Quantifying Sediment Retention and Morphologic Evolution in the Fort St. Phillip Crevasse Complex: Implications to Sediment Diversions

BACKGROUND: Sediment diversions deliver sediment, nutrients, and freshwater from rivers to surrounding estuaries as a strategy to build and sustain wetland areas. Numerical modeling coupled with detailed field observations are valuable science-based tools to provide quantitative information about the morphodynamic behavior of the deltaic formation in response to diverting large quantities of water and sediment (Meselhe et al, 2016; Yuill et al, 2016; White et al, 2019-a an 2019-b; Allison e al, 2017). These models are founded on assumptions regarding composition of the diverted sediment, and the geotechnical properties, especially erodibility and consolidation, of the outfall areas. These assumptions, while based on best available data, contribute uncertainties regarding the response of the receiving basin to diverted water and sediment. Specifically, limitations on the available data regarding the heterogeneous nature of soil erodibility, consolidation rates translate to broad estimates of key model parameters and ultimately broad range of outcomes. These uncertainties affect the ability of managers and decision makers at CPRA to assess the performance of the proposed sediment diversions and the optimum operation strategy post construction. Gathering high-quality field observations is the most effective approach to reduce model uncertainties. Thus, and as outlined in a companion proposal by Dr. Navid Jafari from Louisiana State University, a detailed field-observation collection program is planned to support this proposed modeling effort. The potential improvements to the performance of predictive tools is quite timely as Louisiana CPRA is actively designing the Mid Barataria and Mid Breton sediment diversions to build and sustain coastal wetlands in the Barataria and Breton Sound basins, respectively. The goal of this CSAP proposal is to reduce the uncertainty in the predictive numerical models that can be used to support and inform the quantification of tradeoffs, impacts and operation strategies of sediment diversions.

FORT SAINT PHILIP CREVASSE EVOLUTION: Currently, through a CSAP project funded in 2020, Dr. Allison (Tulane University) is investigating the Fort St. Phillip (FSP) crevasse. With a peak flow in the order of 100,000 cfs, FSP crevasse serves as a suitable analogue for sediment diversions, even though it is uncontrolled. The research performed by Dr. Allison and his student will provide valuable information and insights on the splay evolution and land growth as well as the amount of elevation-loss due to subsidence induced by the self-weight of diverted sediment along with the pre-existing substrate. Further, this CSAP proposal has a companion proposal by Dr. Navid Jafari from LSU, that would build on Dr. Allison's field investigations. The intent of this proposal along with Dr. Jafari's is to perform synergistic morphodynamics and sediment transport numerical modeling and geotechnical in-situ measurements and laboratory testing. The overall goal from these two CSAPs will be a comprehensive and integrated investigation of a crevasse splay that accounts for the geomorphology (and builds on the sediment budget from Prof. Allison ongoing CSAP research), quantifies the sediment retention and land-change while accounting for soil erodibility and consolidation properties and pre-existing substrates. The ultimate deliverable of this research is a field-calibrated high-resolution morphodynamic model to support CPRA's ongoing planning and engineering design activities and to better understand operation strategies for optimizing sediment delivery.

RESEARCH PLAN: Through a collaborative observation-numerical modeling effort performed by LSU and Tulane researchers, this proposal focuses on the numerical modeling component. Dr. Meselhe and his student propose to develop a high-resolution morphodynamic model using the Delft3D system. The model will focus on the FSP site utilizing a high-resolution flexible mesh. This local high-resolution model will be driven by existing regional model recently developed at Tulane University through funding from Environmental Defense Fund (EDF). The existing Delft3D models developed at Tulane utilize high-performance computing to allow for morphodynamic decadal (50 to 80 years) simulations within 14-24 hours of wall-clock time. Computational efficiency is of primary importance to ensure the ability to perform formal and extensive uncertainty analysis. The uncertainty analysis will evaluate the impact of variability in select model parameters and environmental drivers on key model outputs. Two key model outputs will be considered, namely, the change in land area (in acres), and the sediment retention rates (as percent of the diverted sediment). The model parameters that will be evaluated through the uncertainty analysis include: the sediment erosion rate, erosion critical shear stress, and the temporal and spatial local consolidation/compaction rates. Delft3D estimates erosion rates using the following equation $E = A\,(\frac{\tau}{\tau_c} - 1)$ where, E is the erosion rate; A is constant, τ is the shear stress; and τ_c is the erosion critical shear stress. The parameters A and τ_c are user defined. Field observation are required to estimate values for these parameters (see Figure 1 below for high-quality field observation to estimate their values). These parameters are broad in range and can be highly heterogenous. They also have direct and significant impact on the key model outputs listed above. These key model output directly affect CPRA's ability to quantify the tradeoffs and to optimize the operation strategies for controlled sediment diversions.

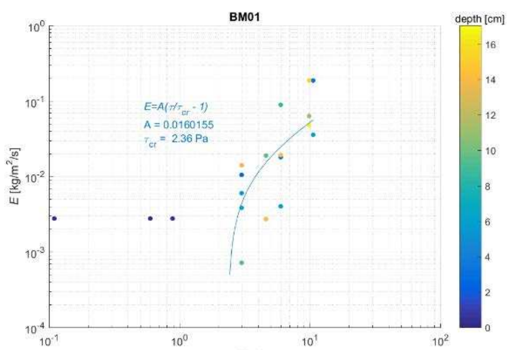
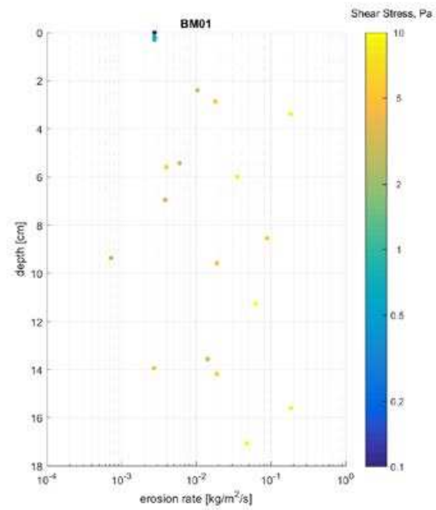


Figure 1: Erosion rate versus shear stress (top); and Erosion rate versus depth (right)



DELIVERABLES AND OUTCOMES; Deliverables of this proposal include peer-reviewed journal articles documenting the primary findings of the research performed under this effort; presentations at national or regional technical conferences, and a final project report documenting the assumptions and parameterizations of the Delft3D morphodynamic models used in the study. Prof. Meselhe did not apply nor receive prior funding from the CSAP program. However, he has long track record of funding from CPRA from the Planning and Engineering sections. Some of the major projects in which Prof. Meselhe was involved include the 2012, 2017, and currently the 2023 Coastal Master Plan; the Mississippi River Hydrodynamic and Delta Management Study; and the Environmental Impact Assessment of the Mid-Barataria and Mid-Breton sediment diversions. These studies resulted in approximately 25 peer-reviewed publications, and over 50 conference presentations.

References

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