Sabine Pass to Galveston Bay, Texas
Coastal Storm Risk Management and Ecosystem Restoration
Final Integrated Feasibility Report and Environmental Impact Study

Appendix C

Economic Analysis

May 2017

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

Page

1 COASTAL STORM RISK MANAGEMENT

1.1 PURPOSE

The purpose of this appendix is to describe the economic methodology, its associated assumptions, and the use of economic and engineering tools used to assess, evaluate, and recommend a plan for the Sabine Pass to Galveston Bay, Texas Coastal Storm Risk Management and Ecosystem Restoration Feasibility Study.

1.2 INITIAL SCREENING OF ALTERNATIVES

Prior to the Alternatives Milestone Meeting, development of an initial array of alternatives from a wide range of measures for three regions covering six counties along the Texas Gulf Coast that would address coastal storm risk management and ecosystem restoration. The initial study was scoped during a planning charrette in August 2012 to comply with SMART Planning guidelines. Following the first Alternatives Milestone Meeting (AMM) in July 2013, a determination was made that a study encompassing the three-region, six-county area could not be done within the constraints of SMART Planning. Options were developed in order to minimize risk as much as possible and while still adhering to the basic tenets of SMART Planning. The Galveston District developed an option for completing a study of low to moderate risk that would cost $4.4 million and would drop the Galveston region concentrating instead on the Brazoria and Sabine regions. The study also dropped any ecosystem restoration measures and would only analyze CSRM alternatives in Brazoria, Jefferson, and Orange Counties.

The initial array of alternatives can be found in Appendix B – Plan Formulation. The final array of alternatives is shown in Table 1-1. This array was agreed to in the Alternatives Milestone Meeting (AMM) that occurred on April 9, 2014. This final array of alternative plans does not include alternatives in Galveston Bay region, nor does it include Ecosystem Restoration (ER) measures. Instead, those potential actions are to be included in future interim feasibility studies, including the ongoing Coastal Texas study. Appendix B further describes the formulation process that produced this final array.

Table 1-1. Sabine Pass to Galveston Bay, TX - Final Array of Alternatives

Alternative Number	Alt Name / Description
No Action	No Action or Future Without Project (FWOP)
S5	Sabine Inland Barrier CSRM Focus (Neches Gate/Sabine Levees/Hurricane Flood Protection)
S11	Sabine Nonstructural Alternative/ Buyouts and Lone Star-type Conservation Plan
B2	Brazoria Coastal Barrier CSRM Focus (revised)

Alternative Number	Alt Name / Description
B5	Brazoria Nonstructural Alternative/ Buyouts and Lone Star-type Conservation Plan

An IPR was conducted on May 30, 2014, to discuss the results in the analysis supporting whether the Neches Gate should be dropped from further consideration. As a result of the decision to drop the Neches Gate and as means of clarifying the nomenclature for the final array, alternatives in the final array were renamed. The Sabine Inland Barrier Alternative has been split into two parts, one addressing the new levee system in Orange and Jefferson Counties, and the other addressing improvements to the existing Port Arthur hurricane flood protection (HFP). The Brazoria Coastal Barrier Coastal Storm Risk Management (CSRM) Focus has been renamed after its primary component – Freeport and Vicinity CSRM. Non-structural plans will be evaluated for both Brazoria and Sabine regions.

- Orange-Jefferson Coastal Storm Risk Management (CSRM)
- Freeport and Vicinity CSRM
- Port Arthur and Vicinity CSRM
- Brazoria and Sabine Non-Structural

1.3 REACH DETERMINATION

The determination of reaches for the initial array of alternatives was based on the original designation of the three regions with measures and the subsequent alternatives being assigned to the appropriate region. Following the approval of the exemption from SMART Planning and the successful concurrence of the final array of alternatives following the April 2014 AMM, reaches were developed for the areas according to the final array of alternatives. This was required since a different methodology would be employed for the optimization of any new proposed levees/floodwalls and for improvements to any of the existing hurricane flood protection systems (HFP). While the initial screening of alternatives used HEC-FIA with 1 % annual chance exceedance (ACE) depth grids in conjunction with HAZUS-MH data to determine without and with-project economic damages, the analysis for evaluating the final array would incorporate a risk-based analysis in compliance with ER-1105-2-101. The following describes the reaches that were established for evaluating the final array.

1.3.1 Orange-Jefferson CSRM

The initial configuration of new levees was based on alignments from the Orange County Flood Protection Planning Study (Orange Report), completed in 2012. Refinement of the alignments was made in some areas to increase potential benefits, reduce costs, and reduce potential

environmental impacts, and to protect critical infrastructure. Without-project storm surge values were used to optimize levee heights and further refinement of the alignment for identification of the National Economic Development (NED) Plan and TSP. As part of the identification of the NED and TSP, analysis was conducted to determine levee sections that are incrementally justified. Alternatives analysis was based on utilizing the without-project surge elevations and frequencies. Without-project storm surge and waves were based on previous work by FEMA and revised to current joint probability method – optimum sampling (JPM-OS) methods to the appropriate ACE values. Figure 1-1 displays the initial configuration to be evaluated for these new levees at Jefferson and Orange Counties following the exclusion of the Neches Gate from further consideration. The system was set up with three major components based on their location. The following lists the major features.

- Orange 1 – 3
- Jefferson Main
- Beaumont A – C

The Orange component runs along the north side of the Neches River and was divided into three sections; Orange 1 on the western end that primarily protects Rose City, Orange 2 which begins just east of Rose City and ends roughly halfway between Rose City and Bridge City, and Orange 3 which encompasses the remainder of the Orange County component. Orange 1 consists of approximately 27,000 linear feet (LF) of levee and 16,500 LF of floodwall (total of 8.2 miles). Orange 2 consists of approximately 34,600 LF of levee (6.6 miles), while Orange 3 consists of a combination of 113,600 LF of levee and 29,800 LF of floodwall (total of 27 miles).

The Jefferson Main component consists of approximately 41,700 LF of levee and 16,200 LF of floodwall (11 miles). Beaumont A is combination of 3,100 LF of levee and 200 LF of floodwall (0.6 mile). Beaumont B is 2,500 LF of levee (0.5 mile) and Beaumont C is 6,800 LF of levee (1.3 mile).

1.3.2 Port Arthur and Vicinity CSRM

The draft findings of the Semi-Quantitative Risk Assessment (SQRA) for the Freeport system (to be discussed next) were applied to the plan formulation for the Port Arthur because one has not yet been done for this system. For the Port Arthur system, the detailed description of the needs is similar to what will be presented in the Freeport HFPS section. However, the Port Arthur system is different because there are no known deferred maintenance issues for the Port Arthur system at this time.

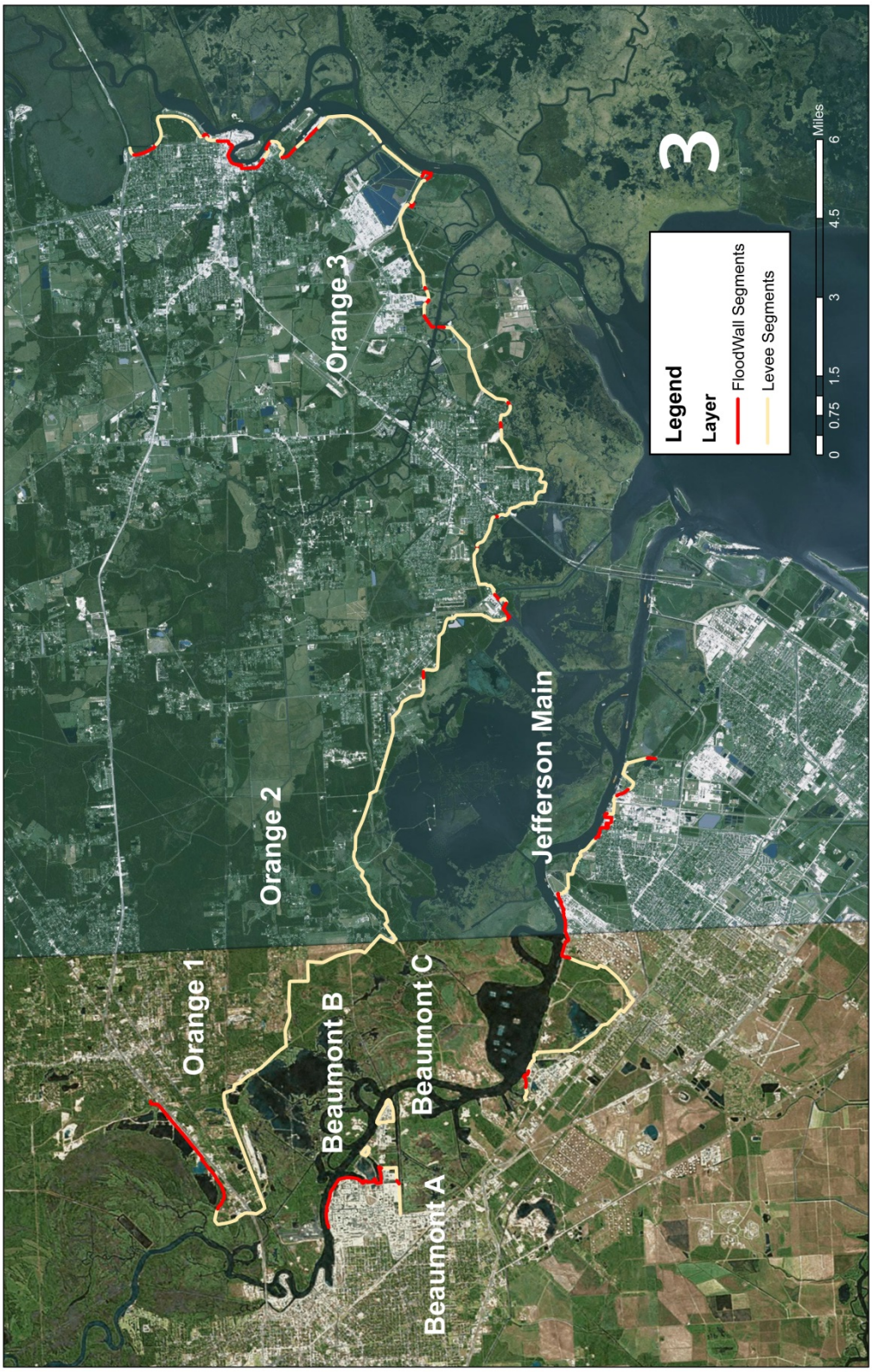


Figure 1-1. Configuration of the Orange-Jefferson CSRM

The formulation of alternatives for the Port Arthur and Vicinity CSRM began with defining reaches for the system. These were based on the failure locations identified by the levee safety program in the absence of a SQRA. Figure 1-2 displays the Port Arthur HFPS failure locations. These locations were included in formulation where improvements would positively impact the system's capacity for protection. The following lists the reaches at Port Arthur.

- Port Arthur 8feet-10feet I-Wall
- Port Arthur Closure Structure
- Port Arthur I-Wall Near Valero
- Port Arthur I-Wall Near Tank Farm

1.3.3 Freeport and Vicinity CSRM

The draft findings of the SQRA for the Freeport system show vulnerabilities primarily associated with floodwall and levee overtopping. Other performance issues identified during the SQRA were the result of deferred local sponsor maintenance, or alterations that local industrial stakeholders have constructed over time. Floodwall performance issues, at locations where the originally constructed floodwall is still in place and has been operated and maintained in an acceptable manner, are being evaluated to include stability and resiliency. Levee reaches that are non-uniform in height or otherwise susceptible to concentrated overtopping erosion during an event are being evaluated for raising or armoring to reduce the likelihood of breach.

The formulation of alternatives for the Freeport and Vicinity CSRM began with defining reaches for the system. These were based on the failure locations identified in the SQRA (Figure 1-3). These locations were then narrowed during formulation to those locations where improvements would positively impact the system's capacity for protection and to reduce any redundancies. For example, improvements to the Dow Barge Canal would negate any failures at the Dow Turning Basin. The following is the resulting list of reaches at the Freeport and Vicinity CSRM.

- Dow Barge Canal
- East Storm Levee
- Freeport Dock
- Old River at Dow Thumb
- Oyster Creek Levee
- South Storm Levee
- Tide Gate I-Wall

Figure 1-2. Port Arthur and Vicinity CSRM

Figure 1-3. Freeport and Vicinity CSRM

2 HEC-FDA ANALYSIS

Note: Sections 2.1 to 2.8 describes the HEC-FDA ANALYSIS used for alternative development, formulation, and evaluation processes that led to the identification of the TSP. The information contained herein was presented in the Sept 11, 2015 DIFR-EIS that was released for public review. Changes to the TSP have occurred since that public review which are briefly described explained in Section 2.9. The changes to the TSP resulted in the Recommended Plan presented in this final section.

2.1 ENGINEERING INPUTS

2.1.1 Stage-Probability Relationships

Water surface profiles representing stage-probability functions were imported into HEC-FDA utilizing data from Advanced Circulation model (ADCIRC) points for without-project storm surge and waves. This sub-set of 62 total storms (based on previous FEMA work and revised by ERDC using subject matter expertise for storms having the most effect on stage-frequency) was used in the revised to current JPM-OS simulation technique for the appropriate ACE values analysis. Mean water level, wave height and wave period responses were defined for each of the modeled return periods. In the absence of a Hydrologic Engineering Centers River Analysis System (HEC-RAS) stationing scheme which would also use a stage-discharge function, those ADCIRC points falling closest to the location of the levee/floodwall footprint were used to develop average ACE values for the seven events modeled by ERDC. For the existing Port Arthur and Freeport HFP systems, ADCIRC points representing average still water levels closest to the failure locations were used to quantify damages. An equivalent record length (15 years) for each study reach was used to generate a stage-probability relationship with uncertainty for the without-project and the with-project alternatives through the use of graphical analysis based on the appropriate gage data. A sensitivity analysis on the 0.1 percent modeled points found a consistent one standard deviation difference of 2.1 feet for the Freeport Region and 2.0 feet difference for the Sabine region. Stage/probability functions entered into HEC-FDA using the fifteen year period of record found the average difference for one standard deviation to be 1.64 for Jefferson, 1.8 feet for Orange, and 2.17 feet for Port Arthur. The average difference for Freeport was 3.18 feet. Increasing the period of record resulted in actual increases in the difference between the stated stage and the subsequent one standard deviation. Based on the fact that the storms ERDC used for modeling all occurred within the historical period of the last fifteen years and considering the results from analyzing the variation between data modeled by ERDC and what was entered into HEC-FDA, the fifteen year period of record is appropriate. The model used the eight stage-probability events together with the equivalent record length to define the full range of the stage-probability or stage-probability functions by interpolating between the data points. Values for the 0.999 and 0.5 percent ACE were

set at 0.25 and 1.0 feet respectively in order to make HEC-FDA operational. Table 2-1 lists these values used for each region. The ADCIRC points for the Orange-Jefferson CSRM are shown in Figure 2-1. Points for the Port Arthur CSRM are shown in Figure 2-2 and the ADCIRC points for the Freeport CSRM are in Figure 2-3.

Still water levels were used to compare the economic efficiency of the alternatives. Once the recommended plan is determined, wave run-up and overtopping will be analyzed at specific system locations in conjunction with any necessary interior drainage analysis. The horizontal and vertical datums used in the engineering inputs are referenced to North American Datum (NAD) of 1983.

Table 2-1. Average Still Water Elevations at HEC-FDA Index Point

Orange-Jefferson

Exceedance Probability/Reach	*0.1 ACE*	*0.05 ACE*	*0.02 ACE*	*0.01 ACE*	*0.005 ACE*	*0.002 ACE*	*0.001 ACE*
Orange 1	3.62	5.05	6.69	7.76	8.66	9.66	10.35
Orange 2	3.6	5.36	7.24	8.52	9.6	10.77	11.57
Orange 3	2.78	4.25	6.11	7.51	8.64	9.81	10.57
Beaumont A	2.92	4.26	6	7.25	8.47	9.73	10.51
Beaumont B	2.71	3.88	5.62	6.86	7.94	9.07	10.34
Beaumont C	3.55	5.1	6.85	8.02	9	10.1	10.85
Jefferson Main	3.08	4.63	6.31	7.49	8.47	9.51	10.22

Port Arthur

Exceedance Probability/Reach	*0.1 ACE*	*0.05 ACE*	*0.02 ACE*	*0.01 ACE*	*0.005 ACE*	*0.002 ACE*	*0.001 ACE*
8ft-10ft I-Wall	2.85	4.31	6.98	9.25	10.94	12.68	13.81
Closure Structure	3.45	5.01	6.9	8.2	9.3	10.46	11.2
I-Wall Near Valero	3.87	5.97	8.47	10.47	12.61	14.77	16.08
I-Wall Near Tank Farm	3.77	5.72	8.1	9.99	12.02	14.08	15.31

Freeport Region

Exceedance Probability/Reach	*0.1 ACE*	*0.05 ACE*	*0.02 ACE*	*0.01 ACE*	*0.005 ACE*	*0.002 ACE*	*0.001 ACE*
South Storm Levee	4.21	6.68	9.59	11.63	13.71	16.31	17.93
Old River levee at Dow Thumb	4.43	7.08	10.15	12.41	14.69	17.43	18.97
Freeport Dock	4.47	7.17	10.3	12.63	14.97	17.79	19.38
Tide Gate	4.46	7.18	10.32	12.65	15.02	17.9	19.52
East Storm Levee	5.08	7.81	11.05	13.38	15.55	17.99	19.5
Dow Barge Canal	4.6	7.46	10.82	13.28	15.76	18.55	20.12
Oyster Creek	4.44	8.49	12.21	14.63	16.62	18.77	20.19

2.1.2 Fragility Curves

Fragility curves (the relationship between water surface stage on the exterior side of the levee versus the probability of levee failure) were developed based on the use of average still water levels for damage estimates. Fragility curves for the Freeport HFP system were initially developed as a result of the Freeport SQRA and were modified slightly due to the use of average still water levels for damage estimates. A similar approach was used for the development of the curves for the Port Arthur system. These curves for the Port Arthur and Freeport systems are listed in Tables 2-2 and 2-3, respectively. These fragility curves assume that all O&M is current and will be accomplished before implementing the Recommended Plan..

Figure 2-1. ADCIRC Points Orange-Jefferson CSRM

Figure 2-2. ADCIRC Points in Port Arthur and Vicinity CSRM

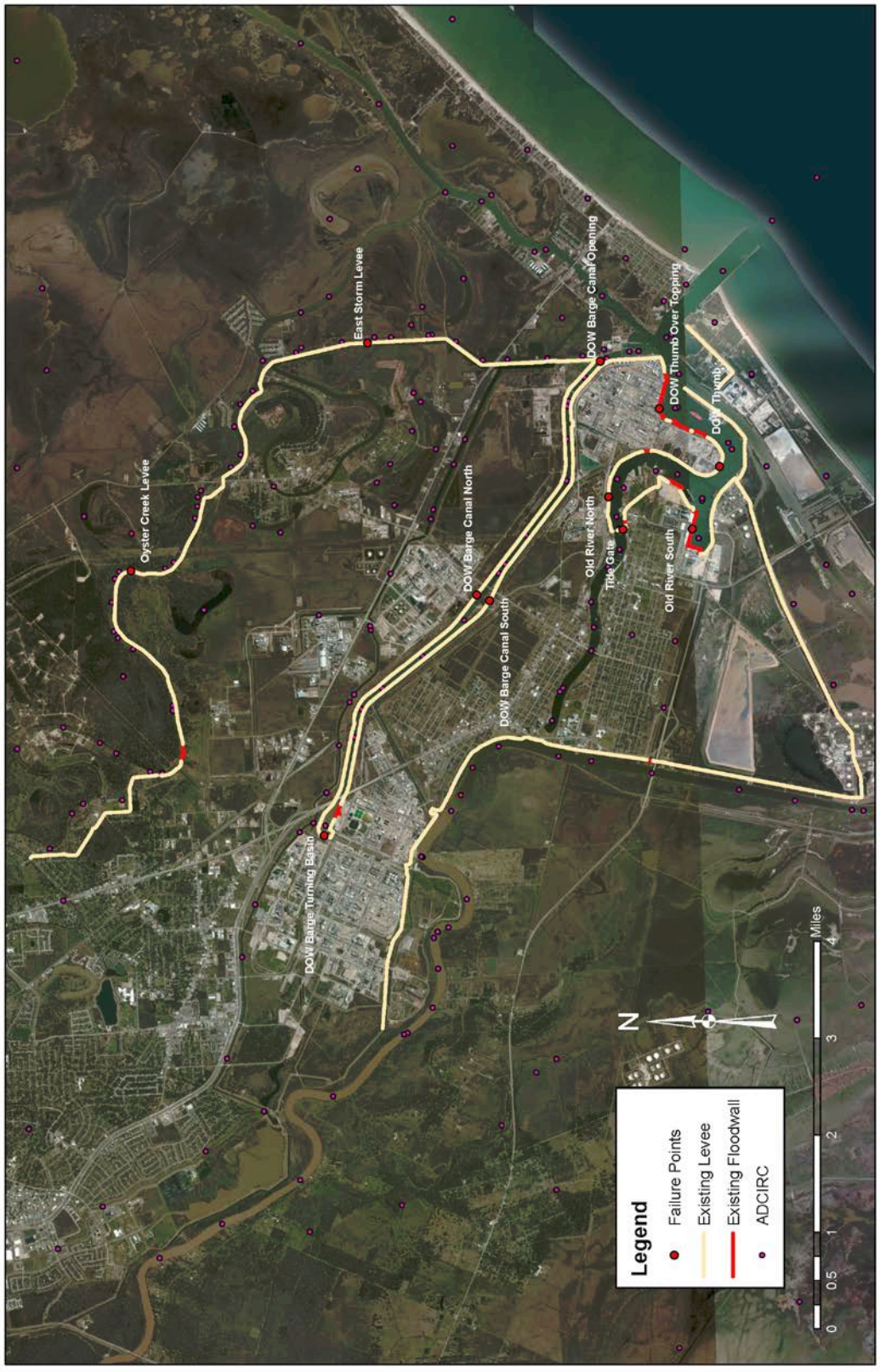


Figure 2-3. ADCIRC Points in Freeport and Vicinity CSRM

Table 2-2. Fragility Curves for Port Arthur and Vicinity CSRM

Stage	Tank Farm	8ft-10ft I-Wall	I-Wall Near Valero	Closure Structure
14	-	0.10	-	-
14.5	-	0.28	0.10	0.20
15	0.20	0.45	0.50	0.40
15.5	0.35	0.63	0.70	0.60
16	0.50	0.80	0.90	0.90
16.5	0.90	0.90	0.92	0.95
17	1.00	1.00	0.93	1.00
17.5	-	-	0.95	-
18	-	-	0.97	-
18.5	-	-	0.98	-
19	-	-	1.00	-

Table 2-3. Fragility Curves for Freeport and Vicinity CSRM

Stage	Dow Barge Canal	East Storm	Oyster Creek Levee	Freeport Dock	Tide Gate I-Wall	Old River at Dow Thumb
10.5	-	-	0.03	-	0.04	0.04
11	-	-	0.06	-	0.08	0.08
11.5	-	-	0.1	-	0.11	0.11
12	-	-	0.13	-	0.15	0.15
12.5	-	-	0.16	0.05	0.19	0.19
13	-	-	0.19	0.75	0.23	0.23
13.5	-	-	0.23	1.00	0.26	0.26
14	-	-	0.26	1.00	0.3	0.3
14.5	-	0.08	0.29	1.00	0.34	0.34
15	-	0.15	0.32	1.00	0.38	0.38
15.5	-	0.23	0.35	-	0.41	0.41
16	-	0.3	0.39	-	0.45	0.45
16.5	-	0.38	0.42	-	0.6	0.68
17	-	0.45	0.45	-	0.75	1.00
17.5	-	0.54	0.68	-	1.00	-
18	-	0.63	1.00	-	-	-
18.5	-	0.72	-	-	-	-
19	-	0.81	-	-	-	-
19.5	-	1.00	-	-	-	-
20	-	-	-	-	-	-
20.5	0.11	-	-	-	-	-
21	0.23	-	-	-	-	-
21.5	0.34	-	-	-	-	-
22	0.45	-	-	-	-	-
22.5	0.53	-	-	-	-	-
23	0.6	-	-	-	-	-

Table 2-3, continued

23.5	0.68	-	-	-	-	-
24	0.75	-	-	-	-	-
24.5	0.83	-	-	-	-	-
25	1.00	-	-	-	-	-

2.2 ECONOMIC INPUTS

2.2.1 Ground Elevations

Centroids were created for each parcel to represent the structures associated with that parcel. Ground elevations were derived from data processed using U.S. Geological Survey Digital Elevation Model (DEM) 0.05m elevation data for the appropriate Gulf Coast Counties. These data were obtained from Texas Natural Resources Information System (TNRIS). Residential structures in inland areas generally received a 0.5-foot floor correction (some areas were raised 1 to 1.5 feet) while many of the coastal areas received much higher raises as appropriate. Industrial, commercial, and public structures received floor corrections from 0 to 5 feet. The point at which damages for many high-value industrial and commercial structures is reflected in the ground elevation making floor correction was necessary. These floor corrections assumptions were verified through spot checks utilizing Google Earth and Google Street View. The horizontal and vertical datums used in the economic inputs are referenced to North American Datum (NAD) of 1983 or North American Vertical Datum (NAVD) of 1988.

2.2.2 Structure Inventory

All three study areas can be described as being relatively fully developed. As discussed under the study area demographics, Brazoria is expected to be the one county among the three that is expected to grow at a rate outpacing the State. Orange and Jefferson Counties are expected to grow at rates well below that of the State of Texas. For the purpose of this analysis, housing stock is assumed to remain relatively constant over the period of analysis. Since commercial and industrial make up a substantial amount of the structure inventory, those developments that are expected to come online with a reasonable amount of certainty and in the relatively near future are include in the inventory. The structure inventory was derived from data obtained from each of the appropriate appraisal districts for the 2015 tax appraisal year (Table 2-4). These data were adjusted to reflect a replacement cost less depreciation value. Due to tax abatements and incentives given to large industrial developers and due to the competitive nature of the petrochemical industry in the region, many high-value industrial and commercial properties are not listed on the tax appraisal rolls. In these instances, square footage values were developed from those properties that were listed on the tax rolls based on square footage values of similar structures from appraisal data. Therefore, a certain amount of uncertainty exists for these values in many cases, which could lead to an over- or underestimation of damages. Values to reflect replacement minus depreciation were

calculated using Marshall and Swift Commercial and Residential Estimator based on information contained within the appraisal district data including structure type, age, square footage, building materials, and condition on a random selection of both residential and non-residential structures on the following the TSP milestone. Samples were taken for each of the residential and non-residential damage categories based on the depth/damage function applied to the specific structures. These adjustments were then averaged and applied to the appropriate damage category. Residential structures were adjusted by 24.4 percent and non-residential structures were adjusted by 14.6 percent. Two separate structure files with a high degree of overlap were created for the system since failures would impact slightly different numbers of structures. One structure file was used for a failure at the Dow Barge Canal and another for the remaining reaches. The following tables and figures depict the structure files used in the damage analyses. Parcels representing the structures at risk for the Orange-Jefferson CSRM are in Figure 2-4, while the parcels representing the structures at risk for the Port Arthur and Freeport CSRM are in Figures 2-5, 2-6, and 2-7 respectively.

Table 2-4. Structure and Content Values of Inventoried Structures by CSRM and Type 2015 Price and Development Levels

Orange-Jefferson CSRM

Orange County				
Category Name	**Count**	**Structure Value**	**Content Value**	**Total**
Commercial	268	$109,778,000	$109,203,000	$218,981,000
Industrial	20	$1,711,063,000	$1,711,061,000	$3,422,124,000
Multi-Family	193	$23,828,000	$23,828,000	$47,656,000
Mobile	699	$10,573,000	$10,573,000	$21,146,000
Public	214	$76,324,000	$83,913,000	$160,237,000
Vehicles	16,045	$200,448,000	$0	$200,448,000
Single-Family	12,734	$1,038,476,000	$1,038,443,000	$2,076,919,000
Grand Total	30,173	$3,170,490,000	$2,977,021,000	$6,147,511,000
Jefferson County				
Category Name	**Count**	**Structure Value**	**Content Value**	**Total**
Commercial	893	$319,062,000	$431,769,000	$750,831,000
Industrial	22	$662,341,000	$827,820,000	$1,490,161,000
Multi-Family	226	$186,264,000	$186,264,000	$372,528,000
Public	140	$124,284,000	$136,882,000	$261,166,000
Vehicles	15,954	$167,781,000	$0	$167,781,000
Single-Family	12,662	$2,539,056,000	$2,538,915,000	$5,077,971,000
Grand Total	29,897	$3,998,788,000	$4,121,650,000	$8,120,438,000

Port Arthur and Vicinity CSRM

Category Name	Count	Structure Value	Content Value	Total

Commercial	1,152	$5,190,935,000	$8,777,567,000	$13,968,502,000
Industrial	9	$201,486,000	$338,497,000	$539,983,000
Multi-Family	269	$69,382,000	$69,382,000	$138,764,000
Public	452	$217,266,000	$228,574,000	$445,840,000
Vehicles	26,431	$350,231,000	$0	$350,231,000
Single-Family	20,977	$1,911,200,000	$1,911,068,000	$3,822,268,000
Grand Total	43,968	$7,869,963,000	$11,325,088,000	19,265,588,000

Freeport and Vicinity CSRM

Dow Barge Canal				
Category Name	**Count**	**Structure Value**	**Content Value**	**Total**
Commercial	903	$117,426,000	$156,275,000	$273,701,000
Industrial	45	$5,557,849,000	$9,339,639,000	$14,897,488,000
Multi-Family	375	$68,916,000	$69,123,000	$138,039,000
Mobile	6	$135,000	$135,000	$270,000
Public	207	$225,032,000	$248,092,000	$473,124,000
Vehicles	8,832	$185,858,000	$0	$185,858,000
Single-Family	8,826	$377,405,000	$377,572,000	$754,977,000
Grand Total	19,194	$6,532,621,000	$10,190,836,000	$16,723,457,000

Lower Reaches				
Category Name	**Count**	**Structure Value**	**Content Value**	**Total**
Commercial	244	$39,019,000	$30,565,000	$69,584,000
Industrial	5	$13,383,000	$22,406,000	$35,789,000
Multi-Family	117	$13,168,000	$13,168,000	$26,336,000
Public	76	$28,620,000	$29,784,000	$58,404,000
Vehicles	2,323	$38,847,000	$0	$38,847,000
Single-Family	1,844	$74,744,000	$74,744,000	$149,488,000
Grand Total	4,609	$207,781,000	$170,667,000	$378,448,000

2.2.3 Vehicle Inventory

The number of vehicles associated with a residence was estimated based on the average number of vehicles per residence characteristic of the study area, and the probability of their being present at the time of a flood. This value is 1.26 vehicles per residence. Values were based on the national average price of new and used vehicles as reported by the U.S. Bureau of Transportation Statistics (BTS) prices for new vehicles. The most recent price reported by BTS is $13,105. Adjusting this value based on the percent difference in median income for each county compared to the median income for the U.S., the resulting value for Orange County vehicles was set at $15,411 and $13,251 for Jefferson County. Vehicle values for Brazoria were set at $21,044.

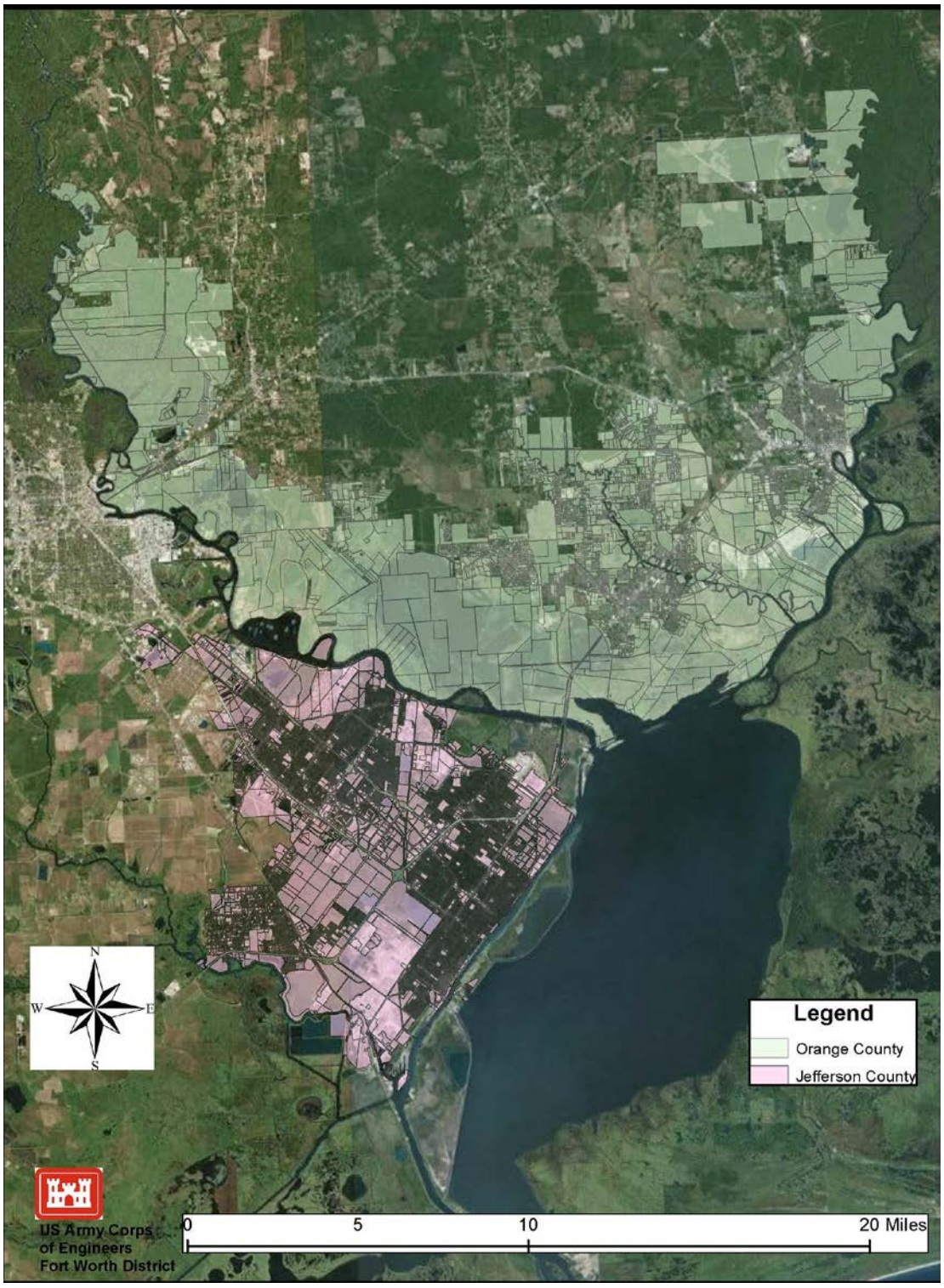


Figure 2-4. Orange-Jefferson CSRM Structures at Risk (Parcels)

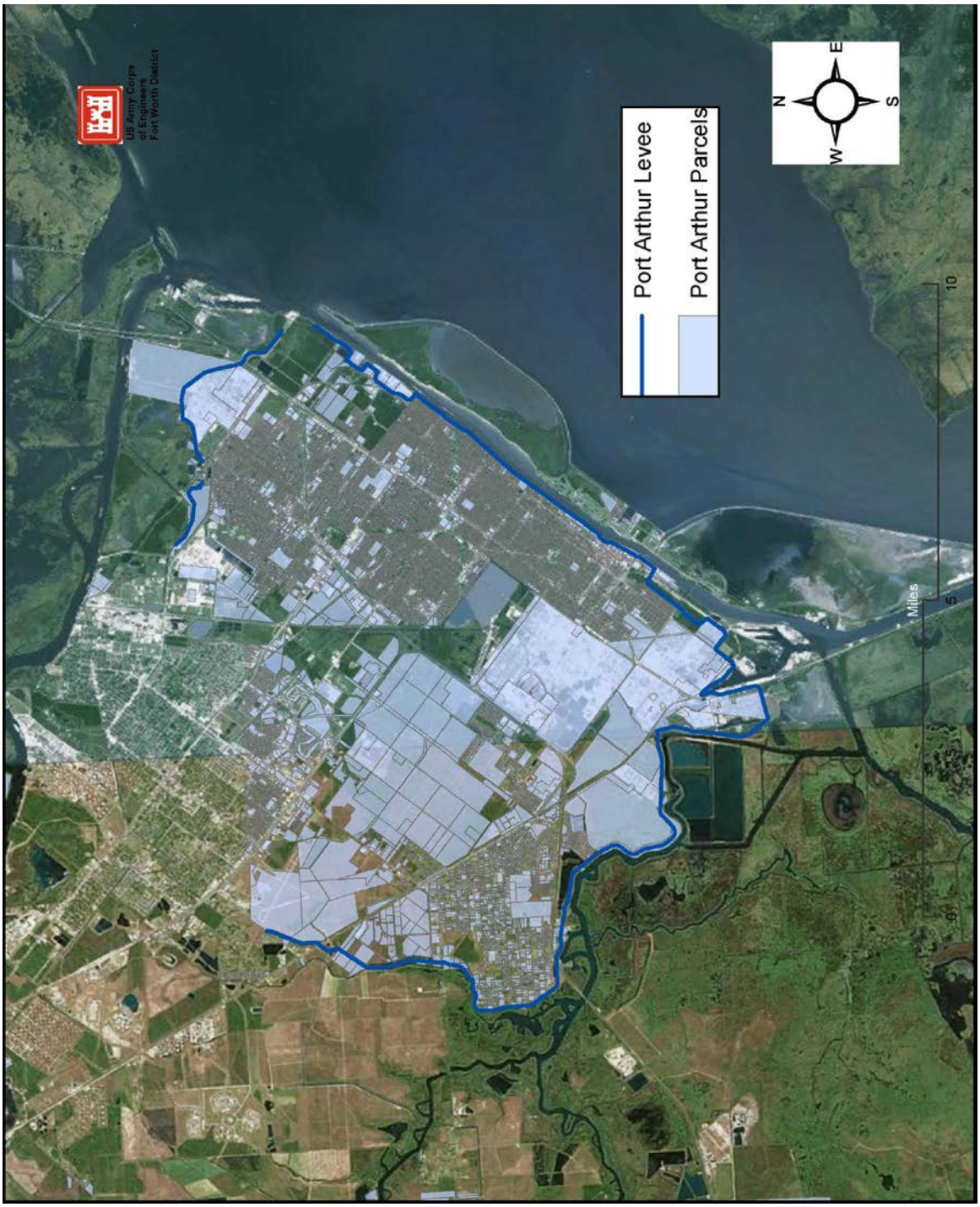


Figure 2-5. Port Arthur and Vicinity CSRM Structures at Risk

Figure 2-6. Freeport and Vicinity CSRM Structures at Risk – Dow Barge Canal Reach

Figure 2-7. Freeport and Vicinity CSRM Structures at Risk – Remaining Reaches

2.2.4 Depth-Damage Functions

Depth-damage functions were obtained from the New Orleans District from the *Lower Atchafalaya and Morganza to the Gulf, Louisiana, Feasibility Study*. These functions reflect saltwater inundation for short durations. The following table lists the functions covering the following structure types and also the content-to-structure value ratio (CSVR) along with the uncertainties associated with the structure content values and the first-floor corrections. Uncertainties assumed a normal distribution (with the exception of vehicles which assumes a triangular distribution) and were based on coefficient of variation calculations for each of the sources of uncertainty and were also based on historic knowledge gleaned from based studies in the region.

These functions were used primarily since they addressed the incidence of inundation from saltwater for short durations and because these damage functions, while not derived from locally oriented data, were more reflective current building guidelines and potential damage estimation. Graphical representations for these for these functions are depicted at the end of this appendix.

Table 2-5. Depth-Damage CSVR, and Uncertainties.

Name	Description	CSVR (%)	Struc. Unc. (%)	Cont. Unc. (%)	FF Unc. (ft.)
1STY-SLAB	One-Story Single -Family Residential Slab Foundation	71	7.5	24	0.70
2STY-PIER	Two-Story single -Family Residential Pier and Beam Foundation	50	7.5	30	0.70
AUTO	Automobiles	0	15.4-21	0	0.55
EAT	Restaurants	428	17.97	36	0.66
GROC	Grocery Stores	128	6.6	98	0.70
MOBHOM	Mobile Homes	148	7.5	69	0.79
MULT	Multi-Family Residential	23	6.6	29.38	0.53
PROF	Professional Businesses	78	8.67	193.4	0.57
PUBL	Public & Semi Public Structures	82	6.5	71.4	0.70
REPA	Repairs & Home Use	251	5.98	62.2	0.71
RETA	Retail & Personal Services	148	13.37	39.7	0.62
WARE	Warehouse & Contractor Services	372	8.72	194.6	0.57
RESEMERG	Residential Emergency Cleanup Costs	-	13	-	0.70
COMEMERG	Commercial Emergency Cleanup Costs	-	20	-	0.65
HWY	Damage to Highways	-	-	-	0.55
RAILROAD	Damage to Railroads	-	-	-	0.80
STREETS	Damage to Streets	-	-	-	0.75

2.3 FUTURE WITHOUT-PROJECT STRUCTURE AND CONTENT DAMAGES

2.3.1 Methodology Overview

The methodology employed for this economic analysis is in accordance with current principles and guidelines and standard economic practices, as outlined in the Planning Guidance Notebook – ER 1105-2-100. Economic analysis is conducted at a given price level using the current Federal discount rate and a period of analysis of 50 years. Per the Planning Guidance Notebook, flood events will be expressed in probabilistic terms rather than the classic "x-Year" event. For example, the 100-Year event will be called a 1 percent ACE (equivalent to the HEC-FDA term Annual Exceedance Probability Event). Other equivalent probabilities can be obtained by dividing 1 by the year occurrence interval; the 500-year event is 1/500 = 0.2 percent ACE, and so forth.

A risk-based analysis (RBA) procedure has been used to evaluate without-project flood damages in the study area. Guidance for conducting RBA is included in Corps Engineering Regulation 1105-2-101, Risk-Based Analysis for Evaluation of Hydrology/Hydraulics, Geotechnical Stability and Economics in Flood Damage Reduction Studies (January 3, 2006).

The guidance specifies that the derivation of expected annual flood damage must take into account the uncertainty in hydrologic, hydraulic, and economic factors. Risk and uncertainty are intrinsic in water resource planning and design. They arise from measurement errors and the inherent variability of complex physical, social and economic situations. Best estimates of key variables, factors, parameters and data components are developed, but are often based on short periods of record, small sample sizes, measurements subject to error, and innate residual variability in estimating methods. RBA explicitly and analytically incorporates these uncertainties by defining key variables in terms of probability distributions, rather than single-point estimates. The focus of RBA is to concentrate on the uncertainties of variables having the largest impact on study conclusions.

The following are the primary sources of uncertainty for coastal storm damage analysis studies along with a discussion of the uncertainties associated with each of these sources.

- Stage/Probability – Uncertainty in the stage/probability curves are addressed by utilizing graphical exceedance probability functions which sets confidence limits for discharges at each discrete exceedance probability based on the equivalent record length. Uncertainties is also addressed by assigning distributions to stage-damage functions. In the case of this

study, the equivalent record length is set at 15 years and the error for the stage-damage functions is set at 0.5 feet.

- Geo-technical Features – Fragility curves were developed for the two existing HFPSs from either completed or draft SQRAs conducted by a risk cadre in accordance to ER 110-2-1156 for various identified breach locations on each of the two systems. These curves were developed as part of the reevaluation of the initial SPRAs at each system. These curves were developed to a much higher definition than is typically done for flood-risk analysis in HEC-FDA. No uncertainties were assigned to the fragility curves themselves since HEC-FDA has no way of entering any uncertainty parameters.
- Structure Elevation – Stated earlier, USGS DEM 0.05m elevation data was obtained from TNRIS and used for ground elevations with the observed foundation elevations added to ground elevation for the first-floor elevations. Uncertainties based on calculated coefficients of variation produced first-floor errors ranging from 0.493 to 0.788 feet depending on structure type.
- Structure and Content Values – Uncertainties for structure and content values are based on calculated standard deviations by structure type. These standard deviations are expressed in terms of percentages and range anywhere from 6.5 to almost eighteen percent for structure values and range from 30 to almost 195 percent for content-to-structure ratios.
- Inundation Depth/Percent Damage – Depth/Damage functions were obtained from the New Orleans District and are based on a triangular probability density functions using minimum, maximum, and most likely estimates for the damage percentage at various stages based on the input from a panel of experts. These estimates were generated for the District's *Lower Atchafalaya and Morganza to the Gulf, Louisiana, Feasibility Study*. These curves are displayed in the back of this appendix.

The Army Corps of Engineers Hydrologic Engineering Center has developed software specifically designed for conducting risk based analysis, referred to as the HEC-FDA Program. Version 1.2.5 was used for this analysis with the exception of the final recommended plan which was run in Version 1.4. This program applies Monte Carlo simulation process, whereby the expected value of damages is determined explicitly through a numerical integration technique accounting for uncertainty in the basic parameters described above. For this analysis, the number of Monte Carlo simulations is set at 100 with the minimum and maximum number of intervals set at 20 and 30 respectively. Data requirements for the program include:

- Structure data, including structure I.D., category (single or multi-family residential, commercial, industrial, and public), stream location, ground and/or first floor elevation, structure value and content value. These data were developed in a Microsoft Excel spreadsheet and imported into the HEC-FDA program

- Hydrologic and hydraulic data, including water surface profiles and stage/probability relationships
- Depth-Damage functions

2.3.2 Future Without-Project Condition Expected Annual Damages

Estimates of Expected Annual Damages (EAD) under future without-project conditions were calculated, using the risk and uncertainty model, through integration of frequency-damage data. The future expected annual damages shown here are projected over the project life of 50 years. Table 2-6 shows a breakdown of where these damages are predicted to occur for each CSRM. Tables 2-7, 2-8, and 2-9 break down the number of structures by event in each reach of the three project areas along with the corresponding still water level for that event.

For the Orange 1, Orange 2, and Orange 3 alternative reaches, significant damages start at approximately the 1 percent ACE; the depth of flooding at the 1 percent ACE is approximately 8 feet. In the Jefferson Main alternative reach, significant damages start between the 2 percent and 1 percent ACE; the depth of flooding between the 2 percent and 1 percent ACE is approximately 6.5 feet and 7.5 feet. For the Beaumont A, Beaumont B and Beaumont C the significant damages start at the 1 percent ACE; the depth of flooding is approximately 7.5 feet.

The estimated start of damages for the Port Arthur and Vicinity alternative reaches is approximately 15 feet, which corresponds to an estimated high probability of failure of the existing HFPS based on the fragility curves. Flooding depths approximate the stage on the exterior side of the existing HFPS, and goes up to approximately 14 feet for the 0.1 percent ACE.

The estimated start of damages for the Freeport and Vicinity alternative reaches is approximately 15 feet, which corresponds to an estimated high probability of failure of the existing HFPS based on the fragility curves. Flooding depths approximate the stage on the exterior side of the existing HFPS, and goes up to approximately 19 feet for the 0.1 percent ACE.

2.4 ALTERNATIVE ANALYSIS

2.4.1 Orange-Jefferson CSRM

As agreed at the Alternative Milestone Meeting (AMM), future without-project (FWOP) damages were run with a rough order of magnitude costs to identify NED benefits. Costs representing a linear foot in both length and height for both levees and floodwalls were developed. The costs per linear foot of levee were estimated at $237.50 and floodwalls were estimated at $475.00. These costs included contingency, engineering and design, and constriction management. Real estate

costs were also included with commercial and residential estimates of $100,000 per acre, industrial at $70,000 per acre, undeveloped land at $9,000 per acre, and marsh at $750. Operation, Maintenance, Repair, Replacement and Rehabilitation

Table 2-6. Equivalent Annual Damages Future Without-Project Condition (2015 price level)
(FY 2015 Price Level/3.375 percent interest rate)

	Damage Categories							
Reach	**Commercial**	**Industrial**	**Multifamily**	**Mobile**	**Public**	**POV**	**SFR**	**Total**
Orange Jefferson CSRM								
Orange 1	$73,000	$0	$0	$7,000	$10,000	$33,000	$190,000	$312,000
Orange 2	$0	$0	$0	$4,000	$0	$10,000	$54,000	$68,000
Orange 3	$21,833,000*	$0	$93,000	$98,000	$409,000	$969,000	$6,585,000	$29,987,000
Beaumont A	$0	$6,937,000	$0	$0	$0	$0	$0	$6,937,000
Beaumont B	$0	$23,000	$0	$0	$0	$0	$0	$23,000
Beaumont C	$0	$262,000	$0	$0	$0	$0	$0	$262,000
Jefferson Main	$4,600,000	$929,000	$4,834,000	$0	$1,824,000	$536,000	$15,509,000	$28,231,000
Port Arthur CSRM								
8ft-10ft I-Wall	$19,302,000	$560,000	$83,000	$0	$368,000	$275,000	$2,824,000	$23,413,000
Closure Structure	$3,128,000	$86,000	$13,000	$0	$59,000	$44,000	$453,000	$3,784,000
I-Wall Near Valero	$50,798,000	$1,587,000	$228,000	$0	$975,000	$726,000	$7,553,000	$61,867,000
I-Wall Near Tank Farm	$31,139,000	$1,012,000	$143,000	$0	$599,000	$446,000	$4,670,000	$38,009,000
Freeport CSRM								
Dow Barge Canal	$3,070,000	$145,903,000	$884,000	$2,000	$4,815,000	$3,088,000	$8,897,000	$166,660,000
East Storm Levee	$346,000	$247,000	$99,000	$0	$233,000	$191,000	$587,000	$1,701,000
Freeport Dock	$768,000	$583,000	$217,000	$0	$549,000	$456,000	$1,387,000	$3,960,000
Old River at Dow Thumb	$489,000	$367,000	$139,000	$0	$349,000	$290,000	$882,000	$2,517,000
South Storm Levee	$52,000	$37,000	$15,000	$0	$35,000	$28,000	$87,000	$254,000
Tide Gate I-Wall	$541,000	$406,000	$154,000	$0	$387,000	$321,000	$977,000	$2,785,000
Oyster Creek	$744,000	$553,000	$211,000	$0	$526,000	$436,000	$1,329,000	$3,800,000

*Most of these commercial values are actually associated with industrial facilities. These were corrected in later analyses

Table 2-7. Structures and Damages by Event for Orange-Jefferson CSRM
(FY 2015 Price Level, $1,000)

Orange 1														
Event (ACE)	**0.1**		**0.05**		**0.02**		**0.01**		**0.005**		**0.002**		**0.001**	
Elevation (MSL)	3.62		5.05		6.69		7.76		8.66		9.66		10.35	
Damage Category	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.
Commercial	0	$0	1	$469	1	$939	1	$1,150	1	$1,229	1	$1,288	7	$1,733
Industrial	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0
MultiFamily	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0
Mobile	2	$24	2	$35	7	$49	7	$69	8	$74	8	$93	19	$326
Public	0	$0	0	$0	2	$49	2	$285	2	$317	2	$410	4	$765
Vehicles	0	$0	11	$139	13	$185	72	$543	81	$1,134	87	$1,251	202	$1,322
Single-Family	2	$262	14	$675	23	$1,473	82	$3,581	92	$4,818	98	$5,899	232	$9,989
Grand Total	4	$286	28	$1,318	46	$2,695	164	$5,629	184	$7,572	196	$8,942	464	$14,136

Orange 2														
Event (ACE)	**0.1**		**0.05**		**0.02**		**0.01**		**0.005**		**0.002**		**0.001**	
Elevation (MSL)	3.60		5.36		7.24		8.51		9.60		10.77		11.57	
Damage Category	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.
Commercial	0	$0	0	$0	1	$0	1	$1	1	$1	1	$1	1	$1
Industrial	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0
Mobile	0	$0	0	$0	4	$61	4	$63	4	$77	11	$301	11	$317
Public	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0
Vehicles	0	$0	3	$31	15	$46	16	$244	18	$270	40	$277	42	$607
Single-Family	1	$3	3	$123	15	$676	17	$999	17	$1,264	35	$2,460	36	$2,906
Grand Total	1	$3	6	$154	35	$783	38	$1,307	40	$1,612	87	$3,038	90	$3,831

Orange 3														
Event (ACE)	**0.1**		**0.05**		**0.02**		**0.01**		**0.005**		**0.002**		**0.001**	
Elevation (MSL)	2.78		4.25		6.11		7.51		8.64		9.81		10.57	
Damage Category	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.

Commercial	0	$0	3	$2,832	4	$7,667	42	$15,849	48	$22,486	51	$31,342	198	$58,526
Industrial	0	$0	1*	$52,625	1*	$139,876	6*	$505,494	6*	$800,283	6*	$1,169,796	8*	$1,572,382
MultiFamily	0	$0	3	$32	3	$72	99	$2,702	102	$4,354	111	$6,810	180	$10,380
Mobile	0	$0	20	$385	23	$565	167	$2,769	173	$2,960	185	$3,489	385	$7,415
Public	2	$0	5	$36	6	$61	70	$10,642	76	$20,067	79	$26,546	166	$48,532
Vehicles	8	$105	267	$170	319	$4,563	3,157	$5,319	3,345	$49,671	3,506	$52,245	9,180	$54,070
Single-Family	11	$772	287	$15,608	347	$27,250	3,247	$171,623	3,404	$236,983	3,621	$294,110	9,146	$591,898
Grand Total	21	$876	586	$71,686	703	$180,054	6,788	$714,399	7,154	$1,136,804	7,559	$1,584,338	19,263	$2,343,202

* Represents the number of actual parcels containing damageable structures. Parcels may contain anywhere from one to several dozen structures.

Jefferson Main														
Event (ACE)	**0.1**		**0.05**		**0.02**		**0.01**		**0.005**		**0.002**		**0.001**	
Elevation (MSL)	3.08		4.63		6.31		7.49		8.47		9.51		10.22	
Damage Category	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.
Commercial	0	$154	20	$22,233	22	$38,014	153	$87,131	160	$138,157	164	$167,493	240	$194,754
Industrial	0	$0	0	$2	1	$684	3	$40,301	3	$53,133	3	$68,150	4	$73,108
MultiFamily	0	$488	9	$33,171	10	$61,258	31	$90,713	31	$106,705	31	$118,311	55	$126,228
Public	1	$1,945	5	$5,859	5	$7,611	22	$14,466	22	$16,132	22	$18,555	32	$21,796
Vehicles	0	$0	267	$2,273	348	$4,137	1909	$5,034	1974	$25,480	2047	$26,425	2097	$27,102
Single-Family	0	$482	290	$63,639	388	$118,128	1940	$398,790	2010	$509,002	2078	$607,949	3418	$762,789
Grand Total	1	$3,070	591	$127,178	774	$229,832	4,058	$636,436	4,200	$848,609	4,345	$1,006,883	5,846	$1,205,777

Beaumont A														
Event (ACE)	**0.1**		**0.05**		**0.02**		**0.01**		**0.005**		**0.002**		**0.001**	
Elevation (MSL)	2.92		4.26		6.00		7.25		8.47		9.73		10.51	
Damage Category	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.
Commercial	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0
Industrial	0	$0	0	$0	0	$0	1	$121,360	1	$207,110	1	$273,565	2	$340,322
MultiFamily	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0
Public	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0
Grand Total	0	$0	0	$0	0	$0	1	$121,360	1	$207,110	1	$273,565	2	$340,322

Beaumont B&C														
Event (ACE)	**0.1**		**0.05**		**0.02**		**0.01**		**0.005**		**0.002**		**0.001**	
Elevation (MSL)	3.55		5.09		6.85		8.02		9.00		10.10		10.85	
Damage Category	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.
Industrial	1	$385	1	$1,119	1	$1,584	1	$1,980	1	$3,334	1	$4,956	1	$4,956
Grand Total	1	$385	1	$1,119	1	$1,584	1	$1,980	1	$3,334	1	$4,956	1	$4,956

Table 2-8. Structures and Damages by Event for Port Arthur CSRM (FY 2015 Price Level, $1,000)

8ft-10ft I-Wall														
Event (ACE)	0.1		0.05		0.02		0.01		0.005		0.002		0.001	
Elevation (MSL)	2.85		4.31		6.98		9.25		10.94		12.68		13.81	
Damage Category	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.
Commercial	50	$12,673	549	$1,964,562	938	$4,551,332	956	$6,636,919	1,050	$7,946,501	1,057	$9,271,555	1,143	$9,589,158
Industrial	0	$0	4	$829	6	$2,068	7	$4,959	9	$92,393	9	$161,616	9	$194,575
MultiFamily	15	$245	119	$7,270	215	$27,158	217	$44,413	249	$55,287	252	$62,567	261	$67,713
Public	16	$2,802	189	$98,180	399	$202,523	401	$275,467	435	$311,283	437	$329,585	445	$337,484
Vehicles	939	$8,440	9,129	$24,024	12,007	$132,922	16,998	$223,811	19,478	$233,279	19,584	$258,901	20,538	$259,840
Single Family	1,197	$52,822	9,262	$486,400	16,626	$1,162,179	16,947	$1,710,962	19,378	$2,122,765	19,492	$2,395,681	20,443	$2,554,936
Grand Total	2,217	$76,981	19,252	$2,581,265	30,191	$6,078,183	35,526	$8,896,531	40,599	$10,761,508	40,831	$12,479,904	42,839	$13,003,707

I-Wall Near Valero														
Event (ACE)	0.1		0.05		0.02		0.01		0.005		0.002		0.001	
Elevation (MSL)	3.87		5.97		8.47		10.47		12.61		14.77		16.08	
Damage Category	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.
Commercial	535	$1,657,699	637	$3,713,146	950	$6,101,335	1,050	$7,593,867	1,056	$9,240,514	1,144	$9,746,974	1,146	$9,866,247
Industrial	4	$586	5	$1,548	7	$4,147	9	$77,050	9	$159,439	9	$236,777	9	$272,478
MultiFamily	117	$5,718	124	$16,147	217	$39,439	247	$52,984	252	$62,231	261	$73,521	262	$81,171
Public	188	$70,949	315	$140,451	400	$256,829	435	$303,194	437	$328,916	445	$346,872	446	$355,637
Vehicles	8,981	$14,225	9,682	$124,636	16,888	$222,467	19,450	$226,172	19,581	$258,840	20,611	$272,392	20,680	$273,417
Single Family	9,126	$405,918	11,610	$750,402	16,838	$1,586,428	19,348	$2,024,867	19,484	$2,388,605	20,500	$2,677,915	20,582	$2,787,254
Grand Total	18,951	$2,155,095	22,373	$4,746,330	35,300	$8,210,645	40,539	$10,278,134	40,819	$12,438,545	42,970	$13,354,449	43,125	$13,636,204

Closure Structure														
Event (ACE)	**0.1**		**0.05**		**0.02**		**0.01**		**0.005**		**0.002**		**0.001**	
Elevation (MSL)	3.45		5.01		6.90		8.20		9.30		10.46		11.20	
Damage Category	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.
Commercial	518	$581,099	562	$2,774,267	938	$4,483,372	948	$5,869,655	956	$6,672,436	1,050	$7,585,987	1,050	$8,139,242
Industrial	3	$193	5	$1,171	6	$2,005	7	$3,841	7	$5,002	9	$76,772	9	$105,511
MultiFamily	114	$2,160	119	$10,779	215	$25,754	216	$37,614	217	$44,713	247	$52,927	250	$56,575
Public	186	$25,192	192	$107,413	399	$195,062	400	$253,214	401	$276,761	435	$303,013	435	$314,034
Vehicles	1,269	$11,581	9,340	$120,815	11,949	$129,070	16,847	$221,849	17,003	$223,898	19,449	$226,151	19,495	$249,305
Single Family	9,002	$180,669	9,493	$582,269	16,611	$1,110,282	16,793	$1,513,337	16,955	$1,718,340	19,348	$2,023,183	19,392	$2,163,792
Grand Total	11,092	$800,894	19,711	$3,596,716	30,118	$5,945,545	35,211	$7,899,510	35,539	$8,941,150	40,538	$10,268,032	40,631	$11,028,459

Tank Farm														
Event (ACE)	**0.1**		**0.05**		**0.02**		**0.01**		**0.005**		**0.002**		**0.001**	
Elevation (MSL)	3.77		5.72		8.10		9.99		12.02		14.08		15.31	
Damage Category	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.
Commercial	531	$1,567,287	572	$3,449,143	946	$5,752,432	1,050	$7,210,661	1,052	$8,861,927	1,143	$9,616,172	1,144	$9,850,235
Industrial	3	$526	5	$1,463	7	$3,743	9	$27,351	9	$140,998	9	$206,100	9	$251,925
MultiFamily	116	$5,323	123	$14,395	216	$36,807	246	$48,984	250	$59,898	261	$68,935	261	$77,359
Public	188	$63,836	208	$129,134	400	$251,210	434	$290,941	436	$322,815	445	$339,456	446	$352,879
Vehicles	1,580	$13,552	9,585	$123,602	16,836	$221,595	17,114	$225,227	19,549	$258,373	20,564	$260,222	20,636	$272,876
Single Family	9,102	$382,410	9,749	$707,373	16,781	$1,479,447	19,319	$1,852,854	19,445	$2,324,783	20,464	$2,590,490	20,530	$2,738,829
Grand Total	11,520	$2,032,933	20,242	$4,425,110	35,186	$7,745,233	38,172	$9,656,019	40,741	$11,968,794	42,886	$13,081,375	43,026	$13,544,104

Table 2-9. Structures and Damages by Event for Freeport CSRM (FY 2015 Price Level, $1,000)

Dow Barge Canal														
Event (ACE)	**0.1**		**0.05**		**0.02**		**0.01**		**0.005**		**0.002**		**0.001**	
Elevation (MSL)	4.60		7.46		10.82		13.28		15.76		18.55		20.12	
Damage Category	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.
Commercial	242	$23,201	284	$46,104	288	$60,385	289	$64,029	289	$65,606	289	$65,967	289	$65,999
Industrial	11	$42,981	13	$768,756	14	$1,859,908	14	$2,567,500	14	$3,217,335	14	$3,381,792	14	$3,382,450
MultiFamily	111	$7,963	115	$14,013	115	$16,356	115	$19,079	115	$23,671	115	$24,386	115	$24,403
Mobile	0	$0	0	$0	2	$64	2	$67	2	$75	2	$75	2	$75
Public	59	$45,413	62	$72,465	65	$85,390	65	$92,968	65	$98,788	65	$99,975	65	$99,987
Vehicles	2,342	$41,345	2,566	$50,260	2,605	$54,308	2,606	$54,830	2,607	$54,851	2,607	$54,851	2,607	$54,851
Single Family	2,348	$103,013	2,571	$142,945	2,605	$166,359	2,607	$173,954	2,607	$177,031	2,607	$177,640	2,607	$177,729
Grand Total	5,113	$263,916	5,611	$1,094,543	5,694	$2,242,770	5,698	$2,972,427	5,699	$3,637,358	5,699	$3,804,687	5,699	$3,805,494

Tide Gate														
Event (ACE)	**0.1**		**0.05**		**0.02**		**0.01**		**0.005**		**0.002**		**0.001**	
Elevation (MSL)	4.46		7.18		10.32		12.65		15.02		17.90		19.52	
Damage Category	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.
Commercial	206	$8,898	238	$23,406	242	$34,982	242	$41,374	243	$46,185	243	$48,705	243	$49,016
Industrial	3	$6,132	3	$12,524	3	$19,426	3	$24,018	3	$25,000	3	$25,107	3	$25,107
MultiFamily	114	$6,788	117	$11,531	117	$13,472	117	$15,579	117	$18,985	117	$20,344	117	$20,380
Public	62	$25,274	68	$38,183	70	$43,033	70	$45,463	70	$46,474	70	$46,860	70	$46,941
Vehicles	1,656	$26,696	1,816	$35,404	1,832	$38,378	1,845	$38,819	1,846	$38,840	1,846	$38,840	1,846	$38,840
Single Family	1,657	$70,032	1,816	$94,166	1,843	$109,968	1,843	$115,628	1,844	$117,760	1,844	$118,518	1,844	$118,682
Grand Total	3,698	$143,821	4,058	$215,214	4,107	$259,258	4,120	$280,881	4,123	$293,244	4,123	$298,373	4,123	$298,966

East Storm Levee														
Event (ACE)	**0.1**		**0.05**		**0.02**		**0.01**		**0.005**		**0.002**		**0.001**	
Elevation (MSL)	5.08		7.81		11.05		13.38		15.55		17.99		19.50	
Damage Category	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.
Commercial	209	$11,308	238	$26,277	242	$37,159	243	$42,674	243	$47,499	243	$48,748	243	$49,016
Industrial	3	$8,117	3	$14,301	3	$20,825	3	$24,693	3	$25,107	3	$25,107	3	$25,107
MultiFamily	115	$8,049	117	$12,212	117	$13,887	117	$16,277	117	$19,717	117	$20,348	117	$20,380
Public	65	$27,074	68	$39,777	70	$43,669	70	$45,664	70	$46,713	70	$46,871	70	$46,941
Vehicles	1,661	$34,822	1,820	$36,906	1,845	$38,622	1,845	$38,819	1,846	$38,840	1,846	$38,840	1,846	$38,840
Single Family	1,666	$78,199	1,819	$98,338	1,843	$111,773	1,844	$116,192	1,844	$118,109	1,844	$118,539	1,844	$118,682
Grand Total	3,719	$167,569	4,065	$227,811	4,120	$265,935	4,122	$284,319	4,123	$295,985	4,123	$298,452	4,123	$298,966

Oyster Creek														
Event (ACE)	**0.1**		**0.05**		**0.02**		**0.01**		**0.005**		**0.002**		**0.001**	
Elevation (MSL)	4.44		8.49		12.21		14.63		16.62		18.77		20.19	
Damage Category	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.
Commercial	206	$8,803	239	$29,591	242	$40,613	243	$45,125	243	$48,497	243	$49,014	243	$49,019
Industrial	3	$6,065	3	$16,061	3	$23,456	3	$24,839	3	$25,107	3	$25,107	3	$25,107
MultiFamily	114	$6,746	117	$12,772	117	$15,171	117	$18,098	117	$20,185	117	$20,373	117	$20,383
Public	62	$25,222	68	$41,228	70	$45,271	70	$46,168	70	$46,777	70	$46,939	70	$46,941
Vehicles	1,656	$26,183	1,821	$38,266	1,845	$38,819	1,846	$38,840	1,846	$38,840	1,846	$38,840	1,846	$38,840
Single Family	1,657	$69,814	1,820	$103,564	1,843	$115,232	1,844	$117,425	1,844	$118,263	1,844	$118,663	1,844	$118,708
Grand Total	3,698	$142,833	4,068	$241,481	4,120	$278,561	4,123	$290,496	4,123	$297,669	4,123	$298,936	4,123	$298,998

Old River at Dow														
Event (ACE)	**0.1**		**0.05**		**0.02**		**0.01**		**0.005**		**0.002**		**0.001**	
Elevation (MSL)	4.43		7.08		10.15		12.41		14.69		17.43		18.97	
Damage Category	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.
Commercial	206	$8,755	238	$22,955	242	$34,546	242	$40,986	243	$45,288	243	$48,539	243	$49,015
Industrial	3	$6,031	3	$12,331	3	$19,097	3	$23,760	3	$24,863	3	$25,107	3	$25,107
MultiFamily	114	$6,725	117	$11,406	117	$13,377	117	$15,346	117	$18,235	117	$20,322	117	$20,375
Public	62	$25,195	68	$37,976	70	$42,839	70	$45,396	70	$46,217	70	$46,821	70	$46,941
Vehicles	1,656	$25,927	1,814	$35,376	1,828	$38,361	1,845	$38,819	1,846	$38,840	1,846	$38,840	1,846	$38,840
Single Family	1,657	$69,706	1,816	$93,721	1,843	$109,306	1,843	$115,488	1,844	$117,485	1,844	$118,440	1,844	$118,672
Grand Total	3,698	$142,339	4,056	$213,765	4,103	$257,526	4,120	$279,794	4,123	$290,930	4,123	$298,069	4,123	$298,949

South Storm Levee														
Event (ACE)	**0.1**		**0.05**		**0.02**		**0.01**		**0.005**		**0.002**		**0.001**	
Elevation (MSL)	4.21		6.68		9.59		11.63		13.71		16.31		17.93	
Damage Category	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.
Commercial	205	$7,965	238	$18,251	241	$33,086	242	$39,164	243	$43,275	243	$48,253	243	$48,719
Industrial	3	$5,396	3	$11,560	3	$18,009	3	$22,091	3	$24,693	3	$25,107	3	$25,107
MultiFamily	114	$6,284	117	$10,879	117	$13,106	117	$14,553	117	$16,658	117	$20,122	117	$20,345
Public	62	$23,852	68	$36,779	69	$42,203	70	$44,466	70	$45,756	70	$46,754	70	$46,864
Vehicles	1,654	$21,887	1,686	$35,277	1,824	$38,320	1,845	$38,819	1,846	$38,819	1,846	$38,840	1,846	$38,840
Single Family	1,657	$66,993	1,814	$89,695	1,825	$107,559	1,843	$113,575	1,844	$116,633	1,844	$118,222	1,844	$118,525
Grand Total	3,695	$132,376	3,926	$202,441	4,079	$252,283	4,120	$272,668	4,123	$285,834	4,123	$297,298	4,123	$298,399

Freeport Dock														
Event (ACE)	**0.1**		**0.05**		**0.02**		**0.01**		**0.005**		**0.002**		**0.001**	
Elevation (MSL)	4.47		7.17		10.30		12.63		14.97		17.79		19.38	
Damage Category	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.	No.	Dam.
Commercial	206	8,946	238	23,361	242	34,931	242	41,340	243	46,050	243	48,652	243	49,016
Industrial	3	6,166	3	12,504	3	19,388	3	23,996	3	24,979	3	25,107	3	25,107
MultiFamily	114	6,809	117	11,519	117	13,461	117	15,560	117	18,872	117	20,338	117	20,379
Public	62	25,301	68	38,162	70	43,011	70	45,457	70	46,437	70	46,848	70	46,941
Vehicles	1,656	26,952	1,816	35,402	1,831	38,376	1,845	38,819	1,846	38,840	1,846	38,840	1,846	38,840
Single Family	1,657	70,141	1,816	94,122	1,843	109,907	1,843	115,615	1,844	117,725	1,844	118,498	1,844	118,679
Grand Total	3,698	144,315	4,058	215,069	4,106	259,072	4,120	280,787	4,123	292,902	4,123	298,282	4,123	298,962

Table 2-10. Economic Performance of Orange-Jefferson CSRM
(FY 2015 Price Level/3.375 percent interest rate)

	Orange 1 New Levee					Orange 2 New Levee					Orange 3 New Levee			
	10 - Foot	**11 - Foot**	**12 - Foot**	**13 - Foot**		**10 - Foot**	**11 - Foot**	**12 - Foot**	**13 - Foot**		**10 - Foot**	**11 - Foot**	**12 - Foot**	**13 - Foot**
INVESTMENT														
Estimated First Cost	$32,300,000	$46,617,000	$60,935,000	$75,252,000		$32,870,000	$41,088,000	$49,305,000	$57,523,000		$205,338,000	$246,811,000	$288,284,000	$329,762,000
Annual Interest Rate	3.375%	3.375%	3.375%	3.375%		3.375%	3.375%	3.375%	3.375%		3.375%	3.375%	3.375%	3.375%
Project Life (years)	50	50	50	50		50	50	50	50		50	50	50	50
Construction Period (months)	36	36	36	36		36	36	36	36		36	36	36	36
Interest During Construction	$1,647,000	$2,377,000	$3,108,000	$3,838,000		$1,676,000	$2,095,000	$2,515,000	$2,934,000		$10,472,000	$12,587,000	$14,702,000	$16,818,000
Investment Cost	$33,947,000	$48,995,000	$64,043,000	$79,090,000		$34,546,000	$43,183,000	$51,820,000	$60,456,000		$215,810,000	$259,398,000	$302,986,000	$346,580,000
Interest	$1,146,000	$1,654,000	$2,161,000	$2,669,000		$1,166,000	$1,457,000	$1,749,000	$2,040,000		$7,284,000	$8,755,000	$10,226,000	$11,697,000
Amortization	$269,000	$388,000	$508,000	$627,000		$274,000	$342,000	$411,000	$479,000		$1,711,000	$2,056,000	$2,402,000	$2,747,000
OMRR&R ($/year)*											$4,084,000	$4,084,000	$4,084,000	$4,084,000
TOTAL ANNUAL COSTS	**$1,415,000**	**$2,042,000**	**$2,669,000**	**$3,296,000**		**$1,440,000**	**$1,800,000**	**$2,160,000**	**$2,520,000**		**$13,078,000**	**$14,895,000**	**$16,711,000**	**$18,528,000**
Without Project EAD	$312,000	$312,000	$312,000	$312,000		$68,000	$68,000	$68,000	$68,000		$29,987,000	$29,987,000	$29,987,000	$29,987,000
Residual EAD	$62,000	$39,000	$23,000	$12,000		$32,000	$26,000	$20,000	$16,000		$8,171,000	$5,242,000	$3,044,000	$1,654,000
Storm Reduction Benefits	$250,000	$273,000	$289,000	$300,000		$36,000	$42,000	$48,000	$52,000		$21,816,000	$24,745,000	$26,943,000	$28,333,000
TOTAL BENEFITS	**$250,000**	**$273,000**	**$289,000**	**$300,000**		**$36,000**	**$42,000**	**$48,000**	**$52,000**		$21,816,000	$24,745,000	$26,943,000	$28,333,000
NET BENEFITS	**($1,165,000)**	**($1,769,000)**	**($2,380,000)**	**($2,996,000)**		**($1,404,000)**	**($1,757,000)**	**($2,112,000)**	**($2,467,000)**		**$8,738,000**	**$9,851,000**	**$10,232,000**	**$9,804,000**
BENEFIT-COST RATIO	**0.2**	**0.1**	**0.1**	**0.1**		**0.0**	**0.0**	**0.0**	**0.0**		**1.7**	**1.7**	**1.6**	**1.5**

***For Mitigation**

Table 2-10. Economic Performance of Orange-Jefferson CSRM (continued)
(FY 2015 Price Level/3.375 percent interest rate)

	Beaumont A New Levee					Beaumont B New Levee					Beaumont C New Levee		
	11 - Foot	**12 - Foot**	**13 - Foot**	**14 - Foot**		**11 - Foot**	**12 - Foot**	**13 - Foot**	**14 - Foot**		**11 - Foot**	**12 - Foot**	**13 - Foot**
INVESTMENT													
Estimated First Cost	$62,661,000	$70,202,000	$77,743,000	$85,284,000		$1,695,000	$2,295,000	$2,895,000	$3,494,000		$15,793,000	$16,078,000	$19,007,000
Annual Interest Rate	3.375%	3.375%	3.375%	3.375%		3.375%	3.375%	3.375%	3.375%		3.375%	3.375%	3.375%
Project Life (years)	50	50	50	50		50	50	50	50		50	50	50
Construction Period (months)	36	36	36	36		36	36	36	36		36	36	36
Interest During Construction	$3,196,000	$3,580,000	$3,965,000	$4,349,000		$86,000	$117,000	$148,000	$178,000		$805,000	$820,000	$969,000
Investment Cost	$65,857,000	$73,782,000	$81,708,000	$89,634,000		$1,782,000	$2,412,000	$3,042,000	$3,673,000		$16,599,000	$16,898,000	$19,977,000
Interest	$2,223,000	$2,490,000	$2,758,000	$3,025,000		$60,000	$81,000	$103,000	$124,000		$560,000	$570,000	$674,000
Amortization	$522,000	$585,000	$648,000	$711,000		$14,000	$19,000	$24,000	$29,000		$132,000	$134,000	$158,000
TOTAL ANNUAL COSTS	**$2,745,000**	**$3,075,000**	**$3,405,000**	**$3,736,000**		**$74,000**	**$101,000**	**$127,000**	**$153,000**		**$692,000**	**$704,000**	**$833,000**
Without Project EAD	$6,937,000	$6,937,000	$6,937,000	$6,937,000		$23,000	$23,000	$23,000	$23,000		$262,000	$262,000	$262,000
Residual EAD	$1,449,000	$870,000	$494,000	$259,000		$7,000	$4,000	$3,000	$1,000		$12,000	$7,000	$4,000
Storm Reduction Benefits	$5,488,000	$6,067,000	$6,442,000	$6,677,000		$17,000	$19,000	$21,000	$22,000		$249,000	$255,000	$258,000
TOTAL BENEFITS	**$5,488,000**	**$6,067,000**	**$6,442,000**	**$6,677,000**		**$17,000**	**$19,000**	**$21,000**	**$22,000**		**$249,000**	**$255,000**	**$258,000**
NET BENEFITS	**$2,743,000**	**$2,992,000**	**$3,037,000**	**$2,942,000**		**($58,000)**	**($82,000)**	**($106,000)**	**($131,000)**		**($442,000)**	**($449,000)**	**($574,000)**
BENEFIT-COST RATIO	**2.0**	**2.0**	**1.9**	**1.8**		**0.2**	**0.2**	**0.2**	**0.1**		**0.4**	**0.4**	**0.3**

Table 2-10. Economic Performance of Orange-Jefferson CSRM (continued)
(FY 2015 Price Level/3.375 percent interest rate)

	Jefferson Main New Levee			
	10 - Foot	**11 - Foot**	**12 - Foot**	**13 - Foot**
INVESTMENT				
Estimated First Cost	$46,948,000	$65,726,000	$87,674,000	$104,747,000
Annual Interest Rate	3.375%	3.375%	3.375%	3.375%
Project Life (years)	50	50	50	50
Construction Period (months)	36	36	36	36
Interest During Construction	$2,394,000	$3,352,000	$4,471,000	$5,342,000
Investment Cost	$49,342,000	$69,078,000	$92,145,000	$110,089,000
Interest	$1,665,000	$2,331,000	$3,110,000	$3,715,000
Amortization	$391,000	$548,000	$730,000	$873,000
OMRR&R ($/year)*	$371,000	$371,000	$371,000	$371,000
TOTAL ANNUAL COSTS	**$2,428,000**	**$3,250,000**	**$4,212,000**	**$4,960,000**
Without Project EAD	$28,231,000	$28,231,000	$28,231,000	$28,231,000
Residual EAD	$4,207,000	$2,520,000	$1,440,000	$776,000
Flood Reduction Benefits	$24,025,000	$25,711,000	$26,791,000	$27,456,000
TOTAL BENEFITS	**$24,025,000**	**$25,711,000**	**$26,791,000**	**$27,456,000**
NET BENEFITS	**$21,597,000**	**$22,461,000**	**$22,580,000**	**$22,496,000**
BENEFIT-COST RATIO	**9.9**	**7.9**	**6.4**	**5.5**

* For Mitigation

(OMRR&R) (with the exception of mitigation) was not taken into account, since these are expected to be proportional among alternatives and would not impact the ranking of alternatives. Mitigation was estimated using the Wetlands Value Assessment Model (WVA), and preliminary wetland mitigation costs were developed for use in plan comparison. These costs were based on compensation for a loss of 85.2 Average Annual Habitat Units (AAHUs) from forested wetlands and 181.7 AAHUs from coastal wetlands and applied to only the Orange 3 and Jefferson Main sections, since Beaumont B and C were already not economically viable, and to Beaumont A because they were small. The same costs were applied to all analyzed levee heights and did not vary. Since the alignment may change as a result of public, technical, and policy review, conceptual mitigation plans and preliminary cost estimates were developed to support TSP plan comparison and selection. The primary determinant in differentiating benefits is the scale of the levee being proposed along with the associated cost for that levee/floodwall height.

It should be noted that the initial evaluations of economic performance, as depicted in Tables up through 2-20, did not incorporate relative sea level change (RSLC). Subsequent analyses will

incorporate a number of changed conditions as the analysis progressed through the study including changes in interest rates, increases and other changes in costs and price levels of structure inventories, addressing the potential for repetitive damages, and the inclusion of additional damage categories. The changes in conditions of the analysis are documented in the appropriate sections of this economics appendix.

Table 2-10 displays the economic evaluation for a range of levee/floodwall heights modifications based on the beginning at 10 feet mean sea level (MSL) up to 13 feet MSL NAVD88. They show the economic performance of the Orange 1, 2, and 3 with new levees and the economic performance of Jefferson Main with new levee as well as Beaumont A, B, and C with new levees. All are calculated at a FY 2015 price level and interest rate.

Based on the information provided in the preceding tables the alternative with the highest net benefits for the Orange-Jefferson CSRM is a levee/floodwall at a height of 12 feet at Orange 3 with Orange 1 and 2 being removed from further consideration. For Beaumont, B and C are removed from consideration and the alternative with the highest net benefits for this area is a 13-foot levee/floodwall at Beaumont A. At Jefferson Main, the alternative with the highest net benefits is a 12-foot levee/floodwall. Residual economic damages in the reaches where an alternative is considered range from $1.7 to $8.1 million in Orange 3. At Beaumont A, annual residual economic damages run from $0.3 to $1.5 million. For the Jefferson Main reach, residual economic damages run from $0.8 to $4.2 million annually.

While both of the 12-foot raises at Orange 3 and Jefferson Main produce higher net benefits than the 11-foot raises, ER-1105-2-100 states “Where two cost-effective plans produce no significantly different levels of net benefits, the less costly plan is to be the NED plan, even though the level of outputs may be less” (Appendix G, pp. G-7 to G-8). The same scenario exists for the 13-foot Raise at Beaumont A versus the 12-foot raise. Based on this guidance, the 11-foot raise at Orange 3 and Jefferson Main and the 12-foot raise at Beaumont A are included as part of the TSP.

2.4.2 Port Arthur and Vicinity CSRM

Just as with the alternative selection with the Freeport CSRM and the Orange-Jefferson CSRM, FWOP damages will have rough order of magnitude costs to identify the NED. Parametric costs were estimated for the first-added resiliency features. The same costs per linear foot both length and height for both levees and floodwalls used for Orange-Jefferson were used for the next added 1- and 2-foot raises to the system. No environmental impacts were identified, and no mitigation costs were included in the comparison. The primary determinant in differentiating benefits lies in the without project damages which is based on the fragility curve at each potential failure location. Additional determinants include the raise of the levee being proposed along with the associated

costs associated with those required features, allowing for the removal of the fragility curve in the analysis and the costs for the increases in the levee/floodwall height.

Just as with the Freeport system, costs for any modifications above these resiliency and raise options begin to escalate significantly since reconstruction would be required for providing additional protection from these features. These additional costs include highway raises, gravity structures, closure structure replacement, replacement of I-wall, and additional pump stations, which are not incrementally justified.

The following tables display the economic evaluation for a range of alternatives beginning with "No Fail" resiliency measures (meaning that the levee/floodwall will not fail prior to overtopping) followed by raises to each reach. All are calculated at a FY 2015 price level and interest rate.

Based on the information provided in Table 2-11, the NED components for the Port Arthur and Vicinity CSRM are generally a "No Fail, One-Foot Raise" for the system. Net benefits for each reach range from $2.9 million to $50.7 million. Residual economic damages for the Port Arthur CSRM range from $3.3 to $10.0 million for 8-foot to10-foot I-Wall, $0.2 to $1.0 million at the Closure Structure, $7.1 to $16.3 million at the I-Wall near Valero, and $10.9 to $25.1 million at the Tank Farm.

2.4.3 Freeport and Vicinity CSRM

Just as with the alternative selection for the Orange-Jefferson CSRM, FWOP damages will have rough order of magnitude costs to identify NED benefits. The same costs per linear foot both length and height for both levees and floodwalls used for Orange-Jefferson were used for the next added 1- and 2-foot raises to the system. No environmental impacts were identified, and no mitigation costs were included in the comparison.

Costs for any modifications above these resiliency and raise options begin to escalate significantly since reconstruction would be required for providing additional protection from these features. These additional costs include features such as high performance turf reinforcement mats, replacement of the Tide gate, gravity structures, intake structures, and rebuilding the dock and floodwalls, which are not incrementally justified.

Table 2-11 displays the economic evaluation for a range of alternatives beginning with "No Fail" resiliency measures followed by raises to each reach. All are evaluated at a FY 2015 price level and interest rate. Just as with the Port Arthur CSRM, the primary determinant in differentiating benefits lies in the without-project damages, which is based on the fragility curve at each potential

failure location. Additional determinants include the raise of the levee being proposed along with the associated costs associated with those required features, allowing for the removal of the fragility curve in the analysis and the costs for the increases in the levee/floodwall height.

Table 2-11. Economic Performance of Port Arthur and Vicinity CSRM
(FY 2015 Price Level/3.375 percent interest rate)

	8ft-10ft I-Wall Raise			Closure Structure Raise			I-Wall Raise Near Valero			I-Wall Raise Near Tank Farm		
	No Fail	**1-Foot Raise**	**2 -Foot Raise**	**No Fail**	**1- Foot Raise**	**2-Foot Raise**	**No Fail**	**1-Foot Raise**	**2-Foot Raise**	**No Fail**	**1-Foot Raise**	**2-Foot Raise**
INVESTMENT												
Estimated First Cost	$3,330,000	$8,915,000	$66,744,000	$3,804,000	$10,654,000	$22,822,000	$7,655,000	$8,948,000	$312,523,000	$2,756,000	$4,627,000	$188,878,000
Annual Interest Rate	3.375%	3.375%	3.375%	3.375%	3.375%	3.375%	3.375%	3.375%	3.375%	3.375%	3.375%	3.375%
Project Life (years)	50	50	50	50	50	50	50	50	50	50	50	50
Construction Period (months)	36	36	36	36	36	36	36	36	36	36	36	36
Interest During Construction	$170,000	$455,000	$3,404,000	$194,000	$543,000	$1,164,000	$390,000	$456,000	$15,938,000	$141,000	$236,000	$9,633,000
Investment Cost	$3,500,000	$9,370,000	$70,148,000	$3,998,000	$11,197,000	$23,986,000	$8,045,000	$9,404,000	$328,461,000	$2,897,000	$4,863,000	$198,511,000
Interest	$118,000	$316,000	$2,367,000	$135,000	$378,000	$810,000	$272,000	$317,000	$11,086,000	$98,000	$164,000	$6,700,000
Amortization	$28,000	$74,000	$556,000	$32,000	$89,000	$190,000	$64,000	$75,000	$2,604,000	$23,000	$39,000	$1,574,000
TOTAL ANNUAL COSTS	**$146,000**	**$391,000**	**$2,924,000**	**$167,000**	**$467,000**	**$1,000,000**	**$335,000**	**$392,000**	**$13,689,000**	**$121,000**	**$203,000**	**$8,273,000**
Without Project EAD	$23,413,000	$23,413,000	$23,413,000	$3,784,000	$3,784,000	$3,784,000	$61,867,000	$61,867,000	$61,867,000	$38,009,000	$38,009,000	$38,009,000
Residual EAD	$9,962,000	$5,730,000	$3,274,000	$995,000	$408,000	$156,000	$16,379,000	$10,813,000	$7,101,000	$25,130,000	$16,874,000	$10,893,000
Flood Reduction Benefits	$13,451,000	$17,683,000	$20,138,000	$2,788,000	$3,375,000	$3,628,000	$45,488,000	$51,054,000	$54,766,000	$12,879,000	$21,135,000	$27,116,000
TOTAL BENEFITS	**$13,451,000**	**$17,683,000**	**$20,138,000**	**$2,788,000**	**$3,375,000**	**$3,628,000**	**$45,488,000**	**$51,054,000**	**$54,766,000**	**$12,879,000**	**$21,135,000**	**$27,116,000**
NET BENEFITS	**$13,305,000**	**$17,292,000**	**$17,215,000**	**$2,622,000**	**$2,908,000**	**$2,628,000**	**$45,153,000**	**$50,662,000**	**$41,076,000**	**$12,758,000**	**$20,932,000**	**$18,843,000**
BENEFIT-COST RATIO	**92.1**	**45.2**	**6.9**	**16.7**	**7.2**	**3.6**	**135.8**	**130.2**	**4.0**	**106.4**	**104.1**	**3.3**

Table 2-12. Economic Performance of Freeport and Vicinity CSRM
(FY 2015 Price Level/3.375 percent interest rate)

	Dow Barge Canal Protection		Oyster Creek Levee Raise				East Storm Levee Raise				Freeport Dock Floodwall Raise		
	No Fail - Closure Structure		No Fail	1-Foot Raise	2 Foot Raise		No Fail	1-Foot Raise	2- Foot Raise		Partial Fail	No Fail	1-Foot Raise
INVESTMENT													
Estimated First Cost	$130,000,000		$1,663,000	$4,869,000	$54,244,000		$3,415,000	$6,530,000	$26,402,000		$1,500,000	$2,850,000	$150,000,000
Annual Interest Rate	3.375%		3.375%	3.375%	3.375%		3.375%	3.375%	3.375%		3.375%	3.375%	3.375%
Project Life (years)	50		50	50	50		50	50	50		50	50	50
Construction Period (months)	36		36	36	36		36	36	36		36	36	36
Interest During Construction	$6,630,000		$85,000	$248,000	$2,766,000		$174,000	$333,000	$1,346,000		$76,000	$145,000	$7,650,000
Investment Cost	$136,630,000		$1,748,000	$5,117,000	$57,010,000		$3,590,000	$6,863,000	$27,748,000		$1,576,000	$2,995,000	$157,650,000
Interest	$4,611,000		$59,000	$173,000	$1,924,000		$121,000	$232,000	$937,000		$53,000	$101,000	$5,321,000
Amortization	$1,083,000		$14,000	$41,000	$452,000		$28,000	$54,000	$220,000		$12,000	$24,000	$1,250,000
TOTAL ANNUAL COSTS	**$5,694,000**		**$73,000**	**$213,000**	**$2,376,000**		**$150,000**	**$286,000**	**$1,156,000**		**$66,000**	**$125,000**	**$6,570,000**
Without Project EAD	$166,660,000		$3,800,000	$3,800,000	$3,800,000		$1,701,000	$1,701,000	$1,701,000		$3,960,000	$3,960,000	$3,960,000
Residual EAD	$47,052,000		$1,717,000	$1,272,000	$933,000		$782,000	$581,000	$425,000		$3,771,000	$1,742,000	$1,333,000
Storm Reduction Benefits	$119,608,000		$2,083,000	$2,527,000	$2,866,000		$919,000	$1,121,000	$1,276,000		$189,000	$2,218,000	$2,627,000
TOTAL BENEFITS	**$119,608,000**		**$2,083,000**	**$2,527,000**	**$2,866,000**		**$919,000**	**$1,121,000**	**$1,276,000**		**$189,000**	**$2,218,000**	**$2,627,000**
NET BENEFITS	**$113,914,000**		**$2,010,000**	**$2,314,000**	**$490,000**		**$769,000**	**$835,000**	**$120,000**		**$123,000**	**$2,093,000**	**($3,944,000)**
BENEFIT-COST RATIO	**21.0**		**28.5**	**11.9**	**1.2**		**6.1**	**3.9**	**1.1**		**2.9**	**17.7**	**0.4**

Table 2-12. Economic Performance of Freeport and Vicinity CSRM (continued)
(FY 2015 Price Level/3.375 percent interest rate)

	Old River Levee Raise at Dow Thumb				South Storm Levee Raise			Tide Gate I-Wall Raise		
	No Fail	1-Foot Raise	2- Foot Raise		1-Foot Raise	2- Foot Raise		No Fail	1-Foot Raise	2- Foot Raise
INVESTMENT										
Estimated First Cost	$7,581,000	$8,294,000	$92,088,000		$3,325,000	$6,650,000		$1,720,000	$3,800,000	$35,644,000
Annual Interest Rate	3.375%	3.375%	3.375%		3.375%	3.375%		3.375%	3.375%	3.375%
Project Life (years)	50	50	50		50	50		50	50	50
Construction Period (months)	36	36	36		36	36		36	36	36
Interest During Construction	$387,000	$423,000	$4,696,000		$170,000	$339,000		$88,000	$194,000	$1,818,000
Investment Cost	$7,968,000	$8,717,000	$96,784,000		$3,495,000	$6,989,000		$1,808,000	$3,994,000	$37,462,000
Interest	$269,000	$294,000	$3,266,000		$118,000	$236,000		$61,000	$135,000	$1,264,000
Amortization	$63,000	$69,000	$767,000		$28,000	$55,000		$14,000	$32,000	$297,000
TOTAL ANNUAL COSTS	**$332,000**	**$363,000**	**$4,034,000**		**$146,000**	**$291,000**		**$75,000**	**$166,000**	**$1,561,000**
Without Project EAD	$2,517,000	$2,517,000	$2,517,000		$254,000	$254,000		$2,785,000	$2,785,000	$2,785,000
Residual EAD	$1,215,000	$913,000	$679,000		$182,000	$127,000		$1,184,000	$897,000	$675,000
Storm Reduction Benefits	$1,302,000	$1,604,000	$1,838,000		$72,000	$127,000		$1,601,000	$1,888,000	$2,110,000
TOTAL BENEFITS	**$1,302,000**	**$1,604,000**	**$1,838,000**		**$72,000**	**$127,000**		**$1,601,000**	**$1,888,000**	**$2,110,000**
NET BENEFITS	**$969,000**	**$1,241,000**	**($2,196,000)**		**($74,000)**	**($164,000)**		**$1,526,000**	**$1,721,000**	**$549,000**
BENEFIT-COST RATIO	**3.9**	**4.4**	**0.5**		**0.5**	**0.4**		**21.4**	**11.4**	**1.4**

Based on the information provided in the preceding table, the NED components for the Freeport and Vicinity CSRM are generally a "No Fail, One-Foot Raise" for the system. The exception is a "No Fail" closure structure at the Dow Barge Canal and a "No Fail" floodwall at Freeport Dock. No further consideration is given to the South Storm Levee, since neither of the two potential raises analyzed is economically justified. A "no fail" alternative was not analyzed, since this levee was not expected to fail prior to overtopping and it also has the highest crest elevation of 21 feet MSL. Residual economic damages are $47.1 million at the Dow Barge Canal, range from $0.9 to 1.7 million at the Oyster Creek Levee, range from $0.4 to $0.8 million at the East Storm Levee, $1.3 to $3.8 at Freeport Dock, $0.7 to $1.2 million at Old River Levee at the Dow thumb, and $0.7 to $1.2 million at the Tide Gate I-Wall.

2.4.4 Brazoria and Sabine Non-Structural

2.4.4.1 Non-Structural Measures

The following describes the non-structural measures considered to reduce the risk of flooding in the study area.

2.4.4.1.1 Floodplain Management

Floodplain management is most effective in controlling future development of the floodplain, thereby assuring that the existing flood problems do not become worse. However, floodplain management cannot, by itself, significantly alleviate existing flooding conditions within a highly urbanized floodplain. The technique of controlled land use is particularly helpful in planning for future development, but is of limited use in highly developed areas.

Effective regulation of the floodplain is dependent on developing enforceable ordinances to ensure that floodplain uses are compatible with the flood hazard. Several means of regulation are available, including zoning ordinances, subdivision regulations, and building codes. Zoning regulations require prudent use and development of the floodplain to prevent excessive property damage, expenditure of public funds, inconvenience, and most importantly, loss of life due to flooding. Subdivision regulations guide the division of large land parcels into smaller lots and requires proof of compliance with other regulations and ordinances. A subdivision ordinance with special reference to flood hazards would require installation of adequate drainage facilities, prohibit encroachment in floodway areas, require the placement of critical streets and utilities above a selected flood elevation, and require that building lots be filled or structures be elevated above a selected flood elevation.

Floodplain management is the most effective means to control future development of the floodplain, and ensure that existing flood problems do not worsen. This alternative did not require

further consideration because the municipalities participate in the National Flood Insurance Program.

2.4.4.1.2 Flood Forecast and Warning Systems

Flood forecasting and warning systems involves the determination of imminent flooding, implementation of a plan to warn the public, and organization of assistance in the evacuation of persons and some personal property. Notification of impending flooding can be accomplished by radio, siren, individual notification, or by elaborate remote sensor devices. Some type of flood warning and emergency evacuation effort should be a part of any FRM plan. These measures normally serve to reduce the hazards to life and damage to portable personal property.

Broad warnings as storm systems develop are coordinated through various agencies, such as the National Weather Service, which provides reports to the essential print and electronic media outlets. The National Weather Service generally releases tropical storm watches 48 hours in advance of any anticipated onset of tropical storm force winds. Since outside preparedness activities become difficult once winds reach tropical storm force, warnings are issued 36 hours in advance of any anticipated onset of tropical storm force winds. The Texas Department of Public Safety's Division of Emergency Management coordinates the state emergency management program, as well as implementing the Texas Emergency Tracking Network (ETN), part of a comprehensive data-management system that provides real-time information before, during, and after a disaster. Orange and Jefferson Counties are members of the Southeast Texas Alerting Network, which can alert users of emergencies, plant operations, traffic, and weather information or other outreach from emergency management. Both counties as well as Brazoria, also have emergency management departments that engage their respective cities, including specific evacuation plans and processes.

2.4.4.1.3 Flood Proofing

Damage to existing structures can be reduced or eliminated through various flood proofing measures. These methods protect damageable property by preventing flood waters from entering the building and/or reaching the contents inside. Flood proofing is most easily applied to new construction, and is most applicable where flooding is of short duration, low velocity, and infrequent occurrence of shallow depths. Flood proofing is usually employed in locations where structural flood protection is not feasible or where collective action is not possible. Typically, flood proofing techniques include water-tight door and window seals, raising of structures, installation of check valves on gravity-flow water and sewer lines, incorporation of seepage controls, and sandbagging of door openings during emergency situations. Due to the relatively large number of structures and the depth of flooding, this measure was not given further consideration.

2.4.4.1.4 Raising Structures in Place

One method of flood proofing involves raising the structures at their existing site. This plan is most applicable where a limited number of structures are receiving a large portion of the total flood damages along a given reach. Structure raising in Port Arthur and Freeport CSRM project areas would be ancillary to the improvement to existing levees/floodwalls system. Since a large portion of the total flood damages were already being addressed by the levee system the structure raising in Port Arthur and Freeport CSRM were removed from consideration. In the other areas the opportunities for structure raising was limited. Most structure would have to be raised several feet off the ground, which then would result in additional problems, such as access concerns, and increased wind damage during storm events. Based on these findings, a raise-in-place plan was determined to be not consistent with the goals and objectives of the project

2.4.4.1.5 Structure Relocation

Plans for structure relocation would involve moving the existing structures to a more non-flood-prone site. The practicality of this measure depends on the frequency of flooding, the value of the property, its importance to the community, and the need for land use areas that are more compatible with floodplain constraints. Relocation of the structures subject to catastrophic flood events within the existing systems to provide additional protection in the event of levee overtopping would be an impractical and potentially cost prohibitive solution. In areas without existing risk reduction systems it was determined that structure relocations were also not consistent with the goals and objectives of the project. Relocation of residential structures would be detrimental to community cohesion in the area. Many of the local industries employ local residents in the area. Due to the large flat floodplain, implementing structure relocations would place residents over an hour's drive away from their work place. Also many of the local communities rely on direct access to waterways to support the good and service in the area. Removing structures would have significant impacts on the local communities ability to provide services if structures would be relocated. Based on these findings, relocation was not considered any further.

2.4.4.1.6 Permanent Evacuation

Evacuation involves the acquisition and removal or demolition of frequently flooded structures from the floodplain. One advantage of floodplain evacuation is it generally provides high marginal benefits, because targeted structures are those being damaged at the most frequent events. Floodplain evacuation can also expand open space and enhance natural and beneficial uses and facilitate the secondary use of newly vacated land. Similar to the relocation measure, evacuation to provide additional protection can be impractical and potentially cost prohibitive. One area was analyzed for the potential for additional risk reduction due to it not receiving and flood risk benefits

from the proposed levee alignments at the Orange-Jefferson CSRM. An examination of the existing damages determined that there were limited opportunities for large scale reductions in damages with permanent structure evacuations due to the fact that there are limited damages to the residential structures associated with the Orange 3 project area. Only 15 percent of the total without equivalent annual damages are to residential structures. 65 percent of the damages in Orange 3 are to the industrial damage category, which are not conducive permanent structure evacuations. As stated above many of these local industries are dependent on the local waterways and transportation corridors.

In addition there would be OSE concerns with leaving local communities exposed while trying to only address industrial damages. Developing risk reduction systems (i.e. levees and floodwalls) for only the industrial areas could potentially induce stages in the local communities. Even with if structure relocations were included (i.e. flood proofing and raising), the area would still face detrimental flooding depths, limiting their ability to recover post storm events in the industrial areas. Based on these findings, permanent structure evacuations was not considered any further.

2.4.4.1.7 Ancillary Permanent Evacuation

Surveys of aerial imagery for the three counties were done to look for the potential for buyouts. Buyouts would be ancillary to the implementation of new levees/floodwalls in Orange and Jefferson Counties and to the enhancement of features in the Freeport and Port Arthur systems. Buyout opportunities in Brazoria are virtually non-existent and very limited in both Orange and Jefferson Counties. Several structures in Jefferson have the potential for being bought out. All of these structures, however, are commercial and buying out these structures is very unlikely to be the economically viable. Figure 2-8 shows the potential for buyouts in Orange County. There are approximately 20 residential structures that could be potentially economically viable and are currently being evaluated. While some of the parcels appeared to have no structures located on them, inspection of county appraisal records in many cases showed improvements on many of these parcels. Visual inspections of aerial photos and further inspection of the appraisal records showed that many of these were agricultural improvements and would therefore not be subject to any permanent evacuation analysis. A quantitative analysis was conducted to determine the viability of any proposed evacuation. Water surface profiles and stage/probability functions were developed from the ADCIRC points that intersected those parcels of interest and imported into HEC-FDA along with depth-damage functions and structure files representing these structures of interest and evaluated. The original list of 20 structures was whittled down to six. Four of these structures were in the 2 percent ACE, with the other two being in the 0.05 percent ACE. Without-project EADs were estimated for these structures which totaled $8,700. Costs for buying out these structures were low-balled to include merely the appraised value of the structure plus $10,000 to demolish the structure. Annual costs for evacuating all six were $21,700, creating net benefits of

-$13,000. Buying only the four in the 2 percent ACE produced net benefits of -$8,600. Based on this analysis, any potential buyouts to be included in the TSP are eliminated. The results of the analysis are captured in Table 2-13.

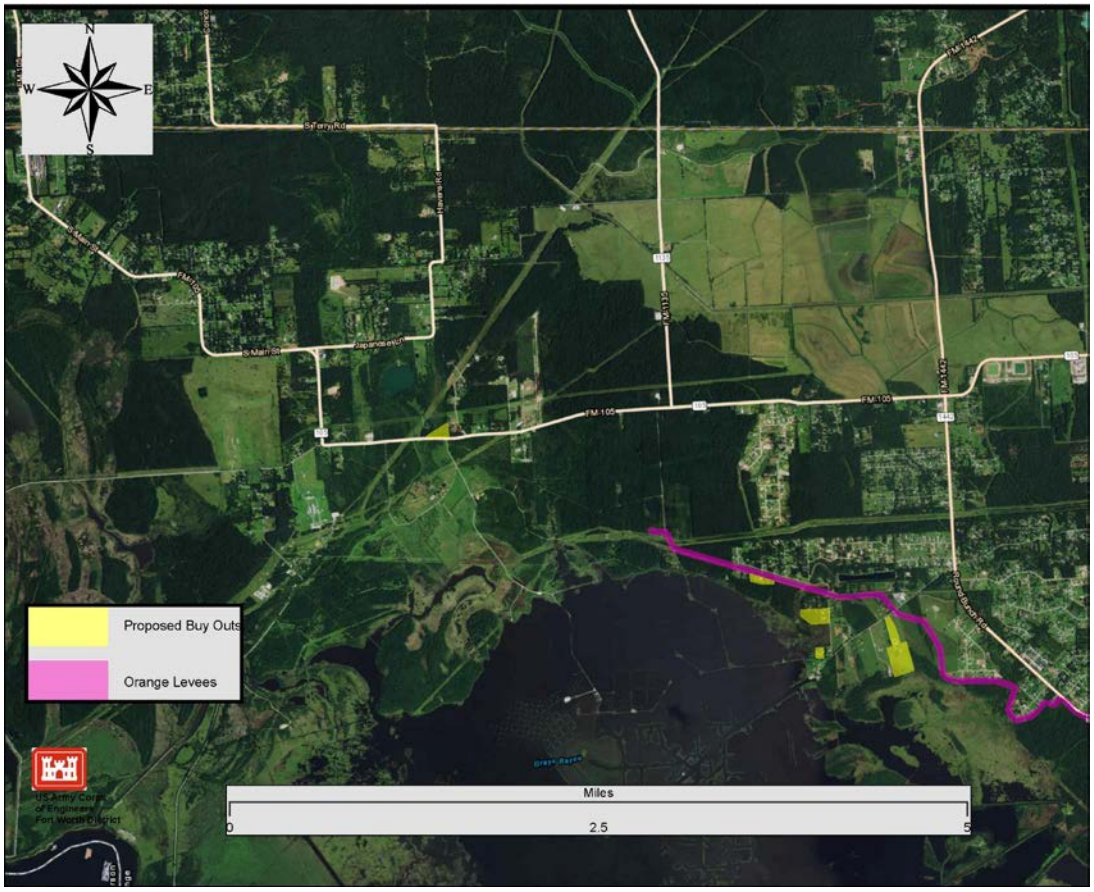


Figure 2-8. Potential Orange County Buyouts

Table 2-13. Non-structural Analysis

	0.02 to 0.01 % ACE Buyout	Total Buyout
INVESTMENT		
Estimated First Cost	$396,400	$511,900
Annual Interest Rate	3.375%	3.375%
Project Life (years)	50	50
Construction Period (months)	12	12
Interest During Construction	$7,200	$9,300
Investment Cost	$403,600	$521,200
Interest	$13,600	$17,600
Amortization	$3,200	$4,100
TOTAL ANNUAL COSTS	**$16,800**	**$21,700**
Without Project EAD	$8,700	$8,700

	0.02 to 0.01 % ACE Buyout	Total Buyout
Residual EAD	$500	$0
Flood Reduction Benefits	$8,200	$8,700
TOTAL BENEFITS	**$8,200**	**$8,700**
NET BENEFITS	**($8,600)**	**($13,000)**
BENEFIT-COST RATIO	**0.5**	**0.4**

2.5 ADJACENT IMPACTS/INDUCED FLOODING

The ERDC surge model ran a full “maximum” footprint for the Freeport, Port Arthur, Jefferson, and Orange levees and showed induced impacts could reach levels of nearly 1 to 1.5 feet in some areas along the Neches River and the Orange County levee. The levees on the Neches River that could induce damages in this area have been removed from the recommended plan eliminating these impacts. The existing systems of Port Arthur and Freeport showed negligible impacts during a 100-year event. Some induced flooding was at Orange 3 but these sections of levee were removed from the final selected plan and impacts in this area were negligible. This drastically reduces adjacent impacts caused by the proposed levee.

Adjacent impacts to the south and southeast of the levee were also analyzed and determined that most areas impacted are vacant areas of grasslands and wetlands. Surge modeling data for a 1 percent ACE were calculated and mapped for differences between the with-project and without-project water surface elevations which showed adjacent impacts to be minimal. The map showing adjacent impacts for a 1 percent ACE can be found in Engineering Map D-11 near the end of the Engineering Appendix. Most values are negligible with the exception of the areas previously mentioned with impacts measuring from 0.02 to 0.05 feet.

2.6 RISK PERFORMANCE OF PROPOSED ACTIONS

Engineer Regulation 1105-2-101 states that risk and uncertainty are intrinsic in water resources planning and design with inaccuracy in all measured or estimated values in project planning and design to some varying degrees. Invariably, the true values are different from any single, point values presently used in project formulation, evaluation, and design. The best estimates of key variables, factors, parameters, and data components in the planning and design of flood damage reduction projects are considered the "most likely" values. These values, however, are frequently based on small periods of record, sample sizes, and measurements that are subject to error.

The ER also states that risk analyses “captures and quantifies the extent of the risk and uncertainty in the various planning and design components of an investment project. The total effect of uncertainty on the project's design and economic viability can be examined and conscious decisions made reflecting an explicit tradeoff between risks and costs. Risk analysis can be used to compare plans in terms of the variability of their physical performance, economic success, and residual risks.”

Engineer Manual 1110-2-1619 identifies a number of potential sources of uncertainty. These include (1) uncertainty about future hydrologic events such as steam flow and rainfall; (2) uncertainty arising from the use of simplified models to describe complex hydraulic phenomena;

(3) economic and social uncertainty, particularly the relationship between depth and inundation damage, inaccuracies in estimates of structure values and locations, and the predictability of how the public will respond to a flood; and (4) uncertainty about structural and geotechnical performance of water-control measures when subjected to rare storm events.

Uncertainty in the hydrology and hydraulics is addressed primarily by utilizing graphical exceedance probability functions which sets confidence limits for discharges at each discrete exceedance probability based on the equivalent record length. Uncertainty for hydrology and hydraulics is also addressed by assigning distributions to stage-damage functions. In the case of this study, the equivalent record length is set at 15 years and the error for the stage-damage functions is set at 0.5 feet. No fragility curves are assigned to the proposed levee, since flooding durations are short and it would be overtopped regardless for those rare events. Economic uncertainties are similarly managed with normal distributions with standard errors assigned to the depth-damage functions and by defining uncertainty parameters for first floor corrections, structure and content values. Uncertainties are further handled by changing, if necessary, the number of Monte Carlo simulations and by varying the range of ordinates in the aggregated stage-damage functions.

HEC-FDA produces project performance reports to display the hydrologic and hydraulic performance of a particular plan. Table 2-14 shows the project performance for the proposed levee raise. For the future without-project condition, the expected annual exceedance probability (AEP) for the Orange Jefferson CSRM ranges from 2.8 percent for Beaumont A to 11.4 percent for Jefferson Main. For the Port Arthur CSRM, the expected AEP ranges from 0.0 percent for the Closure Structure to 0.2 percent for the I-Wall near Valero. For the Freeport CSRM, the expected AEP ranges from 0.1 percent for the South Storm Levee to 6.0 percent for the Dow Barge Canal. Implementing the TSP reduces these expected AEP substantially.

The lack of any long-term performance of the existing conditions at the Orange-Jefferson CSRM shows that the area where levees/floodwalls are being proposed has anywhere from a 76 percent to 99.8 chance of being inundated in 50 years and a virtually zero chance of not being exceeded by the 0.2 percent event. The long-term risk for the existing Port Arthur system is somewhat less, but the long-term risk for the existing Freeport system has a wide variation from the different potential failure locations ranging from 3.7 percent for the South Storm Levee to 95.5 percent for the Dow Barge Canal. Long-term risk is reduced considerably for all three CSRMs with implementation of the TSP. The non-exceedance probability for the 0.2 percent ACE also increases substantially with the implementation of the TSP. These results are also all listed in Table 2-14.

2.6.1 Performance of the Tentatively Selected Plan under Relative Sea Level Change

An analysis was conducted in order to assess how the TSP might perform under various relative sea level change (RSLC) scenarios. As part of this analysis, H&H determined what engineering guidance would need to be for levee/floodwall heights based on EC 1110-2-6067 and CFR 2000 Title 44 and additional guidance for the three CSRMs to address the projected 50-year RSLC under low, intermediate, and high scenarios. These required heights were averaged so that they could be compared to the recommended heights specified in the TSP. Table 2-15 shows these required engineering heights in the left side of the table, while the right side specifies the recommend heights based on the criteria to determine the TSP and the difference between the two sets of criteria. Under the three RSLC scenarios, the TSP addresses relative sea level change well for the Port Arthur and Freeport CSRMs. The Orange-Jefferson CSRM shows deficiencies ranging from 2.24 to 4.77 feet. These results are also in Table 2-15.

Table 2-14. Project Performance for the Tentatively Selected Plan

Without Project

		Long-Term Risk (years)			Assurance by Event					
Damage Reach	**Expected AEP**	**10**	**30**	**50**	**10%**	**4%**	**2%**	**1%**	**0.4%**	**0.2%**
Orange -Jefferson CSRM										
Orange 3	7.7%	55.0%	86.4%	98.2%	85.4%	11.4%	2.1%	0.5%	0.2%	0.0%
Beaumont A	2.8%	24.8%	50.9%	75.9%	100.0%	77.7%	35.3%	13.0%	3.8%	1.8%
Jefferson Main	11.4%	70.2%	95.1%	99.8%	55.7%	5.3%	1.3%	0.4%	0.2%	0.0%
Port Arthur CSRM										
8ft-10ft I-Wall	0.1%	0.5%	1.2%	2.4%	100.0%	100.0%	100.0%	99.8%	94.2%	82.7%
Closure Structure	0.0%	0.0%	0.1%	0.1%	100.0%	100.0%	100.0%	100.0%	99.5%	98.0%
I-Wall Near Valero	0.2%	2.3%	6.8%	11.0%	100.0%	100.0%	99.9%	97.1%	75.4%	55.9%
I-Wall Near Tank Farm	0.1%	1.1%	2.7%	5.2%	100.0%	100.0%	100.0%	99.3%	87.2%	70.7%
Freeport CSRM										
Dow Barge Canal	6.0%	46.3%	78.9%	95.5%	83.6%	59.4%	43.1%	27.2%	12.3%	6.9%
East Storm Levee	0.5%	4.7%	11.3%	21.3%	100.0%	99.9%	97.1%	84.8%	59.2%	42.4%
Freeport Dock	1.2%	10.9%	25.1%	43.8%	100.0%	99.1%	84.2%	52.7%	21.6%	11.3%
Old River at Dow Thumb	0.7%	7.1%	16.8%	30.8%	100.0%	98.9%	91.8%	75.9%	46.4%	29.3%
South Storm Levee	0.1%	0.7%	2.2%	3.7%	100.0%	100.0%	100.0%	100.0%	97.7%	89.4%
Tide Gate I-Wall	0.8%	7.4%	17.5%	32.0%	100.0%	98.7%	91.0%	74.5%	44.9%	27.8%
Oyster Creek	0.6%	6.2%	14.9%	27.5%	100.0%	99.8%	94.2%	76.1%	49.7%	34.8%

Table 2-14. Project Performance for the Tentatively Selected Plan (continued)

With Project

		Long-Term Risk (years)			Assurance by Event					
Damage Reach	**Expected AEP**	**10**	**30**	**50**	**10%**	**4%**	**2%**	**1%**	**0.4%**	**0.2%**
Orange -Jefferson CSRM										
Orange 3 New Levee (11-Foot)	0.2%	1.7%	1.7%	4.1%	100.0%	100.0%	100.0%	98.8%	87.0%	72.5%
Beaumont A New Levee (12-Foot)	0.1%	0.8%	2.1%	4.1%	100.0%	100.0%	100.0%	99.9%	95.9%	86.9%
Jefferson Main New Levee (11-Foot)	0.1%	0.8%	1.9%	3.8%	100.0%	100.0%	100.0%	99.7%	96.1%	89.3%
Port Arthur CSRM										
8- to 10-foot I-Wall Raise (1-foot)	0.4%	0.4%	1.2%	2.0%	100.0%	100.0%	100.0%	100.0%	99.8%	98.3%
Closure Structure Raise (1-foot)	0.0%	0.4%	1.1%	2.1%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
I-Wall Raise Near Valero (1-foot)	0.1%	0.5%	1.6%	2.7%	100.0%	100.0%	100.0%	100.0%	99.0%	94.3%
I-Wall Raise Near Tank Farm (1-foot)	0.1%	0.7%	2.1%	3.6%	100.0%	100.0%	100.0%	100.0%	97.4%	89.5%
Freeport CSRM										
Dow Barge Canal Gate Structure	0.6%	5.8%	16.4%	25.9%	100.0%	100.0%	97.7%	80.9%	45.2%	27.1%
East Storm Levee Raise (1-foot)	0.2%	1.6%	4.8%	7.9%	100.0%	100.0%	100.0%	98.7%	87.3%	72.7%
Freeport Dock (No Fail)	0.5%	4.8%	11.5%	21.7%	100.0%	100.0%	98.9%	87.0%	53.5%	32.9%
Old River Levee Raise at Dow Thumb (1-foot)	0.3%	2.5%	7.4%	12.1%	100.0%	100.0%	99.9%	97.3%	77.1%	55.6%
South Storm Levee	-	-	-	-	-	-	-	-	-	-
Tide Gate I-Wall - 1-foot	0.3%	2.5%	6.1%	11.9%	100.0%	100.0%	100.0%	97.5%	77.6%	55.8%
Tide Gate I-Wall Raise (1-foot)	0.3%	3.3%	8.0%	15.4%	100.0%	100.0%	99.5%	92.3%	69.8%	52.3%

Table 2-15. Tentatively Selected Plan Relative Sea Level Change Project Performance

	Engineering Criteria - FT NAVD				TSP Project Performance				
	Without RSLC	***Low RSLC***	***Intermediate RSLC***	***High RSLC***	***Recommended Height - TSP***	***Surplus/ Deficit (Without)***	***Surplus/ Deficit (Low)***	***Surplus/Deficit (Intermediate)***	***Surplus/ Deficit (High)***
Orange-Jefferson Floodwall	12.50	13.43	13.98	15.77	11.00	-1.50	-2.43	-2.98	-4.77
Orange-Jefferson Levee	12.33	13.24	13.83	15.59	11.00	-1.33	-2.24	-2.83	-4.59
Port Arthur Floodwall	13.25	16.10	16.72	18.25	19.00	5.75	2.90	2.28	0.75
Port Arthur Levee	12.94	13.86	14.43	16.20	18.00	5.06	4.14	3.58	1.80
Dow Barge Canal	15.85	16.58	17.15	18.93	26.00	10.15	9.43	8.85	7.08
Freeport Levee	16.42	17.13	17.66	19.45	20.75	4.33	3.63	3.09	1.30
Oyster Creek	16.41	16.41	16.41	16.41	19.00	2.59	2.59	2.59	2.59

2.6.2 Life Safety Considerations

The population at risk (PAR) is displayed by project area is included in Table 2-16. The PAR was developed based on the 2010 census blocks that intersect the damageable properties in the project areas. This population reflects the residential population that may be exposed to flood risk. This does not include transportation routes for evacuation or those at work in commercial or industrial areas. The PAR the same is due to the fact that virtually the same structures being protected by the levee at Jefferson Main are also being protected by the existing hurricane flood protection system at Port Arthur. In the case of Jefferson Main, the levee is protecting against surge coming up the Neches River. For Port Arthur, damages are being quantified from the failure locations along the HFPS. In the case of Beaumont A – C, all three reaches fall within the same census block.

Table 2-16. Population at Risk by CSRM

CSRM	Population at Risk
Orange-Jefferson	
Orange 1	17,014
Orange 2	13,952
Orange 3	60,044
Beaumont A	2,078
Beaumont B	2,078
Beaumont C	2,078
Jefferson Main	116,762
Port Arthur	116,762
Freeport	16,559

Discussed previously, broad warnings as storm systems develop are coordinated through various agencies, such as the National Weather Service, which provides reports to the essential print and electronic media outlets. The National Weather Service generally releases tropical storm watches 48 hours in advance of any anticipated onset of tropical storm force winds. Since outside preparedness activities become difficult once winds reach tropical storm force, warnings are issued 36 hours in advance of any anticipated onset of tropical storm force winds. The Texas Department of Public Safety's Division of Emergency Management coordinates the state emergency management program, as well as implementing the Texas Emergency Tracking Network (ETN), part of a comprehensive data-management system that provides real-time information before, during, and after a disaster. Orange and Jefferson Counties are members of the Southeast Texas Alerting Network, which can alert users of emergencies, plant operations, traffic, and weather information or other outreach from emergency management. Both counties as well as Brazoria,

also have emergency management departments that engage their respective cities, including specific evacuation plans and processes.

2.7 IDENTIFICATION OF THE TSP

The primary planning objective to select the TSP is to reduce economic damage for the 50-year period of analysis. The TSP also meets the Federal objective of maximizing net benefits. Alternatives were evaluated to show reductions in expected annual damages towards a plan that maximizes net benefits. To that end, the following summarizes each of the CSRMs with their respective alternatives with the highest net benefits to be included in the TSP.

2.7.1 Orange-Jefferson CSRM

- Orange 3 New Levee – 11-Foot Levee/Floodwall
- Jefferson Main New Levee –11-Foot Levee/Floodwall
- Beaumont A New Levee –12-Foot Levee/Floodwall

2.7.2 Port Arthur and Vicinity CSRM

- 8-10 ft I-Wall Raise (1-Foot)
- Closure Structure Raise (1-Foot)
- I-Wall Raise Near Valero (1-Foot)
- I-Wall Raise Near Tank Farm (1-Foot)

2.7.3 Freeport and Vicinity CSRM

- Dow Barge Canal Gate Structure
- Oyster Creek Levee Raise (1-Foot)
- East Storm Levee Raise (1-Foot)
- Freeport Dock No Fail
- Old River Levee Raise at Dow Thumb (1-Foot)
- Tide Gate I-Wall Raise (1-Foot)

The following tables display each of the maximized NED alternatives which comprise the TSP beginning with the Orange-Jefferson CSRM, then the Port Arthur and Vicinity CSRM, and finally the Freeport and Vicinity CSRM (Tables 2-16 through 2-18). It should be noted that no OMRR&R was calculated for Beaumont A since initial estimates were not found to be particularly sensitive across alternative ranking. This was also true for the existing CSRMs.

Table 2-17. TSP for Orange-Jefferson CSRM

(FY 2015 Price Level/3.375 percent interest rate)

	Orange 3	Jefferson Main	Beaumont A
	11 - Foot	11 - Foot	12 - Foot
INVESTMENT			
Estimated First Cost	$246,811,000	$65,726,000	$70,202,000
Annual Interest Rate	3.375%	3.375%	3.375%
Project Life (years)	50	50	50
Construction Period (months)	36	36	36
Interest During Construction	$12,587,000	$3,352,000	$3,580,000
Investment Cost	$259,398,000	$69,078,000	$73,782,000
Interest	$8,755,000	$2,331,000	$2,490,000
Amortization	$2,056,000	$548,000	$585,000
OMRR&R ($/year)	$4,084,000	$371,000	
TOTAL ANNUAL COSTS	**$14,895,000**	**$3,250,000**	**$3,075,000**
Without Project EAD	$29,987,000	$28,231,000	$6,937,000
Residual EAD	$5,242,000	$2,520,000	$870,000
Storm Reduction Benefits	$24,745,000	$25,711,000	$6,067,000
TOTAL BENEFITS	$24,745,000	**$25,711,000**	**$6,067,000**
NET BENEFITS	**$9,851,000**	**$22,461,000**	**$2,992,000**
BENEFIT-COST RATIO	**1.7**	**7.9**	**2.0**

Table 2-18. TSP for Port Arthur and Vicinity CSRM
(FY 2015 Price Level/3.375 percent interest rate)

	8ft-10ft I-Wall	Closure Structure	I-Wall Near Valero	I-Wall Near Tank Farm
	1-Foot Raise	1-Foot Raise	1-Foot Raise	1-Foot Raise
INVESTMENT				
Estimated First Cost	$8,915,000	$10,654,000	$8,948,000	$4,627,000
Annual Interest Rate	3.375%	3.375%	3.375%	3.375%
Project Life (years)	50	50	50	50
Construction Period (months)	36	36	36	36
Interest During Construction	$455,000	$543,000	$456,000	$236,000
Investment Cost	$9,370,000	$11,197,000	$9,404,000	$4,863,000
Interest	$316,000	$378,000	$317,000	$164,000
Amortization	$74,000	$89,000	$75,000	$39,000
TOTAL ANNUAL COSTS	**$391,000**	**$467,000**	**$392,000**	**$203,000**
Without Project EAD	$23,413,000	$3,784,000	$61,867,000	$38,009,000
Residual EAD	$5,730,000	$408,000	$10,813,000	$16,874,000

	8ft-10ft I-Wall	Closure Structure	I-Wall Near Valero	I-Wall Near Tank Farm
	1-Foot Raise	1-Foot Raise	1-Foot Raise	1-Foot Raise
Flood Reduction Benefits	$17,683,000	$3,375,000	$51,054,000	$21,135,000
TOTAL BENEFITS	**$17,683,000**	**$3,375,000**	**$51,054,000**	**$21,135,000**
NET BENEFITS	**$17,292,000**	**$2,908,000**	**$50,662,000**	**$20,932,000**
BENEFIT-COST RATIO	**45.2**	**7.2**	**130.2**	**104.1**

As stated earlier, the TSP for the Orange-Jefferson CSRM includes a 113,600 LF of levee and 29,800 LF of floodwall (total of 27 miles) combination at a levee crest of 11 feet MSL at Orange 3. This has an estimated first cost of $246.8 million annualized to $14.9 million. Total annual benefits are $24.7 million which produces $9.85 million in annual net benefits and benefit-to-cost ratio of 1.7. Also included are a 41,700 LF of levee and 16,200 LF of floodwall (11 miles) combination at Jefferson Main with 11-foot crest elevation and an estimated first cost of $65.7 million with annual costs of $3.3 million. Total annual benefits come to $25.7 million, leaving an estimate of $22.5 million in net benefits and 7.9 benefit-to-cost ratio. Finally, it also includes a combination of 3,100 LF of levee and 200 LF of floodwall (0.6 mile) with a 12-foot crest elevation with first cost of $70.2 million, annual costs of $3.1 million, annual benefits of $6.1 million, and annual net benefits of $3.0 million, and a 2.0 benefit-to-cost ratio.

Table 2-19. TSP for Freeport and Vicinity CSRM
(FY 2015 Price Level/3.375 percent interest rate)

	Dow Barge Canal	Oyster Creek Levee	East Storm Levee	Freeport Dock	Old River Levee at Dow Thumb	Tide Gate I-Wall
	No Fail - Closure Structure	1-Foot Raise	1-Foot Raise	No Fail	1-Foot Raise	1-Foot Raise
INVESTMENT						
Estimated First Cost	$130,000,000	$4,869,000	$6,530,000	$2,850,000	$8,294,000	$3,800,000
Annual Interest Rate	3.375%	3.375%	3.375%	3.375%	3.375%	3.375%
Project Life (years)	50	50	50	50	50	50
Construction Period (months)	36	36	36	36	36	36
Interest During Construction	$6,630,000	$248,000	$333,000	$145,000	$423,000	$194,000
Investment Cost	$136,630,000	$5,117,000	$6,863,000	$2,995,000	$8,717,000	$3,994,000
Interest	$4,611,000	$173,000	$232,000	$101,000	$294,000	$135,000
Amortization	$1,083,000	$41,000	$54,000	$24,000	$69,000	$32,000
TOTALANNUAL COSTS	**$5,694,000**	**$213,000**	**$286,000**	**$125,000**	**$363,000**	**$166,000**
Without Project EAD	$166,660,000	$3,800,000	$1,701,000	$3,960,000	$2,517,000	$2,785,000
Residual EAD	$47,052,000	$1,272,000	$581,000	$1,742,000	$913,000	$897,000
Storm Reduction Benefits	$119,608,000	$2,527,000	$1,121,000	$2,218,000	$1,604,000	$1,888,000
TOTAL BENEFITS	**$119,608,000**	**$2,527,000**	**$1,121,000**	**$2,218,000**	**$1,604,000**	**$1,888,000**
NET BENEFITS	**$113,914,000**	**$2,314,000**	**$835,000**	**$2,093,000**	**$1,241,000**	**$1,721,000**
BENEFIT-COST RATIO	**21.0**	**11.9**	**3.9**	**17.7**	**4.4**	**11.4**

The TSP for the Port Arthur and Vicinity CSRM includes a one-foot raise above the existing elevation of 8-foot to 10-foot I-Wall, 7,500 LF of 15-foot wide scour pad, and 2,000 LF of levee raised one foot. First costs are $8.9 million, annual costs are $0.4 million, and annual benefits are $17.7 million. Net benefits are $17.3 million with a benefit-to-cost ratio of 45.2. Next is a one-foot raise above the existing elevation at the Port Arthur Closure Structure. The structure would be replaced and 300 LF of 100-foot wide scour pad along with 12,000 LF of levee raised one foot. First costs are $10.7 million, annual costs are $0.5 million, annual benefits of $3.4 million with net benefits of $2.9 million, and a benefit-to-cost ration of 7.2. Next is another one-foot raise above the existing elevation at the I-Wall near Valero with 5,000 LF of 15-foot scour pad and 3,000 LF of levee raised one foot. First costs are $8.9 million annualized to $0.4 million, with annual benefits of $51.1 million. Net benefits are $50.7 million and the benefit-to-cost ratio us 130.2. Finally, the TSP would include a one-foot raise above the existing elevation near the Port Arthur Tank Farm and have 1,800 LF of 15-foot-wide scour pad and 7,000 feet of levee raised one foot. First costs are $4.6 million, annual costs are $0.2 million with annual benefits of $21.1 million. Net benefits are $20.9 million with a 104.1 benefit-to-cost ratio.

The TSP for the Freeport and Vicinity CSRM includes a No-Fail closure structure at the Dow Barge Canal with two sector gates approximately 500 feet long and 80 feet in width for vessel traffic with an estimated first cost of $130 million, annual costs of $5.7 million, annual benefits of $119.6 million and $113.9 in annual net benefits. The benefit-to-cost ratio is 21. Also included are a one-foot raise above the existing elevation at the Oyster Creek Levee 10,000 LF in length. First costs are $4.9 million, annual costs are $0.2 million, annual benefits of $2.5 million and net benefits of $2.3 million, with a benefit-to-cost ration of 11.9. Next, it would include a one-foot raise above the existing elevation at the East Storm Levee and 13,115 LF of High Performance Turf Reinforcement Mat (HPTRM). First costs are $6.5 million, annual costs are $0.3 million, annual benefits are $1.1, and net benefits of $0.8 million with a 3.9 benefit-to cost ratio. Next is a 3,000 LF of No-Fail floodwall at Freeport Dock with first costs of $2.9 million, annual costs of $0.1 million and annual benefits of $2.2 million. Net benefits are $2.1 million and the benefit to-cost ratio is 17.7. Next would be a one-foot raise above the existing elevation at the Old River Levee at the Dow Thumb with a distance of 3,000 LF. First costs are $8.3 million, annual costs $0.4 million, annual benefits are $1.6 million, and net benefits are $1.2 million with a benefit-to-cost ratio of 4.4. Finally, it would also include a reconstructed I-Wall raised one foot above the existing elevation, 700 LF in length. It would also have 2,000 LF of levee raised one foot. First costs are $3.8 million, annual costs are $0.2 million, annual benefits are $1.9 million with $1.7 million in net benefits, and an 11.4 benefit-to-cost ratio.

2.8 RE-OPTIMIZATION TO ACCOUNT FOR RELATIVE SEA LEVEL CHANGE (RSLC)

ER 1100-2-8162 provides "guidance for incorporating the direct and indirect physical effects of projected future sea level change across the project life cycle in managing, planning, engineering, designing, constructing, operating, and maintaining USACE projects and systems of projects" and "Alternatives should be evaluated using "low," "intermediate," and "high" rates of future SLC for both "with" and "without" project conditions." ETL 1100-2-1 states that "Using a longer adaptation horizon enables us to improve robustness and resilience compared to planning for shorter time frames" and an "initial assessment that evaluates the exposure and vulnerability of the project area over the 100-year adaptation horizon will assist planners and engineers in determining the long-term approach that best balances risks for the project." The ETL goes on to "strongly recommend that some predictions of how the project or system might perform, as well as its ability to adapt beyond the typical 50-year economic analysis period, be considered in the decision-making."

One approach for addressing RSLC is to consider that the optimization has already taken place with the analysis that identified the TSP and using the identified levee/floodwall crest elevations from the average SWLs as the "base." Any increases to the crest elevation due to wave action and RSLC based on engineering criteria can be added followed by a fresh run HEC-FDA analysis to capture the additional benefits from the increased protection. Another approach is to perform a more rigorous re-optimization based on the 50-year, intermediate RSLC scenario. The following depicts the results for addressing RSLC both for the initial 50-year period of analysis. Based on the 2080 RSLC projections for the USACE intermediate curve at the Freeport NOAA gauge for the Freeport and Vicinity CSRM and the Sabine Pass North NOAA gauge for the Port Arthur and Vicinity CSRM and the Orange-Jefferson CSRM, water surface elevations were adjusted 1.94 and 2.32 feet respectively as provided by SWG's H&H Section. The following graphs depict the water surface elevations as they would be adjusted to reflect various RSLC scenarios for the 20-, 50, and 100-year epochs for each of the three CSRM systems along with the USACE low, intermediate, and high scenarios.

As discussed in the introduction of Section 2.0, after the TSP was verified, the team developed feasibility-level designs for the Recommended Plan. Investigations included detailed cost estimates, benefits, impacts, and implementation requirements. After the ADM, the Beaumont A New Levee (12-foot) and Jefferson Main New Levee (11-foot) were removed from consideration under the Recommended Plan. Beaumont A New Levee (12-foot) was removed due to the local industrial recent actions to reduce the area's risk from storm surges. In the last few years the local industries have developed a levee and floodwall system at the same location as the TSP. The

structural integrity of the existing system is not fully known; however, an assessment of the systems height appears to place it above the heights considered in the Recommended Plan. Additional detailed economic evaluation of Beaumont A was not performed following the ADM; however, it was estimated that the current residual economic damages and life-safety risk are now limited. Risk from storm surge flooding is mainly concentrated to the industrial areas which is now being mitigated for with the newly constructed system. Based on the considerations above the Beaumont A New Levee (12-foot) was removed from the final Recommended Plan.

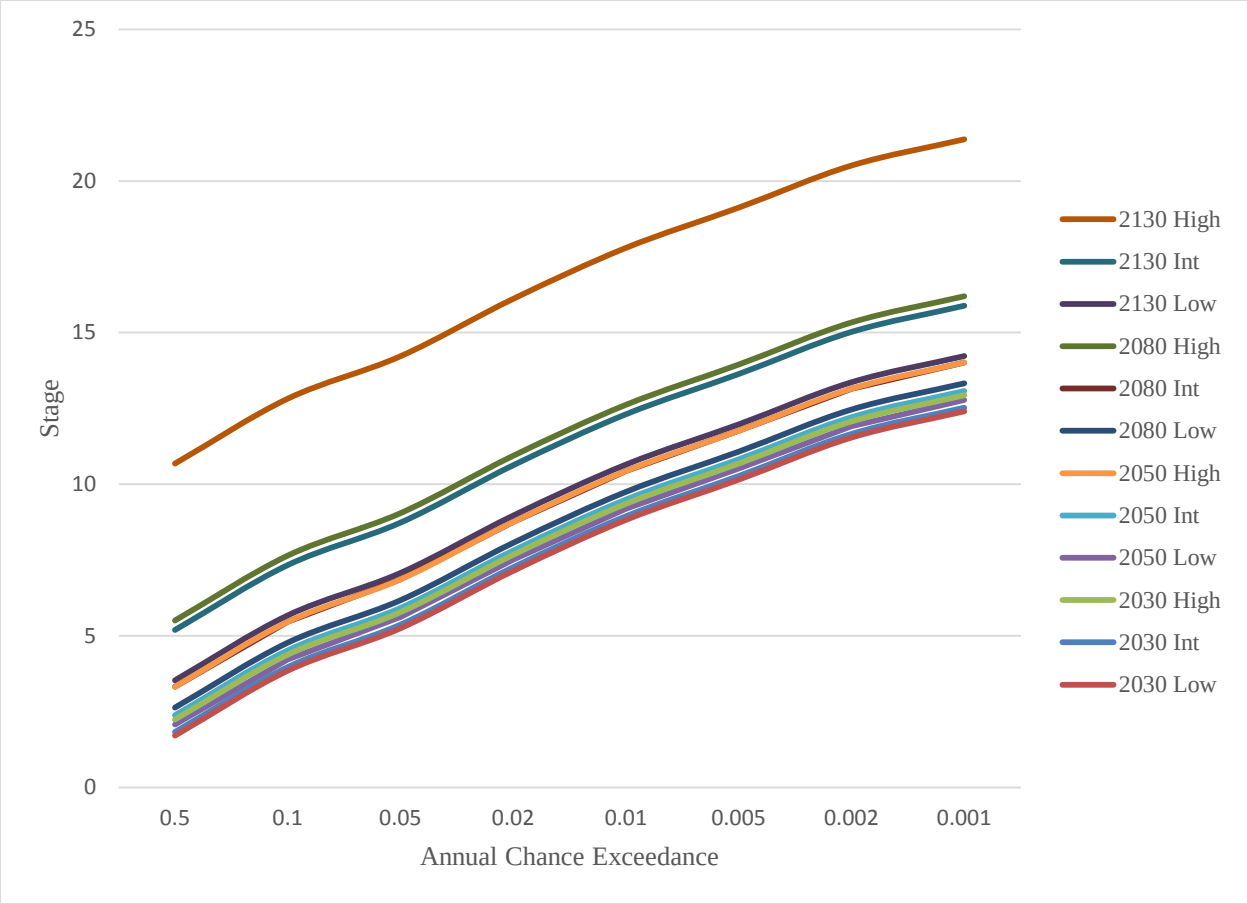


Figure 2-9. Orange-Jefferson CSRM RSLC Scenarios

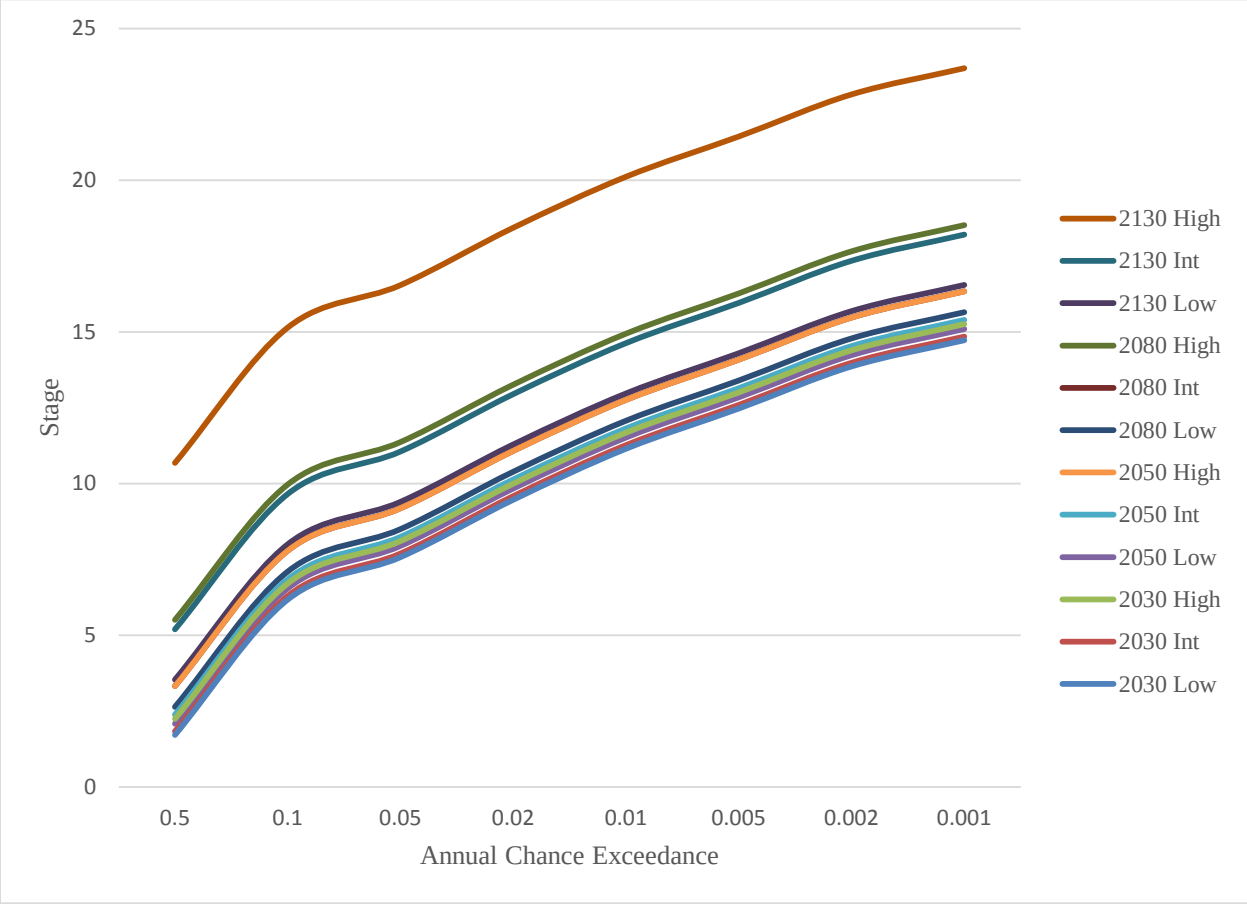


Figure 2-10. Port Arthur CSRM RSLC Scenarios

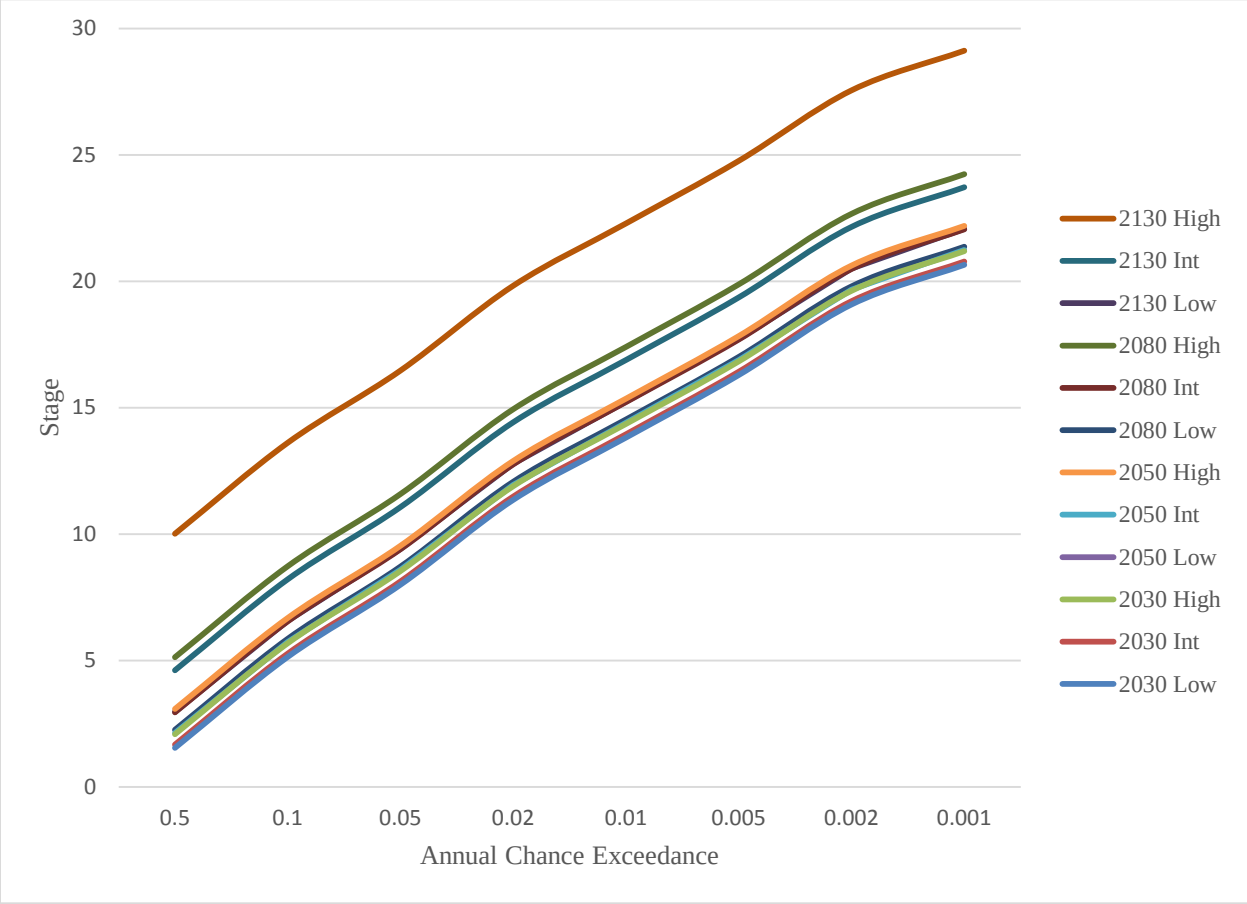


Figure 2-11. Freeport CSRM RSLC Scenarios

Systems Approach for Existing and New CSRMs

The previous analysis related to the identification of the TSP modeled damages at the existing Freeport and Port Arthur CSRMs as independent events at various locations as identified by GeoTech based on either completed or draft SQRAs. As part of the RSLC analysis in response to ATR comments from the Risk Management Center (RMC), without-project damages are estimated at one location identified to be the most likely of having a failure occur. For the Freeport CSRM that location is at the Dow Barge Canal. For the Port Arthur CSRM, that location is at the I-Wall near the Valero Refinery. This approach reduces the potential to overestimate benefits that may accrue at each of these systems. For the Orange-Jefferson CSRM, an "indicator geo-node" was identified for the basis of economic optimization. Once an "optimized" levee crest elevation was identified, the return interval associated with this height would then be applied to the remainder of the system.

Repetitive Damages and Net Benefits of Orange 3 Levee

An additional revision to the RSLC analysis was to address the potential for repetitive damages. No adjustments were done for the Freeport and Port Arthur systems since existing levees are already in place. The following without and with-project damage estimates to compensate for the potential for repetitive damages are based on results done under the 50-year intermediate RSLC scenario and under a reasonably aggressive repetitive damage scenario. All first-floor elevations that fell below the 2050 10-year ACE water surface elevation (4.52 feet) were raised to the 2050 100-year ACE water surface elevation (9.49 feet). This adjustment is similar to the approach used for other Gulf studies but more aggressive than the New Orleans District's *Morganza to the Gulf of Mexico* study and may therefore understate both the without and with-project damages. Damage estimates are based on equivalent annual damages using the water surface elevations and stage-probability functions with 2030 as the base year and 2080 as the most likely future year.

Updated Structure and Content Values

The following tables describe updated structure counts and values to reflect changes made to the structure inventory to match updated costs and to take into account changes due to repetitive damages and by changes in what structures are impacted by annual chance exceedances when RSLC is considered. The first table shows the update structure inventory while the second shows the structure counts by RSLC ACE.

Table 2-20. Updated Structure and Content Values of Inventoried Structures by CSRM and Type - 2016 Price and 2015 Development Levels

Orange 3

Category Name	Count	Structure Value	Content Value	Total
Commercial	265	174,588,000	174,588,000	349,176,000
Industrial	8*	1,908,899,000	1,908,899,000	3,817,798,000
Multi-Family	192	29,482,000	29,482,000	58,964,000
Mobile	600	10,796,000	10,796,000	21,592,000
Public	207	76,621,000	87,546,000	164,167,000
Vehicles	15,033	187,102,000	0	187,102,000
Single-Family	11,931	1,228,101,000	1,228,101,000	2,456,202,000
Grand Total	28,236	3,615,589,000	3,439,412,000	7,055,001,000

* Represents the number of actual parcels containing damageable structures. Parcels may contain anywhere from one to several dozen structures.

Freeport

Category Name	Count	Structure Value	Content Value	Total
Commercial	903	134,576,000	186,747,000	321,323,000

Industrial	49	6,369,294,000	11,160,863,000	17,530,157,000
Multi-Family	375	85,731,000	82,602,000	168,333,000
Mobile	6	168,000	161,000	329,000
Public	207	257,887,000	296,474,000	554,361,000
Vehicles	11,128	212,956,000	0	212,956,000
Single-Family	8,832	469,498,000	451,198,000	920,696,000
Grand Total	21,500	7,530,110,000	12,178,045,000	19,708,155,000

Port Arthur

Category Name	Count	Structure Value	Content Value	Total
Commercial	1,152	5,948,811,000	10,489,192,000	16,438,003,000
Industrial	9	230,903,000	404,504,000	635,407,000
Multi-Family	269	86,311,000	82,911,000	169,222,000
Public	452	248,987,000	273,145,000	522,132,000
Vehicles	26,431	0	0	0
Single-Family	20,977	2,377,533,000	2,283,727,000	4,661,260,000
Grand Total	49,290	8,892,545,000	13,533,479,000	22,426,024,000

Table 2-21. Updated Structure Counts and Damages by CSRM and RSLC ACE
(FY 2016 Price Level, $1,000)

Orange 3

Event (ACE)	**0.1**		**0.05**		**0.02**		**0.01**		**0.005**		**0.002**		**0.001**	
Elevation (MSL Ft.)	5.46		6.86		8.76		10.44		11.76		13.15		14.02	
Damage Category	**No.**	**Dam.**	**No.**	**Dam.**	**No.**	**Dam.**	**No.**	**Dam.**	**No.**	**Dam.**	**No.**	**Dam.**	**No.**	**Dam.**
Commercial	4	$6,532	40	$13,988	49	$26,876	198	$65,768	201	$94,814	257	$139,523	257	$171,585
Industrial	1*	$118,920	6*	$397,175	6*	$964,017	8*	$1,765,198	8*	$2,158,850	8*	$2,606,137	8*	$2,768,134
Multifamily	0	$0	96	$1,624	100	$5,648	180	$12,417	180	$16,580	190	$20,422	190	$23,600
Mobile	2	$53	141	$1,777	154	$3,242	384	$9,092	386	$9,516	537	$10,851	539	$14,425
Public	5	$47	66	$3,565	77	$22,915	166	$49,975	166	$62,312	188	$74,512	188	$93,195
Vehicles	300	$4,296	3,591	$4,935	3,931	$49,927	11,513	$53,731	11,637	$141,890	14,065	$143,549	14,103	$145,123
Single-Family	25	$1,000	2,850	$87,206	3,120	$262,449	9,137	$689,907	9,236	$942,397	11,163	$1,118,302	11,193	$1,337,077
Grand Total	337	$130,848	6,790	$510,270	7,437	$1,335,074	21,586	$2,646,088	21,814	$3,426,358	26,408	$4,113,297	26,478	$4,553,138

* Represents the number of actual parcels containing damageable structures. Parcels may contain anywhere from one to several dozen structures.

Freeport

Elevation (MSL Ft.)	6.54		9.4		12.76		15.22		17.7		20.49		22.06	
Commercial	250	$39,042	287	$57,367	288	$63,783	289	$65,386	289	$65,813	289	66,000	289	$66,005
Industrial	12	$90,361	14	$1,453,293	14	$2,434,612	14	$3,086,560	14	$3,336,371	14	3,382,495	14	$3,382,539
Multifamily	114	$12,536	115	$15,535	115	$18,506	115	$23,168	115	$24,342	115	24,403	115	$24,403
Mobile	0	$0	1	$30	2	$66	2	$74	2	$75	2	75	2	$75
Public	60	$64,140	64	$81,057	65	$92,041	65	$97,818	65	$99,591	65	99,988	65	$100,014
Vehicles	3,018	$49,819	3,250	$54,136	3,284	$54,830	3,285	$54,851	3,285	$54,851	3,285	54,851	3,285	$54,851
Single-Family	2,395	$131,204	2,579	$160,383	2,606	$173,502	2,607	$176,690	2,607	$177,473	2,607	177,746	2,607	$177,795
Grand Total	5,849	$387,103	6,310	$1,821,803	6,374	$2,837,340	6,377	$3,504,548	6,377	$3,758,517	6,377	$3,805,559	6,377	$3,805,684

Port Arthur

Elevation (MSL Ft.)	7.79	9.19	11.08	12.76	14.09	15.47	16.34

Commercial	946	$5,395,927	956	$6,596,122	1,050	$8,050,284	1,057	$9,307,032	1,143	$9,617,172	1,144	$9,858,136	1,147	$9,867,585
Industrial	7	$3,431	7	$4,900	9	$99,457	9	$164,103	9	$206,545	9	$256,028	9	$280,020
Multifamily	216	$34,261	217	$44,040	250	$55,979	252	$62,940	261	$68,980	261	$78,053	262	$82,408
Public	400	$244,265	401	$273,957	435	$312,765	437	$330,352	445	$339,534	446	$353,751	446	$356,272
Vehicles	21,087	$187,352	21,341	$223,699	24,429	$241,933	24,564	$258,971	25,785	$260,236	25,879	$273,027	25,981	$273,594
Single-Family	16,736	$1,406,104	16,937	$1,702,403	19,388	$2,144,891	19,495	$2,403,789	20,464	$2,591,879	20,539	$2,752,980	20,620	$2,799,024
Grand Total	39,392	$7,271,339	39,859	$8,845,121	45,561	$10,905,309	45,814	$12,527,188	48,107	$13,084,346	48,278	$13,571,975	48,465	$13,658,903

HEC-FDA Analysis

Re-optimized Orange-Jefferson CSRM

The re-optimized Orange-Jefferson CSRM (under a 50-year intermediate RSLC scenario) has an estimated first cost of $1,087.799 million annualized to $49.412 million. Total annual benefits are $77.070 million which produces $27.657 million in annual net benefits and benefit-to-cost ratio of 1.6.

Table 2-22. Economic Performance of Orange-Jefferson CSRM (50-Year Intermediate RSLC Scenario) (FY 2016 Price Level/3.125 percent interest rate)

	Orange 3 New Levee		
	11 - Foot	**12 - Foot**	**13 - Foot**
INVESTMENT			
Estimated First Cost	**$1,087,799,000**	**$1,228,785,000**	**$1,439,239,000**
Annual Interest Rate	3.125%	3.125%	3.125%
Project Life (years)	50	50	50
Construction Period (months)	36	36	36
Interest During Construction	$51,304,000	$57,954,000	$67,879,000
Investment Cost	$1,139,103,000	$1,286,738,000	$1,507,118,000
Interest	$35,597,000	$40,211,000	$47,097,000
Amortization	$9,731,000	$10,993,000	$12,875,000
OMRR&R ($/year)*	$4,084,000	$4,084,000	$4,084,000
TOTAL ANNUAL COSTS	**$49,412,000**	**$55,287,000**	**$64,057,000**
Without Project EAD	$102,293,000	$102,293,000	$102,293,000
Residual EAD	$25,223,000	$17,047,000	$10,881,000
Storm Reduction Benefits	$77,070,000	$85,246,000	$91,412,000
TOTAL BENEFITS	**$77,070,000**	**$85,246,000**	**$91,412,000**
NET BENEFITS	**$27,657,000**	**$29,959,000**	**$27,355,000**
BENEFIT-COST RATIO	**1.6**	**1.5**	**1.4**

*****For Mitigation

Re-optimized Port Arthur CSRM

The re-optimized Port Arthur CSRM (under a 50-year intermediate RSLC scenario) has an estimated first cost of $262.011 million annualized to $10.918 million. Total annual benefits are $65.86 million which produces $54.942 million in annual net benefits and benefit-to-cost ratio of 6.0.

Table 2-23. Economic Performance of Port Arthur and Vicinity CSRM
(50-Year Intermediate RSLC Scenario)
(FY 2016 Price Level/3.125 percent interest rate)

	No Fail	NF + 1 Foot	NF + 2 Foot
INVESTMENT			
Estimated First Cost	**$255,275,000**	**$262,011,000**	**$327,011,000**
Annual Interest Rate	3.125%	3.125%	3.125%
Project Life (years)	50	50	50
Construction Period (months)	36	36	36
Interest During Construction	$12,040,000	$12,357,000	$15,423,000
Investment Cost	$267,315,000	$274,369,000	$342,434,000
Interest	$8,354,000	$8,574,000	$10,701,000
Amortization	$2,284,000	$2,344,000	$2,925,000
TOTAL ANNUAL COSTS	**$10,637,000**	**$10,918,000**	**$13,626,000**
Without Project EAD	$70,351,000	$70,351,000	$70,351,000
Residual EAD	$8,641,000	$4,491,000	$2,236,000
Storm Reduction Benefits	$61,711,000	$65,860,000	$68,115,000
TOTAL BENEFITS	**$61,711,000**	**$65,860,000**	**$68,115,000**
NET BENEFITS	**$51,073,000**	**$54,942,000**	**$54,489,000**
BENEFIT-COST RATIO	**5.8**	**6.0**	**5.0**

Re-optimized Freeport and Vicinity CSRM

The re-optimized Freeport and Vicinity CSRM (under a 50-year intermediate RSLC scenario) has an estimated first cost of $304.501 million annualized to $12.688 million. Total annual benefits are $184.077 million which produces $171.389 million in annual net benefits and benefit-to-cost ratio of 14.5.

Table 2-24. Economic Performance of Freeport and Vicinity CSRM (50-Year Intermediate RSLC Scenario) (FY 2016 Price Level/3.125 percent interest rate)

	No Fail	NF + 1 Foot	NF + 2 Foot
INVESTMENT			
Estimated First Cost	**$261,391,000**	**$304,501,000**	**$548,819,000**
Annual Interest Rate	3.125%	3.125%	3.125%
Project Life (years)	50	50	50
Construction Period (months)	36	36	36
Interest During Construction	$12,328,000	$14,361,000	$25,884,000
Investment Cost	$273,719,000	$318,862,000	$574,703,000
Interest	$8,554,000	$9,964,000	$17,959,000
Amortization	$2,338,000	$2,724,000	$4,910,000
TOTAL ANNUAL COSTS	**$10,892,000**	**$12,688,000**	**$22,869,000**
Without Project EAD	$233,118,000	$233,118,000	$233,118,000
Residual EAD	$63,212,000	$49,041,000	$37,797,000
Storm Reduction Benefits	$169,906,000	$184,077,000	$195,320,000
TOTAL BENEFITS	**$169,906,000**	**$184,077,000**	**$195,320,000**
NET BENEFITS	**$159,014,000**	**$171,389,000**	**$172,451,000**
BENEFIT-COST RATIO	**15.6**	**14.5**	**8.5**

The following tables depict the economic performance for the one- and two-foot increments above the "No-Fail" alternatives analyzed at the Orange-Jefferson, Port Arthur, and Freeport CSRMs. The purpose of this analysis is primarily to show that the costs associated with each increment above the least expensive analyzed alternative is economically justified (i.e. benefit-to-cost ratio > 1.0). This was done by using the estimated first cost for the "No-Fail" alternatives at the Port Arthur and Freeport CSRMs and the 11-Foot at the Orange-Jefferson CSRM as the "base" and annualizing the differences in first costs for the other two analyzed alternatives. The same procedure is used for the benefits in order to derive net benefits for each of the "No-Fail + 1 Foot" and "No-Fail + 2 Foot" alternatives at the existing systems and the 12- and 13-Foot alternatives at Orange-Jefferson. As the tables show, the 12-Foot levee/floodwall combination at Orange-

Jefferson generates -$1.783 million in incremental net benefits with a 0.8 benefit-to-cost ratio while the 13-Foot combination generates -$4.386 million incremental net benefits also with a 0.8 benefit-to-cost ratio. At the existing CSRMs, the "No-Fail + 1 Foot" alternative at Port Arthur provides $3.869 million in incremental net benefits while the "No-Fail + 2 Foot" alternative provides -$0.483 million in incremental net benefits with 14.8 and 0.8 benefit-to-cost ratios respectively. At Freeport, the "No-Fail + 1 Foot" alternative generates $12.374 million in incremental net benefits while the "No-Fail + 2 Foot" alternative generates $1.063 million in incremental net benefits with 7.9 and 1.1 respective benefit-to-cost ratios.

Table 2-25. Incremental Benefits for the Orange Jefferson, Port Arthur, and Freeport CSRM Alternatives
(50-Year Intermediate RSLC Scenario - FY 2016 Price Level/3.125 percent interest rate)
Orange-Jefferson CSRM

	11 - Foot	12 - Foot	13 - Foot
INVESTMENT			
Estimated First Cost	**$1,087,799,000**	**$140,986,000**	**$351,440,000**
Annual Interest Rate	3.125%	3.125%	3.125%
Project Life (years)	50	50	50
Construction Period (months)	36	36	36
Interest During Construction	$51,304,000	$6,649,000	$16,575,000
Investment Cost	$1,139,103,000	$147,635,000	$368,015,000
Interest	$35,597,000	$4,614,000	$11,500,000
Amortization	$9,731,000	$1,261,000	$3,144,000
OMRR&R ($/year)*	$4,084,000	$4,084,000	$4,084,000
TOTAL ANNUAL COSTS	**$49,412,000**	**$9,959,000**	**$18,728,000**
Without Project EAD	$102,293,000	$8,176,000	$14,342,000
Residual EAD	$25,223,000	$0	$0
Storm Reduction Benefits	$77,070,000	$8,176,000	$14,342,000
TOTAL BENEFITS	**$77,070,000**	**$8,176,000**	**$14,342,000**
NET BENEFITS	**$27,657,000**	**($1,783,000)**	**($4,386,000)**
BENEFIT-COST RATIO	**1.6**	**0.8**	**0.8**

Port Arthur CSRM

	No Fail	NF + 1 Foot	NF + 2 Foot
INVESTMENT			
Estimated First Cost	**$255,275,000**	**$6,736,000**	**$65,000,000**
Annual Interest Rate	3.125%	3.125%	3.125%
Project Life (years)	50	50	50
Construction Period (months)	36	36	36

Interest During Construction	$12,040,000	$318,000	$3,066,000
Investment Cost	$267,315,000	$7,054,000	$68,066,000
Interest	$8,354,000	$220,000	$2,127,000
Amortization	$2,284,000	$60,000	$581,000
TOTAL ANNUAL COSTS	**$10,637,000**	**$281,000**	**$2,709,000**
Without Project EAD	$70,351,000	$4,149,000	$2,255,000
Residual EAD	$8,641,000	$0	$0
Storm Reduction Benefits	$61,711,000	$4,149,000	$2,255,000
TOTAL BENEFITS	**$61,711,000**	**$4,149,000**	**$2,255,000**
NET BENEFITS	**$51,073,000**	**$3,869,000**	**($453,000)**
BENEFIT-COST RATIO	**5.8**	**14.8**	**0.8**

Freeport and Vicinity CSRM

	No Fail	NF + 1 Foot	NF + 2 Foot
INVESTMENT			
Estimated First Cost	**$261,391,000**	**$43,110,000**	**$244,319,000**
Annual Interest Rate	3.125%	3.125%	3.125%
Project Life (years)	50	50	50
Construction Period (months)	36	36	36
Interest During Construction	$12,328,000	$2,033,000	$11,523,000
Investment Cost	$273,719,000	$45,143,000	$255,841,000
Interest	$8,554,000	$1,411,000	$7,995,000
Amortization	$2,338,000	$386,000	$2,186,000
TOTAL ANNUAL COSTS	**$10,892,000**	**$1,796,000**	**$10,181,000**
Without Project EAD	$233,118,000	$14,171,000	$11,243,000
Residual EAD	$63,212,000	$0	$0
Storm Reduction Benefits	$169,906,000	$14,171,000	$11,243,000
TOTAL BENEFITS	**$169,906,000**	**$14,171,000**	**$11,243,000**
NET BENEFITS	**$159,014,000**	**$12,374,000**	**$1,063,000**
BENEFIT-COST RATIO	**15.6**	**7.9**	**1.1**

The following table depicts the benefits generated by the re-optimized plan for each of the aforementioned RSLC epochs and scenarios. As stated previously, the initially identified TSP was re-optimized under the 50-year intermediate USACE RSLC scenario. The numbers depicted below represent the "gross" benefits generated by taking the re-optimized alternatives evaluated for the TSP and subtracting the annual residual damages of each alternative from the without-project

benefits for each CSRM. Annual costs for each alternative are not taken into account since reformulation was done under 50-year epoch and intermediate RSLC scenario. For each CSRM, using the 50-year epoch as the "base," average annual benefits for the 20- and 100-year epochs are then compared in percentage terms. These changes are displayed in Table 2-26.

As would be expected, benefits for the re-optimized TSP are somewhat reduced under the 20-year epoch as compared to the 50-year epoch. Depending on the scenario, benefits may be reduced from 12 to 19 percent under the low RSLC scenario and increase from 50 to 52 percent under the high scenario for the Orange CSRM. For the existing CSRMs, changes in benefits stay relatively constant across the varying scales of alternatives. Under the 20-year epoch, benefits decrease around five percent at the Freeport CSRM and around ten percent at Freeport. Under the 100-year epoch, benefits increase around 22 to 23 percent for the Port Arthur CSRM under the low RSLC scenario and increase by over 600 percent under the high scenario. At Freeport, benefits decrease five percent under the 20-year low RSLC scenario and all alternatives increase by an average of 189 percent under the 100-year high scenario relative to the 50-year epoch. The bottom line from this analysis is that under these various epochs and RSLC scenarios, there is little variation in benefits in the array of alternative scales. In this regard, there is no compelling case to deviate from the NED in identifying the recommended plan.

Table 2-26. Benefit Sensitivities by CSRM System

	20-Year	50-Year	100-Year	% ch. 20-yr./50-yr.	% ch. 100-yr./50-yr.
Orange					
Low					
11 - Foot	$48,048,000	$54,648,000	$70,511,000	-12.1%	29.0%
12 - Foot	$49,507,000	$60,824,000	$78,093,000	-18.6%	28.4%
13 - Foot	$55,139,000	$66,816,000	$83,988,000	-17.5%	25.7%
Intermediate					
11 - Foot	$53,427,000	$77,070,000	$131,904,000	-30.7%	71.1%
12 - Foot	$59,479,000	$85,246,000	$143,294,000	-30.2%	68.1%
13 - Foot	$64,049,000	$91,412,000	$152,124,000	-29.9%	66.4%
High					
11 - Foot	$75,806,000	$157,082,000	$327,486,000	-51.7%	108.5%
12 - Foot	$83,663,000	$170,341,000	$563,628,000	-50.9%	230.9%
13 - Foot	$89,828,000	$180,418,000	$737,733,000	-50.2%	308.9%
Port Arthur					
Low					
No Fail	$46,324,000	$51,578,000	$63,153,000	-10.2%	22.4%
No Fail + 1	$49,370,000	$54,980,000	$67,538,000	-10.2%	22.8%
No Fail + 2	$50,997,000	$56,808,000	$69,877,000	-10.2%	23.0%
Intermediate					

No Fail	$50,582,000	$61,711,000	$102,307,000	-18.0%	65.8%
No Fail + 1	$53,910,000	$65,860,000	$109,926,000	-18.1%	66.9%
No Fail + 2	$55,699,000	$68,115,000	$114,285,000	-18.2%	67.8%
High					
No Fail	$67,447,000	$123,578,000	$875,555,000	-45.4%	608.5%
No Fail + 1	$71,982,000	$132,928,000	$942,822,000	-45.8%	609.3%
No Fail + 2	$74,454,000	$138,195,000	$986,739,000	-46.1%	614.0%
Freeport					
Low					
No Fail	$143,770,000	$151,311,000	$167,036,000	-5.0%	10.4%
No Fail + 1	$156,279,000	$164,314,000	$181,031,000	-4.9%	10.2%
No Fail + 2	$166,042,000	$174,603,000	$192,171,000	-4.9%	10.1%
Intermediate					
No Fail	$152,242,000	$169,906,000	$231,022,000	-10.4%	36.0%
No Fail + 1	$165,430,000	$184,077,000	$248,595,000	-10.1%	35.0%
No Fail + 2	$175,661,000	$195,320,000	$262,286,000	-10.1%	34.3%
High					
No Fail	$185,139,000	$270,916,000	$793,343,000	-31.7%	192.8%
No Fail + 1	$200,493,000	$290,612,000	$840,024,000	-31.0%	189.1%
No Fail + 2	$212,695,000	$306,323,000	$876,665,000	-30.6%	186.2%

Table 2-27. Economic Performance of Orange-Jefferson CSRM Under 50-Year Low RSLC Scenario
(FY 2016 Price Level/3.125 percent interest rate)

	Orange 3 New Levee		
	11 - Foot	**12 - Foot**	**13 - Foot**
INVESTMENT			
Estimated First Cost	**$1,087,799,000**	**$1,228,785,000**	**$1,439,239,000**
Annual Interest Rate	3.125%	3.125%	3.125%
Project Life (years)	50	50	50
Construction Period (months)	36	36	36
Interest During Construction	$51,304,000	$57,954,000	$67,879,000
Investment Cost	$1,139,103,000	$1,286,738,000	$1,507,118,000
Interest	$35,597,000	$40,211,000	$47,097,000
Amortization	$9,731,000	$10,993,000	$12,875,000
OMRR&R ($/year)	$4,084,000	$4,084,000	$4,084,000
TOTAL ANNUAL COSTS	**$49,412,000**	**$55,287,000**	**$64,057,000**
Without Project EAD	$73,565,000	$73,565,000	$73,565,000
Residual EAD	$18,917,000	$12,742,000	$6,749,000
Storm Reduction Benefits	$54,648,000	$60,824,000	$66,816,000
TOTAL BENEFITS	**$54,648,000**	**$60,824,000**	**$66,816,000**
NET BENEFITS	**$5,236,000**	**$5,537,000**	**$2,760,000**
BENEFIT-COST RATIO	**1.1**	**1.1**	**1.0**

Table 2-28. Economic Performance of Port Arthur and Vicinity CSRM Under 50-Year Low RSLC Scenario
(FY 2016 Price Level/3.125 percent interest rate)

	No Fail	**NF + 1 Foot**	**NF + 2 Foot**
INVESTMENT			
Estimated First Cost	**$255,275,000**	**$262,011,000**	**$327,011,000**
Annual Interest Rate	3.125%	3.125%	3.125%
Project Life (years)	50	50	50
Construction Period (months)	36	36	36
Interest During Construction	$12,040,000	$12,357,000	$15,423,000
Investment Cost	$267,315,000	$274,369,000	$342,434,000
Interest	$8,354,000	$8,574,000	$10,701,000
Amortization	$2,284,000	$2,344,000	$2,925,000
TOTAL ANNUAL COSTS	**$10,637,000**	**$10,918,000**	**$13,626,000**
Without Project EAD	$58,618,000	$58,618,000	$58,618,000
Residual EAD	$7,040,000	$3,638,000	$1,810,000

Storm Reduction Benefits		$51,578,000	$54,980,000	$56,808,000
TOTAL BENEFITS		**$51,578,000**	**$54,980,000**	**$56,808,000**
NET BENEFITS		**$40,941,000**	**$44,062,000**	**$43,182,000**
BENEFIT-COST RATIO		**4.8**	**5.0**	**4.2**

Table 2-29. Economic Performance of Freeport and Vicinity CSRM Under 50-Year Low RSLC Scenario
(FY 2016 Price Level/3.125 percent interest rate)

	No Fail	NF + 1 Foot	NF + 2 Foot
INVESTMENT			
Estimated First Cost	**$261,391,000**	**$304,501,000**	**$548,819,000**
Annual Interest Rate	3.125%	3.125%	3.125%
Project Life (years)	50	50	50
Construction Period (months)	36	36	36
Interest During Construction	$12,328,000	$14,361,000	$25,884,000
Investment Cost	$273,719,000	$318,862,000	$574,703,000
Interest	$8,554,000	$9,964,000	$17,959,000
Amortization	$2,338,000	$2,724,000	$4,910,000
TOTAL ANNUAL COSTS	**$10,892,000**	**$12,688,000**	**$22,869,000**
Without Project EAD	$209,064,000	$209,064,000	$209,064,000
Residual EAD	$57,753,000	$44,750,000	$34,461,000
Storm Reduction Benefits	$151,311,000	$164,314,000	$174,603,000
TOTAL BENEFITS	**$151,311,000**	**$164,314,000**	**$174,603,000**
NET BENEFITS	**$140,419,000**	**$151,625,000**	**$151,734,000**
BENEFIT-COST RATIO	**13.9**	**13.0**	**7.6**

Table 2-30. Economic Performance of Orange CSRM Under 50-Year High RSLC Scenario (FY 2016 Price Level/3.125 percent interest rate)

	Orange 3 New Levee		
	11 - Foot	**12 - Foot**	**13 - Foot**
INVESTMENT			
Estimated First Cost	**$1,087,799,000**	**$1,228,785,000**	**$1,439,239,000**
Annual Interest Rate	3.125%	3.125%	3.125%
Project Life (years)	50	50	50
Construction Period (months)	36	36	36
Interest During Construction	$51,304,000	$57,954,000	$67,879,000
Investment Cost	$1,139,103,000	$1,286,738,000	$1,507,118,000
Interest	$35,597,000	$40,211,000	$47,097,000
Amortization	$9,731,000	$10,993,000	$12,875,000
OMRR&R ($/year)*	$4,084,000	$4,084,000	$4,084,000
TOTAL ANNUAL COSTS	**$49,412,000**	**$55,287,000**	**$64,057,000**
Without Project EAD	$201,203,000	$201,203,000	$201,203,000
Residual EAD	$44,120,000	$30,862,000	$20,785,000
Storm Reduction Benefits	$157,082,000	$170,341,000	$180,418,000
TOTAL BENEFITS	**$157,082,000**	**$170,341,000**	**$180,418,000**
NET BENEFITS	**$107,670,000**	**$115,054,000**	**$116,361,000**
BENEFIT-COST RATIO	**3.18**	**3.08**	**2.82**

***For Mitigation

Table 2-31. Economic Performance of Port Arthur and Vicinity CSRM Under 50-Year High RSLC Scenario (FY 2016 Price Level/3.125 percent interest rate)

	No Fail	**NF + 1 Foot**	**NF + 2 Foot**
INVESTMENT			
Estimated First Cost	**$255,275,000**	**$262,011,000**	**$327,011,000**
Annual Interest Rate	3.125%	3.125%	3.125%
Project Life (years)	50	50	50
Construction Period (months)	36	36	36
Interest During Construction	$12,040,000	$12,357,000	$15,423,000
Investment Cost	$267,315,000	$274,369,000	$342,434,000
Interest	$8,354,000	$8,574,000	$10,701,000
Amortization	$2,284,000	$2,344,000	$2,925,000
TOTAL ANNUAL COSTS	**$10,637,000**	**$10,918,000**	**$13,626,000**
Without Project EAD	$137,926,000	$137,926,000	$137,926,000
Residual EAD	$19,391,000	$10,363,000	$5,331,000
Storm Reduction Benefits	$118,534,000	$127,563,000	$132,595,000
TOTAL BENEFITS	**$118,534,000**	**$127,563,000**	**$132,595,000**
NET BENEFITS	**$107,897,000**	**$116,645,000**	**$118,968,000**
BENEFIT-COST RATIO	**11.1**	**11.7**	**9.7**

Table 2-32. Economic Performance of Freeport and Vicinity CSRM Under 50-Year High RSLC Scenario
(FY 2016 Price Level/3.125 percent interest rate)

	No Fail	NF + 1 Foot	NF + 2 Foot
INVESTMENT			
Estimated First Cost	**$261,391,000**	**$304,501,000**	**$548,819,000**
Annual Interest Rate	3.125%	3.125%	3.125%
Project Life (years)	50	50	50
Construction Period (months)	36	36	36
Interest During Construction	$12,328,000	$14,361,000	$25,884,000
Investment Cost	$273,719,000	$318,862,000	$574,703,000
Interest	$8,554,000	$9,964,000	$17,959,000
Amortization	$2,338,000	$2,724,000	$4,910,000
TOTAL ANNUAL COSTS	**$10,892,000**	**$12,688,000**	**$22,869,000**
Without Project EAD	$358,388,000	$358,388,000	$358,388,000
Residual EAD	$87,473,000	$67,776,000	$52,065,000
Storm Reduction Benefits	$270,916,000	$290,612,000	$306,323,000
TOTAL BENEFITS	**$270,916,000**	**$290,612,000**	**$306,323,000**
NET BENEFITS	**$260,023,000**	**$277,924,000**	**$283,454,000**
BENEFIT-COST RATIO	**24.9**	**22.9**	**13.4**

The following figures recreate the information contained in Table 2-26 to display the annual benefits generated by the revised TSP for the 20-, 50-, and 100-year epochs and under each of the three RSCL scenarios.

Figure 2-12. Orange CSRM Benefits from RSLC Scenarios

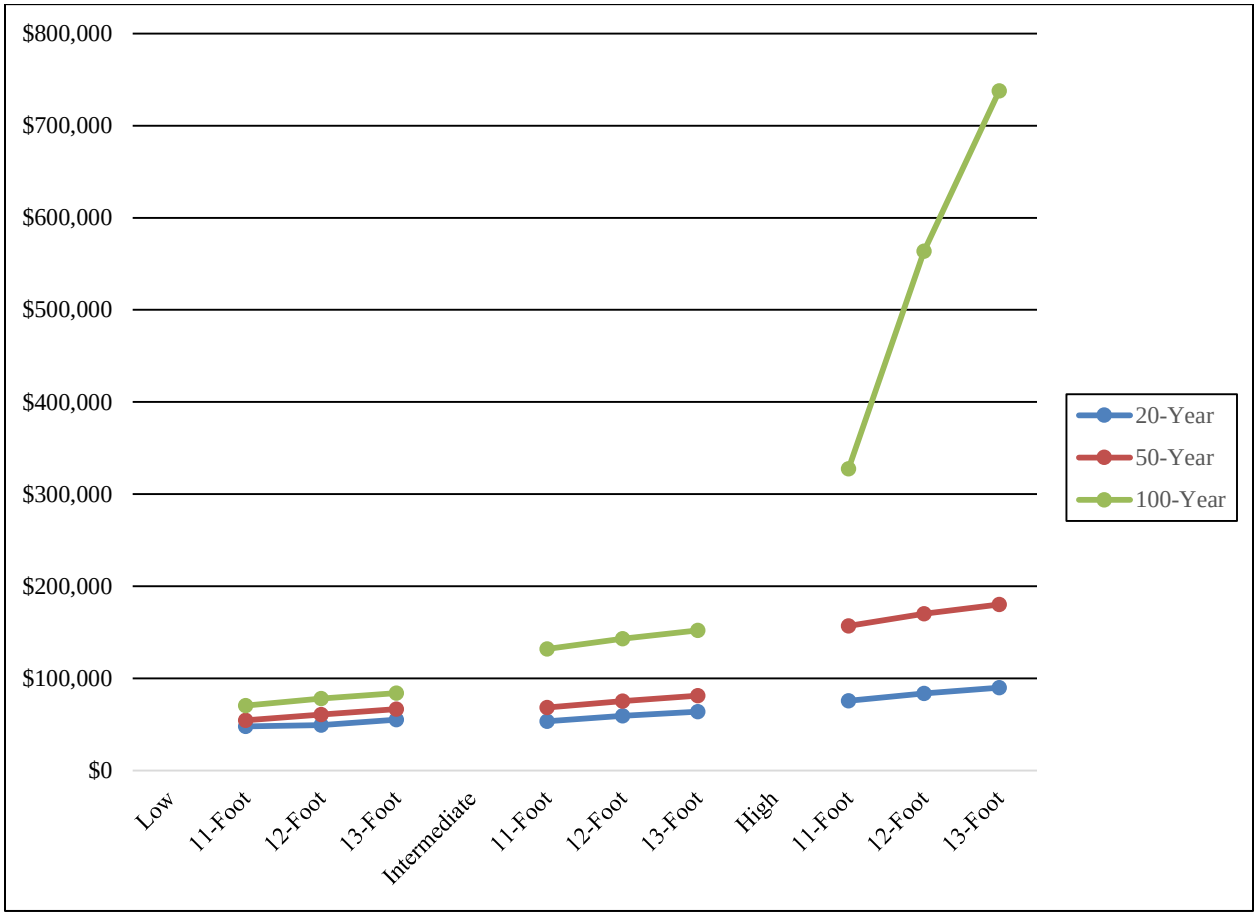


Figure 2-13. Port Arthur CSRM Benefits from RSLC Scenarios

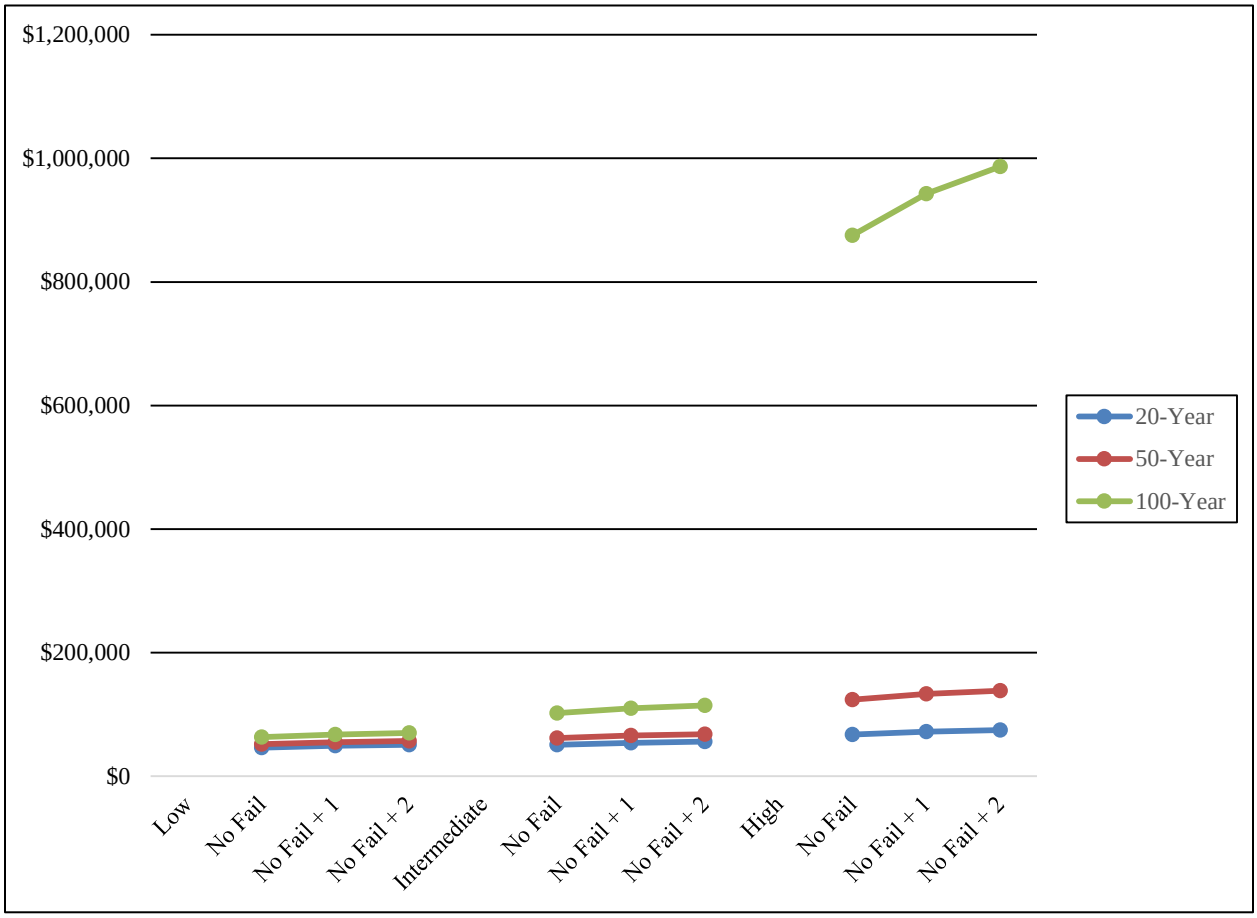
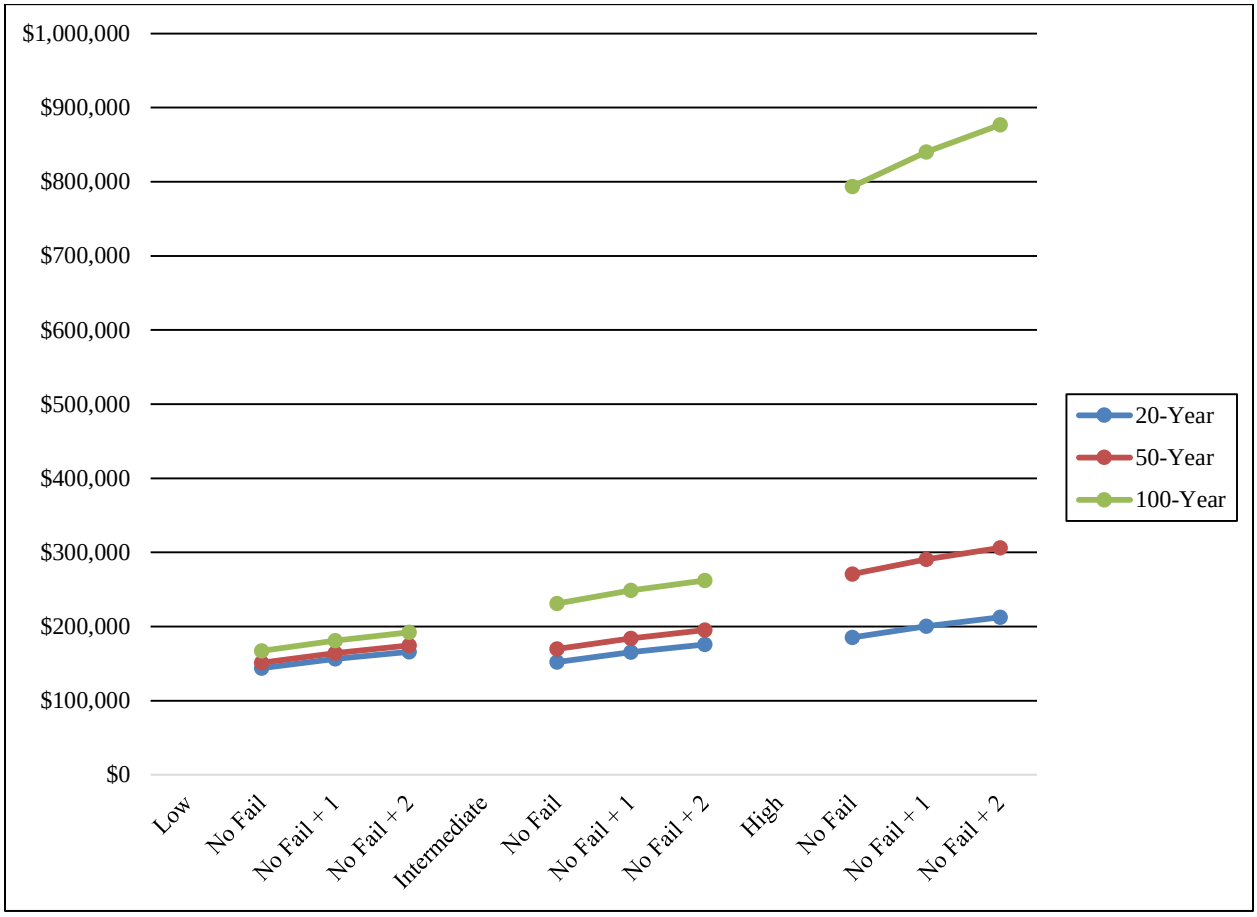


Figure 2-14. Freeport CSRM Benefits from RSLC Scenarios



2.9 RISK PERFORMANCE OF RSLC REVISED PROPOSED ACTIONS

The following table show the risk performance of the revised TSP under the 20-, 50-, and 100-year epochs and under the three RSLC scenarios.

Table 2-33. Project Performance for the Revised Tentatively Selected Plan – 20-Year Epoch

Low

			Long-Term Risk (years)	Assurance by Event					
Damage Reach	**Plan Name**	**Expected AEP**	**10**	**10%**	**4%**	**2%**	**1%**	**0.4%**	**0.2%**
Orange 3 CSRM									
	Without	0.1049	0.6700	0.6083	0.0655	0.0117	0.0023	0.0000	0.0000
	11-Foot	0.0048	0.0473	0.9997	0.9997	0.9953	0.8648	0.5264	0.3327
	12-Foot	0.0053	0.0516	0.9997	0.9997	0.9959	0.8553	0.4686	0.2590
Port Arthur CSRM									
	Without	0.0021	0.0208	1.0000	1.0000	0.9959	0.9460	0.7874	0.6460
	No Fail	0.0006	0.0062	0.9997	0.9997	0.9997	0.9996	0.9908	0.9653
	No Fail + 1	0.0006	0.0057	0.9997	0.9997	0.9997	0.9997	0.9970	0.9859
	No Fail + 2	0.0005	0.0052	0.9997	0.9997	0.9997	0.9997	0.9992	0.9949
Freeport CSRM									
	Without	0.0808	0.5693	0.7823	0.5401	0.3758	0.2203	0.0901	0.0480
	No Fail	0.0073	0.0709	0.9997	0.9995	0.9564	0.7328	0.3616	0.2021
	No Fail + 1	0.0056	0.0550	0.9997	0.9997	0.9826	0.8291	0.4698	0.2789
	No Fail + 2	0.0044	0.0428	0.9998	0.9998	0.9938	0.8994	0.5772	0.3674

Intermediate

			Long-Term Risk (years)	Assurance by Event					
Damage Reach	**Plan Name**	**Expected AEP**	**10**	**10%**	**4%**	**2%**	**1%**	**0.4%**	**0.2%**
Orange 3 CSRM									

	Without	0.1140	0.7019	0.5490	0.0500	0.0082	0.0017	0.0000	0.0000
	11-Foot	0.0055	0.0539	0.9997	0.9997	0.9923	0.8278	0.4633	0.2766
	12-Foot	0.0034	0.0335	0.9997	0.9997	0.9992	0.9422	0.6701	0.4590
Port Arthur CSRM									
	Without	0.0023	0.0233	1.0000	0.9997	0.9942	0.9320	0.7554	0.6065
	No Fail	0.0006	0.0061	0.9997	0.9997	0.9997	0.9995	0.9887	0.9586
	No Fail + 1	0.0006	0.0056	0.9997	0.9997	0.9997	0.9997	0.9963	0.9830
	No Fail + 2	0.0005	0.0052	0.9997	0.9997	0.9997	0.9997	0.9990	0.9939
Freeport CSRM									
	Without	0.0897	0.6094	0.7626	0.5202	0.3559	0.2022	0.0790	0.0408
	No Fail	0.0079	0.0763	0.9997	0.9993	0.9461	0.7013	0.3289	0.1782
	No Fail + 1	0.0061	0.0591	0.9997	0.9997	0.9780	0.8061	0.4351	0.2509
	No Fail + 2	0.0047	0.0457	0.9997	0.9997	0.9921	0.8840	0.5459	0.3372

High

			Long-Term Risk (years)	Assurance by Event					
Damage Reach	**Plan Name**	**Expected AEP**	**10**	**10%**	**4%**	**2%**	**1%**	**0.4%**	**0.2%**
Orange 3 CSRM									
	Without	0.1552	0.8148	0.3298	0.0163	0.0022	0.0000	0.0000	0.0000
	11-Foot	0.0084	0.0811	0.9996	0.9996	0.9678	0.6453	0.2489	0.1188
	12-Foot	0.0053	0.0515	0.9997	0.9997	0.9960	0.8571	0.4686	0.2590
Port Arthur CSRM									
	Without	0.0040	0.0396	1.0000	0.9992	0.9834	0.8710	0.6332	0.4686
	No Fail	0.0006	0.0063	0.9997	0.9997	0.9997	0.9988	0.9771	0.9268
	No Fail + 1	0.0005	0.0055	0.9997	0.9997	0.9997	0.9997	0.9926	0.9693
	No Fail + 2	0.0005	0.0050	0.9997	0.9997	0.9997	0.9997	0.9979	0.9887
Freeport CSRM									

	Without	0.1281	0.7460	0.7003	0.4590	0.2923	0.1479	0.0493	0.0232
	No Fail	0.0100	0.0954	0.9997	0.9975	0.8998	0.5868	0.2289	0.1123
	No Fail + 1	0.0077	0.0744	0.9997	0.9995	0.9551	0.7155	0.3259	0.1686
	No Fail + 2	0.0059	0.0574	0.9997	0.9997	0.9828	0.8212	0.4376	0.2437

Table 2-34. Project Performance for the Revised Tentatively Selected Plan – 50-Year Epoch

Low

			Long-Term Risk (years)			Assurance by Event					
Damage Reach	**Plan Name**	**Expected AEP**	**10**	**30**	**50**	**10%**	**4%**	**2%**	**1%**	**0.4%**	**0.2%**
Orange CSRM											
	Without	0.1208	0.7242	0.9790	0.9984	0.5088	0.0411	0.0064	0.0000	0.0000	0.0000
	11-Foot	0.0062	0.0605	0.1707	0.2679	0.9997	0.9997	0.9885	0.7861	0.4047	0.2281
	12-Foot	0.0038	0.0376	0.1087	0.1745	0.9997	0.9997	0.9988	0.9257	0.6227	0.4071
Port Arthur CSRM											
	Without	0.0029	0.0282	0.0821	0.1331	1.0000	0.9997	0.9922	0.9207	0.7254	0.5709
	No Fail	0.0006	0.0061	0.0182	0.0302	0.9997	0.9997	0.9997	0.9994	0.9862	0.9514
	No Fail + 1	0.0006	0.0056	0.0168	0.0278	0.9997	0.9997	0.9997	0.9997	0.9955	0.9799
	No Fail + 2	0.0005	0.0052	0.0047	0.0140	0.0232	0.9997	0.9997	0.9997	0.9997	0.9977
Freeport CSRM											
	Without	0.0939	0.6270	0.9481	0.9928	0.7542	0.5125	0.3473	0.1945	0.0745	0.0380
	No Fail	0.0081	0.0784	0.2173	0.3353	0.9997	0.9992	0.9413	0.6876	0.3155	0.0169
	No Fail + 1	0.0063	0.0609	0.1719	0.2698	0.9997	0.9997	0.9757	0.7954	0.4205	0.2398
	No Fail + 2	0.0048	0.0471	0.1348	0.2145	0.9997	0.9997	0.9913	0.8769	0.5322	0.3251

Intermediate

			Long-Term Risk (years)			Assurance by Event					
Damage Reach	**Plan Name**	**Expected AEP**	**10**	**30**	**50**	**10%**	**4%**	**2%**	**1%**	**0.4%**	**0.2%**
Orange CSRM											
	Without	0.1544	0.8131	0.9935	0.9998	0.3333	0.0165	0.0022	0.0000	0.0000	0.0000
	11-Foot	0.0084	0.0814	0.2248	0.3459	0.9996	0.9996	0.9670	0.6426	0.2489	0.1188
	12-Foot	0.0053	0.0516	0.1470	0.2327	0.9997	0.9997	0.9997	0.9625	0.7020	0.4675
Port Arthur CSRM											
	Without	0.0040	0.0397	0.1144	0.1833	1.0000	0.9992	0.9833	0.8709	0.6320	0.4687
	No Fail	0.0006	0.0063	0.0188	0.0312	0.9997	0.9997	0.9997	0.9987	0.9768	0.9267
	No Fail + 1	0.0005	0.0055	0.0164	0.0273	0.9997	0.9997	0.9997	0.9997	0.9925	0.9692
	No Fail + 2	0.0005	0.0050	0.0150	0.0249	0.9997	0.9997	0.9997	0.9997	0.9979	0.9887
Freeport CSRM											
	Without	0.1211	0.7248	0.9792	0.9984	0.7096	0.4681	0.3010	0.1556	0.0530	0.0253
	No Fail	0.0096	0.0923	0.2522	0.3840	0.9997	0.9980	0.9075	0.6051	0.2425	0.1209
	No Fail + 1	0.0074	0.0719	0.2006	0.3114	0.9997	0.9996	0.9591	0.7305	0.3411	0.1800
	No Fail + 2	0.0057	0.0555	0.1575	0.2485	0.9997	0.9997	0.9845	0.8321	0.4543	0.2575

High

			Long-Term Risk (years)			Assurance by Event					
Damage Reach	**Plan Name**	**Expected AEP**	**10**	**30**	**50**	**10%**	**4%**	**2%**	**1%**	**0.4%**	**0.2%**
Orange CSRM											
	Without	0.4229	0.9959	1.0000	1.0000	0.0082	0.0000	0.0000	0.0000	0.0000	0.0000
	11-Foot	0.0217	0.1967	0.4816	0.6654	0.9996	0.9468	0.5235	0.0872	0.0077	0.0019
	12-Foot	0.0139	0.1306	0.3430	0.5034	0.9996	0.9957	0.8478	0.2977	0.0436	0.0112
Port Arthur CSRM											
	Without	0.0110	0.1050	0.2831	0.4258	0.9996	0.9786	0.8605	0.5597	0.2683	0.1523
	No Fail	0.0016	0.0161	0.0477	0.0782	0.9998	0.9998	0.9997	0.9865	0.8820	0.7372
	No Fail + 1	0.0009	0.0089	0.0266	0.0439	0.9997	0.9997	0.9997	0.9971	0.9537	0.8663

	No Fail + 2	0.0006	0.0058	0.0172	0.0285	0.9997	0.9997	0.9997	0.9994	0.9854	0.9430
Freeport CSRM											
	Without	0.2474	0.9415	0.9998	1.0000	0.5665	0.3227	0.1556	0.0531	0.0109	0.0042
	No Fail	0.0167	0.1547	0.3960	0.5684	0.9997	0.9746	0.6854	0.2885	0.0632	0.0209
	No Fail + 1	0.0129	0.1214	0.3219	0.4766	0.9997	0.9935	0.8271	0.4350	0.1158	0.0425
	No Fail + 2	0.0098	0.0942	0.2567	0.3901	0.9997	0.9997	0.9693	0.7353	0.2972	0.1320

Table 2-35. Project Performance for the Revised Tentatively Selected Plan – 100-Year Epoch

Low

			Long-Term Risk (years)			Assurance by Event					
Damage Reach	**Plan Name**	**Expected AEP**	**10**	**30**	**50**	**10%**	**4%**	**2%**	**1%**	**0.4%**	**0.2%**
Orange CSRM											
	Without	0.1696	0.8442	0.9962	0.9999	0.2729	0.0116	0.0000	0.0000	0.0000	0.0000
	11-Foot	0.0093	0.0887	0.2432	0.3715	0.9996	0.9995	0.9548	0.5905	0.2063	0.0917
	12-Foot	0.0058	0.0566	0.1605	0.2529	0.9996	0.9996	0.9940	0.8256	0.4167	0.2179
Port Arthur CSRM											
	Without	0.0045	0.0439	0.1261	0.2012	1.0000	0.9988	0.9791	0.8515	0.6006	0.4357
	No Fail	0.0008	0.0076	0.0226	0.0374	0.9997	0.9997	0.9997	0.9984	0.9729	0.9169
	No Fail + 1	0.0005	0.0054	0.0163	0.0269	0.9997	0.9997	0.9997	0.9997	0.9912	0.9646
	No Fail + 2	0.0005	0.0050	0.0148	0.0246	0.9997	0.9997	0.9997	0.9997	0.9974	0.9868
Freeport CSRM											
	Without	0.1220	0.7278	0.9798	0.9985	0.7083	0.4668	0.2997	0.1545	0.0524	0.0250
	No Fail	0.0097	0.0928	0.2533	0.3854	0.9997	0.9979	0.9063	0.6026	0.2404	0.1197
	No Fail + 1	0.0075	0.0722	0.2015	0.3127	0.9997	0.9996	0.9585	0.7284	0.3388	0.1784
	No Fail + 2	0.0057	0.0558	0.1582	0.2496	0.9997	0.9997	0.9843	0.8306	0.4519	0.2556

Intermediate

			Long-Term Risk (years)			Assurance by Event					

Damage Reach	Plan Name	Expected AEP	10	30	50	10%	4%	2%	1%	0.4%	0.2%
Orange CSRM											
	Without	0.3673	0.9897	1.0000	1.0000	0.0186	0.0000	0.0000	0.0000	0.0000	0.0000
	11-Foot	0.0189	0.1736	0.4356	0.6146	0.9996	0.9734	0.6352	0.1415	0.0164	0.0038
	12-Foot	0.0122	0.1156	0.3083	0.4589	0.9996	0.9982	0.9009	0.3953	0.0763	0.0211
Port Arthur CSRM											
	Without	0.0096	0.0924	0.0252	0.3840	1.0000	0.9859	0.8928	0.6186	0.3195	0.1904
	No Fail	0.0014	0.0139	0.0411	0.0675	0.9997	0.9997	0.9997	0.9903	0.9054	0.7789
	No Fail + 1	0.0008	0.0078	0.0232	0.0384	0.9997	0.9997	0.9997	0.9979	0.9643	0.8911
	No Fail + 2	0.0005	0.0051	0.0153	0.0253	0.9997	0.9997	0.9997	0.9996	0.9892	0.9550
Freeport CSRM											
	Without	0.2174	0.9138	0.9994	1.0000	0.6005	0.3580	0.1896	0.0729	0.0172	0.0067
	No Fail	0.0146	0.1369	0.3571	0.5211	0.9997	0.9854	0.7596	0.3657	0.0954	0.0356
	No Fail + 1	0.0112	0.1069	0.2876	0.4318	0.9997	0.9966	0.8742	0.5167	0.1606	0.0658
	No Fail + 2	0.0086	0.0830	0.2290	0.3518	0.9997	0.9993	0.9449	0.6633	0.2512	0.1119

High

			Long-Term Risk (years)			Assurance by Event					
Damage Reach	**Plan Name**	**Expected AEP**	**10**	**30**	**50**	**10%**	**4%**	**2%**	**1%**	**0.4%**	**0.2%**
Orange CSRM											
	Without	0.9019	1.0000	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	11-Foot	0.4296	0.9964	1.0000	1.0000	0.0065	0.0000	0.0000	0.0000	0.0000	0.0000
	12-Foot	0.2343	0.9307	0.9997	1.0000	0.1270	0.0004	0.0000	0.0000	0.0000	0.0000
Port Arthur CSRM											
	Without	0.1135	0.7004	0.9731	0.9976	0.5145	0.1420	0.0417	0.0085	0.0022	0.0015
	No Fail	0.0196	0.1795	0.4476	0.6282	0.9985	0.9216	0.6472	0.2279	0.0396	0.0091
	No Fail + 1	0.0124	0.1176	0.3129	0.4650	0.9997	0.9838	0.8588	0.4665	0.1300	0.0420
	No Fail + 2	0.0078	0.0749	0.2084	0.3226	0.9997	0.9978	0.9627	0.7188	0.3087	0.1316
Freeport CSRM											
	Without	0.5167	0.9993	1.0000	1.0000	0.2454	0.0258	0.0028	0.0010	0.0000	0.0000
	No Fail	0.0594	0.4581	0.8408	0.9533	0.9709	0.1933	0.0149	0.0009	0.0000	0.0000
	No Fail + 1	0.0457	0.3735	0.7541	0.9035	0.9964	0.4097	0.0547	0.0036	0.0001	0.0000

	No Fail + 2	0.0355	0.3030	0.6613	0.8355	0.9997	0.6584	0.1486	0.0144	0.0005	0.0000

HEC-FDA Analysis

2.10 RECOMMENDED PLAN

The Jefferson Main New Levee (11-foot) was removed from the final Recommended Plan based on a lack of local sponsorship and due to the limited perceived benefits. During the concurrent review period, local entities suggested that the economic performance of Jefferson Main should be reevaluated because there was not a perceived need for this component of the TSP. There was limited life-safety risk due to the industrial makeup of the area. Based on results of these evaluation, the sponsor decided to not to pursue this component of the final Recommended Plan.

Following the refinement and update of costs to account for interior drainage and the requisite pumps, costs, particularly for the Orange component (Orange 3) increased significantly. Twelve new pump stations were initially proposed for the Orange 3 levee reach however, due to the high cost of construction and maintenance for these structures, the benefit-to-cost ratio fell to well below unity (<1.0) therefore, a reduction in the pump discharge and number of pump stations was analyzed. A more detailed analysis and changes to the analysis included Joint Probability Analysis (JPA) to estimate discharge rates along with the potential to combine pumps. Additionally, the initial assumption of designing pumps for a 0.04 ACE with an additional ten percent capacity for RSLC was scrubbed in favor of basing pump design on the 0.04 ACE alone. The number of pumps as also reduced to seven from the initial twelve.

On the benefits side, additional benefits for debris removal and potential damages to roads, highways, and railroads were calculated. Information obtained from the New Orleans District included access to the report, *Development of Depth-Emergency Cost and Infrastructure Damage Relationships for Selected South Louisiana Parishes* which developed values as well as depth/damage functions for a number potential damage categories including debris removal and cleanup as well as evacuation activities and damages to transportation and critical infrastructure. Economic assumptions for debris removal and cleanup assumed debris would consist of vegetative (trees, shrubs, etc.), white goods (refrigerators, washers, stoves, etc.), electronic goods (TVs, computers, microwaves), hazardous waste, vehicles, vessels, and tires. Appropriate destination facilities were also identified depending on the type of debris. Assumptions also included consideration for flood-related labor diversion and capital use along with travel cost and the necessity for temporary/rental structures. Roads were divided into two categories; 1) major and secondary highways (assumed to be of the four-laned variety) and 2) streets (those assumed to consist of two lanes). These, along with railroads, were assumed to have been built to completion and are in some stage of depreciation. Unit values for these two damage debris removal and cleanup and roads, highways, and railroads were estimated based on the type of structure (for debris removal and cleanup) and by mile (for roads, highways, and railroads). These values were then adjusted for inflation, based on ENR's Cost Construction Index, and locality, based on the

CPI between Houma, Louisiana and Houston, Texas, the two most appropriate respective areas of analysis. Values for debris removal and cleanup were assigned to structures based on type. To minimize the potential for overestimation of benefits, structures with values below $10,000 were not assigned values for debris removal and cleanup. Roads, highways, and railroads were identified using GIS and values for were assigned per mile for those transportation networks within the protected areas of the recommended plan in each of the three CSRMs. Values for these to benefit categories are shown in the tables below.

Table 2-36. Values for Debris Removal and Cleanup and Roads, Highways, and Railroads

Debris Removal and Cleanup	**$ per structure, $000s**
Mobile Home	$6.09
Single-Family Residence	$5.90
Multi-Family Residence	$10.68
Eating or Recreation Facility	$35.81
Professional Office	$37.04
Public or Semi-Public Facility	$37.04
Warehouse or Construction Facility	$65.69
Streets, Highways, and Railroads	**$ per mile, $000s**
Streets	$255.73
Major and Secondary Highways	$695.72
Railroad	$329.23

As a validity check for estimates to roads and highways, a comparison was done utilizing roads and highway constriction estimates from a report prepared for the Orange County Economic Development Corporation and the Texas Water Development Board titled *Flood Protection Planning Study, Hurricane Flood Protection System, Orange County, Texas* dated December 2012. Estimates were derived using the principle components of road construction, asphalt for minor roads, concrete for major roads such as interstate and state highways, converted into a common unit and then costs calculated per mile. These values are listed in the table below.

Table 2-37. Values for Major and Minor Roads and Highways Based Orange County EDC Report

Minor Roads		
Item Description	**$ per SF**	**$ per Mile (000s)**
Excavation	$0.03	$1.96
Embankment (minus Levee)	$0.06	$3.91

Lime Treatment (6" EXST Material)	$0.44	$28.16
Lime (6% volume)	$1.90	$120.30
8" Asphalt Base	$0.95	$60.15
3" Asphalt Surface	$1.27	$80.20
Swale*	$2.50	$13.20
Signing/Paving Marking*	$15.00	$79.20
Seeding/Sodding	$0.02	$1.02
Total		**$388.10**

Major Roads		
Excavation	$0.03	$2.93
Embankment (minus Levee)	$0.06	$5.87
Lime Treatment for Subgrade	$0.44	$42.24
Lime (6% volume)	$1.90	$180.46
10" Concrete Pavement	$7.22	$686.40
6" Concrete Curb*	$10.00	$52.80
Swale*	$2.50	$13.20
Signing/Paving Marking*	$15.00	$79.20
Seeding/Sodding	$0.02	$1.53
Total		**$1,064.62**

* priced per LF

While these values do not take into consideration depreciation, they are significantly higher than the estimates based on the Louisiana report. In this regard, the values used for the benefit estimation appear valid. Uncertainties for residential and commercial cleanup costs were estimated based on the same method utilizing coefficients of variation for the values themselves assuming a normal distribution while uncertainties for elevations were derived from those used for residential and averages of commercial structures. Uncertainties for highways, streets, and railroads were estimated only for elevation assuming a normal distribution and utilizing coefficients of variation. No uncertainties were estimated for the values themselves.

The following table displays the without and with- project EADs for the recommended plan.

Table 2-38. Without and With-Project Equivalent Annual Damages for the Recommended Plan
(FY 2017 Price Level/2.875 percent interest rate, $1,000)

Without Project

	Damage Categories									
Reach	**Commercial**	**Industrial**	**Multifamily**	**Mobile**	**Public**	**POV**	**SFR**	**Debris**	**Roads**	**Total**
Orange CSRM	5,108	105,374	457	306	1,758	3,367	24,479	1,665	20,229	162,742
Port Arthur CSRM	146,428	4,739	609	0	2,650	1,871	19,904	1,100	637	177,937
Freeport CSRM	5,142	268,742	1,436	3	8,143	4,843	14,238	2,318	2,806	307,670

With Project

	Damage Categories									
Reach	**Commercial**	**Industrial**	**Multifamily**	**Mobile**	**Public**	**POV**	**SFR**	**Debris**	**Roads**	**Total**
Orange CSRM	2,320	36,781	267	152	1,008	1,646	14,660	761	1,633	59,228
Port Arthur CSRM	33,923	1,325	0	161	622	438	4,816	258	149	41,692
Freeport CSRM	991	97,676	318	1	1,687	710	2,352	359	581	104,674

Without Project

	Damage Categories									
Reach	**Commercial**	**Industrial**	**Multifamily**	**Mobile**	**Public**	**POV**	**SFR**	**Debris**	**Roads**	**Total**
Orange CSRM	3%	65%	0%	0%	1%	2%	15%	1%	12%	100%
Port Arthur CSRM	82%	3%	0%	0%	1%	1%	11%	1%	0%	100%
Freeport CSRM	2%	87%	0%	0%	3%	2%	5%	1%	1%	100%

With Project

	Damage Categories									
Reach	**Commercial**	**Industrial**	**Multifamily**	**Mobile**	**Public**	**POV**	**SFR**	**Debris**	**Roads**	**Total**
Orange CSRM	4%	62%	0%	0%	2%	3%	25%	1%	3%	100%
Port Arthur CSRM	81%	3%	0%	0%	1%	1%	12%	1%	0%	100%
Freeport CSRM	1%	93%	0%	0%	2%	1%	2%	0%	1%	100%

Table 2-39. Economic Performance of Recommended Plan
(50-Year Intermediate RSLC Scenario)
(FY 2017 Price Level/2.875 percent interest rate)

	Orange 11 - Foot	Freeport NF + 1 Foot	Port Arthur NF + 1 Foot	Combined
INVESTMENT				
Estimated First Cost	**$1,926,224,000**	**$593,313,000**	**$729,069,000**	**$3,248,606,000**
Annual Interest Rate	2.875%	2.875%	2.875%	2.875%
Project Life (years)	50	50	50	50
Construction Period (months)	120	72	72	120
Interest During Construction	$269,306,000	$44,315,000	$54,454,000	$368,075,000
Investment Cost	$2,195,530,000	$637,628,000	$783,523,000	$3,616,681,000
Interest	$63,121,000	$18,332,000	$22,526,000	$103,980,000
Amortization	$20,195,000	$5,865,000	$7,207,000	$33,267,000
OMRR&R ($/year)	$4,565,000	$708,000	$195,000	$5,467,000
TOTAL ANNUAL COSTS	**$87,881,000**	**$24,904,000**	**$29,928,000**	**$142,713,000**
Without Project EAD	$162,742,000	$307,670,000	$177,937,000	$648,349,000
Residual EAD	$59,228,000	$104,674,000	$41,692,000	$205,594,000
Storm Reduction Benefits	$103,515,000	$202,995,000	$136,246,000	$442,756,000
TOTAL BENEFITS	**$103,515,000**	**$202,995,000**	**$136,246,000**	**$442,756,000**
NET BENEFITS	**$15,634,000**	**$178,091,000**	**$106,318,000**	**$300,043,000**
BENEFIT-COST RATIO	**1.2**	**8.2**	**4.6**	**3.1**

The Orange CSRM recommended plan is a combination of levees and floodwalls designed to reduce the flood-damage potential from storm surge to much of the southern half of Orange County along the Sabine River and Bessie Heights Marsh. The plan consists of 82,169 LF of earthen levee and 56,755 LF of floodwall. The plan also calls for the inclusion of seven pump stations, 56 drainage structures, and 32 closure gates. First costs for this plan at the Orange CSRM reach are $1,926.224 million which annualizes to $87.881 million and produces $103.515 million in benefits with $15.634 million in net benefits for a 1.2 benefit-to-cost ratio.

The recommended plan for the Freeport and Vicinity CSRM consists of the construction of floodwalls, raising of levees, replacement of vehicular closure structures, and constructing a navigable gate structure in an active barge canal. Several sections of floodwall and levee require raising due in order to increase system capacity to prevent system failure. The plan consists of 69,375 LF of earthen levee and 29,205 LF of floodwall. The plan also includes four drainage structures, and ten closure gates. First costs for this plan at this CSRM is $593.313 million which annualizes to $24.904 million and produces $202.995 million in benefits with $178.091 million in net benefits for an 8.2 benefit-to-cost ratio.

The recommended plan for the Port Arthur and Vicinity CSRM consists of the construction of floodwalls, raising of levees, and replacement of vehicular closure structures. Several sections of floodwall and levee require raising due in order to increase system capacity to prevent system failure. The plan consists of 31,030 LF of earthen levee and 30,090 LF of floodwall. The plan also includes 26 closure gates. First costs for this plan at this CSRM is $729.069 million which annualizes to $29.928 million and produces $136.246 million in benefits with $106.318 million in net benefits for a 4.6 benefit-to-cost ratio. The following summarizes each of the CSRMs with their respective alternatives with the highest net benefits to be included as the recommended plan.

Estimates for OMRR&R received from Cost Engineering generally reflects an even stream of expenditures over the life of the project. For each of the CSRMs grassed levees will have to be regularly mowed and the floodwalls and gate structures routinely maintained. Occasional maintenance and repairs of the roadway on the levee crown will also be required. Due to the gate structures at the Orange CSRM, annual expenditures for OMRR&R spike one year per decade due to significant replacements. OMRR&R expenditures for the existing CSRMs at Freeport and Port Arthur spike as well but at much smaller magnitudes. Annual OMRR&R expenditures are therefore averaged over for the life of the project. OMRR&R estimates for the existing Port Arthur and Freeport CSRMs reflect the additional costs necessary for any potential improvements to the systems above what is currently need to operate and maintain the systems. These costs are depicted in Table 2-39.

Orange CSRM

- Orange 3 New Levee – 11-Foot Levee/Floodwall

Port Arthur and Vicinity CSRM

- 8-10 ft I-Wall Raise (1-Foot)
- Closure Structure Raise (1-Foot)
- I-Wall Raise Near Valero (1-Foot)
- I-Wall Raise Near Tank Farm (1-Foot)

Freeport and Vicinity CSRM

- Dow Barge Canal Gate Structure
- Oyster Creek Levee Raise (1-Foot)
- East Storm Levee Raise (1-Foot)
- Freeport Dock No Fail
- Old River Levee Raise at Dow Thumb (1-Foot)
- Tide Gate I-Wall Raise (1-Foot)

Table 2-40. Interest During Construction for the Recommended Plan
(FY 2017 Price Level/2.875 percent interest rate)

		Orange			Freeport			Port Arthur		
	Calendar Year	Construction Total	Compounded Value	Compound Factor	Construction Total	Compounded Value	Compound Factor	Construction Total	Compounded Value	Compound Factor
Base Year	2030	$192,622,000	$248,597,000	1.2906	$98,886,000	$113,941,000	1.1523	$121,512,000	$140,012,000	1.1523
	2031	$192,622,000	$241,649,000	1.2545	$98,886,000	$110,757,000	1.1201	$121,512,000	$136,100,000	1.1201
	2032	$192,622,000	$234,896,000	1.2195	$98,886,000	$107,662,000	1.0888	$121,512,000	$132,296,000	1.0888
	2033	$192,622,000	$228,332,000	1.1854	$98,886,000	$104,653,000	1.0583	$121,512,000	$128,599,000	1.0583
	2034	$192,622,000	$221,950,000	1.1523	$98,886,000	$101,728,000	1.0288	$121,512,000	$125,005,000	1.0288
	2035	$192,622,000	$215,748,000	1.1201	$98,886,000	$98,886,000	1.0000	$121,512,000	$121,512,000	1.0000
	2036	$192,622,000	$209,718,000	1.0888	0	0	0	0	0	0
	2037	$192,622,000	$203,857,000	1.0583	0	0	0	0	0	0
	2038	$192,622,000	$198,160,000	1.0288	0	0	0	0	0	0
	2039	$192,622,000	$192,622,000	1.0000	0	0	0	0	0	0
Total		$1,926,224,000	$2,195,530,000		$593,313,000	$637,628,000		$729,069,000	$783,523,000	

Summary	Orange	Freeport	Port Arthur
Implementation Costs:	$1,926,224,000	$593,313,000	$729,069,000
Interest During Construction:	$269,306,000	$44,315,000	$54,454,000
Total Construction Costs:	$2,195,530,000	$637,628,000	$783,523,000

Table 2-41. Probability Distribution
(FY 2017 Price Level/2.875 percent interest rate)

		Probability Damage Reduced Exceeds Indicated Values		
CSRM	**Equivalent Annual Damages Reduced (2017 prices)**	**0.75**	**0.50**	**0.25**
Orange	$103,515,000	$43,339,000	$98,190,000	$142,736,000
Freeport	$202,995,000	$23,064,000	$116,158,000	$316,250,000
Port Arthur	$136,246,000	$21,931,000	$27,002,000	$193,941,000

The evaluation incorporated uncertainty surrounding the economic and engineering inputs to generate results that can be used to assess the performance of the Recommended Plan. The percentiles displayed in Table 2-41 reflect the percentage chance that benefits may be greater than or equal to the indicated values. The probability distribution for expected and equivalent annual damages would typically be expected to follow a generally normal bell-shaped distribution with minimal skewing particularly for non-structural or where new structural measures are being proposed. This is case when observing the distribution for damages reduced for the Orange CSRM. For areas that are protected by existing systems, damages will tend to start at much less frequent events and can therefore tend to skew the probability distributions. This is the case for both the Freeport and Port Arthur CSRMs. Significant without-project damages for the Orange CSRM begin at around the 0.075 ACE (13-year event) and do not begin again until the 0.01 ACE (100-year event) under the proposed with-project condition. The distribution is somewhat skewed for the Freeport CSRM No without-project damages occur until approximately the 0.1 ACE (10-year event) and do not begin until the 0.01 ACE (100-year event). The probability distribution is extremely skewed for the Port Arthur CSRM due to no without-project damages starting until the 0.007 ACE (143 year-event) and with-project damages not beginning until the highest model water surface elevation at 0.001 ACE (1,000-year event).

2.11 CRITICAL INFRASTRUCTURE

The following describes the existing critical infrastructure in each project area. Critical infrastructure listed here includes industrial and manufacturing facilities as well as public facilities. This is a qualitative discussion of the future without-project condition focused on the impacts associated with potential storm surge flooding. The inventory of critical infrastructure came from information derived from the Homeland Security Infrastructure Program (HSIP), an infrastructure geospatial data inventory. The critical infrastructure is reported for the project areas by type (school, chemical manufacturing, etc.). A North American Industry Classification System (NAICS) code is included in the full listing of the inventory is at the end of this appendix. The

project areas are listed by county; Orange-Jefferson CSRM includes Orange and Jefferson County; Port Arthur and Vicinity CSRM includes Jefferson County; Freeport includes Brazoria County.

Orange CSRM (Orange County)

Public Facilities – Orange County

- 20 Schools
- 14 Law enforcement
- 2 Hospitals/6 nursing homes
- 11 Fire stations

Industrial and Manufacturing – Orange County

- 20 Chemical manufacturing
- 5 Electric generation
- 0 Petroleum refining
- 1 Airport

Some of the significant industrial and manufacturing facilities located in Orange-Jefferson CSRM include Exxon Mobil, DuPont, Honeywell, Firestone, Petrochemical, Chevron, Phillips, Laxness, Solvay Solexis, and Entergy. Exxon Mobil, located in Beaumont, Texas, on the Neches River, processes 345,000 barrels of crude oil per day and produces 2.5 billion gallons of gasoline annually.

Port Arthur and Vicinity CSRM (Jefferson County)

Public Facilities – Jefferson County

- 42 Schools
- 19 Law enforcement
- 13 Hospitals/7 nursing homes
- 26 Fire stations

Industrial and Manufacturing – Jefferson County

- 54 Chemical manufacturing
- 1 Electric generation
- Petroleum refining
- 1 Airport

Significant industrial and manufacturing facilities located in the Port Arthur and Vicinity CSRM include Valero, Premcor, Total, Motiva Enterprises and Huntsman Petrochemical. Jack Brooks

Regional Airport is also in the project area. Motiva is the largest petroleum refinery in the United States, with a capacity of approximately 600,000 barrels of crude oil per day.

Freeport and Vicinity CSRM (Brazoria County)

Public Facilities – Brazoria County

- 6 Schools
- 3 Law enforcement
- 0 Hospitals/0 nursing homes
- 2 Fire stations

Industrial and Manufacturing – Brazoria County

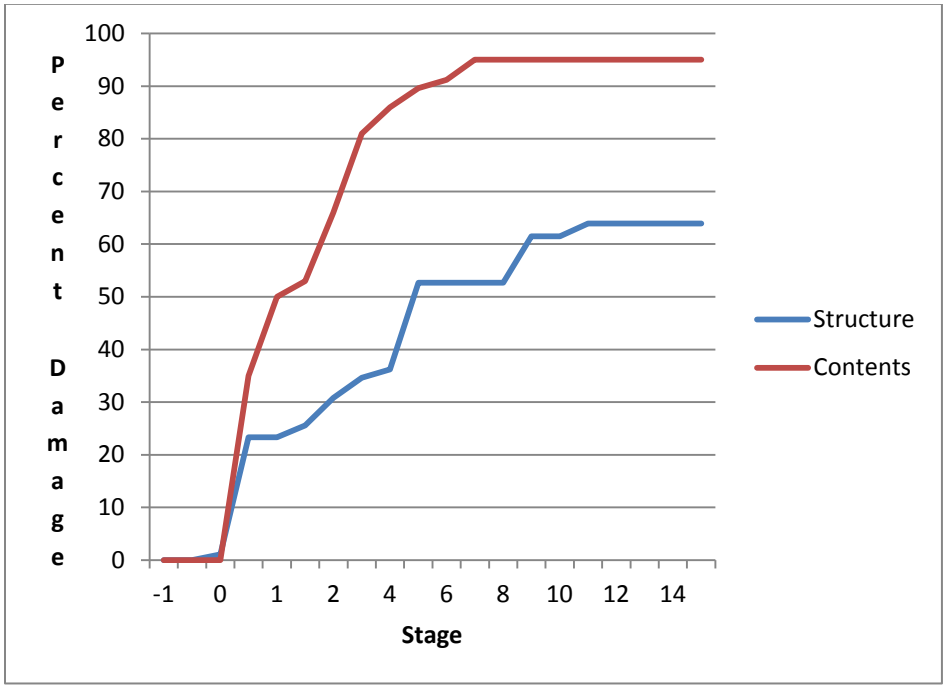
- 24 Chemical manufacturing
- 0 Electric generation
- 0 Petroleum refining

Significant industrial and manufacturing facilities located in the Freeport and Vicinity CSRM include Petroleum Reserve, Dow Chemical, Freeport LNG, Huntsman Gulf Chemicals, Phillips 66 Liquefied Petroleum Gas (LPG) Terminal, SI Group, and NALCO. A detailed description of each critical facility is not provided here; however, to explain one in some detail, Dow Chemical is the largest integrated chemical manufacturing complex in the western hemisphere. The Freeport site produces 44 percent of Dow's products sold in the U.S. and 20 percent of the company's products sold globally. A listing of these facilities is located at the end of this appendix.

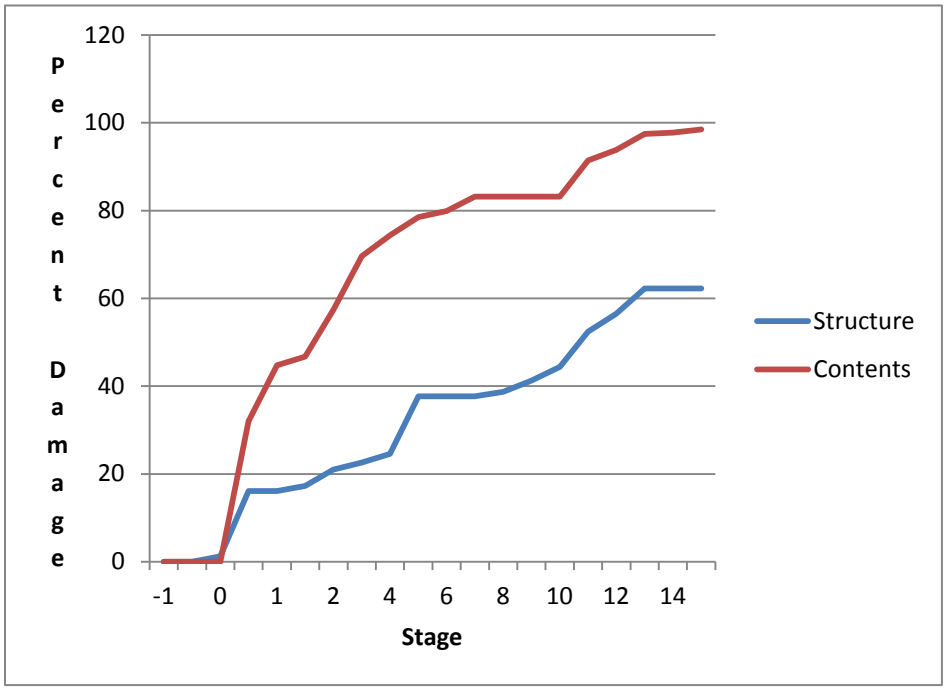
2.12 DEPTH DAMAGE FUNCTIONS

All depth-damage functions were obtained from the New Orleans District as part of their *Lower Atchafalaya and Morganza to the Gulf, Louisiana, Feasibility Study* with the exception of automobiles which are based on EGM, 09-04, *Generic Depth-Damage Relationships for Vehicles.*

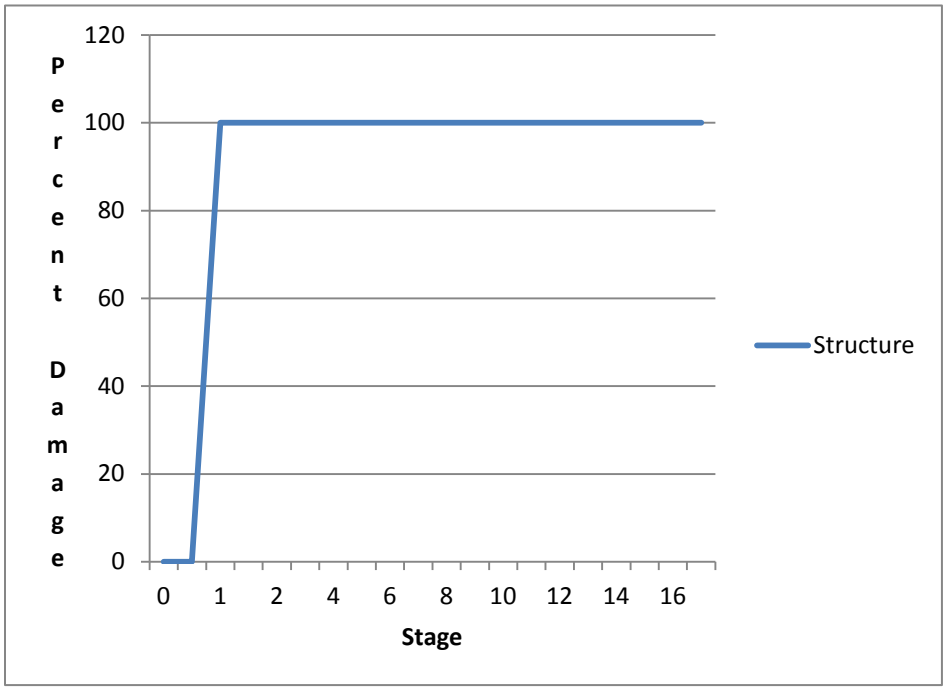
One Story Residence – Slab Foundation



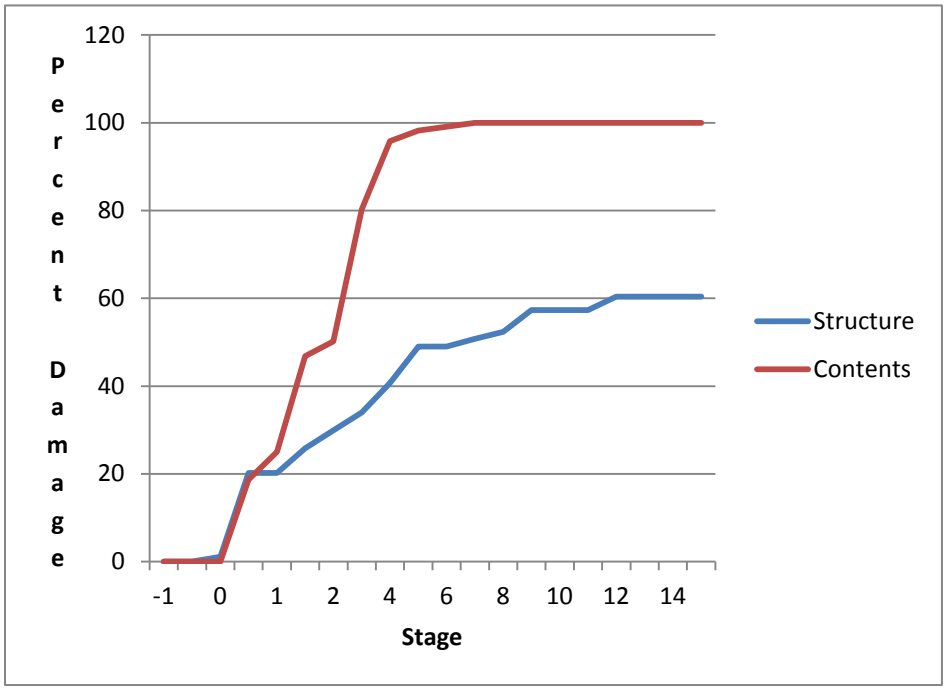
Two Story Residences – Slab Foundation



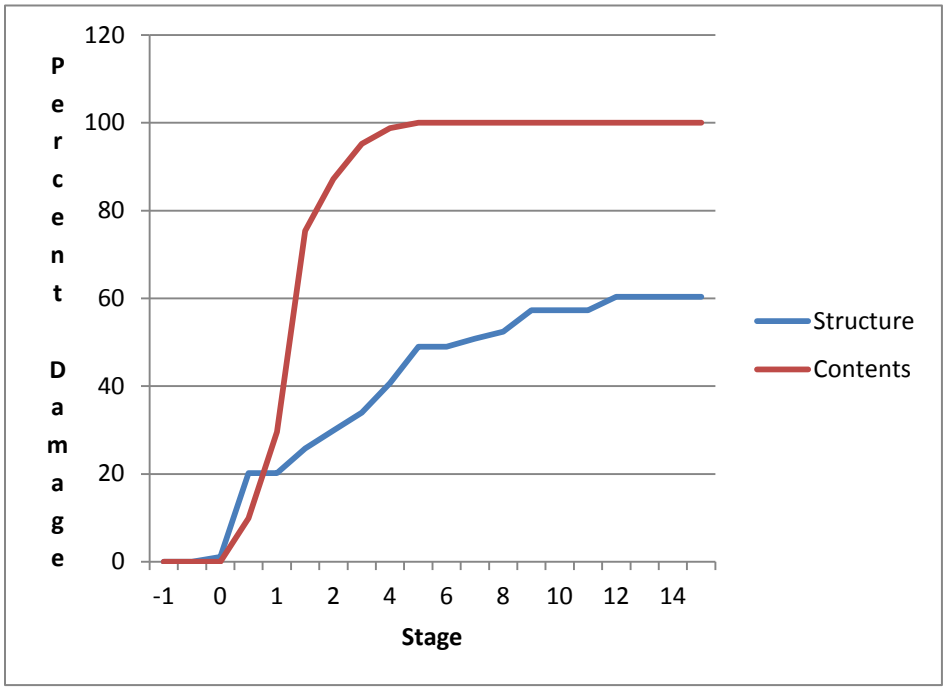
Autos



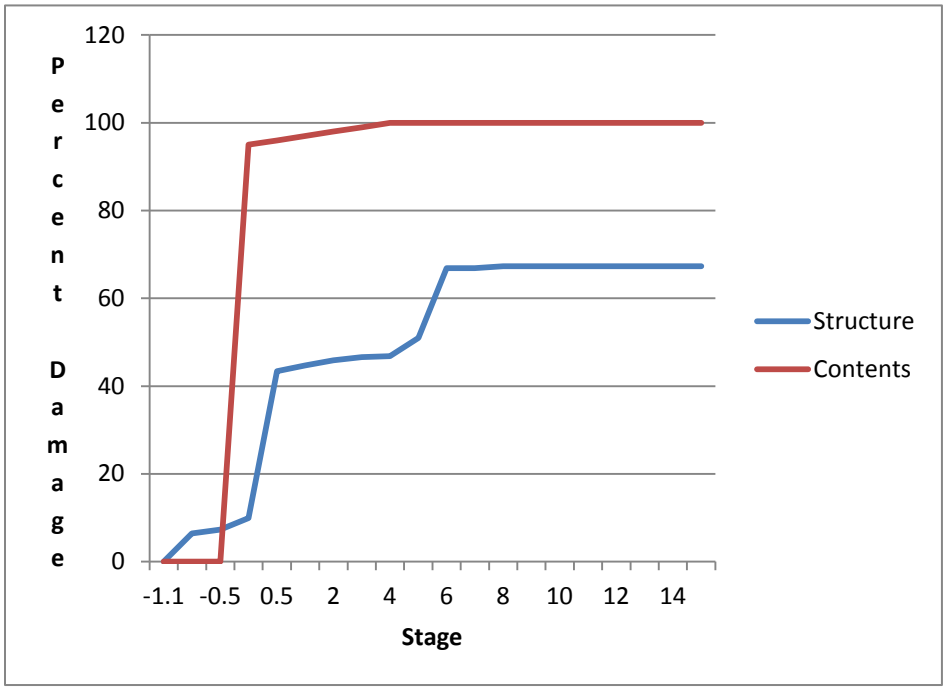
Eating Establishments



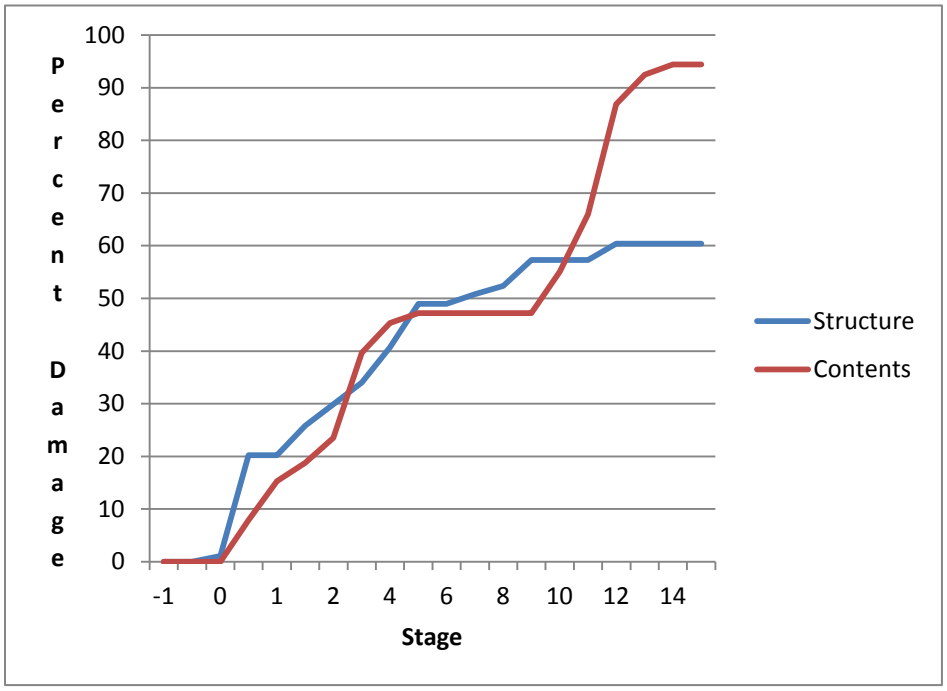
Grocery Stores



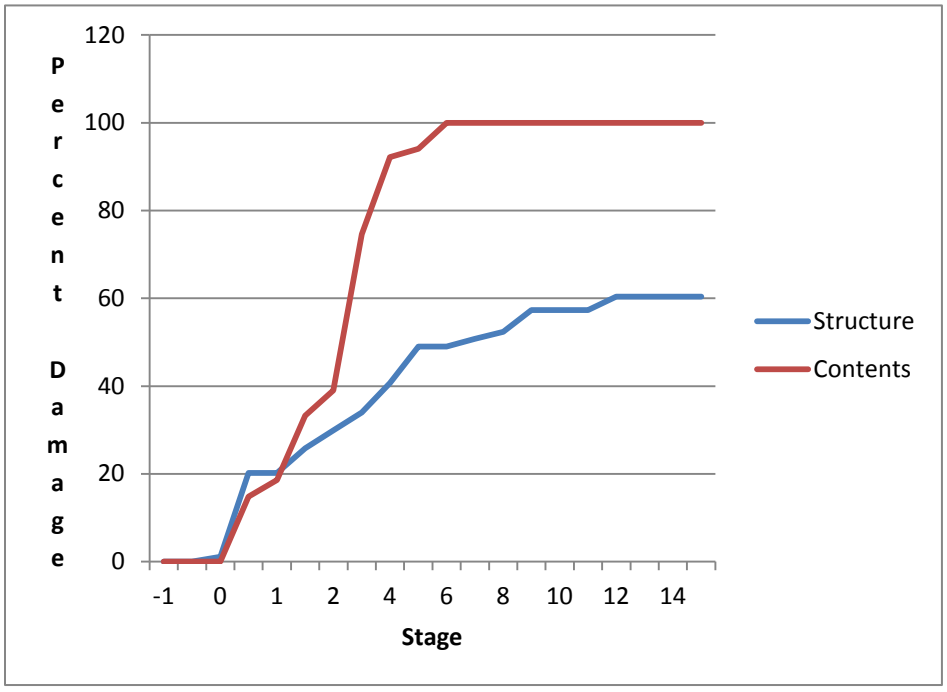
Mobile Residence



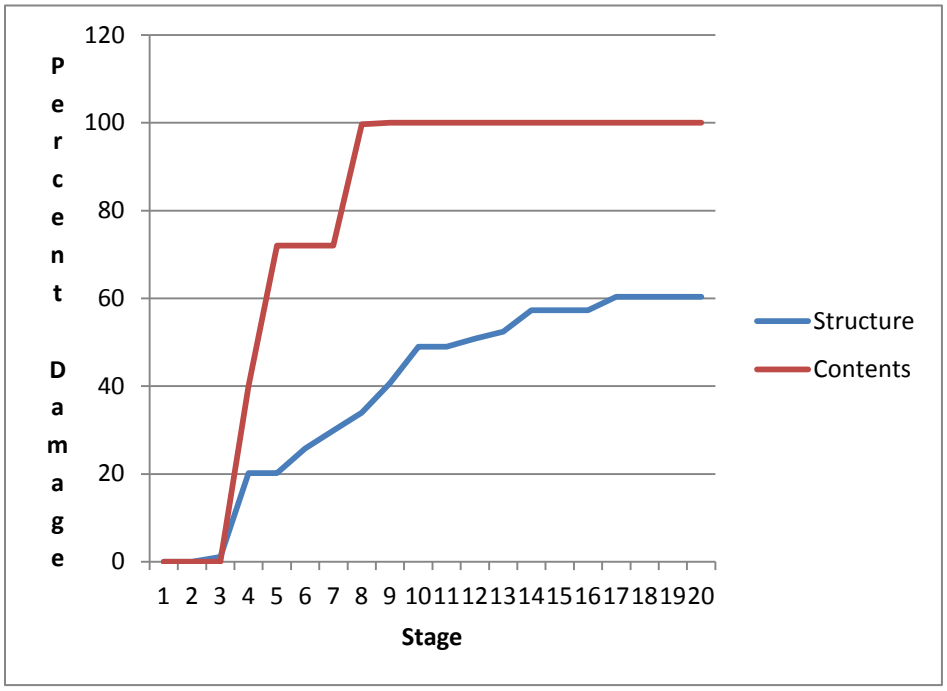
Multi-Family Residence



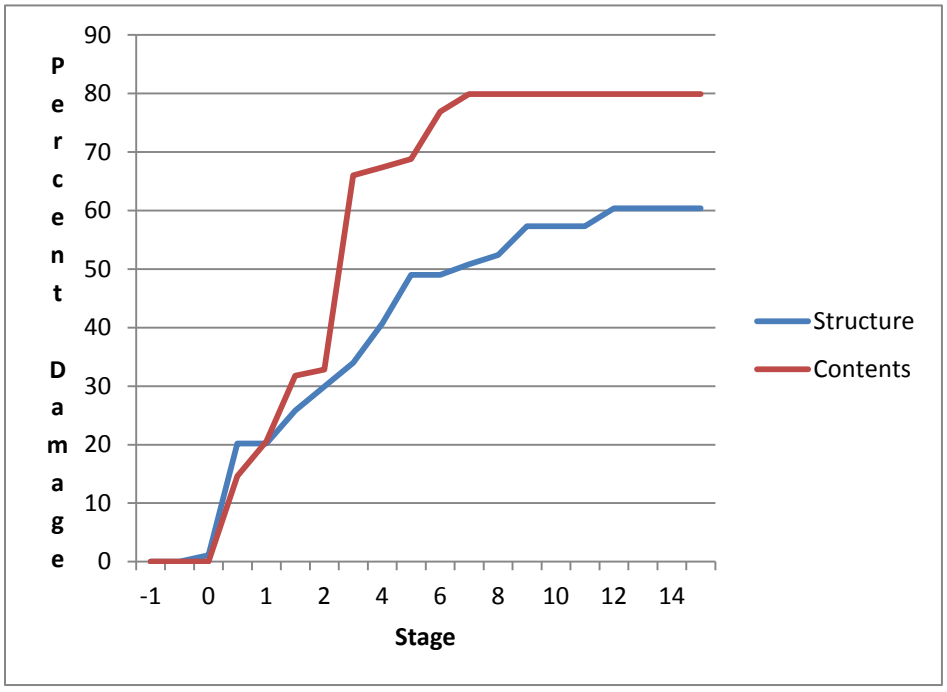
Professional Buildings



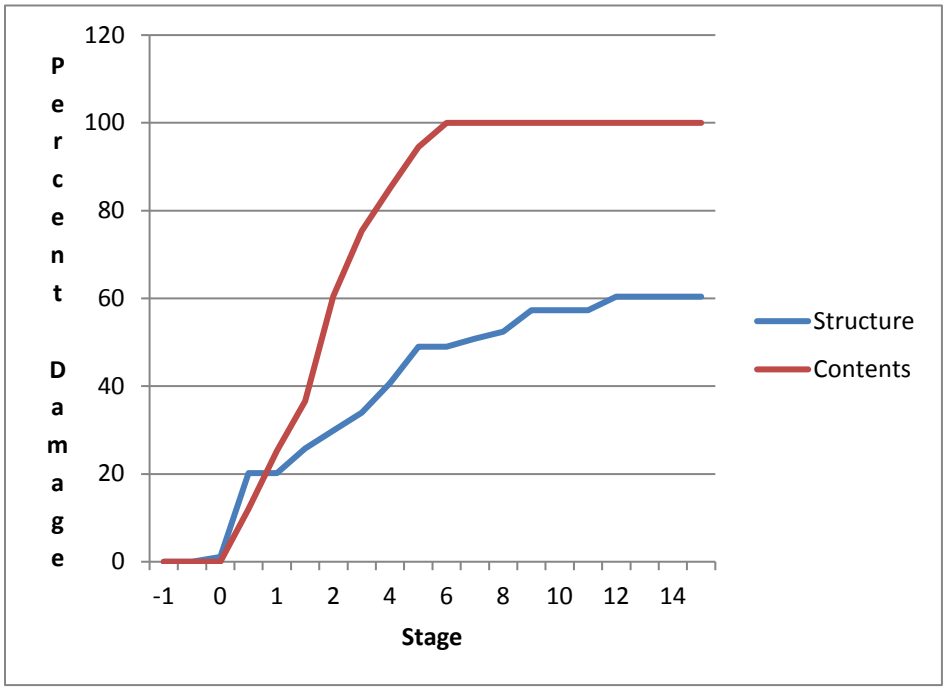
Public Buildings



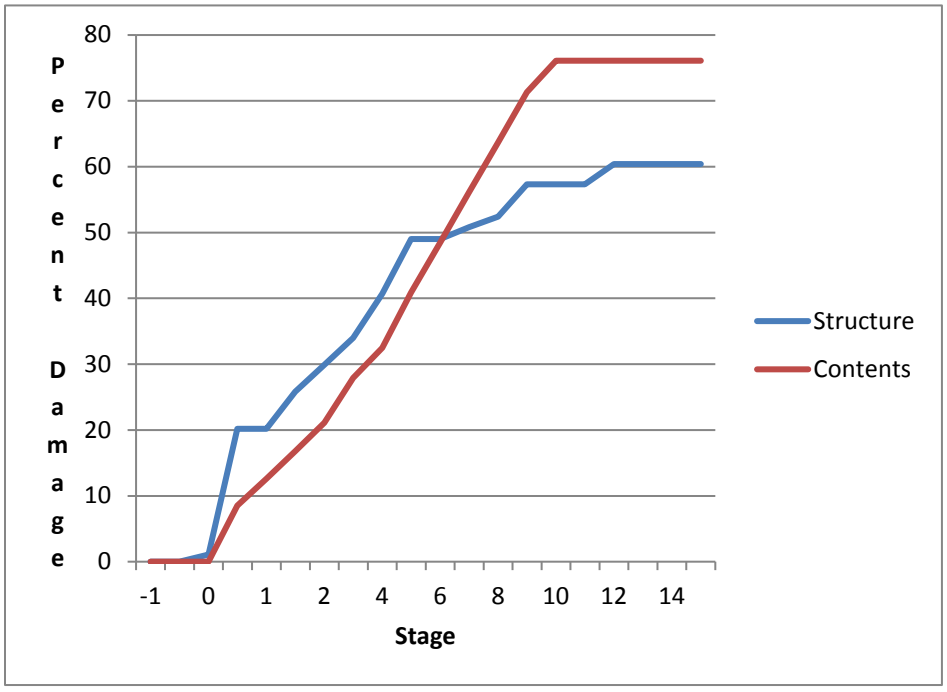
Repair



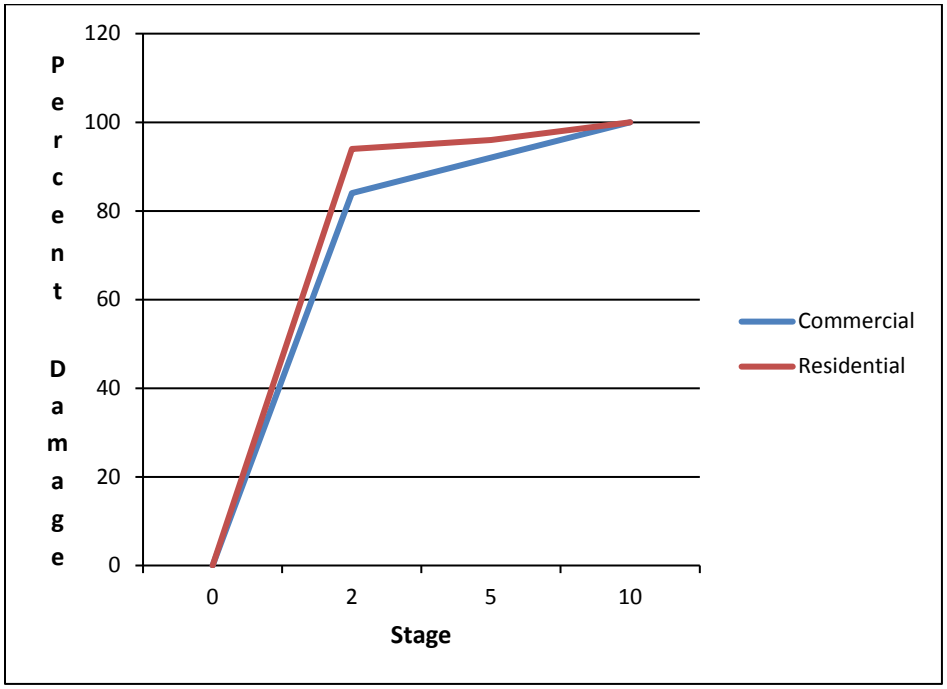
Retail



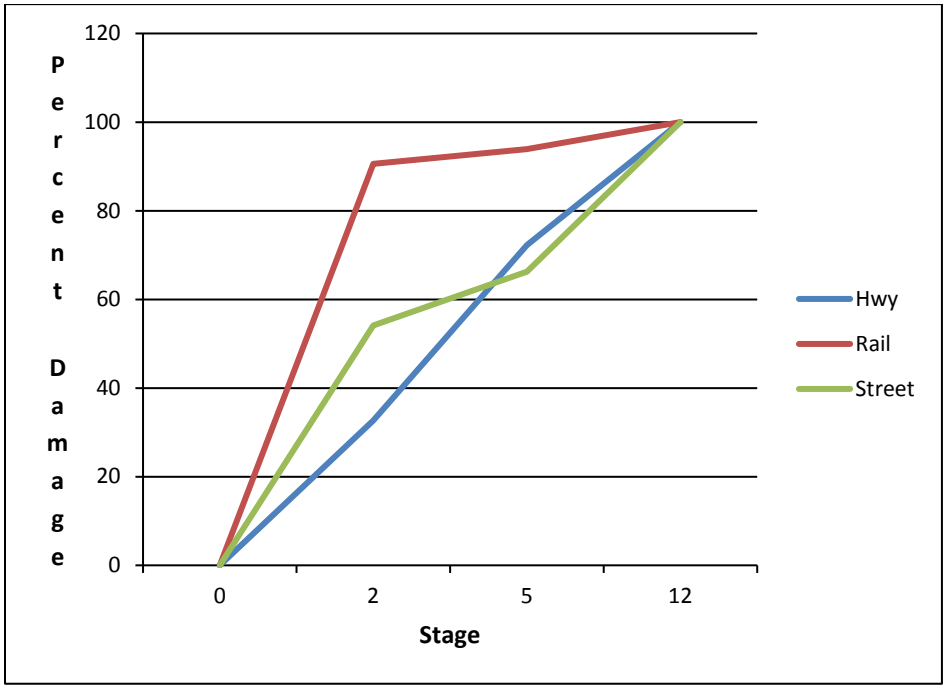
Warehouse



Debris Cleanup



Roads



2.13 LISTING OF CRITICAL INFRASTRUCTURE BY COUNTY

2.13.1 Orange

Chemical Manufacturing		
Business Name	**City**	**NAICS Category**
DuPont Sabine River Works	Orange	Pesticide and Other Agricultural Chemical Manufacturing
Solvay America Inc.	Orange	All Other Basic Inorganic Chemical Manufacturing
Latex Supply Inc.	Orange	All Other Basic Inorganic Chemical Manufacturing
Red Bird Supply, Inc.	Orange	Soap and Other Detergent Manufacturing
A Schulman Inc.	Orange	Plastics Material and Resin Manufacturing
Alloy Polymers, Inc.	Orange	Plastics Material and Resin Manufacturing
Clark & Company Inc.	Orange	All Other Basic Inorganic Chemical Manufacturing
Bourg Distributing Inc.	Bridge City	Polish and Other Sanitation Good Manufacturing
Hyett Manufacturing and Instrument Company, Inc.	Bridge City	All Other Basic Inorganic Chemical Manufacturing
Chevron Phillips Chemical Company LP	Orange	Plastics Material and Resin Manufacturing
Fine Line Colognes	Orange	Toilet Preparation Manufacturing
Lanxess Corporation Rubber Division	Orange	Synthetic Rubber Manufacturing
Invista S.A.R.L.	West Orange	Plastics Material and Resin Manufacturing
Chem32 LLC	West Orange	All Other Basic Inorganic Chemical Manufacturing
E. I. DuPont De Nemours and Company	Orange	Plastics Material and Resin Manufacturing
Nitrogen National	Orange	Industrial Gas Manufacturing
Lanxess Corp	Orange	All Other Basic Organic Chemical Manufacturing
Invista Capital Management, LLC	Orange	All Other Basic Organic Chemical Manufacturing
Invista S.A.R.L.	Orange	Plastics Material and Resin Manufacturing
Chevron Phillips Chemical Company LP	Orange	Plastics Material and Resin Manufacturing
Electric Generation		
Engineered Carbons Echo Cogeneration	Little Cypress	
Entergy Texas	Bridge City	
AirLiquide - Sabine Cogeneration LP	West Orange	
DuPont - Sabine River Works	West Orange	
SRW Cogeneration	West Orange	
Hospitals		
Harbor Hospital of Southeast Texas	Orange	

Memorial Hermann Baptist Orange Hospital	Orange
Nursing Homes	
Golden Years Assisted Living	Orange
Orange Villa Nursing and Rehabilitation	Orange
Pinehurst Nursing and Rehabilitation	Orange
Sabine House	Orange
The Meadows of Orange	Orange
Answered Prayer	Orange
Schools	
Little Cypress Jr. High	Orange
Bridge City High School	Bridge City
Bridge City Middle School	Bridge City
Little Cypress-Mauriceville High School	Orange
Little Cypress Elementary School	Orange
Little Cypress Intermediate	Orange
Oak Forest Elementary	Vidor
Vidor Middle School	Vidor
West Orange-Stark Elementary	Orange
West Orange-Stark Middle School	Orange
West Orange-Stark High School	Orange
North Early Learning Center	Orange
Orangefield Elementary	Orangefield
Orangefield High School	Orangefield
Orangefield Jr. High	Orangefield
Hatton Elementary	Bridge City
Bridge City Elementary	Bridge City
Bridge City Intermediate	Bridge City
OISD DAEP	Bridge City
Tekeo Academy of Accelerated Studies	Orange
Law Enforcement	
Orange County Sheriff Dept./Orange County Jail	Orange
Bridge City ISD Police Dept.	Bridge City
Orange Police Dept.	Orange
Rose City Police Dept.	Rose City
Vidor ISD Police Dept.	Vidor
Pine Forest Police Dept.	Vidor
Pinehurst Police Dept.	Orange
Vidor Police Dept.	Vidor
West Orange Police Dept.	Orange
Bridge City Police Dept.	Bridge City
Orange County Constable - Precinct 1	Orange
Orange County Constable - Precinct 2	Orange
Orange County Constable - Precinct 3	Orange

Orange County Constable - Precinct 4	Vidor
Fire Departments	
Bridge City Volunteer Fire and Rescue - Orangefield Station	Orange
Orange County Emergency Services District Station 1	Vidor
Orange County Emergency Services District Station 2	Vidor
Pinehurst Volunteer Fire Dept.	Orange
West Orange Volunteer Fire Dept.	West Orange
Little Cypress Fire and Rescue Station 1	Orange
Bridge City Volunteer Fire and Rescue	Bridge City
McLewis Volunteer Fire Dept.	Orange
City of Orange Fire Dept. Station 1	Orange
City of Orange Fire Dept. Station 2	Orange
City of Orange Fire Dept. Station 3	Orange
Airport	
Orange County Airport	Orange

2.13.2 Jefferson

Chemical Manufacturing		
Business Name	**City**	**NAICS Category**
Air Liquide America L.P.	Port Neches	Industrial Gas Manufacturing
Air Liquide America L.P.	Beaumont	Industrial Gas Manufacturing
Air Liquide Industrial U.S. LP	Nederland	Industrial Gas Manufacturing
Air Products and Chemicals, Inc.	Port Arthur	Industrial Gas Manufacturing
Arkema, Inc.	Beaumont	All Other Basic Inorganic Chemical Manufacturing
Ashland Elastomers LLC	Port Neches	Synthetic Rubber Manufacturing
Ashland Inc.	Port Neches	All Other Basic Organic Chemical Manufacturing
BASF Petro Chemicals	Port Arthur	All Other Miscellaneous Chemical Product and Preparation Manufacturing
BASF Petro Chemicals	Port Arthur	All Other Miscellaneous Chemical Product and Preparation Manufacturing
BASF Corporation	Beaumont	All Other Basic Organic Chemical Manufacturing
BASF Corporation	Port Arthur	All Other Basic Organic Chemical Manufacturing
Brock Specialty Services, Ltd.	Beaumont	All Other Basic Inorganic Chemical Manufacturing
Calabrian Corporation	Port Neches	All Other Basic Organic Chemical Manufacturing

Chemical Manufacturing		
Business Name	**City**	**NAICS Category**
Chemtrade Refinery Services Inc.	Beaumont	All Other Basic Inorganic Chemical Manufacturing
Chemtreat, Inc.	Nederland	All Other Miscellaneous Chemical Product and Preparation Manufacturing
Chevron Phillips Chemical Company LP	Port Arthur	All Other Miscellaneous Chemical Product and Preparation Manufacturing
DuPont Performance Elastomers L.L.C.	Nederland	Synthetic Rubber Manufacturing
Elegant Designer Essences	Port Arthur	Toilet Preparation Manufacturing
Elixir Incense	Port Arthur	All Other Miscellaneous Chemical Product and Preparation Manufacturing
Ethyl Additives Corporation	Port Arthur	All Other Basic Organic Chemical Manufacturing
Faubion Veterinary Clinic	Nederland	Pharmaceutical Preparation Manufacturing
Flint Hills Resources Port Arthur LLC	Port Arthur	All Other Basic Organic Chemical Manufacturing
G V C Holdings Inc.	Port Neches	Synthetic Rubber Manufacturing
Huntsman Corporation	Port Neches	Plastics Material and Resin Manufacturing
In Your Element Photography	Port Neches	All Other Basic Inorganic Chemical Manufacturing
Ineos Americas LLC	Port Arthur	All Other Miscellaneous Chemical Product and Preparation Manufacturing
J & M Resources	Port Arthur	Toilet Preparation Manufacturing
J F D Enterprises, Inc.	Groves	Toilet Preparation Manufacturing
Kbr Technical Services, Inc.	Beaumont	All Other Miscellaneous Chemical Product and Preparation Manufacturing
Kmtex	Port Arthur	All Other Basic Inorganic Chemical Manufacturing
La Designs	Port Arthur	Toilet Preparation Manufacturing
Nature's Secret	Port Arthur	Medicinal and Botanical Manufacturing
Neo Fuels	Port Arthur	Petrochemical Manufacturing
Oci Partners LP	Nederland	Cyclic Crude, Intermediate, and Gum and Wood Chemical Manufacturing
Pd Glycol LP	Beaumont	Plastics Material and Resin Manufacturing
Penny's Style	Port Arthur	Toilet Preparation Manufacturing
Perfume Palace	Port Arthur	Toilet Preparation Manufacturing
Praxair, Inc.	Groves	Industrial Gas Manufacturing
Pro Star Industries, Inc.	Port Arthur	Polish and Other Sanitation Good Manufacturing
Rbf Port Neches LLC	Port Neches	Petrochemical Manufacturing
Reliable Polymer Services, LP	Port Arthur	Synthetic Rubber Manufacturing
Sally Beauty Supply LLC	Port Arthur	Toilet Preparation Manufacturing
Savage Services Corporation	Port Arthur	All Other Basic Inorganic Chemical Manufacturing

Chemical Manufacturing		
Business Name	**City**	**NAICS Category**
Scan Tech, Inc.	Nederland	All Other Miscellaneous Chemical Product and Preparation Manufacturing
Service Offshore, Inc.	Beaumont	Paint and Coating Manufacturing
Smith and Thome Cardiovascular Consultants, L.L.P.	Port Arthur	Pharmaceutical Preparation Manufacturing
Sophia's International LLC	Port Neches	Toilet Preparation Manufacturing
Sunrose Scents	Nederland	Toilet Preparation Manufacturing
Texas Brine Company LLC	Beaumont	All Other Basic Inorganic Chemical Manufacturing
Texas Petrochemicals LP	Port Neches	All Other Basic Organic Chemical Manufacturing
Texas Petrochemicals LP	Port Neches	All Other Basic Organic Chemical Manufacturing
The Chemours Company Fc LLC	Beaumont	Synthetic Rubber Manufacturing
The Valspar Corporation	Beaumont	Paint and Coating Manufacturing
Worldwide Sorbent Products, Inc.	Port Arthur	Plastics Material and Resin Manufacturing
Petroleum Refining		
Exxon Mobil Refining & Supply Co.	Beaumont	
Total Petrochemicals Inc.	Port Arthur	
Motiva Enterprises LLC	Port Arthur	
Premcor Refining Group	Port Arthur	
Valero Refining Co.	Port Arthur	
Electric Generation	**City**	
JCO Oxides Olefins Plant	Port Neches	
Entergy Texas	Beaumont	
Public Schools	**City**	
Al Price State Juvenile Correctional Facility	Beaumont	
Jefferson County Youth Academy	Beaumont	
Preschool Center	Groves	
Groves Elementary	Groves	
Groves Middle School	Groves	
Van Buren Elementary	Groves	
Highland Park Elementary	Nederland	
Nederland High School	Nederland	
Alternative Education School	Nederland	
Helena Park Elementary	Nederland	
Hillcrest Elementary	Nederland	
Lanham Elementary	Nederland	
Central Middle School	Nederland	
Wilson Middle School	Nederland	
Dowling Elementary	Port Arthur	
Houston Elementary	Port Arthur	

Chemical Manufacturing		
Business Name	**City**	**NAICS Category**
Port Arthur Alternative Center	Port Arthur	
Stilwell Tech Center	Port Arthur	
Memorial High School	Port Arthur	
Tekeo Academy of Accelerated Studies	Port Arthur	
DeQueen Elementary	Port Arthur	
Jefferson Middle School	Port Arthur	
Lee Elementary	Port Arthur	
Travis Elementary	Port Arthur	
Tyrrell Elementary	Port Arthur	
Wheatley School Of Early Childhood Programs	Port Arthur	
Lincoln Middle School	Port Arthur	
Taft Elementary	Port Arthur	
Austin Middle School	Port Arthur	
Tekeo Academy of Accelerated Studies	Port Arthur	
Tekeo Academy of Accelerated Studies	Port Arthur	
Bob Hope School	Port Arthur	
Performing Arts School Of Technology	Port Arthur	
Staff Sergeant Lucien Adams Elementary	Port Arthur	
Washington Elementary	Port Arthur	
Memorial 9th Grade Academy at Austin	Port Arthur	
Woodcrest Elementary	Port Neches	
Port Neches Elementary	Port Neches	
Port Neches Middle School	Port Neches	
Port Neches-Groves High School	Port Neches	
Ridgewood Elementary	Port Neches	
Alter School	Port Neches	
Nursing Homes	**City**	
Gulf Healthcare Center	Port Arthur	
Magnolia Manor	Groves	
Oak Grove Nursing Home	Groves	
Senior Rehabilitation and Skilled Nursing Center	Port Arthur	
Cypress Glen East Nursing and Rehabilitation	Port Arthur	
Cypress Glen Nursing and Rehabilitation	Port Arthur	
Rose House	Port Arthur	
Hospitals	**City**	
Beaumont Bone and Joint Institute	Beaumont	
Christus Spohn Hospital - Saint Elizabeth	Beaumont	
Christus Spohn Hospital - Saint Mary	Port Arthur	
Dubuis Hospital of Beaumont	Beaumont	
Dubuis Hospital of Port Arthur	Port Arthur	

Chemical Manufacturing		
Business Name	**City**	**NAICS Category**
HealthSouth Rehabilitation Hospital - Beaumont	Beaumont	
Kate Dishman Rehabilitation Hospital	Beaumont	
Memorial Hermann Baptist Hospital	Beaumont	
Memorial Hermann Baptist Hospital - Behavioral Health Center	Beaumont	
Mid-Jefferson Extended Care Hospital	Nederland	
Promise Hospital of Southeast Texas	Nederland	
Renaissance Hospital - Groves	Groves	
The Medical Center of Southeast Texas	Port Arthur	
Law Enforcement	**City**	
Lamar University Police Dept.	Beaumont	
Beaumont Police Dept.	Beaumont	
Groves Police Dept.	Groves	
Port of Beaumont Port Authority Police Dept.	Beaumont	
Port Neches Police Department	Port Neches	
Bureau of Alcohol Tobacco & Firearms - Beaumont Field Office	Beaumont	
US Customs and Border Protection - Port of Entry - Port Arthur	Port Arthur	
Port Arthur Police Dept.	Port Arthur	
Jefferson County Sheriff's Office	Beaumont	
Beaumont ISD Police Dept.	Beaumont	
Nederland Police Department	Nederland	
Texas Dept. of Public Safety	Beaumont	
Jefferson County Constable - Precinct 1	Beaumont	
Jefferson County Constable - Precinct 2	Port Arthur	
Jefferson County Constable - Precinct 4	Beaumont	
Jefferson County Constable - Precinct 6	Beaumont	
Jefferson County Constable - Precinct 7	Beaumont	
Jefferson County Constable - Precinct 8	Port Arthur	
US Marshal's Service - Beaumont	Beaumont	
Fire Departments	**City**	
Port Arthur Fire Dept. Central Station	Port Arthur	
Beaumont Fire and Rescue Station 1	Beaumont	
Nederland Fire and Rescue	Nederland	
Beaumont Fire and Rescue Station 10	Beaumont	
Beaumont Fire and Rescue Station 11	Beaumont	
Beaumont Fire and Rescue Station 14	Beaumont	
Beaumont Fire and Rescue Station 2	Beaumont	
Beaumont Fire and Rescue Station 3	Beaumont	
Beaumont Fire and Rescue Station 4	Beaumont	

Chemical Manufacturing		
Business Name	**City**	**NAICS Category**
Beaumont Fire and Rescue Station 5	Beaumont	
Beaumont Fire and Rescue Station 6	Beaumont	
Beaumont Fire and Rescue Station 7	Beaumont	
Beaumont Fire and Rescue Station 7	Beaumont	
Beaumont Fire and Rescue Station 9	Beaumont	
Groves Fire Dept.	Groves	
Jefferson Volunteer Fire Dept.	Nederland	
LaBelle - Fannett Volunteer Fire/Emergency Medical Services - Substation	Beaumont	
Lamar Institute of Technology Regional Fire Academy	Beaumont	
Port Arthur Fire Dept. Station 1	Port Arthur	
Port Arthur Fire Dept. Station 2	Port Arthur	
Port Arthur Fire Dept. Station 3	Port Arthur	
Port Arthur Fire Dept. Station 4	Port Arthur	
Port Arthur Fire Dept. Station 5	Port Arthur	
Port Arthur Fire Dept. Station 6	Port Arthur	
Port Arthur Fire Dept. Station 8	Port Arthur	
Port Neches Fire Dept.	Port Arthur	

2.13.3 Brazoria

Chemical Manufacturing		
Business Name	**City**	**NAICS Category**
L C Huntsman-Cooper	Freeport	Plastics Material and Resin Manufacturing
Ineos Americas LLC	Freeport	All Other Basic Inorganic Chemical Manufacturing
K-Bin, Inc.	Freeport	Plastics Material and Resin Manufacturing
Air Liquide Large Industries U.S. LP	Freeport	Industrial Gas Manufacturing
Air Liquide Industrial U.S. LP	Freeport	Industrial Gas Manufacturing
S F Sulphur Company	Freeport	All Other Basic Inorganic Chemical Manufacturing
Nalco Energy Services L P	Freeport	All Other Miscellaneous Chemical Product and Preparation Manufacturing
Services Enterprise	Freeport	Polish and Other Sanitation Good Manufacturing
Air Liquide America L.P.	Freeport	Industrial Gas Manufacturing
Shintech Incorporated	Freeport	Plastics Material and Resin Manufacturing
Air Liquide Large Industries U.S. LP	Freeport	Industrial Gas Manufacturing
Air Liquide Large Industries U.S. LP	Freeport	Industrial Gas Manufacturing
Samdac Industries	Freeport	Plastics Material and Resin Manufacturing
Si Group, Inc.	Freeport	Petrochemical Manufacturing

Chemical Manufacturing		
Business Name	**City**	**NAICS Category**
The Dow Chemical Company	Freeport	All Other Basic Inorganic Chemical Manufacturing
Avon	Freeport	Toilet Preparation Manufacturing
Solvay USA, Inc.	Freeport	All Other Basic Inorganic Chemical Manufacturing
The Dow Chemical Company	Freeport	Plastics Material and Resin Manufacturing
Matheson Tri-Gas, Inc.	Freeport	Industrial Gas Manufacturing
Vencorex U.S., Inc.	Freeport	All Other Basic Organic Chemical Manufacturing
Vencorex U.S., Inc.	Freeport	All Other Basic Organic Chemical Manufacturing
BASF Corporation	Freeport	All Other Basic Organic Chemical Manufacturing
Ineos	Freeport	All Other Miscellaneous Chemical Product and Preparation Manufacturing
Americas Styrenics LLC	Freeport	Plastics Material and Resin Manufacturing
Schools	**City**	
Brazosport High School	Freeport	
OA Fleming Elementary	Freeport	
Freeport Intermediate	Freeport	
Jane Long Elementary	Freeport	
Velasco Elementary	Freeport	
O'Hara Lanier Middle School	Freeport	
Fire Departments	**City**	
Oyster Creek Volunteer Fire Dept.	Freeport	
Freeport Fire and Emergency Medical Services Dept.	Freeport	
Law Enforcement	**City**	
Freeport City Marshals Office	Freeport	
Freeport Police Dept.	Freeport	
Brazoria County Constable - Precinct 1	Freeport	

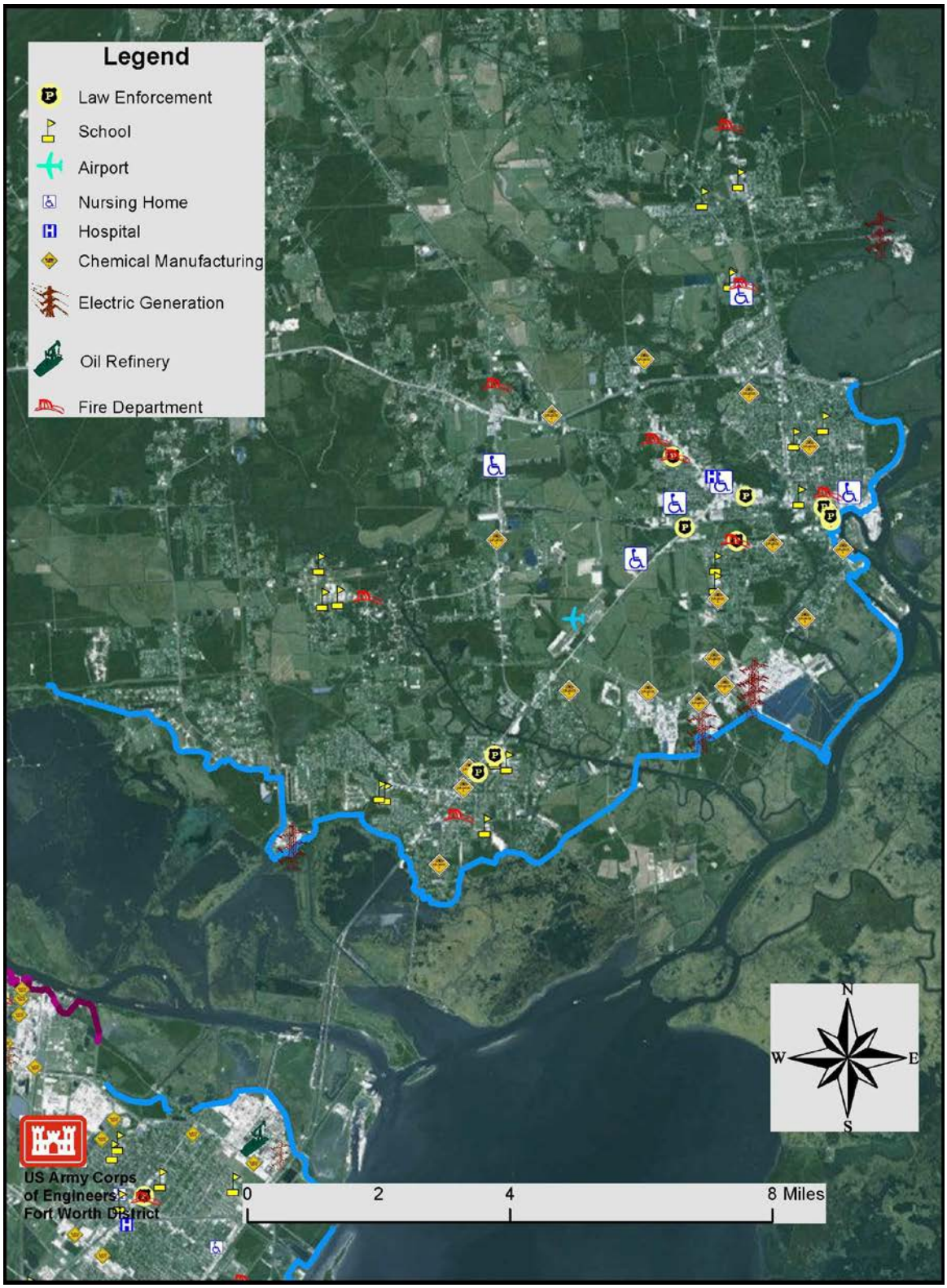


Figure 2-15. Orange County Critical Infrastructure

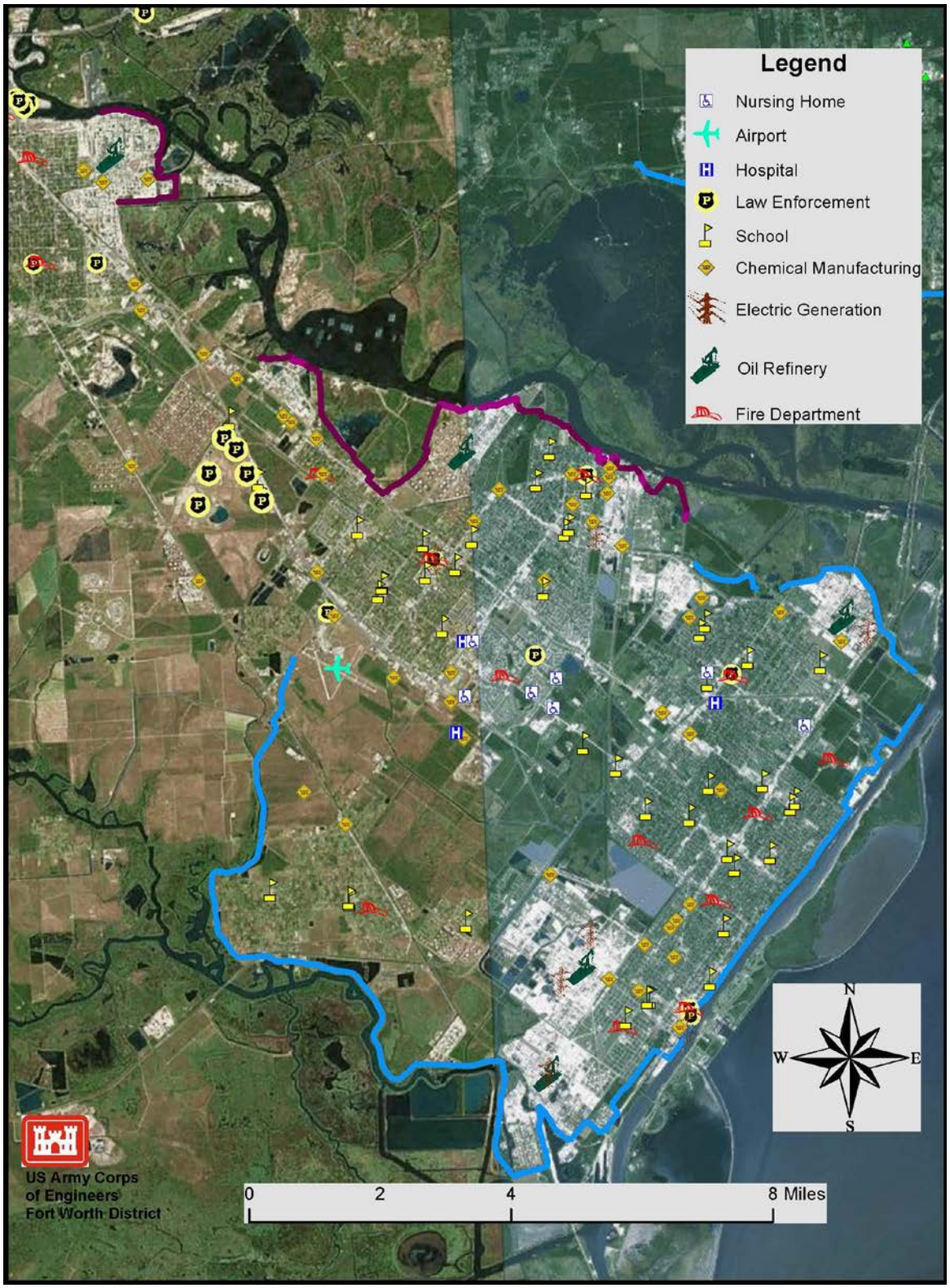


Figure 2-16. Jefferson County Critical Infrastructure

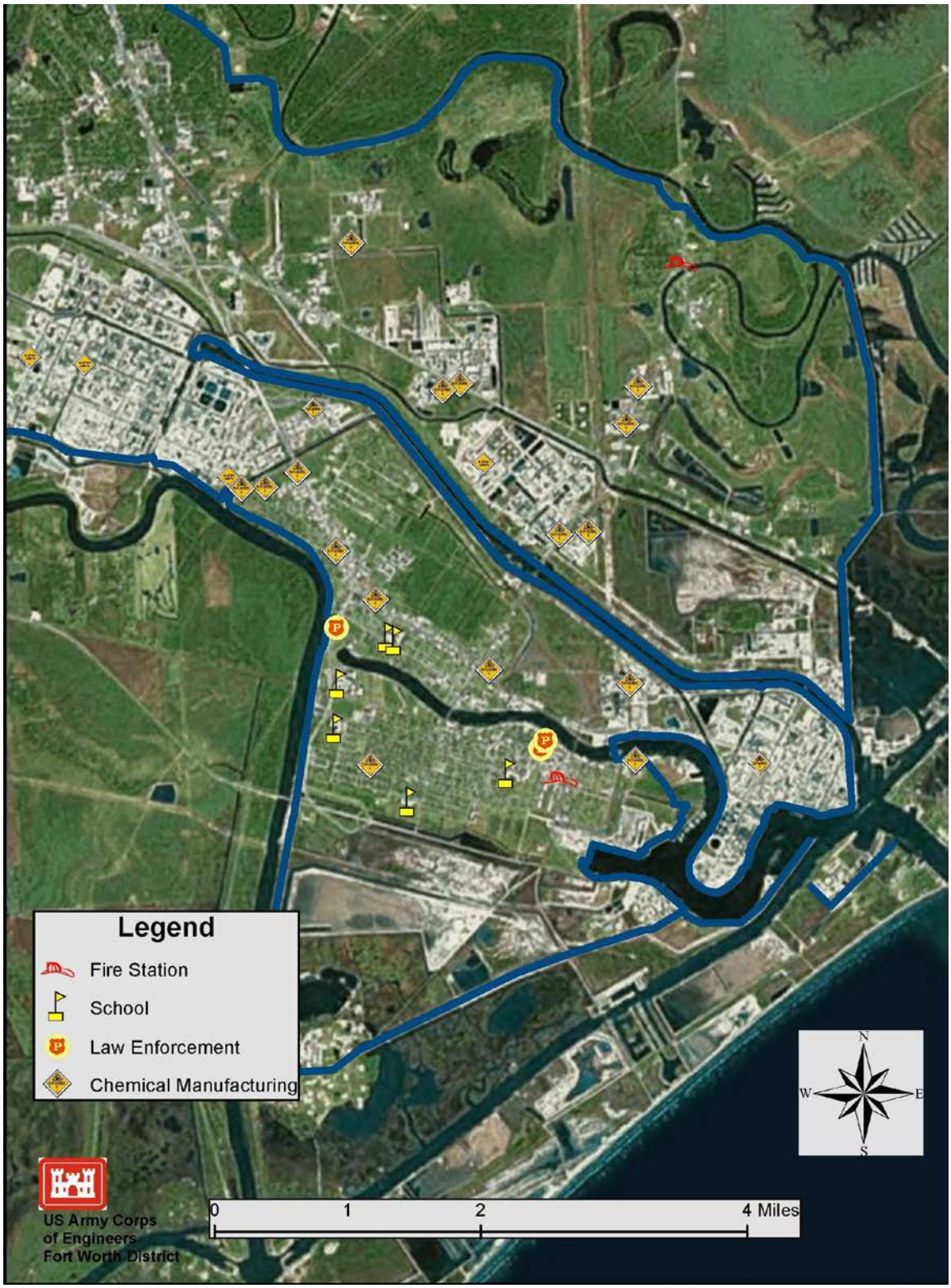


Figure 2-17. Brazoria County Critical Infrastructure