Chapter 1. Summary of Key Points

Introduction

The Coastal Texas Study 2020 Draft Feasibility Report (the Report) documents a comprehensive and integrated study. Work reflected in the Report is clearly rooted in, and linked to, previous studies by the U.S. Army Corps of Engineers (USACE), the Texas General Land Office, Texas A&M University-Galveston (TAMUG) and its technical partners, Technical University of Delft (TUD) and Jackson State University (JSU), and others, and also utilizes international experience. The Report reflects a number of new and informative modeling studies and analyses. Significant improvements have been made to the recommended USACE Plan (the Plan). For example, the 7-10% reduction in tidal exchange associated with the re-designed Bolivar Roads Storm Surge Barrier is very small compared to other barriers around the world, supported by comprehensive environmental flow modelling. The decision to relocate the land barrier, moving it from behind coastal highways to the beach, is sound and evolves the Plan closer to the original Ike Dike concept. The Plan involves a combination of structural and nature-based features, including innovative concepts such as the double dune. New life-cycle dune erosion modelling provides valuable insights regarding performance of the dual dune system. The Report is much improved. The USACE has made an outstanding effort to communicate the Plan to the public through visuals and story lines. The online presentation and visualization materials are both innovative and accessible, effectively communicating the physical aspects and dimensions of Plan features.

The Plan can be and must be improved even more. Comments and recommendations provided throughout this review report are offered by TAMUG and its technical partners, TUD and JSU, in the spirit of improving the Plan to better serve stakeholders throughout the entire region. A summary of key observations and recommendations is provided below in bullet form, organized by these topics: Overall Approach to Flood Risk Reduction, Land Barrier, Gating San Luis Pass, Galveston Ring Barrier and Seawall, Other In-Bay Measures, and Bolivar Roads Storm Surge Barrier. Subsequent report chapters adopt the same topics as chapter headings, and they discuss these main points and others in more detail. The structure of this report is designed to demonstrate failure of the USACE plan to provide comprehensive protection with its coastal line of defense, because of its weak links that are covered in the next two chapters on the land barrier and San Luis Pass. In turn, the next two chapters, on the Galveston Ring Barrier and other In-Bay defenses show how the strength of the primary coastal barrier influences the In-bay lines of defense. Finally, the Bolivar Roads Surge Barrier and its costs are analyzed.

The review report also contains appendices, which provide even more supporting information. Other supporting materials are available from the TAMUG Ike Dike Home Page web site (https://www.tamug.edu/ikedike/). Specific links to other materials found on these websites are referenced in chapters and appendices.

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Overall Approach to Flood Risk Reduction

- USACE has picked up the coastal spine concept, but made it much weaker.
- The Ike Dike concept is intended to shorten and strengthen the coastal surge defenses (like the Dutch approach); and keep water out of the bays to limit internal surges. The USACE Plan severely compromises both core objectives.
- Inclusion of 43 miles of low, weak sand dunes in the USACE Plan violates the strong coastal defense objective of the Ike Dike concept and unnecessarily allows water into the Bays.
- The USACE Plan omits a western section including a gate system at San Luis Pass; unlike the Ike Dike concept. Omission allows the surge forerunner and main surge to enter West and Galveston Bays. Every contribution to water in the Bays increases flood risk and increases the need for, and strength and cost of, all second lines of defense and nonstructural measures.
- When the USACE changed the Tentatively Selected Plan from a high levee behind the highways, in iteration 1 of the Feasibility Report, to a low weak dune at the coastline in the current USACE Plan, they failed to quantify the resulting changes in flood risk and residual damage.
- Despite an expenditure of $26.17B, the USACE Plan performs poorly in reducing flood damage for the region, decreasing average annual damages by only 60% (and by much less, 44%, for the high future sea level rise scenario).
- Even with the USACE Plan in place, average annual residual damage for the region is predicted to be $1.15B (distributed as 55% in West Bay and 45% in Galveston Bay). Average annual residual damage for the high future rate of sea level rise is 3 times higher, $3.28B.
- The region should experience even more damage than predicted because of USACE failure to fully account for their own modeling that predicts the frequent loss of dune protection through erosion and breaching of the low weak sand dunes on Galveston Island and Bolivar Peninsula.
- The USACE's own modeling shows that major hurricanes will completely destroy the dual dune system that is proposed in the USACE Plan, allowing storm surge to pour into the bays.
- The USACE has seemingly drifted far from their own National Economic Development (NED) guidelines that focus on maximizing net benefits, which for this project are primarily storm damage reduction benefits
- We recommend a renewed focus on maximizing flood risk reduction, maximizing net benefits, and increasing the benefit-cost ratio, consistent with USACE National Economic Development planning guidelines.
- The USACE Plan will put the Houston-Galveston region in a poor defensive posture for major hurricanes, now and even more so for higher future sea levels.
- The weak coastal spine in the USACE Plan leads to the need for an excessively high Galveston Ring Barrier and other in-bay defenses
- A higher level of risk reduction is needed for the coastal spine, and it can be achieved.
- A robust 17-ft Ike Dike can remedy many of the shortcomings associated with the USACE Plan. It will significantly reduce residual damage throughout the region, reduce required strength and cost of all in-bay measures, eliminate the need for many of them, reduce the elevation and cost of the Galveston Ring Barrier, enable suitable protection for the City, for future sea level, and increase the project's overall benefit-cost ratio.
- In the USACE Plan, heights of different elements comprising the coastal spine vary considerably (Bolivar Roads Barrier at 21.5 ft, lower Seawall at 21 ft, sand dunes at 14 ft). The shortest

element, the Bolivar Roads Barrier, is the highest and it has water behind it. The variation seems illogical in terms of storm surge reduction and protecting life and property.

- Future sea level appears to be treated inconsistently in the design of different elements of the USACE Plan. It appears to have been considered in all gate designs. However, it is not adequately addressed in design of the Galveston Ring Barrier and Seawall improvements, or in design of the dual sand dunes. Consistency and/or clarification is needed.
- Variability in heights of different components of the coastal spine, and inconsistency in treating future sea level, leads to varying levels of protection. Transparent and effective communication of residual water levels, risk and damage for the entire region is vital and needs improvement.

Land Barrier

- The low dual dune system included in the USACE Plan is simply a refined version of the dune proposed as an environmental restoration feature in the first iteration of the Feasibility Report, except that it is now maintained for 50 years. It provides minimal flood risk reduction benefits.
- USACE storyboards show the proposed land barrier, dual dunes having 12 and 14 ft heights, will breach and overflow at 50- and 100-year conditions with significant flood risk and damage.
- Our independent modeling verifies this.
- The life-cycle beach/dune erosion modeling and analysis done by the USACE indicates that the dune elevation will remain below 12 ft for 75-80% of the time. However, the regional storm surge protection modelling was done assuming the dunes afforded 12-ft solid protection.
- Consequently, the USACE Plan underestimates storm surge entry into the Bays and underestimates residual damages.
- The USACE Plan leaves flattened and breached barrier islands in a degraded and highly vulnerable state for several years, waiting for the next scheduled renourishment (planned every 6 or 7 years), while the region hopes that both State and Federal funds (50%-50% cost sharing) will be available to pay for renourishment.
- We recommend inclusion of a provision for immediate dune renourishment whenever severe erosion occurs. Otherwise, between renourishments, areas local to the land barrier and the entire Houston/Galveston region behind it are highly vulnerable to flooding and damage.
- TUD work shows how large a natural sand dune would need to be to defend against a 100-yr storm. It would need to be 22 ft high, 300 ft wide at the base, with a 150-ft wide crest, much larger than the current dune footprint and more expensive to build and maintain.
- We recommend a fortified dune as a stronger alternative, sand covered but having a hardened core. It can occupy a similar footprint as the USACE design. It can be made higher, if desired, to better match the elevation of the Bolivar Roads Surge Barrier and Seawall.
- Preliminary work indicates that the fortified dune would be effective, from both performance and cost/benefit perspectives.
- The USACE land barrier only provides intermittent protection and periodic renourishment is contingent upon availability of funding. Adoption of a fortified dune would “lock in” protection for the life of the project, and make future project performance and regional flood risk reduction much less dependent on timely renourishment.

Gating San Luis Pass

- The USACE Plan omits a western section including a gate system at San Luis Pass; unlike the Ike Dike concept.
- Our modeling shows that not closing the pass during storm events allows fore-runner surge in the Bay as well as the main surge, which directly effects many structures on Galveston Island, the mainland north of West Bay and around Galveston Bay.
- Leaving the San Luis Pass "back door" open leads to increased flooding and inundation on Galveston Island even for relatively frequent, weaker hurricane events
- It also disallows sealing the Bay at low tide with an approaching hurricane, to minimize in-Bay surge.
- Every contribution to water height in the Bay increases the surge and thus increases the need for and strength of the in-Bay lines of defense.
- The USACE presents no technical analysis to support not gating San Luis Pass, instead relying on hand-waving and unsupported generalities.
- The stated goal for the USACE Plan is to "promote a resilient and sustainable economy by reducing the risk of storm damage to residential structures, industries, and businesses critical to the Nation's economy."
- We recommend that the USACE conduct a thorough analysis of the benefits and costs associated with a western section of the coastal spine, which includes a gate at San Luis Pass.
- Benefits include direct reduction in damage as well as cost avoidances that arise from being able to reduce design water levels and wave conditions for all in-bay second lines of defense and non-structural measures, which in turn reduces the required extent, strength, height and cost of all in-bay measures.

Galveston Ring Barrier and Seawall

- It is crucial that the pump stations, other features, and operations for evacuating water from the Ring Barrier interior be designed to accommodate overtopping of the Galveston Seawall and the Ring Barrier in the event the design conditions are exceeded. While elevations can be designed using a 100-yr design standard, all structural elements must be resilient, designed to remain robust and fully functional, if design overtopping conditions are exceeded. Pumps should be designed using a higher design standard than a 100-yr standard, something like what the Dutch adopt when human life and safety is at risk. Pumps stations must be designed with resiliency and redundancy to reduce their risk of failure to very low levels. This is critical for avoiding loss of life. This entire subject is inadequately addressed in the USACE Plan.
- This is a complex and very difficult project, with both major flood threats increasing – sea level rise and rainfall rates. Coupled rainfall and surge hazards during hurricanes must be effectively considered in the design.
- Present plans call for a wall for protection; this will be obtrusive and divisive. We recommend consideration of a design approach that incorporates city functions into the protection using urban landscape architecture best practices – fewer walls; and consideration of using nature-based features to lower wall elevations or replace walls.
- Much of that protection to accommodate rising sea level probably won't be needed for a number of years. It might be best to take an adaptive management approach that incorporates

actual rates of increase of threats, changes in the built and natural environment, and new technologies in an evolving protection scheme.

- Raising the Galveston Ring Barrier to an elevation of 18 ft, which is recommended in the USACE Plan to accommodate future sea level, is strongly opposed by many local stakeholders.
- Implementation of a strong robust 17-ft Ike Dike concept will lower 100-yr design water levels at the Ring Barrier by 3 to 4 ft, compared to the USACE Plan. Such reductions will greatly improve Ring Barrier design and acceptability, lower its cost significantly, and, it would render a 13 or 14-ft Ring Barrier elevation suitable for accommodating the intermediate future sea level rise scenario.
- The 100-yr design water level, wave and overtopping conditions vary around the Ring Barrier perimeter. Yet, the proposed elevation of the Ring Barrier is a constant 14 ft. We recommend modifying the barrier height as needed to achieve consistency in application of the overtopping design standard, particularly lowering wall elevation in areas sheltered by Pelican Island that have reduced overtopping threats, particularly near the historic downtown area.
- We recommend carefully designing transitions between the lower Ring Barrier and the higher (21-ft) Seawall, avoiding over/under design and potential vulnerabilities (low spots).
- We concur with raising the Seawall to a uniform elevation, eliminating local vulnerabilities.
- Neither the 14-ft Ring Barrier nor the 21-ft Seawall in the USACE Plan appears to adequately account for future sea level rise. Accommodations for future sea level should be planned and designed, and the plan clearly communicated along with the residual risk that remains for the City.
- The City now has active and planned drainage improvements. We are not convinced that these improvements have been adequately interfaced to the USACE Plan for pumping and for delivery of water to the pump stations.
- Adequacy and feasibility of the USACE Plan for using underground conduits to convey water to the location of pump stations has not been demonstrated.
- We recommend that the Seawall elevation be slightly higher (1 or 2 ft) than the top elevations of the adjacent land barrier and Bolivar Roads Surge Barrier, to help divert storm surge away from the City. This is not the case in the USACE Plan.

Other In-Bay Measures

- With such high residual damage for the present USACE Plan, there are probably other in-bay measures in Galveston and West Bays that are cost-effective, but are not included in the Plan.
- No clear rationale is apparent for evaluating and selecting areas for implementation of second lines of defense and non-structural measures to reduce the high residual damage further. Selection of measures included in the Plan appears to be arbitrary, focused on the western side of Galveston Bay, apparently without consideration of other areas that also have significant residual damage, particularly those in West Bay where 55% of the residual damage occurs.
- The short extent of both the Clear Lake and Dickinson wall/gate structures appears to make them vulnerable to flanking by the storm surge. We recommend careful examination and assessment of cost and benefits of mitigation. The effect of storm surge flanking on pump requirements should also be considered and examined.
- JSU and USACE surge modeling results both suggest an overland pathway, near the Shoreacres community, for storm surge to enter the Clear Lake region. This pathway is different from the

one addressed by the wall/gate system at the entrance to Clear Lake. We believe this pathway is a cause for the high residual damage that remains in this area. We recommend careful examination and assessment of cost and benefits of measures to mitigate this pathway and reduce residual damage further.

- JSU and USACE surge modeling results both suggest that the high residual damage in the Texas City area is due to flanking around the southwestern terminus of the Texas City Levee. We recommend careful examination and assessment of cost and benefits of measures to mitigate this flanking and reduce residual damage further.
- The USACE Plan actually induces significant damage in eastern West Bay and, to a lesser degree, in the eastern half of Bolivar Peninsula. We recommend careful examination and assessment of cost and benefits of measures to mitigate the induced damage in both areas, and drive down residual damage in eastern West Bay.
- As is the case for the Galveston Ring Barrier, improving the coastal spine by fully implementing something like the 17-ft Ike Dike concept would help lower water levels everywhere in the Bays, reduce the cost of all other in-bay measures, and eliminate the need for many of them.
- We encourage design and placement of nature based features so that they contribute to shore protection and flood risk reduction. It seems that marshes might be able to reduce wave energy on the bay sides of Galveston Island and Bolivar Peninsula and perhaps areas along the north shore of West Bay, reducing residual risk. Marshes or other nature-based measures might help to partially mitigate damage induced by the USACE Plan.

Bolivar Roads Storm Surge Barrier

- USACE is commended for working with the international ISTORM storm surge barrier group and producing a greatly improved design.
- The proposed floating sector gates are subject to failure from a negative head caused by back surge from the bay side. In this particular coastal setting, there is great potential for large negative heads because of the large size and shallowness of Galveston Bay and the strength of extreme hurricane winds. This critical design issue has not been adequately addressed.
- We recommend consideration of barge gates as the principal navigation gates to circumvent the negative head design issue. Barge gates also would allow for a self-opening design during back surge events.
- Two main channels with navigational gates are proposed, whereas one might be sufficient.
- The cost estimate, $13.8B, seems very high, much higher than international experience suggests. We are concerned that the high estimate adversely skews the overall cost estimate for the project, and led to limited consideration of other means for reducing residual damage.