OVERVIEW OF THE COASTAL TEXAS MEGA PROJECT

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The Gulf of Mexico coastal region is vulnerable to periodic storm surges and rainfall extremes. Since 1900, hurricanes striking in this region have killed 6,000 to 12,000 people and caused tremendous economic damage to infrastructure. The socio-economic risk from these extreme events is projected to grow worse in the coming decades due to urban development and climate change. In 2015, the U.S. Army Corps of Engineers (USACE), in partnership with the Texas General Land Office (GLO), began to explore viable solutions for coastal storm risk management and ecosystem restoration along the Texas coast. The study is known as the comprehensive Coastal Texas Study (USACE 2021a). Detailed maps, graphics, and reports are located at http://coastalstudy.texas.gov.

The Texas Gulf coast is a complex system with numerous narrow inlets and broad back bays with intricate river and bayou networks. Due to its complex settings, the Texas coast is susceptible to extreme compound flooding due to fluvial, pluvial, and surge during hurricanes and tropical storms. Five of the top six largest tropical cyclone rainfall totals in the continental U.S. have occurred in Texas (USACE 2021a). The Texas coast is also one of the United States most dynamic regions in terms of population and economic growth. According to the Bureau of Economic Geology, twenty five percent of the population and thirty three percent of the economic resources of Texas are located along the 360 mile long coast. The objective of the Coastal Texas Study was to improve our capabilities to prepare for, resist, recover and adapt to extreme events.

A “Multiple Lines of Defense” strategy was used in the Coastal Texas study to design cost-effective, environmentally friendly solutions that will reduce risks of storms impacting the coastal communities and restore important wildlife habitat at the same time (Figure 1). With a focus on redundancy and robustness, the first objective is to keep the storm surge in the Gulf. Then, an extreme combination of water from Galveston Bay and Gulf surge that could overtop the front-line defenses must be addressed through a second line of defense.

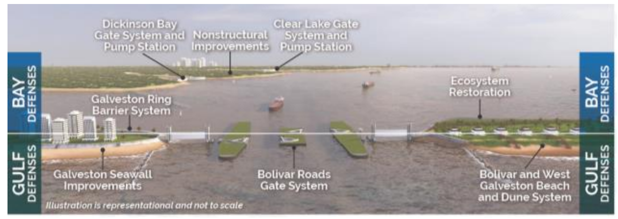

Figure1 : Multiple Line of Defense along the Texas Coast.

GULF DEFENSES

The “Gulf Defenses” meet this challenge with a combination of surge gates at Bolivar Roads, seawall modifications on Galveston, and dune and beach systems on Galveston Island and Bolivar Peninsula. As a first line of defense, the Recommended Plan outlines a Bolivar Roads Gate System made up of a combination of sector gates, vertical lift gates, and shallow water environmental gates that tie-in to the shoreline with combi-walls and levees. Currently, at the heart of the Bolivar Roads Gate System lies a pair of gates spanning the Houston Ship Channel (Figure 2). To improve navigation safety, enhance reliability, and reduce cost, the Recommended Plan calls for the dredging of a second navigation channel to the east of the existing channel, and the construction of three man-made islands to anchor and house two pairs of large floating sector gates.

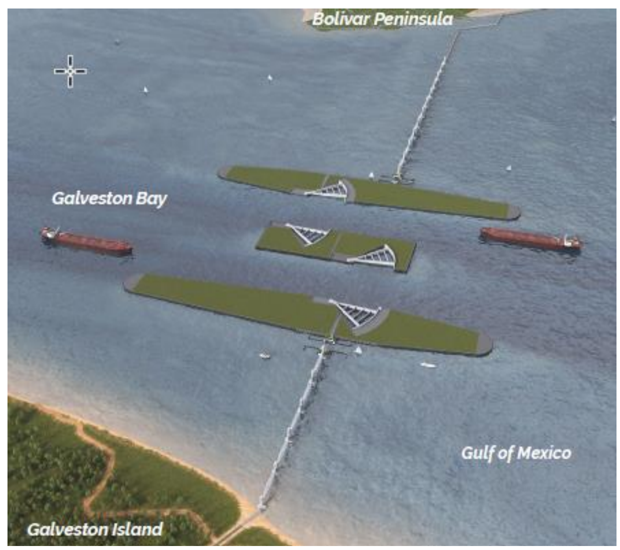

Figure 2: Bolivar Roads Gate System Overview.

The channel openings will be 650 feet wide by 60 feet deep (the current channel is 530 feet wide by 48 feet deep). The Recommended Plan also includes two pairs of smaller sector gates to allow for smaller vessels, such as commercial fishing vessels and recreational boats, to safely move into and out of the Bay. These gates will have 125-foot openings and be approximately 62 feet high (with a sill depth of 40 feet). To fill the gaps, the Recommended Plan calls for a series of 15 Vertical Lift Gates - each 300 feet wide and spanning more than 4,500 feet. These gates will remain open except in the event of a storm. On the Bolivar Peninsula side of the inlet, some areas are as shallow as five feet deep. In addition, we also know that small marine animals use these shallow waters to move in and out of the bay. Thus, the design aims to avoid and minimize impacts to critical species and habitat by including a culvert based system to address these concerns.

BAY DEFENSES

A combination of water from Galveston Bay and Gulf surge that could overtop the front-line defenses must be addressed through a second line of defense. The "Bay Defenses" are comprised of a ring barrier system on Galveston Island, surge gates and pump stations on the mainland, and nonstructural measures such as flood-proofing and the raising of buildings on the mainland, offer this second line defense.

The 18-mile Galveston Ring Barrier System (Figure 3) ties into and improves the historic Galveston Seawall and encompasses the most heavily developed portions of Galveston Island. The system reduces residual risk from bay flooding after gulf defenses are closed. The System is comprised of a navigable barrier at Offats Bayou, 34 road closures, 7 rail closures, 6 new pump stations with approximately 16,550 cfs discharge capacity, and non-structural improvements.

Figure 3: Galveston Ring Barrier.

Navigable closure structures will also be constructed across the Bay at Clear Lake and Dickinson Bay to further reduce residual risk from wind and wave setup in the Bay after the Gulf Defenses are constructed. The Clear Lake System will include a set of sector gates with a 75 ft opening, 9,950 ft of floodwall, and a pump station with approximately 20,000 cfs discharge capacity. The Dickinson Bay System will include a set of sector gates with a 100 ft opening, 6,500 ft of flood wall, and a pump station with approximately 19,500 cfs discharge capacity.

COASTAL ENGINEERING ANALYSES

Various numerical models were used as tools to better understand the potential environmental impacts and enable decision makers to evaluate the largest feasibility decision in USACE history. The integration of a variety of modeling tools, along with qualitative evaluations, was a critical part of the assessment of environmental impacts to the health and ecology of the unique Galveston Bay complex. This presentation will describe the coastal engineering analyses used to develop this world class design.

COASTAL STORM MODELING

The CSTORM - coupled surge and wave modeling system was used to quantify the surge and wave hazards, informing economic and design analyses (USACE 2021b). A suite of 660 tropical cyclones were developed to span the full range of tropical storm hazards and a joint probabilistic model framework including historical storms was also employed. Of those 660 storms, 170 were selected to best capture the Galveston area storm hazard and minimize computational time. New model meshes were developed from the most recent, highest resolution survey data available.

The updated CSTORM model was validated against historical storms. Annual exceedance probabilities (AEP) were then computed for the range 1 to 0.0001 for peak storm water level and spectral significant wave height. AEP storm water level based on the CSTORM model results is the basis for the economic analysis. Structural design and crest elevation were based on the 1% AEP water level combined with wave runup and the appropriate overtopping limit state. Figure 4 includes example ADCIRC results.

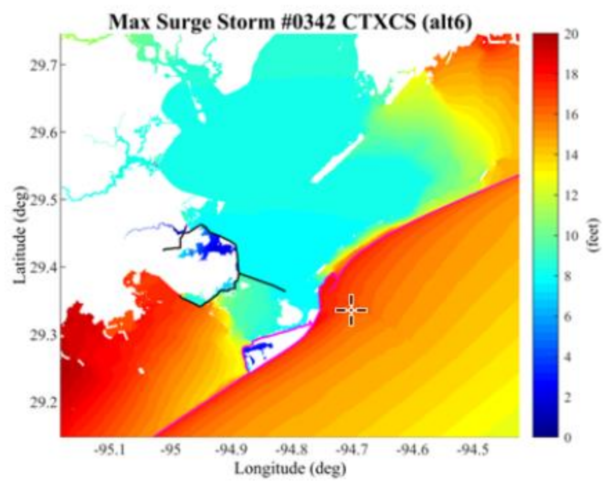

Figure 4: Example of maximum surge elevations (with project storm # 342).

CLIMATE CHANGE

Impacts of climate change were included in evaluation of alternatives. The greatest impact on plan selection driven by climate change was a result of Relative Sea Level Change (RSLC). USACE (2019a and 2019b) require evaluation of three RSLC curves; low, based on the observed rate at nearby water level stations, intermediate following modified National Research Council (NRC) Curve I, and high following modified NRC Curve III. Present conditions to the year 2135 were evaluated resulting in a range of RSLC from about 1m to about 3.4m by 2135 in the Galveston Bay region.

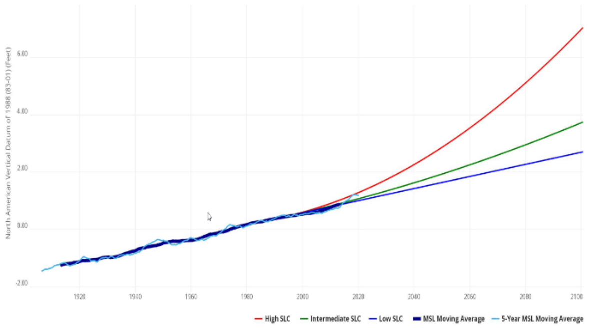

Figure 5: RSLC at Galveston Pier 21 using USACE Sea Level Rise Tracker

The CSTORM model was run for three RSLC conditions which are Low, Intermediate and High curves over 50 years (USACE 2021a). An intermediate curve was applied for design and analyses.

ENVIRONMENTAL MODELING

A three-dimensional Adaptive Hydraulics (ADH) model for Galveston Bay was developed to evaluate environmental impacts that the proposed system might have on Galveston Bay (USACE 2021a). A concern driven by other large scale storm barriers was the potential for reduction of tidal exchange and salinity in Galveston Bay. The ADH model comparison for a representative year showed a reduction in tidal prism between 3 and 7 %, depending on location within the bay. Tidal amplitude comparison ranged from +3% to -6%. Salinity generally varied less than about 2 parts per thousand (PPT).

The Particle Tracking Model (PTM) was used to simulate local larval marine species interacting with the proposed Bolivar Roads Gates based on the results of the ADH model (USACE 2020). Results generally showed little difference and were verified through sensitivity analyses.

BEACH AND DUNE SYSTEM DESIGN

This project includes about 45 miles of beach and dunes. The proposed beach (Figure 6) was designed to reduce coastal storm risk by preventing inundation and breach during all but the largest of storms and to dramatically reduce total inflow during storms that exceed breach conditions. The Beach Morphology Analysis Package was used to layout typical design profiles. The SBEACH model was used to evaluate storm response and optimize dune and beach design. 39 million Cubic Yards (MCY) of sand is needed for initial construction.

USACE (2021b) further modeled beach morphology with a Monte Carlo life cycle simulation using the CSHORE beach morphology model to help anticipate beach maintenance required after large storms. The model showed that switching from a single dune to a dune field reduced the number of times the system would need to be renourished over the 50-year life. Eliminating bedform smoothing in the model reduced both the single dune and dune field renourishment needs. This resulted in a range of total nourishment requirements from 19.32 MCY to 24.95 MCY, depending on RSLC.

Identifying a reliable and affordable sand source is the most complex aspect of this beach design. USACE (2021a) identifies some initial sand sources including Sabine and Heald Banks, one potential source of sediment. The GLO and others are investigating other sand source options.

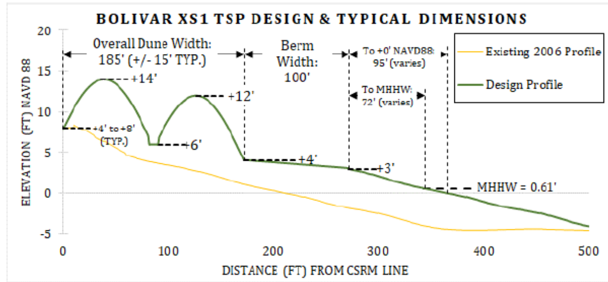

Figure 6: Typical dimensions of the CSRM beach design profile.

REMAINING WORK AND NEXT STEPS

The first construction cost, excluding inflation, for the Coastal Texas Project is approximately $30B. The $20M study evaluated hazards, economics, and the environment sufficiently to make an investment decision, but much work remains to be completed to safely design this Mega Project. Some key remaining coastal analyses include full integration of gate operations into the CSTORM model, physical modeling of the gates and pump stations, additional ship simulation, enhanced environmental modeling and data collection, and higher fidelity beach morphology and coupled storm risk analysis.

As we embark on design of this generational project, USACE and our partners at the Gulf Coast Protection District and Texas General Land Office are seeking to engage the best minds in the industry to innovate and deliver. We have already begun to engage universities and other government organizations to plan innovation and delivery. After the project is authorized and funds are appropriated, we will be engaging industry partners to begin the innovation, design, and construction process.

REFERENCES

USACE (2021a): Coastal Texas Protection and Restoration Feasibility Study, August 2021.
USACE (2021b): Coastal Texas Protection and Restoration Feasibility Study: Coastal Texas Flood Risk Assessment: Hydrodynamic Response and Beach Morphology, ERDC/CHL TR-21-11, June 2021.
USACE (2020): Letter Report Summarizing the Galveston Bay Larval Transport Study, August 2020. USACE (2019a): Incorporating Sea Level Change in Civil Works Programs, ER 1100-2-8162, June 2019.
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