Numerical Investigation of Marsh Terracing as a Coastal Restoration Technique

Katelyn Keller, Hydraulic Engineer, USACE-MVN, New Orleans, La, katelyn.keller@usace.army.mil
Ehab Meselhe, Professor, Tulane University, New Orleans, La, emeselhe@tulane.edu
Kelin Hu, Professor, Tulane University, New Orleans, La, khu1@tulane.edu

Extended Abstract

Marsh terracing is a new coastal restoration technique implemented within the Northern Gulf of Mexico, particularly the Louisiana Coast. Its application is intended to combat the devastating land loss rates occurring as a result of sea level rise, land subsidence, and anthropogenic alterations to the hydrologic system. The technique involves dredging in-situ subtidal marsh soils and placing the excavated material into subaerial berms, or terraces, adjacent to the dredged borrow pit. There is substantial research addressing the ecological benefits of marsh terracing, such as increased marsh edge, enhanced bio productivity, and improved habitability for nekton and waterbird species. However, there is a lack of research investigating the proposed hydrodynamic benefits of marsh terracing, which is hypothesized to promote decreased shoreline erosion and increased marsh emergence. This study aimed to (1) quantify the ability of marsh terracing to reduce shoreline erosion, (2) determine the potential depositional effects and subsequent marsh emergence, and (3) provide a set of metrics to assess project performance and determine the optimal terrace configuration for a specific site. The study site, Four Mile Canal Terracing and Sediment Trapping in Vermilion Bay, Louisiana, was analyzed through the creation of a 2D numerical model using Delft 3D Flexible Mesh.

The coupling of D-Flow and D-Waves Delft modules allowed for the analysis of high-resolution flow and wave dynamics within terrace configurations. The flow model domain (Figure 1A) extends from the mouth of the Vermilion River to Cypremort Point and Southwest Pass, encompassing Weeks Bay, Vermilion Bay, Little White Lake, and Little Vermilion Bay. The flow grid contains 555,318 cells ranging in resolution from 2.5 m to 364 m, with the most refinement within the terrace areas of interest (Figure 1b) and coarser cells elsewhere to save computational time. The wave model (Figure 1c) extends nearly 100 km into the open Gulf to accurately simulate deep water waves reaching the estuary from the Northern Gulf of Mexico. The wave model uses a nested grid approach with five grids, coarsening from 5 m within the areas of interest to 1,000 m in the open Gulf. There are a total of five open boundaries within the flow model, four water level forcings and one discharge forcing, and three calibration points. The wave model has an open gulf boundary at the edges of the coarsest grid to be forced with wave parameter data including significant wave height, wave period, and wave direction and one calibration point.

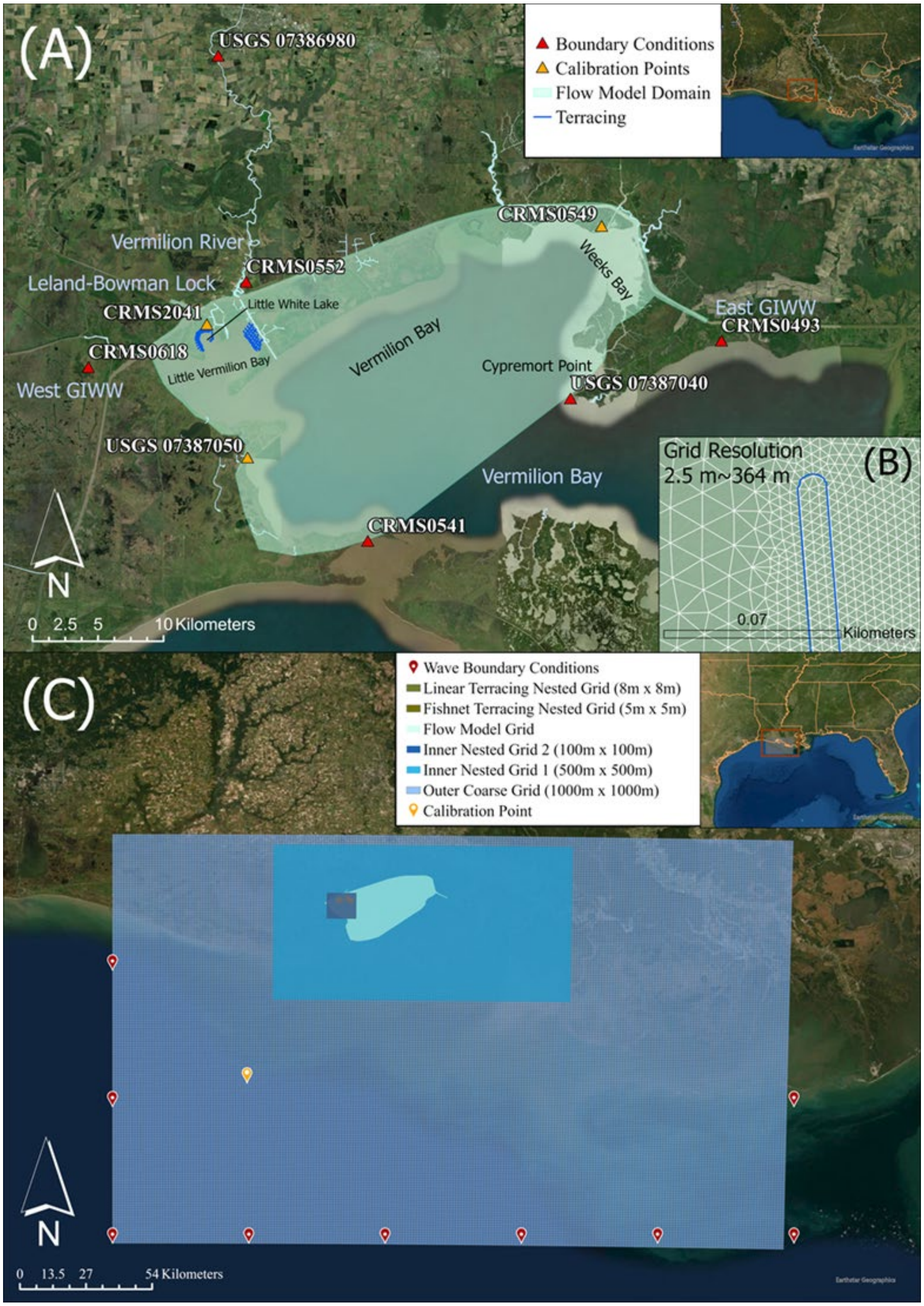

Figure 1. Figure 4. Coupled Flow and Wave Model Setup. The flow model (A) extends from the mouth of the Vermilion River to Southwest Pass and Cypremort Point. There are five open boundaries and 3 calibration points marked in orange. (B) shows the finest refinement of the grid on a terrace crown. The wave model (C) extends 100 km into the open Gulf of Mexico and includes five nested grids, refining towards the terrace areas of interest, with the locations of wave boundary forcings marked in red and the calibration point in orange.

Following model development and calibration, six generalized terrace configurations were examined using post-processing tools and developed metrics, conceptualized in Figure 2. This gave insight to various terrace performance aspects, including [1] the magnitude of wave energy attenuation experienced on the leeward coast, [2] the storm-induced coastline erosion rates and hypothetical amount of coastline saved during a localized wind event, [3] the estimation of depositional area and sedimentation patterns within a configuration in relation to the terrace area constructed, and [4] the optimization of project benefits to project costs. Site specific conclusions were drawn for the terrace configurations within Vermilion Bay, Louisiana. A delta-splay configuration yielded the highest depositional area to constructed terrace area, making it the optimal configuration for marsh building. Terrace widening did not produce additional land commensurate to the amount of land necessary to construct the configuration. Certain individually placed berms were determined to have negative effects on the ability of a configuration to attenuate wave energy. The effectiveness of terraces on wave attenuation was dependent on the length of coastline and the length of terraces constructed. After a terrace length near 2x the coastline, all configurations performed relatively the same. The optimal configuration for a site is dependent on various site-specific characteristics, including hydrodynamics, bathymetry, coastline shape, sediment type, and proximity to a sediment source. However, these findings encourage the use of numerical modeling prior to construction as a tool to minimize costs and maximize performance. The numerical modeling methods and performance metrics presented herein provide a methodology that can be used to determine the optimal configuration for any terrace project site and further provide a strong foundation for future marsh terracing modeling efforts.

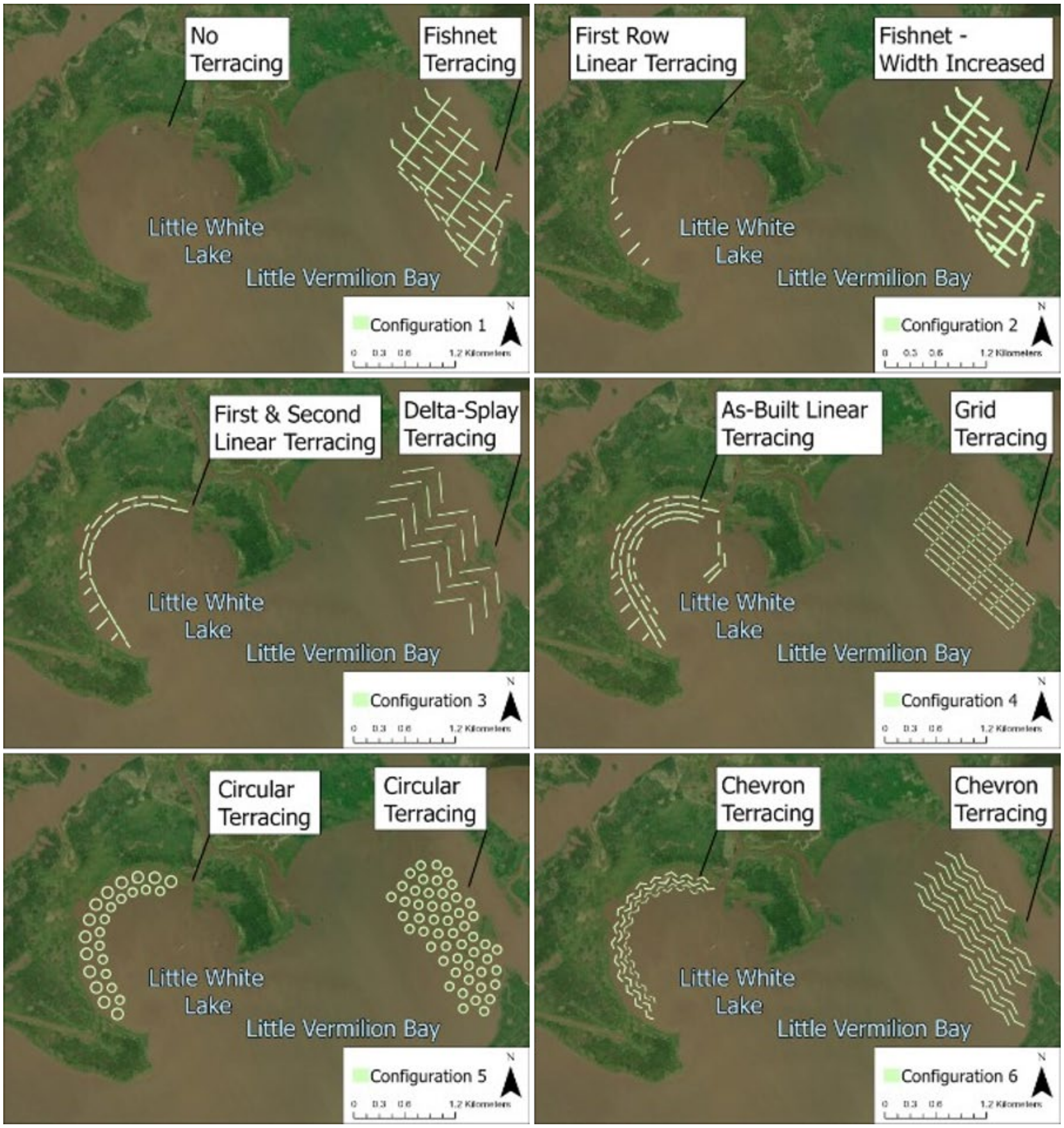

Figure 2. Model Configurations. The figure conceptualizes the shapes of the terrace configurations for each of the six model simulations.