U.S. Army Corps of Engineers – St. Louis District

Geomorphology Study of the Middle Mississippi River

Supplemental report to Brauer, E.J., Busse, D.R., Strauser, C., Davinroy, R.D., Gordon, D.C., Brown, J.L., Myers, J.E., Rhoads, A.M., and Lamm, D. (2005) Geomorphology Study of the Middle Mississippi River. U.S. Army Corps of Engineers, Prepared for Mississippi River Stakeholders, 43 p.

Brauer, E.J., Davinroy, R.D., Briggs, L., Fisher, D.

Background

This document is a supplement to Brauer et al 2005, "Geomorphology Study of the Middle Mississippi River". In Brauer et al 2005 measurements of physical dimensions of the Middle Mississippi River were measured to determine geomorphologic changes that have occurred throughout the period of record. These changes include average river width, average channel width, channel length, sinuosity, number of islands, total and average island area, surface area, wetted bank and cumulative side channel length. The time periods studied were 1817, 1866, 1881, 1928 and 2003.

Brauer et al 2005 also provides a history of the study reach, navigation structure construction, physical attributes of the study reach, and an analysis of previous geomorphology studies. Therefore this will not be covered in this supplemental report.

Brauer et al 2005 documented the major changes that occurred on the Middle Mississippi River over the past two centuries. This supplemental report adds new data sets to better understand the timing of the changes which in turn will help develop cause and effect relationships. Maps, surveys and/or aerial photographs for the years 1908, 1956, 1968, 1976, 1986 and 2011 were georeferenced and measured for this additional study.

Available Surveys, Maps and Photos

The river planforms created for the years 1817, 1866, 1881, 1928 and 2003 in Brauer et al 2005 were imported and used in this analysis. The descriptions of the source data are as follows:

- 1817: United States Government Land Office (GLO) Surveys. State of Missouri surveyed in 1817, State of Illinois surveyed in 1820.
- 1866: "Maps of the Mississippi River from the Junction of the Minnesota to the Junction of the Ohio River in 22 sheets" produced under the direction of Bvt. Major General G.K. Warren, U.S. Army Corps of Engineers, St. Louis District, 1869.
- 1881: Detail Maps of the Upper Mississippi River from the Mouth of the Ohio River to Minneapolis, Minn published by the Mississippi River Commission.
- 1928: Aerial Survey Mississippi River between Missouri and Ohio Rivers, 1928-1929, Major John C. Gotwals, Corps of Engineers, U.S. Army District Engineer, St. Louis, Mo.
- 2003: Aerial Photos of the Mississippi River. Photos taken on 15 October 2003.

Additional maps used in this study were:

- 1908: Mississippi River from St. Louis, MO to Cairo, ILL. In 17 charts made under direction of the Board on Examination and Survey of Mississippi River created by River and Harbor Act of March 2, 1907

- 1956: Hydrographic Survey Maps of the Mississippi River, Mouth of Ohio River Mile 0 to Mile 300. U.S. Army Engineer District, St. Louis, Corps of Engineers, St. Louis, Missouri. Surveyed and sounded between 1956-1959.
- 1968: Hydrographic Survey Maps of the Mississippi River, Mouth of Ohio River Mile 0 to Mile 300. U.S. Army Engineer District, St. Louis, Corps of Engineers, St. Louis, Missouri. Photos taken 4 March 1968.
- 1976: Hydrographic Survey maps of the Mississippi River, River Miles 0 to Mile 202. U.S. Army Engineer District, St. Louis. Photos taken 23 Jan 1976 – 28 Mar 1976
- 1986: Hydrographic Survey Maps of the Mississippi River, Mouth of Ohio River Mile 0 to Mile 300. U.S. Army Engineer District, St. Louis, Corps of Engineers, St. Louis, Missouri. Photos taken 16 September 1983.
- 2011: Orthophotos of the Mississippi River. Photos taken on 18 Nov- 3 Dec 2011.

Methodology

All surveys, maps and photos were digitized and georeferenced into a format that was compatible with ArcGIS. Most of the images were georeferenced using Bentley Microstation and IRAS-C. A polyline file was created and the banklines and islands were outlined for each separate data set. The island and bankline boundaries were determined from the location of vegetation. The bankline polyline was converted to a polygon.

Measurement locations were taken at 0.25 mile increments relative to the established river mile locations. The existing river mile shapefile was divided into 0.25 mile increments. Cross section lines were created for each data set at each measurement location using ArcGIS. The cross section lines were drawn perpendicular to the banklines. Once all of the cross section lines were drawn, the lines were clipped so only the segments of the cross sections that intersected the bankline polygon remained. The result was a set of cross sections spaced 0.25 miles apart that information about channel width, side channel width, and other information could be extracted.

After the cross sections were created, the length of the cross section polylines were calculated using the "calculate geometry" function in the attribute table. The data was then exported to excel.

Physical Changes

Planform Width

Average planform width is shown in Figure 1. The planform width represents the width of the planform from tree line to tree line. This width incorporates all channels, side channels, sandbars and islands. Each cross section was used to measure the average planform width taken perpendicular to the banklines. The average width for 1866 is only incorporated into the reach specific graphs since the survey did not cover River Miles 40-0.

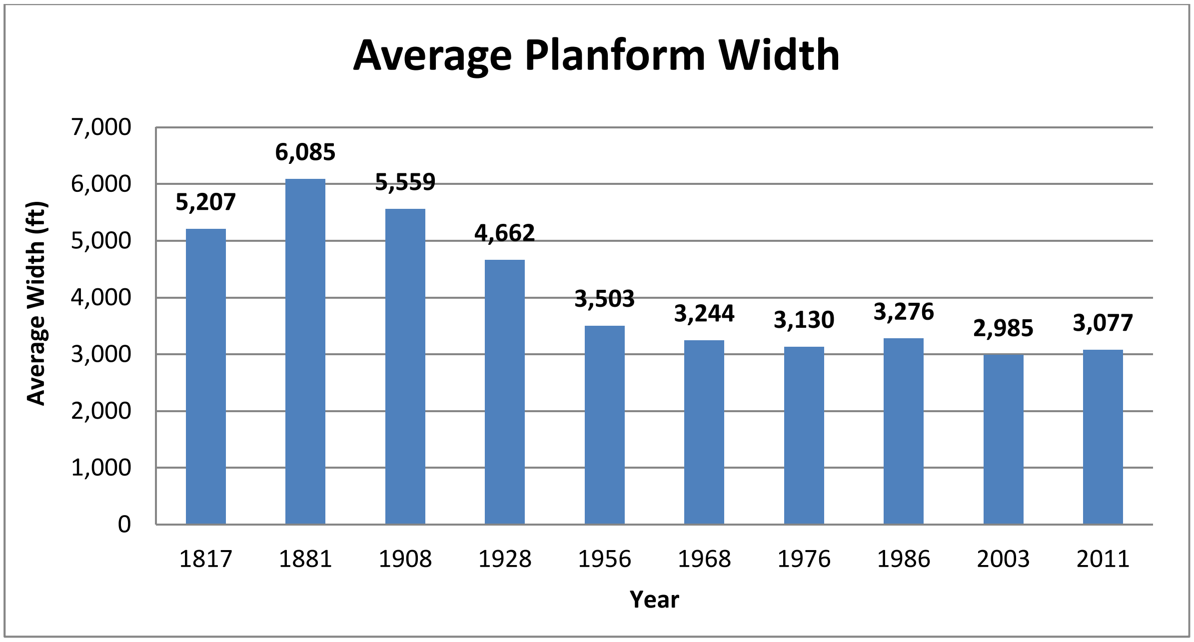

Figure 1: Average Planform Width

From 1817 to 1881 an increase in planform width of 877 feet occurred. With a few exceptions, there were no river stabilization measures or training structures on the Middle Mississippi River prior to 1879. The increase in planform was due to the river's response to changes along the bankline and in the river basin. These changes include clearing of bankline vegetation, changes in land use and changes in runoff (Brauer et al 2005, Heitmeyer 2008). The 1881 planform shows that the Middle Mississippi River became wider, shallower and more braided when compared to 1817.

An important note is that 1817 does not necessarily represent a virgin, "pre-man" condition. The Middle Mississippi River was used prior to 1817 by early settlers who established settlements along the river. 1817 simply represents the first spatially accurate survey of the entire Middle Mississippi River. By 1817, the Middle Mississippi River could have already been reacting to changes due to the alterations in the basin by the early settlers.

Figure 2 shows average planform widths broken down by river reach. A few locations decreased in planform width between 1817 and 1881. The St. Louis Harbor reach, between River Miles 180.0-170.25, saw a decrease in average width of 591 feet. Wilkinson Island, between River Miles 100.0 and 90.25, disappeared between 1866 and 1881 reducing the average planform width by 2,989 feet. Grand Tower Island also became part of the floodplain reducing the average planform width between River Miles 80-70.25 by 1,497 feet. The reaches between River Miles 20-10.25 and 10-2.5 saw reductions in average planform width of 1,156 and 759 feet respectively.

The reach with the most dramatic change in planform width was between River Miles 110.25-120.0 which increased in planform width by 11,859 feet. During the flood of April

1881, a major planform change occurred when the Mississippi River and Kaskaskia River meandered together. The Mississippi River captured the Kaskaskia River channel upstream of the confluence leaving the "old" Mississippi River channel to serve as a side channel. The land between the two rivers became a large island. This change decreased the length of the Mississippi River by 5 miles.

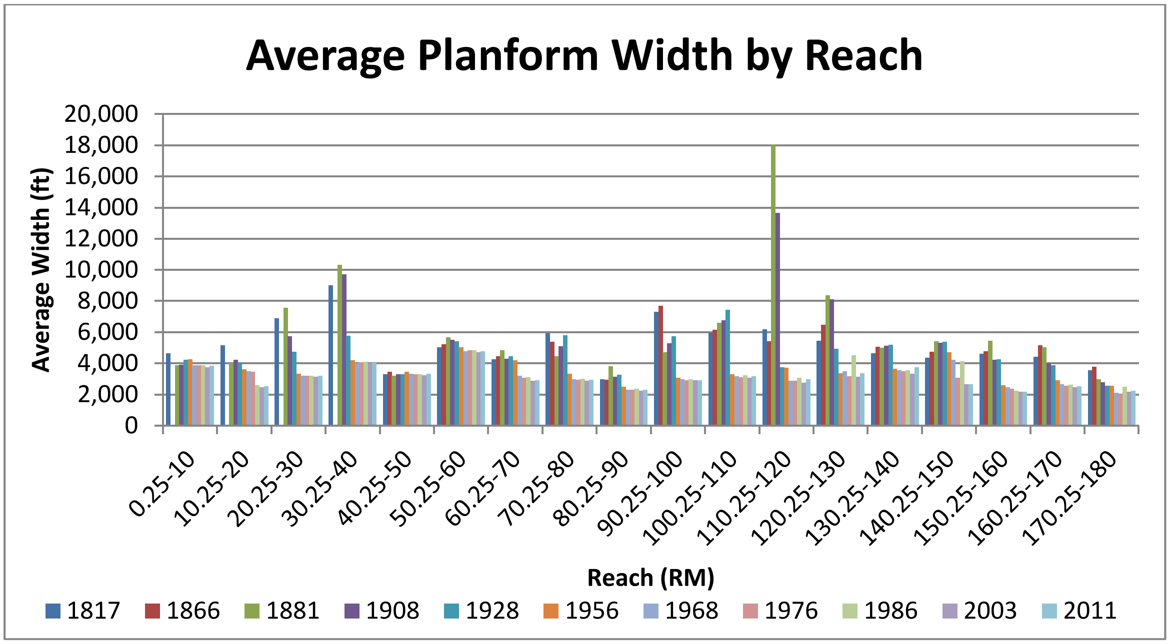

Figure 2: Average Planform Width by River Reach

The reach between River Miles 120.25 and 130 also experienced a notable increase in average planform width of 2,930 feet between 1817 and 1881. In this reach there was a steady increase both between 1817 and 1866 and 1866 and 1881 of 1,042 feet and 1,887 feet respectively.

Following the establishment of the Mississippi River Commission in 1879, a coordinated masterplan for navigation was created and widespread use of river training structures began. The first training structures were mainly permeable structures which focused the river's energy into the main channel by reducing the velocities between the structures, causing sediment to deposit. This sediment deposition caused a significant contractual effect on the channel. Between 1881 and 1908 the average planform width decreased by 526 feet. Dike construction during this period was mostly limited to the 70 river miles from St. Louis downstream.

Between 1908 and 1928 the average planform width decreased by 897 feet. The reach with the most reduction in average planform width was the Kaskaskia Island Reach, between River Miles 120.0 and 110.25, which decreased by 9,906 feet. Powers Island became part of the floodplain resulting in a decrease in average planform width of 3,940 feet between River

Miles 30.25 and 40.0. Between River Miles 20.25-30.0 the average planform width decreased by 3,940 feet. This is likely resulting from the instability of the Mississippi River following the capture of the Kaskaskia River. Wilbourne Island also became part of the floodplain reducing the planform width in the reach between 20.25 and 30.0.

In the time period between 1928 and 1956 a number of side channels disappeared resulting in a decrease in average planform area of 1,159 feet. The islands that were lost due to the side channel disappearances include Puckett Island, Grand Tower Island, Wilkinson Island, Baumstark Towhead and Turkey Island, Schmidts Island and Establishment Island, Griffith Island, Island at Price Towhead and an unnamed island located between River Miles 156-153.

Between 1956 and 1968 an island at Hamburg Landing disappeared which reduced the average planform width by 997 feet between River Miles 60.25-70.0. Throughout the rest of the Middle Mississippi River a slight reduction of planform width occurred. The average reduction in planform width of the other reaches was 259 feet.

In the 1960's, the Corps began constructing impermeable dikes primarily out of stone. The use of impermeable dikes reduced the rate of deposition between the structures when compared to the previously used permeable structures. Another change was the reduction of design elevation of the dike fields. Unlike in the past, the area between the structures didn't fill with sediment, grow vegetation and become part of the floodplain. In the 43 years between 1968 and 2011 the average planform width remained relatively steady with a net reduction in average planform width of 167 feet. This is the result of the change in structure material and elevation.

Channel and Side Channel Width

The planform width was a measure of the width of the entire planform including the main channel, side channels and islands. The creation and destruction of side channels had a great effect on the planform width (a good example is the Kaskaskia Reach). To have a fuller understanding of the effects of dike and revetment construction on the Middle Mississippi River it is more appropriate to look at changes in the main channel width.

From 1817 to 2011 the average main channel width decreased 1,032 feet from 3,358 feet to 2,326 feet. Between 1817 and 1881 the average main channel width increased by 385 feet. The increase in main channel width was relatively uniform throughout the entire Middle Mississippi River. However, some locations observed a decrease in average channel width. The largest decrease was between River Miles 170.25 – 180.0. The construction of dikes and revetment had already begun in this reach and are shown in the 1881 survey.

The construction of river training structures coincided with a constant decrease in average main channel width between 1881 and 1968. After 1968 the main channel width remained relatively steady. Although dikes continued to be constructed through 1968, the change in construction material and top elevation had an effect on the channel width. As discussed previously, impermeable structures do not cause as much deposition between the structures as their permeable predecessors. The lower crown elevation prevents vegetation from being sustained in the deposited sediment between the structures. The combination of the two prevents the dike field from being incorporated into the floodplain.

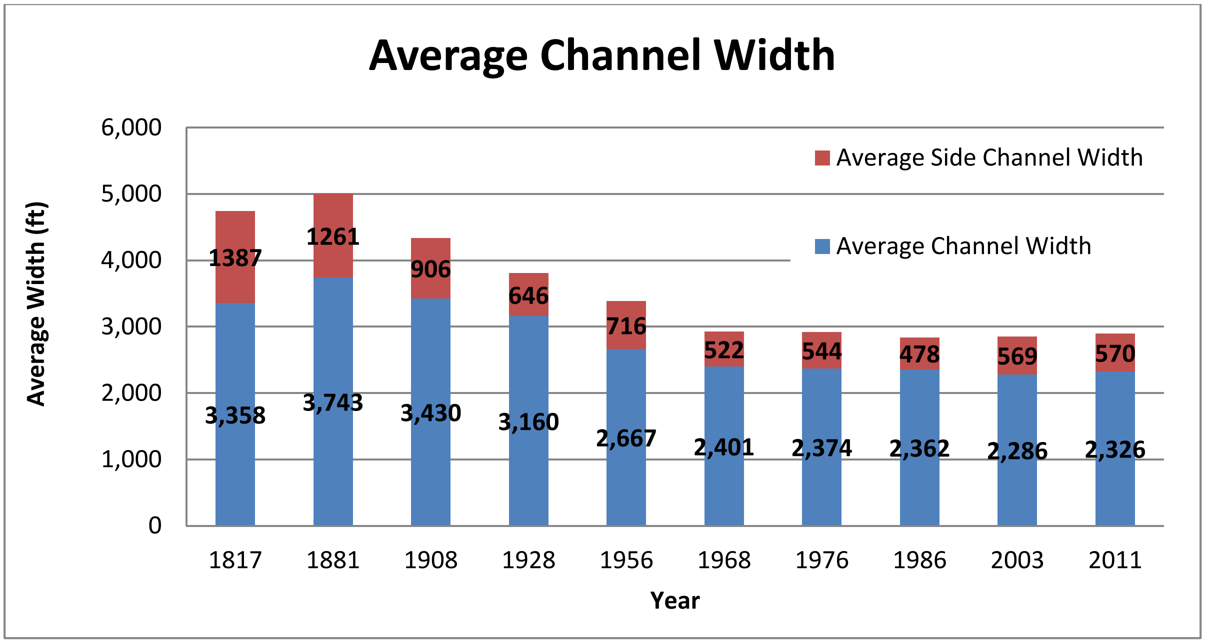

Figure 3: Average Channel Width

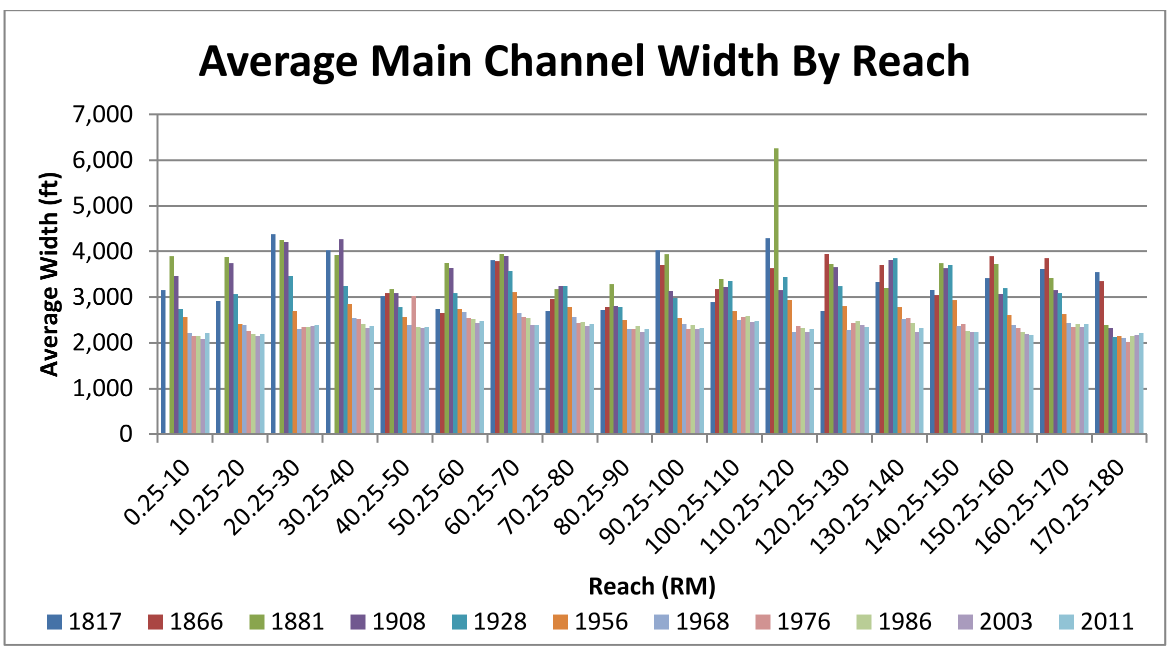

Figure 4: Average Main Channel Width by Reach

Another observation from Figure 4 is that the average main channel width has become more uniform on the Middle Mississippi River. The standard deviation between the reaches in 1817 was 577 feet, in 1881 it was 752 feet. In 2011 it was 96 feet.

Side Channel Changes

The average side channel width is shown in Figure 5. The average side channel width is difficult to interpret independently since it averages the widths of all of the existing side channels and does not directly account for the gain or loss of side channels over time. A more detailed analysis of side channels on the Middle Mississippi River by Tom Keevin and Erin Guntren is ongoing and will be available in the future.

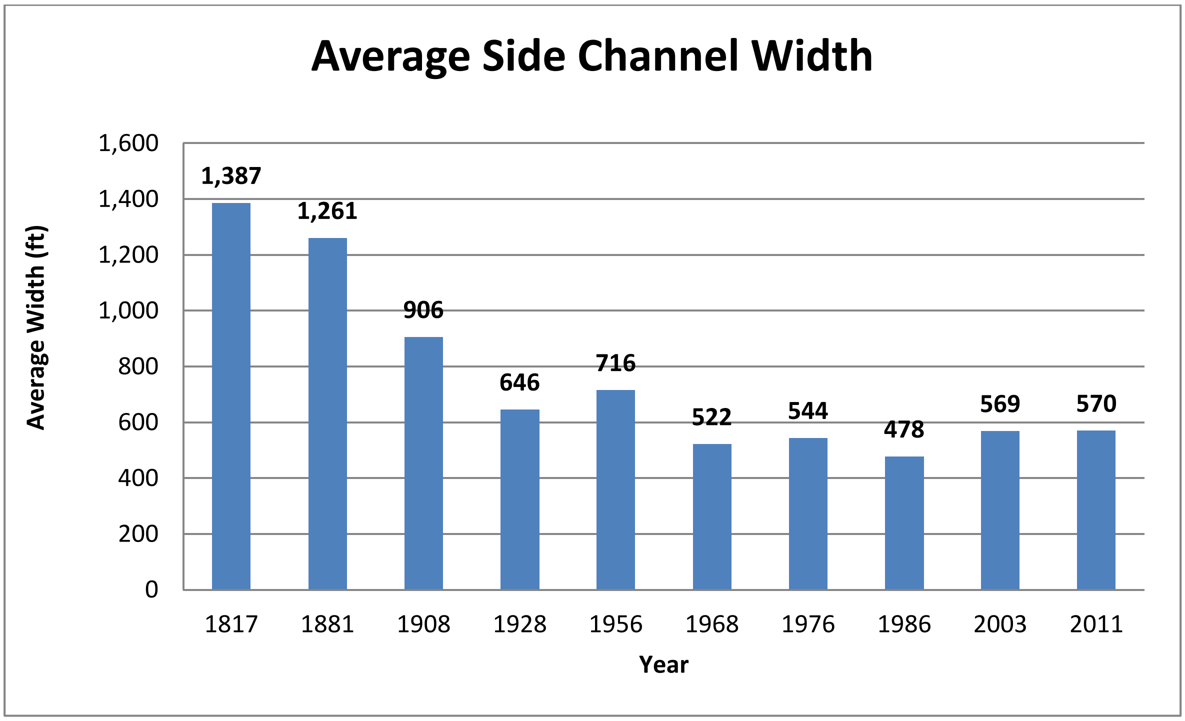

Figure 5: Average Side Channel Width

The average side channel width decreased steadily between 1817 and 1928. After a slight increase in 1956, it remained relatively constant until 2011. To help understand these trends it is necessary to understand the changes in cumulative side channel length. The larger average side channel width in 1817 was primarily due to the presence of split flows. The decrease in side channel width between 1817 and 1881 was due mostly to the increase in the number of smaller islands and the presence of a more braided channel. The braided channel had shorter, narrower side channels than what was present in 1817. Between 1968 and 2011 the average side channel width and cumulative side channel length remained relatively constant.

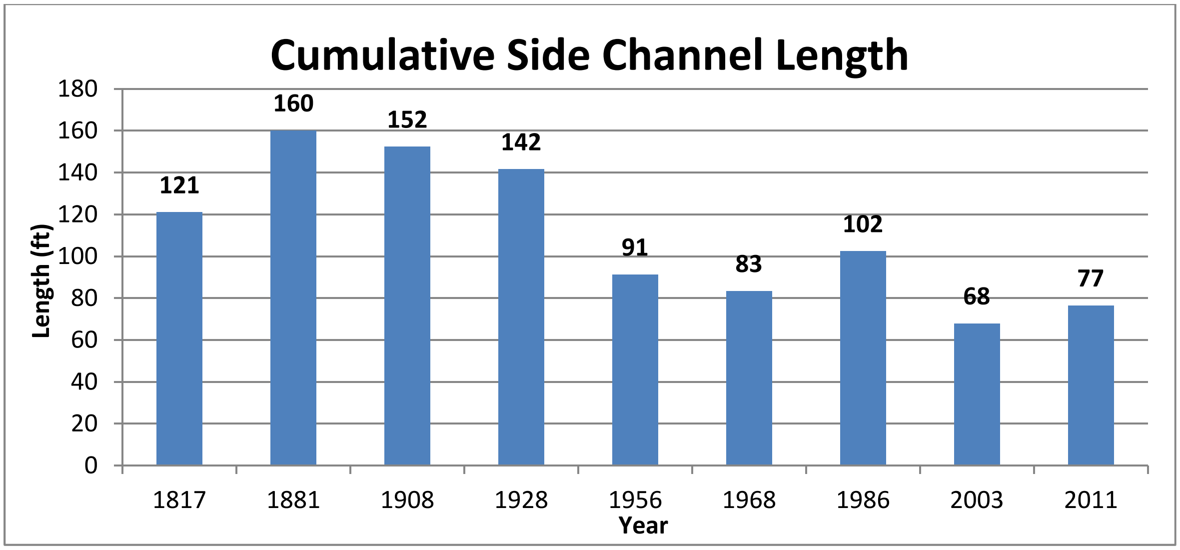

Figure 6: Cumulative Side Channel Length

The average side channel width was broken down into 10 mile river reaches in Figure 7. This figure helps identify changes in specific side channels.

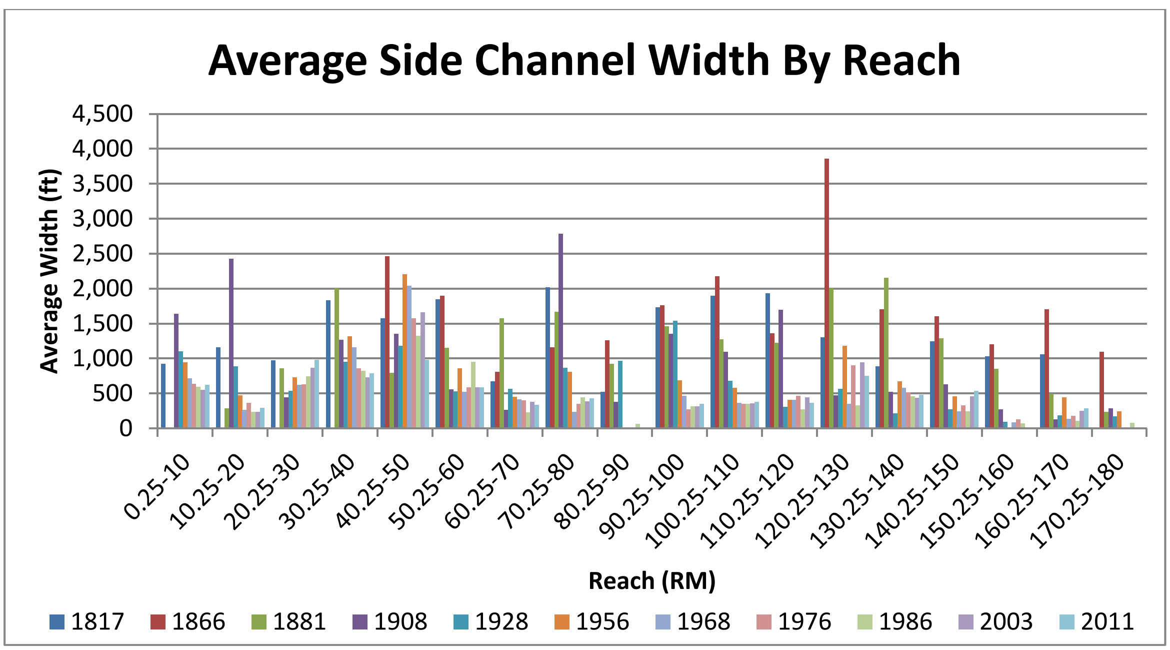

Figure 7: Average Side Channel Width by River Reach

Island Changes

The Island number and area were analyzed in this study (shown in Figures 8 and 9). Between 1817 and 1881 Kaskaskia Island was formed by the capture of the Kaskaskia River by the Mississippi River. This added approximately 25 square miles of island area to the Middle Mississippi River. The "old" Mississippi River channel was cut off from the main channel between 1908 and 1928, reducing the area of islands by 25 square miles. Since 1956 the island area has remained relatively constant.

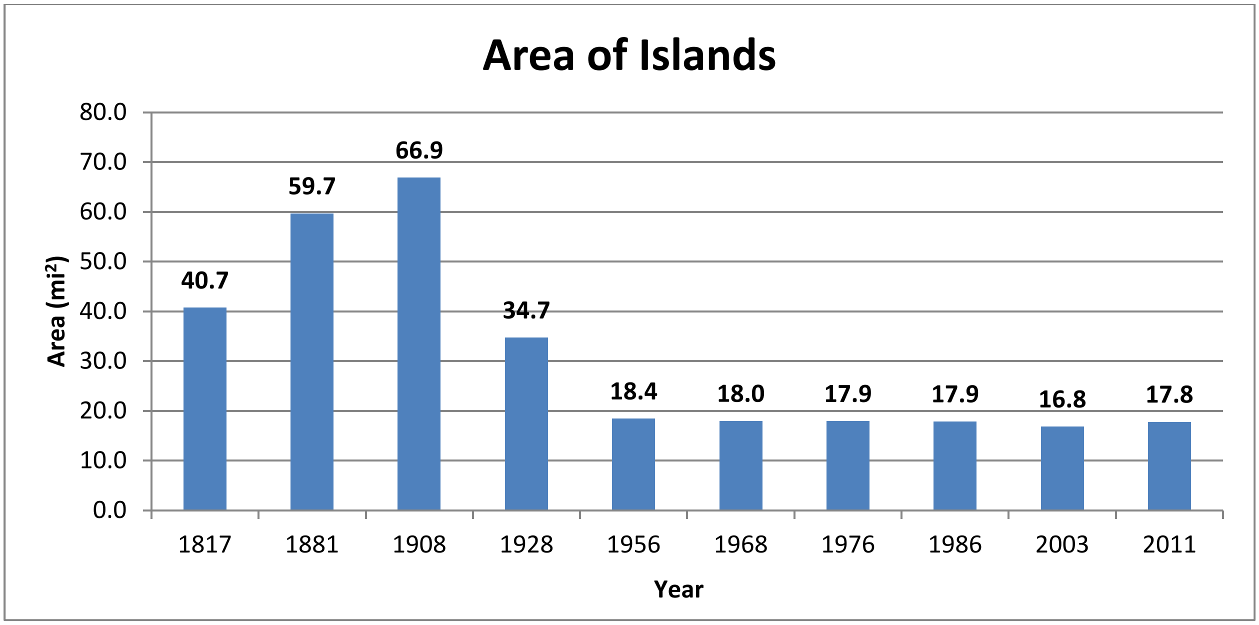

Figure 8: Area of Islands

There is some variability in the number of islands due to the definition of an island. An island was defined as a body of land surrounded by water that contained vegetation. Depending on the vegetation patterns, an island in one survey could be categorized by more than one island in another over the same area. Many early islands were dynamic in nature and evolved between a single land mass and a series of separate land masses.

Surface Area

The planform surface area is shown in Figure 10. This value was calculated by using the area calculation in ArcGIS on the planform polygon. The Kaskaskia Island Reach has the same effect on the planform surface area as it did on island area. The increase between 1817 and 1881 and the decrease between 1908 and 1928, are partially attributed to the addition and later subtraction of approximately 25 square miles of island. Another factor influencing the planform surface area was the loss of side channels and conversion of former side channels and deposition between dikes into vegetated floodplain. The planform surface area remained relatively constant after 1968. This is mainly due to the different structures used as described in previous sections.

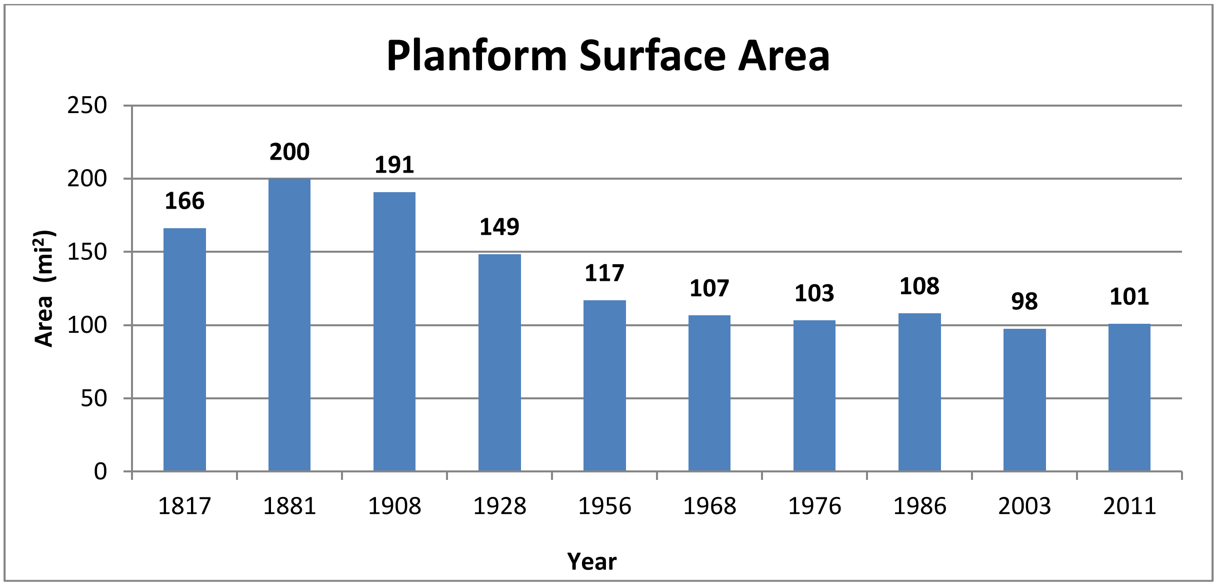

Figure 9: Planform Surface Area

Total channel surface area was calculated by subtracting the island area from the planform surface area. The surface area graph shows the same trends as the ones discussed in the average width section. Similar to the planform surface area the channel surface area has remained relatively constant since 1968.

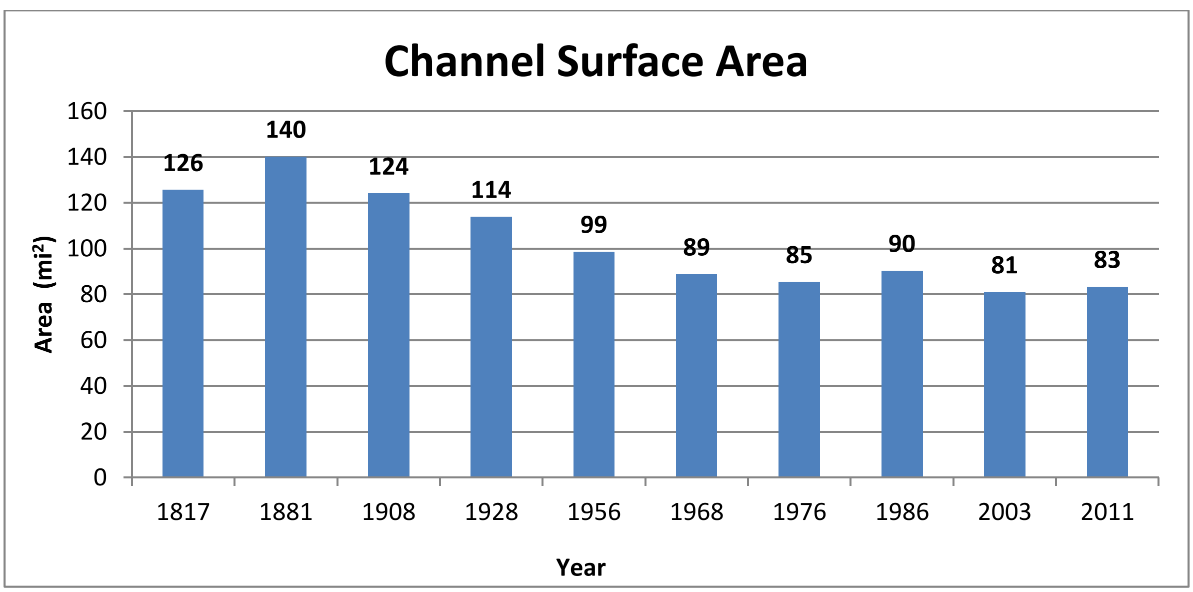

Figure 10: Channel Surface Area

Conclusions

Many changes have occurred on the Middle Mississippi River over time, both natural and man-made. Natural changes include the transformation to a braided channel in the late 1800's in response to the numerous hydrologic changes in the basin, the capture of the Kaskaskia River channel resulting in the decrease in length of the Middle Mississippi River and the creation and elimination of side channels and islands over the study period.

Manmade changes include the construction of levees which separated the river from its floodplain, the construction of navigation structures which stabilized the banklines and provided adequate depth for navigation, and bankline revetment which locked in the channel and prevented additional bankline erosion.

The manmade changes directly mirror the priorities and missions of the U.S. Army Corps of Engineers. In the time period between the late nineteenth century and early twentieth century, navigation and flood protection was the priority. Starting in the late 1960's to early 1970's, the focus shifted towards navigation and environmental projects which included notched dikes and the preservation of side channels.

The Corps' priorities are directly mirrored by the physical changes over time on the Middle Mississippi River. Major physical changes occurred between 1881 and 1968 in planform width, side channel width, side channel length, island area and surface area. Since 1968 the river appears to have reached a more stable state of dynamic equilibrium and the changes have been much more subtle. This equilibrium is partly the result of a change in design and construction material of navigation structures.