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Sediment and nutrient trapping as a result of a temporary Mississippi River floodplain restoration: The Morganza Spillway during the 2011 Mississippi River Flood

Daniel E. Kroes [a,*], Edward R. Schenk [b,c], Gregory B. Noe [b], Adam J. Benthem [b]

[a] U.S. Geological Survey, Louisiana Water Science Center, 3535 S Sherwood Forest Blvd, Suite 120, Baton Rouge, LA 70817, United States
[b] U.S. Geological Survey, National Research Program, 12201 Sunrise Valley Dr, MS 430, Reston, VA 20164, United States
[c] National Park Service, 17 S Entrance Rd, Grand Canyon, AZ 86023, United States

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ABSTRACT

The 2011 Mississippi River Flood resulted in the opening of the Morganza Spillway for the second time since its construction in 1954 releasing 7.6 km^3 of water through agricultural and forested lands in the Morganza Floodway and into the Atchafalaya River Basin. This volume, released over 54 days, represented 5.5% of the Mississippi River (M.R.) discharge and 14% of the total discharge through the Atchafalaya River Basin (A.R.B.) during the Spillway operation and 1.1% of the M.R. and 3.3% of the A.R.B. 2011 water year discharge. During the release, 1.03 teragrams (Tg) of sediment was deposited on the Morganza Forebay and Floodway and 0.26 Tg was eroded from behind the Spillway structure. The majority of deposition (86 %) occurred in the Forebay (upstream of the structure) and within 4 km downstream of the Spillway structure with minor deposition on the rest of the Floodway. There was a net deposition of 26×10^{-4} Tg of N and 5.36×10^{-4} Tg of P, during the diversion, that was equivalent to 0.17% N and 0.33% P of the 2011 annual M.R. load. Median deposited sediment particle size at the start of the Forebay was 13 μm and decreased to 2 μm 15 km downstream of the Spillway structure. Minimal accretion was found greater than 4 km downstream of the structure suggesting the potential for greater sediment and nutrient trapping in the Floodway. However, because of the large areas involved, substantial sediment mass was deposited even at distances greater than 30 km. Sediment and nutrient deposition on the Morganza Floodway was limited because suspended sediment was quickly deposited along the flowpath and not refreshed by incremental water exchanges between the Atchafalaya River (A.R.) and the Floodway. Sediment and nutrient trapping could have been greater and more evenly distributed if additional locations of hydraulic input from and outputs to the A.R. (connectivity) were added.

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1. Introduction

Levee construction along the Mississippi River (the Mississippi) has restricted sediment and nutrient deposition to the area predominantly within its levees, a small fraction of its historic floodplain. The artificial disconnection of the river from its floodplain outside of the levees has exacerbated eutrophication problems in the Gulf of Mexico by limiting the trapping of nitrogen (N) and phosphorus (P) in the river system (Mitsch et al., 2001). In addition, levees have prevented the distribution of sediment across the vast marshes and low swamps of the lower reaches of the Mississippi River Delta contributing to wetland loss (Snedden et al., 2007; Blum and Roberts, 2009; Schaffer et al., 2009).

The Mississippi and Missouri River Floods of 1993 resulted in several levee breaches, spawning numerous propositions for large scale floodplain restoration by levee removal or changing the placement of levees. Models of the effects on nutrient reduction to the Gulf of Mexico were created (Galat et al., 1998; Lane et al., 2003; Mitsch et al., 2009; Opperman et al., 2009). Gergel et al. (2005) modeled different hydrologic scenarios including lakes and leveed rivers as well as natural floodplains. They found that short, frequent floods processed more NO_3 than long infrequent floods. Zhang and Mitsch (2007) found that breaching levees along the Olentangy River, OH resulted in increased deposition of sediment and the associated nutrients. Kroes and Hupp (2010) found that if flood frequency and duration were not affected, frequent levee breaches along the channelized Pocomoke River, MD resulted in

* Corresponding author. Tel.: +1 2252985481X3134.
E-mail address: dkroes@usgs.gov (D.E. Kroes).

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similar sediment deposition between natural and breached levee reaches. Florsheim and Mount (2002) monitored substantial deposition as sand splays from levee breaches along the Cosumnes River, CA. Kronvang et al. (2009) measured sediment and phosphorous retention along restored portions of the Odense River, Denmark. Wolf et al. (2013) showed that connectivity with streams enhanced nitrogen removal in created wetlands.

The study of the effects of floodplain restoration along smaller streams is fairly common. However, restoration studies along large rivers are not common because the restoration of large floodplain areas is fairly rare as a result of the logistics, cost, and uncertainty of benefits. Mitsch et al. (2001, 2005) have suggested that to reduce nutrient loading to the Gulf of Mexico by 40%, there would need to be approximately 21,000–52,000 km^2 of floodplain restoration.

Along larger rivers the volume of transported sediment is considerably higher, and when flow is restored, much greater masses of sediment and their associated nutrients are transported to the floodplain and potentially deposited. However, because the floodplains of large rivers are often vast, there can be order of magnitude spatial heterogeneity in sediment and nutrient trapping, ranging from meters to less than a millimeter of deposition or erosion.

One common theory of floodplain restoration is that if the hydrology is restored most restoration goals will be met (Junk et al., 1989; Lammens and Marteijn, 1992). Hydrologic restoration can be challenging to assess because the duration of flooding is only one variable that may influence material trapping and does not infer connectivity. For the purposes of this study, connectivity refers to the similarity of physical and chemical properties (suspended sediment and nutrients) of water at a point on the floodplain in relation to the adjacent river water. Perfect connectivity would infer no difference between the properties of the water at the point on the floodplain and the river and is achieved by there being no flow resistance or time lag between the two. As flow resistance increases and physical and chemical processes accumulate over time and space between the points, the water properties become increasingly dissimilar until a particular constituent could be considered disconnected from the source. Flow rates, depth, sediment load, vegetation, distance from the river (via flow path) and numerous other factors interact to affect the volume of water

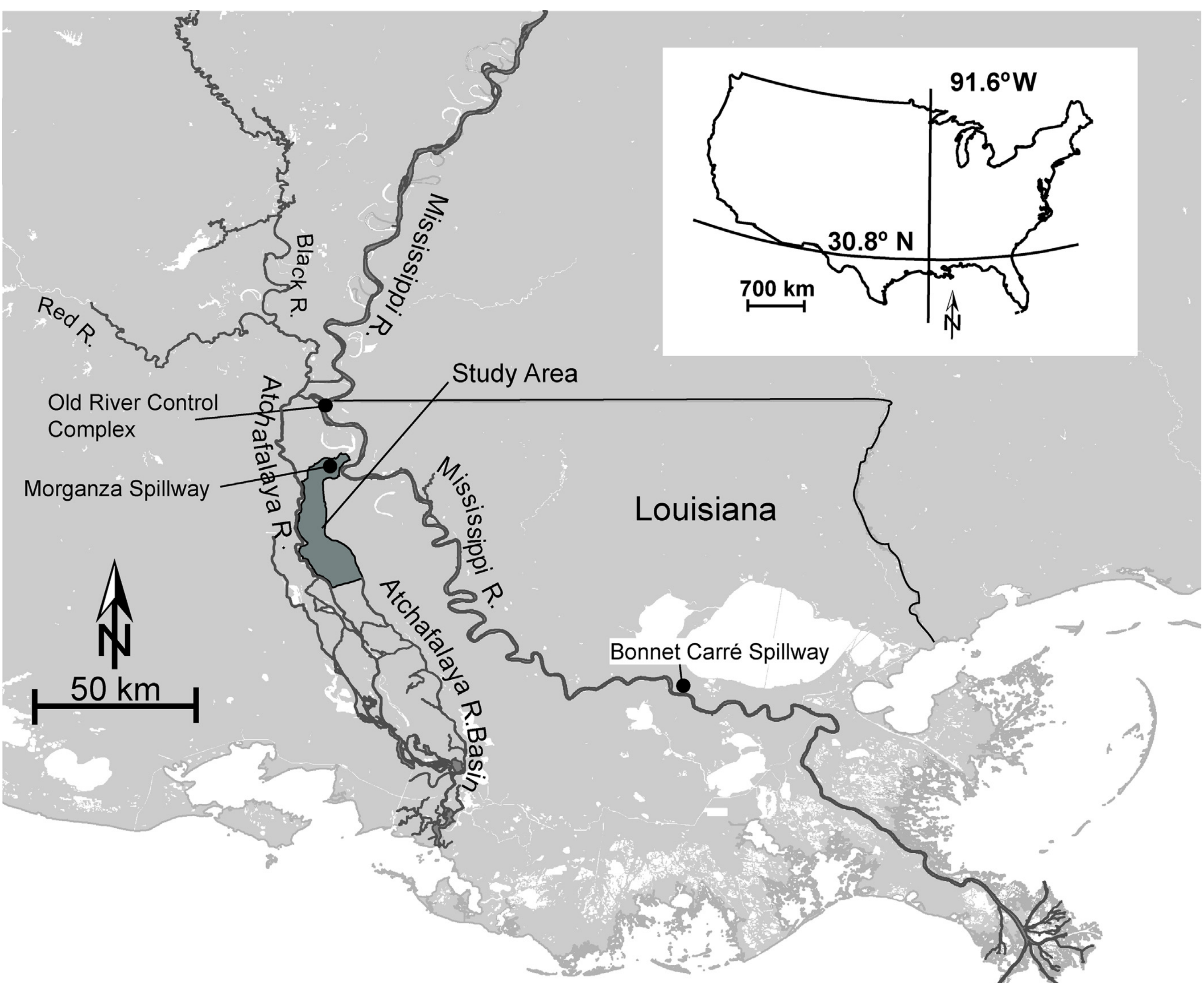

Fig. 1. The study area and locations of constructed diversions. The Old River Control Complex that controls flow from the Mississippi River into the Atchafalaya River is composed of three structures. The Morganza Spillway is an overbank type floodgate located at approximately N 30.8° W 91.6°.