Sediment and nutrient deposition over a reconnected floodplain during large-scale river diversions, the Bonnet Carré spillway in 2011, 2016, and 2019.

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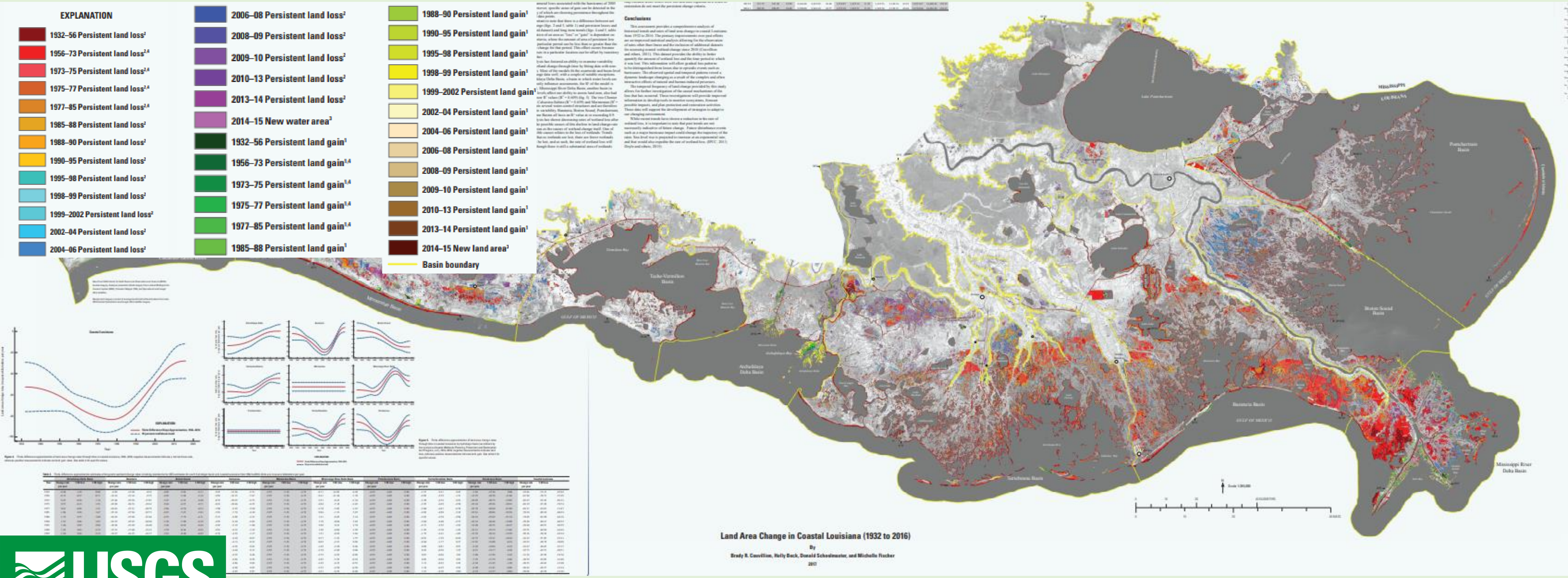
Photo by Cameron Alexander

Subsidence and rising sea levels are resulting in the submergence, degradation, and conversion of coastal and low lying marshes and forests. In addition to this, a dead zone forms annually in the Gulf due to excessive nutrient delivery from the Mississippi River. Many restoration projects focus on diverting water and sediment into areas of the Mississippi River delta in Louisiana, that are subaqueous portions of the floodplain. The depositional effects of these can be difficult to quantify. We examined a large subaerial flood diversion to create sediment and nutrient depositional curves for application elsewhere and in future diversion operation.



Couvillion et al. 2017

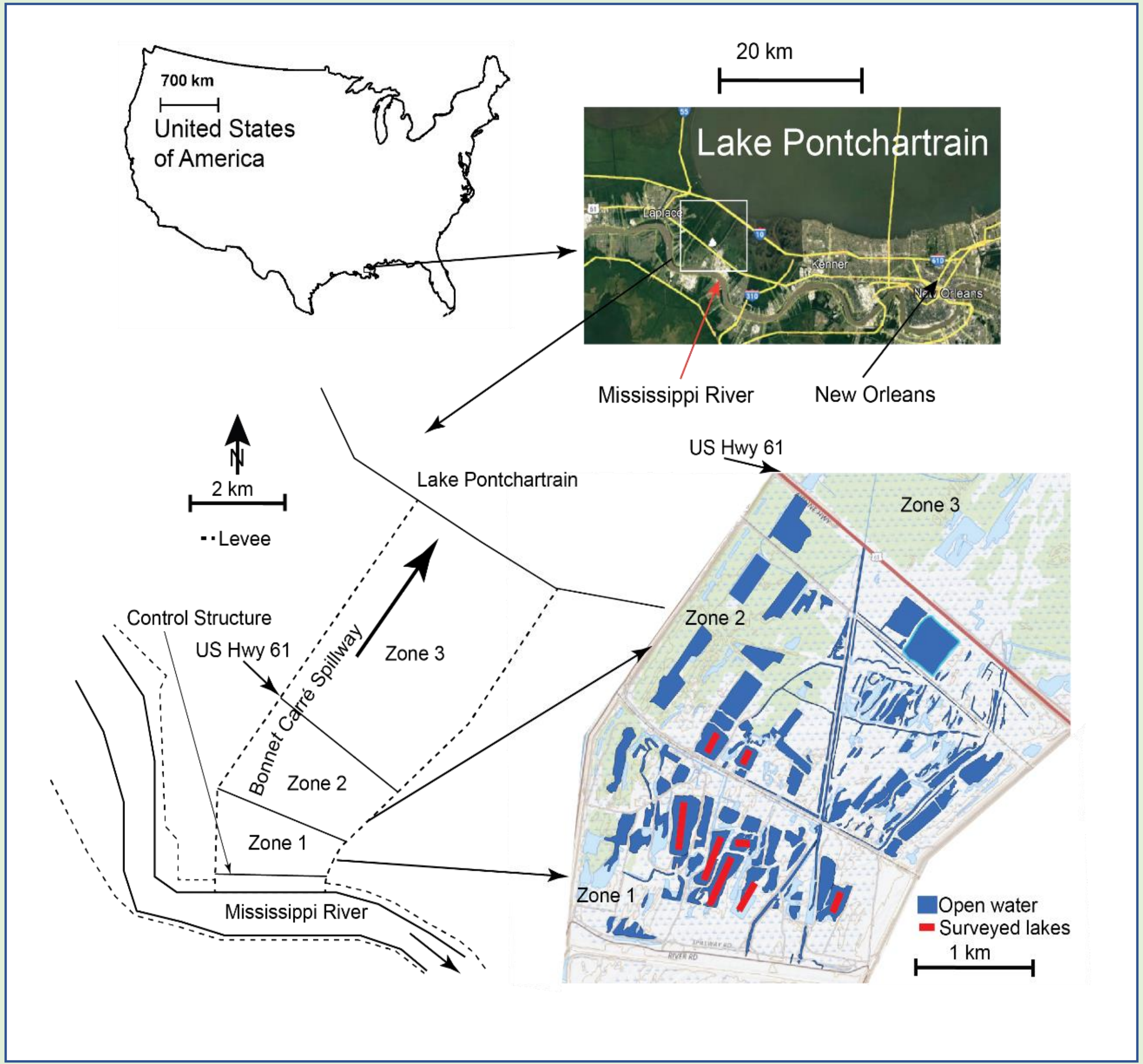
The Bonnet Carré Spillway was constructed in 1931 on the footprint of four naturally forming crevasses that formed from 1849 to 1882 between the Mississippi River and Lake Pontchartrain. This Spillway is part of a comprehensive flood control plan designated in the 1928 Flood Control Act of May 15, 1928, ensuring that the River doesn't exceed the design capacity of the channel at New Orleans, 1,250,000 ft^3/sec, by diverting excess flow to Lake Pontchartrain. When activated, flow crosses a 28 km^2 spillway area before entering the Lake, depositing sediment and nutrients.

Bonnet Carre' Openings

Year	Opening Date	# of days open	# of bays	max flow
1937	30-January	48	285	211,000
1945	23-March	57	350	318,000
1950	10-February	38	350	223,000
1973	8-April	75	350	195,000
1975	14-April	13	225	110,000
1979	18-April	45	350	191,000
1983	20-May	35	350	268,000
1997	17-March	31	298	243,000
2008	11-April	31	160	160,000
2011	9-May	42	330	316,000
2016	10-January	22	210	203,000
2018	8-March	22	183	196,000
2019	27-February	44	206	213,000
2019	10-May	78	168	163,000
2020	3-Apr	28	90	81,000

USACE, 2020

The Bonnet Carré Spillway Is located approximately 50 km upstream of New Orleans between the Mississippi River and Lake Pontchartrain. The Spillway is actively mined for sand and levee materials.



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The Spillway is 2.1 km wide and is opened by removing an assortment of the 7000 timber needles that limit flow through high and low sill bays. It has a designed discharge capacity of 7080 m^3/sec

Photos by Cameron Alexander

Photo by Dennis Demcheck

Discharge, suspended sediment (SSC), and nutrient concentrations were sampled midway down the Spillway at US Highway 61

Photo by Dennis Demcheck

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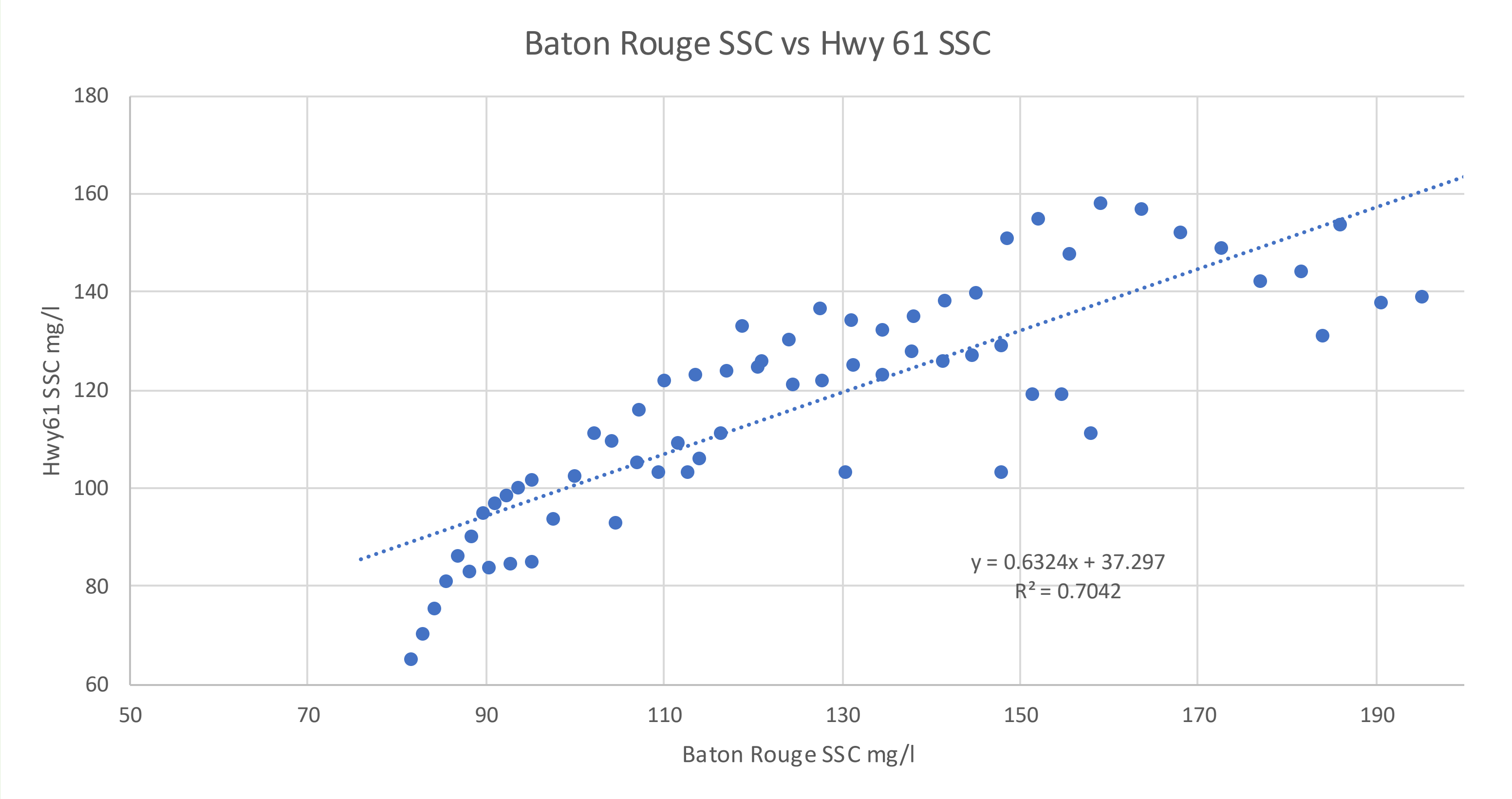
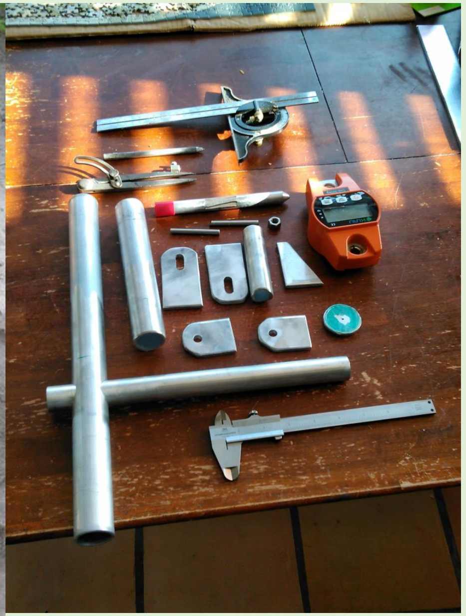
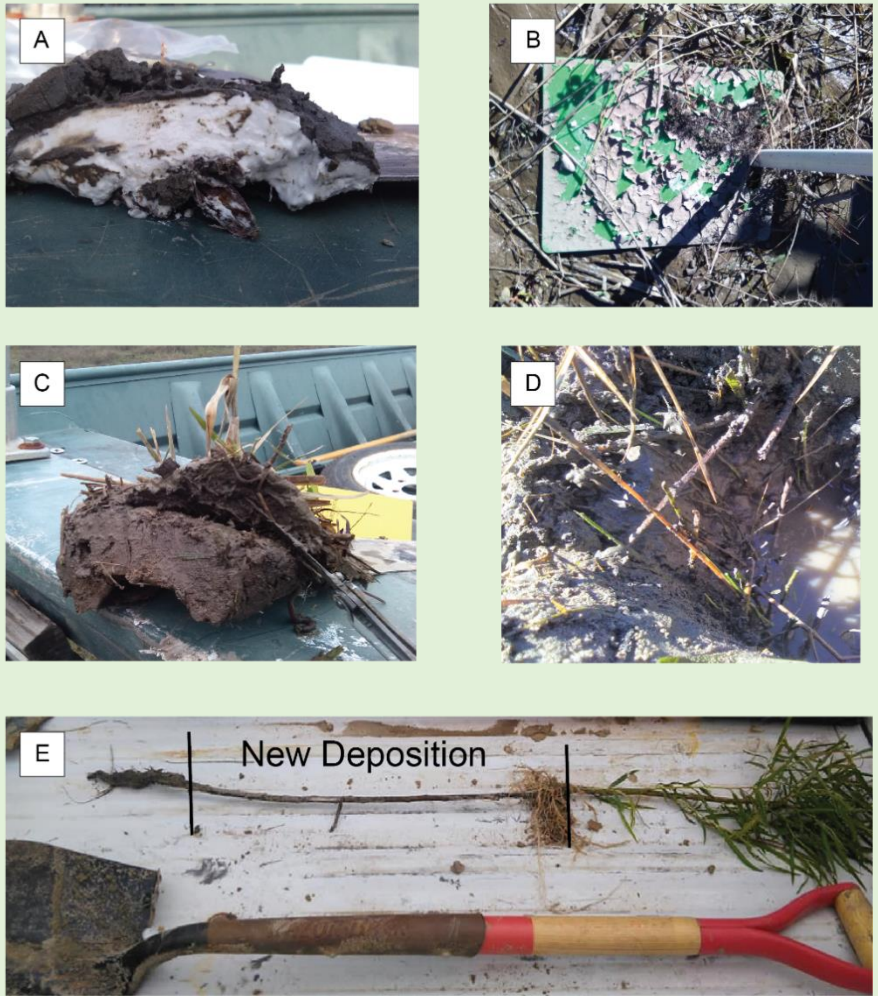
A suspended sediment relationship was developed between Baton Rouge SSC and US Highway 61 SSC from all previous sampling efforts.



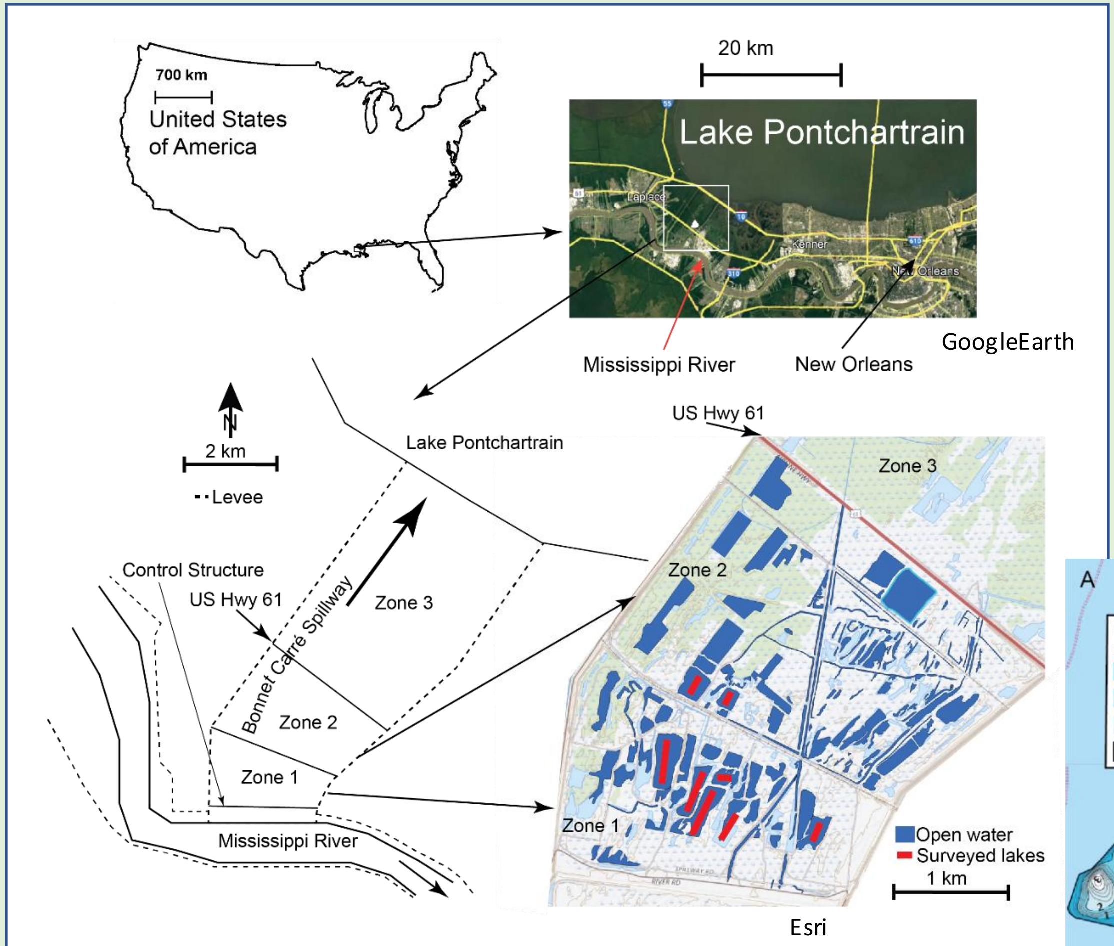
Measurement of deposition: Marker horizons were deployed prior to Spillway opening in 2016 and 2019. A variety of natural markers were also utilized.



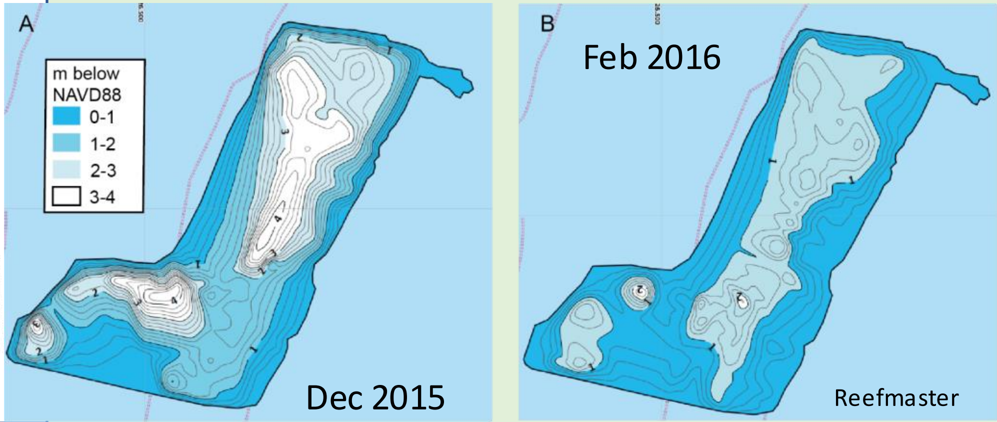
Photos by Dan Kroes



Measurement of lake deposition A subset of lakes were single beam sonar surveyed in 2015-16 and a relationship of deposition around those lakes to deposition within the lakes was developed for Zones 1 and 2.

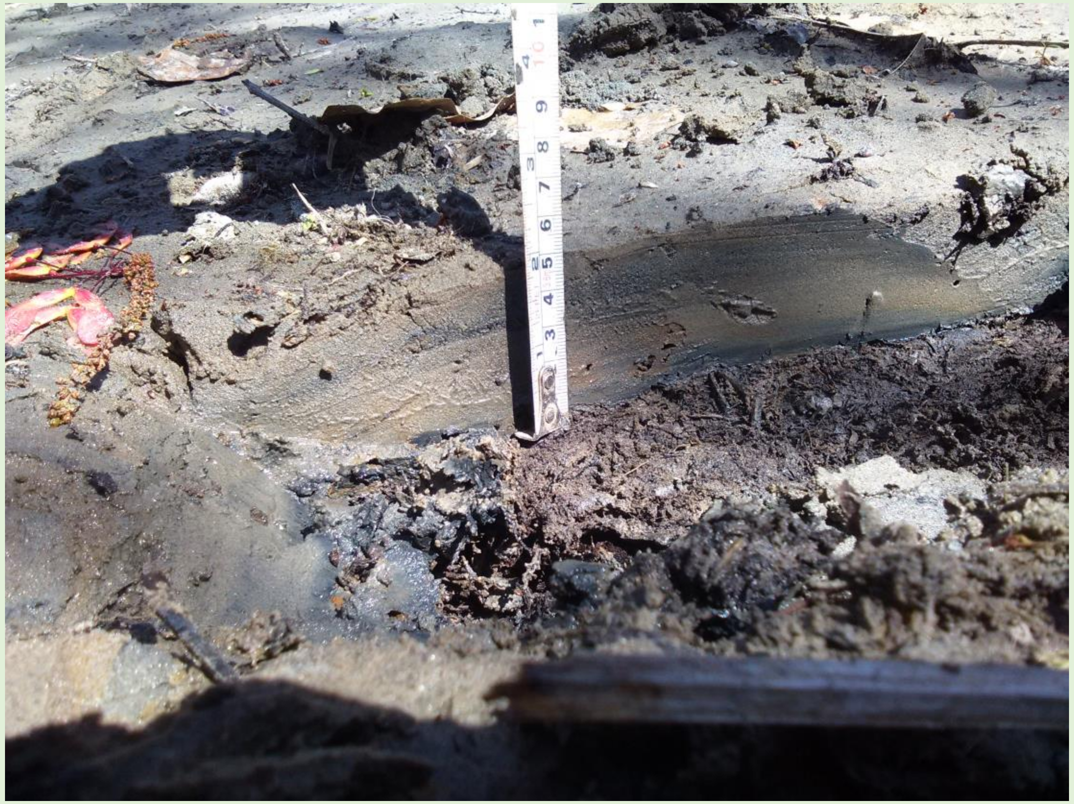


Preliminary information-subject to revision. Not for citation or distribution.



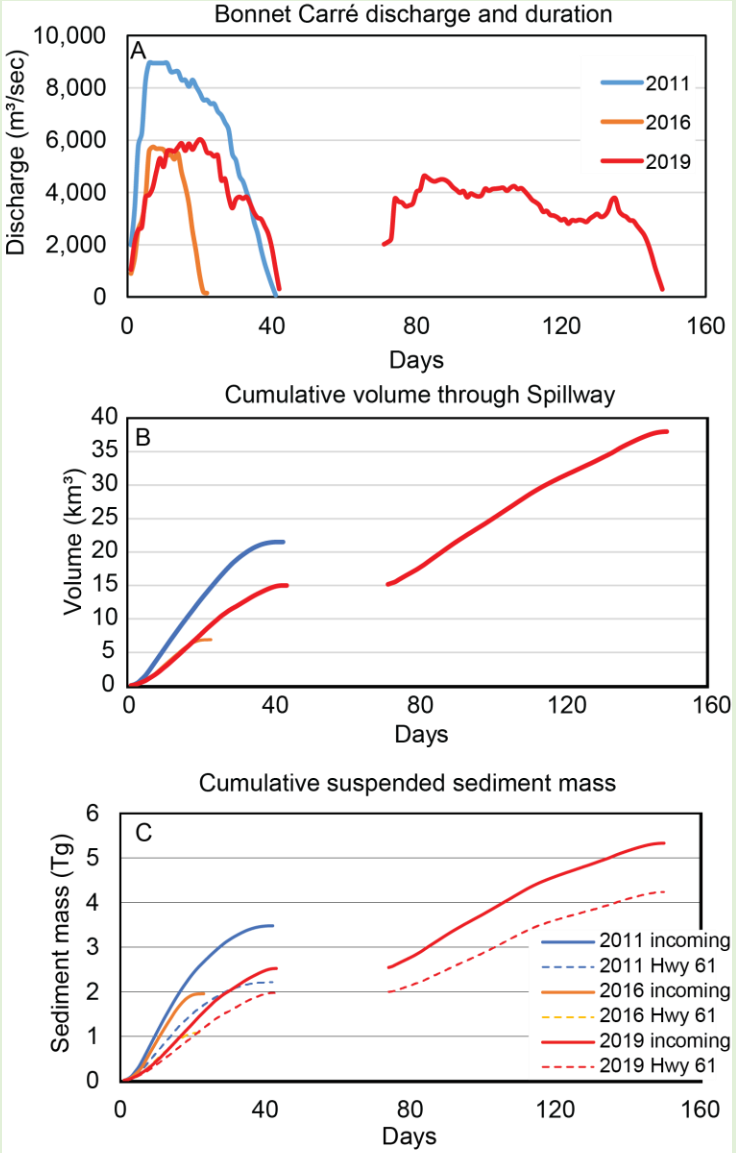
Photos by Dan Kroes

Deposited sediment was sampled and analyzed for particle size and nutrient concentrations (carbon, nitrogen, and phosphorous) and compared to SSC and nutrient concentrations in the Mississippi River at Belle Chase, La.
Deposited sediment nutrient concentrations were compared with nutrient concentrations from the Mississippi River bed and suspended sediments to determine the relative contribution of each source.



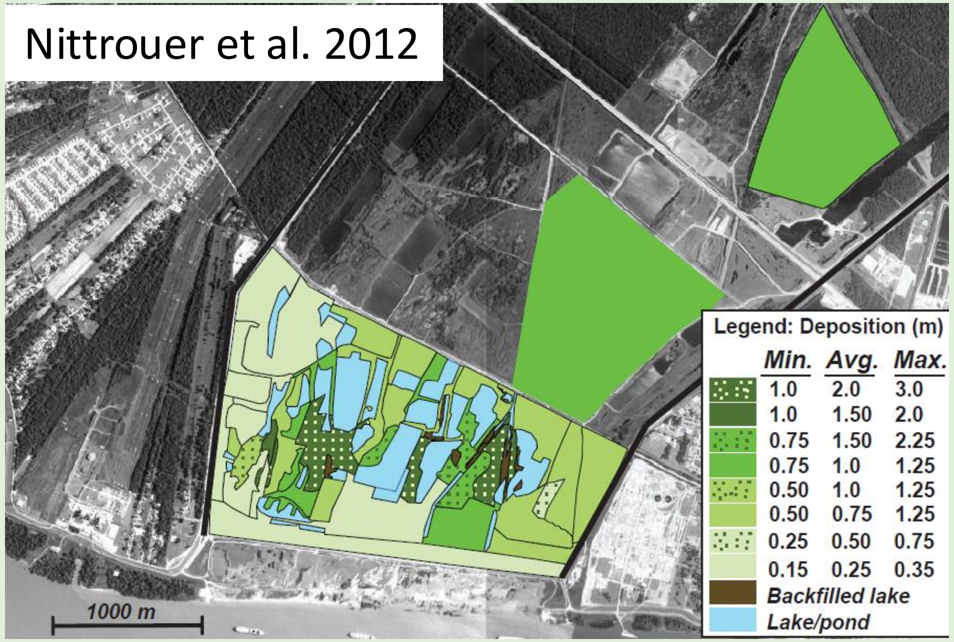
Photos by Dan Kroes

Results: The 2019 operation of the Spillway was the longest and largest opening by volume in its history passing 38 km^3 of river water and 5.4 Tg of the suspended sediment load. Maximum discharge was observed during the 2011 opening, but due to lower SSC in the River and lower total water volume, less transport of the suspended river load to the Spillway occurred.



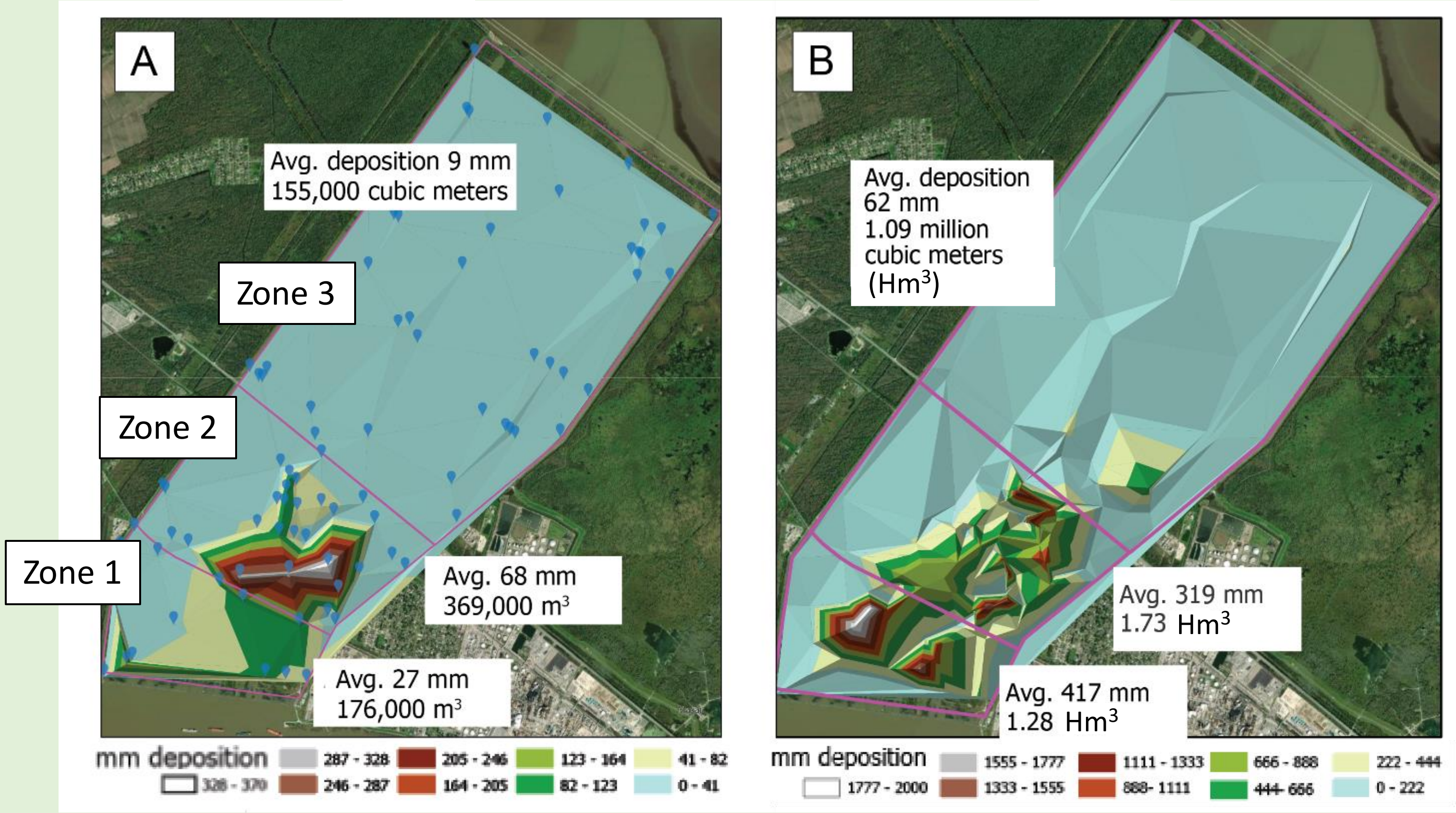
Sediment deposition patterns during the 2011 and 2019 operations were similar, while surface deposition in 2016 was relatively minor. The low 2016 deposition in Zone 1 indicated that Zone 2 deposition may occur first and provide resistance to flow. This process facilitated massive deposition in 2019 Zone 1 under similar flow conditions as 2016. Deposition pattens indicated clear flow preference to established channels in Zone 3, as well as across the corners toward the central drainage at the Lake end of the Spillway. Turbulence caused by bridge pilings between zones caused reduced deposition down-spillway of those structures.

2011



2016

2019



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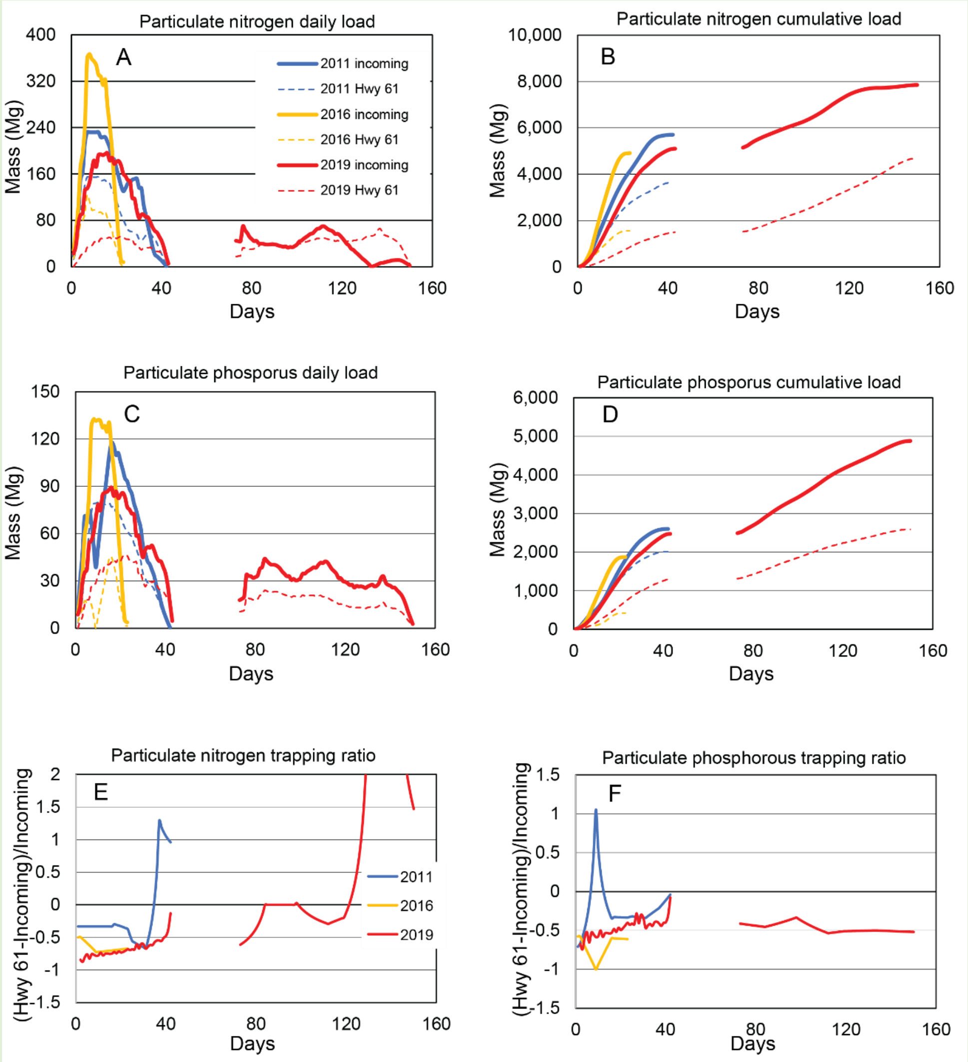
Large masses of nutrients moved through the Spillway representing approximately 15% of the Mississippi River C, N, and P load during the 2011 flood, 12 % in 2016 and 10% in 2019. Almost 75% of that load was deposited in Zones 1 and 2 in 2011, 2016, and 50% in 2019, as measured by suspended loads in the River incoming to the Spillway vs loads at Hwy 61. Nutrient trapping ratios indicated that during larger depositional operations, nitrogen is exported from Zones 1 and 2 during the receding stages of the floodwave as water depths decreased and fine sediment became mobilized. In 2011, during peak discharge, particulate phosphorous was mobilized from Zones 1 and 2.



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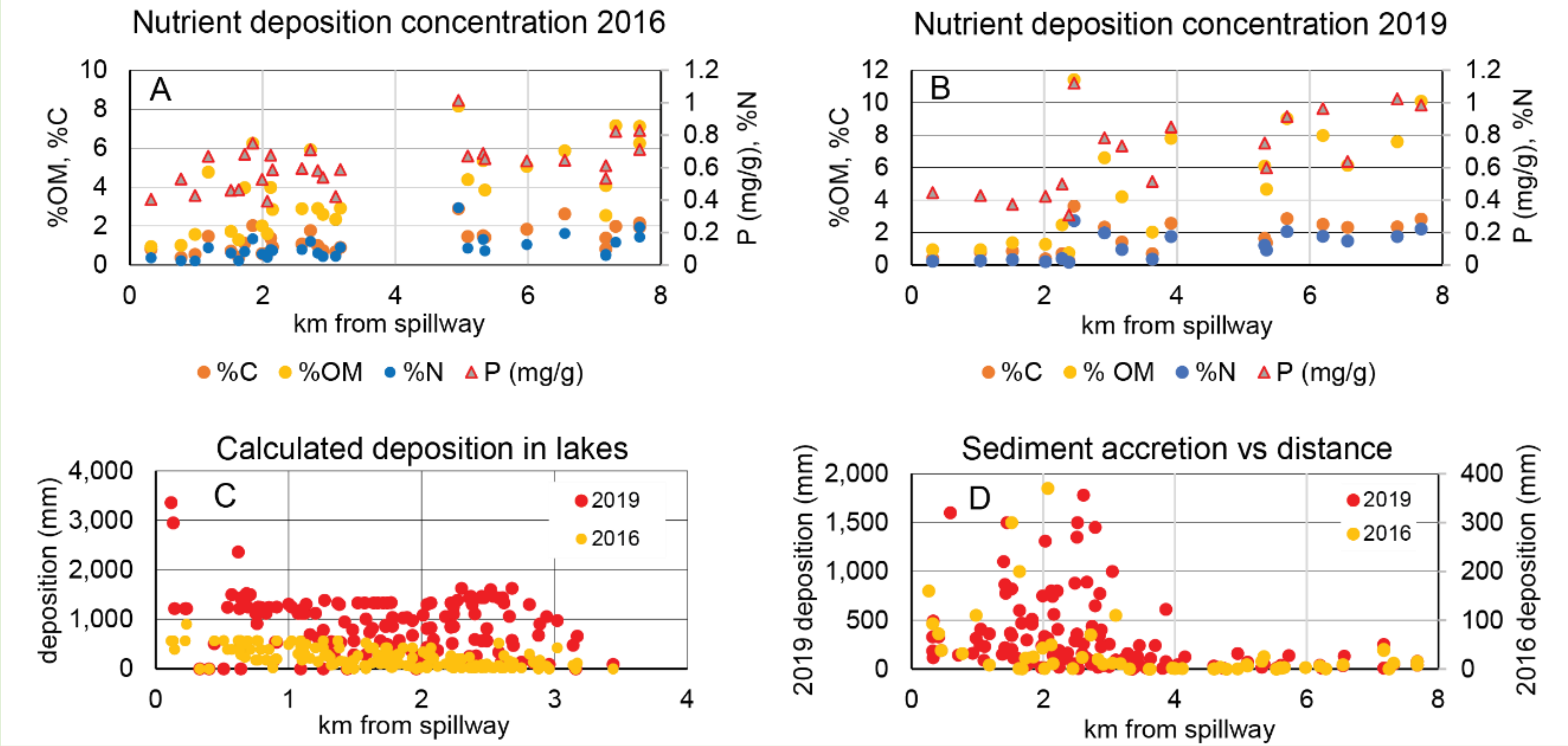
Preliminary information-subject to revision. Not for citation or distribution.

Nutrient deposition on the Spillway was calculated to be 8% of C, 3% N, and 4% P of the total River particulate load during the 2016 operation and 9% C, 7% N, and 7% P in 2019. Deposited nutrient concentrations were nearly constant down the spillway in 2016, while they increased in concentration in 2019. Lakes experienced higher rates of deposition than the surrounding Spillway and would likely be more conducive for fine sediment and nutrient deposition. However, they were not sampled for nutrient concentrations. During 2016 and 2019, Zone 2 experienced the greatest volume of deposition and depth of accretion over the floodway.



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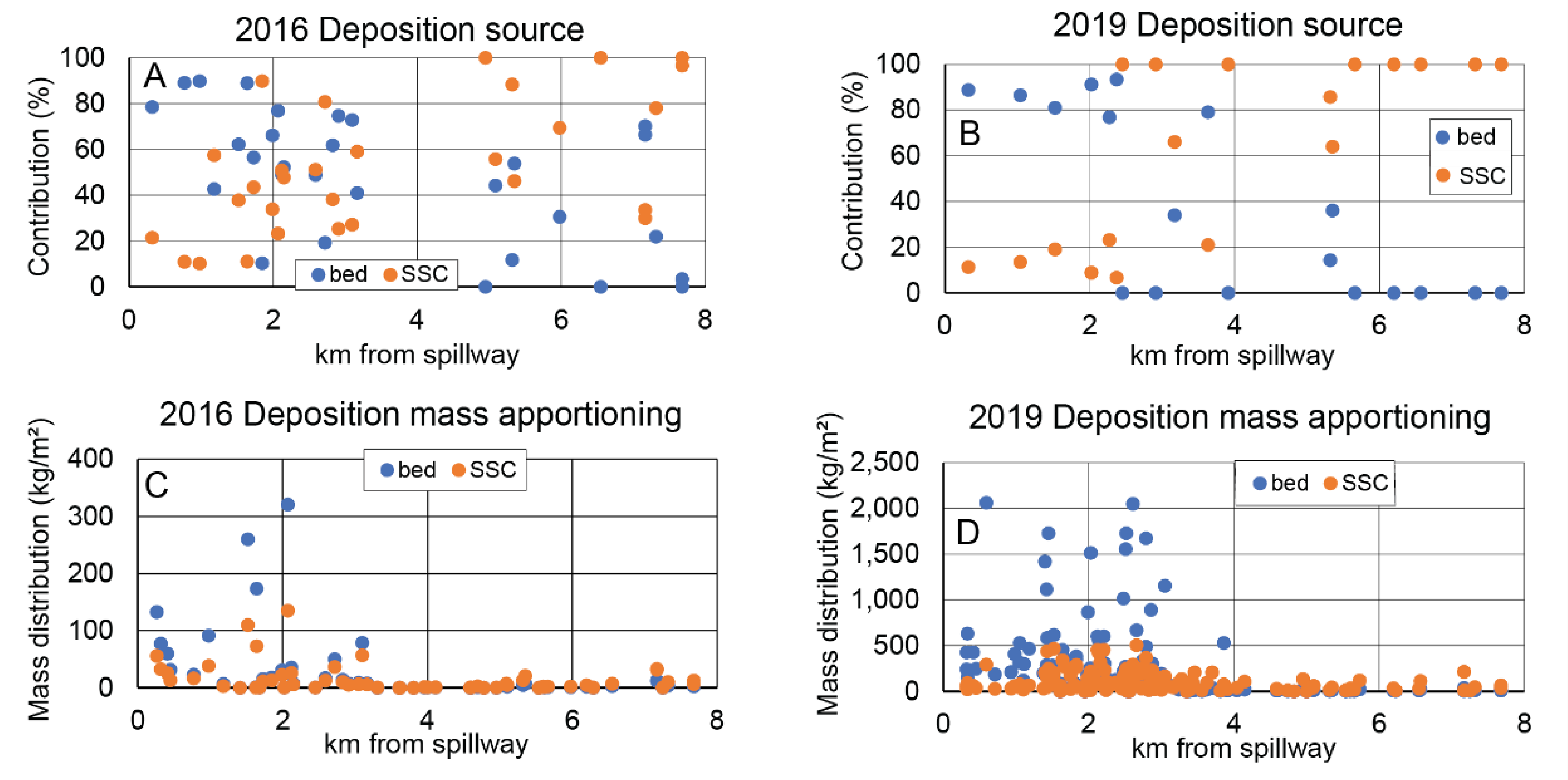
Mississippi River bedload sands were a substantial contributor to the Spillway deposition with the majority of bed load sands deposited in Zones 1 and 2, less than 4 km from the structure. Mass balance calculations indicated bedload contributions to deposition of 5.14 Tg, 0.08 Tg, and 3.73 Tg for 2011, 2016, and 2019.



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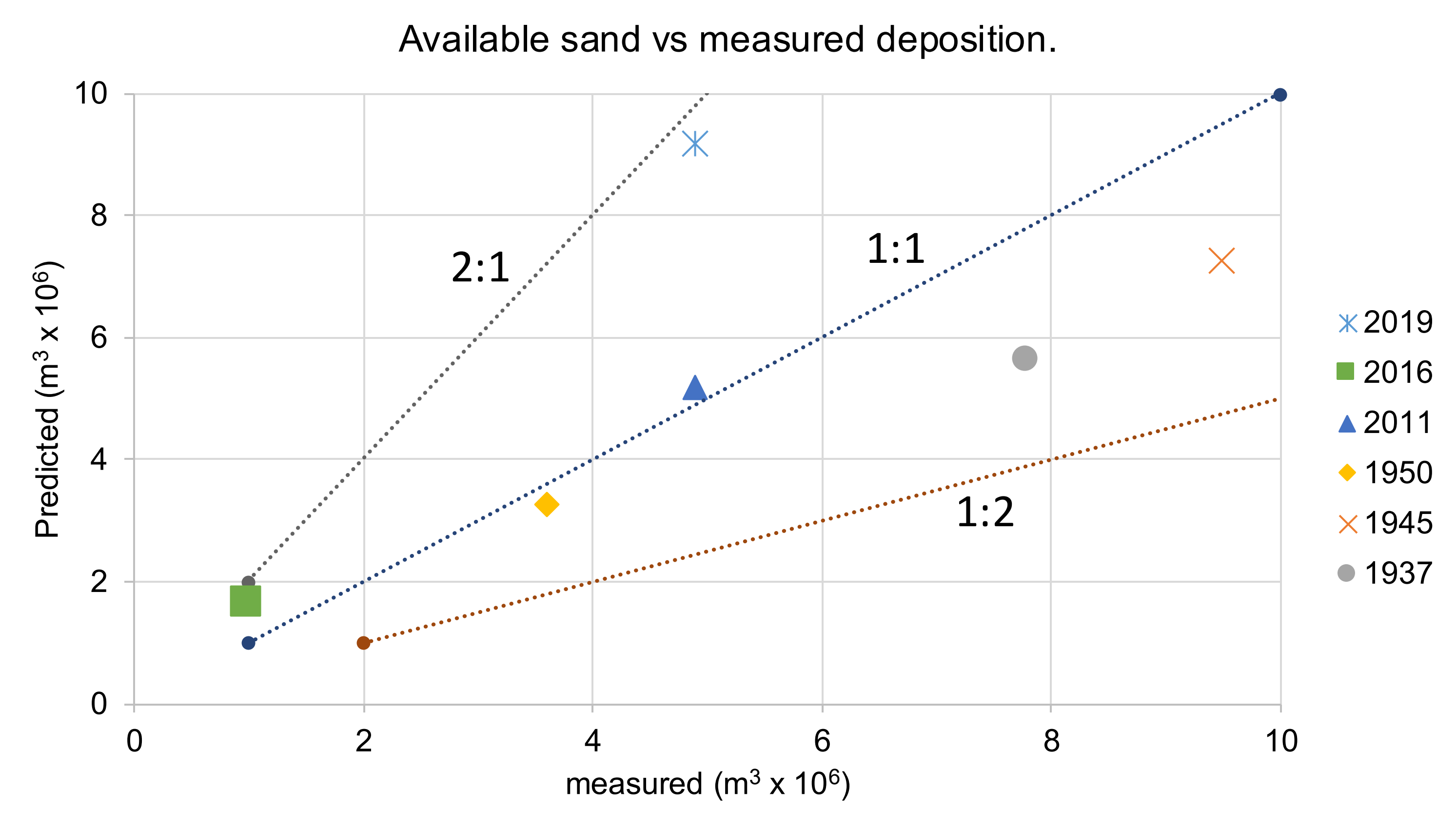
Rouse modelling of available Mississippi River sand load adjacent to the Spillway in comparison to measured* deposition on the Spillway. While 2016 deposition of bedload material may seem small, it falls onto the same 2:1 ratio of predicted vs measured deposition as 2019 measured deposition. 2011 bedload deposition closely matched a 1:1 ratio, indicating that greater discharge through the Spillway was more capable of entraining bed sediments away from the River.



Year	Total volume (m3)	max discharge (cfs)
2019	38,014,088,350	212,000
2016	6,912,664,642	203,000
2011	21,501,499,204	315,000
1950	13,618,618,117	215,000
1945	30,121,504,144	318,000
1937	23,359,903,309	318,000

*measurements before 2011 are based on the number of dump truck loads removed from the Spillway after closure. Predicted load error: 20% lower, 50% higher.

Modified from Nittrouer et al. 2012

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Conclusions: During flood operations the Bonnet Carré spillway is capable of diverting a large portion of suspended sediment, bedload, and nutrients from the Mississippi River. Relative to its small size, it traps a tremendous portion of the River's nutrient load. Nutrient trapping is likely enhanced by mixed fast and slow areas of flow on the Spillway that facilitates fine sediment deposition.

The positioning of this Spillway on the River adjacent to a point bar allows it to capture a large amount of bed load sediment that is essential for building elevation in subsiding receiving areas.

Water volume and velocity from the River through the Spillway plays a large role in bedload entrainment and deposition.

A protracted flood recession may export some deposited nitrogen, although it may be redeposited down Spillway.

Photos by Steve Stone

Questions?