Geomorphic Changes Following Channel Modifications on the St. Francis River

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Extended Abstract

The Lower St. Francis River basin covers approximately 8,400 sq. miles in southeastern Missouri and northeastern Arkansas. Local stakeholders and the U.S. Army Corps of Engineers (USACE) have completed significant flood control and drainage improvements in the basin, including flow diversion of the Castor River, Wappapello Dam, a leveed floodway, channelization and meander cutoffs. The flow regime and sediment transport capacity of the St. Francis River has been significantly altered as a result of these anthropogenic changes. Portions of the Lower St. Francis River within the leveed floodway are heavily aggradational which has caused tree die-offs, debris jams, and standing water during low-flow conditions. The Memphis District USACE constructed a 5.5-mile drainage channel below Arkansas Highway 90 (near Kennett, MO) to provide drainage for the year-round ponded water on the floodway levees. The channel was designed to be cleaned out on a regular maintenance schedule every 5-years and is a difficult task due to frequent high water in the reach. The channel cleanout typically takes 2-3 years and by the end of the construction period, the channel typically fills back in. In addition to the channel blockage, the levees on both sides of the river have experienced seepage issues due to standing water requiring the construction of relief wells and seepage berms. The channel blockage has diverted flow through old borrow pits near the toe of the levee creating scour and requiring rock protection. Between the channel cleanout, seepage berms, relief wells, and scour protection millions of dollars have been invested in this reach within the last several years.

Prior to flood control and drainage improvements made in the early 1900s, the Lower St. Francis Basin had a long history of frequent flooding due to backwater events from the Mississippi River and headwater events from the St. Francis, Mississippi, and Castor Rivers. These frequent floods and the flat terrain of the area created uninhabitable swampland throughout the majority of the Lower St. Francis Basin (USACE 1949). Local drainage districts and logging industries developed a major drainage improvement plan at the turn of the 20th century. To address flooding problems, Congress authorized the USACE Memphis District (MVM) to develop a comprehensive flood control plan in 1936.

Since the flood control plan was developed, USACE MVM has completed significant flood control improvements, including the construction of Wappapello Dam in 1941, levee construction and improvements from 1938-1948, the Wilhelmina Cutoff in 1967, other channelizations from 1964-1973 and the below Hwy 90 drainage channel and sediment trap in 2000. By 1972, following the completion of the Wilhemina cutoff and other channelization, downstream landowners began to report crop losses and other permanent damages due to increased flooding and sedimentation. This initiated a large-scale sediment study and sediment data collection effort for the basin. As a result of the sediment study, a legal determination was made that the federal government had induced flooding and sanding damages (increased deposition) in the river reach between Dekyn's Store and Brown's Ferry with the construction of Wilhelmina Cutoff in 1982. Since then, numerous channel cleanouts (sediment removal), scour repairs, and seepage remediation measures have been completed within the study reach.

Figure 1. Location of study area with gage locations.

The primary objective of this study was to take a comprehensive look at in the 105-mi reach of the St. Francis River below Wappapello Dam to identify sources of sediment to the below Hwy 90 (Holly Island) reach (Figure 1). This study reflects the integration of two efforts funded by the Regional Sediment Management (RSM) program (Enlow et.al, 2020 and Girdner et.al, 2021). Analyses of available gage, survey, LiDAR data, and historical research, have given an understanding of geomorphic trends and river stability. Types of analysis used to determine stage trends included: yearly low stage plots, stage-duration curves, specific gage analysis, water surface slopes, and stream power changes. A list of gages used for analysis can be found in Table 1 and locations are shown in Figure 1. Concurrently, this effort included field reconnaissance and the collection of bed samples and bank samples to help characterize the bed sediment and streambank soils within the study reach.

Table 1. List of gages used for specific gage analysis

Gage ID	Location	River mile	Contributing drainage area (sq mi)	Stage period of record	Discharge period of record
SF114	St. Francis at Iron Bridge	211.9	1,311	1920–1994	1936–Present
SF115	St. Francis at Fisk	202.1	1,370	1917–present	1935–present
SF116	St. Francis at Dekyn's Store	168.3	1,690	1933–Present	1969–1977
SF117	St. Francis at St. Francis	158.4	1,772	1892–Present	1917–present
SF118	St. Francis at Brown's Ferry	152.4	1,776	1916–present	N/A
SF119	St. Francis at Holly Island	139.6	1,787	1935–present	1933–1945
SF123	St. Francis at Lake City	104.1	2,374	1916–present	1917–present

The results from all analyses were synthesized to develop an overall assessment of the study reach. Aerial imagery analysis showed a 28-mile reduction in channel length for the study area between 1966 and 1975 and a significant reduction in sinuosity.

The period of record was divided into three time periods to summarize the results: pre-cutoff (before 1970), post-cutoff (1970-2000), and modern or current time period (2000-2019). Based on visual interpretation of the stage-discharge relationships, yearly low stage plots, and stage duration analysis, a qualitative classification of a decreasing, increasing, or stable trend was assigned to each location (Figure 2). Prior to the widespread channelization, the three upstream gages (i.e., SF114, SF115, and SF116) exhibited a slightly decreasing trend or stable trend for all analyses. Below Crowley's Ridge (SF117), a more pronounced decreasing trend was observed, indicating degradation was occurring prior to the channelization. Local interests were likely altering the channel prior to USACE involvement. Increasing trends occurring at the two downstream gages indicate aggradation.

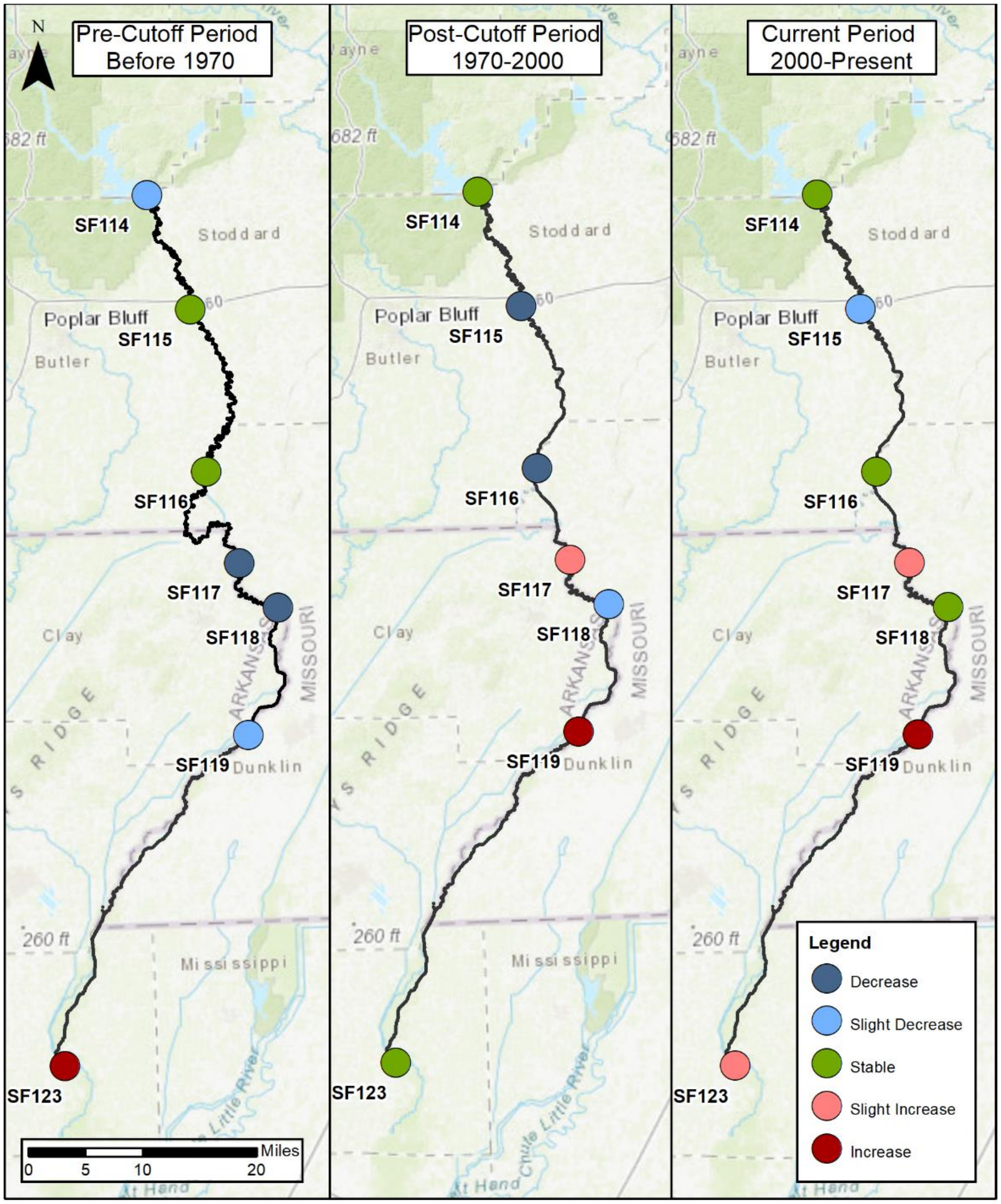

Figure 2. Specific gage trends at each gage location by time period. Blue indicates channel degradation, red indicates aggradation, and green a stable trend.

In the post-cutoff period, a dramatic decrease in stages was observed at SF115 and SF116 (approximately 8-10 ft), which suggests incision in these reaches following channelization. SF117 showed a slightly increasing trend in stages and likely some aggradation. Downstream of Crowley's Ridge, at SF118, degradation was still occurring and increasing stages at SF119 indicate aggradation became a problem. In the current time period, the stage trends began to stabilize at SF115, SF116, and SF118, although slight decreasing trends in stage were still noticeable for SF115 and SF116. Strong increasing trends were still observed at SF119, indicating this reach has a continual tendency to aggrade. Stages at SF114 were mostly stable throughout the period of record. This indicates that the effects of the Wappapello Dam construction and Wilhelmina Cutoff were very minor. However, the two gages downstream of SF114 showed dramatic decreasing trends in stages after channelization.

The authorized channel profile from the original flood control plan was compared with more recent channel surveys (1998 and 2017) and historic geotechnical borings from the banks. The channel profile comparison corroborated the result from the specific gage analysis in Figure 2. The authorized channel was intended to remain above the sand stratum to prevent maintenance issues, however the channel profile and boring comparison indicates the channel has cut into the sand stratum between SF115 and SF117. Borings predominantly show a 10 – 20 ft. layer of clay and silts overlying sand in this reach.

Bed sediment samples collected on the St. Francis River between Iron Bridge and Holly Island show that the St. Francis River consists of a poorly sorted sand-bed. Bank samples indicate most of the study area is comprised of silts and clays which was supported by historic borings and visual classification during field reconnaissance. In reaches that experienced significant degradation (between SF115 and SF116), a sand layer was observed under the silt/clay layer, which was also supported by the soil boring and channel profile comparison.

The results from this study will aid identifying sources of sediment and inform future management of the Lower St. Francis River basin. A deeper understanding of the geomorphic and fluvial processes occurring in the St. Francis basin is vital for evaluating future management practices that incorporate a holistic view of the watershed and a proactive approach. Future analysis will include the development of a sediment budget to further identify sources of sediment to the Below Highway 90 reach.

References

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