Title: Sedimentary Aspects of Land-Building in the Fort St. Phillip Crevasse Complex

Introduction

The State of Louisiana is now on course to spend several billion dollars constructing sediment diversions in the Mississippi River downstream (and immediately upstream) of New Orleans as a primary tool for building and sustaining coastal wetlands in the Barataria and Breton Sound basins. As of late 2019, two large, controlled (gated) sediment diversions (Mid-Breton and Mid-Barataria) have been authorized and are in the design, engineering and permitting phase to introduce between 30,000 and 75,000 cfs of river water into adjacent receiving basins. Key sediment-linked issues that will determine their ultimate usefulness include determining (1) the amount of pre-existing marsh and bay bottom substrate that will be eroded at the end of the conveyance channel when the diversion begins operation (2) how much vertical accretion will be increased in existing marshes in the receiving basins with the introduction of a crevasse splay that mimics the natural river process of lateral growth (*Bomer et al., 2019; Wellner et al., 2005; Shaw et al., 2003*). In addition, an operation strategy that optimizes sediment delivery and minimizes freshwater and nutrient input will need to be in place prior to construction.

Crevassing is the natural process by which the river breaches the natural levee and evolves a subaqueous to subaerial lobate deposit with continued delivery of sediment-laden water that simultaneously progrades seaward and accretes upward (*Yuill et al., 2016*). While analysis of buried late Holocene examples has been conducted through the Mississippi Delta (*Chamberlain et al., 2018; Esposito et al., 2013; Tornqvist et al., 1996*), as well as studies of historical crevassing and evolution along the river corridor below New Orleans (*Coleman & Roberts 1997; Wells & Coleman, 1987; Gagliano 1964*), few modern crevasse splay analogues of equivalent size to Mid-Breton and Mid-Barataria exist in the active growth phase (e.g., Wax Lake, West Bay). In Wax Lake, Shaw et al. (*2013*) demonstrated that progradation of the splay occurs through erosional channel extension and successive bifurcation, coupled with distributary mouth bar deposition. In West Bay, Yuill et al. (*2016)* demonstrated that evolution of the river-side crevasse and discharge into the receiving basin is controlled by the elevation evolution of the adjacent splay. What remains poorly understood in existing studies of modern splay analogues is how plume expansion at the conveyance channel exit, e and geometry of the receiving basin (including pre-existing marsh extent) controls the efficiency of sediment trapping of various grain size classes. It is these particle-size related trapping efficiencies that control the location, composition, and expansion of coarse and fine depositional facies in the splay. Numerical modeling, which is the main basis the State is using to predict splay evolution and existing wetland preservation and Mid-Breton and Mid-Barataria, has a paucity of observational evidence for calibration of key controlling sediment parameters. This includes how much deformation (subsidence) of the pre-existing water body substrate will occur with splay growth into the basin and how it is controlled by sediment type (splay and underlying substrate). Also, what is the rate of mineral trapping (and erosion of the entire marsh substrate in some proximal areas) of the extant marsh wetlands at various distances in the receiving basin from the conveyance channel exit? And finally, how do the grain size characteristics of the river sediment supplied impact splay stratigraphic, evolutionary style, and trapping by the extant marshes?

FORT SAINT PHILIP CREVASSE EVOLUTION

The Mississippi River breached its eastern bank during the large 1973 flood, opening multiple crevasse channels near Ft. St. Phillip (FSP) from River Mile 24 to 16 that remain to the present, stabilized at their river exit with rock. Water discharge through these cuts together reaches more than 100,000 cfs during periods when Bonnet Carre Spillway is open (e.g., 2016, 2018, 2019)--this the same order of magnitude as the proposed Mid-Barataria and Mid-Breton sediment diversions (*Suir et al., 2014*). In 1998 CWPRA implemented project BS-11 to construct marsh terraces in Bay Dennesse to trap some of the sediment flux through these river exits, and made additional artificial crevasse cuts within the FSP complex. The Suir et al. (*2014)* remote sensing study shows significant land loss surrounding the FSP crevasse between 1973 and 2008 mainly through retreat of the bay facing shoreline from wind and wave erosion. Limited subaerial land growth (322 acres) was observed in the interior wetlands between the Mississippi River and Breton Sound, much of that in and around the Bay Dennesse terrace fields. The report concludes that despite constant flow since 1973, the FSP crevasse complex has been a land loss accelerant. Turner et al. (*2019*), partly on the basis of the Suir report that concluded that the FSP crevasse complex has been a land loss accelerant, cites a 58% reduction in land area in the larger area surrounding the FSP crevasses as evidence against the efficacy of river diversions for land building. They suggest that this is a response to (1) marsh scour that is often associated with the initial erosional phase of crevasse formation, and (2) marsh drowning from the increased water levels. The picture of the FSP situation painted by Suir-Turner poses a risk to the ultimate permitting and construction of the Mid Barataria and Mid Breton diversions, and we propose is an inaccurate picture of the situation in this reach.

Early attempts to assign a sediment ratings curve to the FSP discharges suggested a significant proportion of the river's sediment discharge was passing into the FSP receiving area despite the skimming of only suspended sediment from the depleted upper water column (*Allison et al. 2012*). During the 2016 Bonnet Carre opening, a detailed measurement of water and sediment flux out of the river from the 19 largest cuts showed a total loss of 4% of the sand, 10% of the fines, and 15% of the freshwater (*Weathers and Allison, 2016*). Evidence of from a later remote sensing study that compared land change through 2017 (*Costanza and Fran-Gilchrist, 2019*) demonstrates that this large sediment flux has turned the receiving area into net land gain (1,134 acres since 2008) and that does not include the large floods of 2018 and 2019. A summer 2019 Tulane-LPBF field survey of bathymetry in the lower Breton Sound shows the evolution of a subaqueous channel-levee complex with sandy subaqueous distal mouth bars evolving offshore, directly opposite of the two main FSP water exits (*Dutt, 2019*). Together, this newer evidence suggest both that the Suir-Turner hypothesis is false, and that the FSP reach is an excellent analogue for understanding sediment evolution and land growth of the authorized diversions upriver.

The proposed study will explore the sedimentary nature of the subaqueous and subaerial (newly vegetated wetland) accretion occurring today in the FSP receiving basin. Coring surveys will be utilized to examine flood layer deposits and the sediment trapping efficiency of the receiving area as a function of grain size, moving outward from the river exits. We will also conduct detailed elevation/bathymetric mapping of the basin geometry that will be used to determine how controls and rates of splay formation and composition. A 3d mass balance of erosion and deposition within the FSP complex will be developed to better predict future basin evolution. Finally, we will examine and recommend ways to increase sediment trapping efficiency through low-cost green engineering, working with local landowners (who we are already in contact with).