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Sabine Pass to Galveston Bay, TX Pre-Construction, Engineering and Design (PED): Coastal Storm Surge and Wave Hazard Assessment

Report 3 – Orange County

Abigail L. Stehno, Jeffrey A. Melby, Shubhra Misra,
Norberto C. Nadal-Caraballo, and Victor Gonzalez

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Abstract

The US Army Corps of Engineers, Galveston District, is executing the Sabine Pass to Galveston Bay Coastal Storm Risk Management (CSRM) project for Brazoria, Jefferson, and Orange Counties regions. The project is currently in the Pre-construction, Engineering, and Design phase. This report documents coastal storm water level (SWL) and wave hazards for the Orange County CSRM structures. Coastal SWL and wave loading and overtopping are quantified using high-fidelity hydrodynamic modeling and stochastic simulations. The CSTORM coupled water level and wave modeling system simulated 195 synthetic tropical storms on three relative sea level change scenarios for with- and without-project meshes. Annual exceedance probability (AEP) mean values were reported for the range of 0.2 to 0.001 for peak SWL and wave height (H_{mo}) along with associated confidence limits. Wave period and mean wave direction associated with H_{mo} were also computed. A response-based stochastic simulation approach is applied to compute AEP values for overtopping for levees and overtopping, nappe geometry, and combined hydrostatic and hydrodynamic fluid pressures for floodwalls. CSRM crest design elevations are defined based on overtopping rates corresponding to incipient damage. Survivability and resilience are evaluated. A system-wide hazard level assessment was conducted to establish final recommended system-wide elevations.

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Preface

The study summarized in this report was conducted at the request of the US Army Corps of Engineers (USACE), Galveston District (SWG). Dr. Shubhra Misra was the primary engineering point of contact at SWG. The portion of the study reported herein was funded by SWG, under a Cross Charge Labor Code, and primarily conducted at the US Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL), Vicksburg, MS, during the period October 2018–May 2021.

SWG project leadership included Mr. Eddie Irigoyen, SWG Project Manager (PM) for Freeport; Mr. Charles Wheeler, SWG PM for Port Arthur; and Mr. Orlando Ramos-Gines, SWG PM for Orange County. Dr. Shubhra Misra was SWG project technical lead. At the time of this study, Mr. Robert Thomas was Chief, Engineering and Construction, SWG. At ERDC CHL, Mr. Chad Bounds was Chief of Harbors, Entrances, and Structures Branch within the Navigation Division, led by Ms. Ashley Frey, Acting Chief. Mr. Victor Gonzalez was Acting Chief of Coastal Processes Branch within the Flood and Storm Protection Division, led by Dr. Cary A. Talbot. At the time of publication of this report, Dr. Ty V. Wamsley was Director, CHL, and Mr. Keith Flowers was Deputy Director, CHL.

COL Teresa A. Schlosser was Commander of ERDC, and the Director was Dr. David W. Pittman.

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This report underwent the US Army Corps of Engineers review process. Internal SWG review, known as District Quality Control (DQC), included independent review by Dr. Himangshu Das. In addition, Agency Technical Review (ATR) and Independent External Peer Review (IEPR) were thorough. All reviewers are gratefully acknowledged for improving this report.

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Post-DQC Revision	05/04/2020	Extensive changes and updates based on DQC comments
Post-ATR Revision	07/02/2020	Minor updates and revisions based on ATR comments
Post-IEPR Final	07/02/2020	Minor updates and revisions based in IEPR comments

DQC comments, responses, back-checks, and DQC certification are available from the SWG and in ProjNet.

Executive Summary

The US Army Corps of Engineers (USACE), Galveston District, is executing the Sabine Pass to Galveston Bay (S2G) Coastal Storm Risk Management (CSRM) project for Brazoria, Jefferson, and Orange Counties regions. The project is currently in the Pre-construction, Engineering, and Design (PED) phase. As identified during the Final Integrated Feasibility Report – Environmental Impact Statement (USACE 2017), the S2G project CSRM formulated measures consist of reducing risks of tropical storm water level (SWL) impacts by constructing the new Orange 3 CSRM system in Orange County and increasing the level of risk reduction and resiliency of the existing Port Arthur and Vicinity and Freeport and Vicinity CSRM systems in Jefferson and Brazoria Counties, Texas.

As part of the ongoing PED phase of the project, this report documents coastal SWL and wave hazards for the Orange County CSRM system and is part of a larger analysis focused on the evaluation of the entire CSRM systems for Jefferson, Brazoria, and Orange Counties. Coastal SWL, wave loading, and wave and SWL overtopping are quantified using state-of-the-art hydrodynamic modeling and stochastic simulations.

A multivariate probabilistic model of historical hurricane parameters was developed that spans the full range of tropical storm hazards from frequent, low-intensity storms to very rare, very intense storms. The probabilistic model was sampled efficiently to develop a suite of 195 synthetic tropical storms that effectively capture the flood hazard for the region from Freeport to the Louisiana-Texas border. Wind and pressure fields were developed for these 195 storms using the planetary boundary layer model.

The CSTORM coupled circulation, SWL, and wave modeling system was used to accurately quantify the SWL and wave hazards. New model meshes were developed from very-high-resolution land and sub-aqueous surveys for without- and with-project scenarios. With-project meshes include the new Orange CSRM, deepening of Sabine-Neches Waterway, and increased levee and floodwall elevations as authorized under the S2G feasibility study. The new meshes provide the highest-resolution regional SWL and wave modeling done to date for the region. The CSTORM model was validated against historical storms and then used to model the 195 synthetic tropical storms. The storms are run on three relative sea level

change (RSLC) scenarios for without- and with-project meshes. These RSLC scenarios are (1) SLCo corresponding to project completion in 2027 and an associated “Low” RSLC projection, (2) SLC1 corresponding to the end of a 50 yr¹ service lifecycle in 2077 and an associated “Intermediate” RSLC projection, and (3) SLC2 corresponding to the end of a 100 yr service lifecycle in 2127 and an associated “Intermediate” RSLC projection. A “High” RSLC projection over a period of 50 yr is approximately the same as an “Intermediate” RSLC projection over a period of 100 yr, so SLC2 corresponds closely with the end of a 50 yr service life in 2077 under a “High” RSLC projection.

Flood hazard exposure of the project features was quantified by computing hazard curves for the CSTORM output near the structures. Annual exceedance probabilities (AEP) were computed for the range of 1 to 0.0001 for peak SWL and wave height (H_{mo}) but is reported out in tables only between 0.2 to 0.001 AEP. Wave period (T_p) and mean wave direction associated with H_{mo} were also computed. Both mean values and confidence limits (CL) are summarized herein. In this case, CLs are used to describe epistemic uncertainty or levels of assurance. For hazard curves contained herein, the mean and median are indistinguishable. Therefore, only mean values are reported. The 1% AEP (100 yr average recurrence interval) wave parameters H_{mo} and T_p describe small, short waves that would be expected to characterize flood conditions inland, as occur in the area of the Orange County CSRM.

The analysis stochastic simulation uses a response-based approach where the overtopping responses are computed for each storm and then hazard relations are computed from the results. The peaks-based response-based approach yielded a very accurate stochastic response with a reasonable computational requirement.

Crest design elevations were based on overtopping rates corresponding to incipient damage. Limit states for overtopping rate for levees of $q = 0.01$ cfs/ft for the 50% CL and $q = 0.1$ cfs/ft for the 90% CL, and for floodwalls of $q = 0.03$ cfs/ft for the 50% CL and $q = 0.1$ cfs/ft for the 90% CL, were

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¹ For a full list of the spelled-out forms of the units of measure used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office 2016), 248-52, <https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf>.

based on the start of erosion for a good-quality grass cover on a clay levee at 1% AEP. These limit states are accepted standard of practice both within the USACE and internationally. An additional survivability or resilience limit state of $q = 1$ cfs/ft was considered. While not used directly for design, the survivability limit state helped inform decisions by the project delivery team on final crest elevations. For vertical structures (e.g., floodwalls), overtopping nappe geometry and forces and combined hydrostatic and hydrodynamic pressures at various AEPs were computed. Optimized crest elevations for the 1% AEP hazard level satisfying overtopping criteria were also developed along with associated floodwall combined hydrostatic and hydrodynamic pressure and nappe geometry parameters. A system-wide hazard level assessment was conducted to establish final recommended system-wide elevations for both SLC1 and SLC2.

1 Introduction

1.1 Background

The US Army Corps of Engineers (USACE), Galveston District (SWG), is executing the Sabine Pass to Galveston Bay (S2G) Coastal Storm Risk Management (CSRM) project for Brazoria, Jefferson, and Orange Counties regions. The project is currently in the Pre-construction, Engineering, and Design (PED) phase.

The Final Integrated Feasibility Report – Environmental Impact Statement (USACE 2017) identified measures of reducing risks of tropical storm inundation impacts and is described in Melby et al. (2021). The S2G PED project incorporates additions and modifications to CSRM systems in Orange, Jefferson, and Brazoria Counties, Texas (Figure 1). The details of the complete S2G PED project analysis approach are described in Melby et al. (2021). This report describes the Orange County CSRM system (Figure 2), which consists of proposed 56,755 ft^(*) of levee, 82,169 ft of floodwall, 31 road closure gates, 7 pump stations, and 2 vertical lift gates.

Figure 1. CSRM for Brazoria (left), Orange (middle), and Jefferson (right) regions.

* For a full list of the spelled-out forms of the units of measure used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office 2016), 248-52, <https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf>.

Figure 2. Aerial view of Orange County proposed hurricane flood protection system with analysis transects.

1.2 Objective

As part of the ongoing PED phase of the project, this report documents the methodology to analyze coastal storm inundation and wave hazards for Orange County and is part of a larger analysis focused on the evaluation of the CSRM systems for Jefferson, Brazoria, and Orange Counties. Coastal storm inundation, wave loading, and wave and steady flow overtopping and overflow are quantified using state-of-the-art hydrodynamic modeling and stochastic simulations.

1.3 Approach

This study was preceded by the S2G planning study and Coastal Texas Comprehensive Study (CTXCS^{*,†}). The analysis used for this Orange County CSRM system investigation is summarized below. Melby et al. (2021) provides further details of the analysis methods. If the task was completed in prior studies, it is noted.

1. Characterize the CSRM system and components.
2. Characterize bathymetry and topography to 0.3 m accuracy. Described in Melby et al. (2021).
3. Gather Gulf of Mexico tropical cyclone (TC) data since 1938 from HURDAT II database. Completed in CTXCS.
4. Construct joint probability model (JPM) of TC parameters $\hat{x}=(x_o=\text{reference location}, \Delta P=\text{central pressure deficit}, R_{max}=\text{radius of maximum winds}, V_f=\text{forward speed}, \theta=\text{heading direction})$. Completed in CTXCS.
5. Efficiently sample JPM using optimal sampling methods to construct 660 TCs that effectively map practical probability space. Construct synthetic storm suite with parameterized TCs. Completed in CTXCS.
6. Construct numerical model meshes, validate with historical data and quantify modeling uncertainties. Described in Melby et al. (2021).
7. Construct wind and pressure fields using planetary boundary layer (PBL) numerical model. Completed in CTXCS.
8. Model offshore waves with wave model (WAM) and surge and nearshore/inland waves with CSTORM (coupled ADCIRC and STWAVE) of all 660 TCs. Completed in CTXCS.
9. Create efficient subsample of 660 TCs using a genetic algorithm optimization that best matches the hazard with the fewest storms. New sample consisted of 195 storms, of which 189 storms were selected for design analysis. New storm rates were computed with metamodels. Described in Melby et al. (2021).
10. Model storm water levels and nearshore/inland waves with CSTORM for without- and with-project alternatives and three relative sea level

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* Massey, T. C., R. Jensen, M. Cialone, Y. Ding, M. Owensby, N. C. Nadal-Caraballo. 2019. *A Brief Overview of the Coastal Texas Protection and Restoration Feasibility Study: Coastal Storm Model Simulations of Waves and Water Levels*. ERDC/CHL LR-19-7. Vicksburg, MS: US Army Engineer Research and Development Center. NOTE: For access to this document, contact the author.

† Nadal-Caraballo, N. C., A. B. Lewis, V. M. Gonzalez, T. C. Massey, and A. T. Cox. Draft. *Coastal Texas Protection and Restoration Feasibility Study, Probabilistic Modeling of Coastal Storm Hazards*. ERDC/CHL Technical Report, Vicksburg, MS: US Army Engineer Research and Development Center.

- scenarios for 189 synthetic TC. Described in Melby et al. (2021). The with-project condition included CSRM system with feasibility authorized crest elevations.
11. Sample storms stochastically; extract storm water level (SWL), wave height (H_{mo}), wave period (T_p), mean wave direction and incorporate uncertainty; perform JPM integration to compute hazard curves for SWL, H_{mo} , and response parameters (e.g., q , the average overtopping rate). Also compute confidence limits (CL) (also called *level of assurance*). For hazard curves contained herein, the mean and median are indistinguishable. Therefore, only mean values are reported. For USACE projects, q is computed at 50% and 90% upper CLs and compared to overtopping limit states corresponding to start of damage and incipient failure. The details of the stochastic simulation approach and application of uncertainty are summarized in Appendix G of Melby et al. (2021).

The analysis took advantage of previous regional modeling completed under the Federal Emergency Management Agency, Flood Information Study that followed Hurricane Ike*, S2G Feasibility Study† (USACE 2017), and Coastal Texas Comprehensive Study (see Melby et al. [2021], Appendix A for a summary of prior pertinent modeling and analysis studies). Additional hurricane SWL and wave hydrodynamic regional modeling, nearshore wave modeling and overtopping modeling was completed for the S2G PED study. The extremal statistics were computed for the storm responses. The process used in the present analysis is described in Chapter 2 of Melby et al. (2021). Historical storms are described in Chapter 4, Appendix B, and Appendix D of Melby et al. (2021).

1.3.1 Storm hazard development

Probabilistic synthetic storm modeling is used to assess coastal storm hazards in hurricane-prone areas with a lack of adequate storm data. The joint probability method with optimal sampling was used to develop a total

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* FEMA (Federal Emergency Management Agency). 2011 (Unpublished). *Flood Insurance Study: Coastal Counties, Texas. Intermediate Submission 2: Scoping and Data Review*. Joint Report prepared for Federal Emergency Management Agency by the Department of the Army, US Army Corps of Engineers, Washington DC.

† Melby, J. A., N. C. Nadal-Caraballo, J. Ratcliff, T. C. Massey, and R. Jensen. 2015 (Unpublished). *Sabine Pass to Galveston Bay Wave and Water Level Modeling*, ERDC/CHL Technical Report, Vicksburg, MS: US Army Engineer Research and Development Center.

of 660 synthetic storms during the CTXCS study*. For the S2G PED study, a genetic algorithm was used to select an optimal subsample from the 660 CTXCS storms. The details of the approach are presented in Chapter 2 and Appendix C of Melby et al. (2021). The list of the 660 CTXCS model storms and 195 S2G model storms are in Appendix D of Melby et al. (2021). This set was further reduced to 189 storms. The six storms that were not used are noted in Appendix D of Melby et al. (2021).

1.3.2 Regional storm water level (SWL) and wave modeling

Regional wind and surface pressure fields were generated with the PBL model and offshore waves with the third-generation wave model, WAM (Komen et al. 1994). Nearshore wave modeling was done with the STWAVE model. Circulation and water levels were generated with the ADCIRC model. The parameters used to set up ADCIRC, such as the Manning's n value, tidal constituents, river inflows, and wind effects, are detailed in Chapter 4 of Melby et al. (2021). CSTORM modeling validation is summarized in Appendix B of Melby et al. (2021).

LiDAR topography data collected during 2018 were processed to construct a bare-earth digital elevation model for the area. Excerpts from the metadata are given in Appendix E of Melby et al. (2021) that describe data collection, data processing, and quality control. Note that throughout this study, datum references followed requirements published in EM 1110-2-6056 (USACE 2010), including those specifically stated in Chapter 5 of that manual – “Procedures for Referencing Datums on Coastal Hurricane and Shore Protection Projects.” Modeling and grid details of the WAM, STWAVE, and ADCIRC models for S2G are found in Chapter 3 of Melby et al. (2021). ADCIRC mesh and STWAVE grids were modified from those used in CTXCS to more accurately capture the existing and proposed flood protection measures. The details of these modifications are in Chapter 3 of Melby et al. (2021).

Select spatial locations, called *save points* (SP), were identified for CSTORM model parameter outputs. For S2G PED, a total of 5,148 SPs

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* Nadal-Caraballo, N. C., A. B. Lewis, V. M. Gonzalez, T. C. Massey, and A. T. Cox. Draft. *Coastal Texas Protection and Restoration Feasibility Study, Probabilistic Modeling of Coastal Storm Hazards*. ERDC/CHL Technical Report. Vicksburg, MS: US Army Engineer Research and Development Center.

were identified in the Freeport, Port Arthur, and Orange CSRM regions. The SP selection process is detailed in Chapter 3 of Melby et al. (2021).

Tides were not included in the CSTORM synthetic storm modeling but rather included as epistemic uncertainty in the simulation modeling. This is consistent with other recent flood protection studies in the Gulf of Mexico. An error assessment was conducted to confirm that this approach was reasonable, and details are presented in Chapter 3 of Melby et al. (2021). Riverine flows from the Sabine River were not included in the CSTORM modeling, as described in Melby et al. (2021).

1.3.3 Design criteria

The criteria used for design of the levee and floodwall crest elevations are fundamentally based on a serviceability start-of-damage overtopping limit state at an annual exceedance probability (AEP) of 1%. This is consistent with present USACE practice and was followed for the planning phase of S2G and other recent regional projects such as the Hurricane Storm Damage Risk Reduction System (HSDRRS) (USACE 2012).

Defining overtopping design criterion is empirical and exact guidance does not exist. The Coastal Engineering Manual (CEM) (USACE 2008) provides some general criteria, but there is considerable uncertainty due to a wide variation of potential structure configurations and surrounding ground cover. For example, a floodwall on a grass levee would likely be designed for overtopping rates consistent with grass levees while a floodwall on a concrete wharf or quaywall would be designed for overtopping rates consistent with concrete armoring. The following conservative overtopping rate criteria were used for the HSDRRS project and was followed herein:

- For design levee elevation, overtopping rates of 0.1 cfs/ft at 90% confidence limit and 0.01 cfs/ft at 50% confidence limit were used as a limit state for initiation of damage,
- For design floodwall elevation, overtopping rates of 0.1 cfs/ft at 90% confidence limit and 0.03 cfs/ft at 50% confidence limit were used as a limit state for initiation of damage.

Damage here refers to the impact on surrounding soils near a structure due to overtopping. If the surrounding area is entirely concrete, the damage would be limited. Damage, in this sense, does not include settlement, damage to the wall, or geotechnical failure due to wall

separation or levee slip circle failure. Herein, damage is defined only in relation to erosion of the leeside surrounding soil that supports the structure components. Implications of using these limit states over alternatives is described in Melby et al. (2021).

1.3.4 Coastal structure response hazard calculations

As described in Melby et al. (2021), two stochastic simulation approaches are commonly used for large-scale flood protection evaluation: event-based and response-based. Event-based is a partially probabilistic approach where the AEP values of water level and wave forcing parameters, such as the 1% AEP, are used to compute responses. Response-based approaches compute the structure response for each storm and then compute statistics from the peak responses. The design safety level used as a statistical basis for event-based approaches (e.g., AEP = 1%) is applied to the storm hydrodynamic response (e.g., SWL, H_{mo}) whereas the statistical basis for the response-based solution is the final response (e.g., overtopping). The result is that reliability (and risk) for the event-based approach will vary across the CSRM system because the response statistics will vary whereas for the response-based approach, the reliability and risk will be more spatially consistent and will be consistent with the desired safety level. In addition, response-based approaches are more accurate because the multivariate probabilistic forcing and associated uncertainties are carried through the computational workflow along with uncertainties associated with the empirical equations used to compute overtopping and overflow, wave pressures on walls, and the characteristics of wall overtopping nappe. Melby et al. (2021) compared five different stochastic simulation approaches and showed that the response-based approach was much more accurate than event-based methods. Stehno (2021) showed that event-based methods for computing crest elevations based on overtopping rates often yield wildly inaccurate results. It was shown that there is no correlation between structure or storm parameters and the difference between event-based and response-based overtopping rate at 1% AEP. Therefore, herein, the response-based approach is used.

A simplification that was used is that the peak SWL and peak H_{mo} are assumed to occur at the same instant, and responses are computed using these values. This is not always true, so this is a conservative assumption. However, Melby et al. (2021) and Stehno (2021) showed that the added conservativeness from this assumption over the fully time-dependent

approach was negligible. This is because the peaks align for the most intense storms and these storms are much more influential in defining extreme response hazard.

Overtopping rates were computed for floodwalls and levees as in the EurOtop (2018) Manual, as summarized in Appendix F of Melby et al. (2021). An optimization step was completed to compute the required levee elevations that just exceed the no-damage limit states. The response-based stochastic simulation routine was initially used to compute the overtopping response of a relatively low crest elevation at each transect. If the overtopping response was greater than the no-damage limit states of $q=0.01$ cfs/ft for a 50% CL or $q=0.1$ cfs/ft for a 90% CL, the levee crest elevation was increased by 0.5 ft, and the response was recomputed. Similarly for floodwalls, if the overtopping response of a relatively low crest elevation exceeded $q=0.03$ cfs/ft for a 50% CL or $q=0.1$ cfs/ft for a 90% CL, the floodwall crest elevation was increased by 0.5 ft, and the response was recomputed. This crest raising and recomputation cycle was repeated with subsequent 0.5 ft crest height increments until both 50% and 90% CL no-damage limit states were satisfied, thus computing an “optimized” levee crest elevation. Additionally, if the optimized crest elevation was found to be lower than the 1% AEP SWL at 90% CL, then the 1% AEP SWL at 90% CL was selected as the optimized crest elevation. This simulation was completed using the with-project wave and water level responses. Results of the optimized crest elevation for each transect location are presented in Appendix C.

Overtopping nappe geometry characteristics, shown in Figure 3, were calculated for floodwalls. The inputs for SWL, H_{mo} , and q were taken at the corresponding AEP with a 90% CL for a conservative estimate. The equations for nappe geometry characteristics are described in Appendix F of Melby et al. (2021).

Figure 3. Floodwall nappe geometry characteristics.

Distances x_U , x_c , and x_L are measured from flood side of floodwall. For nappe computations, the floodwall is considered a sharp-crested structure with the peak coincident with the seawall face. The distance from the structure to the center of the jet impact x_c generally increases with the increase in water level (increasing relative sea level change conditions and decreasing AEP). The jet velocity and force on the impact location are minimal for low overtopping rates and increase as the overtopping rates increase with decreasing AEP.

The combined hydrostatic and hydrodynamic fluid pressures on floodwalls, shown in Figure 4 and Figure 5, were calculated. Elevation H_w denotes floodwall elevation, h_o denotes water depth five wave heights from the structure, h denotes storm water depth at structure toe, R_c denotes structure freeboard, and p_1 , p_2 , and p_3 are the Goda (1974) hydrodynamic pressures at the SWL, crest elevation, and structure toe, respectively. Hydrostatic pressures can be linearly added to the Goda hydrodynamic pressures. The equations for pressures are described in Appendix F of Melby et al. (2021).

Figure 4. Floodwall fluid hydrodynamic pressure characteristics when SWL is at or below the structure crest elevation (freeboard, R_c , is positive).

Figure 5. Floodwall fluid hydrodynamic pressure characteristics when SWL is higher than the structure crest elevation (freeboard, R_c , is negative).

1.3.5 Forcing and crest elevations

Relative sea level change (RSLC) scenarios were defined according to guidance set forth in USACE ER 1100-2-8162 (USACE 2019a) and EP 1100-2-1 (USACE 2019b). The detailed calculations of RSLC and geoid offsets for CSTORM simulation scenarios are given in Appendix H and in

Chapter 3 of Melby et al. (2021). The total RSLC and final geoid offsets for the CSTORM simulations were as follows:

- SLCo, Beginning of Service Life
  - RSLC=0.17 ft
  - Geoid offset=0.39 ft steric+(0.96 ft LMSL*-NAVD88[†])+0.17 ft=1.52 ft
- SLC1, 50 yr Service Life
  - RSLC=0.22 + 1.36 ft=1.58 ft
  - Geoid offset=0.39 ft steric+(0.96 ft LMSL-NAVD88)+1.58 ft=2.93 ft
- SLC2, 100 yr Service Life
  - RSLC=0.22 + 3.16 ft=3.38 ft
  - Geoid offset=0.39 ft steric+(0.96 ft LMSL-NAVD88)+3.38 ft=4.73 ft.

As only a single water level can be used as an initial water level over the entire model domain in the ADCIRC-STWAVE simulations, an average of the total RSLC and geoid offsets at Sabine Pass North and Freeport was used. The final design SWLs for a given project area were adjusted as the difference between this average value and the values at the Sabine Pass North and Freeport gages for the Sabine and Freeport areas, respectively. As in Appendix H in Melby et al. (2021), the difference between the mean sea level (MSL) at Sabine Pass North gage and the average MSL (used to initialize the numerical model simulations) was 0.11 ft. As such, the final SWLs in the Sabine area include this additional 0.11 ft to reflect the larger “local” MSL compared to the “regional” average MSL used in the geoid offset of the CSTORM simulations.

The final list of forcing scenarios for CSTORM with geoid offset was as follows:

1. Without-project, SLCo.
2. Without-project, SLC1.
3. Without-project, SLC2.
4. With-project, SLCo, with Orange County CSRM system.
5. With-project, SLC1, with Orange County CSRM system.
6. With-project, SLC2, with Orange County CSRM system.

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* Local mean sea level vertical datum

† North American Vertical Datum of 1988.

All with-project simulations were conducted with the feasibility authorized design elevations associated with the 50 yr intermediate RSLC scenario.

1.3.6 Forcing and crest elevation combinations

Multiple structure crest elevation scenarios were evaluated. The without-project (existing) elevations correspond to structure elevations from LiDAR collected in 2018 and from field measurements. The feasibility authorized design elevations (Authorized) were defined in the feasibility study and were used as the structure elevations in the with-project CSTORM modeling. Structure crest elevations were optimized using design criteria under SLC1 and SLC2 with-project storm conditions and are referred to as “optimized” for the corresponding RSLC. The optimized crest elevation computation is described above. The feasibility authorized design elevations and optimized elevations informed the project development team (PDT) to define the “design elevations” corresponding to SLC1 and SLC2. Gates and pump station fronting protection crest elevations were set at the SLC2 design elevation. The combination of forcing and elevation scenarios presented herein are as follows:

1. Design elevation SLC1/SLC1 forcing – Structure response evaluated for structure with design crest elevation computed under SLC1 condition and exposed to with-project SLC1 forcing scenario.
2. Design elevation SLC1/SLC2 forcing – Structure response evaluated for structure with design crest elevation computed under SLC1 condition and exposed to with-project SLC2 forcing scenario.
3. Design elevation SLC2/SLC2 forcing – Structure response evaluated for structure with design crest elevation computed under SLC2 condition and exposed to with-project SLC2 forcing scenario.

Additional combinations were provided to the sponsor but are not included herein.

2 Cow Bayou

Cow Bayou is towards the center of the proposed Orange County CSRM system, shown in Figure 6. Cow Bayou consists primarily of floodwalls, with a levee section for tie-in purposes and a gate, shown in Figure 7. Coastal SWL, wave loading, and coastal structure responses are quantified.

Figure 6. Cow Bayou floodwall for Orange County CSRM system (in pink).

There is currently no existing structure at the Cow Bayou portion for Orange County. The with-project, authorized design includes adding approximately 5,000 ft of floodwall in this area with a 450 ft long gate at the channel.

Figure 7. Aerial image of Cow Bayou for Orange County floodwall section (in yellow), analysis sections (yellow lines), modeling output locations (red dots), and color-shaded LiDAR-based elevations (feet, NAVD88). Image is oriented so north is up and floodside is to south, protected side to north.

2.1 Local wave and water response

The peaks of the top-10 synthetic storms are ranked by SWL for with-project forcing conditions for SP 2712 in Table 1 for with-project forcing conditions. The “MWD” column is mean wave direction (MWD) and is in Euclidean format (0 is east, counterclockwise is positive). Peak wave period T_p and MWD are values associated with the significant wave height H_{mo} peak. Additional information regarding the water level response is found in Chapter 4 of Melby et al. (2021).

Peak SWL and H_{mo} for 189 S2G storms for with-project, SLC1 and SLC2 scenarios for each SP in the Cow Bayou analysis are summarized in Appendices A and B.

Table 1. CSTORM output peaks for the top-10 synthetic storms ranked by SWL for with-project scenario at SP 2712.

SLC 0 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
464	18.5	5.0	4.7	130
357	18.2	4.6	4.3	137
447	17.7	4.3	4.3	139
159	17.0	3.6	5.7	135
633	16.3	3.9	6.3	162
461	16.3	3.7	6.3	111
598	15.4	4.4	4.3	125
589	15.1	3.2	2.9	110
532	15.1	3.4	4.3	123
342	14.8	3.1	4.7	144
SLC 1- With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
464	20.9	5.5	5.2	130
357	20.1	5.1	4.3	139
447	20.1	4.7	4.3	139
633	18.7	4.9	6.3	162
159	18.6	4.3	5.7	135
461	17.7	4.4	6.9	122
598	17.4	5.2	4.7	125
532	17.1	4.1	4.3	123
589	16.9	4.1	3.6	110
342	16.6	3.8	4.7	144
SLC 2 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
464	23.1	6.5	5.2	130
357	22.3	5.7	4.7	149
447	22.2	5.1	4.3	144
633	22.1	6.2	6.3	163
598	21.0	6.1	4.7	137
159	20.9	5.0	5.7	135
461	20.6	6.2	6.3	122
532	20.1	4.8	4.3	123
589	19.8	5.2	4.7	110
342	19.8	4.5	4.7	147

With-project SWL peaks for all storms are plotted against without-project conditions in Figure 8, and similarly, H_{mo} peaks for with-project and without-project conditions are plotted in Figure 9. It can be seen that the SWL and H_{mo} differences between the two alternatives are small.

Figure 8. With-project SWL peaks for all storms plotted against without-project conditions for SPs 2712 (left) and 4533 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

Figure 9. With-project H_{m0} peaks for all storms plotted against without-project conditions for SPs 2712 (left) and 4533 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

Probability masses were computed from the JPM analysis of CTXCS modeling output for 660 storms and 18,332 SPs* and recomputed for the 189 S2G storms and 5,148 SPs using methods discussed in Melby et al. (2021). The associated added uncertainty is described in Chapter 4 and Appendices A and G of Melby et al. (2021).

Figure 10 and Figure 11 show SWL and H_{m0} hazard curves, respectively, at SPs 2712 and 4533 for without- and with-project SLC0, SLC1, and SLC2

* Nadal-Caraballo, N. C., A. B. Lewis, V. M. Gonzalez, T. C. Massey, and A. T. Cox. Draft. *Coastal Texas Protection and Restoration Feasibility Study, Probabilistic Modeling of Coastal Storm Hazards*. ERDC/CHL Technical Report, Vicksburg, MS: US Army Engineer Research and Development Center.

scenarios. In the figures, the 50% and 90% CLs are shown. As can be seen in the figures, SWL hazard curves are similar for the two scenarios, and both locations. SWL and H_{mo} values for a range of AEPs are listed with their corresponding transects in Appendix D, which provides a link to the results, for with-project SLC1 and SLC2 for all of the analyzed SPs in Cow Bayou. Waves in the area are relatively small.

Figure 10. AEP vs. SWL for SP 2712 (left) and SP 4533 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2. Elevations are in feet, NAVD88.

Figure 11. AEP vs. H_{m0} for SP 2712 (left) and SP 4533 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

2.2 Local Coastal Storm Risk Management (CSRM) system response modeling

Cow Bayou consists of levees, floodwalls, and gate structures. The features of the CSRM system corresponding to the transects in the Cow Bayou reach are listed in Table 2. Figure 12 shows schematized analysis transects, which are examples of the idealized structures used for the with-project analysis. The location of the with-project transect in the figures is not the final design location.

The transects for Cow Bayou lie in a marshy area along the northeast edge of Sabine Lake. At high water levels, waves may be able to form across the fetch. However, these waves will be dramatically reduced by shallow water effects, even at the highest water levels. CSTORM (STWAVE) does not model the physics of wave reflection nor does it account for wave diffraction; this results in added wave height uncertainty. Analysis herein assumed that the wave crests are parallel to the structure (waves are propagating shore normal) to ensure conservatism of overtopping.

The transects in Cow Bayou have unique surrounding topographies and bathymetries. The seaside and leeside material for the Cow Bayou floodwalls and levees is currently grass. To be conservative, berm effects that would reduce the wave hazard were not included in the response calculations. This assumption would be expected to have only minor effects because the waves are relatively small and would have little effect from the berm.

Table 2. Features of CSRM system in Cow Bayou area.

GeolD	Transect Number	Station Start	Station End	Associated Save Point	With- project Structure Type	With- project Average Slope	Existing Reach Elevation (Ft, NAVD88)	Authorized Elevation (Ft, NAVD88)
F	82	604+00	608+79	4533	Levee	3	6	15.5
Cow Bayou	83	608+79	624+00	4535	Floodwall	N/A	4	13.5
	84	608+79	624+00	2716	Floodwall	N/A	4	13.5
	85	624+00	650+00	2715	Floodwall	N/A	4	13.5
	86	624+00	650+00	2714	Floodwall	N/A	4	13.5
	87	624+00	650+00	4539	Floodwall	N/A	4	13.5
	88	650+00	651+34	2712	Floodwall	N/A	4	13.5
	89	651+34	657+33	2715	Pump Station #4 / Cow Gate	N/A	-17	15.5
	90	657+33	663+01	2711	Floodwall	N/A	3	13.5
H	91	663+01	668+00	2710	Levee	3	5	17.5

Figure 12. Idealized, with-project structure with measured topography (black), floodwalls with feasibility authorized elevation (blue), and levees with feasibility authorized elevation (red). Elevations are in feet, NAVD88.

2.3 Results

Design elevations were determined by the PDT, which considered the optimized elevations required to just exceed the no-damage limit states under with-project forcing conditions, as described in Chapter 1. The results of the optimization are shown in Appendix C. Appendix D contains

the results of the combined overtopping and overflow for levees, gates, and floodwalls, and overtopping nappe geometry and combined hydrostatic and hydrodynamic wall pressures for floodwalls and gates from response-based analysis for the three forcing and elevation combinations described in Chapter 1.

2.4 Summary and conclusions

As part of the ongoing PED phase of the project, this chapter documents coastal storm inundation, wave loading, and combined overtopping and overflow for the Cow Bayou CSRM system consisting of floodwalls, a gate, and levees. Optimized crest elevations were computed based on no-damage overtopping criteria for floodwalls and levees to inform the PDT during design. Overtopping nappe geometry and combined hydrostatic and hydrodynamic pressures on the seaward face of the floodwall and gate were calculated for each floodwall and gate transect.

3 GeoPoint identifier (GeoID) A

The GeoPoint identifier (GeoID) A reach consists of levees, floodwalls, multiple road crossings, and one pump station along the northeastern edge of the proposed CRSM system, shown in Figure 13. Coastal SWL, wave loading, and combined overtopping and overflow are quantified.

Figure 13. Aerial image of GeoID A levee and floodwall location (in orange).

There is currently no existing structure in the GeoID A area of Orange County. The with-project, authorized design includes adding approximately 10,100 ft of levee and 1,730 ft of floodwall and including two road closure gates and one pump station, shown in Figure 14.

Figure 14. Details of the GeoID A reach, including floodwalls (blue), levees (pink), analysis transects (yellow), SPs (red), and color shaded LiDAR-based elevations (feet, NAVD88). Image is oriented so north is up and floodside is to east, protected side to west.

3.1 Local wave and water response

The peaks of the top-10 synthetic storms are ranked by SWL for with-project conditions for SP 4585 in Table 3. Peak SWL and H_{mo} for 189 S2G storms for with-project, SLC1 and SLC2 scenarios are shown in Appendix A and B.

Table 3. CSTORM output peaks for the top-10 synthetic storms, ranked by SWL, at SP 4585.

SLC 0 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
464	18.9	4.3	5.7	123
357	18.7	5.1	4.7	134
447	17.8	4.7	4.7	135
159	17.1	4.0	6.3	137
461	14.6	2.0	6.9	89
532	14.6	2.4	5.2	96
342	14.0	3.1	4.3	136
153	13.6	3.2	4.7	150
633	13.5	4.1	6.3	163
628	12.9	2.1	4.3	133
SLC 1- With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
464	21.5	5.8	5.2	128
357	20.3	5.7	4.7	139
447	19.9	5.2	4.7	140
159	18.9	4.9	6.3	137
633	18.0	6.1	6.9	160
532	17.6	4.0	4.7	127
461	16.9	2.4	7.6	89
342	16.5	4.0	4.3	141
628	16.4	3.8	4.7	130
598	16.3	4.8	4.7	133
SLC 2 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
464	24.0	6.9	5.7	141
633	22.7	8.2	6.9	163
357	22.6	6.3	5.2	151
447	22.2	5.6	4.7	140
159	21.3	5.7	5.7	138
598	20.8	6.7	5.2	133
532	20.5	5.3	4.7	133
461	20.2	4.5	6.9	112
589	19.5	4.6	5.2	115
342	19.4	4.7	4.7	147

With-project SWL peaks for all storms are plotted against without-project conditions in Figure 15, and similarly, H_{mo} peaks for with-project and without-project conditions are plotted in Figure 16.

Figure 15. With-project SWL peaks for all storms plotted against without-project conditions for SPs 4395 (left) and 4585 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

Figure 16. With-project H_{m0} peaks for all storms plotted against without-project conditions for SPs 4395 (left) and 4585 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

Figure 17 and Figure 18 show SWL and H_{m0} curves, respectively, at SPs 4395 and 4585 for without- and with-project SLC0, SLC1, and SLC2 scenarios. The 50% and 90% CLs are shown in the figures. There is little difference between the without- and with-project for both SWL and H_{m0} hazard curves. SWL and H_{m0} values for a range of AEPs are listed with their corresponding transects in Appendix D for with-project SLC1 and SLC2 for all of the analyzed SPs in GeoID A. Waves in the area are relatively small.

Figure 17. AEP vs. SWL for SPs 4395 (left) and 4585 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2. Elevations are in feet, NAVD88.

Figure 18. AEP vs. H_{m0} for SPs 4395 (left) and 4585 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

3.2 Local CSRM system response modeling

The GeoID A reach consists of levees, floodwalls, pump stations, and gates. The features of the feasibility authorized CSRM system corresponding to the transects in the GeoID A reach are listed in Table 4. Idealized structure geometries were used for the with-project response analysis. Analysis herein assumed that the wave crests are parallel to the structure (waves are propagating shore normal) to ensure conservatism of overtopping. Additionally, berm effects were not included in the hazard calculations, as described above.

Table 4. Features of the CSRM system for the GeoID A reach.

GeoID	Transect Number	Station Start	Station End	Associated Save Point	With- project Structure Type	With- project Average Slope	Existing Reach Elevation	Authorized Elevation
							(Ft, NAVD88)	(Ft, NAVD88)
A	2	0+00	16+71	4592	Levee	3	4	14
	4 wall	16+71	25+29	4387	Floodwall	N/A	4	14
		25+59	31+87					
		31+12	34+01					
	4 gate	25+29	25+59	4387	Pump Station #1 Rode Closure - Gate	N/A	4	14
		31+87	32+12					
	8	34+01	57+00	4395	Levee	3	6	14
	12	57+00	113+49	4403	Levee	3	6	14
	14	113+49	114+44	4585	Floodwall Road Closure - Gate	N/A	6	14.5
	15	114+44	118+30	4585	Levee	3	6	14

3.3 Results

Design elevations were determined by the PDT, which considered the optimized elevations required to just exceed the no-damage limit states under with-project forcing conditions, as described in Chapter 1. The results of the optimization are shown in Appendix C. Appendix D contains the results of the combined overtopping and overflow for levees, gates, and floodwalls, and overtopping nappe geometry and combined hydrostatic and hydrodynamic wall pressures for floodwalls and gates from response-based analysis for the three forcing and elevation combinations described in Chapter 1.

3.4 Summary and conclusions

As part of the ongoing PED phase of the project, this chapter documents coastal storm inundation, wave loading, and combined overtopping and overflow for the GeoID A CSRM system consisting of floodwalls, a gate, and levees. Optimized crest elevations were computed based on no-damage overtopping criteria for floodwalls and levees to inform the PDT during design. Overtopping nappe geometry and combined hydrostatic and hydrodynamic pressures on the seaward face of the floodwall and gate were calculated for each floodwall and gate transect.

4 GeoID B

The GeoID B reach consists of levees, floodwalls, multiple road crossings, and one pump station along the eastern edge of the proposed Orange County CSRM system, shown in Figure 19. Coastal SWL, wave loading, and combined overtopping and overflow are quantified.

Figure 19. Aerial image of Geoid B levee and floodwall location (in orange).

The GeoID B reach includes a proposed 1,051 ft of levee and 8,565 ft of floodwall, shown in Figure 20. This proposed reach includes 13 road closure gates, 1 railroad closure gate, and a pump station.

Figure 20. Details of the GeoID B reach, including floodwalls (blue), levees (pink), analysis transects (yellow), SPs (red), and color shaded LiDAR-based elevations (feet, NAVD88). Image is oriented so north is up and floodside is to east, protected side to west.

4.1 Local wave and water response

The peaks of the top-10 synthetic storms are ranked by SWL for with-project conditions for SP 4420 in Table 5. Peak SWL and H_{mo} for 189 S2G storms for with-project, SLC1 and SLC2 scenarios are shown in Appendix A and B.

Table 5. CSTORM output peaks for the top-10 synthetic storms, ranked by SWL, at SP 4420.

SLC 0 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
464	18.7	3.0	5.2	134
357	18.6	4.1	4.3	139
447	17.7	3.9	4.3	140
159	17.1	2.6	6.3	136
461	14.5	3.1	3.2	92
532	14.5	2.3	2.9	95
633	14.1	2.8	6.9	162
342	14.0	2.2	4.3	136
153	13.6	2.6	4.3	149
628	12.9	2.1	2.9	92
SLC 1- With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
464	21.2	4.6	4.7	140
357	20.2	4.9	4.7	145
447	19.8	4.6	4.3	140
159	18.9	3.2	6.3	137
633	18.2	4.5	7.6	162
532	17.5	3.0	4.3	139
461	16.8	2.9	3.6	92
342	16.5	3.2	4.3	140
598	16.3	3.3	5.2	142
628	16.2	2.5	4.7	134
SLC 2 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
464	23.9	5.9	5.2	140
633	22.6	7.0	6.9	162
357	22.4	5.7	4.7	147
447	22.2	5.0	4.3	145
159	21.3	4.1	5.7	137
598	20.7	5.7	5.2	142
532	20.4	4.4	4.3	139
461	20.0	2.7	6.3	111
589	19.5	3.2	4.7	128
342	19.4	4.3	4.7	147

With-project SWL peaks for all storms are plotted against without-project conditions in Figure 21, and similarly, H_{mo} peaks for with-project and without-project conditions are plotted in Figure 22. It can be seen that the SWL and H_{mo} differences between the two alternatives are small.

Figure 21. With-project SWL peaks for all storms plotted against without-project conditions for SPs 4411 (left) and 4420 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

Figure 22. With-project H_{m0} peaks for all storms plotted against without-project conditions for SPs 4411 (left) and 4420 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

Figure 23 and Figure 24 show SWL and H_{m0} curves, respectively, at SPs 4411 and 4420 for without- and with-project SLC0, SLC1, and SLC2 scenarios. The 50% and 90% CLs are shown in the figures. There is little difference between the without- and with-project for both SWL and H_{m0} hazard curves. SWL and H_{m0} values for a range of AEPs are listed with their corresponding transects in Appendix D for with-project SLC1 and SLC2 for all of the analyzed SPs in GeoID B. Waves in the area are relatively small.

Figure 23. AEP vs. SWL for SPs 4411 (left) and 4420 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2. Elevations are in feet, NAVD88.

Figure 24. AEP vs. H_{m0} for SPs 4411 (left) and 4420 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

4.2 Local CSRM system response modeling

The GeoID B reach consists of levees, floodwalls, pump stations, and gates. The features of the feasibility authorized CSRM system corresponding to the transects in the GeoID B reach are listed in Table 6. Idealized structure geometries were used for the with-project response analysis. Analysis herein assumed that the wave crests are parallel to the structure (waves are propagating shore normal) to ensure conservatism of overtopping. Additionally, berm effects were not included in the hazard calculations, as described above.

4.3 Results

Design elevations were determined by the PDT, which considered the optimized elevations required to just exceed the no-damage limit states under with-project forcing conditions, as described in Chapter 1. The results of the optimization are shown in Appendix C. Appendix D contains the results of the combined overtopping and overflow for levees and floodwalls, and overtopping nappe geometry and combined hydrostatic and hydrodynamic wall pressures for floodwalls from response-based analysis for the three forcing and elevation combinations described in Chapter 1.

4.4 Summary and conclusions

As part of the ongoing PED phase of the project, this chapter documents coastal storm inundation, wave loading, and combined overtopping and overflow for the GeoID B CSRM system consisting of floodwalls and levees. Optimized crest elevations were computed based on the no-damage overtopping criteria for floodwalls and levees. Overtopping nappe geometry and combined hydrostatic and hydrodynamic pressures on the seaward face of the floodwall were calculated for each floodwall transect.

Table 6. Features of the CSRM system for the GeoID B reach.

GeoID	Transect Number	Station Start	Station End	Associated Save Point	With- project Structure Type	With- project Average Slope	Existing Reach Elevation	Authorized Elevation
							(Ft, NAVD88)	(Ft, NAVD88)
B	17 - wall	118+30 125+96	121+10 126+28	4411	Floodwall	N/A	4	14.5
	17 - gate	121+10	125+96	4411	Road Closure - Gate Pump Station # 2	N/A	4	14.5
	19	126+28	136+78	4582	Levee	3	6	12
	21 - wall	136+78 137+40 140+99 144+39 147+98 151+93 152+39 153+84	137+07 140+57 144+12 147+68 151+63 152+12 153+49 154+00	4418	Floodwall	N/A	7	14.5
	21 - gate	137+07 140+57 144+12 147+68 151+63 152+12 153+49	137+40 140+99 144+39 147+98 151+93 152+39 153+84	4418	Road Closure - Gate	N/A	7	14.5
	22 - wall	154+00 188+57 193+77 200+58 209+68 213+05	188+37 193+51 200+20 209+38 212+75 214+49	4420	Floodwall	N/A	7	14.5
	22 - gate	188+37 193+51 200+20 209+38 212+75	188+57 193+77 200+58 209+68 213+05	4420	Road Closure - Gate	N/A	7	14.5
	27 - wall	154+00 188+57 193+77 200+58 209+68 213+05	188+37 193+51 200+20 209+38 212+75 214+49	4429	Floodwall	N/A	7	14.5
	27 - gate	188+37 193+51 200+20 209+38 212+75	188+57 193+77 200+58 209+68 213+05	4429	Road Closure - Gate	N/A	7	14.5

5 GeoID C

The GeoID C reach consists of levees, floodwalls, and multiple road crossings along the east edge of the proposed Orange County CSRM system, shown in Figure 25. Coastal SWL, wave loading, and combined overtopping and overflow are quantified.

Figure 25. Aerial image of Geoid C levee and floodwall location (in orange).

The GeoID C reach includes a proposed 3,515 ft of levee and 3,131 ft of floodwalls, shown in Figure 26. There are three proposed road closure gates in this reach area.

Figure 26. Details of the GeoID C reach, including floodwalls (blue), levees (pink), analysis transects (yellow), SPs (red), and color shaded LiDAR-based elevations (feet, NAVD88). Image is oriented so north is up and floodside is to east, protected side to west.

5.1 Local wave and water response

The peaks of the top-10 synthetic storms are ranked by SWL for with-project conditions for SP 4445 in Table 7. Peak SWL and H_{mo} for 189 S2G storms for with-project, SLC1 and SLC2 scenarios are shown in Appendices A and B.

Table 7. CSTORM output peaks for the-top 10 synthetic storms, ranked by SWL, at SP 4445.

SLC 0 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
464	18.5	3.7	5.2	121
357	18.4	4.0	4.3	133
447	17.6	3.7	4.3	134
159	16.9	3.1	6.3	136
461	14.4	3.0	2.9	92
532	14.4	2.6	2.9	107
633	14.0	3.7	6.3	161
342	13.9	2.3	4.7	133
153	13.6	2.5	4.3	151
628	12.8	2.4	2.9	116
SLC 1- With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
464	21.0	4.6	5.2	114
357	20.1	4.6	4.3	135
447	19.7	4.2	4.3	134
159	18.7	3.6	6.3	136
633	18.1	5.2	6.3	161
532	17.4	3.2	4.3	119
461	16.6	3.7	3.2	110
342	16.4	2.9	4.7	133
598	16.2	3.9	5.2	130
628	16.1	3.0	3.9	116
SLC 2 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
464	23.6	5.7	5.2	133
633	22.4	6.8	6.3	161
357	22.3	5.3	4.7	144
447	22.0	4.7	4.3	144
159	21.1	4.4	6.3	137
598	20.6	5.3	5.2	141
532	20.3	4.2	4.3	132
461	19.8	4.2	6.9	110
589	19.3	3.9	4.7	119
342	19.3	3.8	4.7	147

With-project SWL peaks for all storms are plotted against without-project conditions in Figure 27, and similarly, H_{mo} peaks for with-project and without-project conditions are plotted in Figure 28. It can be seen that the SWL differences between the two alternatives are relatively small and H_{mo} differences are relatively small for most storms, but there is a large positive bias for the without-project alternative for the highest wave heights.

Figure 27. With-project SWL peaks for all storms plotted against without-project conditions for SPs 4445 (left) and 1306 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

Figure 28. With-project H_{m0} peaks for all storms plotted against without-project conditions for SPs 4445 (left) and 1306 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

Figure 29 and Figure 30 show SWL and H_{m0} curves, respectively, at SPs 4445 and 1306 for without- and with-project SLC0, SLC1, and SLC2 scenarios. The 50% and 90% CLs are shown in the figures. There is little difference between the without- and with-project for both SWL hazard curves. However, the large positive bias for the without-project alternative for the highest wave heights causes the without project curves to be higher than the with-project. SWL and H_{m0} values for a range of AEPs values are listed with their corresponding transects in Appendix D for with-project SLC1 and SLC2 for all of the analyzed SPs in GeoID C. Waves in the area are relatively small.

Figure 29. AEP vs. SWL for SPs 4445 (left) and 1306 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2. Elevations are in feet, NAVD88.

Figure 30. AEP vs. H_{m0} for SPs 4445 (left) and 1306 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

5.2 Local CSRM system response modeling

The GeoID C reach consists of levees, floodwalls, and gates. The features of the CSRM system corresponding to the transects in the GeoID C reach are listed in Table 8. Idealized structure geometries were used for the with-project response analysis, as shown for Cow Bayou. The transects in the GeoID C reach are located near a river, with marshy area to the seaward side of the structure; therefore, conservative assumptions were used, as described for Cow Bayou.

Table 8. Features of the CSRM system for the GeoID C reach.

GeoID	Transect Number	Station Start	Station End	Associated Save Point	With- project Structure Type	With-project Average Slope	Existing Reach Elevation	Authorized Elevation
							(Ft, NAVD88)	(Ft, NAVD88)
C	30	214+49	219+70	4435	Levee	3	7	15.5
	31	219+70	220+57	1306	Road Closure - Gate	N/A	7	14.5
	32	220+57	227+84	1306	Levee	3	7	15.5
	34	227+84	237+94	4442	Floodwall	N/A	1	16
	35	237+94	246+26	4444	Levee	3	5	15.5
	36	237+94	246+26	4445	Levee	3	5	15.5
	37	246+26	247+57	4565	Floodwall / Road Closure - Gate	N/A	5	16
	38	247+57	261+99	4448	Levee	3	5	15.5
	40 - wall	261+99 262+25	262+59 280+96	4562	Floodwall	N/A	2	16
	40 - gate	262+25	262+59	4562	Road Closure - Gate	N/A	2	16

5.3 Results

Design elevations were determined by the PDT, which considered the optimized elevations required to just exceed the no-damage limit states under with-project forcing conditions, as described in Chapter 1. The results of the optimization are shown in Appendix C. Appendix D contains the results of the combined overtopping and overflow for levees, gates, and floodwalls, and overtopping nappe geometry and combined hydrostatic and hydrodynamic wall pressures for floodwalls and gates from response-based analysis for the three forcing and elevation combinations described in Chapter 1.

5.4 Summary and conclusions

As part of the ongoing PED phase of the project, this chapter documents coastal storm inundation, wave loading, and combined overtopping and overflow for the GeoID C CSRM system consisting of floodwalls, gates, and

levees. Optimized crest elevations were computed based on no-damage overtopping criteria for floodwalls and levees to inform the PDT during design. Overtopping nappe geometry and combined hydrostatic and hydrodynamic pressures on the seaward face of the floodwall and gate were calculated for each floodwall and gate transect.

6 GeoID D

The GeoID D reach consists of levee and floodwall on the east edge of the proposed Orange County CSRM system, shown in Figure 31. Coastal SWL, wave loading, and combined overtopping and overflow are quantified.

Figure 31. Aerial image of Geoid D levee and floodwall location (in orange).

The GeoID D reach includes a proposed 1,103 ft of levee and 1,794 ft of floodwall, shown in Figure 32.

Figure 32. Details of the GeoID D reach, including floodwalls (blue), levees (pink), analysis transects (yellow), SPs (red), and color-shaded LiDAR-based elevations (feet, NAVD88). Image is oriented so north is up and floodside is to east, protected side to west.

6.1 Local wave and water response

The peaks of the top-10 synthetic storms are ranked by SWL for with-project conditions for SP 4561 in Table 9. Peak SWL and H_{mo} for 189 S2G storms for with-project, SLC1 and SLC2 scenarios are shown in Appendix A and B.

Table 9. CSTORM output peaks for the top-10 synthetic storms, ranked by SWL, at SP 4561.

SLC 0 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
464	18.4	2.3	3.9	120
357	18.4	2.5	4.7	140
447	17.5	2.4	4.3	137
159	16.9	2.1	6.3	135
461	14.4	2.0	2.7	109
532	14.4	1.6	2.7	126
633	14.0	2.5	6.3	160
342	13.9	1.4	3.9	129
153	13.5	1.7	3.9	149
598	12.7	2.1	2.9	156
SLC 1- With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
464	21.0	3.3	6.3	99
357	20.1	3.2	4.7	144
447	19.7	3.0	4.3	137
159	18.7	2.4	6.3	135
633	18.1	3.8	5.7	160
532	17.3	2.0	3.9	126
461	16.5	2.6	3.6	136
342	16.4	2.0	4.7	142
598	16.2	2.4	4.7	129
628	16.0	1.9	3.2	126
SLC 2 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
464	23.5	4.3	5.7	103
633	22.4	5.2	5.7	160
357	22.3	4.0	4.7	150
447	22.0	3.6	4.3	137
159	21.0	3.1	6.3	136
598	20.6	3.7	4.7	149
532	20.2	2.9	4.7	94
461	19.8	2.7	7.6	88
342	19.3	2.8	4.7	147
589	19.3	2.4	5.2	71

With-project SWL peaks for all storms are plotted against without-project conditions in Figure 33, and similarly, H_{mo} peaks for with-project and without-project conditions are plotted in Figure 34. It can be seen that the SWL differences between the two alternatives are small and H_{mo} differences are relatively small for most storms, but there is a large positive bias for the without-project alternative for the highest wave heights.

Figure 33. With-project SWL peaks for all storms plotted against without-project conditions for SPs 4561 (left) and 4562 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

Figure 34. With-project H_{m0} peaks for all storms plotted against without-project conditions for SPs 4561 (left) and 4562 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

Figure 35 and Figure 36 show SWL and H_{m0} curves, respectively, at SPs 4561 and 4562 for with-project SLC0, SLC1, and SLC2 scenarios. The 50% and 90% CLs are shown in the figures. There is little difference between the without- and with-project for the SWL hazard curves. However, the large positive bias for the without-project alternative for the highest wave heights causes the without project curves to be higher than the with-project. SWL and H_{m0} values for a range of AEPs are listed with their corresponding transects in Appendix D for with-project SLC1 and SLC2 for all of the analyzed SPs in GeoID D. Waves in the area are relatively small.

Figure 35. AEP vs. SWL for SPs 4561 (left) and 4562 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2. Elevations are in feet, NAVD88.

Figure 36. AEP vs. H_{m0} for SPs 4561 (left) and 4562 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

6.2 Local CSRM system response modeling

The GeoID D reach consists of levees and floodwalls. The features of the CSRM system corresponding to the transects in the GeoID D reach are listed in Table 10. Idealized structure geometries were used for the with-project response analysis, as shown for Cow Bayou. The transects in the GeoID D reach are located near a river, with marshy area to the seaward side of the structure; therefore, conservative assumptions were used, as described for Cow Bayou.

Table 10. Features of the CSRM system for the GeoID D reach.

GeoID	Transect Number	Station Start	Station End	Associated Save Point	With- project Structure Type	With-project Average Slope	Existing Reach Elevation	Authorized Elevation
							(Ft, NAVD88)	(Ft, NAVD88)
D	41	280+96	291+98	4561	Levee	3	4	14
	42	291+98	309+91	4462	Floodwall	N/A	2	13

6.3 Results

Design elevations were determined by the PDT, which considered the optimized elevations required to just exceed the no-damage limit states under with-project forcing conditions, as described in Chapter 1. The results of the optimization are shown in Appendix C. Appendix D contains the results of the combined overtopping and overflow for levees and floodwalls, and overtopping nappe geometry and combined hydrostatic and hydrodynamic wall pressures for floodwalls from response-based analysis for the three forcing and elevation combinations described in Chapter 1.

6.4 Summary and conclusions

As part of the ongoing PED phase of the project, this chapter documents coastal storm inundation, wave loading, and combined overtopping and overflow for the GeoID D CSRM system consisting of floodwalls and levees. Optimized crest elevations were computed based on no-damage overtopping criteria for floodwalls and levees to inform the PDT during design. Overtopping nappe geometry and combined hydrostatic and hydrodynamic pressures on the seaward face of the floodwall were calculated for the floodwall transect.

7 GeoID E

The GeoID E reach consists primarily of levees but also has a floodwall and pump station portion along the southeast corner of the proposed Orange County CSRM system, shown in Figure 37. Coastal SWL, wave loading, and combined overtopping and overflow are quantified.

Figure 37. Aerial image of Geoid E levee and floodwall location (in orange).

The GeoID E reach includes 11,163 ft of proposed levees and 456 ft of proposed floodwall with one vertical lift gate and one pump station, shown in Figure 38.

Figure 38. Details of the GeoID E reach, including floodwalls (blue), levees (pink), analysis transects (yellow), SPs (red), and color-shaded LiDAR-based elevations (feet, NAVD88). Image is oriented so north is up and floodside is to east, protected side to west.

7.1 Local wave and water response

The peaks of the top-10 synthetic storms are ranked by SWL for with-project conditions for SP 2744 in Table 11. Peak SWL and H_{m0} for 189 S2G storms for with-project, SLC1 and SLC2 scenarios are shown in Appendix A and B.

Table 11. CSTORM output peaks for the top-10 synthetic storms, ranked by SWL, at SP 2744.

SLC 0 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
464	18.1	5.7	5.2	131
357	18.1	5.6	5.2	137
447	17.2	5.2	4.7	136
159	16.6	4.9	5.7	134
461	14.6	3.4	6.9	107
532	14.3	4.1	4.7	117
633	14.2	5.6	6.3	158
342	13.8	4.0	4.7	135
153	13.4	3.8	4.7	150
598	13.1	4.8	5.2	127
SLC 1- With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
464	20.6	6.7	5.7	131
357	19.8	6.2	5.2	139
447	19.5	5.6	4.7	138
159	18.4	5.5	5.7	135
633	17.7	7.1	6.9	158
532	17.1	5.0	4.7	124
461	16.4	4.1	6.9	114
342	16.3	4.6	4.7	140
598	16.3	6.0	5.2	127
628	15.7	4.7	5.2	127
SLC 2 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
464	23.0	7.5	5.7	137
357	22.0	6.7	5.2	146
633	21.8	8.7	6.9	158
447	21.8	5.9	4.7	143
159	20.7	6.2	5.7	135
598	20.4	7.4	5.7	139
532	20.0	5.7	4.7	124
461	19.6	6.9	6.3	125
589	19.3	5.9	5.2	112
342	19.2	5.3	5.2	147

With-project SWL peaks for all storms are plotted against without-project conditions in Figure 39, and similarly, H_{mo} peaks for with-project and without-project conditions are plotted in Figure 40. It can be seen that the SWL and H_{mo} differences between the two alternatives are fairly small.

Figure 39. With-project SWL peaks for all storms plotted against without-project conditions for SPs 2744 (left) and 4472 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

Figure 40. With-project H_{m0} peaks for all storms plotted against without-project conditions for SPs 2744 (left) and 4472 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

Figure 41 and Figure 42 show SWL and H_{m0} curves, respectively, at SPs 2744 and 4472 for with-project SLC0, SLC1, and SLC2 scenarios. The 50% and 90% CLs are shown in the figures. There is little difference between the without- and with-project for both SWL and H_{m0} hazard curves. SWL and H_{m0} values for a range of AEPs are listed with their corresponding transects in Appendix D for with-project SLC1 and SLC2 for all of the analyzed SPs in GeoID E. Waves in the area are relatively small.

Figure 41. AEP vs. SWL for SPs 2744 (left) and 4472 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2. Elevations are in feet, NAVD88.

Figure 42. AEP vs. H_{m0} for SPs 2744 (left) and 4472 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

7.2 Local CSRM system response modeling

The GeoID E reach consists of levees, floodwall, pump station, and gates. The features of the CSRM system corresponding to the transects in the GeoID E reach are listed in Table 12. Idealized structure geometries were used for the with-project response analysis, as shown for Cow Bayou. The transects in the GeoID E reach are located near a river, with marshy area to the seaward side of the structure; therefore, conservative assumptions were used, as described for Cow Bayou.

Table 12. Features of the CSRM system for the GeoID E reach.

GeoID	Transect Number	Station Start	Station End	Associated Save Point	With- project Structure Type	With-project Average Slope	Existing Reach Elevation	Authorized Elevation
							(Ft, NAVD88)	(Ft, NAVD88)
E	44	309+91	322+00	4559	Levee	3	7	14
	47	322+00	386+84	4472	Levee	3	7	14
	49	386+84	391+40	2744	Floodwall / Pump Station # 3 / Adams Gate	N/A	1	15
	50	386+84	391+40	2744		N/A	1	15
	51	386+84	391+40	2744		N/A	1	15
	53	391+40	426+10	4482	Levee	3	4	14

7.3 Results

Design elevations were determined by the PDT, which considered the optimized elevations required to just exceed the no-damage limit states under with-project forcing conditions, as described in Chapter 1. The results of the optimization are shown in Appendix C. Appendix D contains the results of the combined overtopping and overflow for levees and gates, and overtopping nappe geometry and combined hydrostatic and hydrodynamic wall pressures for floodwalls and gates from response-based analysis for the three forcing and elevation combinations described in Chapter 1.

7.4 Summary and conclusions

As part of the ongoing PED phase of the project, this chapter documents coastal storm inundation, wave loading, and combined overtopping and overflow for the GeoID E CSRM system consisting of gates and levees. Optimized crest elevations were computed based on no-damage overtopping criteria for gates and levees to inform the PDT during design. Overtopping nappe geometry and combined hydrostatic and hydrodynamic pressures on the seaward face of the gate were calculated for each gate transect.

8 GeoID F

The GeoID F reach consists of levees, floodwalls, and multiple road crossings along the south facing edge of the Orange County proposed CSRM system, shown in Figure 43. Coastal SWL, wave loading, and combined overtopping and overflow are quantified.

Figure 43. Aerial image of GeoID F levee and floodwall location (in orange).

The GeoID F reach includes 14,021 ft of proposed floodwalls, which includes three road closure gates, and 4,247 ft of proposed levee, shown in Figure 44 and Figure 45.

Figure 44. Details of the east half of the GeoID F reach, including floodwalls (blue), levees (pink), analysis transects (yellow), SPs (red), and color-shaded LiDAR-based elevations (feet, NAVD88). Image is oriented so north is up and floodside is to south, protected side to north.

Figure 45. Details of the west half of the GeoID F reach, including floodwalls (blue), levees (pink), analysis transects (yellow), SPs (red), and color-shaded LiDAR-based elevations (feet, NAVD88).

8.1 Local wave and water response

The peaks of the top-10 synthetic storms are ranked by SWL for with-project conditions for SP 2738 in Table 13. Peak SWL and H_{m0} for 189 S2G storms for with-project, SLC1 and SLC2 scenarios are shown in Appendix A and B.

Table 13. CSTORM output peaks for the top-10 synthetic storms, ranked by SWL, at SP 2738.

SLC 0 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
464	18.1	5.6	5.2	130
357	18.0	5.7	4.7	136
447	17.2	5.4	4.7	136
159	16.6	4.7	5.7	134
461	15.0	3.5	3.6	143
633	14.6	5.7	6.3	157
532	14.4	3.9	4.7	130
342	14.0	4.1	4.3	139
598	13.6	4.5	5.7	137
153	13.4	3.9	4.7	150
SLC 1- With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
464	20.6	6.5	5.2	136
357	19.8	6.4	5.2	139
447	19.5	5.8	4.7	136
159	18.4	5.4	5.7	135
633	17.9	7.4	6.9	157
532	17.0	4.9	4.7	136
461	16.6	3.5	7.6	113
598	16.5	6.1	5.2	137
342	16.3	4.7	4.7	144
589	15.7	3.6	5.7	111
SLC 2 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
464	22.9	7.5	5.7	136
357	22.1	6.9	5.2	148
633	21.9	9.0	6.9	157
447	21.8	6.1	4.7	143
159	20.6	6.2	5.7	135
598	20.5	7.4	5.2	137
532	19.9	5.8	4.7	136
461	19.5	6.0	6.9	123
342	19.3	5.3	4.7	146
589	19.3	5.3	4.7	129

With-project SWL peaks for all storms are plotted against without-project conditions in Figure 46, and similarly, H_{mo} peaks for with-project and without-project conditions are plotted in Figure 47. It can be seen that the SWL and H_{mo} differences between the two alternatives are small, but there is a noticeable high bias for without-project H_{mo} .

Figure 46. With-project SWL peaks for all storms plotted against without-project conditions for SPs 2738 (left) and 4532 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

Figure 47. With-project H_{m0} peaks for all storms plotted against without-project conditions for SPs 2738 (left) and 4532 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

Figure 48 and Figure 49 show SWL and H_{m0} curves, respectively, at SPs 2738 and 4532 for with-project SLC0, SLC1, and SLC2 scenarios. The 50% and 90% CLs are shown in the figures. There is little difference between the without- and with-project for both SWL and H_{m0} hazard curves. However, the small bias for without-project H_{m0} can be seen in the hazard curves. SWL and H_{m0} values for a range of AEPs are listed with their corresponding transects in Appendix D for with-project SLC1 and SLC2 for all of the analyzed SPs in GeoID F. Waves in the area are relatively small.

Figure 48. AEP vs. SWL for SPs 2738 (left) and 4532 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2. Elevations are in feet, NAVD88.

Figure 49. AEP vs. H_{m0} for SPs 2738 (left) and 4532 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

8.2 Local CSRM system response modeling

The GeoID F reach consists of levees, floodwalls, and gates. The features of the feasibility authorized CSRM system corresponding to the transects in the GeoID F reach are listed in Table 14. Idealized structure geometries were used for the with-project response analysis, as shown for Cow Bayou. The transects in the GeoID F reach are located with marshy area to the seaward side of the structure and Sabine Lake beyond that; therefore, conservative assumptions were used, as described for Cow Bayou.

Table 14. Features of the CSRM system for the GeoID F reach.

GeoID	Transect Number	Station Start	Station End	Associated Save Point	With- project Structure Type	With-project Average Slope	Existing Reach Elevation	Authorized Elevation
							(Ft, NAVD88)	(Ft, NAVD88)
F	56	426+10	454+00	4486	Floodwall	N/A	5	15
	57	426+10	454+00	2738	Floodwall	N/A	5	15
	60	454+00	494+00	4493	Floodwall	N/A	5	15
	68	494+00	516+50	4505	Floodwall	N/A	5	15
	71	516+50	560+00	4510	Floodwall	N/A	5	15
	73 - wall	560+00 586+12	562+71 564+66	4517	Floodwall	N/A	6	15
	73 - gate	562+71	562+98	4517	Road Closure - Gate	N/A	6	15
	74	564+66	582+00	4521	Levee	3	6	15.5
	75	582+00	585+82	2720	Levee	3	6	15.5
	76	585+82	586+62	2720	Floodwall / Road Closure - Gate	N/A	6	15
	77	586+62	595+00	2720	Levee	3	6	15.5
	78	595+00	597+01	4532	Levee	3	6	15.5
	79	597+01	597+86	4532	Floodwall / Road Closure - Gate	N/A	6	15
	80	597+86	604+00	4532	Levee	3	6	15.5

8.3 Results

Design elevations were determined by the PDT, which considered the optimized elevations required to just exceed the no-damage limit states under with-project forcing conditions, as described in Chapter 1. The results of the optimization are shown in Appendix C. Appendix D contains the results of the combined overtopping and overflow for levees, gates, and floodwalls, and overtopping nappe geometry and combined hydrostatic and hydrodynamic wall pressures for floodwalls and gates from response-based analysis for the three forcing and elevation combinations described in Chapter 1.

8.4 Summary and conclusions

As part of the ongoing PED phase of the project, this chapter documents coastal storm inundation, wave loading, and combined overtopping and overflow for the GeoID F CSRM system consisting of floodwalls, gates, and levees. Optimized crest elevations were computed based on no-damage overtopping criteria for floodwalls and levees to inform the PDT during design. Overtopping nappe geometry and combined hydrostatic and hydrodynamic pressures on the seaward face of the floodwall and gate were calculated for each floodwall and gate transect.

9 GeoID H

The GeoID H reach consists of levees, floodwalls, multiple road crossings, and two pump stations along the south facing side of the Orange County proposed CSRM system, shown in Figure 50. Coastal SWL, wave loading, and combined overtopping and overflow are quantified.

Figure 50. Aerial image of GeoID H levee and floodwall location (in orange).

The GeoID H reach includes 17,895 ft of proposed levee and 13,727 ft of proposed floodwalls, shown in Figure 51 and Figure 52. This also includes two pump stations and five proposed road closure gates.

Figure 51. Details of the east end of GeoID H reach, including floodwalls (blue), levees (pink), analysis transects (yellow), SPs (red), and color-shaded LiDAR-based elevations (feet, NAVD88). Image is oriented so north is up and floodside is to south, protected side to north.

Figure 52. Details of the west end of Geold H reach, including floodwalls (blue), levees (pink), analysis transects (yellow), SPs (red), and color-shaded LiDAR-based elevations (feet, NAVD88).

9.1 Local wave and water response

The peaks of the top-10 synthetic storms are ranked by SWL for with-project conditions for SP 4358 in Table 15. Peak SWL and H_{m0} for 189 S2G storms for with-project, SLC1 and SLC2 scenarios are shown in Appendix A and B.

Table 15. CSTORM output peaks for the top-10 synthetic storms, ranked by SWL, at SP 4358.

SLC 0 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
357	18.4	3.4	5.2	148
464	17.9	3.3	4.7	150
447	17.8	3.0	4.7	146
159	16.6	3.1	6.3	134
461	16.5	4.0	2.9	99
633	16.4	3.7	2.9	166
598	15.4	2.5	3.6	122
532	15.0	2.1	3.6	78
342	14.9	1.4	2.7	152
589	14.7	3.1	3.6	79
SLC 1- With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
464	20.3	3.8	5.7	150
447	20.2	2.9	4.3	158
357	20.1	3.3	3.9	161
633	18.5	3.8	2.7	172
159	18.4	3.4	6.3	134
461	18.2	4.2	3.2	99
598	17.4	3.4	5.2	145
532	16.8	2.6	4.7	135
342	16.8	2.8	5.2	147
589	16.7	3.5	3.9	79
SLC 2 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
464	22.8	3.7	2.9	101
357	22.5	2.6	2.9	112
447	22.3	2.8	3.2	117
633	21.8	3.2	3.2	173
461	20.8	4.5	3.2	99
598	20.6	2.9	3.2	15
159	20.4	3.3	6.9	141
532	19.9	2.8	2.9	94
342	19.9	2.7	3.9	165
589	19.4	3.7	3.9	79

With-project SWL peaks for all storms are plotted against without-project conditions in Figure 53, and similarly, H_{mo} peaks for with-project and without-project conditions are plotted in Figure 54. It can be seen that the SWL and H_{mo} differences between the two alternatives are small.

Figure 53. With-project SWL peaks for all storms plotted against without-project conditions for SPs 4358 (left) and 4367 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

Figure 54. With-project H_{m0} peaks for all storms plotted against without-project conditions for SPs 4358 (left) and 4367 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

Figure 55 and Figure 56 show SWL and H_{m0} curves, respectively, at SPs 4358 and 4367 for with-project SLC0, SLC1, and SLC2 scenarios. The 50% and 90% CLs are shown in the figures. There is little difference between the without- and with-project for both SWL and H_{m0} hazard curves. SWL and H_{m0} values for a range of AEPs are listed with their corresponding transects in Appendix D for with-project SLC1 and SLC2 for all of the analyzed SPs in GeoID H. Waves in the area are relatively small.

Figure 55. AEP vs. SWL for SPs 4358 (left) and 4367 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2. Elevations are in feet, NAVD88.

Figure 56. AEP vs. H_{m0} for SPs 4358 (left) and 4367 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

9.2 Local CSRM system response modeling

The GeoID H reach consists of levees, floodwalls, pump stations, and gates. The features of the CSRM system corresponding to the transects in the GeoID H reach are listed in Table 16. Idealized structure geometries were used for the with-project response analysis, as shown for Cow Bayou. The transects in the GeoID H reach are located with marshy area to the seaward side of the structure and Sabine Lake beyond that; therefore, conservative assumptions were used, as described for Cow Bayou.

Table 16. Features of the CSRM system for the GeoID H reach.

GeoID	Transect Number	Station Start	Station End	Associated Save Point	With- project Structure Type	With-project Average Slope	Existing Reach Elevation	Authorized Elevation
							(Ft, NAVD88)	(Ft, NAVD88)
H	92	668+00	699+00	1193	Levee	3	5	17.5
	93	699+00	743+97	4367	Levee	3	5	17.5
	98	744+98	762+00	4302	Levee	3	5	17.5
	100	743+97	744+98	1411	Floodwall / Road Closure - Gate	N/A	5	15.5
	103	762+00	771+27	1454	Levee	3	5	17.5
	105 - wall	771+27 776+80	776+40 805+00	2696	Floodwall	N/A	6	15.5
	105 - PS	776+40	776+80	2696	Pump Station #5	N/A	6	15.5
	112 - wall	805+00 837+17	836+97 854+58	1233	Floodwall	N/A	6	15.5
	112 - gate	836+97	837+17	1233	Road Closure - Gate	N/A	6	15.5
	117	854+58	855+00	1452	Levee	3	4	17.5
	123	855+00	906+75	2678	Levee	3	4	17.5
	126 - wall	906+75 915+20	914+10 920+97	2675	Floodwall	N/A	3	15.5
	126 - gate	914+10	915+20	2675	Pump Station #6	N/A	3	15.5
	128	920+97	940+48	2673	Levee	3	5	17.5
	132	940+48 943+99	943+74 977+51	4358	Floodwall	N/A	6	15.5
	136 - wall	940+48 943+99	943+74 977+51	1324	Floodwall	N/A	6	15.5
	136 - gate	943+74	943+99	1324	Road Closure - Gate	N/A	6	15.5
	138 - wall	978+40	979+24	1167	Floodwall	N/A	6	15.5
	138 - gate	977+51	978+40	1167	Floodwall / Road Closure - Gate	N/A	6	15.5

9.3 Results

Design elevations were determined by the PDT, which considered the optimized elevations required to just exceed the no-damage limit states under with-project forcing conditions, as described in Chapter 1. The results of the optimization are shown in Appendix C. Appendix D contains the results of the combined overtopping and overflow for levees, gates, and floodwalls, and overtopping nappe geometry and combined hydrostatic and hydrodynamic wall pressures for floodwalls and gates from response-based analysis for the three forcing and elevation combinations described in Chapter 1.

9.4 Summary and conclusions

As part of the ongoing PED phase of the project, this chapter documents coastal storm inundation, wave loading, and combined overtopping and overflow for the GeoID H CSRM system consisting of floodwalls, gates, and levees. Optimized crest elevations were computed based on the no-damage overtopping criteria for floodwalls and levees to inform the PDT during design. Overtopping nappe geometry and combined hydrostatic and hydrodynamic pressures on the seaward face of the floodwall and gate were calculated for each floodwall and gate transect.

10 GeoID N

The GeoID N reach consists of levees, floodwalls, multiple road crossings, and one pump station along the southwest end of the proposed Orange County CSRM system, shown in Figure 57. Coastal SWL, wave loading, and combined overtopping and overflow are quantified.

Figure 57. Aerial image of GeoID N levee and floodwall location (in orange).

The GeoID N reach includes 33,190 ft of proposed levee and 9,946 ft of proposed floodwall, shown in Figure 58 through Figure 60. This also includes four road closure gates and one pump station.

Figure 58. Details of the east end of GeoID N reach, including floodwalls (blue), levees (pink), analysis transects (yellow), SPs (red), and color-shaded LiDAR-based elevations (feet, NAVD88). Image is oriented so north is up and floodside is to south and west, protected side to north and east.

Figure 59. Details of the middle area of GeoID N reach, including floodwalls (blue), levees (pink), analysis transects (yellow), SPs (red), and color-shaded LiDAR-based elevations (feet, NAVD88).

Figure 60. Details of the west end of GeoID N reach, including floodwalls (blue), levees (pink), analysis transects (yellow), SPs (red), and color-shaded LiDAR-based elevations (feet, NAVD88).

10.1 Local wave and water response

The peaks of the top 10 synthetic storms are ranked by SWL for with-project conditions for SP 4220 in Table 17. Peak SWL and H_{mo} for 189 S2G storms for with-project, SLC1 and SLC2 scenarios are shown in Appendix A and B.

Table 17. CSTORM output peaks for the top-10 synthetic storms, ranked by SWL, at SP 4220.

SLC 0 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
357	18.2	3.4	3.2	136
447	17.7	2.8	3.2	139
464	17.6	3.6	3.2	92
159	15.8	2.9	2.9	135
461	15.3	4.3	3.2	99
633	14.9	2.9	2.9	171
532	14.7	2.6	2.9	95
342	14.4	2.1	2.7	144
589	14.3	3.6	3.6	70
598	14.2	3.1	3.9	15
SLC 1- With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
464	20.2	3.8	3.6	137
357	20.1	3.7	3.9	136
447	19.9	3.2	3.9	139
159	17.8	3.0	2.7	135
633	17.2	3.2	2.9	171
461	16.9	4.6	3.6	118
532	16.5	2.8	3.2	71
342	16.3	2.3	2.9	137
589	16.3	4.0	3.9	66
598	16.2	3.5	3.9	14
SLC 2 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
464	22.8	4.3	4.3	137
357	22.4	3.9	3.6	139
447	22.3	3.4	3.9	139
633	21.1	3.5	5.2	168
159	20.0	3.4	5.2	137
598	20.0	3.7	3.9	146
532	19.8	3.0	3.2	67
461	19.8	5.2	3.9	129
342	19.6	2.9	3.6	140
589	19.0	4.3	3.9	66

With-project SWL peaks for all storms are plotted against without-project conditions in Figure 61, and similarly, H_{mo} peaks for with-project and without-project conditions are plotted in Figure 62. It can be seen that the SWL and H_{mo} differences between the two alternatives are small.

Figure 61. With-project SWL peaks for all storms plotted against without-project conditions for SPs 4179 (left) and 4220 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

Figure 62. With-project H_{m0} peaks for all storms plotted against without-project conditions for SPs 4179 (left) and 4220 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

Figure 63 and Figure 64 show SWL and H_{m0} curves, respectively, at SPs 4179 and 4220 for with-project SLC0, SLC1, and SLC2 scenarios. The 50% and 90% CLs are shown in the figures. There is little difference between the without- and with-project for both SWL and H_{m0} hazard curves. SWL and H_{m0} values for a range of AEPs are listed with their corresponding transects in Appendix D for with-project SLC1 and SLC2 for all of the analyzed SPs in GeoID N. Waves in the area are relatively small.

Figure 63. AEP vs. SWL for SPs 4179 (left) and 4220 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2. Elevations are in feet, NAVD88.

Figure 64. AEP vs. H_{m0} for SPs 4179 (left) and 4220 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

10.2 Local CSRM system response modeling

The GeoID N reach consists of levees, floodwalls, pump stations, and gates. The features of the feasibility authorized CSRM system corresponding to the transects in the GeoID N reach are listed in Table 18. Idealized structure geometries were used for the with-project response analysis, as shown for Cow Bayou. The transects in the GeoID N reach are located with marshy area to the seaward side of the structure and Sabine Lake beyond that; therefore, conservative assumptions were used.

Table 18. Features of the CSRM system for the GeoID N reach.

GeoID	Transect Number	Station Start	Station End	Associated Save Point	With- project Structure Type	With-project Average Slope	Existing Reach Elevation	Authorized Elevation
							(Ft, NAVD88)	(Ft, NAVD88)
N	139	979+24	993+52	1164	Levee	3	5	16.5
	144	993+52	1032+79	4220	Floodwall	N/A	3	14
	149	1032+79	1080+40	4232	Levee	3	5	16.5
	155	1080+40	1117+00	4249	Floodwall	N/A	5	14
	159 - wall	1117+00 1120+04	1119+79 1129+88	4257	Floodwall	N/A	5	14
	159 - gate	1119+79	1120+04	4257	Road Closure - Gate	N/A	5	14
	162	1129+88	1160+00	4263	Levee	3	9	16.5
	171	1160+00	1215+32	4279	Levee	3	9	16.5
	172	1215+32	1216+12	1137	Floodwall / Road Closure - Gate	N/A	9	14
	173	1216+12	1217+69	1137	Levee	3	9	16.5
	174	1215+32 1217+69	1216+12 1218+49	1137	Floodwall / Road Closure - Gate	N/A	9	14
	175	1218+49	1244+51	1243	Levee	3	9	16.5
	176	1244+51	1251+59	1252	Floodwall	N/A	10	14
	179	1251+59	1272+00	2633	Levee	3	9	16.5
	184	1272+00 1277+08	1275+83 1340+00	4179	Levee	3	9	16.5
	185	1275+83	1277+08	4179	Floodwall / Pump Station # 7	N/A	9	16.5
	191	1340+00	1355+80	4193	Levee	3	9	16.5
	192	1355+80	1356+65	4193	Floodwall / Road Closure - Gate	N/A	9	14
	197	1356+65	1410+61	1408	Levee	3	9	16.5

10.3 Results

Design elevations were determined by the PDT, which considered the optimized elevations required to just exceed the no-damage limit states under with-project forcing conditions, as described in Chapter 1. The results of the optimization are shown in Appendix C. Appendix D contains the results of the combined overtopping and overflow for levees, gates, and floodwalls, and overtopping nappe geometry and combined hydrostatic and hydrodynamic wall pressures for floodwalls and gates from response-based analysis for the three forcing and elevation combinations described in Chapter 1.

10.4 Summary and conclusions

As part of the ongoing PED phase of the project, this chapter documents coastal storm inundation, wave loading, and combined overtopping and overflow for the GeoID N CSRM system consisting of floodwalls, gates and levees. Optimized crest elevations were computed based on no-damage overtopping criteria for floodwalls and levees to inform the PDT during design. Overtopping nappe geometry and combined hydrostatic and hydrodynamic pressures on the seaward face of the floodwall and gate were calculated for each floodwall and gate transect.

11 High Ground Analysis

Orange County high grounds designate the areas adjacent to the Orange County CSRM system that, during the feasibility study, were determined to not require any CSRM features due to existing high land elevation. This chapter documents coastal SWL and wave hazards analysis that has been performed in PED for the high ground regions near the Orange County CSRM system, shown in Figure 65. Details for these areas are shown in Figure 66 and Figure 67.

Figure 65. High ground locations (circled in green).

Figure 66. Details of the high grounds at the GeoID A terminus of the Orange County CSRM system and color-shaded LiDAR-based elevations (feet, NAVD88).

Figure 67. Details of the high grounds at the GeoID N terminus of the Orange County CSRM system and color-shaded LiDAR-based elevations (feet, NAVD88).

The area adjacent to the GeoID A terminus of the CSRM system is generally lower than 11 ft, NAVD88. There is a roadway approximately 80 ft from the GeoID A terminus that provides a high ground of approximately 13 ft, NAVD88. The existing high ground area adjacent to the GeoID N terminus of the CSRM system is higher than 19 ft, NAVD88.

11.1 Local wave and water level response

The 1% AEP SWL and H_{mo} values were computed for SPs in each high ground area at both a 50% and 90% CL. The SP with the highest 1% AEP SWL at a 90% CL for SLC0 was used to characterize the local SWL and wave response for each of the RSLC conditions and are marked in Figure 66 and Figure 67. These values are listed in Table 19 and corresponding 1% AEP H_{mo} values are listed in Table 20. Only with-project SWL and wave responses were used in this analysis.

Table 19. SWL, in feet, NAVD88, for 1% AEPs for Orange County high ground areas at 50% CL and 90% CL, with-project.

Scenario	Terminus at GeoID A	Terminus at GeoID N
	SP 1422	SP 1408
With SLC0 50%	10.67	10.54
With SLC0 90%	11.32	11.72
With SLC1 50%	13.26	13.42
With SLC1 90%	13.70	14.00
With SLC2 50%	18.41	17.23
With SLC2 90%	18.90	17.77

Table 20. H_{mo} , in feet, for 1% AEPs for Orange County high ground areas at 50% CL and 90% CL, with-project.

Scenario	Terminus at GeoID A	Terminus at GeoID N
	SP 1422	SP 1408
With SLC0 50%	0.45	1.0
With SLC0 90%	0.60	1.3
With SLC1 50%	0.81	1.5
With SLC1 90%	1.2	1.6
With SLC2 50%	1.3	2.1
With SLC2 90%	2.1	2.9

For the terminus at GeoID A, it can be seen that the existing elevation is higher than the 1% AEP SWL at only SLC₀ at 50%. All 1% AEP SWL values were lower than the existing high ground elevations for GeoID N.

A nodal hazard analysis showed inundation behind the authorized CSRM system at the Interstate 10 (I-10) terminus at GeoID A for SLC₁ at the 1% AEP, shown in Figure 68 for 50% CL and Figure 69 for 90% CL. Inundation was shown throughout the inside of the CSRM system for SLC₂ at 1% AEP, shown in Figure 70 for 50% CL. The CSRM system terminus is tied into I-10 elevation, so there would be no flooding between I-10 and the structure. The Business 90 overpass gap, shown as the downward pointing arrow in Figure 70, would likely allow flooding into the area behind the CSRM system. There is potentially overtopping of the CSRM structure built to feasibility authorized elevations under SLC₂ conditions.

Figure 68. Inundation shown behind levee at OC GeoID A I-10 and colored regional nodal output locations corresponding to SWL for SLC₁ at 1% AEP, 50% CL.

Figure 69. Inundation shown behind levee at OC GeoID A I-10 and colored regional nodal output locations corresponding to SWL for SLC₁ at 1% AEP, 90% CL.

Figure 70. Inundation shown behind levee at OC GeoID A I-10 and colored regional nodal output locations corresponding to SWL for SLC2 at 1%, 50% CL.

11.2 Optimized levee elevation

An optimization step was completed to compute an optimized levee crest elevation required to just exceed the no-damage limit states in the high ground areas using the with-project wave and water level responses. The SP that produced the highest 1% AEP SWL at a 90% CL in the area for SLC0 was used with its associated wave conditions. As a representative geometry, a 1:3 slope was used to compute levee overtopping rates. A summary of the results is listed in Table 21.

Table 21. Optimized levee crest elevations that most nearly match the no-damage overtopping limit states.

Scenario	Terminus at GeoID A	Terminus at GeoID N
SLC0	11.5	12
SLC1	15	17
SLC2	22.5	22

It can be seen that the existing elevation at the GeoID A terminus is lower than the optimized elevations for all RSLC conditions. The existing elevation at the GeoID N terminus is adequate for SLC0 and SLC1 but not SLC2. This indicates that additional CSR features will be needed in these areas to provide the same level of risk reduction as the rest of the CSR system. These additional CSR features will be designed by others and their detailed local and regional SWL, and wave response will be quantified in due course of the S2G project.

As discussed in Melby et al. (2021), extensive riverine analysis has been conducted, and compound flooding impacts have been assessed

separately. They note that the design SWL elevations are dominated by hurricane storm surge and wave contributions, not by riverine flows or by the compounding effect of the two. The multivariate probabilistic combinations of surge and hydrologic impacts are much more rare than would be a consideration for CSRM design. If combined flooding of the 1% AEP SWL tropical storm occurs with rare high river flows, there would likely be greater flooding; however, this was not investigated herein.

11.3 Summary and conclusions for high ground areas

The 1% AEP SWLs were compared to the elevations in the high ground areas to determine if the high ground would provide adequate level of risk reduction that is comparable to the rest of the CSRM system. High ground elevations were lower than the 1% AEP SWL for the terminus at GeoID A for all RSLC conditions. High ground elevations were higher for SLCo and SLC1 1% AEP SWL at the GeoID N terminus. Additionally, and considering overtopping hazards, all of the existing high ground elevations were lower than the optimized elevations for GeoID A for all conditions and for GeoID N at SLC2 but were lower for GeoID N at SLCo and SLC1. This indicates that additional CSRM features will be needed in these areas.

12 Conclusions and Recommendations

The USACE SWG is executing the S2G CSRM project for Brazoria, Jefferson, and Orange Counties regions. The project is currently in the PED phase. As identified during the Final Integrated Feasibility Report – Environmental Impact Statement (USACE 2017), the S2G project CSRM formulated measures consist of reducing the risks of tropical storm SWL impacts by constructing the new Orange 3 CSRM system in Orange County and increasing the level of risk reduction and resiliency of the existing Port Arthur and Vicinity and Freeport and Vicinity CSRM systems in Jefferson and Brazoria Counties, Texas.

As part of the ongoing PED phase of the project, this report documents SWL and wave hazards for the proposed Orange County CSRM system. Coastal storm water level and wave loading, and wave and SWL overtopping are quantified.

A multivariate probabilistic model of historical hurricane parameters was developed that spans the full range of tropical storm hazards. The model was sampled effectively to develop a suite of 189 synthetic tropical storms that effectively capture the flood hazard for the region from Freeport to the Louisiana-Texas border. The CSTORM coupled circulation, water level, and wave modeling system was used to accurately quantify the SWL and wave hazards. Storm water levels consist of storm surge, tides, wave setup, seasonal variations, and other local storm effects from currents and winds. The storms were run on three RSLC scenarios for the with- and without-project meshes. These RSLC scenarios are referred to as SLC₀ corresponding to project completion in 2027 with associated “Low” RSLC rate, SLC₁ corresponding to the end of a 50 yr service life in 2077 with associated “Intermediate” RSLC rate, and SLC₂ corresponding to the end of a 100 yr service lifecycle in 2127 with associated “Intermediate” RSLC rate. Further details are provided in Melby et al. (2021).

The flood hazard exposure of the project features was quantified by computing hazard curves for the CSTORM output near the structures. AEP were computed for the range of 1 to 0.0001 for SWL and H_{mo} at 50% and 90% CLs. Wave direction and T_p associated with peak H_{mo} were also computed. In this case, CLs are used to describe epistemic uncertainty or levels of assurance. For hazard curves contained herein, the mean and median are indistinguishable. Therefore, only mean values are reported.

Typically, the with-project SWL hazard curves are shown to be approximately the same as the without-project. Waves at 1% AEP are typically shown to be small and short in length that would be expected to characterize wind wave conditions inland, as occur in the area of Freeport. The modeling does not include infragravity waves, so conservative assumptions were made to assure waves were conservative. An analysis of the nonlinear residual was completed in Melby et al. (2021) that illustrated the need for coupled circulation and wave modeling.

An analysis of stochastic workflows was completed for overtopping in Melby et al. (2021). It was shown that a peaks-based response-based approach yielded a very accurate stochastic response, so this was used to compute the design. No-damage limit states for overtopping a levee of $q = 0.01$ cfs/ft for the 50% CL and $q = 0.1$ cfs/ft for the 90% CL were based on previous studies. Limit states for overtopping a floodwall of $q = 0.03$ cfs/ft for the 50% CL and $q = 0.1$ cfs/ft for the 90% CL were based on previous studies. These limit states are accepted standard of practice both within USACE and internationally. An additional ultimate limit state of $q = 1$ cfs/ft was evaluated to determine the vulnerability to severe damage. The optimized levee and floodwall elevations were computed using the limit states. The PDT selected final design elevations based on the optimized elevations and local considerations. In addition to overtopping, combined hydrostatic and hydrodynamic pressures and overtopping nappe characteristics was calculated for floodwall reaches.

Most with-project reach elevations were shown to not meet overtopping criteria for SLC1 and SLC2 whereas approximately half with-project reach elevations met the criteria for SLCo. Flooding potential in natural high ground areas adjacent to the CSRM systems was identified, and associated additional CSRM features will be needed to provide a consistent system-wide level of risk reduction against coastal hazards.

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Appendix A: Peak Storm Water Level (SWL) by Storm

A.1 Cow Bayou

Figure A-1. Peak SWL for with-project and SLC1 for SPs in the Cow Bayou area. SWL is in feet, NAVD88.

Figure A-2. Peak SWL for with-project and SLC2 for SPs in the Cow Bayou area. SWL is in feet, NAVD88.

A.2 GeoID A

Figure A-3. Peak SWL for with-project and SLC1 for SPs in the GeoID A area. SWL is in feet, NAVD88.

Figure A-4. Peak SWL for with-project and SLC2 for SPs in the GeoID A area. SWL is in feet, NAVD88.

A.3 GeolD B

Figure A-5. Peak SWL for with-project and SLC1 for SPs in the GeolD B area. SWL is in feet, NAVD88.

Figure A-6. Peak SWL for with-project and SLC2 for SPs in the GeoID B area. SWL is in feet, NAVD88.

A.4 GeolD C

Figure A-7. Peak SWL for with-project and SLC1 for SPs in the GeolD C area. SWL is in feet, NAVD88.

Figure A-8. Peak SWL for with-project and SLC2 for SPs in the GeoID C area. SWL is in feet, NAVD88.

A.5 GeoID D

Figure A-9. Peak SWL for with-project and SLC1 for SPs in the GeoID D area. SWL is in feet, NAVD88.

Figure A-10. Peak SWL for with-project and SLC2 for SPs in the GeoID D area. SWL is in feet, NAVD88.

A.6 Geold E

Figure A-11. Peak SWL for with-project and SLC1 for SPs in the Geold E area. SWL is in feet, NAVD88.

Figure A-12. Peak SWL for with-project and SLC2 for SPs in the GeoID E area. SWL is in feet, NAVD88.

A.7 Geold F

Figure A-13. Peak SWL for with-project and SLC1 for SPs in the Geold F area. SWL is in feet, NAVD88.

Figure A-14. Peak SWL for with-project and SLC2 for SPs in the GeoID F area. SWL is in feet, NAVD88.

A.8 GeoID H

Figure A-15. Peak SWL for with-project and SLC1 for SPs in the GeoID H area. SWL is in feet, NAVD88.

Figure A-16. Peak SWL for with-project and SLC2 for SPs in the GeoID H area. SWL is in feet, NAVD88.

A.9 GeoID N

Figure A-17. Peak SWL for with-project and SLC1 for SPs in the GeoID N area. SWL is in feet, NAVD88.

Figure A-18. Peak SWL for with-project and SLC2 for SPs in the GeoID N area. SWL is in feet, NAVD88.

Appendix B: Peak H_{m0} by Storm

B.1 Cow Bayou

Figure B-1. Peak H_{m0} for with-project and SLC1 for SPs in the Cow Bayou area. H_{m0} is in feet.

Figure B-2. Peak H_{m0} for with-project and SLC2 for SPs in the Cow Bayou area. H_{m0} is in feet.

B.2 GeoID A

Figure B-3. Peak H_{m0} for with-project and SLC1 for SPs in the GeoID A area. H_{m0} is in feet.

Figure B-4. Peak H_{m0} for with-project and SLC2 for SPs in the GeoID A area. H_{m0} is in feet.

B.3 Geold B

Figure B-5. Peak H_{m0} for with-project and SLC1 for SPs in the Geold B area. H_{m0} is in feet.

Figure B-6. Peak H_{m0} for with-project and SLC2 for SPs in the Geold B area. H_{m0} is in feet.

B.4 GeolD C

Figure B-7. Peak H_{m0} for with-project and SLC1 for SPs in the GeolD C area. H_{m0} is in feet.

Figure B-8. Peak H_{m0} for with-project and SLC2 for SPs in the GeolD C area. H_{m0} is in feet.

B.5 GeoID D

Figure B-9. Peak H_{m0} for with-project and SLC1 for SPs in the GeoID D area. H_{m0} is in feet.

Figure B-10. Peak H_{m0} for with-project and SLC2 for SPs in the Geold D area. H_{m0} is in feet.

B.6 Geold E

Figure B-11. Peak H_{m0} for with-project and SLC1 for SPs in the Geold E area. H_{m0} is in feet.

Figure B-12. Peak H_{m0} for with-project and SLC2 for SPs in the Geold E area. H_{m0} is in feet.

B.7 GeoID F

Figure B-13. Peak H_{m0} for with-project and SLC1 for SPs in the GeoID F area. H_{m0} is in feet.

Figure B-14. Peak H_{m0} for with-project and SLC2 for SPs in the Geold F area. H_{m0} is in feet.

B.8 Geold H

Figure B-15. Peak H_{m0} for with-project and SLC1 for SPs in the Geold H area. H_{m0} is in feet.

Figure B-16. Peak H_{m0} for with-project and SLC2 for SPs in the GeoID H area. H_{m0} is in feet.

B.9 GeoID N

Figure B-17. Peak H_{m0} for with-project and SLC1 for SPs in the GeoID N area. H_{m0} is in feet.

Figure B-18. Peak H_{m0} for with-project and SLC2 for SPs in the GeoID N area. H_{m0} is in feet.

Appendix C: Optimized and Design Crest Elevations

This appendix presents the optimized elevations, computed as described in Chapter 1, for levees, floodwalls, fronting protection, and gates. The optimized crest elevations were used to inform the PDT during the selection of the final Design Elevations for SLC1 and SLC2. The final Construction and Design elevations for the levees, floodwalls, and gates are presented on the right side of the table. Gates were designed to the Adaptability Elevation, which is based off of the SLC2 optimized crest elevation.

Table C-1. Optimized and design elevations for Orange County transects 2 to 19. Elevations are in feet, NAVD88.

ERDC Transect number	Contract Stationing		Feature Type Used For Modeling	PED Optimized Crest Elevation (1% AEP Risk Reduction) (ft, NAVD88)		Levee Embankment - Design Grade (SLC1/SLC2, ft)	Floodwall - Construction Elevation (SLC1/SLC2, ft)	Gates - Construction Elevation (SLC2, ft)	Adaptability Elevation - (SLC2, ft)
	Begin	End		Design Scenario (SLC1)	Adaptability Scenario (SLC2)				
2	0+00	16+71	Levee	15.50	21.10	15.50			21.25
4 wall / 4 gate	16+71	24+50	Floodwall	15.50	20.80		15.50		21.00
	24+50	25+29	Floodwall				15.50		21.00
	25+29	25+59	Pump Station #1 (Floodwall)				21.00		21.00
	25+59	26+50	Floodwall				15.50		21.00
	26+50	31+87	Floodwall				15.50		21.00
	31+87	32+12	Road Closure - Gate					21.00	21.00
	32+12	34+01	Floodwall				15.50		21.00
8	34+01	57+00	Levee	17.50	25.00	17.50			25.00
12	57+00	113+49	Levee	18.00	26.50	18.00			26.50
14	113+49	113+79	Floodwall	15.50	22.50		22.50		22.50
	113+79	114+14	Road Closure - Gate					22.50	22.50
	114+14	114+44	Floodwall				22.50		22.50
15	114+44	118+00	Levee	18.00	26.50	18.00			26.50
	118+00	118+30	Levee			18.00			26.50
17 wall / 17 gate	118+30	121+10	Floodwall	16.50	23.00		16.50		23.00
	121+10	121+40	Road Closure - Gate					23.00	23.00
	121+40	125+61	Pump Station #2 (Floodwall)				23.00		23.00
	125+61	125+96	Road Closure - Gate					23.00	23.00
	125+96	126+28	Floodwall				16.50		23.00
19	126+28	127+00	Levee	18.00	24.50	18.00			24.50
	127+00	136+78	Levee			18.00			24.50

Table C-2. Optimized and design elevations for Orange County transects 21 to 27. Elevations are in feet, NAVD88.

ERDC Transect number	Contract Stationing		Feature Type Used For Modeling	PED Optimized Crest Elevation (1% AEP Risk Reduction) (ft, NAVD88)		Levee Embankment - Design Grade (SLC1/SLC2, ft)	Floodwall - Construction Elevation (SLC1/SLC2, ft)	Gates - Construction Elevation (SLC2, ft)	Adaptability Elevation - (SLC2, ft)
	Begin	End		Design Scenario (SLC1)	Adaptability Scenario (SLC2)				
21 wall / 21 gate	136+78	137+07	Floodwall	15.40	20.50		15.50		20.50
	137+07	137+40	Road Closure - Gate					20.50	20.50
	137+40	140+57	Floodwall				15.50		20.50
	140+57	140+99	Road Closure - Gate					20.50	20.50
	140+99	144+12	Floodwall				15.50		20.50
	144+12	144+39	Road Closure - Gate					20.50	20.50
	144+39	147+68	Floodwall				15.50		20.50
	147+68	147+98	Road Closure - Gate					20.50	20.50
	147+98	151+63	Floodwall				15.50		20.50
	151+63	151+93	Road Closure - Gate					20.50	20.50
	151+93	152+12	Floodwall				15.50		20.50
	152+12	152+39	Road Closure - Gate (railroad)					20.50	20.50
	152+39	153+49	Floodwall				15.50		20.50
	153+49	153+84	Road Closure - Gate					20.50	20.50
	153+84	154+00	Floodwall				15.50		20.50
22 wall / 27 wall / 22 gate / 27 gate	154+00	188+37	Floodwall	15.50	21.00		15.50		21.00
	188+37	188+57	Road Closure - Gate					21.00	21.00
	188+57	193+51	Floodwall				15.50		21.00
	193+51	193+77	Road Closure - Gate					21.00	21.00
	193+77	200+20	Floodwall				15.50		21.00
	200+20	200+58	Road Closure - Gate					21.00	21.00
	200+58	209+38	Floodwall				15.50		21.00
	209+38	209+68	Road Closure - Gate					21.00	21.00
	209+68	212+75	Floodwall				15.50		21.00
	212+75	213+05	Road Closure - Gate					21.00	21.00
	213+05	214+49	Floodwall				15.50		21.00

Table C-3. Optimized and design elevations for Orange County transects 30 to 57. Elevations are in feet, NAVD88.

ERDC Transect number	Contract Stationing		Feature Type Used For Modeling	PED Optimized Crest Elevation (1% AEP Risk Reduction) (ft, NAVD88)		Levee Embankment - Design Grade (SLC1/SLC2, ft)	Floodwall - Construction Elevation (SLC1/SLC2, ft)	Gates - Construction Elevation (SLC2, ft)	Adaptability Elevation - (SLC2, ft)
	Begin	End		Design Scenario (SLC1)	Adaptability Scenario (SLC2)				
30	214+49	219+70	Levee	16.00	21.00	16.00			21.00
31	219+70	219+97	Floodwall	15.30	20.00		20.00		20.00
	219+97	220+30	Road Closure - Gate					20.00	20.00
	220+30	220+57	Floodwall				20.00		20.00
32	220+57	227+84	Levee	16.00	21.50	16.00			21.50
34	227+84	237+94	Floodwall	16.00	21.00		16.00		21.00
35/36	237+94	246+26	Levee	17.50	24.50	17.50			24.50
37	246+26	246+72	Floodwall	15.30	20.50		20.50		20.50
	246+72	247+07	Road Closure - Gate			20.50			20.50
	247+07	247+57	Floodwall				20.50		20.50
38	247+57	261+99	Levee	16.00	22.50	16.00			22.50
40 wall / 40 gate	261+99	262+25	Floodwall	15.30	20.00		15.50		20.00
	262+25	262+59	Road Closure - Gate					20.00	20.00
	262+59	280+96	Floodwall				15.50		20.00
41	280+96	291+98	Levee	16.50	20.00	16.50			22.00
42	291+98	309+91	Floodwall	15.50	20.00		15.50		20.00
44	309+91	322+00	Levee	17.50	25.00	17.50			25.00
47	322+00	385+00	Levee	20.00	29.00	20.00			29.00
	385+00	386+84	Levee			20.00			29.00
49/50/51	386+84	387+14	Floodwall	17.00	25.00		25.00		25.00
	387+14	388+24	Pump Station #3 (Floodwall)				25.00		25.00
	388+24	391+10	Adams Gate (w/vert lift gate)					25.00	25.00
	391+10	391+40	Floodwall				25.00		25.00
53	391+40	393+00	Levee	20.00	28.00	20.00			28.00
	393+00	426+10	Levee			20.00			28.00
56/57	426+10	454+00	Floodwall	17.00	25.00		17.00		25.00

Table C-4. Optimized and design elevations for Orange County transects 60 to 93. Elevations are in feet, NAVD88.

ERDC Transect number	Contract Stationing		Feature Type Used For Modeling	PED Optimized Crest Elevation (1% AEP Risk Reduction) (ft, NAVD88)		Levee Embankment - Design Grade (SLC1/SLC2, ft)	Floodwall - Construction Elevation (SLC1/SLC2, ft)	Gates - Construction Elevation (SLC2, ft)	Adaptability Elevation - (SLC2, ft)
	Begin	End		Design Scenario (SLC1)	Adaptability Scenario (SLC2)				
60	454+00	494+00	Floodwall	16.00	23.00		16.00		23.00
68	494+00	516+50	Floodwall	16.50	23.50		16.50		23.50
71	516+50	560+00	Floodwall	17.50	24.50		17.50		24.50
73 wall / 73 gate	560+00	562+71	Floodwall	15.90	21.50		16.00		21.50
	562+71	562+98	Road Closure - Gate					21.50	21.50
	562+98	564+66	Floodwall				16.00		21.50
74	564+66	582+00	Levee	17.50	25.50	17.50			25.50
75	582+00	585+82	Levee	15.90	23.00	16.00			23.00
76	585+82	586+12	Floodwall	15.90	20.00		20.00		20.00
	586+12	586+32	Road Closure - Gate					20.00	20.00
	586+32	586+62	Floodwall				20.00		20.00
77	586+62	595+00	Levee	15.90	23.00	16.00			23.00
78	595+00	597+01	Levee	18.00	25.50	18.00			25.50
79	597+01	597+33	Floodwall	16.00	21.50		21.50		21.50
	597+33	597+53	Road Closure - Gate					21.50	21.50
	597+53	597+86	Floodwall				21.50		21.50
80	597+86	604+00	Levee	18.00	25.50	18.00			25.50
82	604+00	608+79	Levee	18.00	25.50	18.00			25.50
83/84	608+79	624+00	Floodwall	16.00	22.00		16.00		22.00
85/86/87	624+00	650+00	Floodwall	16.50	22.50		16.50		22.50
88	650+00	651+34	Floodwall	17.00	23.00		17.00		23.00
89	651+34	653+07	Pump Station #4 (Floodwall)	16.50	22.00		22.00		22.00
	653+07	657+33	Cow Gate (w/vert lift gate)					22.00	22.00
90	657+33	663+01	Floodwall	16.50	22.00		16.50		22.00
91	663+01	668+00	Levee	19.00	25.00	19.00			25.00
92	668+00	699+00	Levee	21.00	28.00	21.00			28.00
93	699+00	743+97	Levee	20.50	27.50	20.50			27.50

Table C-5. Optimized and design elevations for Orange County transects 100 to 136. Elevations are in feet, NAVD88.

ERDC Transect number	Contract Stationing		Feature Type Used For Modeling	PED Optimized Crest Elevation (1% AEP Risk Reduction) (ft, NAVD88)		Levee Embankment - Design Grade (SLC1/SLC2, ft)	Floodwall - Construction Elevation (SLC1/SLC2, ft)	Gates - Construction Elevation (SLC2, ft)	Adaptability Elevation - (SLC2, ft)
	Begin	End		Design Scenario (SLC1)	Adaptability Scenario (SLC2)				
100	743+97	744+31	Floodwall	18.00	24.00		24.00		24.00
	744+31	744+48	Road Closure - Gate					24.00	24.00
	744+48	744+98	Floodwall				24.00		24.00
98	744+98	762+00	Levee	23.00	29.50	23.00			29.50
103	762+00	771+27	Levee	25.50	31.00	25.50			31.00
105 wall / 105 PS	771+27	775+50	Floodwall	22.00	27.50		22.00		27.50
	775+50	776+40	Floodwall				22.00		27.50
	776+40	776+80	Pump Station #5 (Floodwall)				27.50		27.50
	776+80	805+00	Floodwall				22.00		27.50
112 wall / 112 gate	805+00	836+97	Floodwall	17.00	21.00		17.00		21.00
	836+97	837+17	Road Closure - Gate					21.00	21.00
	837+17	854+58	Floodwall				17.00		21.00
117	854+58	855+00	Levee	24.50	31.50	24.50			31.50
123	855+00	906+75	Levee	24.50	31.00	24.50			31.50
126 wall / 126 gate	906+75	913+50	Floodwall	22.50	28.00		22.50		28.00
	913+50	914+10	Floodwall				22.50		28.00
	914+10	915+20	Pump Station #6 (Floodwall)				28.00		28.00
	915+20	916+50	Floodwall				22.50		28.00
	916+50	920+97	Floodwall				22.50		28.00
128	920+97	940+48	Levee	24.50	31.00	24.50			31.00
132 / 136 wall / 136 gate	940+48	943+74	Floodwall	16.50	20.50		16.50		20.50
	943+74	943+99	Road Closure - Gate					20.50	20.50
	943+99	977+51	Floodwall				16.50		20.50

Table C-6. Optimized and design elevations for Orange County transects 138 to 176. Elevations are in feet, NAVD88.

ERDC Transect number	Contract Stationing		Feature Type Used For Modeling	PED Optimized Crest Elevation (1% AEP Risk Reduction) (ft, NAVD88)		Levee Embankment - Design Grade (SLC1/SLC2, ft)	Floodwall - Construction Elevation (SLC1/SLC2, ft)	Gates - Construction Elevation (SLC2, ft)	Adaptability Elevation - (SLC2, ft)
	Begin	End		Design Scenario (SLC1)	Adaptability Scenario (SLC2)				
138 gate / 138 wall	977+51	977+91	Road Closure - Gate	16.00	20.00			20.00	20.00
	977+91	978+00	Floodwall				20.00		20.00
	978+00	978+40	Road Closure - Gate					20.00	20.00
	978+40	979+24	Floodwall				16.00		20.00
139	979+24	993+52	Levee	17.00	21.00	17.00			21.00
144	993+52	1032+79	Floodwall	16.50	20.50		16.50		20.50
149	1032+79	1080+40	Levee	20.50	26.50	20.50			26.50
155	1080+40	1117+00	Floodwall	16.00	21.00		16.00		21.00
159 wall / 159 gate	1117+00	1119+79	Floodwall	17.50	22.50		17.50		22.50
	1119+79	1120+04	Road Closure - Gate					22.50	22.50
	1120+04	1129+88	Floodwall				17.50		22.50
162	1129+88	1160+00	Levee	16.00	20.50	16.00			20.50
171	1160+00	1215+32	Levee	15.80	19.70	16.00			19.75
172/174	1215+32	1215+58	Floodwall	15.70	19.70		19.75		19.75
	1215+58	1215+80	Road Closure - Gate					19.75	19.75
	1215+80	1216+12	Floodwall				19.75		19.75
173	1216+12	1217+69	Levee	15.70	19.70	15.75			19.75
174	1217+69	1217+99	Floodwall	15.70	19.70		19.75		19.75
	1217+99	1218+19	Road Closure - Gate					19.75	19.75
	1218+19	1218+49	Floodwall				19.75		19.75
175	1218+49	1244+51	Levee	15.70	19.70	15.75			19.75
176	1244+51	1251+59	Floodwall	15.80	19.70		16.00		19.75

Table C-7. Optimized and design elevations for Orange County transects 179 to 197. Elevations are in feet, NAVD88.

ERDC Transect number	Contract Stationing		Feature Type Used For Modeling	PED Optimized Crest Elevation (1% AEP Risk Reduction) (ft, NAVD88)		Levee Embankment - Design Grade (SLC1/SLC2, ft)	Floodwall - Construction Elevation (SLC1/SLC2, ft)	Gates - Construction Elevation (SLC2, ft)	Adaptability Elevation - (SLC2, ft)
	Begin	End		Design Scenario (SLC1)	Adaptability Scenario (SLC2)				
179	1251+59	1272+00	Levee	18.00	23.50	18.00			23.50
184	1272+00	1275+83	Levee	19.00	24.00	19.00			24.00
185	1275+83	1276+13	Floodwall	19.00	24.00		24.00		24.00
	1276+13	1276+78	Pump Station #7 (Floodwall)				24.00		24.00
	1276+78	1277+08	Floodwall				24.00		24.00
184	1277+08	1279+00	Levee	19.00	24.00	19.00			24.00
	1279+00	1340+00	Levee			19.00			24.00
191	1340+00	1355+80	Levee	16.50	22.00	16.50			22.00
192	1355+80	1356+10	Floodwall	16.00	20.10		20.25		20.25
	1356+10	1356+31	Road Closure - Gate					20.25	20.25
	1356+31	1356+65	Floodwall				20.25		20.25
197	1356+65	1410+61	Levee	17.00	22.00	17.00			22.00

Appendix D : Final Project Development Team (PDT) Design and Adaptability

This appendix summarizes the hydraulic response parameters for AEPs that are associated with the Final Design and Adaptability elevations determined by the PDT. Note that the response-based stochastic simulation method was used to determine the elevations and this computation included epistemic uncertainties associated with both the forcing and response. Therefore, using these hydraulic response parameters in a pseudo-deterministic event-based computation will not yield the same results summarized herein.

The combination of forcing and elevation scenarios presented herein are as follows:

1. Design elevation SLC1/SLC1 forcing - Structure response evaluated for structure with design crest elevation computed under SLC1 condition and exposed to with-project SLC1 forcing scenario.
2. Design elevation SLC1/SLC2 forcing - Structure response evaluated for structure with design crest elevation computed under SLC1 condition and exposed to with-project SLC2 forcing scenario.
3. Design elevation SLC2/SLC2 forcing - Structure response evaluated for structure with design crest elevation computed under SLC2 condition and exposed to with-project SLC2 forcing scenario.

The Appendix D file is available under "Files in This Item" located here: <http://dx.doi.org/10.21079/11681/41902>. The file name will indicate that it is an appendix.

Unit Conversion Factors

A sponsor requirement for this study was the use of English Customary units of measurement. Most measurements and calculations were done in International System (SI) units and then converted to English Customary. The following table can be used to convert back to SI units.

Multiply	By	To Obtain
feet	0.3048	meters
cubic feet	0.02831685	cubic meters
pounds (force)	4.448222	Newtons
square feet	0.09290304	square meters

Acronyms and Abbreviations

AEP	Annual exceedance probability
CL	Confidence limits
CSRM	Coastal Storm Risk Management
CTXCS	Coastal Texas Comprehensive Study
HSDRRS	Hurricane Storm Damage Risk Reduction System
JPM	Joint probability model
LMSL	Local mean sea level
MSL	Mean sea level
MWD	Mean wave direction
PBL	Planetary boundary layer
PED	Pre-construction, Engineering, and Design
RSLC	Relative sea level change
S2G	Sabine Pass to Galveston Bay
SLCo	Beginning of Service Life
SLC1	50 yr Service Life
SLC2	100 yr Service Life
SP	Save point
SWG	Galveston District
SWL	Storm water level
TC	Tropical cyclone
USACE	US Army Corps of Engineers
WAM	Wave model

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