Impacts of a Persisting Flood on the Missouri River's Bank Stabilization and Navigation Project

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Abstract

The Missouri River experienced sustained high flows both in 2019 and 2020. Levee over-toppings and breaches experienced throughout the lower basin during the 2019 flood event visibly showcased the impacts of the sustained high flows on the upper portions of the floodplain. However, the lower portions of this sand bed river also experienced dramatic, evolving changes that remained hidden under the high stages. The Bank Stabilization and Navigation Project (BSNP) of the Missouri River is composed of stone river training structures to provide a self-scouring navigation channel to meet the authorized channel dimensions of 9 ft by 300 ft. Navigation impacts were noted throughout 735 miles of the BSNP as flow dropped rapidly from above-average discharges to near below average discharge in 2020. Shifting shoals within the navigation channel developed in 2020 as the riverbed adjusted to the change in flow and sediment loads. The readjustment of the river was exacerbated by degraded river training structures damaged during the high water. These shoals caused navigation channel depths of less than 9 feet, greatly limiting the passage of commercial navigation traffic, and caused vessel safety concerns due to the constant shift in shallow areas. Managing engineered features of a navigation channel on an alluvial river requires rapid communication of field observations and tailored engineering responses. The Kansas City District of the United States Army Corps of Engineers (NWK) recognized these needs during the period of 2019-2020.

Introduction

Bank Stabilization and Navigation Project

Three major authorities have shaped the present condition of the BSNP. Those are the River and Harbor Acts (RHA) of 1912, 1927 and 1945. The 1912 RHA authorized a 6-ft (1.8 m) deep channel from the mouth to Kansas City, MO. The 1927 act authorized a 6-ft (1.8 m) deep by 200-ft (61 m) wide channel, and extended the project to Sioux City, IA. The 1945 act increased the authorized channel to 9-ft (2.7 m) deep by 300-ft (91 m) wide. Construction of the BSNP was completed in 1980 and the project has been in an operations and maintenance status since that time. The navigation channel created by the BSNP extends 735 river miles from near Sioux City, Iowa to the mouth in St. Louis, Missouri (see Figure 1).

Figure 1. Missouri River Basin and BSNP Project Extents

The BSNP consists of a series of stone fill and wood piling dikes and revetments which provides for an open river continuous navigation channel 9 feet deep and 300 foot wide, (8 feet deep by 200 foot wide during drought conditions) which is designed to flow along the concave side of the bends and through the crossings between bends. The project is designed to be a self-scouring channel that utilizes the erosive force of flowing water to maintain authorized channel widths and depths. The normal flow supported commercial navigation season is April 1 through November 30. The season may be extended or shortened based on main-stem reservoir storage levels. Ice conditions and low winter flows usually precludes navigation during the remainder of the year. During drought and normal runoff years, navigation flows are supported with releases from the main-stem reservoirs dams which are operated to meet navigation flow targets at Sioux City, Omaha, Nebraska City, and Kansas City. The Kansas City navigation flow targets are partially supported from three reservoirs located in the Kansas River watershed.

The authorized navigation channel on the Missouri River is located between two Rectified Channel Lines (RCLs). The RCLs were established during the early years of construction of the BSNP to define the riverward limit of the BSNP structures. During the later years of construction, dikes were extended up to 200 feet riverward of the RCLs (sills) to correct channel meander during low flow conditions. The distance between the RCLs vary from 1,100 feet at the mouth and decreases incrementally to 600 feet at Sioux City. The distance between the RCLs

exceeds the width of the authorized navigation channel to allow for flow conveyance during normal and high river stages. The 300 foot wide navigation channel does not occupy a fixed location between the RCLs and will shift location slightly as flow conditions change. The distance between RCLs is closer in the channel crossings and further apart in the bends. Figure 2 depicts a typical layout of BSNP structures (revetments, dikes, sills) in relation to the navigation channel, channel margin, and RCLs.

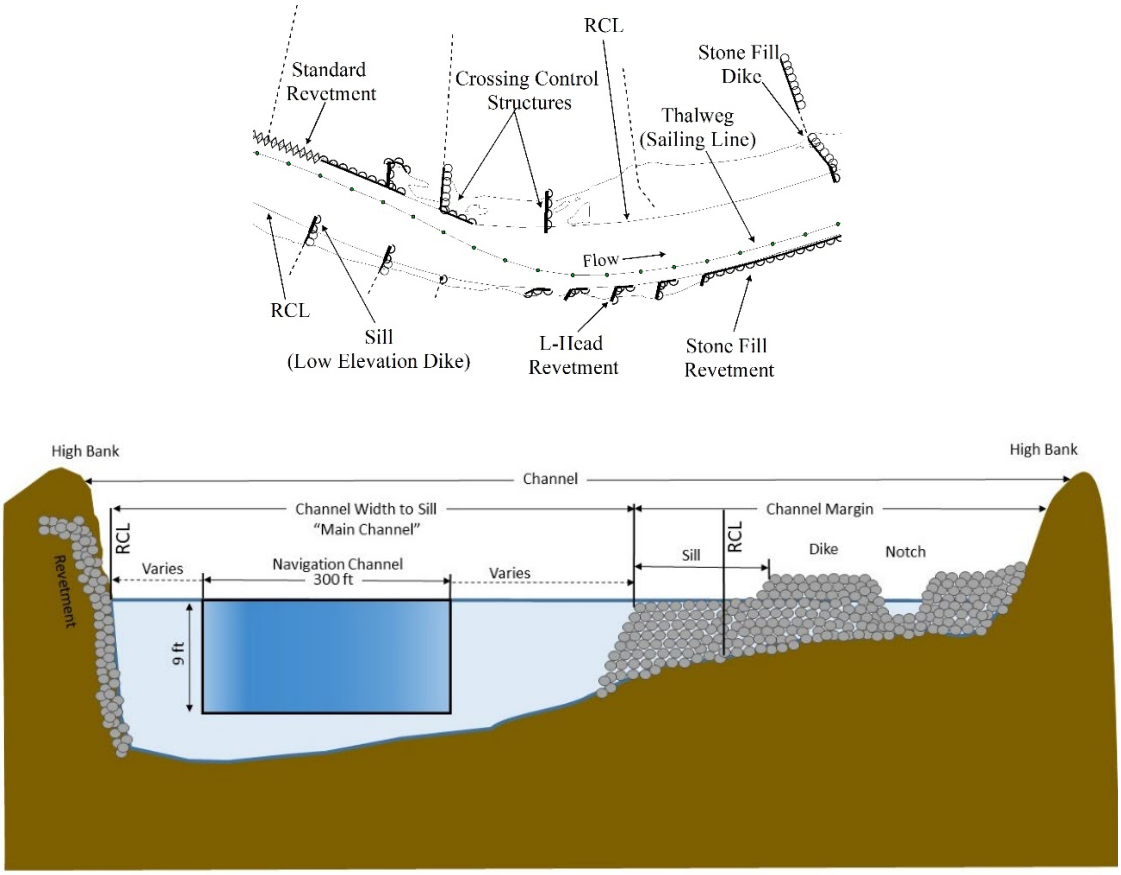

Figure 2. Missouri River Navigation Channel Typical Plan view (above) and Cross Section (below)

2019 and 2020 High Flows Followed by Drought Conditions

Sustained high flows were experienced both in 2019 and 2020. The 2019 flood was the longest declared flood in NWK history, lasting 278 days from 13 March 2019 to 16 December 2019. The 2020 discharges did not fall consistently below the 75th percentile (post-dam period from 1957-2022 at the USGS 06934500 Missouri River at Hermann, MO gage) until August of 2020, at which point discharges dropped to just above the breakpoint of the 25th percentile or what USGS would define as “below normal”. Generally, 2021 discharges remained within the “normal” range of discharges with jumps up into the “above normal” range in late March, early April and the flood of late June/early July. Drought conditions in 2021 and 2022 in the upper basin resulted in reduced navigation flow support releases kept discharges between the normal to below normal range.

Figure 3 shows the USGS daily recorded discharges (shown as a black line) at Hermann, Missouri between 2018 and 2022. Daily flow statistics for the period of record shown using the solid bands in the background provide a relative historical comparison of the discharges experienced in the past five years.

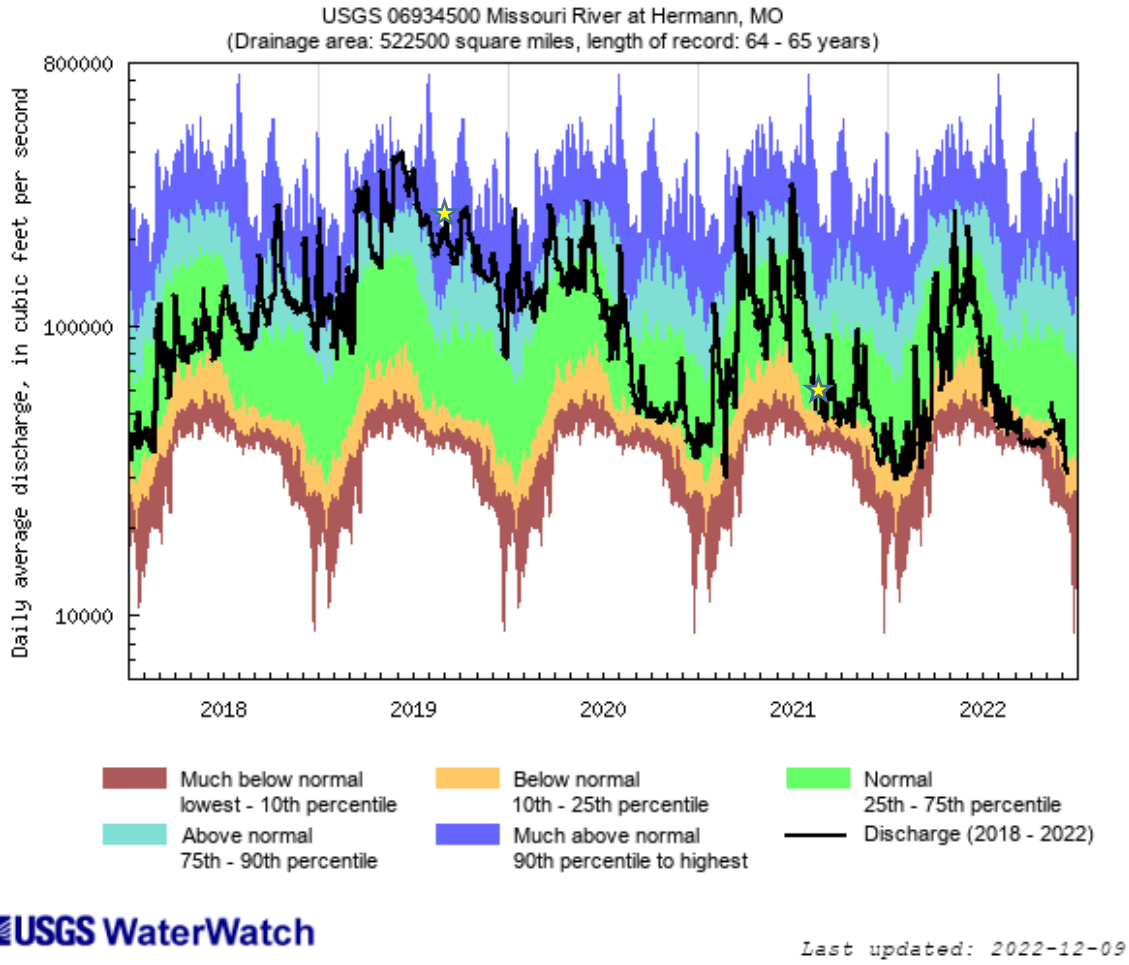

Figure 3. Daily average discharge from 01 January 2018 to 31 December 2022 at Hermann, MO USGS 06934500 gage at RM 97.9, overlain daily flow statistics over the post-dam period of 1957-2022 for this gage. Stars indicate collection date of 2019 and 2021 surveys shown in Figure 6

Riverbed Impacts to Floodings

Initial Response of Riverbed

During the period of extended high flow between 2019 and 2020, the riverbed experienced a leveling effect. The main channel experienced aggradation on the order of 15 feet and the channel margin in several location degraded. This resulted in more uniform cross sections (Figure 4) that was evident across the BSNP system. Given high stages exceeded the BSNP structures by several feet for over a year and high flows utilized the floodplain for several

months, the lack of confinement of flow between the BSNP structures and the added sediment loads from a wider cross section reduced the energy needed to flush out the main channel. When comparing the cross sections in Figure 3, note that the water surface elevation in 2019 at RM 91.8 was about 14 feet above the CRP (497') and about 0.3 feet below CRP in 2013 (482 ft). Depth in the navigation channel (approximate stationing between 1600-2000) was about 17 feet deep in the 2019 survey and about 15 feet deep in the 2013 survey with the 2013 stage 15 feet lower than in 2019.

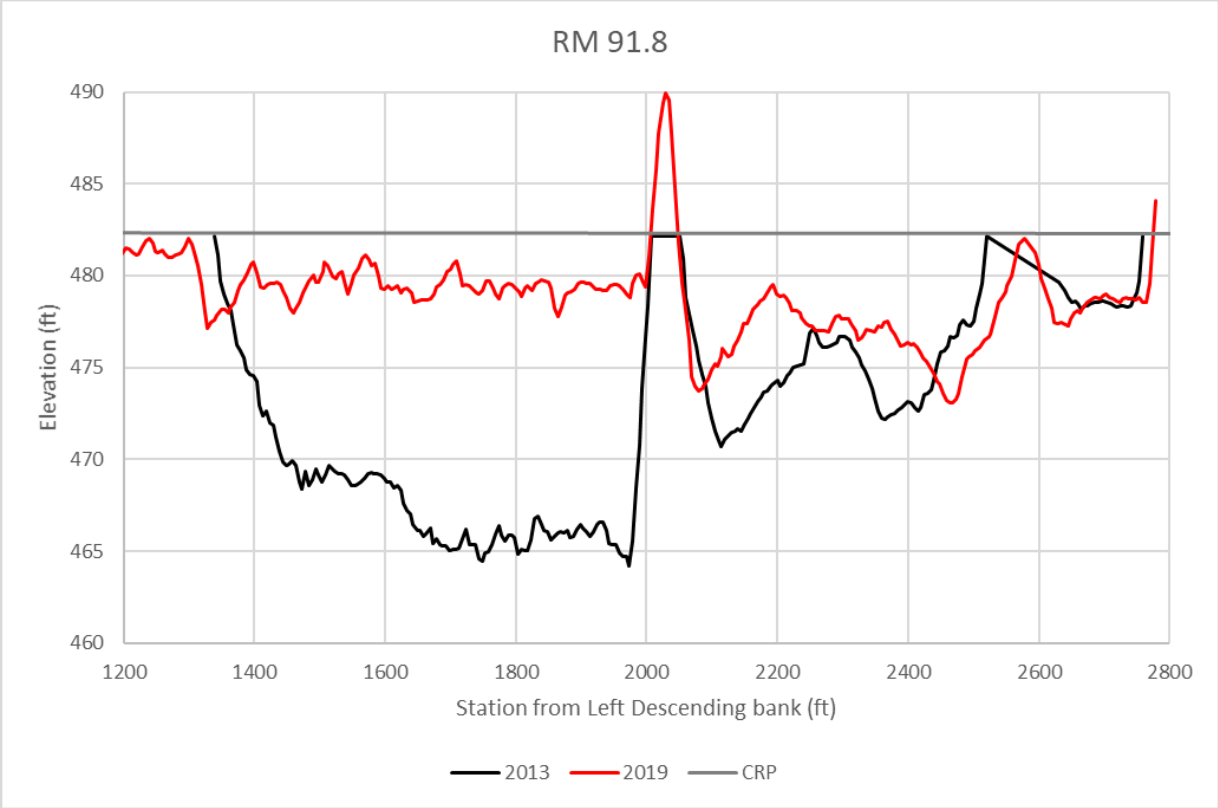

Figure 4. Cross Section at River Mile 91.8, Construction Reference Plane (CRP) shown to indicate water surface elevation at which flow is exceeded 75% of time during navigation flow support season.

As stages dropped in the Fall of 2020, navigation depths became limited across the Missouri River navigation channel as the sand bed lagged in adjusting to a dramatically lower flow regime. Additionally, damaged river training structures (dikes and revetments) resulted in a slower and less pronounced self-souring effect to aid in deepening the channel back to pre-flood conditions. Navigation surveys reported depths of less than 9 feet at locations scattered throughout the lower 500 river miles of the Missouri River that persisted through 2020 and 2021. Figure 5 provides an example of one the many locations that experienced shoaling.

The Kansas City District (NWK) utilized every means and method available to mitigate the impacts of the shoaling on navigators. NWK communicated daily the field observations to the navigation industry to include weekly multibeam depth surveys of shallow areas, forecasts, boat traffic, and coordinate locations of shoals and obstructions. Additionally, NWK's River Engineers responded with real time site assessments, split flow measurements, BSNP structure assessments, design, and emergency placement of new and repair of existing river training

structures. Communicate of conditions with frequent surveys was the greatest assets in mitigating the negative impacts to navigations.

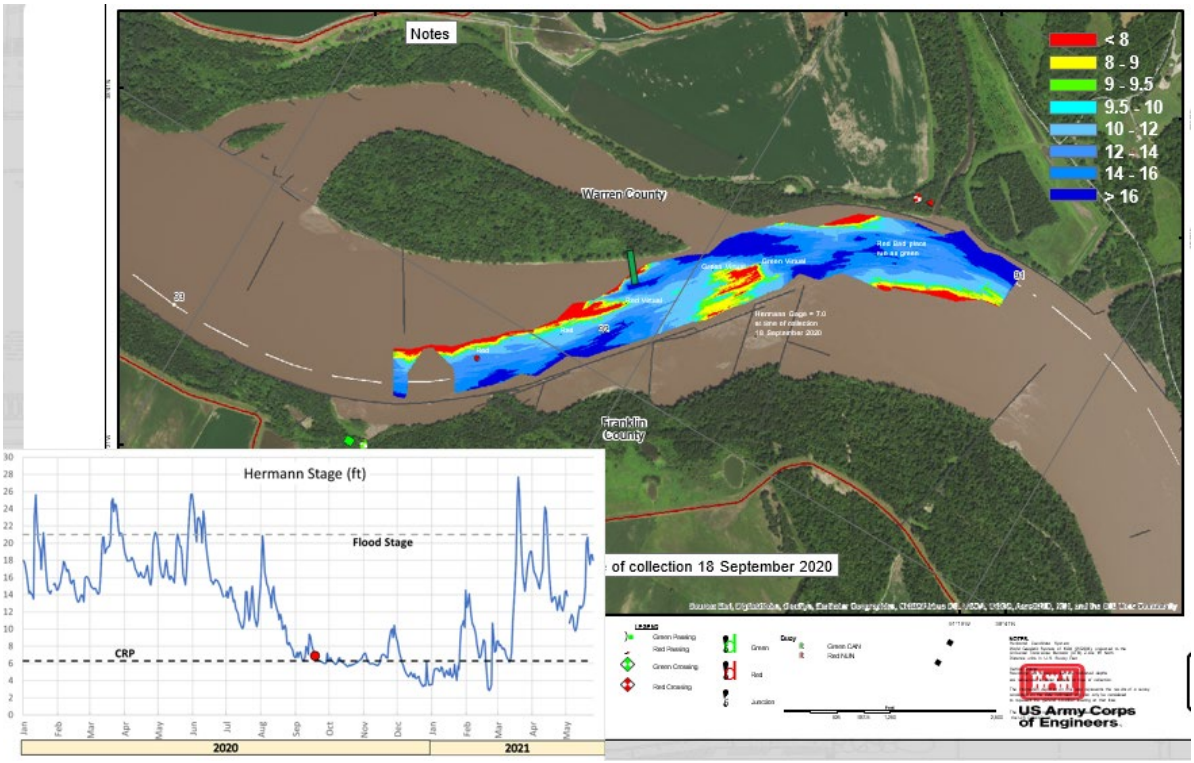

Figure 5. Navigation Survey at River Mile 91 indicating areas less than 8 feet (red) in the late summer of 2020

Riverbed Adjustments

With time, the conglomeration of the emergency river engineering actions and the natural adjustment of the riverbed to a confined flow allowed for the riverbed to respond and adjust to pre-flood conditions. Based on initial observations and comparisons across the BSNP system, the emergency structural work done in the form of new placement and repaired structures accelerated the lowering of the main channel back to pre-flood conditions, which may have taken a longer period and fallen shy of the pre-flood depths if structural interventions were not taken. A further BSNP-wide review of data collected during the 2019-2022 period in light of engineering actions is necessary to confirm this initial hypothesis. Figure 6 shows a return to a similar cross section shape in 2021 as in 2013 with a deepened passable channel on the left descending side of the cross section. Note that in 2021 at RM 91.8 the water surface elevation was about 1.5 feet above the CRP (an elevation of 484 ft).

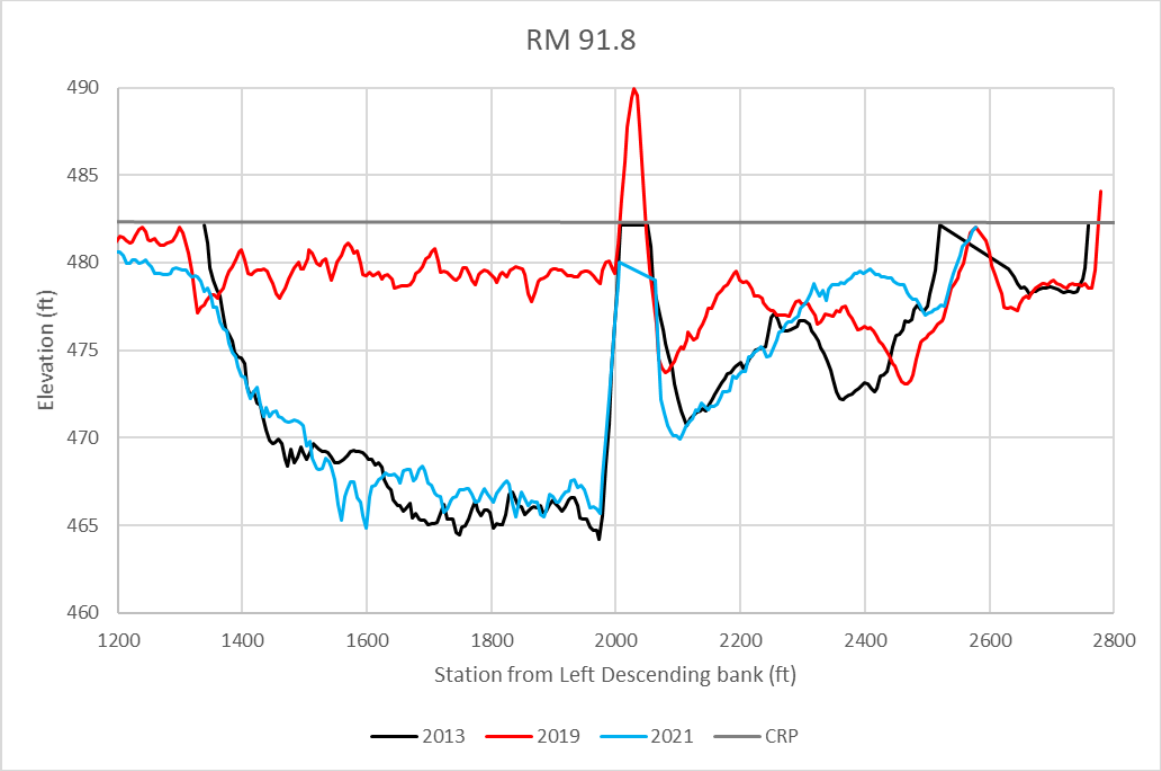

Figure 6. Cross Section at River Mile 91.8, showing 2021 condition returned to conditions similar in 2013.

Conclusions

Navigation impacts were noted throughout 735 miles of the Missouri River's BSNP as flow dropped rapidly from above-average discharges to near below average discharge in 2020. Shifting shoals within the navigation channel developed in 2020 as the riverbed adjusted to the change in flow and sediment loads. The readjustment of the river was exacerbated by degraded river training structures damaged during the high water. Shoals caused navigation channel depths of less than 9 feet, greatly limiting the passage of commercial navigation traffic, and caused vessel safety concerns. Lessons learned for the future management of the BSNP system include scheduling routine surveys during low water conditions, documenting the effects of engineering actions, having contracting mechanisms in place to be able to implement engineered solutions, and recognizing the need to adapt solutions to site specific and condition specific needs. Ongoing communication of field observations and engineering responses by the Kansas City District allowed for channel improvements to be realized in following navigation seasons.

References

North Arrow Research, 2016, Cross Section Viewer Software, accessed September 1, 2022, at URL https://xsviewer.northarrowresearch.com/.

U.S. Geological Survey, 2022, National Water Information System data available on the World Wide Web (USGS Water Data for the Nation), accessed September 1, 2022, at URL http://waterdata.usgs.gov/nwis/.