Chapter 5. Galveston Ring Barrier and Seawall

Introduction

Instead of the proposed Ring Barrier, we recommend consideration of a design approach that incorporates city functions into the protection using urban landscape architecture best practices. Because much of the surge protection from sea level rise 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 aimed at defending the City of Galveston from increasing nuisance flooding caused by higher tides and increased rainfall as well as from major surge events. It is important to integrate major surge protection with protection from the issue of ever-increasing nuisance flooding. Galveston will see nuisance flooding much more often as sea level and associated king tides increase. And it will see nuisance flooding much more often than major surge events from hurricanes. A ring barrier that requires the securing of many road, railroad and bayou gates is not feasible as a defense against constant small floods. Implementing the barrier would most likely be more disruptive than the small flood itself.

We recommend that the USACE continue to work closely with landscape architects, City departments, and local stakeholders to optimize implementation and quality of the solution. It appears that considerable additional engineering analyses and design work remain, in order to develop a technically sound, well-coordinated barrier and pump system, that meshes well with the urban setting and watershed within which it will be built. A goal should be to use fewer unappealing concrete walls; and, where walls are required, incorporate them into the urban landscape as unobtrusively as possible.

While we support a different design concept, even with a coastal spine in place, there is a residual risk of flooding from the bay side due to internal surge generation within the Bay and to the low elevation of the City adjacent to the Bay. The present USACE coastal protection strategy, as discussed in Chapter 2, provides little protection so Bay defenses have to be stronger. Should the coastal defenses be improved as argued in this response, the Bay measures could be much less intrusive and costly.

The USACE has developed its ring concept and it is an approach to providing bay-side protection so we will review it in this chapter. We do have concerns with the Ring Barrier's elevation, its composition and intrusiveness, and its performance for higher future sea level. The Ring Barrier's footprint in shown in Figure 5-1.

Figure 5-1. Footprint and features of the proposed Galveston Ring Barrier

The Galveston Seawall, which forms the Gulf side of the Ring Barrier, is to be raised to an elevation of 21 ft. The rest of the Ring Barrier is presently comprised of concrete floodwalls (inverted T-walls) having a crest elevation of 14 ft, with retractable navigation gates and environmental gates that open into Offatts Bayou. The USACE Plan includes a number features to promote internal drainage and retractable gates across roads and rail lines. Detached breakwaters are being considered, where the bay side of the Ring Barrier is most exposed to waves generated within Galveston Bay. The apparent purpose of the breakwaters is to reduce wave energy that reaches the floodwall, reducing wave overtopping to acceptable levels. As part of the Plan, a series of pump stations are to be located along the bay side of the Barrier. The pumps evacuate water that accumulates inside the Ring Barrier, discharging it over the floodwall and into the bay. In general, the City has to get the water near the barrier (i.e. near the pump stations) – the New Orleans problem. This could be a problem in Galveston if the interface with the City's interior drainage system is not well coordinated, planned and designed. All figures and tables presented in this chapter were extracted from the Feasibility Report.

Figure 5-2 shows the terrain contours of the watershed inside the Ring Barrier. The eastern half of the interior watershed slopes toward the bays; the western half is quite low in elevation and very flat. Consequently, the eastern half includes rather well drained areas, while the western half includes the poorly drained near Offatts Bayou.

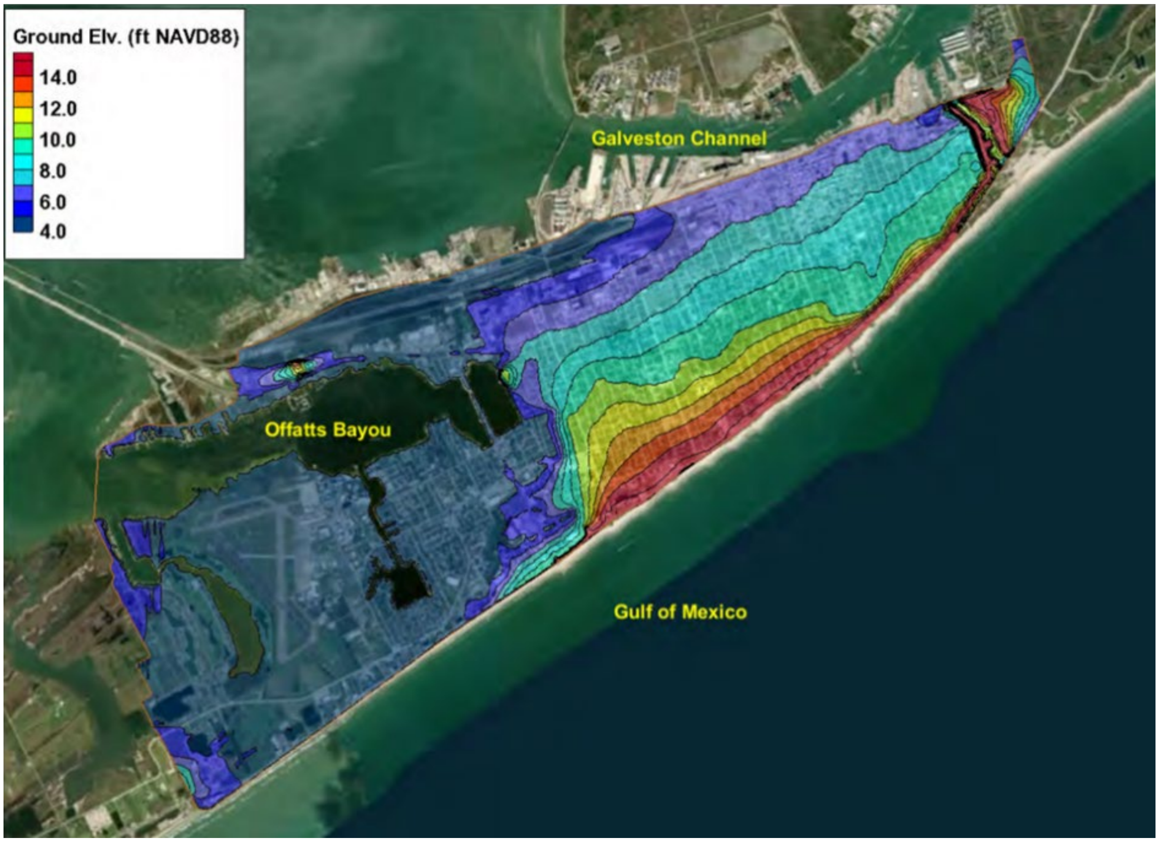

Figure 5-2. Ground elevation contours inside the Ring Barrier

Design of the western half is complicated because of the flat low topography and numerous flows into a gated Offatts Bayou.

Figure 5-2 provides a clear illustration of just how vulnerable the City is to flooding from the bay side, even with the USACE Plan in place. The with-project 100-yr water surface elevations (WSE) on the bay side of the City of Galveston range from 10 to 12 ft NAVD88 for present sea level. They are estimated to be approximately 2 ft higher (12 to 14 ft) for the intermediate-rise future sea level scenario. Areas in the City that are lower than the yellow-shaded area shown in Figure 5-2 are inundated for a WSE of 11 ft, which is nearly the entire City except for the small higher areas immediately adjacent to the Seawall.

Overall Approach to Design and Implementation

The overall approach being taken by the USACE to design and implement the Ring Barrier and Seawall improvements is unclear. The current design for both components was done for present sea level. However, the design standard stated in the Feasibility Report seems to include consideration of future sea level, using the intermediate rate-of-rise scenario. This future sea level scenario was considered in designing all the gate systems included in the USACE Plan (the Bolivar Roads Storm Surge Barrier and the wall/gate systems at the entrances to Clear Lake and Dickinson). The Feasibility Report mentions raising the elevation of the Ring Barrier from 14 ft to 18 ft in the future to accommodate rising sea level. What about the Seawall? What pumping capacities are required in the future, which are dependent upon future elevations of not only the Ring Barrier but also the Seawall.

Does the approach involve design and construction for present sea level, and then adapting the entire system at some future time as sea level rise unfolds? Much of the protection associated with a future sea level rise will not 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. However, this puts added demands on the current design, to enable future adaptions of the Ring Barrier, pump stations and the Seawall. Adaptability of all three components did not seem to be addressed much, if at all, in the Report.

There are other unanswered questions regarding the design approach. The elevation of the proposed Ring Barrier, 14 ft, is uniform along its entire length. Is uniformity in elevation an important design criterion, even though the overtopping threat varies around the periphery of the Ring Barrier? Is the 100-yr overtopping rate the design standard, or something else? Is the "ultimate limit" overtopping rate of 1 cfs/ft the standard, or is it a lower value? What is the ultimate limit value of overtopping for the inverted T-wall, that has a concrete pad on the land side to withstand overtopping and overflow, and how was it determined? Can the overtopping design standard be increased by extending or strengthening the scour pad, or by armoring the pad with stone riprap?

Clarification is needed for the overall design and implementation approach that is being recommended for both the Ring Barrier and Seawall improvements, and for the exact design standards that are being applied. The Feasibility Report states that additional work on designing the Ring Barrier will be done at the PED stage. We concur that there is much more work that needs to be done to find an acceptable solution for the City of Galveston that performs well for present and future sea levels.

Ring Barrier Composition and Elevation

We recommend a design approach that thoroughly incorporates city functions into the protection using urban landscape architecture best practices. Present plans call for a concrete floodwall (inverted T-wall) for most of the Ring Barrier perimeter. This solution can be visually unappealing, obtrusive and divisive in some areas such as the historic downtown area. In heavily industrialized areas, such as the Port, a plain concrete floodwall might be fine and unobtrusively integrate well into existing infrastructure. Walls certainly have a place, particularly where space is limited. In open less developed areas, natural-looking turf covered earthen/clay levees could be an attractive alternative. More work needs to be done to select the best solution for the area in which it is to be implemented.

Figure 5-3 shows the reaches that were considered in the analysis of wave overtopping, to aid in the design of the Ring Barrier and sizing of pumps. Representative 100-yr significant wave heights and water surface elevation (WSE) were calculated for each reach, then both were used to calculate overtopping rates and volumes for each reach.

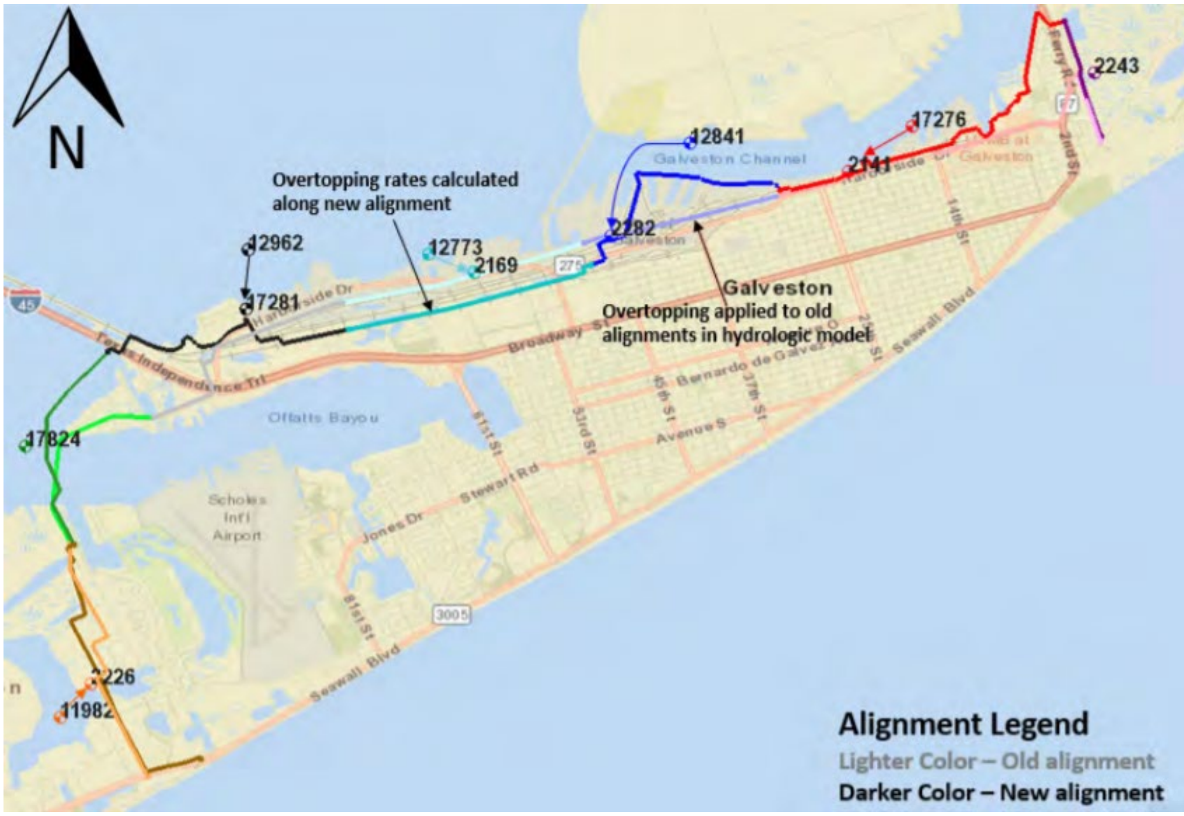

Figure 5-3. Reaches consider in designing the Galveston Ring Barrier

Table 5-1 shows the calculated design WSEs and significant wave heights, for the different reaches shown in Figure 5-3. The 90% confidence limit (CL) values correspond to the adopted design standard. All design WSEs shown in Table 5-1 are for the present sea level. Table 5-2 shows calculated overtopping rates, 50% and 90% CL values, for the 100-yr wave and water level conditions, representing both present and future sea levels. Overtopping values in Table 5-2 utilized the WSEs and wave heights from Table 5-1, and a 2.1 ft increase in water level was used to represent the effects of rising sea level for the intermediate rise scenario.

Results in Table 5-1 show that, for present seal level, design WSEs appear to monotonically increase from east to west around the periphery of the Ring Barrier. The with-project 100-yr WSE is lowest, 10.3 ft, near the historic downtown area, increases to 11.3 ft in the industrial area to the west of the Port, to 11.8 ft at Offatts Bayou, and to a maximum of 12.3 ft along the western side of the Ring Barrier. The highest wave heights (6 to 7 ft) occur where the Ring Barrier is subjected to the largest waves that are generated in Galveston Bay, areas not protected by Pelican Island. Pelican Island affords sheltering and protection from wave energy to the UTMB campus area, historic downtown area, and the Port of Galveston. Design wave heights behind Pelican Island range from 2.4 to 3.9 ft. Due to the very limited fetch, wave periods must be quite small as well, so total wave energy in this area is relatively low. Design wave heights along the western side of the Ring Barrier range from 2.5 to 4.4 ft.

Table 5-1. Design water surface elevation (WSE) and significant wave height for the 100-yr year case and present sea level

Point	WSE [ft NAVD88] - 50% CI	WSE [ft NAVD88] - 90% CI	Hs [ft] - 50% CI	Hs [ft] - 90% CI
11892	10.0	12.3	2.1	2.5
12773	9.2	11.3	5.3	6.2
12841	8.6	10.6	2.0	2.4
12962	9.6	11.7	5.8	6.8
17276	8.3	10.3	3.3	3.9
17284	9.6	11.8	4.0	4.6

Table 5-2. Summary of overtopping rates [cfs/ft] for design wave and water level conditions, and present and future sea level

Point	100-year, 50% CI, 0.0' SLR [cfs/ft]	100-year, 90% CI, 0.0' SLR [cfs/ft]	100-year, 50% CI, 2.1' SLR [cfs/ft]	100-year, 90% CI, 2.1' SLR [cfs/ft]
11892	0.03	0.61	0.11	1.08
17284	0.30	1.76	0.58	2.98
12962	0.07	1.06	0.64	4.17
12773	0.003	0.19	0.18	1.86
12841	0.002	0.01	0.001	0.11
17276	0.05	0.39	0.03	0.90

In the USACE Plan, a uniform Ring Barrier elevation of 14 ft is proposed for the entire perimeter. The rationale for selecting a uniform elevation is unclear, in light of the variability of overtopping rates shown in Table 5-2. Overtopping rates near the historic downtown area are much smaller than rates calculated for the other reaches. For present sea level, rates in that area are a factor of 20 or more less than rates in other reaches; and for future sea level, a factor of 10 or more less than rates experienced elsewhere. This occurs because of the low WSE and low wave energy due to sheltering by Pelican Island. Overtopping rates suggest that a lower barrier elevation might be possible in the historic downtown area; a lower barrier there is certainly desirable. We recommend further investigation into the possibility that a lower barrier can be implemented in the historic downtown area. Beyond the sheltering effect of Pelican Island, where WSEs increase and wave energy increases greatly, overtopping rates are highest. It seems that a higher barrier or some other land-based measure can be implemented to reduce overtopping in this area to an acceptable amount. A higher wall in the industrial area west of the Port might be quite acceptable. Other possible methods for reducing the relatively high rates of overtopping in this area are discussed more in a later section.

The transition from the 14-ft Ring Barrier to the 21-ft Seawall at its western end will have to be closely examined and designed carefully. An abrupt transition in elevation should be avoided. The gradient of storm surge and wave conditions as surge levels decrease from the Gulf side to the bay side in this area should be considered in designing this transition. Missteps could lead to vulnerabilities and unanticipated leakage of storm surge into the Ring Barrier's interior. This area is likely to have high and turbulent flow directed toward the bay. The transition also might require armoring of the front side of the Ring Barrier.

Seawall Modifications

The USACE plans to raise the Galveston Seawall and incorporate measures to reduce the rate of overtopping into the raising. A 4ft additional vertical wall on the landward side of Seawall Blvd. has been proposed to raise the Seawall. This addition would be quite disruptive to businesses along the seawall. Alternatives could be attractive such as small berms. Also, the structural integrity of the Galveston Seawall in the (new) design condition has to be verified.

We concur with the plan to ensure that the Galveston Seawall has a uniform crest elevation over its length, eliminating any non-uniformities (vulnerabilities) that exist, which could serve as conduits for unanticipated overtopping and overflow into the City.

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.

In the USACE Plan, design of pump stations assumes that overtopping of the Galveston Seawall is negligible. It appears that this assumption has not been demonstrated for the present sea level. The Feasibility Report indicates that if overtopping is non-negligible, then pump capacities will have to be increased. It will be important to design improvements to the Seawall such that overtopping is reduced to an amount that is consistent with assumptions made to size the pumps. We recommend laboratory scale modeling be done to aid the design of Seawall improvements. We also recommend that scale modeling be done to quantify how much overtopping occurs for hurricane events that exceed the design standard, which are used to assess resiliency of the entire system, such as a 500-yr overtopping event.

Some places in the Feasibility Report indicate that the Seawall raising is a "future adaption" but the main report says the seawall be one of the initial focusses for design and construction. Clarify when construction of the seawall raising is to begin. If planned for the future, what will trigger the construction? The current elevation of the Seawall is 17 ft, and the with-project 100-yr water level is 16.5 ft for present sea level (from Figure 2-22 in the Feasibility Report). The current seawall is quite vulnerable to substantial overtopping for the 100-yr design standard. If raising is to wait, it is of concern that sizing of the pump stations for present sea level assumes negligible overtopping of the Seawall.

Detached Breakwaters for Reducing Overtopping

As shown in Figure 5-1, detached breakwaters are being considered to reduce overtopping in the area just to the west of the Port, which is unprotected by Pelican Island and experiences the highest overtopping rates among all reaches. That seems like a rather expensive solution. If reduction in overtopping is the sole purpose, why isn't raising the height of the Ring Barrier in this area being considered, or if it was considered, why was it rejected?

There are other land-based options for dissipating wave energy and reducing overtopping that have a lower cost, such as …

- a different type of wall, like a recurved wall face to reduce overtopping
- a low rubble dike some distance in front of the inverted T-wall to trip and break the waves, such as elevating the bed of a rail line on a small rubble dike
- use of more natural features such as grass covered berms or dikes, perhaps in concert with dense vegetation. The Dutch use a technique of excavating soil to increase water storage capacity and using the excavated soil to construct a berm. Perhaps excavation could be done to enhance movement of water toward Offatts Bayou, with the material used to construct the berms. Or, bring in more erosion resistant clay to form an earthen dike or berm, compact it, then add top soil and grass cover like what is done in the Netherlands for levee construction, and was done in New Orleans. The wave action will not last very long so severe erosion potential is reduced, and the overtopping threat is addressed by the inverted T-wall
- A line of readily available precast concrete forms that are filled with sand or soil and capped with concrete, or perhaps covered with soil and vegetated

We recommend consideration and analysis of other alternatives to the detached breakwaters, and evaluation of their benefits, costs and acceptability to local stakeholders.

Armoring

Following the lessons of New Orleans, where walls are used, it is important to armour on the land side to withstand overflow/overtopping without breaching (a resilience requirement). All elements of the Ring Barrier need to be able to withstand the effects of overtopping and steady overflow, for the system to be resilient and remain robust when design conditions are exceeded. We recommend evaluating overtopping and overflow for a hurricane from the simulated set of storms that produces the highest overtopping conditions along the Ring Barrier periphery and the Seawall, and using these conditions to design scour protection for all elements of the Barrier, to ensure its resiliency.

Lessons learned from Hurricane Katrina also indicated that failures can occur where there are abrupt changes in elevation of walls/levees and at transitions between walls and levees. Failures at such locations generally occurred because of flow concentrations and/or overtopping and steady overflow that caused scour and subsequent breaching. Perhaps this a reason for the uniform elevation for the Ring Barrier in the USACE Plan. We expect that well-designed scour protection can be implemented at transitions involving small changes in barrier elevation, avoiding any potential scour problems.

Environmental Forcing (Surge, Rainfall and Sea level Rise)

The Galveston Ring Barrier needs to deal with coupled hazards, i.e. rainfall and surge during a hurricane. Over the long term, this is a difficult project to design and operate, with both major flood threats increasing – sea level and rainfall rates. Drainage and retention systems need to be designed to accommodate this. The co-occurrence (i.e. dependence) between rainfall and surge need to be further studied and characterized for inclusion in the design process. This also applies to the Clear Creek and Dickinson gate and pumping systems that are also affected by rainfall, runoff and surge simultaneously.

The updated H&H work examined the newly published NOAA precipitation rates, but they have not yet been included in the modeling. The 25-yr rainfall rates used previously (12.7 in) is approximately 10% higher than the new NOAA rate (11.5 in). How much do the 50-yr, 100-yr, and 500-yr rates used before differ from the new NOAA rates?

Interface with the Local Drainage System

The New Orleans' experience with rain-induced flooding inside their ring barrier teaches us that their city's drainage system cannot efficiently get the water to the ring, to be pumped over the barrier. The City of Galveston, like New Orleans, is responsible for its internal drainage. The City has active and planned drainage improvements. We are not convinced that these improvements have been adequately interfaced to the USACE Plan. It is not clear that all the areas within the proposed Ring Barrier will be able to drain efficiently to the ring boundary and reach the USACE-planned pumps. Proper interfacing is essential for the project to protect from rain-induced flooding.

The USACE Plan relies on considerable lengths of large buried enclosed channels/conduits for transporting water to the pump stations. Feasibility of this aspect of the Plan has not been demonstrated. In light of possible obstructions posed by utilities or other factors, the feasibility of constructing such channels should be evaluated.

Pump and Barrier Operations

The 100-yr design standard is not a particularly high one, far lower than that used in the Netherlands when they design ring barriers around concentrations of people. What back-up systems or redundancies are planned in the event pumps are overwhelmed or inoperable? It will be critical to make sure the gates leading to Offatt's Bayou can be operated during the widest possible range of head differences that can exist between interior and exterior water levels in order to dewater the ring interior.

When hurricanes approach the coast, they deposit a considerable volume of water onto the continental shelf. Once the eye moves through and winds subside, and the Bolivar Roads gates are reopened, the head difference between the Gulf and Bay water levels will force water to flow in the bays. This could raise levels inside the bays by several feet, changing tail water elevations. How might this process influence pump operations and a desire to reopen the gates leading to Offatt's Bayou? What about the pump stations at Dickinson and Clear Lake?

Most of the H&H modeling assumes a tail water elevation of MHW. However, seasonal steric effects, which vary from hurricane season to season, and within a season, and the surge forerunner that accompanies an approaching major hurricane might increase the water surface by up to several feet above MHW. How would such increases in tail water effect the design and operation of the pumps, and time required to pump down Offatt's Bayou? Same question for a higher future sea level.

Removable floodwalls are proposed. How long does it take to install and remove them, and what equipment/manpower is required? Where are they stored in relation to the deployment site(s)? What is the risk of encountering a problem with such a measure? It seems preferable to have something “in-place” that just has to be closed by swinging, dropping, or lifting. Suggest the USACE reevaluate the design if it cannot be operated in this manner.

Resiliency to Rising Sea level and Extreme Events

It is important that the Ring Barrier be resilient for rising sea level and for extreme hurricanes that exceed the design standard. The Ring Barrier should experience minimal damage and remain robust and operational for extreme hurricanes, including for another hurricane that occurs later during the same hurricane season.

Neither the 14-ft Ring Barrier nor the 21-ft Seawall appears to account for future sea level rise. To do so requires raising the elevation of the Ring Barrier by 4 ft; and, as yet undetermined, modifications to the Seawall and perhaps to the pump stations and other component that transport water to the pump stations. With rising sea level the City becomes increasingly more susceptible to greater amounts of overtopping and overflow.

What is the plan for evacuating water from within the Ring Barrier when the pump capacity is exceeded and possibly overwhelmed? Resilience in the face of increasing future sea level and extreme events that exceed the design standard should be assessed and planned for, and the plan clearly communicated, including an assessment of the residual risk. This topic should be addressed in the Feasibility Report.

Implications of a Stronger Coastal Spine

The City of Galveston would benefit greatly from a stronger coastal spine. JSU research suggests that a robust 17-ft Ike Dike would lower the 100-yr WSE along the bay side of Galveston by approximately 3 ft, compared to the USACE Plan. Wave conditions (significant height and energy) also will be reduced because of the reduction in surge levels. The reduction in 100-yr design water level and wave height will reduce the overtopping threat considerably. Consequently, we expect that for present sea level, a Ring Barrier elevation of 11 to 12 ft would meet the 100-yr design standard, compared to the 14 ft elevation in the USACE Plan. We expect that a Ring Barrier elevation of 13 to 14 ft would meet the 100-yr design standard for the intermediate future sea level rise scenario, instead of 18 ft in the USACE Plan. A significantly lower Ring Barrier elevation is a highly positive outcome, in light of stakeholder desires to minimize stick-up heights and make it the barrier less intrusive.

The lower elevation also will result in a significantly lower cost for the Ring Barrier or other flood protection schemes.