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

Draft Appendix C

Economic Analysis

September 2015

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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 ultimately conclude 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.

1.3 FINAL ARRAY OF ALTERNATIVES

The screening of the evaluation array along with the recommended study scope from the exemption resulted in the modification of a final array of alternative plans. The final array of alternative plans did not include Ecosystem Restoration (ER) measures because those are to be included in future interim feasibility studies, along with the Galveston region. Based on the successful Alternatives Milestone Meeting (AMM) that occurred on April 9, 2014, the final array of alternatives is shown in Table 1-1.

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)

Alternative Number	Alt Name / Description
S11	Sabine Nonstructural Alternative/ Buyouts and Lone Star-type Conservation Plan
B2	Brazoria Coastal Barrier CSRM Focus (revised)
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

1.4 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.

1.4.1 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).

1.4.2 Port Arthur and Vicinity CSRM

The draft findings of the 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.

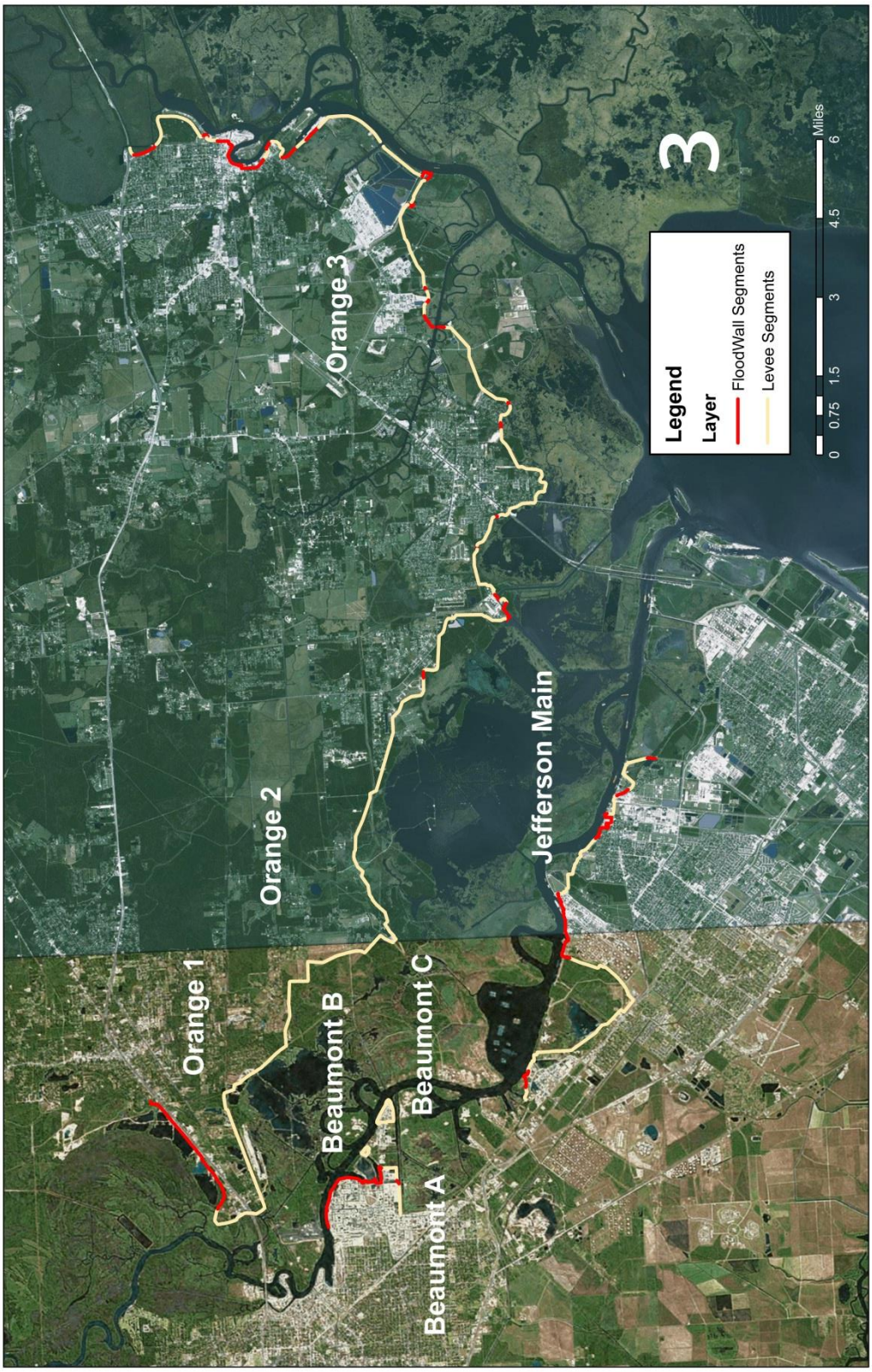


Figure 1-1. Configuration of the Orange-Jefferson CSRM

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

1.4.3 Freeport and Vicinity CSRM

The draft findings of the Semi-Quantitative Risk Assessment (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

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. 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 % 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 determine the overall economic efficiency, since these are more reliable as a means of determining high-level overall economic efficiency, as opposed to also trying to incorporate low-probability wave run-up and/or overtopping that can be analyzed later and applied to specific locations where it is applicable along a levee/floodwall system in conjunction with any necessary interior drainage analysis on the final recommended plan.

Table 2-1. Average Still Water Elevations and Discharges 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.

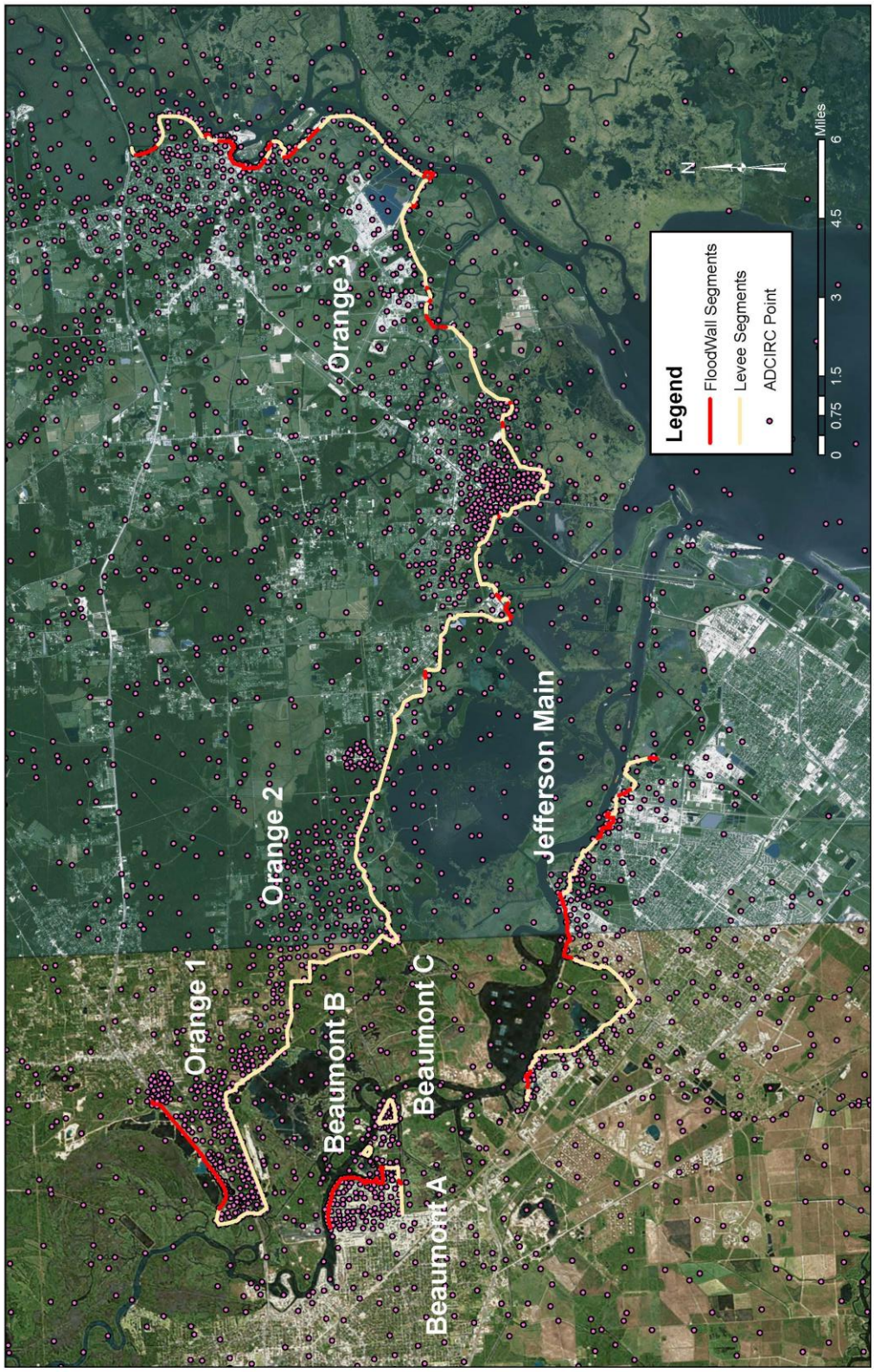


Figure 2-1. ADCIRC Points Orange-Jefferson CSRM

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

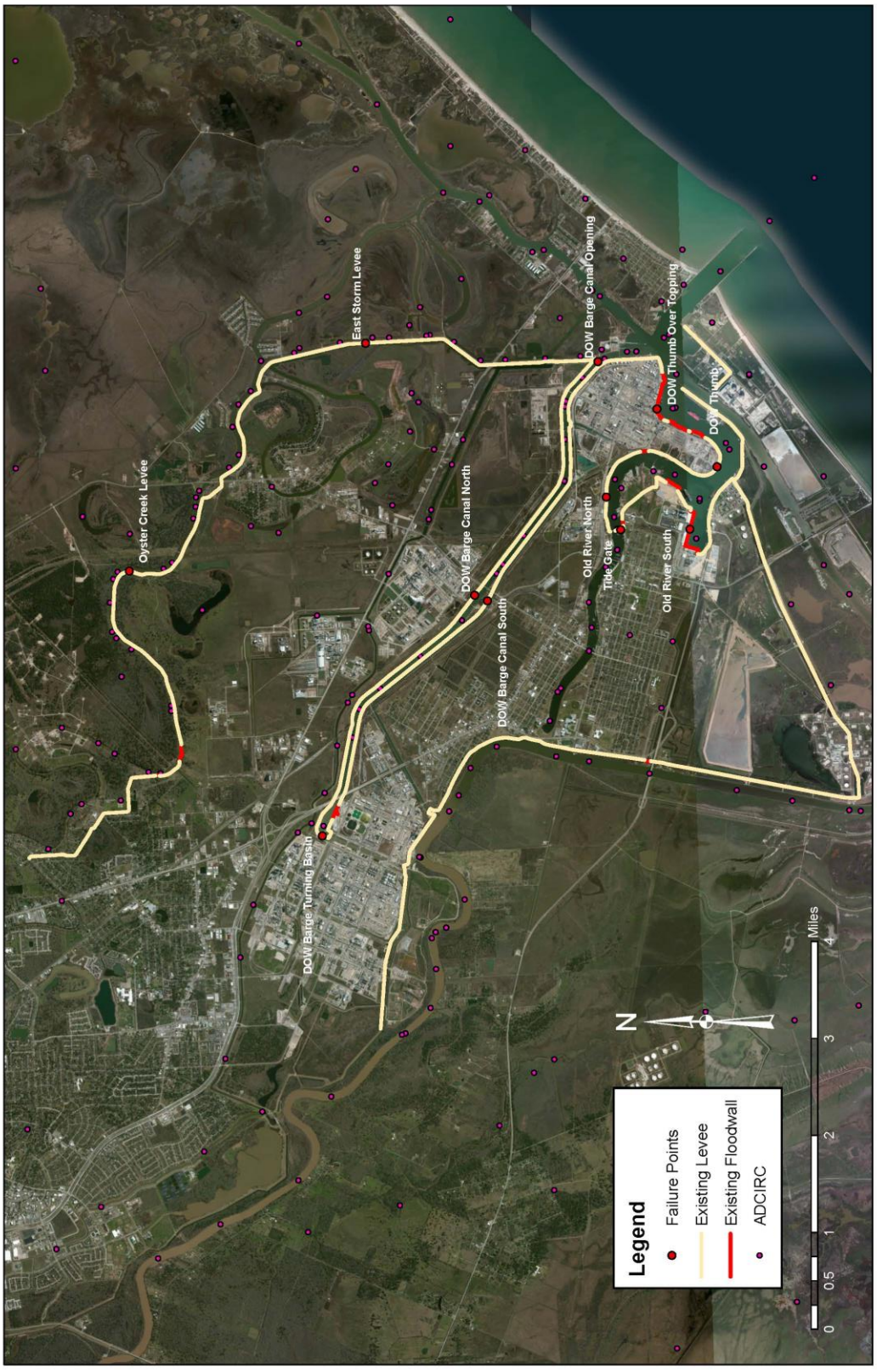


Figure 2-3. ADCIRC Points in Freeport and Vicinity CSRM

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

Stage/Location	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

Word 2010	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

Word 2010	Dow Barge Canal	East Storm	Oyster Creek Levee	Freeport Dock	Tide Gate I-Wall	Old River at Dow Thumb
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 received a 0.5-foot floor correction while 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.

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 not adjusted to reflect market nor a replacement cost less depreciation value. Because of this, structures in many cases may be undervalued. 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. 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	27,135	$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	26,605	$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	$19,195,051,000

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	4,132	$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.

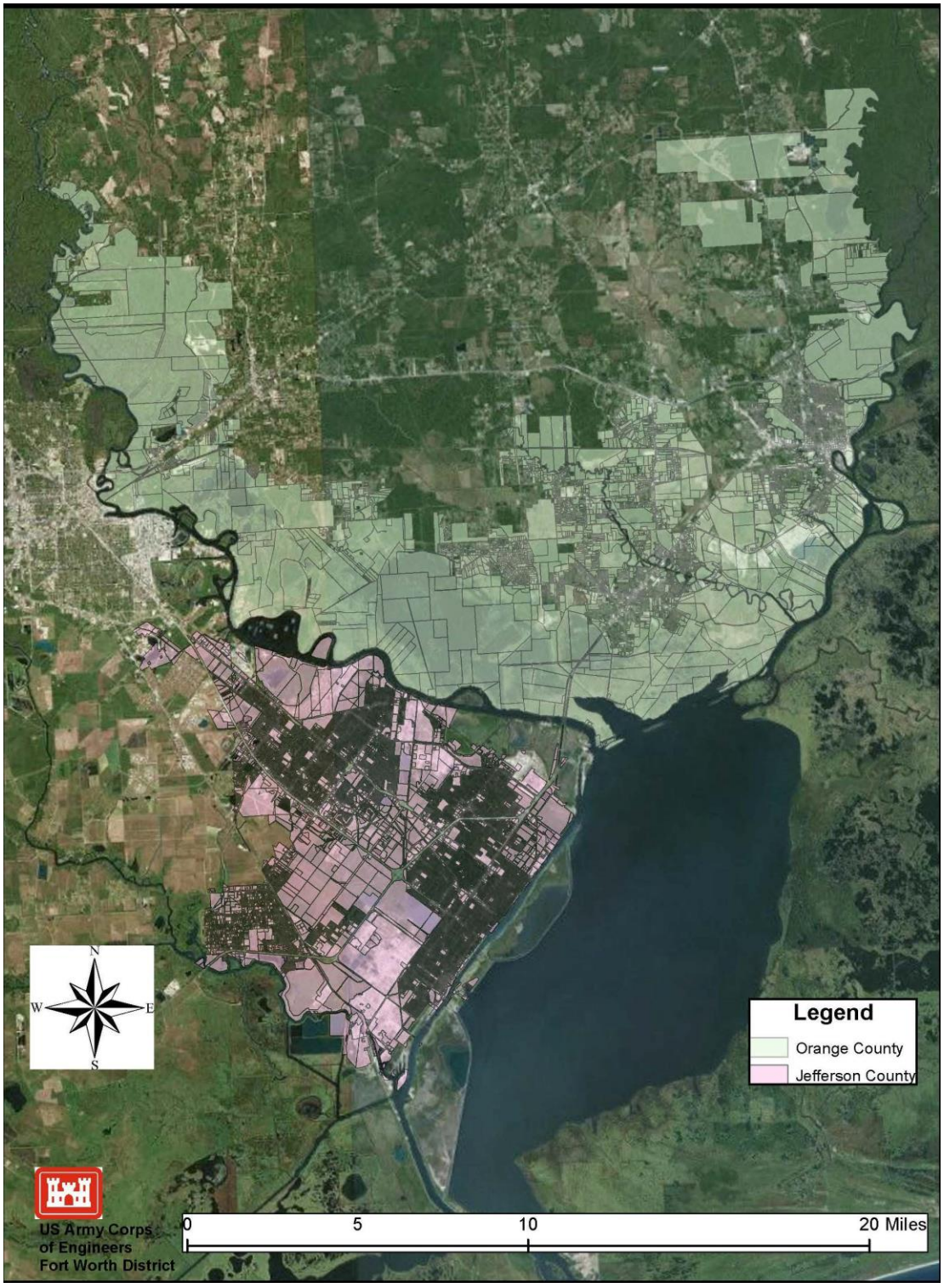


Figure 2-4. Orange-Jefferson CSRM Structures at Risk (Parcels)

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

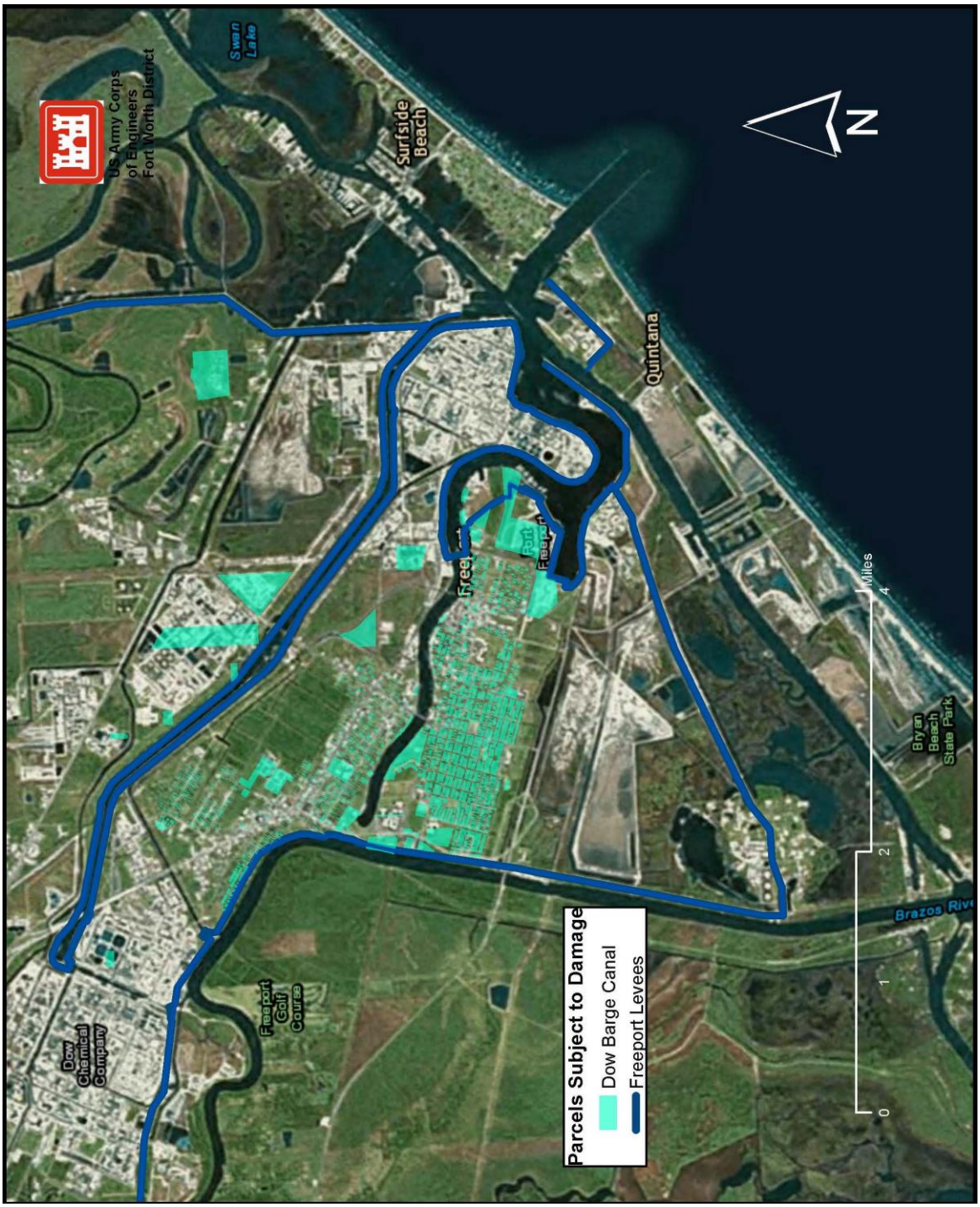


Figure 2-6. Freeport and Vicinity CSRM Structures at Risk – Dow Barge Canal Reach

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 Plaquemines Parish study. These functions reflect saltwater inundation for short durations. The functions cover the following structure types:

1STY-SLAB	One-Story Single -Family Residential Slab Foundation
2STY- SLAB	To-Story single -Family Residential Slab Foundation
AUTO	Automobiles
EAT	Restaurants
GROC	Grocery Stores
MOBHOM	Mobile Homes
MULT	Multi-Family Residential
PROF	Professional Businesses
PUBL	Public & Semi Public Structures
REPA	Repairs & Home Use
RETA	Retail & Personal Services
WARE	Warehouse & Contractor Services

Graphical representations for these for these functions are depicted at the end of this appendix.

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 % 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 % 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:

- Stage/Probability
- Geo-technical Features
- Structure Elevation
- Structure and Content Values
- Inundation Depth/Percent Damage

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. 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 2-5 shows a breakdown of where these damages are predicted to occur for each CSRM. Tables 2-6, 2-7, and 2-8 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% ACE; the depth of flooding at the 1% ACE is approximately 8 feet. In the Jefferson Main alternative reach, significant damages start between the 2% and 1% ACE; the depth of flooding between the 2% and 1% 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% 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% 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% 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 2-5. Expected Annual Damages Future Without-Project Condition (2015 price level)

	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

Table 2-6. Structures by Event for Orange-Jefferson CSRM

Orange 1							
Event (ACE)	0.1	0.05	0.02	0.01	0.005	0.002	0.001
Elevation (MSL Ft.)	3.62	5.05	6.69	7.76	8.66	9.66	10.35
Damage Category							
Commercial	0	1	1	1	1	1	7
Industrial	0	0	0	0	0	0	0
Multifamily	0	0	0	0	0	0	0
Mobile	2	2	7	7	8	8	19
Public	0	0	2	2	2	2	4
Vehicles	0	11	13	72	81	87	202
Single-Family	2	14	23	82	92	98	232
Grand Total	4	28	46	164	184	196	464

Orange 2							
Event (ACE)	0.1	0.05	0.02	0.01	0.005	0.002	0.001
Elevation (MSL Ft.)	3.60	5.36	7.24	8.51	9.60	10.77	11.57
Damage Category							
Commercial	0	0	1	1	1	1	1
Industrial	0	0	0	0	0	0	0
Mobile	0	0	4	4	4	11	11
Public	0	0	0	0	0	0	0
Vehicles	0	3	15	16	18	40	42
Single-Family	1	3	15	17	17	35	36
Grand Total	1	6	35	38	40	87	90

Orange 3							
Event (ACE)	0.1	0.05	0.02	0.01	0.005	0.002	0.001
Elevation (MSL Ft.)	2.78	4.25	6.11	7.51	8.64	9.81	10.57
Damage Category							
Commercial	0	3	4	42	48	51	198
Industrial	0	1	1	6	6	6	8
Multifamily	0	3	3	99	102	111	180
Mobile	0	20	23	167	173	185	385
Public	2	5	6	70	76	79	166
Vehicles	8	267	319	3,157	3,345	3,506	9,180
Single-Family	11	287	347	3,247	3,404	3,621	9,146
Grand Total	21	586	703	6,788	7,154	7,559	19,263

Jefferson Main							
Event (ACE)	0.1	0.05	0.02	0.01	0.005	0.002	0.001
Elevation (MSL Ft.)	3.08	4.63	6.31	7.49	8.47	9.51	10.22
Damage Category							
Commercial	0	20	22	153	160	164	240
Industrial	0	0	1	3	3	3	4
Multifamily	0	9	10	31	31	31	55
Public	1	5	5	22	22	22	32
Vehicles	0	267	348	1909	1974	2047	2097
Single-Family	0	290	388	1940	2010	2078	3418
Grand Total	1	591	774	4,058	4,200	4,345	5,846

Table 2-6, continued

Beaumont A							
Event (ACE)	0.1	0.05	0.02	0.01	0.005	0.002	0.001
Elevation (MSL Ft.)	2.92	4.26	6.00	7.25	8.47	9.73	10.51
Damage Category							
Commercial	0	0	0	0	0	0	0
Industrial	0	0	0	1	1	1	2
Multifamily	0	0	0	0	0	0	0
Public	0	0	0	0	0	0	0
Grand Total	0	0	0	1	1	1	2
Beaumont C							
Event (ACE)	0.1	0.05	0.02	0.01	0.005	0.002	0.001
Elevation (MSL Ft.)	3.55	5.09	6.85	8.02	9.00	10.10	10.85
Damage Category							
Industrial	1	1	1	1	1	1	1
Grand Total	1	1	1	1	1	1	1

Beaumont B							
Event (ACE)	0.1	0.05	0.02	0.01	0.005	0.002	0.001
Elevation (MSL Ft.)	2.71	3.88	5.62	6.86	7.94	9.07	10.34
Damage Category							
Industrial	0	0	0	0	1	1	1
Grand Total	0	0	0	0	1	1	1

Table 2-7. Structures by Event for Port Arthur CSRM

8ft-10ft I-Wall							
Event (ACE)	0.1	0.05	0.02	0.01	0.005	0.002	0.001
Elevation (MSL Ft.)	2.85	4.31	6.98	9.25	10.94	12.68	13.81
Damage Category							
Commercial	50	549	938	956	1,050	1,057	1,143
Industrial	0	4	6	7	9	9	9
Multifamily	15	119	215	217	249	252	261
Public	16	189	399	401	435	437	445
Vehicles	939	9,129	12,007	16,998	19,478	19,584	20,538
Single Family	1,197	9,262	16,626	16,947	19,378	19,492	20,443
Grand Total	2,217	19,252	30,191	35,526	40,599	40,831	42,839

Closure Structure							
Event (ACE)	0.1	0.05	0.02	0.01	0.005	0.002	0.001
Elevation (MSL Ft.)	3.45	5.01	6.90	8.20	9.30	10.46	11.20
Damage Category							
Commercial	518	562	938	948	956	1,050	1,050
Industrial	3	5	6	7	7	9	9
Multifamily	114	119	215	216	217	247	250
Public	186	192	399	400	401	435	435
Vehicles	1,269	9,340	11,949	16,847	17,003	19,449	19,495
Single Family	9,002	9,493	16,611	16,793	16,955	19,348	19,392
Grand Total	11,092	19,711	30,118	35,211	35,539	40,538	40,631

I-Wall Near Valero							
Event (ACE)	0.1	0.05	0.02	0.01	0.005	0.002	0.001
Elevation (MSL Ft.)	3.87	5.97	8.47	10.47	12.61	14.77	16.08
Damage Category							
Commercial	535	637	950	1,050	1,056	1,144	1,146
Industrial	4	5	7	9	9	9	9
Multifamily	117	124	217	247	252	261	262
Public	188	315	400	435	437	445	446
Vehicles	8,981	9,682	16,888	19,450	19,581	20,611	20,680
Single Family	9,126	11,610	16,838	19,348	19,484	20,500	20,582
Grand Total	18,951	22,373	35,300	40,539	40,819	42,970	43,125

I-Wall Near Tank Farm							
Event (ACE)	0.1	0.05	0.02	0.01	0.005	0.002	0.001
Elevation (MSL Ft.)	3.77	5.72	8.10	9.99	12.02	14.08	15.31
Damage Category							
Commercial	531	572	946	1,050	1,052	1,143	1,144
Industrial	3	5	7	9	9	9	9
Multifamily	116	123	216	246	250	261	261
Public	188	208	400	434	436	445	446
Vehicles	1,580	9,585	16,836	17,114	19,549	20,564	20,636
Single Family	9,102	9,749	16,781	19,319	19,445	20,464	20,530
Grand Total	11,520	20,242	35,186	38,172	40,741	42,886	43,026

Table 2-8. Structures by Event for Freeport CSRM

Dow Barge Canal							
Event (ACE)	**0.1**	**0.05**	**0.02**	**0.01**	**0.005**	**0.002**	**0.001**
Elevation (MSL Ft.)	4.60	7.46	10.82	13.28	15.76	18.55	20.12
Damage Category							
Commercial	242	284	288	289	289	289	289
Industrial	11	13	14	14	14	14	14
Multifamily	111	115	115	115	115	115	115
Mobile	0	0	2	2	2	2	2
Public	59	62	65	65	65	65	65
Vehicles	2,342	2,566	2,605	2,606	2,607	2,607	2,607
Single Family	2,348	2,571	2,605	2,607	2,607	2,607	2,607
Grand Total	5,113	5,611	5,694	5,698	5,699	5,699	5,699

Oyster Creek							
Event (ACE)	**0.1**	**0.05**	**0.02**	**0.01**	**0.005**	**0.002**	**0.001**
Elevation (MSL Ft.)	4.44	8.49	12.21	14.63	16.62	18.77	20.19
Damage Category							
Commercial	206	239	242	243	243	243	243
Industrial	3	3	3	3	3	3	3
Multifamily	114	117	117	117	117	117	117
Public	62	68	70	70	70	70	70
Vehicles	1,656	1,821	1,845	1,846	1,846	1,846	1,846
Single Family	1,657	1,820	1,843	1,844	1,844	1,844	1,844
Grand Total	3,698	4,068	4,120	4,123	4,123	4,123	4,123

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							
Commercial	206	238	242	242	243	243	243
Industrial	3	3	3	3	3	3	3
Multifamily	114	117	117	117	117	117	117
Public	62	68	70	70	70	70	70
Vehicles	1,656	1,816	1,831	1,845	1,846	1,846	1,846
Single Family	1,657	1,816	1,843	1,843	1,844	1,844	1,844
Grand Total	3,698	4,058	4,106	4,120	4,123	4,123	4,123

Tide Gate							
Event (ACE)	**0.1**	**0.05**	**0.02**	**0.01**	**0.005**	**0.002**	**0.001**
Elevation (MSL Ft.)	4.46	7.18	10.32	12.65	15.02	17.90	19.52
Damage Category							
Commercial	206	238	242	242	243	243	243
Industrial	3	3	3	3	3	3	3
Multifamily	114	117	117	117	117	117	117
Public	62	68	70	70	70	70	70
Vehicles	1,656	1,816	1,832	1,845	1,846	1,846	1,846
Single Family	1,657	1,816	1,843	1,843	1,844	1,844	1,844
Grand Total	3,698	4,058	4,107	4,120	4,123	4,123	4,123

Old River at Dow							
Event (ACE)	**0.1**	**0.05**	**0.02**	**0.01**	**0.005**	**0.002**	**0.001**
Elevation (MSL Ft.)	4.43	7.08	10.15	12.41	14.69	17.43	18.97
Damage Category							
Commercial	206	238	242	242	243	243	243
Industrial	3	3	3	3	3	3	3
Multifamily	114	117	117	117	117	117	117
Public	62	68	70	70	70	70	70
Vehicles	1,656	1,814	1,828	1,845	1,846	1,846	1,846
Single Family	1,657	1,816	1,843	1,843	1,844	1,844	1,844
Grand Total	3,698	4,056	4,103	4,120	4,123	4,123	4,123

East Storm Levee							
Event (ACE)	**0.1**	**0.05**	**0.02**	**0.01**	**0.005**	**0.002**	**0.001**
Elevation (MSL Ft.)	5.08	7.81	11.05	13.38	15.55	17.99	19.50
Damage Category							
Commercial	209	238	242	243	243	243	243
Industrial	3	3	3	3	3	3	3
Multifamily	115	117	117	117	117	117	117
Public	65	68	70	70	70	70	70
Vehicles	1,661	1,820	1,845	1,845	1,846	1,846	1,846
Single Family	1,666	1,819	1,843	1,844	1,844	1,844	1,844
Grand Total	3,719	4,065	4,120	4,122	4,123	4,123	4,123

South Storm Levee							
Event (ACE)	**0.1**	**0.05**	**0.02**	**0.01**	**0.005**	**0.002**	**0.001**
Elevation (MSL Ft.)	4.21	6.68	9.59	11.63	13.71	16.31	17.93
Damage Category							
Commercial	205	238	241	242	243	243	243
Industrial	3	3	3	3	3	3	3
Multifamily	114	117	117	117	117	117	117
Public	62	68	69	70	70	70	70
Vehicles	1,654	1,686	1,824	1,845	1,846	1,846	1,846
Single Family	1,657	1,814	1,825	1,843	1,844	1,844	1,844
Grand Total	3,695	3,926	4,079	4,120	4,123	4,123	4,123

Table 2-9. 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	$2,747,000
O&M ($/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 2-9. 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 2-9. 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	$873,000
O&M ($/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.

Table 2-9 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 2-10, 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 2-10. 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 2-11. 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 2-11. 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

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 % ACE, with the other two being in the 0.05 % 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 % 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 2-12.

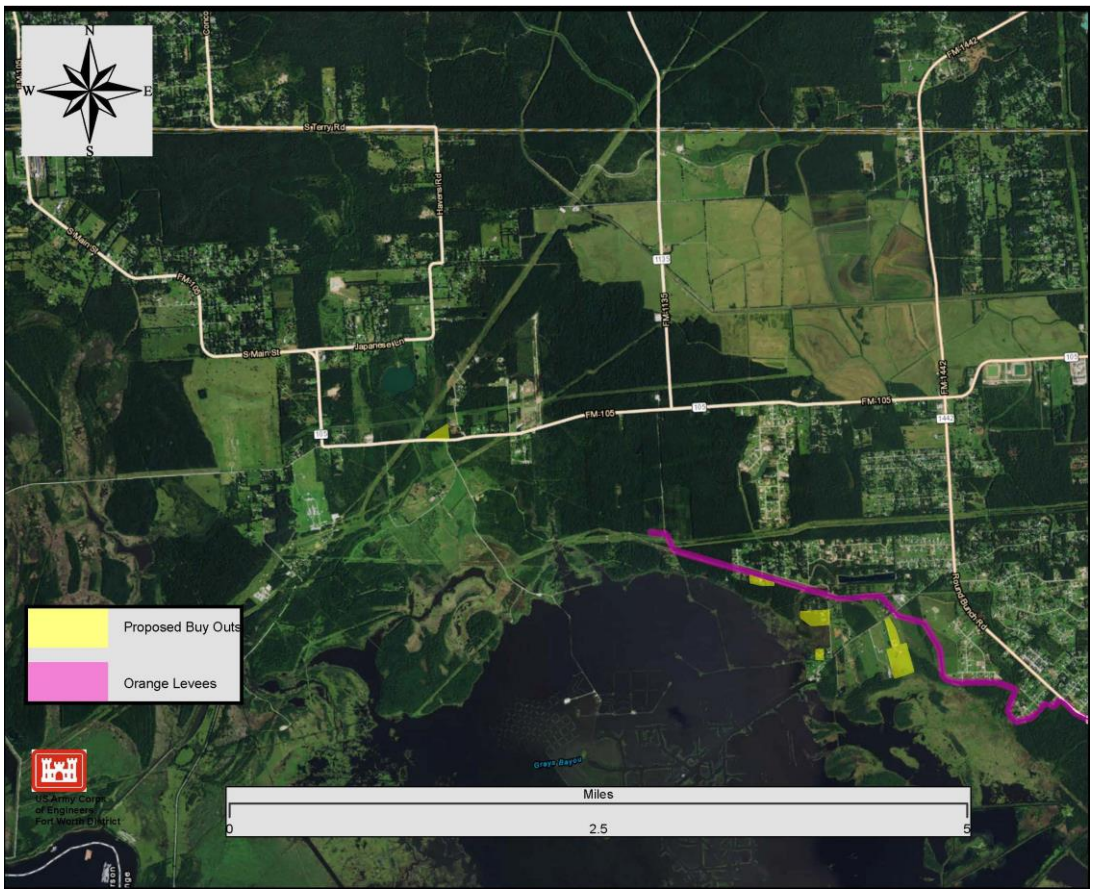


Figure 2-8. Potential Orange County Buyouts

Table 2-12. 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
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 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 30 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 2-13 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 % ACE also increases substantially with the implementation of the TSP. These results are also all listed in Table 2-13.

2.5.1 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 2-14 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 2-14.

Table 2-13. 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 2-13. 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 2-14. 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

2.5.2 Life Safety Considerations

The population at risk (PAR) is displayed by project area is included in Table 2-15. 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 2-15. 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

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 Altering 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.

2.5.3 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 – Jefferson CSRM (Orange and Jefferson 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

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

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.

2.6 CONCLUSION AND 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.

2.6.1 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

2.6.2 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)

2.6.3 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).

Table 2-16. 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	$585,000
O&M ($/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 2-17. 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

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

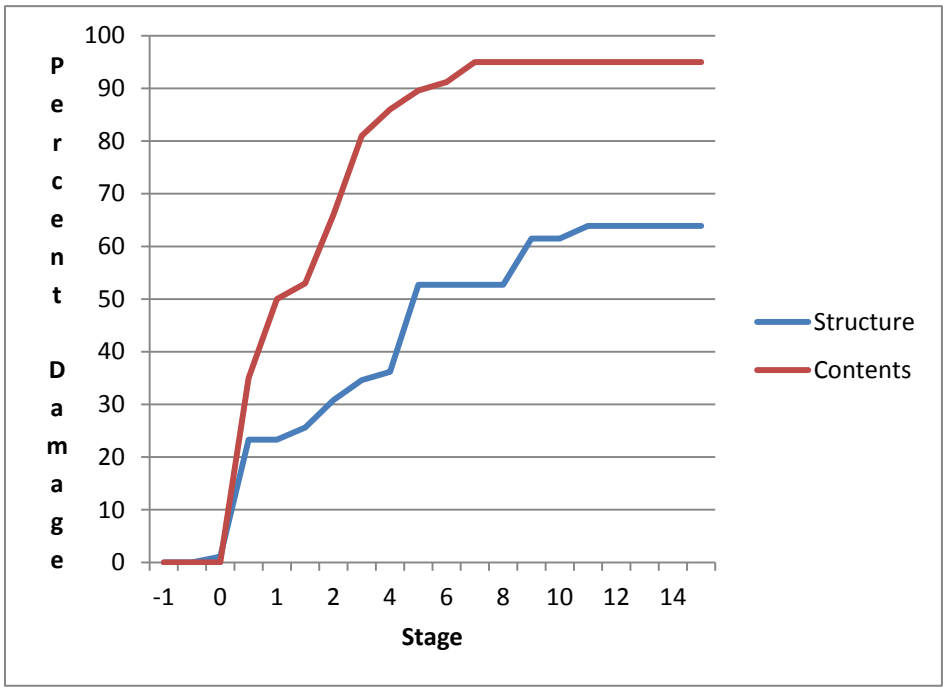
	Dow Barge Canal	Oyster Creek Levee	East Storm Levee	Freeport Dock	Old River Levee at Dow Thumb	Tide Gate I-Wall
	No Fail - Closure Structure	1-Foot Raise	1-Foot Raise	No Fail	1-Foot Raise	1-Foot Raise
INVESTMENT						
Estimated First Cost	$130,000,000	$4,869,000	$6,530,000	$2,850,000	$8,294,000	$3,800,000
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
TOTAL ANNUAL 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.

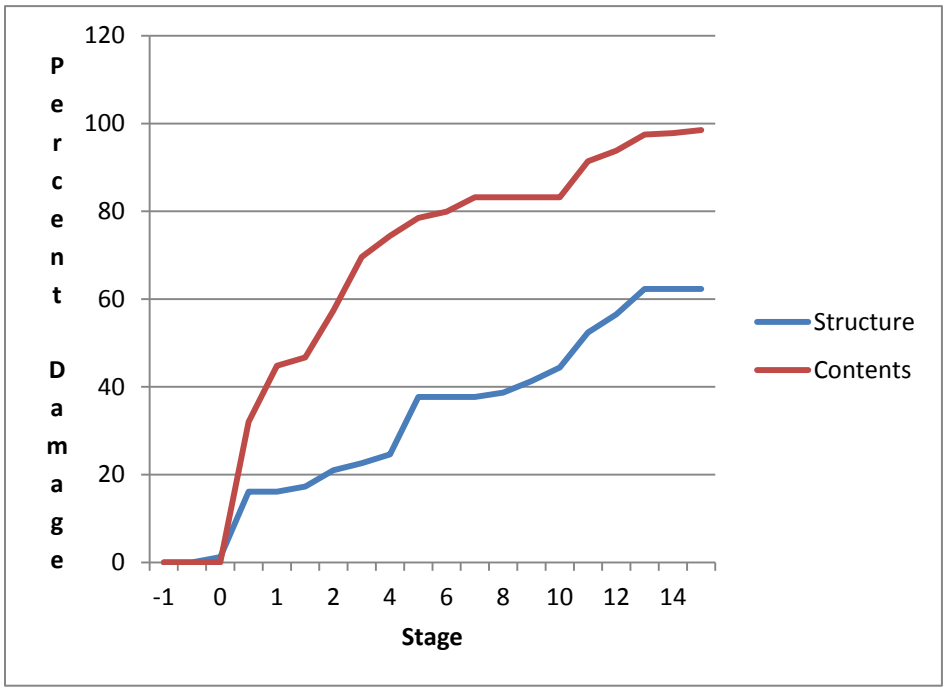
The TSP for the Freeport and Vicinity CSRM includes a No-Fail closure structure at the Dow Barge Canal with two sector gates approximately 500 feet long and 80 feet in width for vessel traffic with an estimated first cost of $130 million, annual costs of $5.7 million, annual benefits of $119.6 million 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 a 11.4 benefit-to-cost ratio.

2.7 DEPTH DAMAGE FUNCTIONS

One Story Residence – Slab Foundation



Two Story Residences – Slab Foundation



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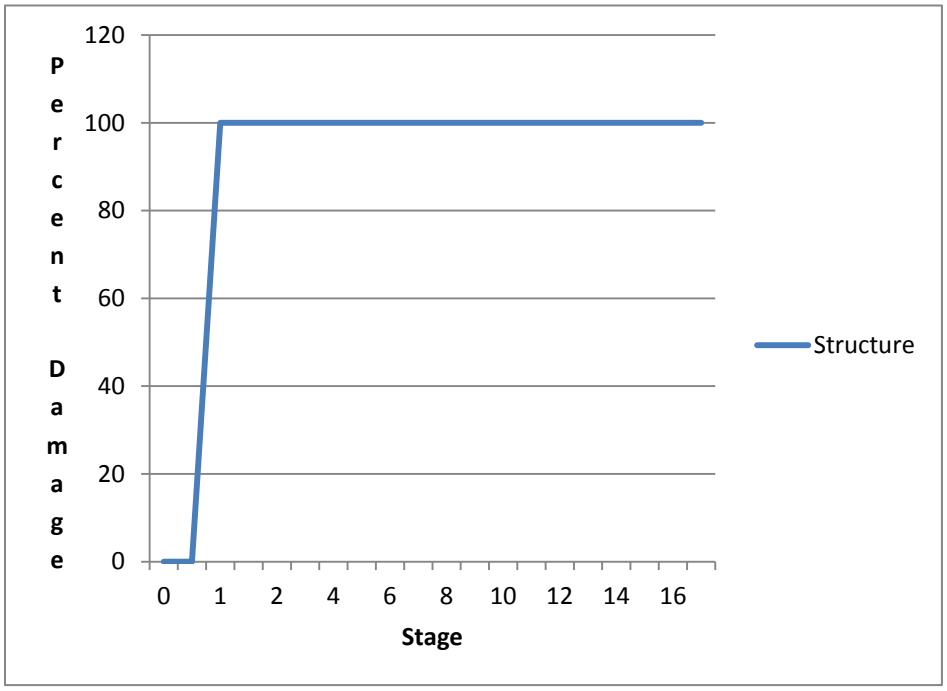
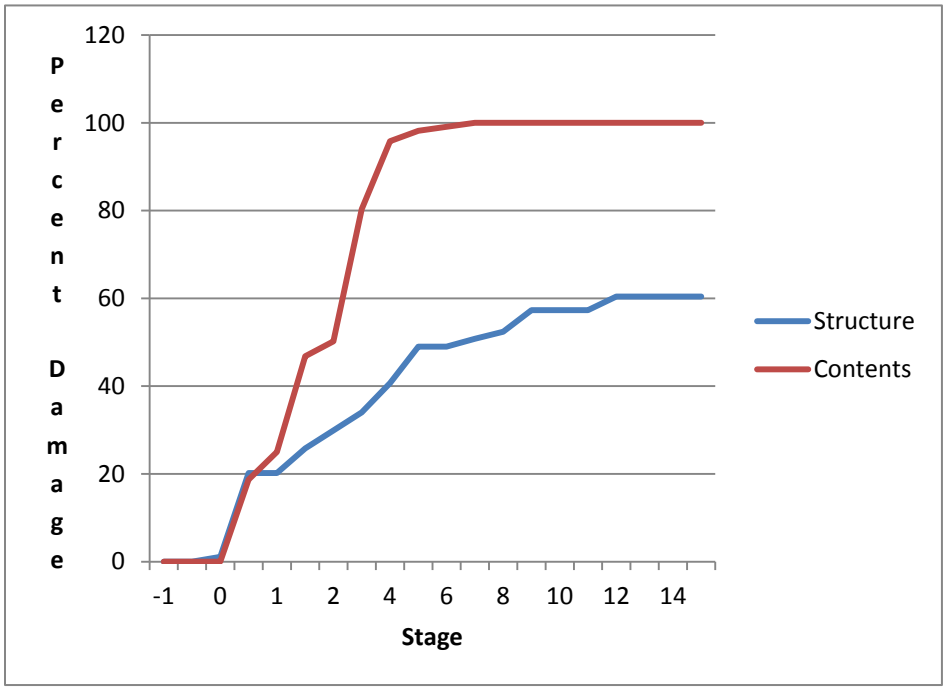
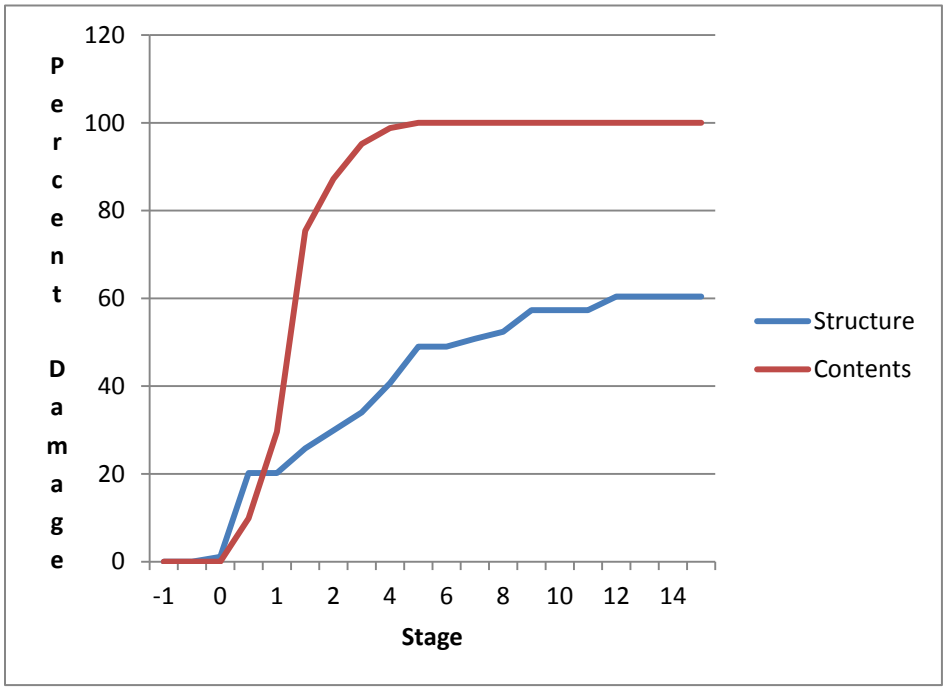


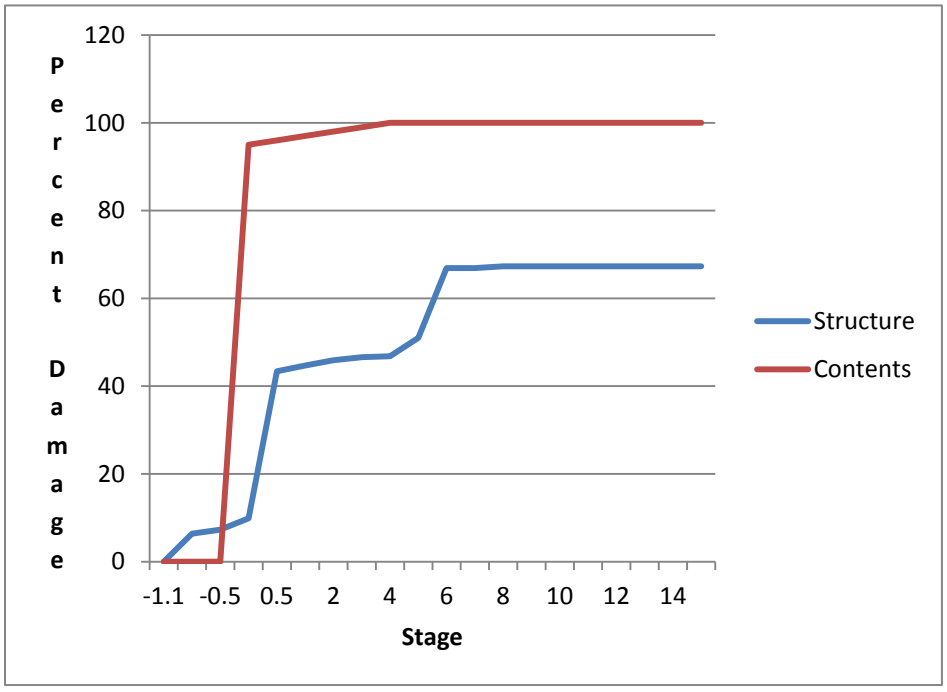
Eating Establishments



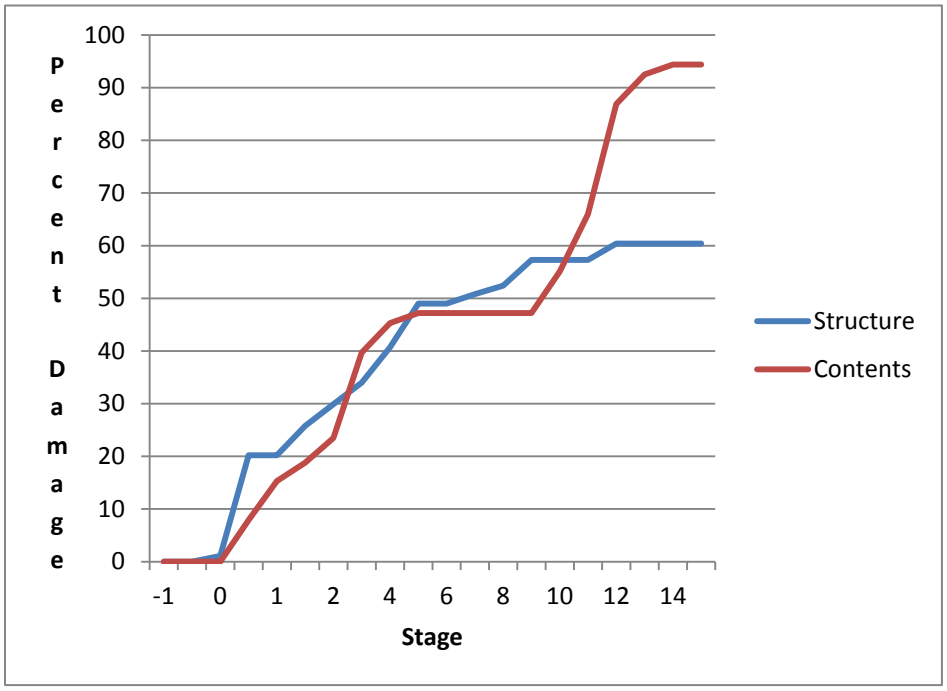
Grocery Stores



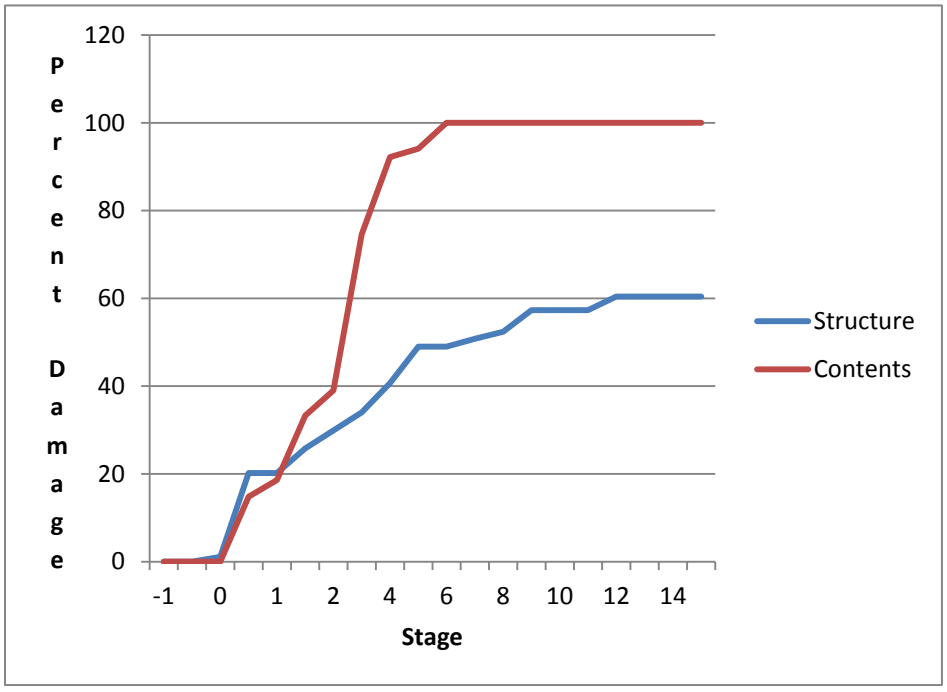
Mobile Residence



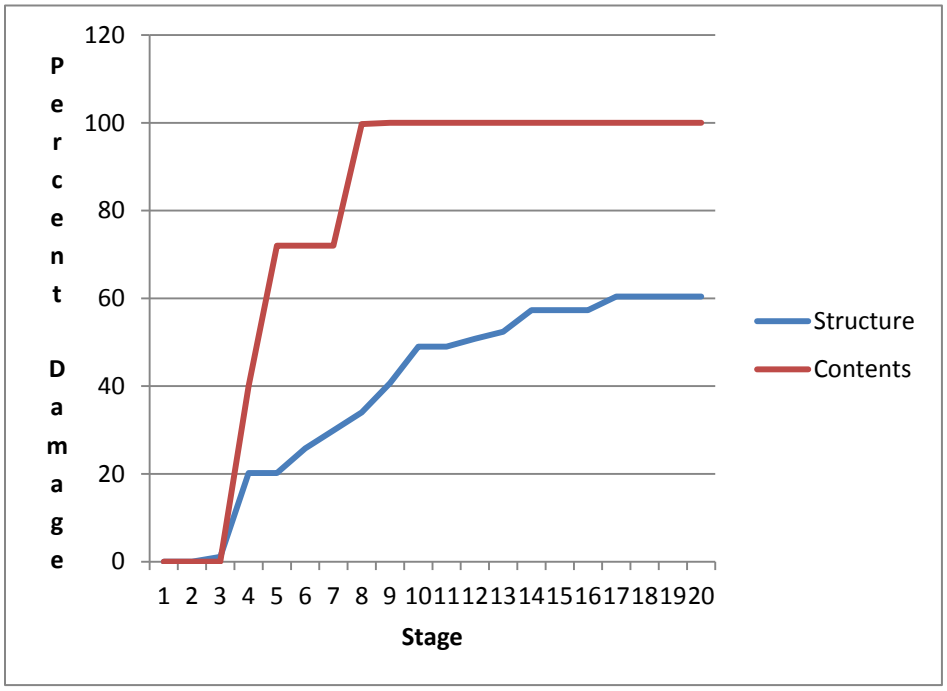
Multi-Family Residence



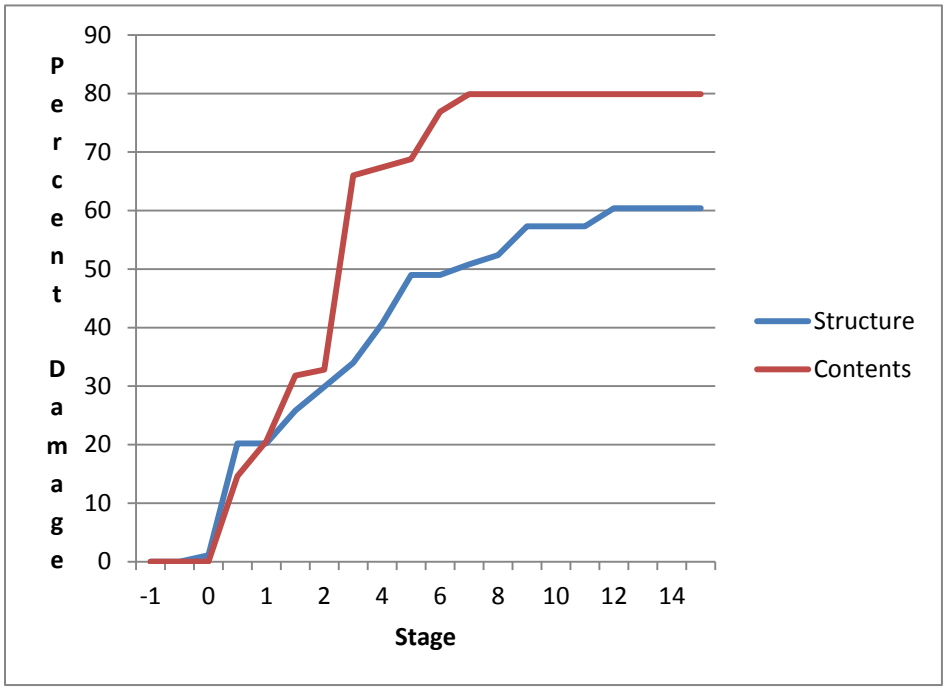
Professional Buildings



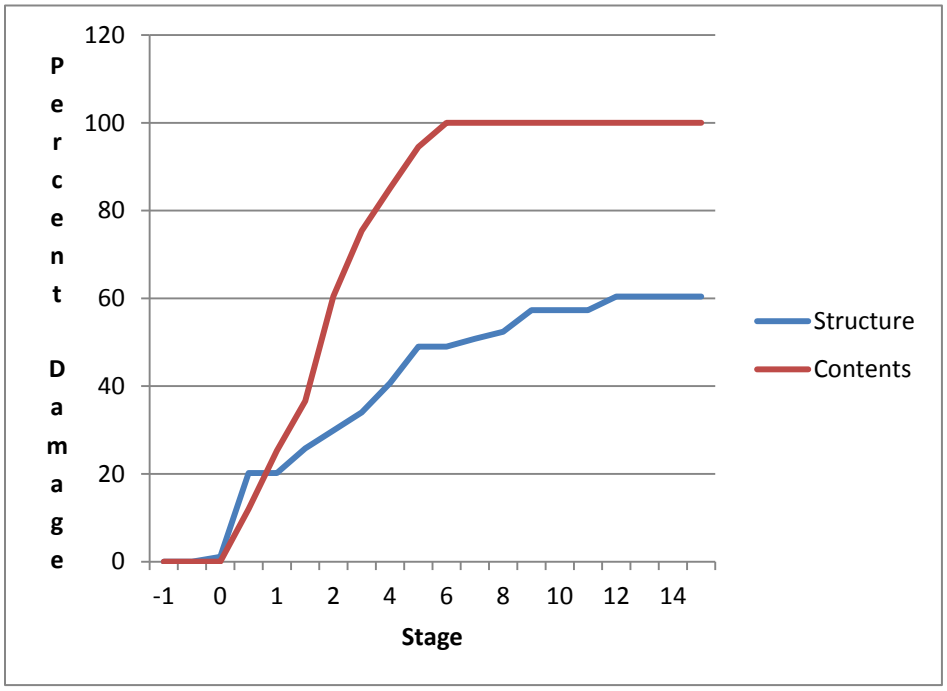
Public Buildings



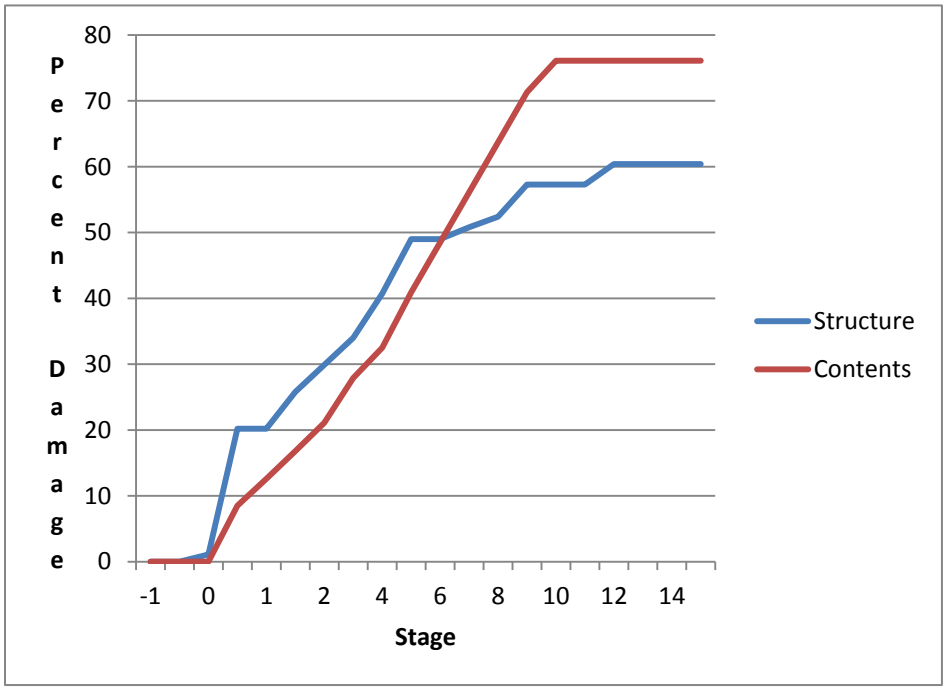
Repair



Retail



Warehouse



2.8 LISTING OF CRITICAL INFRASTRUCTURE BY COUNTY

2.8.1 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

2.8.2 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	

2.8.3 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

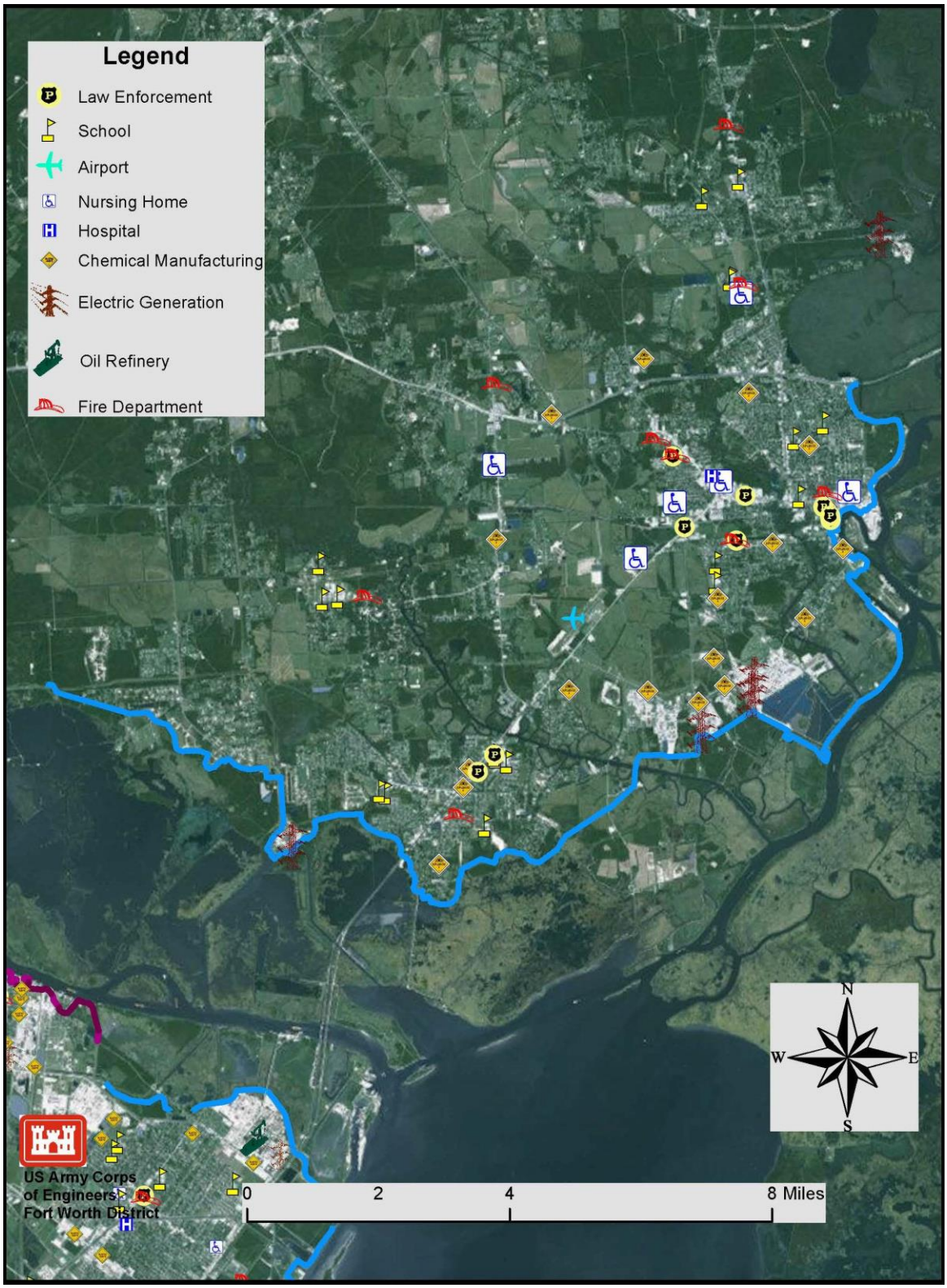


Figure 2-9. Orange County Critical Infrastructure

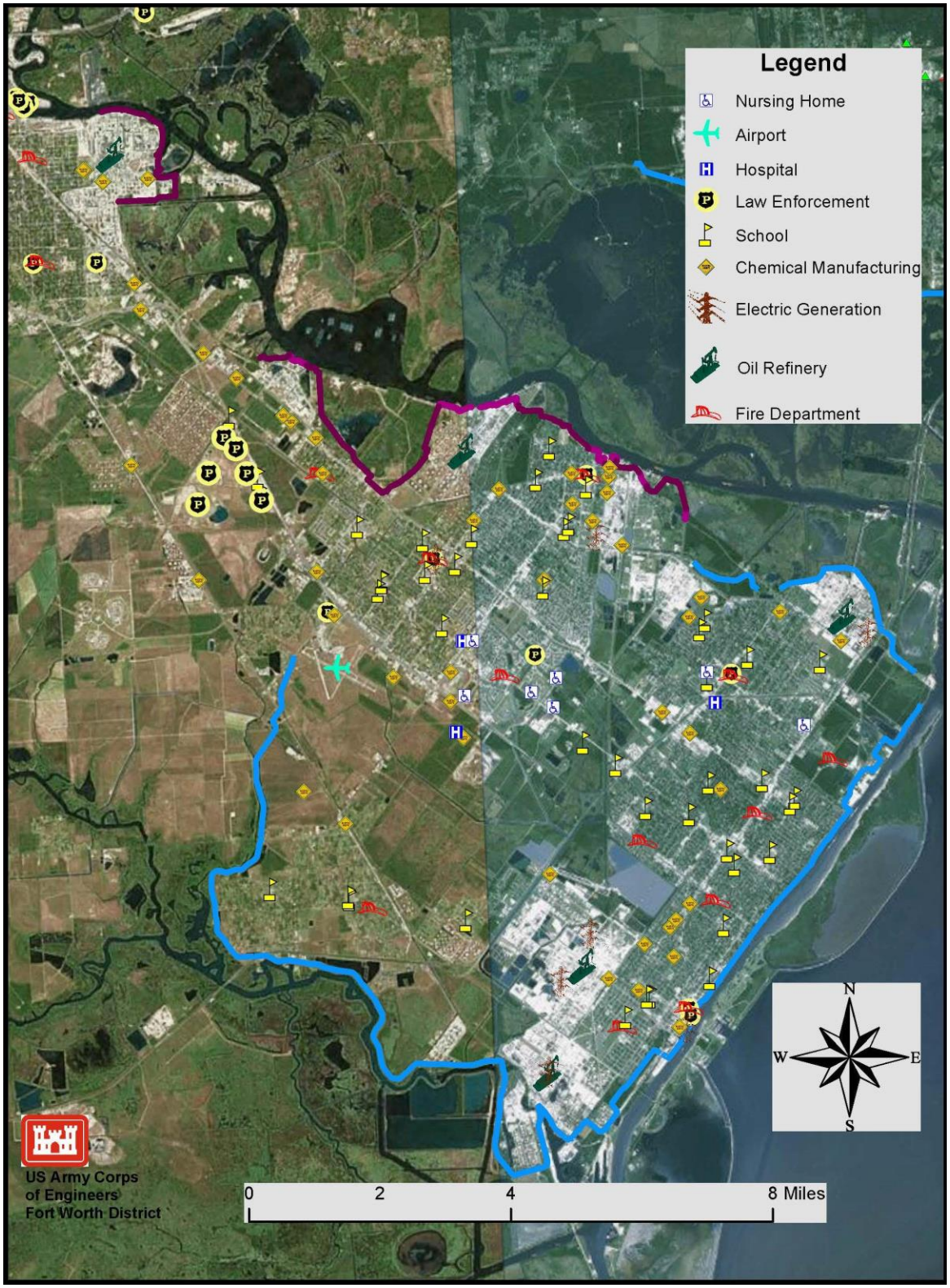


Figure 2-10. Jefferson County Critical Infrastructure

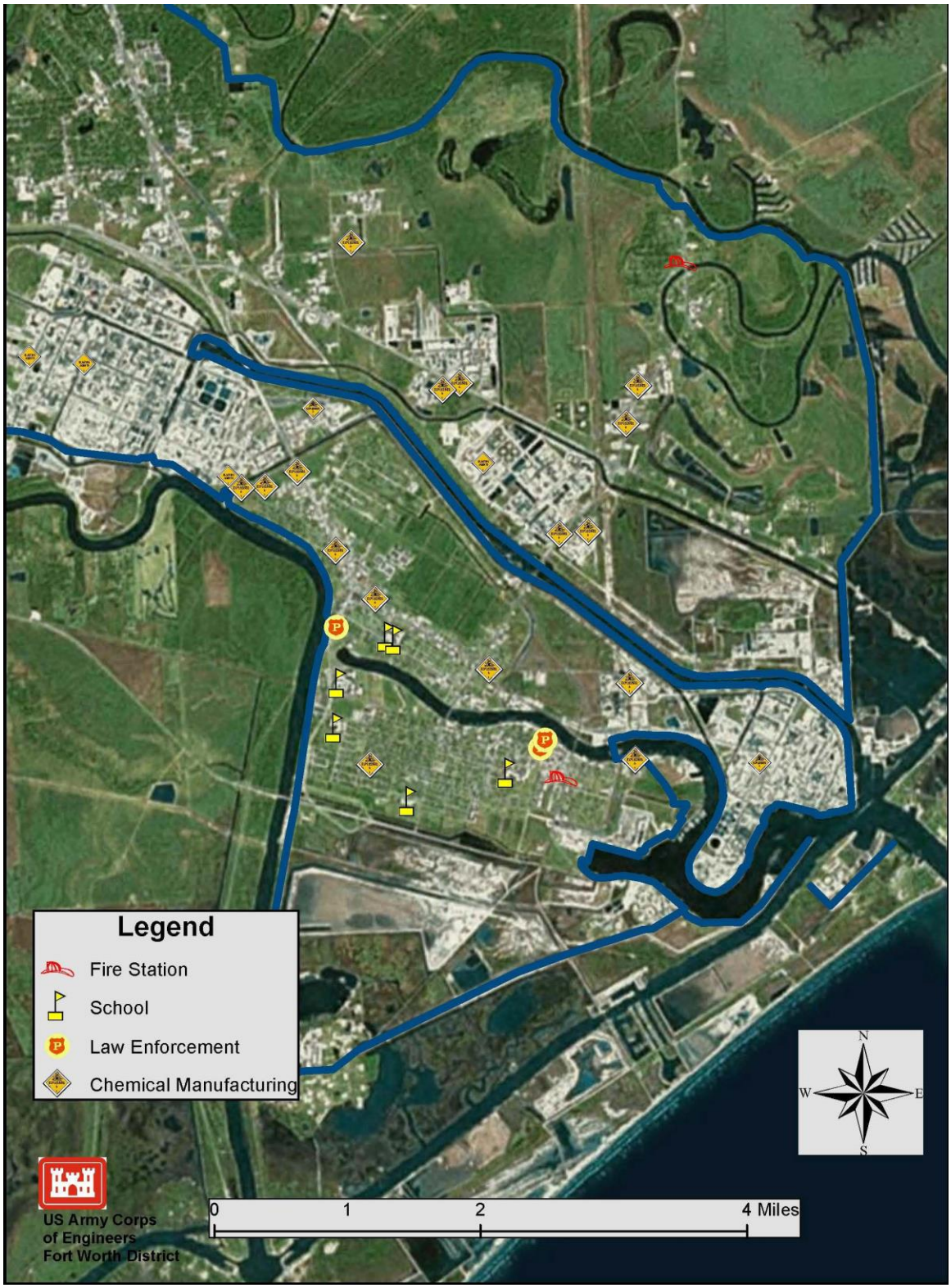


Figure 2-11. Brazoria County Critical Infrastructure