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Particle size distribution of main-channel-bed sediments along the upper Mississippi River, USA

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ABSTRACT

In this study, we compared pre-lock-and-dam (ca. 1925) with a modern longitudinal survey of main-channel-bed sediments along a 740-km segment of the upper Mississippi River (UMR) between Davenport, IA, and Cairo, IL. This comparison was undertaken to gain a better understanding of how bed sediments are distributed longitudinally and to assess change since the completion of the UMR lock and dam navigation system and Missouri River dams (i.e., mid-twentieth century). The comparison of the historic and modern longitudinal bed sediment surveys showed similar bed sediment sizes and distributions along the study segment with the majority (>90%) of bed sediment samples having a median diameter (D_{50}) of fine to coarse sand. The fine tail ($\leq D_{10}$) of the sediment size distributions was very fine to medium sand, and the coarse tail ($\geq D_{90}$) of sediment-size distribution was coarse sand to gravel. Coarsest sediments in both surveys were found within or immediately downstream of bedrock-floored reaches. Statistical analysis revealed that the particle-size distributions between the survey samples were statistically identical, suggesting no overall difference in main-channel-bed sediment-size distribution between 1925 and present. This was a surprising result given the magnitude of river engineering undertaken along the study segment over the past ~90 years. The absence of substantial differences in main-channel-bed-sediment size suggests that flow competencies within the highly engineered navigation channel today are similar to conditions within the less-engineered historic channel.

1. Introduction

The upper Mississippi River (UMR) and its major tributaries serve as important cultural, economic, and ecological resources for the United States. However, nearly 200 years of river engineering for the facilitation of commercial navigation, flood-risk mitigation, hydropower, and water supply have altered the hydrologic, hydraulic, and geomorphic processes along these rivers. Dams and other river engineering practices have substantially impacted the flow and sediment transport regimes along portions of the UMR and its major tributary, the Missouri River (Jacobson et al., 2009; Meade and Moody, 2010). Dam and river engineering-related changes in sediment transport and bedforms are often difficult to predict because of complex interactions between flow regime, sediment supply, and riparian vegetation (Jacobson et al., 2009). Given the magnitude of interaction between the flow regime, sediment regime, bank materials, channel slope, and riparian vegetation, the channel downstream of the dam may incise, aggrade, widen, narrow, stabilize, or increase its lateral erosion rate (Brandt, 2000; Grams and Schmidt, 2005; Schmidt and Wilcock, 2008). Such changes may prompt subsequent changes in economic value or ecological health. For example, inundation of valley bottoms, alternations of in-channel habitat quality or quantity, and erosional threats to property and infrastructure may increase or decrease. Because of these potential impacts, dam and other river engineering-related changes to sediment transport are of concern to river managers and are a substantive constraint on river rehabilitation efforts (Harmar et al., 2005; Jacobson et al., 2009; Remo et al., 2013).

Along the Mississippi and Missouri rivers, water and suspended sediment discharge data have been collected at some gaging stations for over 50 years (Meade and Moody, 2010). However, the same is not true for bed sediment and/or bedload or data. Relatively little quantitative, systematically collected, bed sediment data (spatially or temporally) have been published for the Mississippi River. On the lower Mississippi River (LMR; i.e., confluence with the Ohio River to the Gulf of Mexico), there are two notable exceptions to the general absence of bed sediment data. These include (i) the seminal work of the Waterway Experiment Station (WES, 1935) that stands today as one of the most important empirical examples of downstream fining in large alluvial rivers (Leopold et al., 1964), and (ii) a follow-up study conducted by Nordin and Queen (1992) that aimed to assess potential changes in bed sediment characteristics of the LMR related to river engineering driven changes to water and sediment fluxes along this portion of the river.

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While the LMR has paired bed sediment studies (WES, 1935; Nordin and Queen, 1992) to assess longitudinal and temporal changes in bed sediment size and character, no similar comparative bed sediment assessments exist for the UMR (the Mississippi River upstream of the Ohio River confluence). However, we have recently rediscovered a little-known 1925 study by Dr. Alfred Lugn in the Special Collections

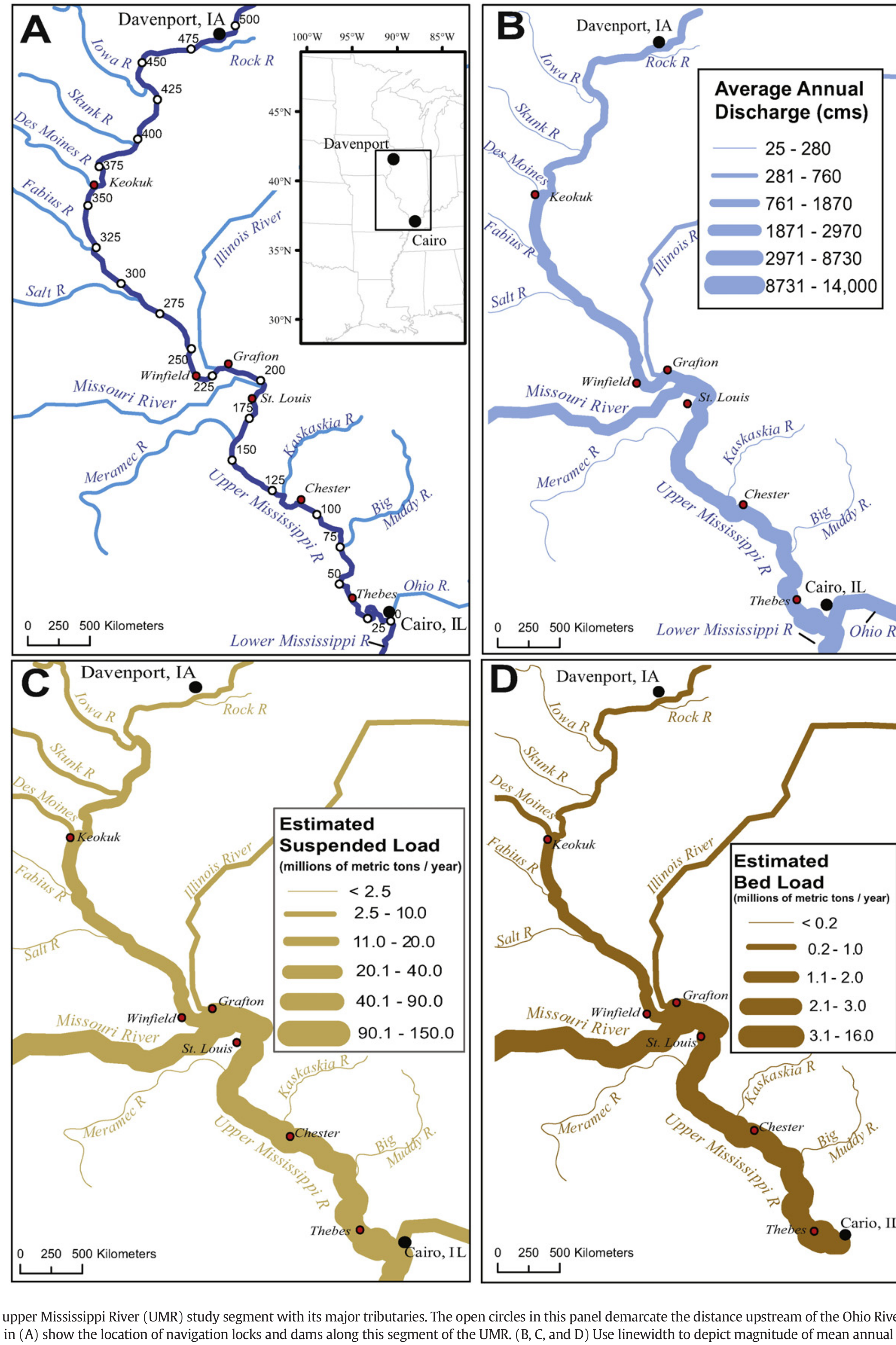

Fig. 1. (A) The upper Mississippi River (UMR) study segment with its major tributaries. The open circles in this panel demarcate the distance upstream of the Ohio River confluence. The black triangles in (A) show the location of navigation locks and dams along this segment of the UMR. (B, C, and D) Use linewidth to depict magnitude of mean annual discharge (WEST, 2000; Benke and Cushing, 2011), mean annual suspended load, and mean annual bedload (Nakato, 1981; WEST, 2000), respectively, along the UMR and its principal tributaries.