Rates and processes of sedimentation in two USACE reservoirs

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Extended Abstract

Reservoir sedimentation is a critical issue because it reduces water storage capacity and downstream delivery of sediment to coastal environments. Aggradation of sand and gravel deltas at the upstream ends of impoundments, a common aspect of reservoir sedimentation, has implications for flood risk and infrastructure. These deltas are also interesting for understanding the processes of fluvial response to base-level rise. We seek to compare the processes observed in modern systems with observations of legacy sedimentation associated with dams built 150-300 years ago (e.g., Merritts et al. 2011). We study sedimentation in two USACE reservoirs: Lewis and Clark Lake in South Dakota and Nebraska, and Lake Seminole in Georgia and Florida. Both are the result of dams completed in 1957 (Gavins Point Dam and Jim Woodruff Dam, respectively) and both exhibit active progradation of deltas since that time.

Based on analysis of orthorectified aerial photographs, the Missouri River delta in Lewis and Clark Lake prograded at rates of 0.32 km^2/year in 1973-1993 and 0.42 km^2/year in 1993-2018 (Figure 1). The sand-bedded Niobrara River, which joins the Missouri River just upstream of the reservoir, supplies ~55% of the sediment to the reservoir (West Consultants, 2013). Based on analysis of USACE surveys (West Consultants, 2013), base level has risen at the mouth of the Niobrara River at 30 mm/year, with deposition of an alluvial fan and infilling of the valley. This sedimentation was a factor in the relocation of the town of Niobrara in the mid-1970s, and construction of a new highway bridge in 2021. By 2019, measurable aggradation reached at least 14 km upstream from the mouth (Figures 2-3), highlighting the long distance that the effects of dams can propagate into river networks (e.g., Volke et al., 2019). We find that slope of the Niobrara River has decreased linearly over the study period (Figure 3). This result is consistent with expectations from a simple one-dimensional model for the response of an alluvial river to rising base level (Parker, 2004; Parker et al., 2004). The process of aggradation in the mainstem of the Missouri River causing aggradation and channel flattening in the Niobrara River valley is consistent with observations of tributaries upstream of historical milldams in the mid-Atlantic region by Merritts et al. (2011).

On Lake Seminole, we investigate sedimentation rates and processes in two arms of the reservoir that correspond to the two major tributaries of the Apalachicola River. The mouth of the Chattahoochee River has a large subaerial delta composed of sand, with two active lobes at present. Sediment cores collected in April 2022 capture the transition from bottomset mud to foreset sand as the delta front progrades. The Flint River does not show an obvious delta in Lake Seminole, and has an apparently lower sedimentation rate. In our ongoing work, we will be estimating reservoir sedimentation rates, measured through analysis of cores and remote-sensing data (including repeat lidar elevation and multibeam bathymetric surveys, and historical topographic maps and orthophotographs). We are also making Sr and Nd isotopic measurements from the reservoir sediment sampled in Lake Seminole, to explore provenance in relation to watershed land use and bedrock geology. Further, we are using several approaches to model sediment transport on the Chattahoochee River, as influenced by a series of dams, river management, and land-use changes in the watersheds.

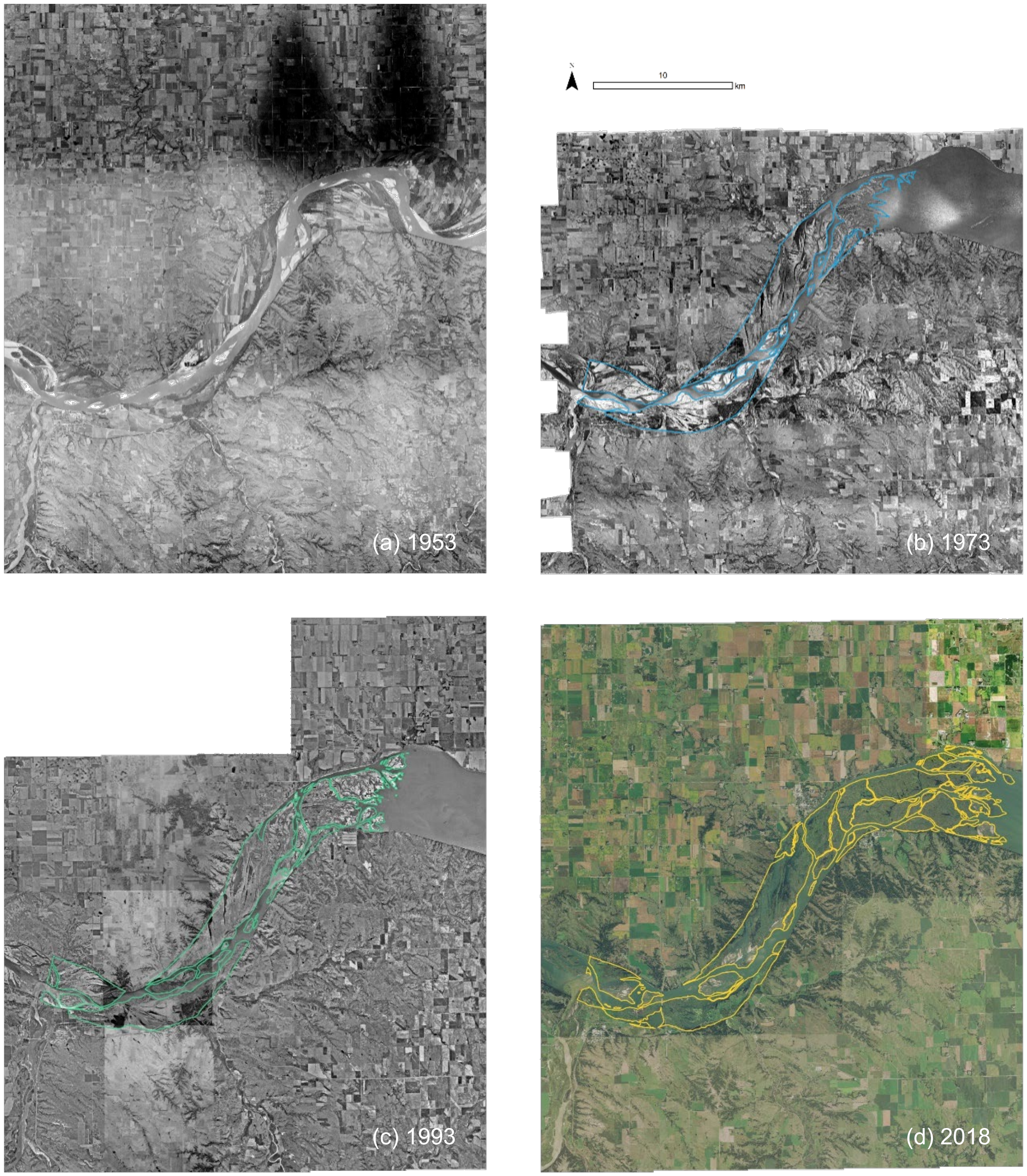

Figure 1. Orthophotographs of the Missouri River delta in Lewis and Clark Lake in (a) 1953 (pre-dam), (b) 1973, (c) 1993, and (d) 2018. The Niobrara River flows north into the Missouri River in the southwest corner of these images.

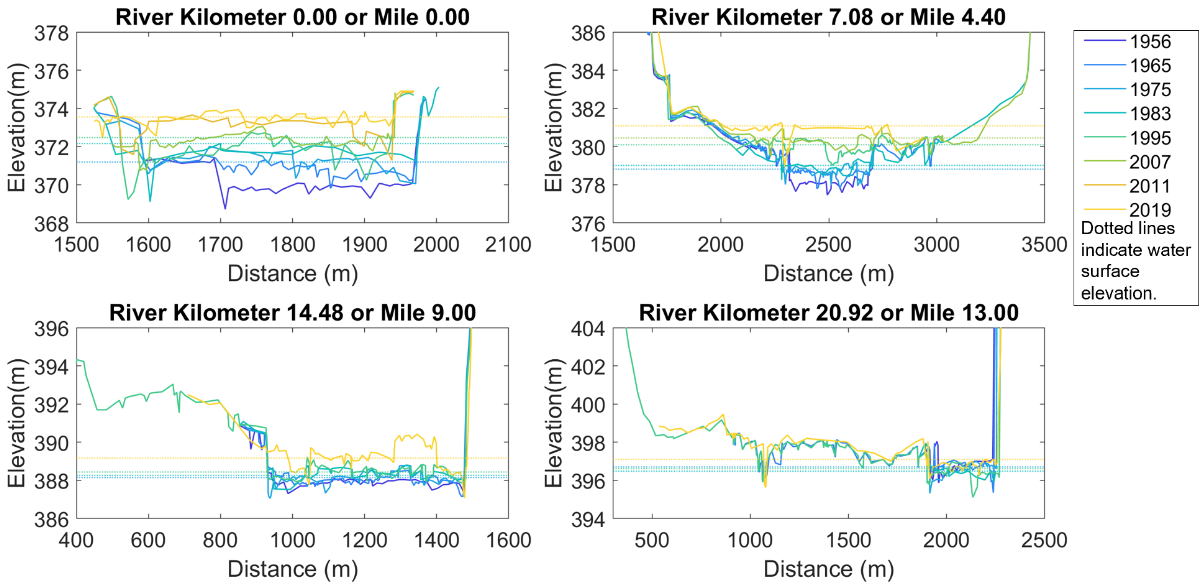

Figure 2. Examples of channel cross sections for select years. Over the 63 years, the channel bed aggraded approximately 2.6 m at the mouth, and 0.6 m at the cross section 14.5 km upstream. The farthest upstream cross section experienced fluctuations in aggradation and erosion during the study period.

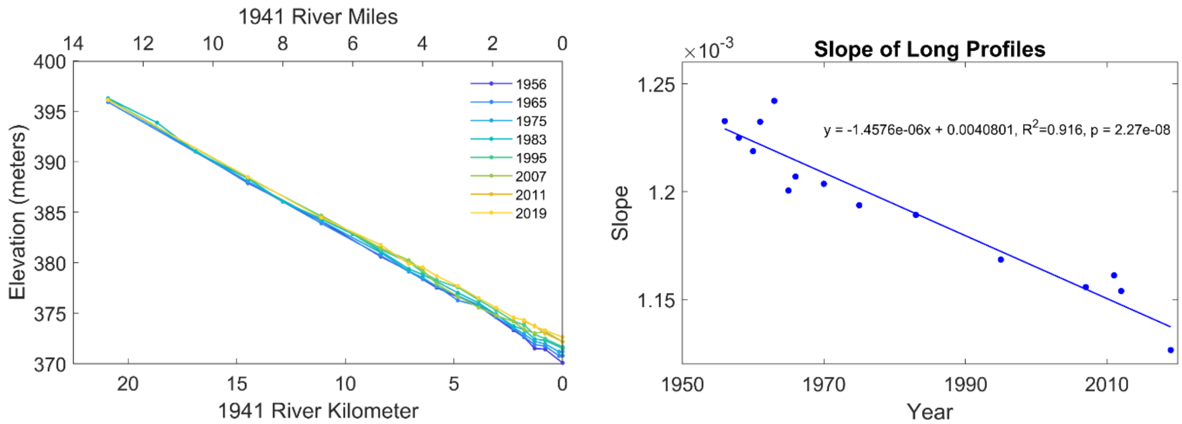

Figure 3. Left: Longitudinal profiles for select years calculated as the average bed elevation below the 2019 water surface at each cross section. Right: Slopes from linear regression of long profiles for each year. The channel slope decreased linearly from 0.00123 in 1956 to 0.00113 in 2019.

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