate separate dataframes with the following metrics for each spatial scale – all channels, main channel, and side channels
    i. Average depth: the average of water depth
    ii. Inundated area: the sum of node areas
    iii. Inundated volume: the sum of node areas multiplied by water depth
    iv. Area with depth < 1 ft: The sum of node areas with depth less than 1 ft
    v. Suitable whooping crane roosting area: The sum of node areas with depth less than 1ft which also have suitable unobstructed width (WC_XXXX=1) for a given year
    vi. Volumetric flow: approximate volumetric flow for each node by multiplying node area, water depth, and X velocity together. The sum volumetric flow in the main and side channels can then be compared to estimate the main:side channel flow splits for each reach

5. Analyze wetted width. Note: This workflow is best implemented with an ArcPy Python script. A script that accomplishes this workflow will be stored on the Headwaters server to be utilized for future analyses
    a. Use R to create and export text files of each model run representing only XY coordinates and water depth
    b. Use XY table to point to create a point shapefile for every model run
    c. Create water depth TINs for each model run from the point shapefile using the Mass Points option
    d. Use the Delineate TIN Data Area tool with Max Edge Length set to 36 ft and Method as “All”
    e. Use the TIN Triangle tool to convert the water depth TINs to polygon shapefiles
    f. Add a field called “Dissolve,” populate it with 1, and attempt to use the Dissolve tool to dissolve the TIN polygon by the Dissolve field. The tool will fail for some of the larger-extent flows
    g. Clip cross-station lines to the TIN triangle polygons. These lines represent wetted width
    h. For all reaches besides the two from Lexington to Overton, clip the wetted width lines to the main channel
    i. For both all channels and main channels wetted width shapefiles, add a field called Length_ft and calculate the length of each clipped cross-station line
    j. Use the Table to Table tool to export the attribute table as a text file
    k. Summarize the mean and standard deviation of each flow, re

Appendix A2. Land Cover Classification Protocol

1. Compile stock shapefiles used in analysis
    a. Bank Hull—shapefile representing all channels in the AHR extending 50-100 ft overbank. Excludes bridges and powerline footprints
    b. Geomorphic reaches – the Bank Hull clipped at bridges dividing the reaches
    c. Main Channel and Side Channel, stored as separate shapefiles – the Bank Hull clipped to channel type
    d. Cross-station lines, labeled with Cross Station ID value in Attribute Table. Oriented approximately perpendicular to the main channel
    e. Polygon representing 5,000 cfs extent from 2D modeling results. Attempt to dissolve the triangular polygons into one polygon. This has failed for me every time, but give it a shot—maybe an update to ArcGIS Pro will improve tool performance in the future
    f. Polygons representing managed and unmanaged areas of the main channel. managed areas are under any ownership

2. Collect field validation data within a week of the data collection flight

    Note: A variety of methods have been used in the past to collect this data. This represents the methods implemented in 2021 and which should be followed in future years

    a. Identify 5-8 areas throughout the AHR which represent diversity in the following areas: geomorphic reach, management type, and channel type. Each area should be located in a unique geomorphic reach. Approximately ½ of the sites should be located on private or unmanaged areas that are not managed to reduce in-channel vegetation, and at least one should be located on a side channel. The database of landowners who allowed access for the RWM field surveys prior to 2016 can be utilized to request access on private lands. Additionally, access to state Wildlife Management Areas (WMAs) can be requested.
    b. At each area, walk or wade approximately 1-2 miles throughout the channel and overbank areas within the Bank Hull analysis mask. Identify points within patches of vegetation which have consistent plant composition and density within a radius of 3 ft. Collect point with the Trimble RTK GPS, with the class labeled.
    c. Collect approximately equal number of points of the following categories:
        i. Water and sand
        ii. Vegetation < 2ft in height
        iii. Vegetation 2-6 ft in height
        iv. Vegetation > 6 ft in height
    d. Collect approximately 500 points in total

3. Prepare imagery and LiDAR rasters for classification
    a. Mosaic together the fall topobathymetric and highest-hit LiDAR rasters
    b. Subtract the topobathymetric rasters from the highest-hit rasters to yield rasters representing vegetation height

c. Clip vegetation height raster to geomorphic reach masks, without maintaining extent
d. Mosaic together the fall 4-band imagery tiles that intersect with the analysis mask, while resampling from 6 inch to 3 ft resolution
e. Clip imagery raster to geomorphic reach masks, without maintaining extent

4. Run classification in E-Cognition
    a. Load in imagery and vegetation height rasters (as DSM) and assign numbers to R,G,B,NIR bands
    b. Load the project configuration which will autopopulate the steps with schema
    c. Segment objects at the scale of 10 pixels
    d. Classify water based on NDWI. Cut-off values may range 0-0.1 between years. For each year of data, visually calibrate the cut-off value by iteratively testing values and comparing the classified area of water to the extent evident in RGB, CIR, and NDWI displays
    e. Classify vegetation greater than 15 ft in height (Veg >15ft) from the vegetation height raster
    f. Classify vegetation 6 to 15 ft in height (Veg 6-15ft) from the vegetation height raster
    g. Classify vegetation 2 to 6 ft in height (Veg 2-6ft) from the vegetation height raster
    h. Separate sand and vegetation less than 2 ft in height based on the NDVI. Cut-off values from 2017-2020 ranged from 0.03 to 0.09 and values in future years may be higher or lower. For each year of data, calibrate the NDVI cut-off value visually by iteratively testing values and comparing the classified area of vegetation to the extent evident in RGB, CIR, and NDVI displays
    i. Export the classified area as a shapefile

5. Compare classified results to field validation data in order to assess accuracy with ArcGIS
    a. Add the classified polygon class attribute to the field points with the Spatial Join tool
    b. Export the shapefile into Excel and create confusion matrices comparing the field-measured and Ecognition-assigned classes for all points
    c. Check the agreement rate between sand and vegetation < 2 ft in height. If there appears to be a systematic bias towards one class or another, rerun Ecognition with adjusted values. This may be an iterative process with multiple repetitions

6. Process E-Cognition output and calculate statistics with ArcGIS
    Note: Due to the large number of steps in the following workflow, and their repetition at 20+ spatial scales for each year of data, this workflow must be automated to a degree. Individually implementing each step for each spatial scale is time-consuming and lends itself to mistakes. An Arcpy script will be stored on the Headwaters Drive to implement

the following steps. The steps could also be implemented with ModelBuilder or with batch processing.

a. Reclip the output to the geomorphic reach bank hull polygon. This represents the All Channels shapefile
b. For each year, merge the shapefiles for geomorphic reaches from Overton to Chapman into an All Reaches shapefile. Note: the All Reaches shapefile excludes the two geomorphic reaches from Lexington to Overton
c. Clip the All Channels shapefile to both the main channel and side channel polygons
d. For each reach and channel type, use the Summary Statistics tool to sum the area of each class, exporting each table as a .csv file
e. For every shapefile representing every geomorphic reach and channel type, select by attributes for the unobstructed classes—Water, Sand, and Veg <2ft
f. Clip cross-station lines to the classified shapefiles with the unobstructed areas selected. These represent unobstructed width lines
g. Double-check that the "Length" field in the line Attribute Table is in feet. If it is not, add a Length_ft field and use Calculate Geometry to calculate the length in feet of each cross-section
h. For each reach and channel type, use the Summarize Statistics tool to sum the length of line segments by Cross Station ID, exporting each table as .csv file. These represent TUCW
i. Use the Multipart to Singlepart tool to separate the unobstructed width lines into individual line segments
j. Again, double-check that the Length field is populated with the correct length in ft. If it is not, recalculate a Length_ft field
k. For each reach and channel type, use the Summarize Statistics tool to find the maximum line segment for each Cross-Station ID, exporting each table as a .csv file. This represents MUCW.
l. Using R or with (a lot of) copying and pasting from individual spreadsheets, summarize the MUCW and TUCW values for each year, reach, and spatial scale by mean and standard deviation
m. To complete the managed vs nonmanaged analysis, clip the main channel classified polygon to the managed and other shapefile
n. Re-run steps d-l with the managed and nonmanaged classified shapefiles to calculate comparative metrics

Appendix A4. Volume Change Analysis Protocol

1. Prepare topobathymetric rasters
    a. In ArcGIS, clip each topobathymetric raster to the geomorphic reach masks

2. Prepare uncertainty rasters
    a. Locate the bathymetric coverage polygon shapefile provided by Quantum and load into ArcGIS
    b. Locate the uncertainty values provided by Quantum, which are estimated with ground control check points. Identify the values that represent 95% confidence for wet and dry areas. These will be used as accuracy values in error estimation
    c. Use the union tool with batch processing to join the bathymetric coverage polygon to each geomorphic reach mask. Create a field called “Uncertainty.” Select the areas with bathymetric coverage and calculate the field with the 95% confidence “wet” accuracy value. For unmanaged areas, calculate the field with the “dry” accuracy value.
    d. Use the Polygon to Raster tool to convert the shapefiles into accuracy rasters for each geomorphic reach, with grid values representing uncertainty in wet and dry areas
    e. Clip the uncertainty rasters to the main channel

3. Run volume differencing analysis with Geomorphic Change Detection software (GCD)
    a. Download the GCD standalone or ArcMap plug-in toolbar from http://gcd.riverscapes.xyz/. This website has a variety of useful background information on volume differencing methods and tutorials for using the software. The standalone software runs faster, but the ArcMap plug-in has the advantage of displaying analysis outputs in real-time. When using the standalone software, periodically open outputs in ArcGIS to double-check processing
    b. Create a new project
    c. Right-click on DEM Surveys and load in the topobathymetric surfaces for each reach for two of the years—for example 2017 and 2018. Loading in each raster may take up to 30 minutes.
    d. Expand the drop-down for each DEM, right-click on Error Surfaces, and upload both the All Channels and Main Channel (if applicable) uncertainty surface for each raster. This will also involve lengthy wait times.
    e. Right click on Change Detection under Analyses and select Batch Change Detection. Select the New and Old DEM for each reach. Select Probabilistic thresholding with a Confidence level of 0.95. Select the appropriate uncertainty surface with the Error drop-down under the Surface. For reaches that are included in the Main Channel analysis, run one analysis with the All Channels Error surface, and another with the Main Channel Error surface. Click Run Batch, and after lengthy processing, the results are visible under Change Detection. Each

analysis includes helpful pie-charts and histograms for preliminary interpretation of results

4. Classify areas of significant elevation change

    a. Locate thresholded difference rasters under the project directory > Analyses > CD > DoDXXXX. The analyses are assigned a number XXXX in the directory in the order that they are run. It is helpful to create a table to keep track of the analysis name and number. In order to find the analysis number, right click on each analysis under the Change Detection folder in GCD, view Change Detection Results, click on the Analysis Details tab, and find the number next to DoD Analysis Folder
    b. Copy and paste the thresh.tif raster under each DoDXXXX folder into a new folder, taking care to rename the raster to include its reach and difference years.
    c. Open the thresholded difference rasters with ArcGIS. Use the Band Math tool to multiply the raster values by 100. The raster values are now in the units of hundredths of a foot
    d. Export the transformed rasters into a new folder in 32 bit signed format, which transforms them from float to integer format
    e. Use the Raster to Polygon tool to convert the integer rasters into polygon shapefiles
    f. Create a new field in the shapefiles called DiffType with text data type
    g. Select by Attributes to select all polygons with raster value greater than 0. Calculate field as “Agg”
    h. Select by Attributes to select all polygons with raster value less than 0. Calculate field as “DegPrelim.”
    i. Use to Dissolve tool to dissolve the Agg and DegPrelim polygons together. Do not create multipart features.
    j. In order to separate bed degradation from lateral erosion, a bank buffer is needed to select degradational areas near the bank. These are created with the 5000 cfs polygons from each year. Load in 5000 cfs polygons for each reach for each year from the 2D modeling output. To reduce processing time, dissolve the polygons into one multipart polygon. Create a field called “Dissolve,” populate all rows with the number 1, and use the Dissolve tool to make one multipart feature for each reach
    k. Use the Buffer tool to create a bank buffer polygon. Use -20 ft for distance so that the buffer extends internally into the polygon rather than externally. Check the option that dissolves all features into one output polygon
    l. Select the “DegPrelim” thresholded difference polygons, and subset the selection with Select by Location for the polygons that intersect the 20 ft internal bank buffer. Use the bank buffer that corresponds to that reach and the most recent year of the difference analysis. For example, when analyzing the 2018-2017 difference

rasters, use the 2018 bank buffer. When these polygons are select, use Calculate Field to classify them in Diff Type as "Lat."

m. Select the polygons that remain labeled as "DegPrelim" and Calculate Field to label them "Deg."
n. For each analysis year, merge the reach classified shapefiles together into one classified shapefile representing All Reaches
o. In GCD, right-click on Masks and select Add Existing Regular Mask. Load in the classified shapefile for that difference year
p. For each analysis under Change Detection, right-click and select Add Budget Segregation. Select the classified shapefile from the drop-down and click Save

5. Extract results from GCD
    a. Results for net volume change and associated error are easiest to extract from the project directory > Analyses > IC. Folders within this directory store intercomparisons of all budget analyses run within the software
    b. Results for the classified areas must be extracted from each DoD folder under Analyses > CD > DoDXXXX > BS > BS0001 > Intercompare
    c. Copy and paste relevant results from the locations in a and b into a separate spreadsheet

Appendix B. Mechanical Management Results

Table B1. Area of in-channel management actions implemented throughout the AHR. Years of remote monitoring are highlighted in green.

Year	Spraying (ac)	Disking (ac)	Tree Clearing (ac)
2005	-	-	-
2006	-	2,721	-
2007	335.2	3,125	-
2008	2,763.3	1,283	-
2009	3,369.3	199	60
2010	1,085.4	137	53
2011	1,269.7	-	81
2012	824.6	509	279
2013	922.6	944	41
2014	1,204.6	1,601	32
2015	977.0	-	1
2016	519.5	6	53
2017	803.1	67	50
2018	592.9	351	1
2019	593.1	-	1
2020	594.9	539	47

Appendix C. Hydrologic Results

Table C1. Table of hydrologic parameters collected the Overton USGS Gage (06768000) data. Years of remote monitoring are highlighted in green. Parameters are: Q_{AVG} - Mean Annual Discharge (cfs), V_{af} - Annual Flow Volume (AFY), Q_P - Annual Mean Daily Peak Discharge (cfs), Q_{Py} - Annual Peak Flow Return Interval (years), $Q_{Max\ 40}$ - Annual 40-Day Maximum Flow (cfs) , Q_{June} - Mean June Flow (cfs).

Year	Q_{AVG}	V_{af}	Q_P	Q_{Py}	$Q_{Max\ 40}$	Q_{June}
2007	800	579340	3,500	1.4	1,273	1,362
2008	791	572578	10,700	6.8	1,586	701
2009	942	681929	3,600	1.5	1,811	1,282
2010	2,157	1561636	7,370	3.4	4,108	4,536
2011	3,877	2807021	8,720	4.6	7,503	7,675
2012	1,114	806776	3,430	1.4	2,796	319
2013	1,140	824993	12,400	9.9	4,129	303
2014	1,249	904099	7,360	3.4	3,150	3,822
2015	3,506	2538110	15,300	16.6	12,708	12,920
2016	2,950	2137701	8,600	4.5	7,364	6,433
2017	1,550	1122462	4,440	1.8	2,768	2,069
2018	1,415	1024113	2,960	1.3	1,834	1,343
2019	2,274	1646137	9,750	5.6	3,089	2,822
2020	1,802	1305700	3,820	1.5	2,977	1,966

Table C2. Table of hydrologic parameters collected the Grand Island USGS Gage (06770500) data. Years of remote monitoring are highlighted in green. Parameters are: Q_{AVG} - Mean Annual Discharge (cfs), V_{af} - Annual Flow Volume (AFY), Q_{P} - Annual Mean Daily Peak Discharge (cfs), Q_{Py} - Annual Peak Flow Return Interval (years), $Q_{Max\ 40}$ - Annual 40-Day Maximum Flow (cfs) , Q_{June} - Mean June Flow (cfs).

Year	Q_{AVG}	V_{af}	Q_{P}	Q_{Py}	$Q_{Max\ 40}$	Q_{June}
2007	800	579340	3,500	1.4	1,273	1,362
2008	791	572578	10,700	6.8	1,586	701
2009	942	681929	3,600	1.5	1,811	1,282
2010	2,157	1561636	7,370	3.4	4,108	4,536
2011	3,877	2807021	8,720	4.6	7,503	7,675
2012	1,114	806776	3,430	1.4	2,796	319
2013	1,140	824993	12,400	9.9	4,129	303
2014	1,249	904099	7,360	3.4	3,150	3,822
2015	3,506	2538110	15,300	16.6	12,708	12,920
2016	2,950	2137701	8,600	4.5	7,364	6,433
2017	1,550	1122462	4,440	1.8	2,768	2,069
2018	1,415	1024113	2,960	1.3	1,834	1,343
2019	2,274	1646137	9,750	5.6	3,089	2,822
2020	1,802	1305700	3,820	1.5	2,977	1,966

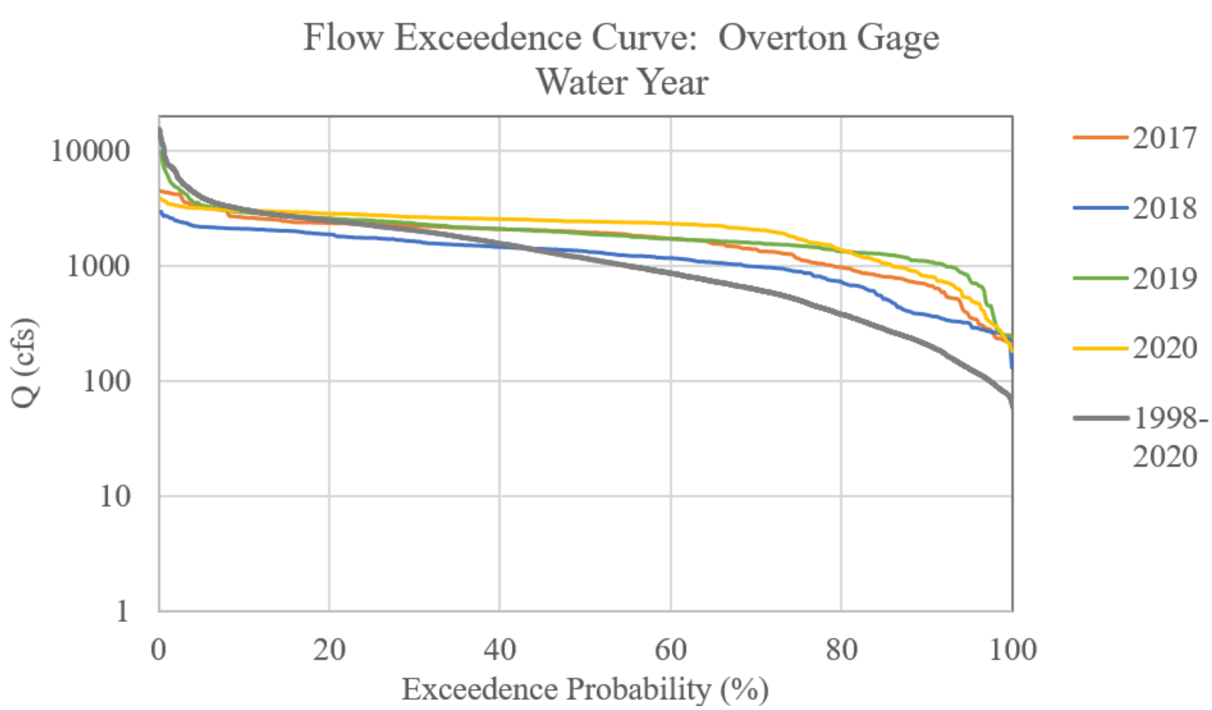

Fig. C1. Flow Exceedance curves for each water year from 2017-2020, as well as the period from 1998-2020, developed from the mean daily data from the USGS Overton gage (06768000).

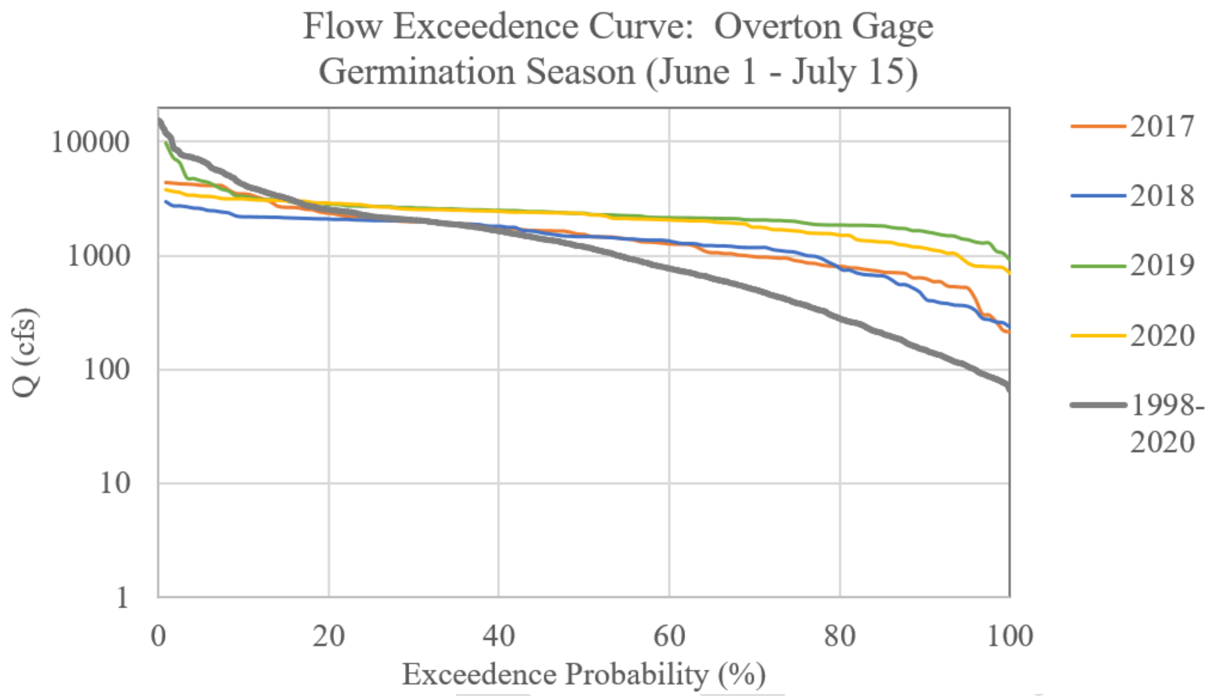

Fig. C2. Flow Exceedance curves for the germination season of each water year from 2017-2020, as well as the period from 1998-2020, developed from the mean daily data from the USGS Overton gage (06768000).

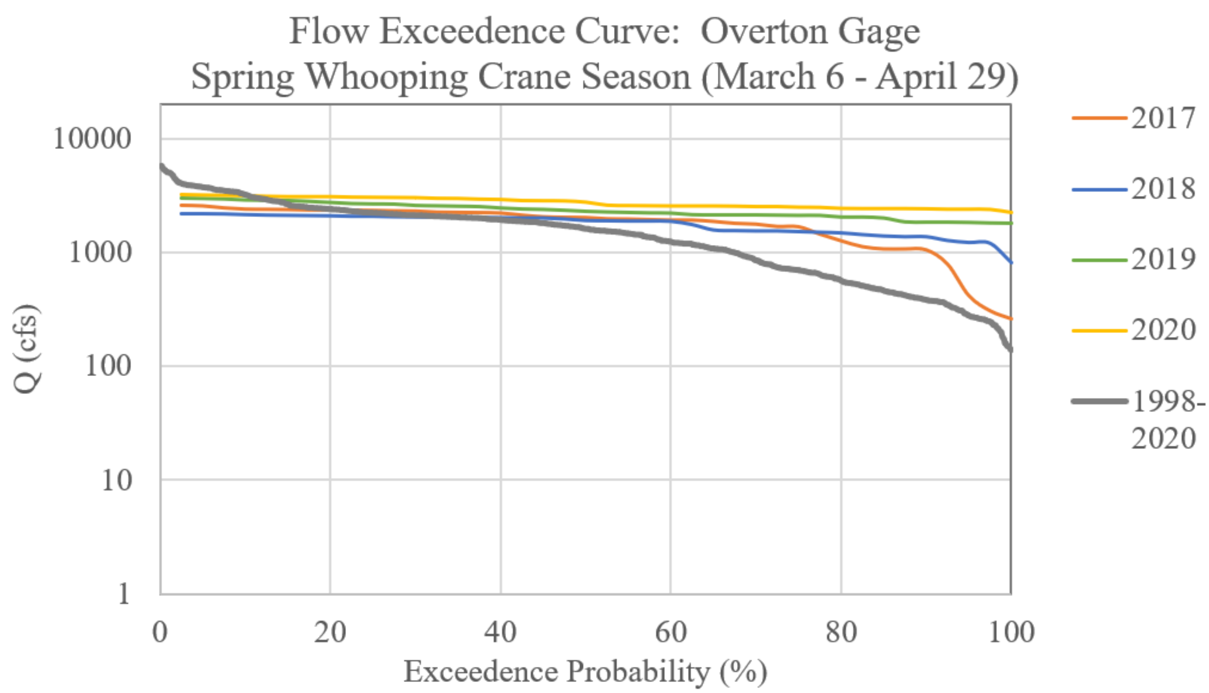

Fig. C3. Flow Exceedance curves for the spring whooping crane migration season of each water year from 2017-2020, as well as the period from 1998-2020, developed from the mean daily data from the USGS Overton gage (06768000).

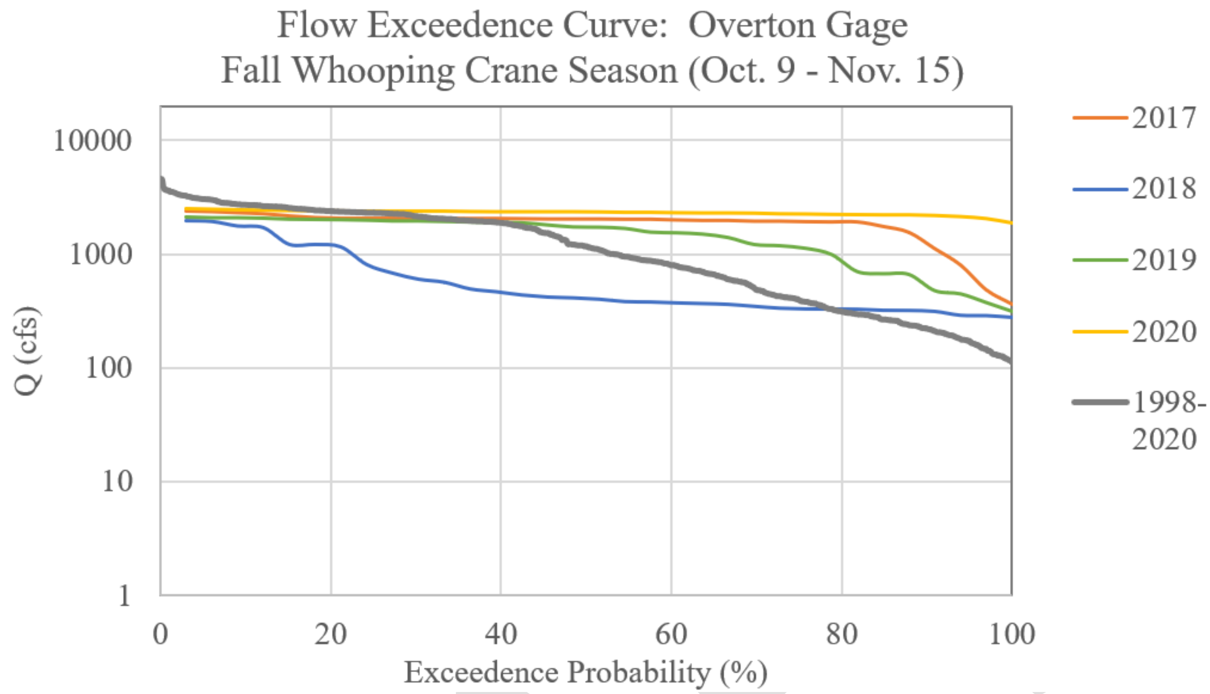

Fig. C4. Flow Exceedance curves for the fall whooping crane migration season of each water year from 2017-2020, as well as the period from 1998-2020, developed from the mean daily data from the USGS Overton gage (06768000).

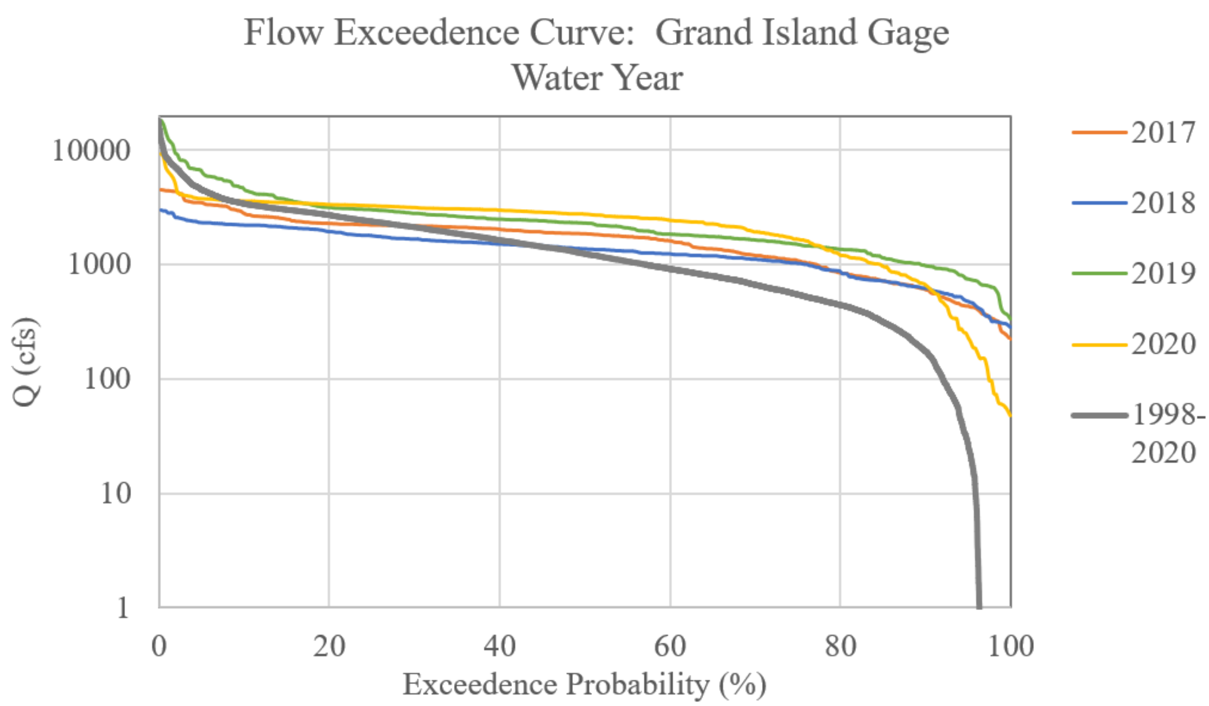

Fig. C5. Flow Exceedance curves for each water year from 2017-2020, as well as the period from 1998-2020, developed from the mean daily data from the USGS Grand Island gage (06770500).

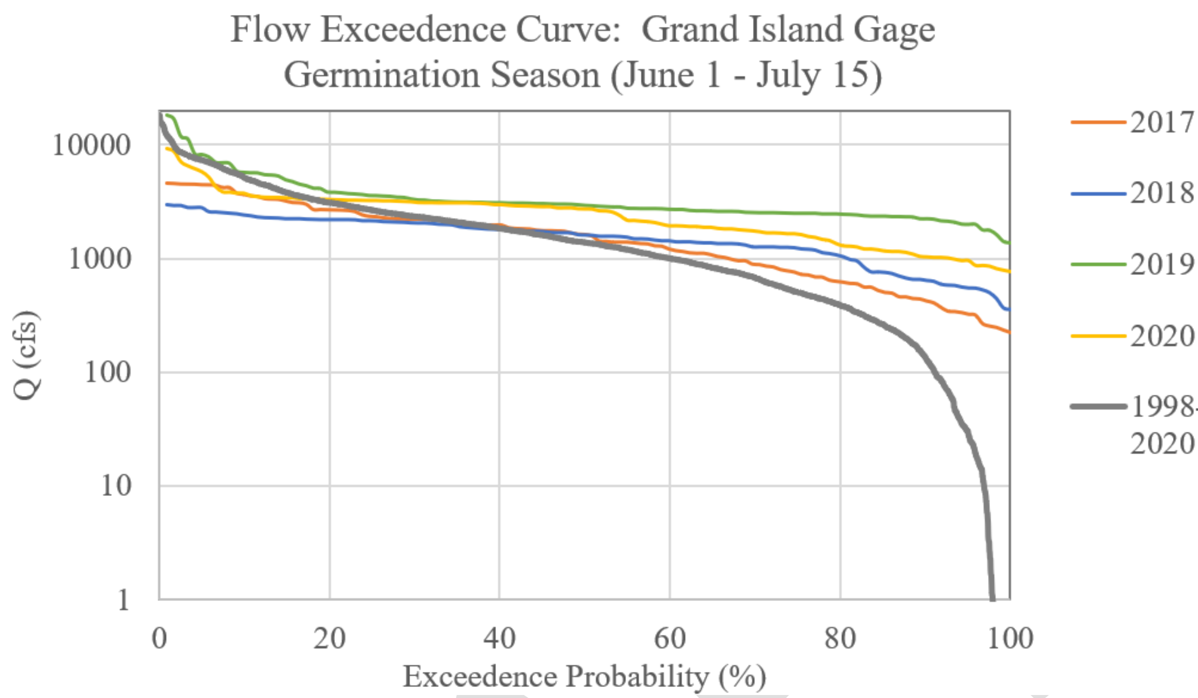

Fig. C6. Flow Exceedance curves for the germination season of each water year from 2017-2020, as well as the period from 1998-2020, developed from the mean daily data from the USGS Grand Island gage (06770500).

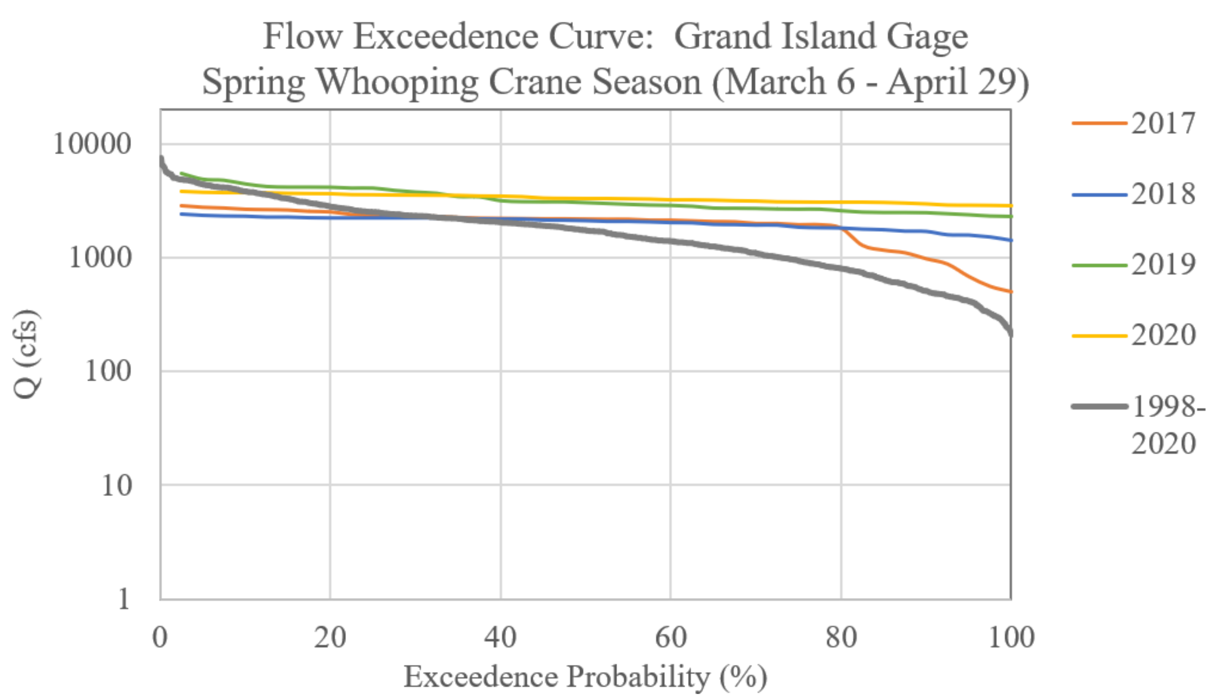

Fig. C7. Flow Exceedance curves for the spring whooping crane season of each water year from 2017-2020, as well as the period from 1998-2020, developed from the mean daily data from the USGS Grand Island gage (06770500).

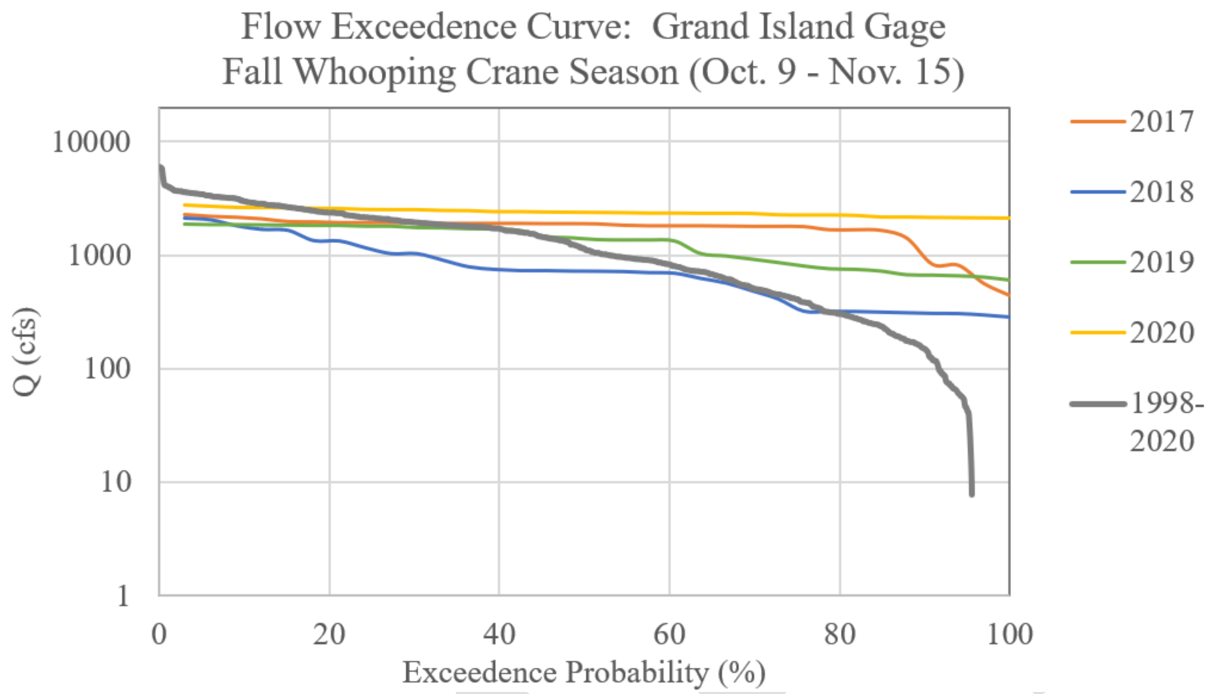

Fig. C8. Flow Exceedance curves for the fall whooping crane season of each water year from 2017-2020, as well as the period from 1998-2020, developed from the mean daily data from the USGS Grand Island gage (06770500).

Appendix D. Hydrodynamic Modeling Results

Table D1a. Modeled inundated volume and area for all channels of All Reaches (Overton to Chapman), Overton to Elm Creek, and Elm Creek to Odessa.

Reach	Q (cfs)	Inundated area (ac)				Inundated volume (acft)			
		2017	2018	2019	2020	2017	2018	2019	2020
All-Reaches	500	9713	10278	9987	10484	5205	5287	5909	5323
All-Reaches	750	10544	11095	10935	11441	6672	6966	7325	6863
All-Reaches	1000	11026	11513	11308	11610	7949	8130	8512	8100
All-Reaches	1200	10891	11340	11326	11735	8571	8730	9148	8780
All-Reaches	1500	11473	11735	11637	12092	10215	10336	10655	10389
All-Reaches	2000	11822	12000	11832	12311	12253	12347	12618	12413
All-Reaches	2500	12172	12240	12088	12533	14135	14238	14473	14351
All-Reaches	3000	12618	12688	12381	12824	16068	16161	16327	16223
All-Reaches	3500	12993	13061	12664	13126	17876	17933	18049	18032
All-Reaches	4000	13373	13481	12994	13426	19595	19694	19750	19736
All-Reaches	4500	13627	13733	13240	13635	21063	21138	21199	21193
All-Reaches	5000	13930	14068	13541	13879	22819	22888	22908	22924
N-lexington-overton	500	379	511	436	484	235	425	400	420
N-lexington-overton	750	380	511	462	536	235	425	418	430
N-lexington-overton	1000	383	549	460	537	236	432	413	431
N-lexington-overton	1200	380	547	463	534	236	432	418	430
N-lexington-overton	1500	381	550	453	538	236	432	403	431
N-lexington-overton	2000	384	548	437	539	238	432	403	432
N-lexington-overton	2500	382	511	451	536	239	426	402	432
N-lexington-overton	3000	510	618	532	611	452	697	645	678
N-lexington-overton	3500	589	687	622	705	645	888	868	912
N-lexington-overton	4000	646	747	713	785	816	1051	1083	1110
N-lexington-overton	4500	703	802	776	830	979	1232	1258	1272
N-lexington-overton	5000	814	882	853	863	1154	1377	1422	1424
J2-overton	500	290	273	272	301	388	298	316	310
J2-overton	750	308	299	284	332	462	380	388	393
J2-overton	1000	335	357	303	350	534	462	461	465
J2-overton	1200	336	373	307	367	583	518	508	530
J2-overton	1500	354	387	337	384	662	599	586	598
J2-overton	2000	386	410	360	406	785	726	706	726
J2-overton	2500	427	400	381	432	906	842	824	847
J2-overton	3000	447	400	381	431	965	850	832	854
J2-overton	3500	460	408	382	431	1015	884	840	864
J2-overton	4000	473	421	382	431	1060	927	849	880
J2-overton	4500	484	427	386	416	1101	951	874	906
J2-overton	5000	500	457	401	421	1141	1003	904	934

Table D1b. Modeled inundated volume and area for all channels of Overton to Elm Creek, Elm Creek to Odessa, and Odessa to Minden.

Reach	Q (cfs)	Inundated area (ac)				Inundated volume (acft)			
		2017	2018	2019	2020	2017	2018	2019	2020
overton_elmcreek	500	640	629	685	685	397	392	464	412
overton_elmcreek	750	670	694	731	732	521	519	574	545
overton_elmcreek	1000	702	727	758	765	624	634	673	650
overton_elmcreek	1200	728	746	776	782	711	718	752	734
overton_elmcreek	1500	770	773	799	799	830	826	865	847
overton_elmcreek	2000	802	813	820	822	1029	1009	1037	1012
overton_elmcreek	2500	835	848	844	855	1195	1212	1223	1228
overton_elmcreek	3000	859	867	860	869	1352	1361	1376	1363
overton_elmcreek	3500	887	889	881	895	1503	1506	1504	1515
overton_elmcreek	4000	931	940	924	940	1653	1685	1657	1662
overton_elmcreek	4500	976	983	967	983	1801	1820	1812	1811
overton_elmcreek	5000	998	1003	985	1003	1932	1949	1942	1938
elmcreek_odessa	500	532	575	597	594	318	332	377	326
elmcreek_odessa	750	582	616	637	643	424	436	464	435
elmcreek_odessa	1000	608	635	657	664	507	525	544	518
elmcreek_odessa	1200	627	644	667	674	576	590	607	585
elmcreek_odessa	1500	649	654	673	684	664	670	693	673
elmcreek_odessa	2000	668	667	682	694	794	807	823	802
elmcreek_odessa	2500	689	686	697	707	921	932	942	936
elmcreek_odessa	3000	699	696	703	711	1039	1043	1058	1038
elmcreek_odessa	3500	715	713	711	722	1152	1152	1153	1149
elmcreek_odessa	4000	730	729	722	735	1256	1275	1257	1248
elmcreek_odessa	4500	745	745	742	753	1359	1369	1365	1352
elmcreek_odessa	5000	754	754	754	763	1456	1464	1461	1447
odessa_minden	500	2576	2598	2327	2495	1326	1305	1421	1287
odessa_minden	750	2692	2791	2643	2847	1691	1704	1807	1709
odessa_minden	1000	2834	2882	2714	2834	2035	2046	2115	2034
odessa_minden	1200	2710	2745	2698	2843	2240	2259	2336	2277
odessa_minden	1500	2929	2901	2793	2963	2624	2632	2677	2643
odessa_minden	2000	3038	2970	2864	3022	3165	3159	3195	3188
odessa_minden	2500	3114	3061	2926	3064	3666	3657	3678	3680
odessa_minden	3000	3211	3178	3006	3148	4143	4132	4132	4153
odessa_minden	3500	3310	3272	3069	3208	4594	4574	4563	4595
odessa_minden	4000	3431	3393	3148	3283	5033	5011	4987	5025
odessa_minden	4500	3427	3439	3202	3338	5425	5411	5378	5429
odessa_minden	5000	3471	3486	3277	3408	5826	5814	5777	5837

Table D1c. Modeled inundated volume and area for all channels of Minden to Gibbon, Gibbon to Wood River, and Wood River to Grand Island.

Reach	Q (cfs)	Inundated area (ac)				Inundated volume (acft)			
		2017	2018	2019	2020	2017	2018	2019	2020
minden_gibbon	500	687	683	667	684	318	297	336	296
minden_gibbon	750	749	787	753	776	406	403	431	391
minden_gibbon	1000	789	813	777	783	487	485	505	465
minden_gibbon	1200	761	775	769	789	532	533	554	520
minden_gibbon	1500	825	828	793	821	626	627	636	607
minden_gibbon	2000	840	835	809	837	748	748	756	732
minden_gibbon	2500	848	844	817	848	861	860	866	847
minden_gibbon	3000	865	859	829	854	968	966	970	953
minden_gibbon	3500	880	875	836	862	1068	1065	1066	1053
minden_gibbon	4000	903	904	853	878	1165	1164	1161	1150
minden_gibbon	4500	896	913	861	887	1252	1255	1249	1241
minden_gibbon	5000	900	914	873	898	1338	1341	1335	1329
gibbon_woodriver	500	1665	1742	1773	1888	846	834	983	869
gibbon_woodriver	750	1783	1925	1933	2030	1087	1106	1230	1129
gibbon_woodriver	1000	1892	1986	2007	2058	1312	1329	1440	1350
gibbon_woodriver	1200	1892	1964	2024	2077	1467	1483	1593	1514
gibbon_woodriver	1500	2002	2025	2059	2148	1709	1717	1812	1752
gibbon_woodriver	2000	2083	2065	2098	2167	2061	2061	2153	2101
gibbon_woodriver	2500	2137	2107	2143	2195	2383	2378	2471	2422
gibbon_woodriver	3000	2193	2170	2172	2226	2687	2682	2764	2724
gibbon_woodriver	3500	2260	2236	2216	2271	2979	2969	3046	3015
gibbon_woodriver	4000	2301	2281	2247	2297	3253	3241	3312	3288
gibbon_woodriver	4500	2307	2320	2273	2319	3506	3500	3563	3544
gibbon_woodriver	5000	2349	2366	2302	2344	3766	3759	3812	3799
woodriver_gi	500	1808	1899	1972	2016	834	822	985	837
woodriver_gi	750	1932	2065	2148	2140	1073	1091	1232	1086
woodriver_gi	1000	2060	2156	2241	2231	1300	1316	1443	1310
woodriver_gi	1200	2126	2199	2296	2284	1465	1478	1601	1479
woodriver_gi	1500	2217	2268	2304	2343	1702	1712	1817	1714
woodriver_gi	2000	2317	2312	2355	2382	2058	2061	2160	2067
woodriver_gi	2500	2395	2366	2400	2432	2387	2383	2479	2395
woodriver_gi	3000	2444	2422	2434	2464	2693	2685	2775	2701
woodriver_gi	3500	2488	2472	2468	2507	2982	2970	3054	2991
woodriver_gi	4000	2533	2524	2509	2544	3257	3244	3323	3266
woodriver_gi	4500	2561	2563	2538	2577	3517	3505	3578	3529
woodriver_gi	5000	2597	2608	2573	2613	3771	3759	3827	3788

Table D1d. Modeled inundated volume and area for all channels of Grand Island to Chapman.

Reach	Q (cfs)	Inundated area (ac)				Inundated volume (acft)			
		2017	2018	2019	2020	2017	2018	2019	2020
gi_chapman	500	1202	1358	1258	1337	617	579	626	567
gi_chapman	750	1297	1375	1345	1404	771	758	779	744
gi_chapman	1000	1344	1407	1391	1454	912	902	917	884
gi_chapman	1200	1371	1412	1411	1462	1014	985	1039	989
gi_chapman	1500	1381	1350	1426	1412	1156	1120	1165	1124
gi_chapman	2000	1402	1380	1408	1441	1383	1343	1380	1353
gi_chapman	2500	1426	1417	1430	1465	1588	1547	1588	1562
gi_chapman	3000	1455	1478	1464	1511	1781	1744	1774	1758
gi_chapman	3500	1470	1509	1479	1523	1956	1924	1955	1938
gi_chapman	4000	1486	1542	1495	1533	2121	2095	2122	2107
gi_chapman	4500	1501	1566	1509	1544	2275	2260	2282	2269
gi_chapman	5000	1517	1599	1524	1566	2435	2421	2429	2428

Table D2a. Modeled mean wetted width and depth for all channels for All Reaches (Overton to Chapman), Lexington to Overton north channel, and the J2 Return to Overton.

Reach	Q (cfs)	Mean Wetted Width (ft)				Depth (ft)			
		2017	2018	2019	2020	2017	2018	2019	2020
All_Reaches	500	678	743	745	768	0.5	0.5	0.6	0.5
All_Reaches	750	750	805	819	832	0.6	0.6	0.6	0.6
All_Reaches	1000	802	837	852	867	0.7	0.7	0.7	0.7
All_Reaches	1200	826	845	868	886	0.8	0.8	0.8	0.7
All_Reaches	1500	864	875	887	909	0.9	0.9	0.9	0.8
All_Reaches	2000	900	901	908	932	1.0	1.0	1.0	1.0
All_Reaches	2500	927	927	926	951	1.1	1.1	1.2	1.1
All_Reaches	3000	949	951	943	966	1.3	1.3	1.3	1.2
All_Reaches	3500	968	972	959	981	1.4	1.4	1.4	1.4
All_Reaches	4000	988	995	976	998	1.4	1.4	1.5	1.5
All_Reaches	4500	1003	1012	991	1012	1.5	1.5	1.6	1.5
All_Reaches	5000	1019	1030	1006	1028	1.6	1.6	1.7	1.6
N-lexington_overton	500	241	331	283	313	0.6	0.8	0.9	0.9
N-lexington_overton	750	241	331	295	318	0.6	0.8	0.9	0.8
N-lexington_overton	1000	241	341	292	316	0.6	0.8	0.9	0.8
N-lexington_overton	1200	242	341	294	317	0.6	0.8	0.9	0.8
N-lexington_overton	1500	242	341	294	318	0.6	0.8	0.9	0.8
N-lexington_overton	2000	242	340	283	317	0.6	0.8	0.9	0.8
N-lexington_overton	2500	242	332	293	318	0.6	0.8	0.9	0.8
N-lexington_overton	3000	323	402	345	367	0.9	1.1	1.2	1.1
N-lexington_overton	3500	378	445	402	431	1.1	1.3	1.4	1.3
N-lexington_overton	4000	415	483	460	479	1.3	1.4	1.5	1.4
N-lexington_overton	4500	451	511	496	514	1.4	1.5	1.6	1.5
N-lexington_overton	5000	500	538	529	535	1.4	1.6	1.7	1.6
J2_overton	500	295	275	273	280	1.3	1.1	1.2	1.0
J2_overton	750	317	304	294	314	1.5	1.3	1.4	1.2
J2_overton	1000	344	344	319	336	1.6	1.3	1.5	1.3
J2_overton	1200	353	364	324	358	1.7	1.4	1.7	1.4
J2_overton	1500	372	384	351	378	1.9	1.5	1.7	1.6
J2_overton	2000	405	412	374	407	2.0	1.8	2.0	1.8
J2_overton	2500	447	424	401	431	2.1	2.1	2.2	2.0
J2_overton	3000	465	424	402	431	2.2	2.1	2.2	2.0
J2_overton	3500	479	430	402	432	2.2	2.2	2.2	2.0
J2_overton	4000	490	439	402	433	2.2	2.2	2.2	2.0
J2_overton	4500	498	445	407	431	2.3	2.2	2.3	2.2
J2_overton	5000	504	461	417	437	2.3	2.2	2.3	2.2

Table D2b. Modeled mean wetted width and depth for all channels for Overton to Elm Creek, Elm Creek to Odessa, and Odessa to Minden.

Reach	Q (cfs)	Mean Wetted Width (ft)				Depth (ft)			
		2017	2018	2019	2020	2017	2018	2019	2020
overton_elmcreek	500	558	569	624	612	0.6	0.6	0.7	0.6
overton_elmcreek	750	611	638	673	668	0.8	0.7	0.8	0.7
overton_elmcreek	1000	643	677	698	703	0.9	0.9	0.9	0.8
overton_elmcreek	1200	669	699	715	720	1.0	1.0	1.0	0.9
overton_elmcreek	1500	709	723	732	741	1.1	1.1	1.1	1.1
overton_elmcreek	2000	736	754	749	760	1.3	1.2	1.3	1.2
overton_elmcreek	2500	764	780	770	782	1.4	1.4	1.4	1.4
overton_elmcreek	3000	782	796	785	796	1.6	1.6	1.6	1.6
overton_elmcreek	3500	807	820	805	815	1.7	1.7	1.7	1.7
overton_elmcreek	4000	829	841	825	836	1.8	1.8	1.8	1.8
overton_elmcreek	4500	853	863	856	864	1.8	1.9	1.9	1.8
overton_elmcreek	5000	870	877	869	879	1.9	1.9	2.0	1.9
elmcreek_odessa	500	616	681	706	697	0.6	0.6	0.6	0.5
elmcreek_odessa	750	687	734	760	757	0.7	0.7	0.7	0.7
elmcreek_odessa	1000	722	753	786	788	0.8	0.8	0.8	0.8
elmcreek_odessa	1200	748	768	796	799	0.9	0.9	0.9	0.9
elmcreek_odessa	1500	774	781	805	816	1.0	1.0	1.0	1.0
elmcreek_odessa	2000	794	798	814	827	1.2	1.2	1.2	1.2
elmcreek_odessa	2500	814	813	824	841	1.3	1.4	1.4	1.3
elmcreek_odessa	3000	827	825	832	844	1.5	1.5	1.5	1.5
elmcreek_odessa	3500	841	840	839	855	1.6	1.6	1.6	1.6
elmcreek_odessa	4000	856	855	849	865	1.7	1.7	1.7	1.7
elmcreek_odessa	4500	867	866	866	879	1.8	1.8	1.8	1.8
elmcreek_odessa	5000	875	874	875	885	1.9	1.9	1.9	1.9
odessa_minden	500	586	648	621	653	0.5	0.5	0.6	0.5
odessa_minden	750	654	693	691	720	0.6	0.6	0.7	0.6
odessa_minden	1000	707	727	722	750	0.7	0.7	0.8	0.7
odessa_minden	1200	723	740	735	771	0.8	0.8	0.9	0.8
odessa_minden	1500	766	772	758	797	0.9	0.9	1.0	0.9
odessa_minden	2000	809	808	792	830	1.0	1.1	1.1	1.1
odessa_minden	2500	843	844	815	854	1.2	1.2	1.3	1.2
odessa_minden	3000	868	870	836	874	1.3	1.3	1.4	1.3
odessa_minden	3500	893	892	860	897	1.4	1.4	1.5	1.4
odessa_minden	4000	925	925	886	921	1.5	1.5	1.6	1.5
odessa_minden	4500	947	941	904	940	1.6	1.6	1.7	1.6
odessa_minden	5000	968	965	928	962	1.7	1.7	1.8	1.7

Table D2c. Modeled mean wetted width and depth for all channels for Minden to Gibbon, Gibbon to Wood River, and Wood River to Grand Island.

Reach	Q (cfs)	Mean Wetted Width (ft)				Depth (ft)			
		2017	2018	2019	2020	2017	2018	2019	2020
minden_gibbon	500	857	940	924	942	0.5	0.4	0.5	0.4
minden_gibbon	750	957	1033	1024	1032	0.5	0.5	0.6	0.5
minden_gibbon	1000	1030	1075	1064	1080	0.6	0.6	0.6	0.6
minden_gibbon	1200	1052	1080	1083	1107	0.7	0.7	0.7	0.7
minden_gibbon	1500	1106	1120	1110	1137	0.8	0.8	0.8	0.7
minden_gibbon	2000	1140	1145	1132	1161	0.9	0.9	0.9	0.9
minden_gibbon	2500	1159	1164	1149	1177	1.0	1.0	1.1	1.0
minden_gibbon	3000	1183	1185	1164	1192	1.1	1.1	1.2	1.1
minden_gibbon	3500	1196	1206	1178	1205	1.2	1.2	1.3	1.2
minden_gibbon	4000	1218	1235	1197	1223	1.3	1.3	1.4	1.3
minden_gibbon	4500	1228	1246	1209	1236	1.4	1.4	1.5	1.4
minden_gibbon	5000	1240	1258	1225	1255	1.5	1.5	1.5	1.5
gibbon_woodriver	500	612	697	707	751	0.5	0.5	0.6	0.5
gibbon_woodriver	750	677	757	778	809	0.6	0.6	0.6	0.6
gibbon_woodriver	1000	729	783	805	837	0.7	0.7	0.7	0.7
gibbon_woodriver	1200	750	783	813	849	0.8	0.8	0.8	0.7
gibbon_woodriver	1500	790	811	831	870	0.9	0.8	0.9	0.8
gibbon_woodriver	2000	825	832	850	883	1.0	1.0	1.0	1.0
gibbon_woodriver	2500	850	853	868	895	1.1	1.1	1.2	1.1
gibbon_woodriver	3000	871	876	884	906	1.2	1.2	1.3	1.2
gibbon_woodriver	3500	891	898	898	919	1.3	1.3	1.4	1.3
gibbon_woodriver	4000	906	917	910	932	1.4	1.4	1.5	1.4
gibbon_woodriver	4500	919	933	920	941	1.5	1.5	1.6	1.5
gibbon_woodriver	5000	936	956	933	954	1.6	1.6	1.7	1.6
woodriver_gi	500	702	788	798	809	0.5	0.4	0.5	0.4
woodriver_gi	750	783	867	887	879	0.6	0.5	0.6	0.5
woodriver_gi	1000	848	906	929	925	0.6	0.6	0.6	0.6
woodriver_gi	1200	882	906	953	949	0.7	0.7	0.7	0.6
woodriver_gi	1500	926	954	974	978	0.8	0.8	0.8	0.7
woodriver_gi	2000	978	980	996	1006	0.9	0.9	0.9	0.9
woodriver_gi	2500	1012	1005	1015	1026	1.0	1.0	1.0	1.0
woodriver_gi	3000	1035	1030	1030	1043	1.1	1.1	1.1	1.1
woodriver_gi	3500	1054	1050	1043	1058	1.2	1.2	1.2	1.2
woodriver_gi	4000	1071	1071	1060	1073	1.3	1.3	1.3	1.3
woodriver_gi	4500	1083	1086	1071	1086	1.4	1.4	1.4	1.4
woodriver_gi	5000	1098	1102	1084	1098	1.5	1.4	1.5	1.4

Table D2d. Modeled mean wetted width and depth for all channels for Grand Island to Chapman.

Reach	Q (cfs)	Mean Wetted Width (ft)				Depth (ft)			
		2017	2018	2019	2020	2017	2018	2019	2020
gi_chapman	500	878	922	897	941	0.5	0.4	0.5	0.4
gi_chapman	750	956	963	967	994	0.6	0.6	0.6	0.5
gi_chapman	1000	996	986	1007	1026	0.7	0.6	0.7	0.6
gi_chapman	1200	1014	998	1024	1043	0.7	0.7	0.7	0.7
gi_chapman	1500	1026	998	1037	1053	0.8	0.8	0.8	0.8
gi_chapman	2000	1044	1023	1047	1075	1.0	1.0	1.0	0.9
gi_chapman	2500	1063	1051	1063	1093	1.1	1.1	1.1	1.1
gi_chapman	3000	1083	1083	1084	1111	1.2	1.2	1.2	1.2
gi_chapman	3500	1094	1106	1095	1121	1.3	1.3	1.3	1.3
gi_chapman	4000	1107	1128	1108	1130	1.4	1.4	1.4	1.4
gi_chapman	4500	1117	1147	1118	1138	1.5	1.4	1.5	1.5
gi_chapman	5000	1129	1169	1132	1157	1.6	1.5	1.6	1.6

Table D3a. Modeled area with depth < 1ft and width:depth ratio for All Reaches (Overton to Chapman), Lexington to Overton north channel, and the J2 Return to Overton.

Reach	Q (cfs)	Area with Depth <1ft (ac)				Width:Depth Ratio			
		2017	2018	2019	2020	2017	2018	2019	2020
All_Reaches	500	7928	8593	7752	8969	1325	1546	1332	1621
All_Reaches	750	7847	8755	8087	9128	1219	1372	1280	1457
All_Reaches	1000	7688	8439	7887	8608	1143	1227	1177	1298
All_Reaches	1200	7128	7760	7520	8108	1054	1102	1089	1194
All_Reaches	1500	6885	7164	7047	7439	1000	1015	995	1084
All_Reaches	2000	6010	5847	6083	6148	893	889	871	941
All_Reaches	2500	5182	4703	5157	4996	816	810	787	841
All_Reaches	3000	4495	3900	4314	4100	759	759	728	775
All_Reaches	3500	3964	3342	3578	3374	716	720	684	724
All_Reaches	4000	3576	3029	3009	2847	686	692	652	686
All_Reaches	4500	3096	2758	2542	2454	651	663	623	655
All_Reaches	5000	2772	2575	2220	2194	625	639	601	629
N-lexington_overton	500	301	337	255	286	389	398	308	361
N-lexington_overton	750	301	337	274	337	390	398	326	396
N-lexington_overton	1000	304	375	275	337	391	433	324	394
N-lexington_overton	1200	301	373	275	335	390	432	326	394
N-lexington_overton	1500	302	375	271	338	390	433	330	396
N-lexington_overton	2000	304	373	254	338	391	431	307	396
N-lexington_overton	2500	301	337	270	335	387	398	328	394
N-lexington_overton	3000	317	289	207	256	365	356	285	331
N-lexington_overton	3500	287	255	217	269	345	344	288	333
N-lexington_overton	4000	257	253	246	299	329	343	303	339
N-lexington_overton	4500	247	248	262	304	323	332	306	335
N-lexington_overton	5000	301	288	295	300	353	344	318	325
J2_overton	500	125	143	145	168	220	251	234	272
J2_overton	750	118	134	128	166	211	239	215	265
J2_overton	1000	122	162	122	158	216	266	209	253
J2_overton	1200	108	158	109	153	203	262	196	248
J2_overton	1500	102	145	114	150	198	248	202	242
J2_overton	2000	101	129	102	138	199	233	191	228
J2_overton	2500	114	87	93	132	211	201	185	220
J2_overton	3000	122	85	91	129	215	200	184	218
J2_overton	3500	124	84	89	128	217	198	183	215
J2_overton	4000	127	89	87	125	218	200	181	213
J2_overton	4500	130	90	86	104	219	200	180	198
J2_overton	5000	138	110	94	104	221	210	185	197

Table D3b. Modeled area with depth < 1ft and width:depth ratio for all channels from Overton to Elm Creek, Elm Creek to Odessa, and Odessa to Minden.

Reach	Q (cfs)	Area with Depth <1ft (ac)				Width:Depth Ratio			
		2017	2018	2019	2020	2017	2018	2019	2020
overton_elmcreek	500	640	629	685	685	397	392	464	412
overton_elmcreek	750	670	694	731	732	521	519	574	545
overton_elmcreek	1000	702	727	758	765	624	634	673	650
overton_elmcreek	1200	728	746	776	782	711	718	752	734
overton_elmcreek	1500	770	773	799	799	830	826	865	847
overton_elmcreek	2000	802	813	820	822	1029	1009	1037	1012
overton_elmcreek	2500	835	848	844	855	1195	1212	1223	1228
overton_elmcreek	3000	859	867	860	869	1352	1361	1376	1363
overton_elmcreek	3500	887	889	881	895	1503	1506	1504	1515
overton_elmcreek	4000	931	940	924	940	1653	1685	1657	1662
overton_elmcreek	4500	976	983	967	983	1801	1820	1812	1811
overton_elmcreek	5000	998	1003	985	1003	1932	1949	1942	1938
elmcreek_odessa	500	532	575	597	594	318	332	377	326
elmcreek_odessa	750	582	616	637	643	424	436	464	435
elmcreek_odessa	1000	608	635	657	664	507	525	544	518
elmcreek_odessa	1200	627	644	667	674	576	590	607	585
elmcreek_odessa	1500	649	654	673	684	664	670	693	673
elmcreek_odessa	2000	668	667	682	694	794	807	823	802
elmcreek_odessa	2500	689	686	697	707	921	932	942	936
elmcreek_odessa	3000	699	696	703	711	1039	1043	1058	1038
elmcreek_odessa	3500	715	713	711	722	1152	1152	1153	1149
elmcreek_odessa	4000	730	729	722	735	1256	1275	1257	1248
elmcreek_odessa	4500	745	745	742	753	1359	1369	1365	1352
elmcreek_odessa	5000	754	754	754	763	1456	1464	1461	1447
odessa_minden	500	2576	2598	2327	2495	1326	1305	1421	1287
odessa_minden	750	2692	2791	2643	2847	1691	1704	1807	1709
odessa_minden	1000	2834	2882	2714	2834	2035	2046	2115	2034
odessa_minden	1200	2710	2745	2698	2843	2240	2259	2336	2277
odessa_minden	1500	2929	2901	2793	2963	2624	2632	2677	2643
odessa_minden	2000	3038	2970	2864	3022	3165	3159	3195	3188
odessa_minden	2500	3114	3061	2926	3064	3666	3657	3678	3680
odessa_minden	3000	3211	3178	3006	3148	4143	4132	4132	4153
odessa_minden	3500	3310	3272	3069	3208	4594	4574	4563	4595
odessa_minden	4000	3431	3393	3148	3283	5033	5011	4987	5025
odessa_minden	4500	3427	3439	3202	3338	5425	5411	5378	5429
odessa_minden	5000	3471	3486	3277	3408	5826	5814	5777	5837

Table D3c. Modeled area with depth < 1ft and width:depth ratio for all channels from Minden to Gibbon, Gibbon to Wood River, and Wood River to Grand Island.

Reach	Q (cfs)	Area with Depth <1ft (ac)				Width:Depth Ratio			
		2017	2018	2019	2020	2017	2018	2019	2020
minden_gibbon	500	687	683	667	684	318	297	336	296
minden_gibbon	750	749	787	753	776	406	403	431	391
minden_gibbon	1000	789	813	777	783	487	485	505	465
minden_gibbon	1200	761	775	769	789	532	533	554	520
minden_gibbon	1500	825	828	793	821	626	627	636	607
minden_gibbon	2000	840	835	809	837	748	748	756	732
minden_gibbon	2500	848	844	817	848	861	860	866	847
minden_gibbon	3000	865	859	829	854	968	966	970	953
minden_gibbon	3500	880	875	836	862	1068	1065	1066	1053
minden_gibbon	4000	903	904	853	878	1165	1164	1161	1150
minden_gibbon	4500	896	913	861	887	1252	1255	1249	1241
minden_gibbon	5000	900	914	873	898	1338	1341	1335	1329
gibbon_woodriver	500	1665	1742	1773	1888	846	834	983	869
gibbon_woodriver	750	1783	1925	1933	2030	1087	1106	1230	1129
gibbon_woodriver	1000	1892	1986	2007	2058	1312	1329	1440	1350
gibbon_woodriver	1200	1892	1964	2024	2077	1467	1483	1593	1514
gibbon_woodriver	1500	2002	2025	2059	2148	1709	1717	1812	1752
gibbon_woodriver	2000	2083	2065	2098	2167	2061	2061	2153	2101
gibbon_woodriver	2500	2137	2107	2143	2195	2383	2378	2471	2422
gibbon_woodriver	3000	2193	2170	2172	2226	2687	2682	2764	2724
gibbon_woodriver	3500	2260	2236	2216	2271	2979	2969	3046	3015
gibbon_woodriver	4000	2301	2281	2247	2297	3253	3241	3312	3288
gibbon_woodriver	4500	2307	2320	2273	2319	3506	3500	3563	3544
gibbon_woodriver	5000	2349	2366	2302	2344	3766	3759	3812	3799
woodriver_gi	500	1808	1899	1972	2016	834	822	985	837
woodriver_gi	750	1932	2065	2148	2140	1073	1091	1232	1086
woodriver_gi	1000	2060	2156	2241	2231	1300	1316	1443	1310
woodriver_gi	1200	2126	2199	2296	2284	1465	1478	1601	1479
woodriver_gi	1500	2217	2268	2304	2343	1702	1712	1817	1714
woodriver_gi	2000	2317	2312	2355	2382	2058	2061	2160	2067
woodriver_gi	2500	2395	2366	2400	2432	2387	2383	2479	2395
woodriver_gi	3000	2444	2422	2434	2464	2693	2685	2775	2701
woodriver_gi	3500	2488	2472	2468	2507	2982	2970	3054	2991
woodriver_gi	4000	2533	2524	2509	2544	3257	3244	3323	3266
woodriver_gi	4500	2561	2563	2538	2577	3517	3505	3578	3529
woodriver_gi	5000	2597	2608	2573	2613	3771	3759	3827	3788

Table D3d. Modeled area with depth < 1ft and width:depth ratio for Grand Island to Chapman.

Reach	**Q (cfs)**	**Mean Wetted Width (ft)**				**Depth (ft)**			
		2017	**2018**	**2019**	**2020**	**2017**	**2018**	**2019**	**2020**
gi_chapman	500	1202	1358	1258	1337	617	579	626	567
gi_chapman	750	1297	1375	1345	1404	771	758	779	744
gi_chapman	1000	1344	1407	1391	1454	912	902	917	884
gi_chapman	1200	1371	1412	1411	1462	1014	985	1039	989
gi_chapman	1500	1381	1350	1426	1412	1156	1120	1165	1124
gi_chapman	2000	1402	1380	1408	1441	1383	1343	1380	1353
gi_chapman	2500	1426	1417	1430	1465	1588	1547	1588	1562
gi_chapman	3000	1455	1478	1464	1511	1781	1744	1774	1758
gi_chapman	3500	1470	1509	1479	1523	1956	1924	1955	1938
gi_chapman	4000	1486	1542	1495	1533	2121	2095	2122	2107
gi_chapman	4500	1501	1566	1509	1544	2275	2260	2282	2269
gi_chapman	5000	1517	1599	1524	1566	2435	2421	2429	2428

Table D4a. Modeled inundated volume and area for the main channel of All Reaches (Overton to Chapman), Overton to Elm Creek, and Elm Creek to Odessa.

Reach	Q (cfs)	Inundated area (ac)				Inundated volume (acft)			
		2017	2018	2019	2020	2017	2018	2019	2020
All_Reaches	500	6328	6710	6736	6935	3287	3097	3708	3149
All_Reaches	750	6908	7312	7355	7488	4269	4159	4612	4138
All_Reaches	1000	7293	7580	7633	7741	5129	5045	5387	4968
All_Reaches	1200	7440	7640	7747	7869	5764	5658	5989	5606
All_Reaches	1500	7771	7831	7900	8058	6683	6562	6813	6503
All_Reaches	2000	8056	8005	8039	8222	8050	7938	8115	7856
All_Reaches	2500	8262	8194	8166	8349	9312	9193	9327	9115
All_Reaches	3000	8409	8376	8283	8458	10494	10355	10461	10242
All_Reaches	3500	8560	8545	8398	8567	11608	11455	11511	11337
All_Reaches	4000	8698	8717	8518	8675	12653	12542	12530	12360
All_Reaches	4500	8785	8836	8612	8760	13640	13518	13508	13339
All_Reaches	5000	8897	8966	8708	8862	14610	14487	14444	14290
overton_elmcreek	500	482	464	509	519	316	240	325	311
overton_elmcreek	750	518	520	544	555	414	338	399	408
overton_elmcreek	1000	540	546	563	576	490	426	464	482
overton_elmcreek	1200	556	561	574	589	556	491	518	547
overton_elmcreek	1500	580	577	586	600	642	574	596	630
overton_elmcreek	2000	596	594	597	611	765	710	720	755
overton_elmcreek	2500	611	610	610	623	884	835	834	886
overton_elmcreek	3000	623	620	619	630	999	949	950	987
overton_elmcreek	3500	634	631	628	642	1108	1058	1046	1097
overton_elmcreek	4000	648	648	642	656	1207	1182	1149	1195
overton_elmcreek	4500	664	662	657	670	1307	1274	1256	1294
overton_elmcreek	5000	673	671	667	680	1399	1368	1351	1384
elmcreek_odessa	500	522	571	591	586	315	331	374	323
elmcreek_odessa	750	575	611	631	632	421	433	462	431
elmcreek_odessa	1000	601	629	650	653	503	522	541	513
elmcreek_odessa	1200	620	639	659	663	573	586	604	580
elmcreek_odessa	1500	643	649	667	675	660	666	689	668
elmcreek_odessa	2000	661	661	675	684	788	802	818	796
elmcreek_odessa	2500	679	678	685	696	913	924	934	928
elmcreek_odessa	3000	689	687	690	700	1030	1034	1049	1028
elmcreek_odessa	3500	702	700	698	709	1140	1140	1143	1138
elmcreek_odessa	4000	712	713	708	719	1242	1261	1245	1235
elmcreek_odessa	4500	722	722	719	731	1343	1351	1350	1335
elmcreek_odessa	5000	729	729	726	738	1436	1444	1443	1427

Table D4b. Modeled inundated volume and area for the main channel of Odessa to Minden, Minden to Gibbon, and Gibbon to Wood River.

Reach	Q (cfs)	Inundated area (ac)				Inundated volume (acft)			
		2017	2018	2019	2020	2017	2018	2019	2020
odessa_minden	500	1212	1291	1274	1312	685	689	831	682
odessa_minden	750	1331	1412	1403	1444	902	913	1026	893
odessa_minden	1000	1409	1463	1452	1481	1091	1102	1190	1072
odessa_minden	1200	1412	1453	1460	1499	1220	1235	1308	1204
odessa_minden	1500	1504	1517	1499	1553	1427	1439	1485	1400
odessa_minden	2000	1564	1554	1541	1599	1721	1739	1758	1700
odessa_minden	2500	1610	1603	1567	1626	1992	2012	2016	1969
odessa_minden	3000	1643	1643	1596	1649	2244	2265	2258	2220
odessa_minden	3500	1687	1687	1627	1676	2487	2507	2489	2459
odessa_minden	4000	1729	1733	1660	1705	2716	2738	2710	2684
odessa_minden	4500	1743	1758	1681	1726	2928	2951	2916	2895
odessa_minden	5000	1770	1779	1707	1750	3140	3164	3124	3106
minden_gibbon	500	505	524	537	511	214	182	247	164
minden_gibbon	750	552	582	586	567	276	248	304	212
minden_gibbon	1000	585	603	601	589	329	301	349	257
minden_gibbon	1200	595	602	603	600	367	339	382	293
minden_gibbon	1500	623	621	615	621	423	397	431	346
minden_gibbon	2000	639	633	624	632	505	482	507	427
minden_gibbon	2500	645	641	628	638	579	557	578	498
minden_gibbon	3000	653	650	635	643	649	625	644	564
minden_gibbon	3500	659	658	640	648	714	688	706	626
minden_gibbon	4000	667	668	649	654	775	748	765	684
minden_gibbon	4500	668	673	653	657	831	804	819	739
minden_gibbon	5000	673	681	658	664	886	858	871	793
gibbon_woodriver	500	1282	1382	1394	1472	686	657	779	678
gibbon_woodriver	750	1393	1513	1529	1578	886	874	976	883
gibbon_woodriver	1000	1477	1561	1585	1617	1067	1056	1142	1061
gibbon_woodriver	1200	1501	1563	1602	1638	1198	1185	1263	1192
gibbon_woodriver	1500	1576	1606	1633	1686	1390	1373	1437	1380
gibbon_woodriver	2000	1639	1636	1662	1706	1674	1651	1706	1657
gibbon_woodriver	2500	1685	1668	1688	1726	1934	1904	1954	1909
gibbon_woodriver	3000	1717	1705	1709	1746	2175	2141	2183	2144
gibbon_woodriver	3500	1752	1740	1735	1768	2404	2365	2401	2366
gibbon_woodriver	4000	1778	1772	1754	1787	2619	2578	2608	2576
gibbon_woodriver	4500	1794	1795	1770	1800	2819	2778	2802	2774
gibbon_woodriver	5000	1823	1827	1788	1816	3019	2978	2995	2970

Table D4c. Modeled inundated volume and area for the main channel of Wood River to Grand Island and Grand Island to Chapman.

Reach	Q (cfs)	Inundated area (ac)				Inundated volume (acft)			
		2017	2018	2019	2020	2017	2018	2019	2020
woodriver_gi	500	1133	1225	1216	1256	458	440	533	437
woodriver_gi	750	1253	1368	1361	1366	603	608	675	581
woodriver_gi	1000	1347	1440	1429	1436	740	749	792	714
woodriver_gi	1200	1395	1473	1471	1474	841	850	883	816
woodriver_gi	1500	1468	1518	1502	1521	988	996	1017	959
woodriver_gi	2000	1558	1553	1537	1556	1216	1216	1230	1173
woodriver_gi	2500	1609	1586	1564	1583	1428	1418	1428	1368
woodriver_gi	3000	1639	1621	1583	1604	1623	1607	1610	1551
woodriver_gi	3500	1665	1651	1602	1624	1807	1783	1779	1724
woodriver_gi	4000	1687	1676	1623	1644	1982	1952	1940	1889
woodriver_gi	4500	1703	1695	1637	1656	2147	2113	2093	2044
woodriver_gi	5000	1722	1716	1653	1671	2306	2268	2241	2195
gi_chapman	500	1192	1253	1215	1281	614	558	618	554
gi_chapman	750	1286	1305	1301	1347	767	744	770	731
gi_chapman	1000	1334	1338	1353	1388	908	888	909	869
gi_chapman	1200	1360	1351	1379	1405	1010	972	1032	975
gi_chapman	1500	1378	1343	1397	1404	1153	1117	1158	1120
gi_chapman	2000	1399	1374	1404	1433	1379	1339	1376	1349
gi_chapman	2500	1422	1408	1425	1457	1582	1542	1582	1556
gi_chapman	3000	1446	1450	1451	1486	1774	1734	1766	1748
gi_chapman	3500	1461	1478	1467	1499	1948	1913	1947	1927
gi_chapman	4000	1476	1507	1481	1510	2113	2083	2113	2096
gi_chapman	4500	1491	1531	1495	1520	2266	2247	2272	2258
gi_chapman	5000	1506	1563	1510	1543	2425	2407	2418	2415

Table D5a. Modeled mean wetted width and depth for the main channel of All Reaches (Overton to Chapman), Overton to Elm Creek, and Elm Creek to Odessa.

Reach	Q (cfs)	Mean Wetted Width (ft)				Depth (ft)			
		2017	2018	2019	2020	2017	2018	2019	2020
All_Reaches	500	555	601	608	620	0.5	0.5	0.6	0.5
All_Reaches	750	615	655	666	672	0.6	0.6	0.6	0.6
All_Reaches	1000	656	681	691	701	0.7	0.7	0.7	0.6
All_Reaches	1200	675	688	703	715	0.8	0.7	0.8	0.7
All_Reaches	1500	704	709	716	732	0.9	0.8	0.9	0.8
All_Reaches	2000	730	727	730	748	1.0	1.0	1.0	1.0
All_Reaches	2500	749	746	742	761	1.1	1.1	1.1	1.1
All_Reaches	3000	764	762	753	771	1.2	1.2	1.3	1.2
All_Reaches	3500	776	777	763	779	1.4	1.3	1.4	1.3
All_Reaches	4000	788	792	774	789	1.5	1.4	1.5	1.4
All_Reaches	4500	798	803	784	798	1.6	1.5	1.6	1.5
All_Reaches	5000	809	815	793	808	1.6	1.6	1.7	1.6
overton_elmcreek	500	449	426	483	484	0.7	0.5	0.6	0.6
overton_elmcreek	750	489	485	518	524	0.8	0.7	0.7	0.7
overton_elmcreek	1000	509	517	534	546	0.9	0.8	0.8	0.8
overton_elmcreek	1200	528	533	547	558	1.0	0.9	0.9	0.9
overton_elmcreek	1500	557	549	558	568	1.1	1.0	1.0	1.1
overton_elmcreek	2000	570	568	568	580	1.3	1.2	1.2	1.2
overton_elmcreek	2500	584	583	580	594	1.4	1.4	1.4	1.4
overton_elmcreek	3000	595	593	587	601	1.6	1.5	1.5	1.6
overton_elmcreek	3500	608	607	601	614	1.7	1.7	1.7	1.7
overton_elmcreek	4000	620	621	614	626	1.9	1.8	1.8	1.8
overton_elmcreek	4500	634	635	630	642	2.0	1.9	1.9	1.9
overton_elmcreek	5000	645	643	638	650	2.1	2.0	2.0	2.0
elmcreek_odessa	500	613	679	705	695	0.6	0.6	0.6	0.6
elmcreek_odessa	750	684	731	758	755	0.7	0.7	0.7	0.7
elmcreek_odessa	1000	719	750	784	785	0.8	0.8	0.8	0.8
elmcreek_odessa	1200	744	764	793	795	0.9	0.9	0.9	0.9
elmcreek_odessa	1500	770	777	801	812	1.0	1.0	1.0	1.0
elmcreek_odessa	2000	789	793	810	822	1.2	1.2	1.2	1.2
elmcreek_odessa	2500	808	809	820	836	1.3	1.4	1.4	1.3
elmcreek_odessa	3000	821	820	827	839	1.5	1.5	1.5	1.5
elmcreek_odessa	3500	835	835	834	849	1.6	1.6	1.6	1.6
elmcreek_odessa	4000	849	848	844	859	1.7	1.8	1.8	1.7
elmcreek_odessa	4500	859	859	860	873	1.9	1.9	1.9	1.8
elmcreek_odessa	5000	867	868	869	878	2.0	2.0	2.0	1.9

Table D5b. Modeled mean wetted width and depth for the main channel of Odessa to Minden, Minden to Gibbon, and Gibbon to Wood River.

Reach	Q (cfs)	Mean Wetted Width (ft)				Depth (ft)			
		2017	2018	2019	2020	2017	2018	2019	2020
odessa_minden	500	433	482	480	481	0.6	0.5	0.7	0.5
odessa_minden	750	485	518	528	530	0.7	0.6	0.7	0.6
odessa_minden	1000	521	541	547	552	0.8	0.8	0.8	0.7
odessa_minden	1200	530	548	553	567	0.9	0.8	0.9	0.8
odessa_minden	1500	562	573	567	586	0.9	0.9	1.0	0.9
odessa_minden	2000	587	591	584	607	1.1	1.1	1.1	1.1
odessa_minden	2500	609	612	595	620	1.2	1.3	1.3	1.2
odessa_minden	3000	623	627	605	629	1.4	1.4	1.4	1.3
odessa_minden	3500	638	640	617	638	1.5	1.5	1.5	1.5
odessa_minden	4000	654	659	630	651	1.6	1.6	1.6	1.6
odessa_minden	4500	666	669	640	659	1.7	1.7	1.7	1.7
odessa_minden	5000	679	681	652	668	1.8	1.8	1.8	1.8
minden_gibbon	500	700	743	769	719	0.4	0.3	0.5	0.3
minden_gibbon	750	767	826	834	810	0.5	0.4	0.5	0.4
minden_gibbon	1000	841	862	860	851	0.6	0.5	0.6	0.4
minden_gibbon	1200	850	869	871	873	0.6	0.6	0.6	0.5
minden_gibbon	1500	900	897	889	899	0.7	0.6	0.7	0.6
minden_gibbon	2000	908	916	887	915	0.8	0.8	0.8	0.7
minden_gibbon	2500	935	932	913	927	0.9	0.9	0.9	0.8
minden_gibbon	3000	951	943	924	934	1.0	1.0	1.0	0.9
minden_gibbon	3500	957	958	931	942	1.1	1.0	1.1	1.0
minden_gibbon	4000	952	974	944	951	1.2	1.1	1.2	1.0
minden_gibbon	4500	957	962	950	956	1.2	1.2	1.3	1.1
minden_gibbon	5000	963	970	958	968	1.3	1.3	1.3	1.2
gibbon_woodriver	500	540	606	616	651	0.5	0.5	0.6	0.5
gibbon_woodriver	750	598	659	678	701	0.6	0.6	0.6	0.6
gibbon_woodriver	1000	641	681	701	724	0.7	0.7	0.7	0.7
gibbon_woodriver	1200	659	682	705	734	0.8	0.8	0.8	0.7
gibbon_woodriver	1500	693	705	720	751	0.9	0.9	0.9	0.8
gibbon_woodriver	2000	721	722	735	761	1.0	1.0	1.0	1.0
gibbon_woodriver	2500	741	738	746	769	1.1	1.1	1.2	1.1
gibbon_woodriver	3000	755	754	760	778	1.3	1.3	1.3	1.2
gibbon_woodriver	3500	769	769	771	786	1.4	1.4	1.4	1.3
gibbon_woodriver	4000	778	782	778	794	1.5	1.5	1.5	1.4
gibbon_woodriver	4500	787	792	785	801	1.6	1.5	1.6	1.5
gibbon_woodriver	5000	800	806	793	809	1.7	1.6	1.7	1.6

Table D5c. Modeled mean wetted width and depth for the main channel of Wood River to Grand Island and Grand Island to Chapman.

Reach	Q (cfs)	Mean Wetted Width (ft)				Depth (ft)			
		2017	2018	2019	2020	2017	2018	2019	2020
woodriver_gi	500	461	516	512	525	0.4	0.4	0.4	0.3
woodriver_gi	750	520	583	577	576	0.5	0.4	0.5	0.4
woodriver_gi	1000	568	614	607	610	0.5	0.5	0.6	0.5
woodriver_gi	1200	595	614	625	627	0.6	0.6	0.6	0.6
woodriver_gi	1500	626	647	639	646	0.7	0.7	0.7	0.6
woodriver_gi	2000	664	662	655	663	0.8	0.8	0.8	0.8
woodriver_gi	2500	685	678	667	674	0.9	0.9	0.9	0.9
woodriver_gi	3000	700	693	674	684	1.0	1.0	1.0	1.0
woodriver_gi	3500	711	706	681	691	1.1	1.1	1.1	1.1
woodriver_gi	4000	719	717	692	700	1.2	1.2	1.2	1.1
woodriver_gi	4500	725	724	697	706	1.3	1.2	1.3	1.2
woodriver_gi	5000	734	731	704	712	1.3	1.3	1.4	1.3
gi_chapman	500	878	922	897	941	0.5	0.4	0.5	0.4
gi_chapman	750	956	963	967	994	0.6	0.6	0.6	0.5
gi_chapman	1000	996	986	1007	1026	0.7	0.7	0.7	0.6
gi_chapman	1200	1014	998	1024	1043	0.7	0.7	0.7	0.7
gi_chapman	1500	1026	998	1037	1053	0.8	0.8	0.8	0.8
gi_chapman	2000	1044	1023	1047	1075	1.0	1.0	1.0	0.9
gi_chapman	2500	1063	1051	1063	1093	1.1	1.1	1.1	1.1
gi_chapman	3000	1083	1083	1084	1111	1.2	1.2	1.2	1.2
gi_chapman	3500	1094	1106	1095	1121	1.3	1.3	1.3	1.3
gi_chapman	4000	1107	1128	1108	1130	1.4	1.4	1.4	1.4
gi_chapman	4500	1117	1147	1118	1138	1.5	1.5	1.5	1.5
gi_chapman	5000	1129	1169	1131	1156	1.6	1.5	1.6	1.6

Table D6a. Modeled area with depth < 1ft and width:depth ratio for the main channel of All Reaches (Overton to Chapman), Overton to Elm Creek, and Elm Creek to Odessa.

Reach	**Q (cfs)**	**Area with Depth <1ft (ac)**				**Width:Depth Ratio**			
		2017	**2018**	**2019**	**2020**	**2017**	**2018**	**2019**	**2020**
All_Reaches	500	5501	6185	5678	6530	427	520	414	542
All_Reaches	750	5599	6383	5919	6651	383	425	383	458
All_Reaches	1000	5504	6192	5828	6411	348	365	351	399
All_Reaches	1200	5259	5862	5625	6093	320	332	322	361
All_Reaches	1500	5018	5393	5312	5597	293	292	291	320
All_Reaches	2000	4396	4378	4623	4629	255	251	248	271
All_Reaches	2500	3762	3464	3911	3725	226	226	221	239
All_Reaches	3000	3176	2755	3231	2975	206	207	203	217
All_Reaches	3500	2710	2263	2639	2367	191	195	188	199
All_Reaches	4000	2325	1940	2145	1912	179	184	176	186
All_Reaches	4500	1974	1699	1734	1564	169	175	166	175
All_Reaches	5000	1715	1553	1439	1338	162	168	159	167
overton_elmcreek	500	385	406	401	439	156	199	185	205
overton_elmcreek	750	352	415	401	407	139	172	173	176
overton_elmcreek	1000	317	388	387	370	131	154	158	164
overton_elmcreek	1200	285	358	369	331	130	145	144	147
overton_elmcreek	1500	252	314	339	280	129	135	130	131
overton_elmcreek	2000	197	228	273	203	114	120	114	117
overton_elmcreek	2500	158	159	209	142	104	108	102	105
overton_elmcreek	3000	127	114	142	107	97	99	93	97
overton_elmcreek	3500	108	92	104	84	93	94	89	92
overton_elmcreek	4000	96	83	82	76	91	91	86	90
overton_elmcreek	4500	90	81	77	75	92	92	87	92
overton_elmcreek	5000	82	77	74	75	91	91	84	90
elmcreek_odessa	500	432	490	473	521	199	250	243	250
elmcreek_odessa	750	418	470	472	500	183	199	216	217
elmcreek_odessa	1000	387	425	450	458	166	174	187	200
elmcreek_odessa	1200	359	386	424	413	150	159	167	182
elmcreek_odessa	1500	325	334	380	352	137	140	149	160
elmcreek_odessa	2000	262	237	298	258	121	120	125	133
elmcreek_odessa	2500	206	167	222	179	105	104	107	110
elmcreek_odessa	3000	158	118	146	131	92	93	95	99
elmcreek_odessa	3500	129	94	101	94	84	84	89	87
elmcreek_odessa	4000	110	81	72	76	75	76	82	80
elmcreek_odessa	4500	93	77	60	67	70	69	72	73
elmcreek_odessa	5000	78	73	57	62	64	66	67	69

Table D6b. Modeled area with depth < 1ft and width:depth ratio for the main channel of Odessa to Minden, Minden to Gibbon, and Gibbon to Wood River.

Reach	Q (cfs)	Area with Depth <1ft (ac)				Width:Depth Ratio			
		2017	2018	2019	2020	2017	2018	2019	2020
odessa_minden	500	1011	1135	1004	1190	262	272	210	279
odessa_minden	750	1010	1143	1044	1204	230	243	215	259
odessa_minden	1000	972	1070	1008	1110	218	224	201	231
odessa_minden	1200	886	957	947	1022	197	201	183	215
odessa_minden	1500	849	865	879	918	203	201	175	201
odessa_minden	2000	724	664	744	733	185	178	157	181
odessa_minden	2500	615	529	601	579	169	167	144	164
odessa_minden	3000	522	435	483	461	157	156	135	151
odessa_minden	3500	468	381	388	378	151	149	131	142
odessa_minden	4000	425	356	321	323	146	146	126	138
odessa_minden	4500	368	326	269	277	142	140	122	131
odessa_minden	5000	335	305	243	249	139	137	119	127
minden_gibbon	500	477	516	487	507	203	315	227	412
minden_gibbon	750	503	565	517	559	270	254	214	267
minden_gibbon	1000	511	573	515	574	176	222	193	238
minden_gibbon	1200	499	557	502	575	250	203	175	227
minden_gibbon	1500	493	547	490	576	162	177	160	201
minden_gibbon	2000	448	495	453	538	206	150	202	166
minden_gibbon	2500	390	423	407	481	130	138	132	157
minden_gibbon	3000	339	351	357	416	120	128	121	142
minden_gibbon	3500	288	282	303	351	108	116	110	126
minden_gibbon	4000	246	226	252	289	150	114	108	125
minden_gibbon	4500	203	177	198	229	141	152	101	117
minden_gibbon	5000	171	145	152	180	135	146	95	113
gibbon_woodriver	500	1106	1274	1167	1396	293	370	311	378
gibbon_woodriver	750	1120	1327	1216	1417	263	320	294	341
gibbon_woodriver	1000	1100	1279	1190	1344	242	279	268	303
gibbon_woodriver	1200	1039	1193	1142	1265	227	253	250	278
gibbon_woodriver	1500	987	1084	1075	1153	226	236	228	255
gibbon_woodriver	2000	853	846	934	914	206	206	199	219
gibbon_woodriver	2500	727	644	789	707	185	187	177	193
gibbon_woodriver	3000	613	499	646	542	168	169	163	175
gibbon_woodriver	3500	530	405	519	420	157	160	153	164
gibbon_woodriver	4000	462	348	408	330	147	151	143	151
gibbon_woodriver	4500	404	309	318	264	139	142	135	142
gibbon_woodriver	5000	367	295	258	224	135	137	128	136

Table D6b. Modeled area with depth < 1ft and width:depth ratio for the main channel of Odessa to Minden, Minden to Gibbon, and Gibbon to Wood River.

Reach	Q (cfs)	Area with Depth <1ft (ac)				Width:Depth Ratio			
		2017	2018	2019	2020	2017	2018	2019	2020
odessa_minden	500	1011	1135	1004	1190	262	272	210	279
odessa_minden	750	1010	1143	1044	1204	230	243	215	259
odessa_minden	1000	972	1070	1008	1110	218	224	201	231
odessa_minden	1200	886	957	947	1022	197	201	183	215
odessa_minden	1500	849	865	879	918	203	201	175	201
odessa_minden	2000	724	664	744	733	185	178	157	181
odessa_minden	2500	615	529	601	579	169	167	144	164
odessa_minden	3000	522	435	483	461	157	156	135	151
odessa_minden	3500	468	381	388	378	151	149	131	142
odessa_minden	4000	425	356	321	323	146	146	126	138
odessa_minden	4500	368	326	269	277	142	140	122	131
odessa_minden	5000	335	305	243	249	139	137	119	127
minden_gibbon	500	477	516	487	507	203	315	227	412
minden_gibbon	750	503	565	517	559	270	254	214	267
minden_gibbon	1000	511	573	515	574	176	222	193	238
minden_gibbon	1200	499	557	502	575	250	203	175	227
minden_gibbon	1500	493	547	490	576	162	177	160	201
minden_gibbon	2000	448	495	453	538	206	150	202	166
minden_gibbon	2500	390	423	407	481	130	138	132	157
minden_gibbon	3000	339	351	357	416	120	128	121	142
minden_gibbon	3500	288	282	303	351	108	116	110	126
minden_gibbon	4000	246	226	252	289	150	114	108	125
minden_gibbon	4500	203	177	198	229	141	152	101	117
minden_gibbon	5000	171	145	152	180	135	146	95	113
gibbon_woodriver	500	1106	1274	1167	1396	293	370	311	378
gibbon_woodriver	750	1120	1327	1216	1417	263	320	294	341
gibbon_woodriver	1000	1100	1279	1190	1344	242	279	268	303
gibbon_woodriver	1200	1039	1193	1142	1265	227	253	250	278
gibbon_woodriver	1500	987	1084	1075	1153	226	236	228	255
gibbon_woodriver	2000	853	846	934	914	206	206	199	219
gibbon_woodriver	2500	727	644	789	707	185	187	177	193
gibbon_woodriver	3000	613	499	646	542	168	169	163	175
gibbon_woodriver	3500	530	405	519	420	157	160	153	164
gibbon_woodriver	4000	462	348	408	330	147	151	143	151
gibbon_woodriver	4500	404	309	318	264	139	142	135	142
gibbon_woodriver	5000	367	295	258	224	135	137	128	136

Table D6c. Modeled area with depth < 1ft and width:depth ratio for the main channel of Wood River to Grand Island and Grand Island to Chapman.

Reach	Q (cfs)	Area with Depth <1ft (ac)				Width:Depth Ratio			
		2017	2018	2019	2020	2017	2018	2019	2020
woodriver_gi	500	1063	1185	1097	1233	602	802	593	882
woodriver_gi	750	1138	1296	1194	1317	548	641	546	725
woodriver_gi	1000	1178	1330	1219	1345	499	542	507	612
woodriver_gi	1200	1179	1324	1222	1340	455	489	468	542
woodriver_gi	1500	1168	1295	1187	1307	413	422	414	469
woodriver_gi	2000	1100	1162	1102	1181	361	356	349	385
woodriver_gi	2500	985	988	1001	1028	312	312	307	336
woodriver_gi	3000	860	819	888	862	279	279	275	300
woodriver_gi	3500	747	676	776	705	257	257	253	272
woodriver_gi	4000	647	559	666	567	238	238	236	250
woodriver_gi	4500	557	463	553	449	222	222	221	232
woodriver_gi	5000	487	394	452	362	210	210	208	218
gi_chapman	500	1027	1178	1049	1245	287	328	301	358
gi_chapman	750	1058	1167	1074	1248	255	263	267	288
gi_chapman	1000	1039	1128	1059	1210	229	225	237	249
gi_chapman	1200	1011	1086	1020	1147	209	214	207	223
gi_chapman	1500	944	954	962	1011	180	183	186	197
gi_chapman	2000	811	746	819	803	153	158	152	162
gi_chapman	2500	681	555	682	609	136	139	135	141
gi_chapman	3000	557	420	568	456	122	126	122	127
gi_chapman	3500	439	331	446	334	114	118	111	117
gi_chapman	4000	338	287	344	251	106	111	102	109
gi_chapman	4500	259	265	259	202	99	106	97	102
gi_chapman	5000	196	264	203	186	94	101	94	98

Table D7a. Mean modeled width (ft) for managed vs. unmanaged areas for the main channel of All Reaches (Overton to Chapman), Overton to Elm Creek, and Elm Creek to Odessa.

Reach	**Q (cfs)**	**2017**		**2018**		**2019**		**2020**	
		managed	un-managed	managed	un-managed	managed	un-managed	managed	un-managed
All_Reaches	500	563	550	614	596	636	595	629	617
All_Reaches	750	629	608	676	646	690	655	690	665
All_Reaches	1000	676	646	706	670	715	681	722	691
All_Reaches	1200	700	664	715	675	725	693	738	706
All_Reaches	1500	737	688	741	695	739	706	757	721
All_Reaches	2000	763	715	759	712	752	721	768	740
All_Reaches	2500	780	736	775	732	762	733	782	752
All_Reaches	3000	791	752	786	752	772	745	789	763
All_Reaches	3500	802	765	799	768	783	755	796	773
All_Reaches	4000	814	777	815	783	795	765	806	783
All_Reaches	4500	822	788	822	796	803	775	814	791
All_Reaches	5000	832	799	831	809	811	786	822	802
overton_elmcreek	500	473	437	420	458	499	494	507	501
overton_elmcreek	750	516	468	493	493	538	523	550	534
overton_elmcreek	1000	534	495	531	522	557	538	569	560
overton_elmcreek	1200	558	514	550	533	572	551	579	579
overton_elmcreek	1500	591	541	570	551	579	570	588	589
overton_elmcreek	2000	599	566	590	575	589	581	598	607
overton_elmcreek	2500	613	588	605	594	598	600	612	626
overton_elmcreek	3000	623	608	612	612	603	611	617	641
overton_elmcreek	3500	629	639	622	644	616	634	625	668
overton_elmcreek	4000	638	666	633	675	627	654	636	686
overton_elmcreek	4500	649	697	642	708	639	693	645	728
overton_elmcreek	5000	657	717	647	722	644	709	650	746
elmcreek_odessa	500	641	570	731	599	762	617	733	637
elmcreek_odessa	750	725	621	785	649	817	666	807	675
elmcreek_odessa	1000	765	648	806	666	845	689	842	697
elmcreek_odessa	1200	792	671	820	678	854	699	857	701
elmcreek_odessa	1500	821	690	834	691	861	709	871	720
elmcreek_odessa	2000	843	706	850	707	868	722	879	734
elmcreek_odessa	2500	857	733	860	730	876	733	890	754
elmcreek_odessa	3000	866	753	867	748	881	745	891	760
elmcreek_odessa	3500	875	774	877	770	886	755	894	781
elmcreek_odessa	4000	886	794	886	791	892	770	900	795
elmcreek_odessa	4500	892	810	894	806	901	797	910	816
elmcreek_odessa	5000	897	821	900	819	908	809	913	826

Table D7b. Mean modeled width (ft) for managed vs. unmanaged areas for the main channel of Odessa to Minden, Minden to Gibbon, and Gibbon to Wood River.

Reach	Q (cfs)	2017		2018		2019		2020	
		managed	un-managed	managed	un-managed	managed	un-managed	managed	un-managed
odessa_minden	500	390	450	436	500	440	494	419	513
odessa_minden	750	441	501	478	529	487	540	468	558
odessa_minden	1000	480	534	500	553	503	561	496	576
odessa_minden	1200	492	540	506	560	505	570	510	590
odessa_minden	1500	526	568	531	583	518	583	531	607
odessa_minden	2000	547	596	548	603	532	603	546	633
odessa_minden	2500	571	615	566	625	542	615	562	642
odessa_minden	3000	582	631	581	640	554	622	573	650
odessa_minden	3500	595	646	589	656	563	637	579	660
odessa_minden	4000	612	662	610	672	576	648	593	671
odessa_minden	4500	618	678	617	683	586	658	602	679
odessa_minden	5000	630	691	624	700	597	670	608	690
minden_gibbon	500	710	--	757	561	--	603	746	--
minden_gibbon	750	792	--	842	612	--	659	828	--
minden_gibbon	1000	855	--	878	644	--	675	867	--
minden_gibbon	1200	879	--	884	665	--	675	889	--
minden_gibbon	1500	914	--	911	703	--	683	914	--
minden_gibbon	2000	935	--	929	745	--	566	929	--
minden_gibbon	2500	946	--	943	772	--	722	941	--
minden_gibbon	3000	963	--	955	781	--	741	948	--
minden_gibbon	3500	967	--	969	818	--	750	954	--
minden_gibbon	4000	979	--	986	810	--	761	965	--
minden_gibbon	4500	985	--	991	653	--	767	970	--
minden_gibbon	5000	991	--	999	654	--	785	981	--
gibbon_woodriver	500	618	515	711	573	719	584	758	617
gibbon_woodriver	750	683	570	772	624	776	646	818	664
gibbon_woodriver	1000	743	609	804	642	803	668	857	682
gibbon_woodriver	1200	776	623	813	641	814	670	868	692
gibbon_woodriver	1500	836	649	851	661	842	682	891	708
gibbon_woodriver	2000	877	674	872	676	860	696	903	717
gibbon_woodriver	2500	892	695	888	692	871	707	913	725
gibbon_woodriver	3000	904	709	901	708	892	719	921	734
gibbon_woodriver	3500	923	722	922	722	912	727	936	740
gibbon_woodriver	4000	931	731	937	734	919	734	936	750
gibbon_woodriver	4500	945	739	948	744	927	740	946	755
gibbon_woodriver	5000	966	750	970	756	935	749	962	762

Table D7c. Mean modeled width (ft) for managed vs. unmanaged areas for Wood River to Grand Island and Grand Island to Chapman.

Reach	Q (cfs)	2017		2018		2019		2020	
		managed	un-managed	managed	un-managed	managed	un-managed	managed	un-managed
woodriver_gi	500	734	415	866	459	845	457	886	465
woodriver_gi	750	820	470	933	525	913	522	950	514
woodriver_gi	1000	903	513	972	554	966	547	994	546
woodriver_gi	1200	944	537	972	554	982	565	1013	563
woodriver_gi	1500	989	566	1008	587	997	580	1034	582
woodriver_gi	2000	1057	599	1029	600	1015	595	1036	600
woodriver_gi	2500	1070	622	1056	615	1033	606	1056	610
woodriver_gi	3000	1081	636	1067	631	1042	613	1066	620
woodriver_gi	3500	1098	646	1087	643	1056	619	1074	628
woodriver_gi	4000	1110	654	1107	652	1075	628	1085	636
woodriver_gi	4500	1118	660	1114	658	1081	633	1090	642
woodriver_gi	5000	1129	668	1125	665	1087	640	1096	648
gi_chapman	500	--	878	--	922	--	897	--	941
gi_chapman	750	--	956	--	963	--	967	--	994
gi_chapman	1000	--	996	--	986	--	1007	--	1026
gi_chapman	1200	--	1014	--	998	--	1024	--	1043
gi_chapman	1500	--	1026	--	998	--	1037	--	1053
gi_chapman	2000	--	1044	--	1023	--	1047	--	1075
gi_chapman	2500	--	1063	--	1051	--	1063	--	1093
gi_chapman	3000	--	1083	--	1083	--	1084	--	1111
gi_chapman	3500	--	1094	--	1106	--	1095	--	1121
gi_chapman	4000	--	1107	--	1128	--	1108	--	1130
gi_chapman	4500	--	1117	--	1147	--	1118	--	1138
gi_chapman	5000	--	1129	--	1169	--	1131	--	1156

Table D8a. Mean modeled depth (ft) for managed vs. unmanaged areas for the main channel of All Reaches (Overton to Chapman), Overton to Elm Creek, and Elm Creek to Odessa.

Reach	Q (cfs)	2017		2018		2019		2020	
		managed	un-managed	managed	un-managed	managed	un-managed	managed	un-managed
All_Reaches	500	0.5	0.5	0.4	0.5	0.5	0.6	0.4	0.5
All_Reaches	750	0.6	0.6	0.5	0.6	0.6	0.6	0.5	0.6
All_Reaches	1000	0.7	0.7	0.6	0.7	0.7	0.7	0.6	0.7
All_Reaches	1200	0.8	0.8	0.7	0.8	0.8	0.8	0.7	0.7
All_Reaches	1500	0.8	0.9	0.8	0.9	0.8	0.9	0.8	0.8
All_Reaches	2000	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.0
All_Reaches	2500	1.1	1.1	1.1	1.1	1.1	1.2	1.1	1.1
All_Reaches	3000	1.2	1.3	1.2	1.3	1.2	1.3	1.2	1.2
All_Reaches	3500	1.3	1.4	1.3	1.4	1.3	1.4	1.3	1.3
All_Reaches	4000	1.4	1.5	1.4	1.5	1.4	1.5	1.4	1.4
All_Reaches	4500	1.5	1.6	1.5	1.5	1.5	1.6	1.5	1.5
All_Reaches	5000	1.6	1.7	1.6	1.6	1.6	1.7	1.6	1.6
overton_elmcreek	500	0.6	0.7	0.4	0.6	0.6	0.7	0.6	0.6
overton_elmcreek	750	0.7	0.9	0.6	0.7	0.7	0.8	0.7	0.8
overton_elmcreek	1000	0.8	1.0	0.7	0.9	0.7	0.9	0.8	0.9
overton_elmcreek	1200	0.9	1.1	0.8	1.0	0.8	1.0	0.9	1.0
overton_elmcreek	1500	1.0	1.2	0.9	1.1	0.9	1.1	1.0	1.1
overton_elmcreek	2000	1.2	1.4	1.1	1.3	1.1	1.3	1.2	1.3
overton_elmcreek	2500	1.3	1.6	1.2	1.5	1.3	1.5	1.3	1.5
overton_elmcreek	3000	1.5	1.7	1.4	1.7	1.4	1.6	1.5	1.6
overton_elmcreek	3500	1.6	1.9	1.5	1.8	1.5	1.8	1.6	1.8
overton_elmcreek	4000	1.7	2.0	1.7	2.0	1.7	1.9	1.7	1.9
overton_elmcreek	4500	1.8	2.1	1.8	2.1	1.8	2.0	1.8	2.0
overton_elmcreek	5000	2.0	2.2	1.9	2.2	1.9	2.1	1.9	2.1
elmcreek_odessa	500	0.6	0.6	0.6	0.6	0.6	0.7	0.5	0.6
elmcreek_odessa	750	0.7	0.8	0.7	0.7	0.7	0.8	0.7	0.7
elmcreek_odessa	1000	0.8	0.9	0.8	0.9	0.8	0.9	0.8	0.8
elmcreek_odessa	1200	0.9	1.0	0.9	1.0	0.9	1.0	0.8	0.9
elmcreek_odessa	1500	1.0	1.1	1.0	1.1	1.0	1.1	1.0	1.1
elmcreek_odessa	2000	1.2	1.3	1.2	1.3	1.2	1.3	1.1	1.2
elmcreek_odessa	2500	1.3	1.4	1.3	1.4	1.3	1.4	1.3	1.4
elmcreek_odessa	3000	1.5	1.5	1.5	1.5	1.5	1.6	1.4	1.5
elmcreek_odessa	3500	1.6	1.7	1.6	1.7	1.6	1.7	1.6	1.7
elmcreek_odessa	4000	1.7	1.8	1.8	1.8	1.7	1.8	1.7	1.8
elmcreek_odessa	4500	1.8	1.9	1.9	1.9	1.9	1.9	1.8	1.9
elmcreek_odessa	5000	2.0	2.0	2.0	2.0	2.0	2.0	1.9	2.0

Table D8b. Mean modeled depth (ft) for managed vs. unmanaged areas for the main channel of Odessa to Minden, Minden to Gibbon, and Gibbon to Wood River.

Reach	Q (cfs)	2017		2018		2019		2020	
		managed	un-managed	managed	un-managed	managed	un-managed	managed	un-managed
odessa_minden	500	0.5	0.6	0.5	0.6	0.6	0.7	0.5	0.5
odessa_minden	750	0.6	0.7	0.6	0.7	0.7	0.7	0.6	0.7
odessa_minden	1000	0.7	0.8	0.7	0.8	0.8	0.8	0.6	0.8
odessa_minden	1200	0.8	0.9	0.8	0.9	0.9	0.9	0.7	0.9
odessa_minden	1500	0.9	1.0	0.9	1.0	0.9	1.0	0.8	1.0
odessa_minden	2000	1.0	1.1	1.0	1.2	1.1	1.2	1.0	1.1
odessa_minden	2500	1.2	1.3	1.2	1.3	1.2	1.3	1.1	1.3
odessa_minden	3000	1.3	1.4	1.3	1.4	1.4	1.5	1.2	1.4
odessa_minden	3500	1.4	1.5	1.4	1.5	1.5	1.6	1.4	1.5
odessa_minden	4000	1.5	1.6	1.5	1.6	1.6	1.7	1.5	1.6
odessa_minden	4500	1.6	1.7	1.6	1.7	1.7	1.8	1.6	1.7
odessa_minden	5000	1.7	1.8	1.7	1.8	1.7	1.9	1.7	1.8
minden_gibbon	500	0.4	--	0.3	--	0.5	--	0.3	--
minden_gibbon	750	0.5	--	0.4	--	0.5	--	0.4	--
minden_gibbon	1000	0.6	--	0.5	--	0.6	--	0.4	--
minden_gibbon	1200	0.6	--	0.6	--	0.6	--	0.5	--
minden_gibbon	1500	0.7	--	0.6	--	0.7	--	0.6	--
minden_gibbon	2000	0.8	--	0.8	--	0.8	--	0.7	--
minden_gibbon	2500	0.9	--	0.9	--	0.9	--	0.8	--
minden_gibbon	3000	1.0	--	0.9	--	1.0	--	0.9	--
minden_gibbon	3500	1.1	--	1.0	--	1.1	--	1.0	--
minden_gibbon	4000	1.1	--	1.1	--	1.2	--	1.0	--
minden_gibbon	4500	1.2	--	1.2	--	1.2	--	1.1	--
minden_gibbon	5000	1.3	--	1.2	--	1.3	--	1.2	--
gibbon_woodriver	500	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.5
gibbon_woodriver	750	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
gibbon_woodriver	1000	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.7
gibbon_woodriver	1200	0.7	0.8	0.7	0.8	0.8	0.8	0.7	0.7
gibbon_woodriver	1500	0.8	0.9	0.8	0.9	0.8	0.9	0.8	0.8
gibbon_woodriver	2000	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.0
gibbon_woodriver	2500	1.1	1.2	1.1	1.2	1.1	1.2	1.1	1.1
gibbon_woodriver	3000	1.2	1.3	1.2	1.3	1.2	1.3	1.2	1.2
gibbon_woodriver	3500	1.3	1.4	1.3	1.4	1.3	1.4	1.3	1.4
gibbon_woodriver	4000	1.4	1.5	1.4	1.5	1.4	1.5	1.4	1.5
gibbon_woodriver	4500	1.5	1.6	1.5	1.6	1.5	1.6	1.5	1.6
gibbon_woodriver	5000	1.6	1.7	1.6	1.7	1.6	1.7	1.6	1.7

Table D8c. Mean modeled depth (ft) for managed vs. unmanaged areas for Wood River to Grand Island and Grand Island to Chapman.

Reach	**Q (cfs)**	**2017**		**2018**		**2019**		**2020**	
		managed	un-managed	managed	un-managed	managed	un-managed	managed	un-managed
woodriver_gi	500	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3
woodriver_gi	750	0.5	0.5	0.5	0.4	0.5	0.5	0.5	0.4
woodriver_gi	1000	0.6	0.5	0.5	0.5	0.6	0.6	0.5	0.5
woodriver_gi	1200	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5
woodriver_gi	1500	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6
woodriver_gi	2000	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7
woodriver_gi	2500	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
woodriver_gi	3000	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
woodriver_gi	3500	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1
woodriver_gi	4000	1.1	1.2	1.1	1.2	1.2	1.2	1.1	1.1
woodriver_gi	4500	1.2	1.3	1.2	1.3	1.2	1.3	1.2	1.2
woodriver_gi	5000	1.3	1.4	1.3	1.3	1.3	1.4	1.3	1.3
gi_chapman	500	--	0.5	--	0.4	--	0.5	--	0.4
gi_chapman	750	--	0.6	--	0.6	--	0.6	--	0.5
gi_chapman	1000	--	0.7	--	0.7	--	0.7	--	0.6
gi_chapman	1200	--	0.7	--	0.7	--	0.7	--	0.7
gi_chapman	1500	--	0.8	--	0.8	--	0.8	--	0.8
gi_chapman	2000	--	1.0	--	1.0	--	1.0	--	0.9
gi_chapman	2500	--	1.1	--	1.1	--	1.1	--	1.1
gi_chapman	3000	--	1.2	--	1.2	--	1.2	--	1.2
gi_chapman	3500	--	1.3	--	1.3	--	1.3	--	1.3
gi_chapman	4000	--	1.4	--	1.4	--	1.4	--	1.4
gi_chapman	4500	--	1.5	--	1.5	--	1.5	--	1.5
gi_chapman	5000	--	1.6	--	1.5	--	1.6	--	1.6

Table D9a. Mean modeled percent area with depth < 1ft for managed vs. unmanaged areas for the main channel of All Reaches (Overton to Chapman), Overton to Elm Creek, and Elm Creek to Odessa.

Reach	Q (cfs)	2017		2018		2019		2020	
		managed	un-managed	managed	un-managed	managed	un-managed	managed	un-managed
All_Reaches	500	88	86	93	92	85	84	94	94
All_Reaches	750	82	81	89	87	81	80	90	88
All_Reaches	1000	76	75	83	81	78	76	84	82
All_Reaches	1200	71	70	78	76	74	72	79	77
All_Reaches	1500	65	64	71	68	69	66	71	69
All_Reaches	2000	56	54	58	53	59	57	59	55
All_Reaches	2500	47	45	45	41	50	47	48	43
All_Reaches	3000	39	37	36	31	40	38	39	33
All_Reaches	3500	33	31	29	25	32	31	31	26
All_Reaches	4000	28	26	24	21	26	25	25	20
All_Reaches	4500	24	22	20	19	21	20	20	17
All_Reaches	5000	20	19	17	17	17	16	17	14
overton_elmcreek	500	84	76	94	82	82	75	88	81
overton_elmcreek	750	73	63	87	73	79	69	79	68
overton_elmcreek	1000	65	52	80	63	75	63	70	59
overton_elmcreek	1200	58	45	73	55	71	58	61	51
overton_elmcreek	1500	50	37	63	46	65	51	51	42
overton_elmcreek	2000	39	27	47	30	53	39	37	30
overton_elmcreek	2500	31	21	33	19	40	28	25	20
overton_elmcreek	3000	24	17	23	14	27	19	19	15
overton_elmcreek	3500	19	15	17	12	19	14	14	12
overton_elmcreek	4000	16	13	14	12	14	11	12	11
overton_elmcreek	4500	14	13	12	12	12	12	11	12
overton_elmcreek	5000	11	13	11	12	10	12	10	12
elmcreek_odessa	500	83	82	86	85	81	78	89	89
elmcreek_odessa	750	74	70	78	75	76	73	80	77
elmcreek_odessa	1000	66	61	70	64	71	66	72	66
elmcreek_odessa	1200	60	54	63	56	66	61	65	57
elmcreek_odessa	1500	53	46	55	46	59	53	56	45
elmcreek_odessa	2000	43	34	39	30	46	40	42	30
elmcreek_odessa	2500	33	26	26	22	34	29	29	20
elmcreek_odessa	3000	24	21	17	17	22	19	21	15
elmcreek_odessa	3500	18	18	12	15	15	14	14	13
elmcreek_odessa	4000	15	17	9	15	9	12	10	12
elmcreek_odessa	4500	11	16	8	15	6	12	7	13
elmcreek_odessa	5000	8	15	7	14	5	12	6	12

Table D9b. Mean modeled percent area with depth < 1ft for managed vs. unmanaged areas for the main channel of Odessa to Minden, Minden to Gibbon, and Gibbon to Wood River.

Reach	Q (cfs)	2017		2018		2019		2020	
		managed	un-managed	managed	un-managed	managed	un-managed	managed	un-managed
odessa_minden	500	86	82	92	85	80	78	95	88
odessa_minden	750	79	74	86	78	76	74	89	80
odessa_minden	1000	72	67	78	70	71	69	82	71
odessa_minden	1200	66	61	71	63	67	64	75	64
odessa_minden	1500	60	54	61	54	61	57	66	55
odessa_minden	2000	49	44	46	41	50	47	52	42
odessa_minden	2500	41	36	35	32	40	37	40	33
odessa_minden	3000	34	30	27	26	31	30	31	26
odessa_minden	3500	29	27	23	23	24	24	24	21
odessa_minden	4000	26	24	21	21	19	19	20	18
odessa_minden	4500	22	21	19	18	16	16	17	16
odessa_minden	5000	19	19	17	17	14	14	15	14
minden_gibbon	500	95	--	99	--	91	--	99	--
minden_gibbon	750	92	--	97	--	89	--	99	--
minden_gibbon	1000	88	--	95	--	86	--	98	--
minden_gibbon	1200	85	--	93	--	84	--	96	--
minden_gibbon	1500	80	--	89	--	80	--	94	--
minden_gibbon	2000	71	--	79	--	74	--	86	--
minden_gibbon	2500	62	--	67	--	66	--	77	--
minden_gibbon	3000	53	--	55	--	58	--	66	--
minden_gibbon	3500	45	--	44	--	49	--	56	--
minden_gibbon	4000	38	--	35	--	40	--	46	--
minden_gibbon	4500	31	--	27	--	31	--	36	--
minden_gibbon	5000	26	--	22	--	24	--	28	--
gibbon_woodriver	500	86	82	92	85	80	78	95	88
gibbon_woodriver	750	79	74	86	78	76	74	89	80
gibbon_woodriver	1000	72	67	78	70	71	69	82	71
gibbon_woodriver	1200	66	61	71	63	67	64	75	64
gibbon_woodriver	1500	60	54	61	54	61	57	66	55
gibbon_woodriver	2000	49	44	46	41	50	47	52	42
gibbon_woodriver	2500	41	36	35	32	40	37	40	33
gibbon_woodriver	3000	34	30	27	26	31	30	31	26
gibbon_woodriver	3500	29	27	23	23	24	24	24	21
gibbon_woodriver	4000	26	24	21	21	19	19	20	18
gibbon_woodriver	4500	22	21	19	18	16	16	17	16
gibbon_woodriver	5000	19	19	17	17	14	14	15	14

Table D9c. Mean modeled percent area with depth < 1ft for managed vs. unmanaged areas for Wood River to Grand Island and Grand Island to Chapman.

Reach	Q (cfs)	2017		2018		2019		2020	
		managed	un-managed	managed	un-managed	managed	un-managed	managed	un-managed
woodriver_gi	500	88	86	93	92	86	83	95	95
woodriver_gi	750	82	80	89	87	82	79	90	90
woodriver_gi	1000	77	74	83	81	78	74	83	83
woodriver_gi	1200	72	68	78	76	74	70	77	77
woodriver_gi	1500	67	61	70	67	69	65	69	68
woodriver_gi	2000	57	50	56	50	60	55	56	53
woodriver_gi	2500	48	41	43	37	51	45	45	40
woodriver_gi	3000	41	34	34	28	42	36	35	30
woodriver_gi	3500	35	29	28	22	34	29	28	22
woodriver_gi	4000	30	25	23	18	27	22	22	17
woodriver_gi	4500	25	21	20	16	21	17	18	14
woodriver_gi	5000	22	19	18	15	17	13	15	11
gi_chapman	500	--	86	--	94	--	86	--	97
gi_chapman	750	--	82	--	89	--	83	--	93
gi_chapman	1000	--	78	--	84	--	78	--	87
gi_chapman	1200	--	74	--	80	--	74	--	82
gi_chapman	1500	--	69	--	71	--	69	--	72
gi_chapman	2000	--	58	--	54	--	58	--	56
gi_chapman	2500	--	48	--	39	--	48	--	42
gi_chapman	3000	--	39	--	29	--	39	--	31
gi_chapman	3500	--	30	--	22	--	30	--	22
gi_chapman	4000	--	23	--	19	--	23	--	17
gi_chapman	4500	--	17	--	17	--	17	--	13
gi_chapman	5000	--	13	--	17	--	13	--	12

Table D10. Modeled percent flow in the main channel at 2000 cfs.

Reach	2017	2018	2019	2020
All_Reaches	71	70	69	68
overton_elmcreek	79	69	68	75
elmcreek_odessa	100	100	100	100
odessa_minden	55	56	56	53
minden_gibbon	62	58	62	47
gibbon_woodriver	83	81	80	79
woodriver_gi	54	54	53	52
gi_chapman	100	100	100	100

Appendix E. Full Land Cover Classification Results

Table E1. Parameters used in E-Cognition classification.

Year	NDVI	NDWI
2017	0.09	0
2018	0.05	0
2019	0.06	0
2020	0.03	0.05

Table E2. Confusion matrix comparing 2018 E-Cognition classification results to field-sampled data.

Class		Field Observations					
		Water/Sand	**Veg <2ft**	**Veg 2-6ft**	**Veg 6-15ft**	**Veg >15ft**	**Total**
E-Cognition Classification	**Water/Sand**	130	0	0	0	0	130
	Veg <2ft	0	167	35	4	1	207
	Veg 2-6ft	0	1	57	15	1	74
	Veg 6-15ft	0	0	0	13	4	17
	Veg >15ft	0	0	0	0	12	12
	Total	130	168	92	32	18	440

Table E3. Confusion matrix comparing 2019 E-Cognition classification results to field-sampled data.

Class		Field Observations					
		Water/Sand	**Veg <2ft**	**Veg 2-6ft**	**Veg 6-15ft**	**Veg >15ft**	**Total**
E-Cognition Classification	**Water/Sand**	22	0	0	0	0	22
	Veg <2ft	0	97	26	1	0	124
	Veg 2-6ft	0	1	9	0	0	10
	Veg 6-15ft	0	0	1	0	0	1
	Veg >15ft	0	0	0	0	0	0
	Total	22	98	36	1	0	157

Table E4. Confusion matrix comparing 2020 E-Cognition classification results to field-sampled data.

Class		Field Observations					
		Water/Sand	Veg <2ft	Veg 2-6ft	Veg 6-15ft	Veg >15ft	Total
E-Cognition Classification	Water/Sand	58	0	0	0	0	58
	Veg <2ft	0	26	1	0	0	27
	Veg 2-6ft	0	2	32	3	0	37
	Veg 6-15ft	0	0	0	1	0	1
	Veg >15ft	0	0	0	1	0	1
	Total	58	28	33	5	0	124

Table E5a. Classified area of water and sand (summed together) and vegetation less than 2 ft in height (Veg <2ft) for all channels.

Reach	Water/Sand (ac)				Veg <2ft (ac)			
	2017	2018	2019	2020	2017	2018	2019	2020
All_Reaches	7760	8846	10007	9022	3408	2626	2579	2084
N-lexington_overton	489	486	610	511	404	335	316	220
J2_overton	367	459	397	506	297	198	294	139
overton_elmcreek	680	855	913	834	492	295	354	266
elmcreek_odessa	543	711	701	679	237	72	135	90
odessa_minden	1317	1582	1796	1682	843	636	686	503
minden_gibbon	655	763	837	734	259	177	164	174
gibbon_woodriver	1365	1511	1755	1622	558	506	490	330
woodriver_gi	1974	2135	2544	2153	670	599	454	477
gi_chapman	1195	1290	1461	1317	349	340	296	244

Table E5b. Classified area of vegetation from 2-6 ft in height (Veg 2-6ft) and vegetation 6-15 ft in height (Veg 6-15ft) for all channels.

Reach	Veg 2-6ft (ac)				Veg 6-15ft (ac)			
	2017	2018	2019	2020	2017	2018	2019	2020
All_Reaches	2037	1871	831	2281	2281	533	402	348
N-lexington_overton	107	189	76	261	261	35	28	38
J2_overton	49	60	25	72	72	16	12	13
overton_elmcreek	123	170	55	218	218	57	38	37
elmcreek_odessa	87	89	39	106	106	19	14	12
odessa_minden	447	424	177	464	464	123	99	87
minden_gibbon	167	152	93	182	182	36	28	27
gibbon_woodriver	466	407	188	481	481	109	79	71
woodriver_gi	461	406	168	523	523	109	83	66
gi_chapman	286	221	111	308	308	80	60	47

Table E5c. Classified area of vegetation greater than 15 ft in height (Veg>15ft) for all channels.

Reach	Veg >15ft (ac)			
	2017	2018	2019	2020
All_Reaches	563	527	507	540
N-lexington_overton	65	62	61	64
J2_overton	13	13	12	12
overton_elmcreek	76	71	71	74
elmcreek_odessa	28	27	26	27
odessa_minden	186	175	171	181
minden_gibbon	28	26	25	28
gibbon_woodriver	96	91	90	93
woodriver_gi	98	89	78	90
gi_chapman	51	48	46	48

Table E6a. Classified percent area of water and sand (summed together) and vegetation less than 2 ft in height (Veg <2ft) for all channels.

Reach	Water/Sand (%)				Veg <2ft (%)			
	2017	2018	2019	2020	2017	2018	2019	2020
All_Reaches	54	62	70	63	24	18	18	15
N-lexington_overton	44	44	55	46	37	30	29	20
J2_overton	50	62	54	68	40	27	40	19
overton_elmcreek	48	60	64	58	34	21	25	19
elmcreek_odessa	59	78	77	74	26	8	15	10
odessa_minden	45	54	62	58	29	22	24	17
minden_gibbon	57	67	73	64	23	15	14	15
gibbon_woodriver	53	58	68	63	22	20	19	13
woodriver_gi	60	64	77	65	20	18	14	14
gi_chapman	61	66	75	67	18	17	15	12

Table E6b. Classified percent area of vegetation from 2-6 ft in height (Veg 2-6ft) and vegetation 6-15 ft in height (Veg 6-15ft) for all channels.

Reach	Veg 2-6ft (%)				Veg 6-15ft (%)			
	2017	2018	2019	2020	2017	2018	2019	2020
All_Reaches	14	13	6	16	4	3	2	2
N-lexington_overton	10	17	7	24	3	3	3	4
J2_overton	7	8	3	10	2	2	2	2
overton_elmcreek	9	12	4	15	4	3	3	2
elmcreek_odessa	10	10	4	12	2	2	1	1
odessa_minden	15	15	6	16	4	3	3	3
minden_gibbon	15	13	8	16	3	2	2	3
gibbon_woodriver	18	16	7	19	4	3	3	3
woodriver_gi	14	12	5	16	3	3	2	2
gi_chapman	15	11	6	16	4	3	2	2

Table E6c. Classified percent area of vegetation greater than 15 ft in height (Veg>15ft) for all channels.

Reach	Veg >15ft (%)			
	2017	2018	2019	2020
All_Reaches	4	4	4	4
N-lexington_overton	6	6	6	6
J2_overton	2	2	2	2
overton_elmcreek	5	5	5	5
elmcreek_odessa	3	3	3	3
odessa_minden	6	6	6	6
minden_gibbon	2	2	2	2
gibbon_woodriver	4	3	3	4
woodriver_gi	3	3	2	3
gi_chapman	3	2	2	2

Table E7. Classified total unobstructed area (ac) for all channels.

Reach	2017	2018	2019	2020
All_Reaches	11168	11472	12586	11106
N-lexington_overton	893	821	926	731
J2_overton	664	657	691	645
overton_elmcreek	1172	1150	1267	1100
elmcreek_odessa	780	783	836	770
odessa_minden	2160	2218	2482	2185
minden_gibbon	914	939	1001	907
gibbon_woodriver	1923	2017	2245	1952
woodriver_gi	2644	2734	2999	2631
gi_chapman	1544	1631	1757	1561

Table E8. Classified total percent unobstructed area for all channels.

Reach	2017	2018	2019	2020
All_Reaches	78	80	88	78
N-lexington_overton	81	75	84	66
J2_overton	90	89	93	87
overton_elmcreek	82	80	89	77
elmcreek_odessa	85	86	91	84
odessa_minden	74	76	85	75
minden_gibbon	80	82	87	79
gibbon_woodriver	74	78	87	75
woodriver_gi	80	83	91	79
gi_chapman	79	83	90	80

Table E9a. Classified area of water and sand (summed together) and vegetation less than 2 ft in height (Veg <2ft) for the main channel.

Reach	Water/Sand (ac)				Veg <2ft (ac)			
	2017	2018	2019	2020	2017	2018	2019	2020
All_Reaches	6231	7060	7784	7122	2373	1768	1779	1426
overton_elmcreek	506	623	641	604	237	108	157	107
elmcreek_odessa	540	703	696	675	226	66	125	83
odessa_minden	980	1153	1282	1210	494	361	385	278
minden_gibbon	494	586	631	546	209	138	117	146
gibbon_woodriver	1176	1290	1450	1377	414	367	377	240
woodriver_gi	1314	1414	1623	1393	444	388	324	328
gi_chapman	1195	1290	1460	1317	348	339	295	243

Table E9b. Classified area of vegetation from 2-6 ft in height (Veg 2-6ft) and vegetation 6-15 ft in height (Veg 6-15ft) for the main channel.

Reach	Veg 2-6ft (ac)				Veg 6-15ft (ac)			
	2017	2018	2019	2020	2017	2018	2019	2020
All_Reaches	1441	1300	608	1617	321	232	200	192
overton_elmcreek	71	97	33	118	27	15	14	14
elmcreek_odessa	83	85	37	100	17	13	11	10
odessa_minden	270	252	107	283	58	44	38	37
minden_gibbon	122	106	80	136	18	13	15	15
gibbon_woodriver	340	294	130	340	65	48	43	41
woodriver_gi	270	245	110	334	55	40	32	32
gi_chapman	284	220	110	307	79	60	47	43

Table E9c. Classified area of vegetation greater than 15 ft in height (Veg>15ft) for the main channel.

Reach	Veg >15ft (ac)			
	2017	2018	2019	2020
All_Reaches	275	255	245	258
overton_elmcreek	28	25	24	26
elmcreek_odessa	22	21	21	21
odessa_minden	86	80	77	81
minden_gibbon	4	3	3	4
gibbon_woodriver	54	50	49	51
woodriver_gi	30	27	25	28
gi_chapman	51	48	46	48

Table E10a. Classified percent area of water and sand (summed together) and vegetation less than 2 ft in height (Veg <2ft) for the main channel.

Reach	Water/Sand (%)				Veg <2ft (%)			
	2017	2018	2019	2020	2017	2018	2019	2020
All_Reaches	59	67	73	67	22	17	17	13
overton_elmcreek	58	72	74	70	27	12	18	12
elmcreek_odessa	61	79	78	76	25	7	14	9
odessa_minden	52	61	68	64	26	19	20	15
minden_gibbon	58	69	75	64	25	16	14	17
gibbon_woodriver	57	63	71	67	20	18	18	12
woodriver_gi	62	67	77	66	21	18	15	16
gi_chapman	61	66	75	67	18	17	15	12

Table E10b. Classified percent area of vegetation from 2-6 ft in height (Veg 2-6ft) and vegetation 6-15 ft in height (Veg 6-15ft) for the main channel.

Reach	Veg 2-6ft (%)				Veg 6-15ft (%)			
	2017	2018	2019	2020	2017	2018	2019	2020
All_Reaches	14	12	6	15	3	2	2	2
overton_elmcreek	8	11	4	14	3	2	2	2
elmcreek_odessa	9	10	4	11	2	1	1	1
odessa_minden	14	13	6	15	3	2	2	2
minden_gibbon	14	13	9	16	2	2	2	2
gibbon_woodriver	17	14	6	17	3	2	2	2
woodriver_gi	13	12	5	16	3	2	2	2
gi_chapman	15	11	6	16	4	3	2	2

Table E10c. Classified percent area of vegetation greater than 15 ft in height (Veg>15ft) for the main channel.

Reach	Veg >15ft (%)			
	2017	2018	2019	2020
All_Reaches	3	2	2	2
overton_elmcreek	3	3	3	3
elmcreek_odessa	2	2	2	2
odessa_minden	5	4	4	4
minden_gibbon	0	0	0	0
gibbon_woodriver	3	2	2	3
woodriver_gi	1	1	1	1
gi_chapman	3	2	2	2

Table E11. Classified total unobstructed area (ac) for the main channel.

Reach	2017	2018	2019	2020
All_Reaches	8604	8828	9563	8548
overton_elmcreek	743	732	798	711
elmcreek_odessa	767	769	820	758
odessa_minden	1474	1514	1667	1488
minden_gibbon	703	724	748	692
gibbon_woodriver	1590	1657	1827	1617
woodriver_gi	1758	1802	1947	1720
gi_chapman	1543	1629	1755	1560

Table E12. Classified total percent unobstructed area for the main channel.

Reach	2017	2018	2019	2020
All_Reaches	81	83	90	81
overton_elmcreek	85	84	92	82
elmcreek_odessa	86	87	92	85
odessa_minden	78	80	88	79
minden_gibbon	83	86	88	82
gibbon_woodriver	78	81	89	79
woodriver_gi	83	85	92	81
gi_chapman	79	83	90	80

Table E13a. Classified percent area of water and sand (summed together) for managed channel areas and unmanaged areas of the main channel.

Reach	2017		2018		2019		2020	
	managed	un-managed	managed	un-managed	managed	un-managed	managed	un-managed
All_Reaches	58	58	70	64	75	72	70	65
overton_elmcreek	57	50	77	56	78	62	73	57
elmcreek_odessa	66	54	89	66	86	67	84	65
odessa_minden	49	54	60	62	66	69	63	65
minden_gibbon	58	--	70	--	75	--	65	--
gibbon_woodriver	57	57	61	64	68	72	71	66
woodriver_gi	66	61	74	65	84	75	74	64
gi_chapman	--	61	--	66	--	75	--	67

Table E13b. Classified percent area of vegetation less than 2 ft in height (Veg <2ft) for managed channel areas and unmanaged areas of the main channel.

Reach	2017		2018		2019		2020	
	managed	un-managed	managed	un-managed	managed	un-managed	managed	un-managed
All_Reaches	26	20	16	17	17	17	15	13
overton_elmcreek	34	22	13	13	18	21	14	9
elmcreek_odessa	26	25	5	11	11	19	8	11
odessa_minden	28	24	22	17	23	19	17	13
minden_gibbon	25	--	16	--	14	--	17	--
gibbon_woodriver	21	20	19	18	20	18	12	12
woodriver_gi	26	20	18	19	11	16	17	15
gi_chapman	--	18	--	17	--	15	--	12

Table E13c. Classified percent area of vegetation 2-6 ft in height (Veg 2-6ft) for managed channel areas and unmanaged areas of the main channel.

Reach	2017		2018		2019		2020	
	managed	un-managed	managed	un-managed	managed	un-managed	managed	un-managed
All_Reaches	12	15	11	13	6	6	12	17
overton_elmcreek	6	14	8	20	3	7	11	23
elmcreek_odessa	7	13	6	15	2	7	7	17
odessa_minden	16	13	14	13	7	5	15	15
minden_gibbon	14	--	12	--	10	--	16	--
gibbon_woodriver	15	17	14	14	7	6	13	18
woodriver_gi	6	14	6	13	4	6	7	18
gi_chapman	--	15	--	11	--	6	--	16

Table E13d. Classified percent area of vegetation 6-15 ft in height (Veg 6-15ft) for managed channel areas and unmanaged areas of the main channel.

Reach	2017		2018		2019		2020	
	managed	un-managed	managed	un-managed	managed	un-managed	managed	un-managed
All_Reaches	14	18	12	16	7	8	14	19
overton_elmcreek	7	21	8	24	3	11	12	27
elmcreek_odessa	8	17	6	18	2	10	7	20
odessa_minden	19	16	15	16	8	7	17	17
minden_gibbon	16	--	14	--	11	--	18	--
gibbon_woodriver	19	20	17	17	9	8	14	20
woodriver_gi	8	17	7	15	4	7	8	20
gi_chapman	--	4	--	3	--	2	--	2

Table E13e. Classified percent area of vegetation greater than 15 ft in height (Veg >15ft) for managed channel areas and unmanaged areas of the main channel.

Reach	2017		2018		2019		2020	
	managed	un-managed	managed	un-managed	managed	un-managed	managed	un-managed
All_Reaches	2	3	1	3	1	3	1	3
overton_elmcreek	1	7	1	7	1	6	1	7
elmcreek_odessa	1	5	1	5	1	5	1	5
odessa_minden	3	6	3	5	3	5	3	5
minden_gibbon	0	--	0	--	0	--	0	--
gibbon_woodriver	3	2	3	2	3	2	3	2
woodriver_gi	1	2	1	1	0	1	1	1
gi_chapman	--	3	--	2	--	2	--	2

Table E14. Mean MUCW and TUCW values, as measured in the field, with visual remote sensing (RS – visual), and object-based classification (RS—object-based).

Year	Mean MUCW- All Channels			Mean TUCW- Main Channel		
	Field	RS – visual	RS – object-based	Field	RS – visual	RS – object-based
2007	--	303	--	--	474	--
2008	--	447	--	--	599	--
2009	597	377	--	411	529	--
2010	699	412	--	540	551	--
2011	755	482	--	697	686	--
2012	716	457	--	476	587	--
2013	497	486	--	293	606	--
2014	608	435	--	604	592	--
2015	644	628	--	792	824	--
2016	610	644	--	843	814	--
2017	--	630	588	--	804	771
2018	--	608	601	--	790	780
2019	--	644	682	--	822	781
2020	--	635	625	--	815	774

Table E15. Classified percent unobstructed area for managed channel areas and unmanaged areas of the main channel.

Reach	2017		2018		2019		2020	
	managed	un-managed	managed	un-managed	managed	un-managed	managed	un-managed
All_Reaches	84	79	86	81	91	89	85	78
overton_elmcreek	91	72	90	69	95	83	87	67
elmcreek_odessa	92	78	93	77	97	86	92	76
odessa_minden	78	78	82	79	89	88	80	78
minden_gibbon	83	--	86	--	88	--	82	--
gibbon_woodriver	78	77	80	81	88	90	83	78
woodriver_gi	92	81	92	84	95	91	92	79
gi_chapman	--	79	--	83	--	90	--	80

Table E16. Mean and standard deviation of MUCW for all channels. Note: this is the standard spatial scale of MUCW.

Reach	MUCW Mean (ft)				MUCW Standard Deviation (ft)			
	2017	2018	2019	2020	2017	2018	2019	2020
All_Reaches	588	601	682	625	244	253	262	272
N-lexington_overton	352	290	347	248	146	126	129	95
J2_overton	472	472	529	458	180	182	195	213
overton_elmcreek	508	514	563	488	206	211	225	171
elmcreek_odessa	713	742	797	748	215	236	225	219
odessa_minden	438	464	547	476	144	154	191	154
minden_gibbon	896	876	888	913	184	224	181	244
gibbon_woodriver	540	581	693	642	198	220	249	270
woodriver_gi	585	574	651	595	251	257	256	288
gi_chapman	689	704	816	750	274	287	314	290

Table E17. Mean and standard deviation of MUCW for the main channel. Note: this is the not standard spatial scale of MUCW.

Reach	MUCW Mean (ft)				MUCW Standard Deviation (ft)			
	2017	2018	2019	2020	2017	2018	2019	2020
All_Reaches	584	594	675	618	247	256	264	276
overton_elmcreek	507	508	562	487	205	204	224	170
elmcreek_odessa	713	739	795	748	215	231	222	219
odessa_minden	432	450	533	463	144	150	190	154
minden_gibbon	892	872	884	910	199	236	197	254
gibbon_woodriver	539	577	685	634	197	215	243	264
woodriver_gi	581	565	648	584	254	265	259	298
gi_chapman	689	704	816	750	274	287	314	290

Table E18. Mean and standard deviation of TUCW for all channels. Note: this is the not standard spatial scale of TUCW and is not referenced in the report text.

Reach	TUCW Mean (ft)				TUCW Standard Deviation (ft)			
	2017	2018	2019	2020	2017	2018	2019	2020
All_Reaches	963	976	988	974	209	211	205	210
N-lexington_overton	469	469	489	411	147	142	149	115
J2_overton	473	442	408	410	180	172	160	164
overton_elmcreek	828	839	847	814	163	161	150	148
elmcreek_odessa	841	845	864	850	140	143	138	146
odessa_minden	893	895	905	889	179	178	168	163
minden_gibbon	1195	1204	1207	1205	199	205	204	216
gibbon_woodriver	885	908	921	913	199	197	197	197
woodriver_gi	1051	1053	1070	1054	214	209	201	204
gi_chapman	1061	1117	1120	1116	154	148	151	152

Table E19. Mean and standard deviation of TUCW for the main channel. Note: this is the standard spatial scale of TUCW.

Reach	TUCW Mean (ft)				TUCW Standard Deviation (ft)			
	2017	2018	2019	2020	2017	2018	2019	2020
All_Reaches	771	780	781	774	256	265	264	266
overton_elmcreek	618	617	627	612	174	170	166	160
elmcreek_odessa	835	839	858	845	142	146	140	148
odessa_minden	640	644	641	634	225	224	211	204
minden_gibbon	941	944	947	945	173	178	123	135
gibbon_woodriver	760	771	785	779	214	216	215	219
woodriver_gi	712	706	696	690	281	278	282	287
gi_chapman	1061	1117	1120	1116	154	148	151	152

Table E20a. Mean main channel MUCW in managed areas and unmanaged areas.

Reach	2017		2018		2019		2020	
	managed	un-managed	managed	un-managed	managed	un-managed	managed	un-managed
All_Reaches	663	545	681	551	742	643	714	571
overton_elmcreek	606	331	622	330	670	386	568	337
elmcreek_odessa	837	523	870	538	912	616	864	571
odessa_minden	393	458	420	467	504	550	443	470
minden_gibbon	928	--	915	--	919	--	958	--
gibbon_woodriver	575	525	653	553	736	666	787	588
woodriver_gi	852	535	807	524	943	599	934	526
gi_chapman	--	274	--	287	--	314	--	290

Table E20b. Main channel MUCW standard deviation in managed areas and unmanaged areas.

Reach	2017		2018		2019		2020	
	managed	un-managed	managed	un-managed	managed	un-managed	managed	un-managed
All_Reaches	283	222	279	239	274	258	313	248
overton_elmcreek	224	94	217	90	246	113	177	97
elmcreek_odessa	158	139	163	165	156	186	155	180
odessa_minden	148	136	149	151	193	186	163	149
minden_gibbon	140	--	182	--	138	--	194	--
gibbon_woodriver	214	194	262	200	283	235	370	214
woodriver_gi	326	215	298	241	287	224	403	238
gi_chapman	--	689	--	704	--	816	--	750

Table E21a. Mean main channel TUCW in managed areas and unmanaged areas.

Reach	**2017**		**2018**		**2019**		**2020**	
	managed	un-managed	managed	un-managed	managed	un-managed	managed	un-managed
All_Reaches	805	756	806	768	768	772	798	764
overton_elmcreek	645	646	639	648	648	676	628	645
elmcreek_odessa	878	770	886	768	768	794	894	771
odessa_minden	594	652	594	659	659	659	580	652
minden_gibbon	969	--	974	--	617	--	961	--
gibbon_woodriver	917	712	925	724	724	741	928	733
woodriver_gi	1110	646	1095	641	641	632	1078	626
gi_chapman	--	1061	--	1117	--	1120	--	1116

Table E21b. Main channel TUCW standard deviation in managed areas and unmanaged areas.

Reach	**2017**		**2018**		**2019**		**2020**	
	managed	un-managed	managed	un-managed	managed	un-managed	managed	un-managed
All_Reaches	278	246	274	263	268	265	270	267
overton_elmcreek	204	136	195	138	186	127	181	120
elmcreek_odessa	131	137	129	145	132	131	137	135
odessa_minden	231	207	218	210	204	197	198	191
minden_gibbon	118	--	121	--	116	--	125	--
gibbon_woodriver	265	184	267	188	267	191	268	193
woodriver_gi	322	220	315	219	310	228	316	232
gi_chapman	--	154	--	148	--	151	--	152

Appendix F. Full Volume Change Results

Table F1. LiDAR accuracy (ft) in wet and dry, unvegetated areas, as measured by Quantum Spatial Inc (Quantum, 2017-2020) with ground control check points. Reported accuracy measurements represent 95% confidence.

Year	Dry	Wet
2016	0.14	0.26
2017	0.18	0.38
2018	0.10	0.35
2019	0.10	0.75
2020	0.18	0.26

Table F2. Net volume change from Overton to Grand Island in thousand cubic yards (KCY), as estimated with transects collected in the field (Field) and by differencing LiDAR-derived DEMs (RS – Remote Sensing). Error for field-based values was estimated with an asymmetrical confidence limit with upper and lower bounds, while remote sensing error was estimated with a symmetrical confidence interval (+/-). Due to fundamental differences between the field and remote sensing methods and error quantification, the values across methods are not comparable.

Year	Volume Change (KCY)		Error (KCY)		
	Field	RS	Field – Lower CI	Field – Upper CI	RS – CI (+/-)
2010-2009	-1010	--	1027	514	--
2011-2010	-986	--	1226	613	--
2012-2011	2841	--	1226	613	--
2013-2012	447	--	1158	579	--
2014-2013	32	--	1158	579	--
2015-2014	-1644	--	1158	579	--
2016-2015	338	--	1158	579	--
2017-2016	--	-841	--	--	1052
2018-2017	--	-270	--	--	729
2019-2018	--	-286	--	--	556
2020-2019	--	-38	--	--	364

Table F3. Estimated net channel bed volume change and estimated error, in thousand cubic yards (KCY) for all channels.

Reach	Net Bed Volume Change (KCY)				Error (KCY)			
	2017-2016	2018-2017	2019-2018	2020-2019	2017-2016	2018-2017	2019-2018	2020-2019
All_Reaches	-640	-333	627	74	1385	935	624	471
N-lexington_overton	69	3	76	-55	96	28	55	30
J2_overton	68	-5	33	14	76	57	47	35
overton_elmcreek	37	-97	-8	14	130	90	61	49
elmcreek_odessa	-5	-87	-31	43	110	81	44	40
odessa_minden	25	-33	185	-7	278	182	137	98
minden_gibbon	-62	-81	54	-28	118	84	45	34
gibbon_woodriver	-303	72	144	50	270	174	118	91
woodriver_gi	-151	11	158	15	297	201	137	105
gi_chapman	-182	-118	125	-12	188	130	85	56

Table F4. Estimated aggradation volume and error, in thousand cubic yards (KCY) for all channels.

Reach	Aggradation Volume (KCY)				Error (KCY)			
	2017-2016	2018-2017	2019-2018	2020-2019	2017-2016	2018-2017	2019-2018	2020-2019
All_Reaches	2930	1873	1883	1021	887	632	456	394
N-lexington_overton	276	62	181	47	78	21	44	17
J2_overton	260	159	125	85	59	41	33	28
overton_elmcreek	335	158	139	110	97	53	39	40
elmcreek_odessa	270	136	76	99	76	46	23	37
odessa_minden	698	397	455	209	201	128	103	79
minden_gibbon	236	135	138	60	75	47	34	24
gibbon_woodriver	466	408	371	208	143	136	89	81
woodriver_gi	592	425	427	222	189	148	102	87
gi_chapman	333	214	278	114	106	73	66	46

Table F5. Estimated bed degradation volume and error, in thousand cubic yards (KCY) for all channels.

Reach	Bed Degradation Volume (KCY)				Error (KCY)			
	2017-2016	2018-2017	2019-2018	2020-2019	2017-2016	2018-2017	2019-2018	2020-2019
All_Reaches	3570	2207	1256	947	1064	690	425	258
N-lexington_overton	207	59	105	102	56	18	33	25
J2_overton	192	164	92	71	48	40	33	22
overton_elmcreek	298	255	147	96	87	73	47	28
elmcreek_odessa	275	223	107	56	80	66	38	16
odessa_minden	673	430	270	216	193	128	90	58
minden_gibbon	297	216	84	88	91	70	28	25
gibbon_woodriver	768	336	227	157	228	108	78	42
woodriver_gi	743	415	269	207	229	136	91	58
gi_chapman	515	333	153	127	156	107	53	32

Table F6. Estimated lateral erosion volume and error, in thousand cubic yards (KCY) for all channels.

Reach	Lateral Erosion Volume (KCY)				Error (KCY)			
	2017-2016	2018-2017	2019-2018	2020-2019	2017-2016	2018-2017	2019-2018	2020-2019
All_Reaches	549	247	1104	387	57	28	235	48
N-lexington_overton	35	2	38	21	4	0	8	2
J2_overton	168	112	196	70	14	10	35	10
overton_elmcreek	49	35	114	30	4	4	23	4
elmcreek_odessa	50	19	89	40	5	2	18	5
odessa_minden	139	63	270	73	13	6	54	10
minden_gibbon	31	12	59	18	3	2	12	3
gibbon_woodriver	125	49	234	80	13	6	50	10
woodriver_gi	104	34	190	69	11	4	43	9
gi_chapman	50	36	149	78	6	4	35	8

Table F7. Estimated net channel bed volume change and estimated error, in thousand cubic yards (KCY) for the main channel.

Reach	Net Bed Volume Change (KCY)				Error (KCY)			
	2017-2016	2018-2017	2019-2018	2020-2019	2017-2016	2018-2017	2019-2018	2020-2019
All_Reaches	-550	-403	380	91	1096	765	452	372
overton_elmcreek	24	59	-6	14	96	150	37	35
elmcreek_odessa	-5	-62	-31	43	110	134	44	40
odessa_minden	1	-76	73	8	195	72	89	71
minden_gibbon	-49	-18	33	-31	88	139	29	24
gibbon_woodriver	-244	-102	85	53	226	66	88	76
woodriver_gi	-96	-87	101	18	198	81	82	72
gi_chapman	-182	-118	125	-12	188	130	85	56

Table F8. Estimated aggradation volume and error, in thousand cubic yards (KCY) for the main channel.

Reach	Aggradation Volume (KCY)				Error (KCY)			
	2017-2016	2018-2017	2019-2018	2020-2019	2017-2016	2018-2017	2019-2018	2020-2019
All_Reaches	2275	1463	1294	814	696	494	318	316
overton_elmcreek	242	352	80	81	70	117	22	30
elmcreek_odessa	270	270	76	99	76	89	23	37
odessa_minden	475	127	263	154	139	43	60	59
minden_gibbon	171	282	84	37	56	99	23	15
gibbon_woodriver	395	81	259	174	121	28	64	68
woodriver_gi	390	136	254	155	127	46	60	61
gi_chapman	333	214	278	114	106	73	66	46

Table F9. Estimated bed degradation volume and error, in thousand cubic yards (KCY) for the main channel.

Reach	Bed Degradation Volume (KCY)				Error (KCY)			
	2017-2016	2018-2017	2019-2018	2020-2019	2017-2016	2018-2017	2019-2018	2020-2019
All_Reaches	2825	1866	914	723	847	584	322	196
overton_elmcreek	218	292	86	67	66	94	30	19
elmcreek_odessa	275	332	107	56	80	100	38	16
odessa_minden	474	203	190	146	136	58	65	39
minden_gibbon	220	300	52	68	68	98	18	20
gibbon_woodriver	638	183	173	121	190	60	62	33
woodriver_gi	485	223	153	137	151	66	56	38
gi_chapman	515	333	153	127	156	107	53	32

Table F10. Estimated lateral erosion volume and error, in thousand cubic yards (KCY) for the main channel.

Reach	Lateral Erosion Volume (KCY)				Error (KCY)			
	2017-2016	2018-2017	2019-2018	2020-2019	2017-2016	2018-2017	2019-2018	2020-2019
All_Reaches	377	181	763	303	39	20	165	36
overton_elmcreek	36	40	69	23	3	4	14	3
elmcreek_odessa	50	40	89	40	5	4	18	5
odessa_minden	83	26	180	51	8	3	37	7
minden_gibbon	10	15	22	7	1	2	5	1
gibbon_woodriver	106	5	176	66	11	1	38	8
woodriver_gi	41	19	78	39	5	2	18	5
gi_chapman	50	36	149	78	6	4	35	8

Table F11a. Estimated areas of significant aggradation and bed degradation for all channels.

Reach	Aggradation Area (ac)				Bed Degradation Area (ac)			
	2017-2016	2018-2017	2019-2018	2020-2019	2017-2016	2018-2017	2019-2018	2020-2019
All_Reaches	1841	1219	1563	426	2198	1563	671	640
N-lexington_overton	170	48	172	35	126	36	67	65
J2_overton	125	82	76	25	98	91	41	34
overton_elmcreek	201	108	126	42	184	172	81	63
elmcreek_odessa	155	92	57	33	165	154	47	32
odessa_minden	437	274	363	81	426	313	149	146
minden_gibbon	157	87	116	25	189	166	48	65
gibbon_woodriver	291	243	310	87	465	229	125	105
woodriver_gi	384	280	363	102	460	305	142	144
gi_chapman	215	135	227	55	310	224	79	84

Table F11b. Estimated area of lateral erosion for all channels.

Reach	Lateral Erosion Area (ac)			
	2017-2016	2018-2017	2019-2018	2020-2019
All_Reaches	115	51	220	82
N-lexington_overton	8	1	7	4
J2_overton	27	23	33	15
overton_elmcreek	10	7	22	6
elmcreek_odessa	10	4	17	7
odessa_minden	28	13	51	15
minden_gibbon	7	3	12	4
gibbon_woodriver	25	10	46	17
woodriver_gi	23	8	40	16
gi_chapman	11	8	31	17

Table F12a. Estimated areas of significant aggradation and bed degradation for the main channel.

Reach	Aggradation Area (ac)				Bed Degradation Area (ac)			
	2017-2016	2018-2017	2019-2018	2020-2019	2017-2016	2018-2017	2019-2018	2020-2019
All_Reaches	1440	956	1074	326	1732	1326	468	492
overton_elmcreek	138	83	66	29	130	138	46	43
elmcreek_odessa	155	189	57	33	165	240	47	32
odessa_minden	303	59	211	56	296	144	99	98
minden_gibbon	123	205	82	16	146	198	31	53
gibbon_woodriver	244	194	213	69	379	227	89	81
woodriver_gi	262	135	219	69	307	224	78	101
gi_chapman	215	92	227	55	310	154	79	84

Table F12b. Estimated area of lateral erosion for the main channel.

Reach	Lateral Erosion Area (ac)			
	2017-2016	2018-2017	2019-2018	2020-2019
All_Reaches	78	38	153	64
overton_elmcreek	7	5	13	4
elmcreek_odessa	10	8	17	7
odessa_minden	17	1	34	11
minden_gibbon	2	8	5	2
gibbon_woodriver	21	3	35	14
woodriver_gi	9	8	17	9
gi_chapman	11	4	31	17

Appendix G. Full Suitable whooping crane Roosting Area Results

Table G1a. Suitable whooping crane roosting area (ac) for all channels of All Reaches (Overton to Chapman), the north Lexington to Overton channel, and the J2 Return to Overton.

Reach	Q (cfs)	2017	2018	2019	2020
All_Reaches	500	2068	2549	2983	2894
All_Reaches	750	2138	2612	3115	2965
All_Reaches	1000	2116	2542	3081	2889
All_Reaches	1200	2054	2446	2994	2769
All_Reaches	1500	1956	2267	2837	2548
All_Reaches	2000	1707	1854	2482	2099
All_Reaches	2500	1427	1414	2099	1647
All_Reaches	3000	1161	1029	1715	1255
All_Reaches	3500	932	747	1365	931
All_Reaches	4000	737	543	1060	686
All_Reaches	4500	574	407	801	503
All_Reaches	5000	440	317	607	372
N-lexington_overton	500	22	8	8	0
N-lexington_overton	750	22	8	9	0
N-lexington_overton	1000	22	8	9	0
N-lexington_overton	1200	22	8	9	0
N-lexington_overton	1500	22	8	10	0
N-lexington_overton	2000	22	8	8	0
N-lexington_overton	2500	21	8	10	0
N-lexington_overton	3000	23	6	6	0
N-lexington_overton	3500	21	5	7	0
N-lexington_overton	4000	21	7	9	0
N-lexington_overton	4500	21	9	11	0
N-lexington_overton	5000	22	10	12	0
J2_overton	500	62	36	46	38
J2_overton	750	61	35	44	39
J2_overton	1000	62	37	43	38
J2_overton	1200	56	35	39	36
J2_overton	1500	53	31	37	35
J2_overton	2000	53	24	32	30
J2_overton	2500	57	17	29	25
J2_overton	3000	58	15	28	24
J2_overton	3500	57	13	27	23
J2_overton	4000	55	12	25	22
J2_overton	4500	55	11	25	20
J2_overton	5000	53	11	26	19

Table G1b. Suitable whooping crane roosting area (ac) for all channels of Overton to Elm Creek, Elm Creek to Odessa, and Odessa to Minden.

Reach	Q (cfs)	2017	2018	2019	2020
overton_elmcreek	500	103	124	148	103
overton_elmcreek	750	101	134	152	101
overton_elmcreek	1000	96	133	149	96
overton_elmcreek	1200	91	128	145	89
overton_elmcreek	1500	85	119	136	78
overton_elmcreek	2000	72	96	116	60
overton_elmcreek	2500	59	72	94	41
overton_elmcreek	3000	47	53	68	29
overton_elmcreek	3500	37	39	49	20
overton_elmcreek	4000	29	28	35	14
overton_elmcreek	4500	23	22	28	9
overton_elmcreek	5000	17	18	24	7
elmcreek_odessa	500	276	331	368	371
elmcreek_odessa	750	271	320	367	360
elmcreek_odessa	1000	253	291	350	330
elmcreek_odessa	1200	235	264	330	299
elmcreek_odessa	1500	213	230	295	254
elmcreek_odessa	2000	171	163	230	185
elmcreek_odessa	2500	126	107	168	121
elmcreek_odessa	3000	90	68	107	82
elmcreek_odessa	3500	63	44	67	50
elmcreek_odessa	4000	45	30	38	31
elmcreek_odessa	4500	29	24	23	19
elmcreek_odessa	5000	17	19	18	12
odessa_minden	500	99	137	273	194
odessa_minden	750	100	136	282	195
odessa_minden	1000	97	128	275	186
odessa_minden	1200	91	118	262	177
odessa_minden	1500	86	105	245	161
odessa_minden	2000	74	80	206	127
odessa_minden	2500	61	59	167	99
odessa_minden	3000	50	45	133	75
odessa_minden	3500	41	35	105	58
odessa_minden	4000	33	29	84	46
odessa_minden	4500	27	25	67	36
odessa_minden	5000	21	22	56	28

Table G1c. Suitable whooping crane roosting area (ac) for all channels of Minden to Gibbon, Gibbon to Wood River, and Wood River to Grand Island.

Reach	Q (cfs)	2017	2018	2019	2020
minden_gibbon	500	687	683	667	684
minden_gibbon	750	749	787	753	776
minden_gibbon	1000	789	813	777	783
minden_gibbon	1200	761	775	769	789
minden_gibbon	1500	825	828	793	821
minden_gibbon	2000	840	835	809	837
minden_gibbon	2500	848	844	817	848
minden_gibbon	3000	865	859	829	854
minden_gibbon	3500	880	875	836	862
minden_gibbon	4000	903	904	853	878
minden_gibbon	4500	896	913	861	887
minden_gibbon	5000	900	914	873	898
gibbon_woodriver	500	1665	1742	1773	1888
gibbon_woodriver	750	1783	1925	1933	2030
gibbon_woodriver	1000	1892	1986	2007	2058
gibbon_woodriver	1200	1892	1964	2024	2077
gibbon_woodriver	1500	2002	2025	2059	2148
gibbon_woodriver	2000	2083	2065	2098	2167
gibbon_woodriver	2500	2137	2107	2143	2195
gibbon_woodriver	3000	2193	2170	2172	2226
gibbon_woodriver	3500	2260	2236	2216	2271
gibbon_woodriver	4000	2301	2281	2247	2297
gibbon_woodriver	4500	2307	2320	2273	2319
gibbon_woodriver	5000	2349	2366	2302	2344
woodriver_gi	500	1808	1899	1972	2016
woodriver_gi	750	1932	2065	2148	2140
woodriver_gi	1000	2060	2156	2241	2231
woodriver_gi	1200	2126	2199	2296	2284
woodriver_gi	1500	2217	2268	2304	2343
woodriver_gi	2000	2317	2312	2355	2382
woodriver_gi	2500	2395	2366	2400	2432
woodriver_gi	3000	2444	2422	2434	2464
woodriver_gi	3500	2488	2472	2468	2507
woodriver_gi	4000	2533	2524	2509	2544
woodriver_gi	4500	2561	2563	2538	2577
woodriver_gi	5000	2597	2608	2573	2613

Table G1d. Suitable whooping crane roosting area (ac) for Grand Island to Chapman.

Reach	Q (cfs)	2017	2018	2019	2020
gi_chapman	500	424	517	556	613
gi_chapman	750	438	513	574	618
gi_chapman	1000	431	493	570	598
gi_chapman	1200	418	475	550	569
gi_chapman	1500	392	430	519	512
gi_chapman	2000	334	333	447	398
gi_chapman	2500	274	230	370	286
gi_chapman	3000	215	144	300	189
gi_chapman	3500	161	88	227	117
gi_chapman	4000	113	57	165	71
gi_chapman	4500	75	43	112	45
gi_chapman	5000	44	37	75	33

Table G2a. Suitable whooping crane roosting area (ac) for the main channel of All Reaches (Overton to Chapman), Overton to Elm Creek, and Elm Creek to Odessa.

Reach	Q (cfs)	2017	2018	2019	2020
All_Reaches	500	2064	2535	2960	2869
All_Reaches	750	2134	2599	3090	2940
All_Reaches	1000	2113	2530	3057	2866
All_Reaches	1200	2051	2434	2971	2748
All_Reaches	1500	1953	2255	2816	2529
All_Reaches	2000	1705	1844	2464	2083
All_Reaches	2500	1425	1406	2083	1633
All_Reaches	3000	1160	1022	1701	1244
All_Reaches	3500	931	741	1353	920
All_Reaches	4000	735	538	1050	676
All_Reaches	4500	572	401	792	494
All_Reaches	5000	439	312	598	363
overton_elmcreek	500	102	124	148	102
overton_elmcreek	750	101	133	151	101
overton_elmcreek	1000	96	132	149	96
overton_elmcreek	1200	91	127	144	89
overton_elmcreek	1500	85	118	136	78
overton_elmcreek	2000	71	95	116	60
overton_elmcreek	2500	59	71	94	40
overton_elmcreek	3000	47	52	68	29
overton_elmcreek	3500	37	38	49	19
overton_elmcreek	4000	29	27	35	14
overton_elmcreek	4500	23	21	28	9
overton_elmcreek	5000	17	17	24	7
elmcreek_odessa	500	276	331	368	371
elmcreek_odessa	750	271	320	367	360
elmcreek_odessa	1000	253	291	350	330
elmcreek_odessa	1200	235	264	330	299
elmcreek_odessa	1500	213	230	295	254
elmcreek_odessa	2000	171	163	230	185
elmcreek_odessa	2500	126	107	168	121
elmcreek_odessa	3000	90	68	106	82
elmcreek_odessa	3500	63	44	67	50
elmcreek_odessa	4000	45	30	38	31
elmcreek_odessa	4500	29	24	23	19
elmcreek_odessa	5000	17	19	17	12

Table G2b. Suitable whooping crane roosting area (ac) for the main channel of Odessa to Minden, Minden to Gibbon, and Gibbon to Wood River.

Reach	Q (cfs)	2017	2018	2019	2020
odessa_minden	500	98	128	257	181
odessa_minden	750	99	127	265	182
odessa_minden	1000	97	119	259	174
odessa_minden	1200	91	110	246	166
odessa_minden	1500	85	98	230	151
odessa_minden	2000	74	74	194	119
odessa_minden	2500	61	55	157	91
odessa_minden	3000	50	41	125	69
odessa_minden	3500	41	32	98	53
odessa_minden	4000	33	26	78	41
odessa_minden	4500	27	22	62	31
odessa_minden	5000	20	19	51	24
minden_gibbon	500	414	429	428	433
minden_gibbon	750	438	461	450	473
minden_gibbon	1000	446	468	448	489
minden_gibbon	1200	445	464	440	495
minden_gibbon	1500	436	451	428	493
minden_gibbon	2000	395	408	395	463
minden_gibbon	2500	344	349	354	416
minden_gibbon	3000	294	283	309	361
minden_gibbon	3500	247	221	259	302
minden_gibbon	4000	205	167	209	245
minden_gibbon	4500	167	122	159	191
minden_gibbon	5000	135	91	116	143
gibbon_woodriver	500	268	430	561	514
gibbon_woodriver	750	276	444	591	530
gibbon_woodriver	1000	274	432	581	514
gibbon_woodriver	1200	264	414	564	488
gibbon_woodriver	1500	251	380	534	444
gibbon_woodriver	2000	218	302	468	355
gibbon_woodriver	2500	181	223	396	272
gibbon_woodriver	3000	150	158	321	200
gibbon_woodriver	3500	123	114	251	145
gibbon_woodriver	4000	101	84	189	105
gibbon_woodriver	4500	83	65	139	77
gibbon_woodriver	5000	68	52	103	58

Table G2c. Suitable whooping crane roosting area (ac) for the main channel of Wood River to Grand Island and Grand Island to Chapman.

Reach	Q (cfs)	2017	2018	2019	2020
woodriver_gi	500	481	577	643	655
woodriver_gi	750	510	601	693	676
woodriver_gi	1000	516	595	701	665
woodriver_gi	1200	507	580	696	643
woodriver_gi	1500	491	548	674	597
woodriver_gi	2000	442	470	614	504
woodriver_gi	2500	379	371	545	407
woodriver_gi	3000	314	278	472	313
woodriver_gi	3500	259	204	402	233
woodriver_gi	4000	209	147	335	170
woodriver_gi	4500	169	106	269	122
woodriver_gi	5000	137	77	212	86
gi_chapman	500	424	516	556	612
gi_chapman	750	438	513	574	617
gi_chapman	1000	431	493	570	597
gi_chapman	1200	418	475	549	569
gi_chapman	1500	392	430	519	512
gi_chapman	2000	334	332	447	398
gi_chapman	2500	274	230	370	286
gi_chapman	3000	215	144	299	189
gi_chapman	3500	161	88	227	117
gi_chapman	4000	113	57	165	71
gi_chapman	4500	75	43	112	45
gi_chapman	5000	44	37	75	33

Table G3a. Percent suitable whooping crane roosting area for all channels of All Reaches (Overton to Chapman), the north Lexington to Overton channel, and the J2 Return to Overton.

Reach	Q (cfs)	2017	2018	2019	2020
All_Reaches	500	23	27	32	30
All_Reaches	750	22	25	31	28
All_Reaches	1000	21	24	29	27
All_Reaches	1200	20	23	28	25
All_Reaches	1500	18	21	26	23
All_Reaches	2000	15	17	22	18
All_Reaches	2500	12	12	19	14
All_Reaches	3000	10	9	15	11
All_Reaches	3500	8	6	12	8
All_Reaches	4000	6	4	9	6
All_Reaches	4500	5	3	7	4
All_Reaches	5000	3	2	5	3
N-lexington_overton	500	6	2	2	0
N-lexington_overton	750	6	2	2	0
N-lexington_overton	1000	6	2	2	0
N-lexington_overton	1200	6	2	2	0
N-lexington_overton	1500	6	1	2	0
N-lexington_overton	2000	6	2	2	0
N-lexington_overton	2500	6	2	2	0
N-lexington_overton	3000	5	1	1	0
N-lexington_overton	3500	4	1	1	0
N-lexington_overton	4000	3	1	1	0
N-lexington_overton	4500	3	1	1	0
N-lexington_overton	5000	3	1	1	0
J2_overton	500	21	13	17	13
J2_overton	750	20	12	16	12
J2_overton	1000	18	10	14	11
J2_overton	1200	17	9	13	10
J2_overton	1500	15	8	11	9
J2_overton	2000	14	6	9	7
J2_overton	2500	13	4	8	6
J2_overton	3000	13	4	7	6
J2_overton	3500	12	3	7	5
J2_overton	4000	12	3	7	5
J2_overton	4500	11	3	6	5
J2_overton	5000	11	2	7	4

Table G3b. Percent suitable whooping crane roosting area for all channels of Overton to Elm Creek, Elm Creek to Odessa, and Odessa to Minden.

Reach	Q (cfs)	2017	2018	2019	2020
overton_elmcreek	500	16	20	22	15
overton_elmcreek	750	15	19	21	14
overton_elmcreek	1000	14	18	20	13
overton_elmcreek	1200	13	17	19	11
overton_elmcreek	1500	11	15	17	10
overton_elmcreek	2000	9	12	14	7
overton_elmcreek	2500	7	9	11	5
overton_elmcreek	3000	5	6	8	3
overton_elmcreek	3500	4	4	6	2
overton_elmcreek	4000	3	3	4	1
overton_elmcreek	4500	2	2	3	1
overton_elmcreek	5000	2	2	2	1
elmcreek_odessa	500	52	58	62	63
elmcreek_odessa	750	47	52	58	56
elmcreek_odessa	1000	42	46	53	50
elmcreek_odessa	1200	37	41	50	44
elmcreek_odessa	1500	33	35	44	37
elmcreek_odessa	2000	26	24	34	27
elmcreek_odessa	2500	18	16	24	17
elmcreek_odessa	3000	13	10	15	12
elmcreek_odessa	3500	9	6	9	7
elmcreek_odessa	4000	6	4	5	4
elmcreek_odessa	4500	4	3	3	2
elmcreek_odessa	5000	2	3	2	2
odessa_minden	500	4	5	12	8
odessa_minden	750	4	5	11	7
odessa_minden	1000	3	4	10	7
odessa_minden	1200	3	4	10	6
odessa_minden	1500	3	4	9	5
odessa_minden	2000	2	3	7	4
odessa_minden	2500	2	2	6	3
odessa_minden	3000	2	1	4	2
odessa_minden	3500	1	1	3	2
odessa_minden	4000	1	1	3	1
odessa_minden	4500	1	1	2	1
odessa_minden	5000	1	1	2	1

Table G3c. Percent suitable whooping crane roosting area for all channels of Minden to Gibbon, Gibbon to Wood River, and Wood River to Grand Island.

Reach	Q (cfs)	2017	2018	2019	2020
minden_gibbon	500	60	63	64	63
minden_gibbon	750	59	59	60	61
minden_gibbon	1000	57	58	58	62
minden_gibbon	1200	58	60	57	63
minden_gibbon	1500	53	55	54	60
minden_gibbon	2000	47	49	49	55
minden_gibbon	2500	41	41	43	49
minden_gibbon	3000	34	33	37	42
minden_gibbon	3500	28	25	31	35
minden_gibbon	4000	23	18	25	28
minden_gibbon	4500	19	13	18	22
minden_gibbon	5000	15	10	13	16
gibbon_woodriver	500	16	25	32	28
gibbon_woodriver	750	16	23	31	27
gibbon_woodriver	1000	15	22	29	25
gibbon_woodriver	1200	14	21	28	24
gibbon_woodriver	1500	13	19	26	21
gibbon_woodriver	2000	10	15	23	17
gibbon_woodriver	2500	9	11	19	13
gibbon_woodriver	3000	7	7	15	9
gibbon_woodriver	3500	5	5	11	7
gibbon_woodriver	4000	4	4	9	5
gibbon_woodriver	4500	4	3	6	3
gibbon_woodriver	5000	3	2	5	3
woodriver_gi	500	27	30	33	33
woodriver_gi	750	26	29	32	32
woodriver_gi	1000	25	28	31	30
woodriver_gi	1200	24	26	30	28
woodriver_gi	1500	22	24	29	26
woodriver_gi	2000	19	20	26	21
woodriver_gi	2500	16	16	23	17
woodriver_gi	3000	13	11	19	13
woodriver_gi	3500	10	8	16	9
woodriver_gi	4000	8	6	13	7
woodriver_gi	4500	7	4	11	5
woodriver_gi	5000	5	3	8	3

Table 3d. Percent suitable whooping crane roosting area for Grand Island to Chapman.

Reach	Q (cfs)	2017	2018	2019	2020
gi_chapman	500	35	38	44	46
gi_chapman	750	34	37	43	44
gi_chapman	1000	32	35	41	41
gi_chapman	1200	31	34	39	39
gi_chapman	1500	28	32	36	36
gi_chapman	2000	24	24	32	28
gi_chapman	2500	19	16	26	20
gi_chapman	3000	15	10	20	13
gi_chapman	3500	11	6	15	8
gi_chapman	4000	8	4	11	5
gi_chapman	4500	5	3	7	3
gi_chapman	5000	3	2	5	2

Table G4a. Percent suitable whooping crane roosting area for the main channel of All Reaches (Overton to Chapman), Overton to Elm Creek, and Elm Creek to Odessa.

Reach	Q (cfs)	2017	2018	2019	2020
All_Reaches	500	33	38	44	41
All_Reaches	750	31	36	42	39
All_Reaches	1000	29	33	40	37
All_Reaches	1200	28	32	38	35
All_Reaches	1500	25	29	36	31
All_Reaches	2000	21	23	31	25
All_Reaches	2500	17	17	26	20
All_Reaches	3000	14	12	21	15
All_Reaches	3500	11	9	16	11
All_Reaches	4000	8	6	12	8
All_Reaches	4500	7	5	9	6
All_Reaches	5000	5	3	7	4
overton_elmcreek	500	21	27	29	20
overton_elmcreek	750	19	26	28	18
overton_elmcreek	1000	18	24	26	17
overton_elmcreek	1200	16	23	25	15
overton_elmcreek	1500	15	20	23	13
overton_elmcreek	2000	12	16	19	10
overton_elmcreek	2500	10	12	15	6
overton_elmcreek	3000	8	8	11	5
overton_elmcreek	3500	6	6	8	3
overton_elmcreek	4000	4	4	5	2
overton_elmcreek	4500	3	3	4	1
overton_elmcreek	5000	3	3	4	1
elmcreek_odessa	500	53	58	62	63
elmcreek_odessa	750	47	52	58	57
elmcreek_odessa	1000	42	46	54	51
elmcreek_odessa	1200	38	41	50	45
elmcreek_odessa	1500	33	35	44	38
elmcreek_odessa	2000	26	25	34	27
elmcreek_odessa	2500	19	16	25	17
elmcreek_odessa	3000	13	10	15	12
elmcreek_odessa	3500	9	6	10	7
elmcreek_odessa	4000	6	4	5	4
elmcreek_odessa	4500	4	3	3	3
elmcreek_odessa	5000	2	3	2	2

Table G4b. Percent suitable whooping crane roosting area for the main channel of Odessa to Minden, Minden to Gibbon, and Gibbon to Wood River.

Reach	Q (cfs)	2017	2018	2019	2020
odessa_minden	500	8	10	20	14
odessa_minden	750	7	9	19	13
odessa_minden	1000	7	8	18	12
odessa_minden	1200	6	8	17	11
odessa_minden	1500	6	6	15	10
odessa_minden	2000	5	5	13	7
odessa_minden	2500	4	3	10	6
odessa_minden	3000	3	2	8	4
odessa_minden	3500	2	2	6	3
odessa_minden	4000	2	2	5	2
odessa_minden	4500	2	1	4	2
odessa_minden	5000	1	1	3	1
minden_gibbon	500	82	82	80	85
minden_gibbon	750	79	79	77	83
minden_gibbon	1000	76	78	74	83
minden_gibbon	1200	75	77	73	82
minden_gibbon	1500	70	73	70	79
minden_gibbon	2000	62	64	63	73
minden_gibbon	2500	53	54	56	65
minden_gibbon	3000	45	43	49	56
minden_gibbon	3500	38	34	41	47
minden_gibbon	4000	31	25	32	37
minden_gibbon	4500	25	18	24	29
minden_gibbon	5000	20	13	18	22
gibbon_woodriver	500	21	31	40	35
gibbon_woodriver	750	20	29	39	34
gibbon_woodriver	1000	19	28	37	32
gibbon_woodriver	1200	18	26	35	30
gibbon_woodriver	1500	16	24	33	26
gibbon_woodriver	2000	13	18	28	21
gibbon_woodriver	2500	11	13	23	16
gibbon_woodriver	3000	9	9	19	11
gibbon_woodriver	3500	7	7	14	8
gibbon_woodriver	4000	6	5	11	6
gibbon_woodriver	4500	5	4	8	4
gibbon_woodriver	5000	4	3	6	3

Table G4c. Percent suitable whooping crane roosting area for the main channel of Wood River to Grand Island and Grand Island to Chapman.

Reach	Q (cfs)	2017	2018	2019	2020
woodriver_gi	500	42	47	53	52
woodriver_gi	750	41	44	51	49
woodriver_gi	1000	38	41	49	46
woodriver_gi	1200	36	39	47	44
woodriver_gi	1500	33	36	45	39
woodriver_gi	2000	28	30	40	32
woodriver_gi	2500	24	23	35	26
woodriver_gi	3000	19	17	30	20
woodriver_gi	3500	16	12	25	14
woodriver_gi	4000	12	9	21	10
woodriver_gi	4500	10	6	16	7
woodriver_gi	5000	8	4	13	5
gi_chapman	500	36	41	46	48
gi_chapman	750	34	39	44	46
gi_chapman	1000	32	37	42	43
gi_chapman	1200	31	35	40	40
gi_chapman	1500	28	32	37	36
gi_chapman	2000	24	24	32	28
gi_chapman	2500	19	16	26	20
gi_chapman	3000	15	10	21	13
gi_chapman	3500	11	6	15	8
gi_chapman	4000	8	4	11	5
gi_chapman	4500	5	3	8	3
gi_chapman	5000	3	2	5	2

Table G5a. Percent suitable whooping crane roosting area on managed areas of the main channel and unmanaged areas.

Reach	Q (cfs)	2017		2018		2019		2020	
		managed	un-managed	managed	un-managed	managed	un-managed	managed	un-managed
All_Reaches	500	48	25	53	30	58	37	56	34
All_Reaches	750	45	24	50	28	55	35	54	32
All_Reaches	1000	42	22	48	26	53	34	51	30
All_Reaches	1200	40	21	46	25	51	32	49	28
All_Reaches	1500	37	19	42	22	47	30	45	25
All_Reaches	2000	32	16	35	17	41	25	38	19
All_Reaches	2500	26	13	27	12	35	21	32	14
All_Reaches	3000	22	10	21	8	28	17	26	9
All_Reaches	3500	18	8	16	5	23	13	20	6
All_Reaches	4000	14	6	12	3	17	10	16	4
All_Reaches	4500	11	4	9	2	13	7	12	3
All_Reaches	5000	9	3	7	2	10	5	9	2
overton_elmcreek	500	41	2	52	3	54	4	37	2
overton_elmcreek	750	38	1	50	3	52	3	35	2
overton_elmcreek	1000	35	1	47	2	50	3	32	1
overton_elmcreek	1200	32	1	44	2	48	3	29	1
overton_elmcreek	1500	28	1	40	2	45	2	26	1
overton_elmcreek	2000	23	1	31	1	38	2	19	0
overton_elmcreek	2500	19	1	23	1	30	1	13	0
overton_elmcreek	3000	14	1	17	0	21	1	9	0
overton_elmcreek	3500	11	1	12	0	15	1	6	0
overton_elmcreek	4000	8	1	8	0	10	1	4	0
overton_elmcreek	4500	6	1	6	0	8	1	3	0
overton_elmcreek	5000	5	1	5	0	7	1	2	0
elmcreek_odessa	500	74	18	78	22	77	35	81	32
elmcreek_odessa	750	66	15	71	19	72	32	73	28
elmcreek_odessa	1000	59	12	63	16	67	29	65	24
elmcreek_odessa	1200	53	10	56	14	63	27	59	21
elmcreek_odessa	1500	47	8	49	11	56	23	50	16
elmcreek_odessa	2000	37	5	35	6	44	16	37	10
elmcreek_odessa	2500	27	3	23	3	32	11	24	5
elmcreek_odessa	3000	19	2	15	2	21	6	17	3
elmcreek_odessa	3500	14	1	9	1	13	4	10	2
elmcreek_odessa	4000	10	1	6	1	7	2	6	1
elmcreek_odessa	4500	6	1	5	1	4	2	3	1
elmcreek_odessa	5000	3	1	4	1	3	2	2	1

Table G5b. Percent suitable whooping crane roosting area on managed areas of the main channel and unmanaged areas.

Reach	Q (cfs)	2017		2018		2019		2020	
		managed	un-managed	managed	un-managed	managed	un-managed	managed	un-managed
odessa_minden	500	6	9	8	11	21	20	15	13
odessa_minden	750	6	9	7	10	19	18	14	12
odessa_minden	1000	5	8	7	9	19	17	13	11
odessa_minden	1200	5	7	6	8	18	16	13	10
odessa_minden	1500	5	6	6	7	16	15	11	9
odessa_minden	2000	4	5	4	5	14	12	9	6
odessa_minden	2500	3	4	3	4	11	9	7	5
odessa_minden	3000	2	3	2	3	9	7	6	3
odessa_minden	3500	2	3	2	2	7	6	4	3
odessa_minden	4000	1	2	1	2	5	4	3	2
odessa_minden	4500	1	2	1	1	4	3	2	1
odessa_minden	5000	1	1	1	1	3	3	2	1
minden_gibbon	500	84	--	86	--	83	--	89	--
minden_gibbon	750	82	--	83	--	80	--	88	--
minden_gibbon	1000	79	--	82	--	77	--	88	--
minden_gibbon	1200	77	--	81	--	76	--	87	--
minden_gibbon	1500	72	--	77	--	72	--	84	--
minden_gibbon	2000	64	--	68	--	66	--	77	--
minden_gibbon	2500	55	--	58	--	59	--	69	--
minden_gibbon	3000	47	--	46	--	51	--	59	--
minden_gibbon	3500	39	--	36	--	42	--	49	--
minden_gibbon	4000	32	--	27	--	34	--	40	--
minden_gibbon	4500	26	--	19	--	26	--	31	--
minden_gibbon	5000	21	--	14	--	19	--	23	--
gibbon_woodriver	500	21	21	40	28	43	39	49	30
gibbon_woodriver	750	21	20	39	26	42	37	48	29
gibbon_woodriver	1000	19	18	37	24	40	35	45	27
gibbon_woodriver	1200	18	17	35	23	39	34	43	25
gibbon_woodriver	1500	17	16	32	21	36	31	38	22
gibbon_woodriver	2000	15	13	26	16	32	27	31	17
gibbon_woodriver	2500	12	10	20	11	28	22	25	12
gibbon_woodriver	3000	10	8	15	7	23	17	19	9
gibbon_woodriver	3500	8	7	11	5	18	13	14	6
gibbon_woodriver	4000	7	5	9	3	14	10	11	4
gibbon_woodriver	4500	5	4	6	3	10	7	8	3
gibbon_woodriver	5000	4	4	5	2	8	5	7	2

Table G5c. Percent suitable whooping crane roosting area on managed areas of the main channel and unmanaged areas.

Reach	Q (cfs)	2017		2018		2019		2020	
		managed	un-managed	managed	un-managed	managed	un-managed	managed	un-managed
woodriver_gi	500	60	37	56	45	72	47	65	48
woodriver_gi	750	59	36	55	41	71	45	64	45
woodriver_gi	1000	57	33	53	38	69	44	62	42
woodriver_gi	1200	55	31	52	36	67	42	61	39
woodriver_gi	1500	53	28	49	32	64	40	57	34
woodriver_gi	2000	48	23	44	26	59	35	51	27
woodriver_gi	2500	43	18	38	20	53	30	45	20
woodriver_gi	3000	37	14	31	13	47	25	38	14
woodriver_gi	3500	32	11	26	9	41	21	32	10
woodriver_gi	4000	28	8	20	6	35	17	26	6
woodriver_gi	4500	23	6	16	4	30	13	20	4
woodriver_gi	5000	20	5	12	2	25	10	16	2
gi_chapman	500	--	36	--	41	--	46	--	48
gi_chapman	750	--	34	--	39	--	44	--	46
gi_chapman	1000	--	32	--	37	--	42	--	43
gi_chapman	1200	--	31	--	35	--	40	--	40
gi_chapman	1500	--	28	--	32	--	37	--	36
gi_chapman	2000	--	24	--	24	--	32	--	28
gi_chapman	2500	--	19	--	16	--	26	--	20
gi_chapman	3000	--	15	--	10	--	21	--	13
gi_chapman	3500	--	11	--	6	--	15	--	8
gi_chapman	4000	--	8	--	4	--	11	--	5
gi_chapman	4500	--	5	--	3	--	8	--	3
gi_chapman	5000	--	3	--	2	--	5	--	2