Appendix D2:

Climate Change Effects on Pool 2

Lower Pool 2 Channel Management Study:
Boulanger Bend to Lock and Dam No. 2

CLIMATE CHANGE

ECB No. 2016-25 (USACE 2016) provides guidance for incorporating climate change information in hydrologic analyses in accordance with the USACE overarching climate change adaption policy. It calls for a qualitative analysis and provides links to online tools that can be used in this qualitative analysis. The goal of a qualitative analysis of potential climate threats and impacts to USACE hydrology-related projects and operations is to describe the observed present and possible future climate threats, vulnerabilities, and impacts specific to the study goals or engineering designs. This includes consideration of both past (observed) changes as well as potential future (projected) changes to relevant climatic and hydrologic variables.

CLIMATE CHANGE REGIONAL SCALE

Projected data being modeled in this region was looked at to support some broader statements about how the climate may change over the 50 year project life. Important driving climate variables include seasonal precipitation and temperature. Figure 1, from the US Global Change Research Program's (USGCRP) Third National Climate Assessment completed in 2014, shows estimates of increased precipitation throughout the Upper Midwest. In this assessment it is stated that "in the Upper Midwest extreme heat, heavy downpours, and flooding will affect infrastructure, health, agriculture, forestry, transportation, air and water quality, and more. Climate change will tend to amplify existing risks climate poses to people, ecosystems, and infrastructure. Direct effects will include increased heat stress, flooding, drought, and late spring freezes."

A series of regional summary reports on climate change were written under USACE contract in 2015 (Civil Works Technical Report CWTS-2015-13, USACE (2015)). A significant amount of literature was summarized including Mauget (2004) who analyzed 42 daily streamflow gages throughout the U.S., nine of which are located within the Upper Mississippi Region. Mauget identified an increasing trend (1939 – 1998) in river flow in the Mississippi watershed as a whole, including the Upper Mississippi. He also quantified a significant increase in "surplus" flow days and a decrease in drought incidences for the latter part of the record compared to earlier years.

Climate change modeling and analysis at the regional scale suggests increasing river flows and higher air temperatures, but with greater inter-annual variation in the future. This could affect sediment loading in the study area and the engineering resilience of project features and should be considered during planning and design.

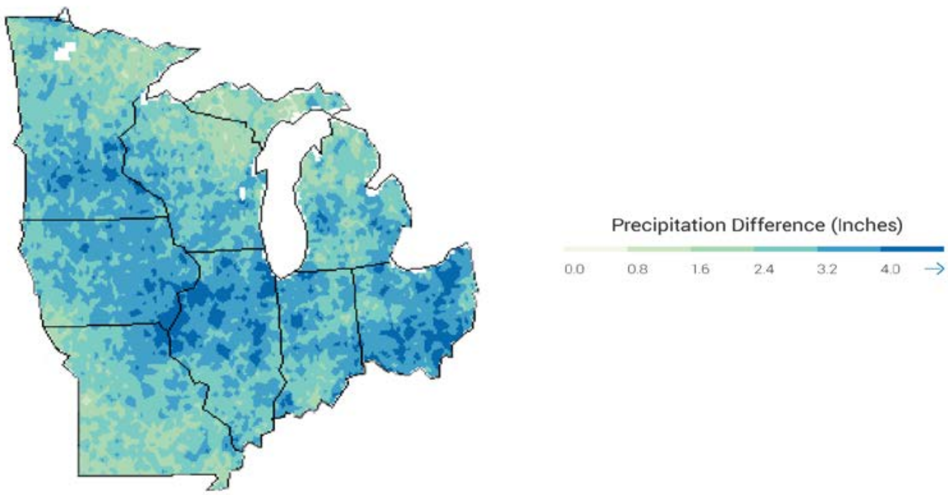


Figure 1. This map show projected changes for the middle of the current century (2041-2070) relative to the end of the last century (1971-2000) across the Midwest under continued emissions (A2 scenario). This map shows the changes in total annual average precipitation. Across the entire Midwest, the total amount of water from rainfall and snowfall is projected to increase. (Figure source: NOAA NCDC / CICS-NC).

CLIMATE CHANGE PROJECT SCALE

The important hydrologic variables affecting the project area include water surface elevation (stage) and river discharge. Climate change, by altering precipitation and evapotranspiration, could influence these variables, however there are other factors also. Stage, which is directly related to discharge, can be influenced by long-term geomorphic change, changes to Lock and Dam operating plans, and gage relocation. Discharge can be influenced by changes in upstream water storage due to dam construction or land-use change, and by measurement techniques. These factors can make it difficult to determine the role of climate change in affecting the hydrologic signal. The relevant question to answer at the project scale is whether there has been, or will be a change that affects sediment transport or engineering resilience. Since sediment transport is partly a function of flow characteristics (e.g. volume and speed of flow), discharge was chosen as the primary hydrologic variable to analyze for this study.

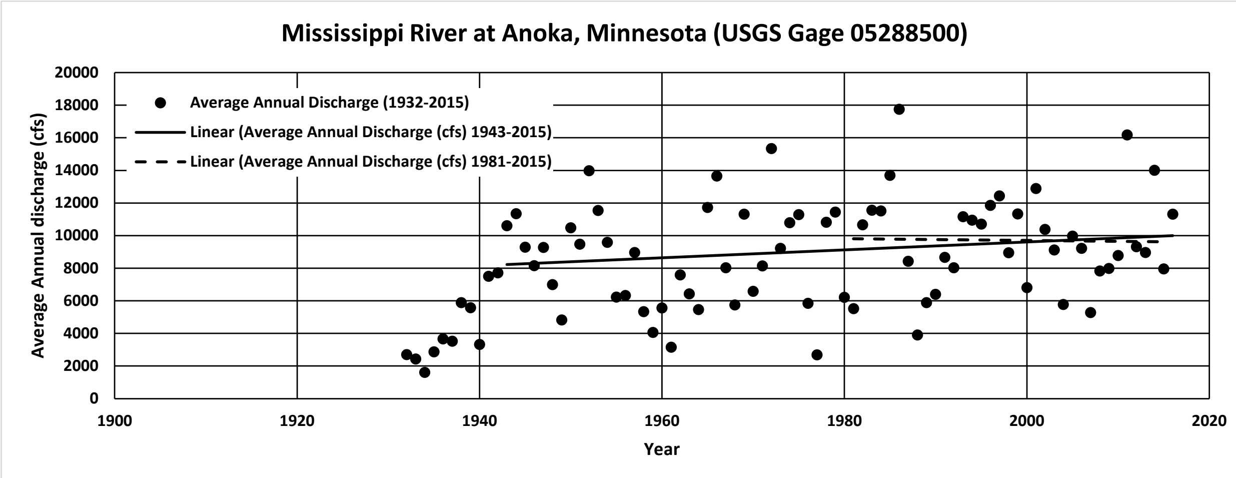
Relevant components of river discharge that affect sediment transport and engineering resilience include its magnitude, frequency, and duration. Recent sediment data collected by the USGS on the Minnesota River, which is the primary source of sediment to Pool 2 indicates that suspended sediment concentration and bed load were not correlated with stream flow for high discharges (Groten et al. 2016). Reasons for this included hysteresis, backwater effects from the Mississippi River, and floodplain sediment deposition during high flow events. Because of this, rather than using flood data (e.g. peak flow or days of flooding) to explain hydrology changes, average annual discharge in the project area will be used to explain the potential for increased sediment loading. This data is available for the Mississippi River at Anoka and St. Paul, Minnesota and the Minnesota River at Jordan, Minnesota (table 1).

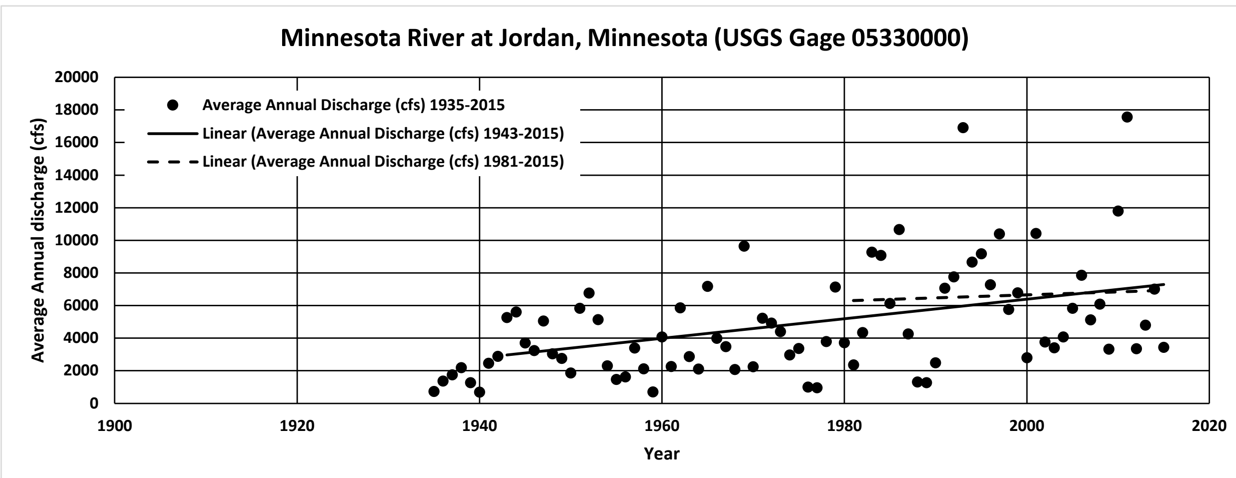
Table 1. USGS gages in the project area.

USGS gage number	Location	Period of Record	
05288500	Mississippi River at Anoka, Minnesota River Mile 865	1932 - 2015	Gage is located 18 miles upstream of Pool 2
05330000	Minnesota River at Jordan, Minnesota	1935 - 2015	Gage is located 35 miles upstream of the confluence with the Mississippi River
05331000	Mississippi River at St. Paul, Minnesota, River Mile 839	1901 - 2015	Gage is located near the upstream end of Pool 2

The gages located at Anoka and Jordan represent hydrologic conditions on the two primary sources of inflows to Pool 2. The gage at St. Paul is located near River Mile 839 at the upstream end of Pool 2. Previous analysis done for the USGS gage on the Mississippi River at Prescott, Wisconsin (gage number 05344490), which is located four miles downstream of Pool 2 indicated a cluster of non-stationarities in the late 1930s and early 1940s time period (USACE Climate Preparedness and Resilience Group, Friedman pers. com., May 2016). This was based on analysis of the peak annual discharge and the number of days each year that discharge exceeded 58,000 cfs (50-percent AEP flood). An analysis of peak annual discharge done for the USGS gage on the Minnesota River at Mankato (gage number 05325000) indicates a non-stationarity in the early 1940s. The gages listed in table 1 exhibit strong evidence of non-stationarities for peak flow in the early 1940s also. This pattern (consistently low values in the 1930s, then higher values with greater inter-annual variation beginning in the early 1940s) is evident in the average annual discharge also. Because of this discharge data prior to 1943, while shown on the plots, was not used to determine trend lines.

Figure 2 shows the average annual discharge at Anoka, Jordan, and St. Paul over time with trend lines fitted to the time periods 1943 to 2015, and 1981 to 2015. At Anoka, there is an upward trend, however it is not statistically significant. There is a statistically significant trend of increasing average annual discharge for the period 1943 to 2015 ($p < 0.01$) at both the Jordan and St. Paul gages. In addition, at both of these gages the six years in the period of record having the highest average annual flows have occurred since the early 1980s. The 35 year time period 1981 to 2015 was compared to the previous 35 year time period 1946 to 1980 at all three gages. There were increases in average annual flow of 16-percent, 80-percent, and 38-percent at Anoka, Jordan, and St. Paul respectively along with greater inter-annual variation at Jordan and St. Paul as determined by the standard deviation (table 2). Linear trend lines fitted to the 1981 to 2015 time period don’t indicate a statistically significant increasing trend in average annual discharge at these three gages.





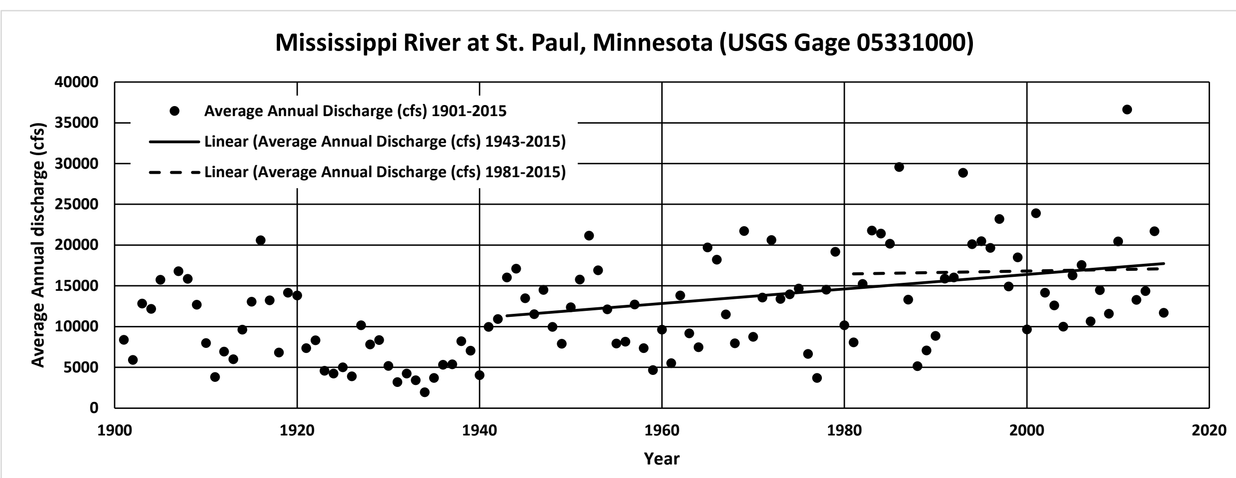


Figure 2. Average Annual Discharge at the Anoka, Jordan, and St. Paul USGS Gages With Time.

Table 2. Average Annual Discharge and Standard Deviation at Anoka, Jordan, and St. Paul.

Gage	Average Annual Discharge (cfs) 1946 to 1980	Average Annual Discharge (cfs) 1981 to 2015	Percent Increase in Average Discharge	Standard Deviation 1946 to 1980	Standard Deviation 1981 to 2015
Anoka	8350	9710	16.2	3070	3010
Jordan	3670	6620	80.1	2000	3800
St. Paul	12190	16780	37.6	4790	6660

It is unknown what the role of climate change versus upstream land use change is, but this isn't needed at the project scale, since the important thing is whether there are obvious changes that could affect conditions in the project area. Although non-stationarities were not detected in the early 1980s, there appears to have been an increase in the average annual discharge starting with this decade. Future projected dredging volumes should be based on data from this more recent time period, with adjustments made to the beginning year as needed based on dredging records. Project design features, should be adjusted if needed, however engineering resilience will primarily be maintained by using lessons learned from successful and stable projects constructed during the 1981 to 2015 time period.

Dredging in Lower Pool 2 from the Pine Bend Landing dredge cut (RM 824.3 to 824.6) to the Freeborn Light dredge cut (RM 818.0 to 818.9) has increased since the 1980s. The main factor causing this increase in dredging is increased annual discharges on the Minnesota and Mississippi Rivers. Data obtained at USGS gages at Anoka, Jordan, and St. Paul indicate that average annual discharges were 16-percent, 80-percent, and 38-percent higher respectively for the 35 year time period from 1981 to 2015, compared to the previous 35 year time period 1946 – 1980. The increases in discharge results in increased sediment loads from both the Minnesota River and the Mississippi above the confluence with the Minnesota River. Other factors that might also be affecting dredging in lower pool 2, but to a lesser degree include: 1) reductions in dredging in upstream pools, 2) reduced off channel sediment storage, 3) increased secondary channel flows to backwaters, 4) construction of channel training structures.

References

Groten, J.T., Ellison, C.A., and Hendrickson, J.S., 2016, Suspended-sediment concentrations, bedload, particle sizes, surrogate measurements, and annual sediment loads for selectyed sites in the lower Minnesota River Basin, water years 2011 through 2016: U.S. Geological Survey Scientific Investigations Report 2016-5174, 29 p., https://doi.org/10.3133/sir20165174.

U.S. Army Corps of Engineers, Civil Works Technical Series. 2015. Recent US Climate Change and Hydrology Literature Applicable to US Army Corps of Engineers Missions – Upper Mississippi Region 07.

U.S. Army Corps of Engineers, Engineering and Construction Bulletin (ECB) 2016-25, Subject: Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, and Projects, 16 September 2016.