Volume II – Results

CONTENTS

		Page
CONTENTS		I
LIST OF FIGURES		III
LIST OF TABLES		VI
LIST OF ANNEXES		VI
1	INTRODUCTION	1
1.1	Background	1
1.2	Purpose of LACPR	1
1.3	Planning Area with Planning Units	1
1.4	LACPR in brief	5
1.5	Hydraulic evaluation	6
1.6	Scope and limitations	7
1.7	Report outline	7
2	HYDRODYNAMIC RESULTS	8
2.1	Introduction	8
2.2	2007 Base Condition	9
2.3	East Models	12
2.3.1	2010 Base Condition	12
2.3.2	Closure Options of Lake Pontchartrain and the Barataria Basin	13
2.3.3	Other Alternative Models Considered	15
2.4	West Models	17
2.5	Statistics of Storm Surges and Wave Conditions	21
2.6	Discussion on East Models	31
2.6.1	Comparison of weir with full barrier (EB with EA)	31
2.6.2	Comparison of closure with openings and no closure (EC with BS)	34
2.6.3	Comparison of full block more seaward with weir closure (ED with EB)	36
2.6.4	Weir alternative (EB) to Base - Impacts on Mississippi	37
2.6.5	Conclusion	40
2.7	Discussion on West Models	40
3	COMPUTATION PROCESS FOR STAGE FREQUENCIES	42
3.1	Introduction	42
3.2	Overview of approach	42
3.2.1	Typology of planning subunits based on their relative location	42
3.2.2	Hydraulic coding system	43
3.3	Future Scenarios	48
3.3.1	Factors affecting the future conditions	48
3.3.2	Effects on levee heights and stages	50

4 PLANNING UNIT 1 53
4.1 Introduction 53
4.2 Levee height 54
4.3 Interior and exterior frequency curves 62
4.4 Interconnected Drainage Areas 71
4.4.1 St Charles 72
4.4.2 New Orleans 72
4.5 Hydraulic Results to Planning Alternatives 73
4.6 Plaquemines 75

5 PLANNING UNIT 2 78
5.1 Introduction 78
5.2 Levee heights 78
5.3 Interior and exterior frequency curves 86

6 PLANNING UNIT 3A 88
6.1 Introduction 88
6.2 Levee height 89
6.2.1 General 89
6.2.2 Ring levee alignment with secondary defense 92
6.3 Interior and exterior frequency curves 94
6.4 Hydraulic Results of Planning Alternatives 96

7 PLANNING UNIT 3B 97
7.1 Introduction 97
7.2 Levee height 98
7.3 Interior and exterior frequency curves 103
7.4 Hydraulic Results of Planning Alternatives 104

8 PLANNING UNIT 4 106
8.1 Introduction 106
8.2 Levee height 107
8.2.1 General 107
8.2.2 12 feet GIWW levee alignment with return 111
8.3 Interior and exterior frequency curves 112
8.4 Hydraulic Results of Planning Alternatives 117

9 CONCLUSIONS AND RECOMMENDATIONS 119
9.1 Conclusions 119
9.2 Discussion 119
9.3 Recommendations 121

10 REFERENCES 123

LIST OF FIGURES

Figure 1.1 - LACPR planning area 2
Figure 1.2 - Planning Unit 1 3
Figure 1.3 - Planning Unit 2 3
Figure 1.4 - Planning Unit 3a 4
Figure 1.5 - Planning Unit 3b 4
Figure 1.6 - Planning Unit 4 5
Figure 1.7 - From levee alignments and scenarios to frequency curves for plan evaluation 7
Figure 2.1 - Maximum surge level (ft) for the 2007 base case for all East 152 storms 9
Figure 2.2 - Maximum surge level (ft) for the 2007 base case for all West 152 storms 10
Figure 2.3 - Maximum wave height (ft) for the 2007 base case for all 152 storms - southeast STWAVE grid 11
Figure 2.4 - Maximum wave height (ft) for the 2007 base case for all 152 storms - West STWAVE grid 11
Figure 2.5 Difference in maximum surge level between the 2010 levee configuration and the 2007 base case for the 2010 storm suite 12
Figure 2.6 Difference in maximum surge level between alternative EB and the base case for the EB storm suite 14
Figure 2.7 Difference in maximum surge level between alternative ED and the base case for the ED storm suite 15
Figure 2.8 Outline of CLEAR/NIA landscape changes 16
Figure 2.9 Difference in maximum surge level (ft) between the CLEAR/NIA configuration and the 2007 and 2010 base cases for the NIA marsh storm suite 17
Figure 2.10 Difference in maximum surge level between alternative WA and the 2007 base case for the WA storm suite 18
Figure 2.11 Difference in maximum surge level between alternative WB and the 2007 base case for the WB storm suite 19
Figure 2.12 Difference in maximum surge level between alternative WC and the 2007 base case for the WC storm suite 20
Figure 2.13 Difference in maximum surge level (ft) between the CLEAR/NIA configuration and the 2007 base case for the LAWEST NIA marsh storm suite 21
Figure 2.14 Statistical Water Surface for the 100 year event, Planning Unit 1 22
Figure 2.15 Statistical Water Surface for the 400 year event, Planning Unit 1 23
Figure 2.16 Statistical Water Surface for the 100 year event, Planning Unit 2 23
Figure 2.17 Statistical Water Surface for the 400 year event, Planning Unit 2 24
Figure 2.18 Statistical Water Surface for the 100 year event, Planning Unit 3a 25
Figure 2.19 Statistical Water Surface for the 400 year event, Planning Unit 3a 25
Figure 2.20 Statistical Water Surface for the 100 year event, Planning Unit 3b 26
Figure 2.21 Statistical Water Surface for the 400 year event, Planning Unit 3b 26
Figure 2.22 Statistical Water Surface for the 100 year event, Planning Unit 4 27
Figure 2.23 Statistical Water Surface for the 400 year event, Planning Unit 4 27
Figure 2.24 L 274 point set locations in Planning Units 1 and 2 29
Figure 2.25 W 177 point set locations in Planning Units 3a, 3b and 4 30
Figure 2.26 Q 835 point set locations for whole coastline 30

Figure 2.27 Average Differences in Surge between EA and EB models on Mississippi Coast 32
Figure 2.28 Maximum Differences in Surge between EA and EB models on Mississippi Coast 32
Figure 2.29 Differences in 100 year Surge Level between EA and EB Model Grids 33
Figure 2.30 Differences in 1000 year Surge Level between EA and EB Model Grids 34
Figure 2.31 Difference in 100 year Surge Level between the EC and 2010 Base Model Grids 35
Figure 2.32 Difference in 1000 year Surge Level between the EC and 2010 Base Model Grids 35
Figure 2.33 Differences in 100 year Surge Level between the ED and EB model grids 36
Figure 2.34 Differences in 1000 year Surge Level between the ED and EB model grids 37
Figure 2.35 Difference in 100 year Surge Level between EB and 2010 Base Model Grids 38
Figure 2.36 Difference in 400 year Surge Level between EB and 2010 Base Model Grids 39
Figure 2.37 Difference in 1000 year Surge Level between EB and 2010 Base Model Grids 40
Figure 3.1 Illustration of categories of planning subunits, relative to the levee system 42
Figure 3.2 Future factors in the framework of LACPR 49
Figure 4.1 Planning Unit 1 54
Figure 4.2 2010 Base Model Grid, 100 year design heights 56
Figure 4.3 2010 Base Model Grid, 400 year design heights 57
Figure 4.4 2010 Base Model Grid, 1000 year design heights 58
Figure 4.5 East Model Grid B, 100 year design heights 59
Figure 4.6 East Model Grid B, 400 year design heights 60
Figure 4.7 East Model Grid B, 1000 year design heights 61
Figure 4.8 Plaquemines - Storage Areas and Existing Levee Heights 75
Figure 5.1 Planning Unit 2 78
Figure 5.2 2010 base model, 100 year design heights 80
Figure 5.3 2010 base model, 400 year design heights 81
Figure 5.4 2010 base model, 1000 year design heights 82
Figure 5.5 East Hydro Model grid B, 100 year design heights 83
Figure 5.6 East Hydro Model grid B, 400 year design heights 84
Figure 5.7 East Hydro Model grid B, 1000 year design heights 85
Figure 6.1 Planning Subunits in Planning Unit 3a 88
Figure 6.2 West model grid A (WA), 100 year design heights 89
Figure 6.3 West model grid A (WA), 400 year design heights 90
Figure 6.4 West model grid A (WA), 1000 year design heights 90
Figure 6.5 West model grid B (WB), 100 year design heights - Morgan City 91
Figure 6.6 West model grid B (WB), 400 year design heights - Morgan City 91
Figure 6.7 West model grid B (WB), 1000 year design heights - Morgan City 92
Figure 6.8 Ring Levee alignment with secondary defence, 400 year design heights 93
Figure 6.9 Ring Levee alignment with secondary defense, 1000 year design heights 94
Figure 7.1 Planning Subunits in Planning Unit 3b 97
Figure 7.2 West model grid A (WA), 100 year design heights 98
Figure 7.3 West model grid A (WA), 400 year design heights 99
Figure 7.4 West model grid A (WA), 1000 year design heights 99
Figure 7.5 West model grid B (WB), 100 year design heights 100
Figure 7.6 West model grid B (WB), 400 year design heights 100
Figure 7.7 West model grid B (WB), 1000 year design heights 101
Figure 7.8 2007 model grid (WT), 100 year design heights 101

Figure 7.9 2007 model grid (WT), 400 year design heights 102
Figure 7.10 2007 model grid (WT), 1000 year design heights 102
Figure 8.1 Planning Subunits in Planning Unit 4 106
Figure 8.2 West model grid A (WA), 100 year design heights 108
Figure 8.3 West model grid A (WA), 400 year design heights 108
Figure 8.4 West model grid A (WA), 1000 year design heights 109
Figure 8.5 2007 model grid (WT), 100 year design heights 109
Figure 8.6 2007 model grid (WT), 400 year design heights 110
Figure 8.7 2007 model grid (WT), 1000 year design heights 110
Figure 8.8 12 feet GIWW levee alignment with return, 2007 model grid A (WA), 400 year design heights 111
Figure 8.9 12 feet GIWW levee alignment with return, 2007 model grid A (WA), 1000 year design heights 112

LIST OF TABLES

Table 3.1 Hydraulic Coding System for the East 44
Table 3.2 Alternatives within Hydraulic Codes (East) 44
Table 3.3 Example of the coding of the stage frequency results per planning subunit per alternative 46
Table 3.4 Hydraulic Coding System for the West 46
Table 3.5 Alternatives within Hydraulic Codes (West) 47
Table 3.6 Example of the coding of the stage frequency results per planning subunit per alternative 48
Table 3.7 Sea level rise 49
Table 3.8 Effects on levee heights and exterior and interior stages for different future scenarios 50
Table 4.1. Interior and Semi-interior Planning Subunits 62
Table 4.2. Planning subunit to Hydraulic Alternative Matrix 65
Table 4.3. Planning Subunit Interior Stage Frequency Alternatives 70
Table 4.4. Specific Planning Subunit Comments 71
Table 4.5. Planning Subunit to Planning Alternative Matrix 74
Table 4.6. Authorized levee heights 76
Table 4.7. Stage values in feet for Plaquemines Storage Areas - based on 50% confidence level results 76
Table 5.1. Interior and Semi-interior Planning Subunits 86
Table 6.1 Input parameters used for design height of the Morganza back levee (stages taken from interior frequency curves) 93
Table 6.2 - Specific Planning Unit Comments 95
Table 6.3 Internal Drainage Area to Planning Alternative Sets 96
Table 7.1 Drainage areas - relationship to alternative sets and Hydrodynamic Models 103
Table 7.2 Interior drainage Area to Hydraulic Alternative Matrix 104
Table 7.3 Specific Planning Unit Comments 104
Table 7.4 Internal Drainage Area to Planning Alternative Sets 105
Table 8.1 Drainage areas - relationship to alternative sets and Hydrodynamic Models 113
Table 8.2 Interior Drainage Area to Hydraulic Alternative Matrix 115
Table 8.3 Specific Planning Unit Comments 117
Table 8.4 Internal Drainage Area to Planning Alternative Sets 118

LIST OF ANNEXES

ANNEX A Hydrodynamic Results
ANNEX B Fact Sheets for Sub Basins

1 INTRODUCTION

1.1 Background

Hurricanes have caused extensive damages to coastal parishes in Louisiana since the time of earliest settlement. Over 40 hurricanes have impacted the coast of Louisiana during the last century. From 1900 to 1950, ten major storms (27 total) struck Louisiana's coastline killing 671 people. After 1950 the National Weather Service started naming storms and since then, thirteen hurricanes (Flossy, Audrey, Betsy, Camille, Carmen, Juan, Andrew, Georges, Isidore, Lili, Cindy, Katrina, and Rita) have caused extensive destruction and loss of life in Louisiana. In 2005 alone, hurricanes Katrina and Rita, which both grew to powerful Category 5 strength as they approached the Louisiana coast, claimed over 1,500 lifes and could result in a total economic impact in the hundreds of billions of dollars in the State.

In response to the devastating destruction caused by hurricanes Katrina and Rita, both the Louisiana legislature and the United States Congress provided legislative directives to investigate and integrate flood control, hurricane risk reduction and coastal restoration for South Louisiana. Development of plans to meet these directives is being undertaken as a joint effort of multiple parts of the Federal government and in partnership with the State of Louisiana. Although the State and Federal legislative directives are not identical, they do share the common fundamental objectives of considering the entire spectrum of landscape level uses and needs, and of incorporating a full range of potential risk reduction measures into an integrated plan. This plan will be evaluated based on its benefits in reducing storm damage to coastal communities and infrastructure, as well as for its ecosystem impacts and benefits.

Authorization and direction for such plan, the Louisiana Coastal Protection and Restoration (LACPR) project, was granted in November 2005. The U.S. Congress has directed the Secretary of the Army, through the Chief of the U.S. Army Corps of Engineers to "conduct a comprehensive hurricane protection analysis and design to develop and present a full range of flood control, coastal restoration, and hurricane protection measures and the Secretary shall consider providing protection for a storm surge equivalent to a Category 5 hurricane and the analysis shall be conducted in close coordination with the State of Louisiana."

1.2 Purpose of LACPR

The purpose of LACPR is to identify risk reduction measures that can be integrated to form a system that will provide enhanced protection of coastal communities and infrastructure, as well as restoration of coastal ecosystems. The scope of LACPR is to address the full range of flood control, coastal restoration, and hurricane protection measures available, including those needed to provide comprehensive "Category 5" protection.

1.3 Planning Area with Planning Units

The LACPR planning area stretches across Louisiana's coast from the Pearl River on the Mississippi border to the Sabine River on the Texas border. The planning area is comprised of two wetland-dominated ecosystems, the Deltaic Plain of the Mississippi River and the closely linked Chenier Plain, both of which are influenced by the Mississippi River. The Deltaic Plain contains ecologically important estuaries fronted by numerous barrier islands and headlands, including the Chandeleur Islands, Barataria Basin Barrier Islands, and Terrebonne Basin Barrier Islands. The Chenier Plain contains important diverse wildlife and fisheries habitat that extends from the

Teche/Vermilion Bays to Louisiana's western border with Texas, and is characterized by several large inland lakes, marshes, cheniers (oak ridges), and coastal beaches.

Figure 1.1 - LACPR planning area

For the purposes of LACPR the area has been divided into five planning units. Planning Unit 1 is situated on the east bank of the Mississippi and includes Lake Pontchartrain. Planning Unit 2 covers the west bank of the Mississippi and the Barataria Basin as far as Bayou Lafouche. Planning Unit 3a covers the Morganza region, from Bayou Lafouche to Morgan City, and Planning Unit 3b contains the Achafalaya basin and the coast as far as the Vermillion River and Abbeville. Planning Unit 4 covers the area between the Vermillion River and the Texas border, including Lake Charles in the west The planning units are shown in Figure 1.2 up to Figure 1.6

Each planning unit is divided into planning subunits. These are based on the census blocks used for economic data collection. Where these planning subunits fall within the authorized levee systems or where levees are being planned, these areas are the subject of calculations to determine flooding with the levees in place. Within the existing levee systems of the metropolitan areas of New Orleans and along the West Bank of the Mississippi the planning subunits were established as larger groups of census blocks and which were defined either by parish boundaries or other physical features (such as raised roads or existing internal levees). In other areas the census blocks were grouped based on flooding similarity, but limited in size by parish boundaries, proposed levee alignments and physical features.

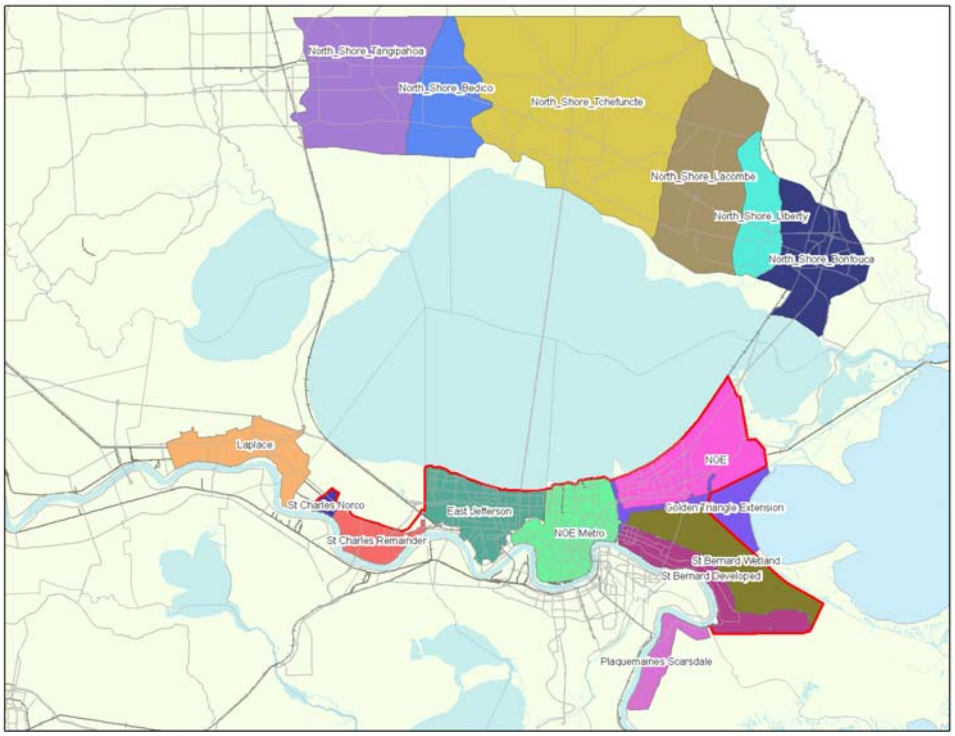


Figure 1.2 - Planning Unit 1

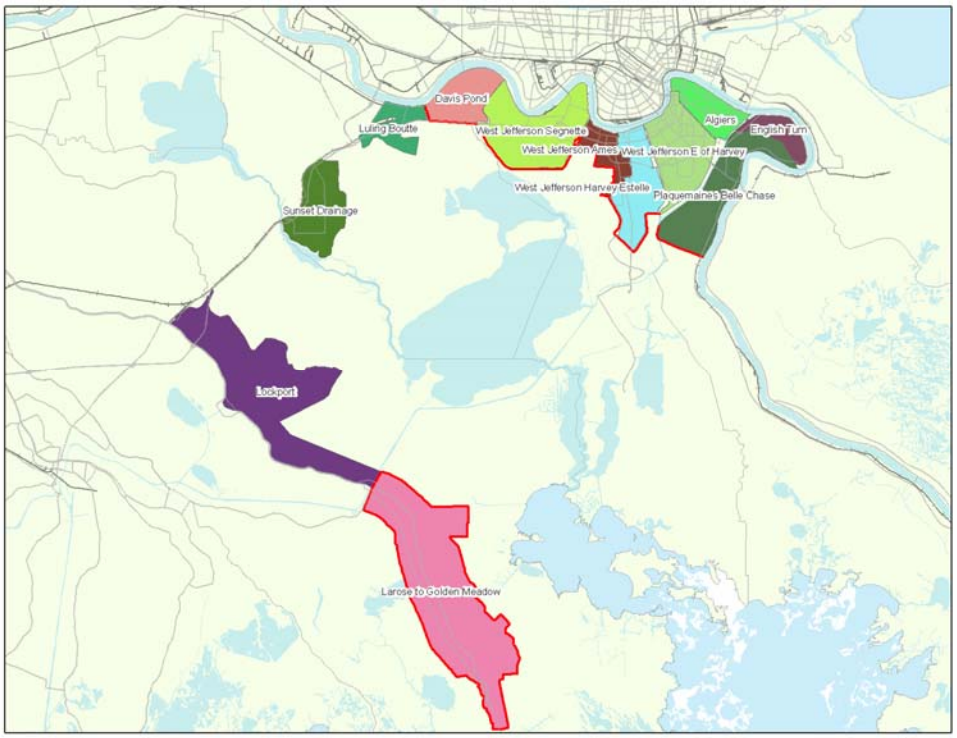


Figure 1.3 - Planning Unit 2

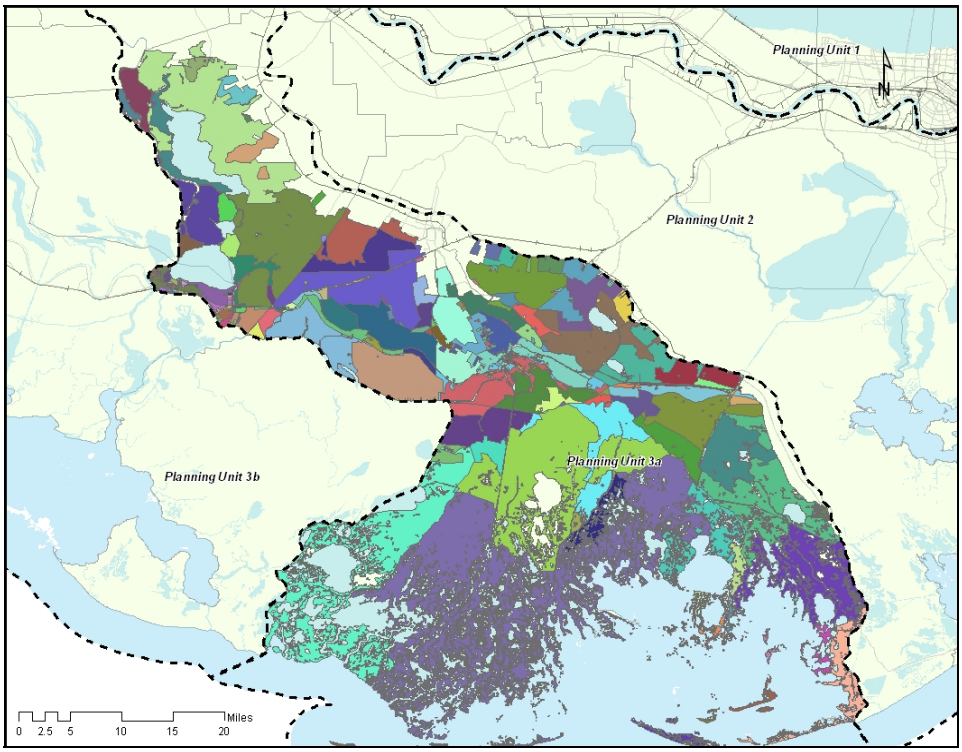


Figure 1.4 - Planning Unit 3a

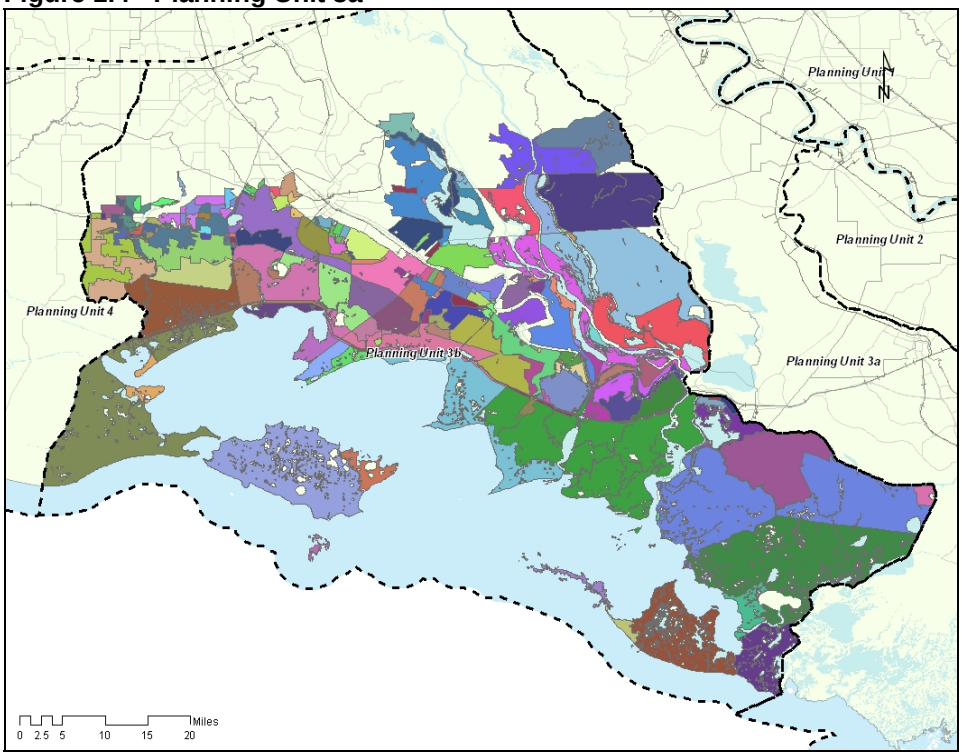


Figure 1.5 - Planning Unit 3b

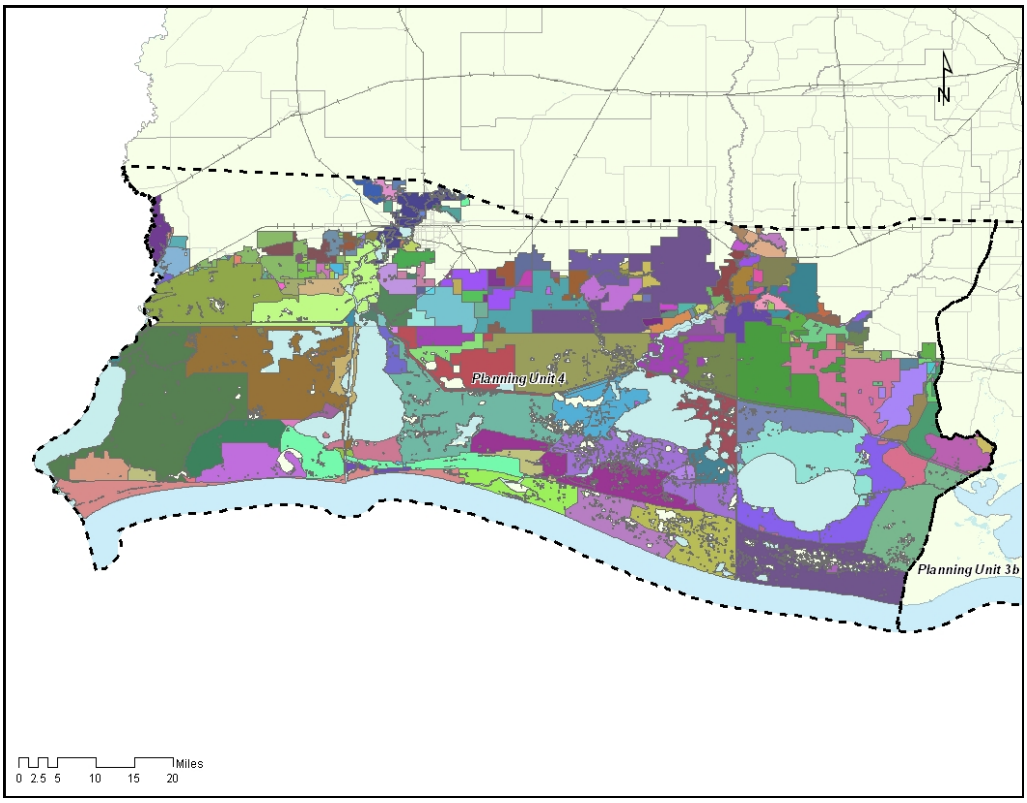


Figure 1.6 - Planning Unit 4

In the west the planning subunits are derived purely from the census blocks, which are combined to form the planning subunits. These units have been split along any proposed levee alignment so that groups of planning subunits (called drainage areas) can be used within the calculations.

1.4 LACPR in brief

Within LACPR for all five planning units various *planning alternatives* (sets of measures) have been developed and evaluated. A planning alternative may be the construction of a particular alignment of levees, it may include structures or landscape changes which reduce surge elevations further offshore, it may include non structural measures, such as buy out or raising of property. Most often, alternatives are proposed in combination, like the construction of levees together with the raising of property. For this report the following (groups of) planning alternatives have been considered:

- No Action - represents the current situation and allows for a degrading coastline with sea level rise in the future;
- Maintain Coast - represent an alternative where the defenses are maintained but not improved and the coastal features are also maintained at their current levels;
- Structural alternatives to specific levels of protection - including weirs and modifications to levee alignments.

Planning alternatives (proposed sets of levees in terms of alignment and height) are designed to provide protection against flooding events of a certain magnitude. The *level of protection* provided by a planning alternative indicates the frequency of the flooding to which the specific alternative is to provide protection, indicated in “once per a certain number of years”. For this report, three particular levels of protection have been considered. These are 100 year, 400 year, and 1000 year. The selection of these levels of protection has been based on the request to provide the 100 year level of protection, plus protection against a range of hurricanes up to CAT5.

For the evaluation of the planning alternatives, the designed levee systems have been confronted with a standard set of flooding events. Here, an *event* is the representation of surge elevation, wave height, and wave period that might be expected to occur at any location with a defined frequency. The range of return periods used is 10, 100, 400, 1000, and 2000. The middle 3 events match with the proposed levels of protection, whilst the 10 gives a lower limit and the 2000 year provides an event which will overtop all levels of protection.

In this way, per planning alternative with a given level of protection, the amount of overtopping can be computed in case of an event of a certain return period. The amount of overtopping results in a water level (stage) in the protected area. Thus, a planning alternative which is designed to provide a 400-year level of protection should not overtop when it is confronted with a 100-year event, but it will overtop in case of a 1000-year event. The next section describes the main elements of this hydraulic evaluation. Details on the actual planning alternatives are given in the main technical report and in the chapters per planning unit in this report.

1.5 Hydraulic evaluation

This report (Volume II) presents the results of the hydraulic evaluation of the planning alternatives in the framework of LACPR. The methodology that was developed for this evaluation is discussed in a separate report (Volume I). In the hydraulic evaluation hydrodynamic results (storm surges and waves) are used to compute the levee heights and the stage frequency curves (see Figure 1.7). The stage frequency curves in their turn are an important input for the economic analysis to estimate the damage in the planning subunits. In addition the levee heights are required so that the cost of construction and ongoing maintenance can be established.

Step 1: Determination of the levee heights
The levee height is computed for three different levels of protection (100-year, 400-year, 1000-year). Given the level of protection, the overtopping volumes are computed for four return periods of the outside surge level and wave characteristics (100-year, 400-year, 1000-year, and 2000-year). The resulting overtopping volumes are used to compute the interior frequency curves in the planning subunits (step 2).

Step 2: Determination of the stage frequency curves
For each planning subunit the frequency curves are extracted from the hydraulic results estimated for different levee alignments and scenarios. A single planning subunit can have either an internal stage frequency, an external stage frequency, or in some cases both an internal and an external stage frequency for a particular hydraulic model condition. A planning subunit has both internal

and external stage frequencies in those cases where no levee currently exists in the model, but where a levee is planned in one of the alternatives. The stage frequency curves are used in the economic evaluation to estimate the damages caused by flooding.

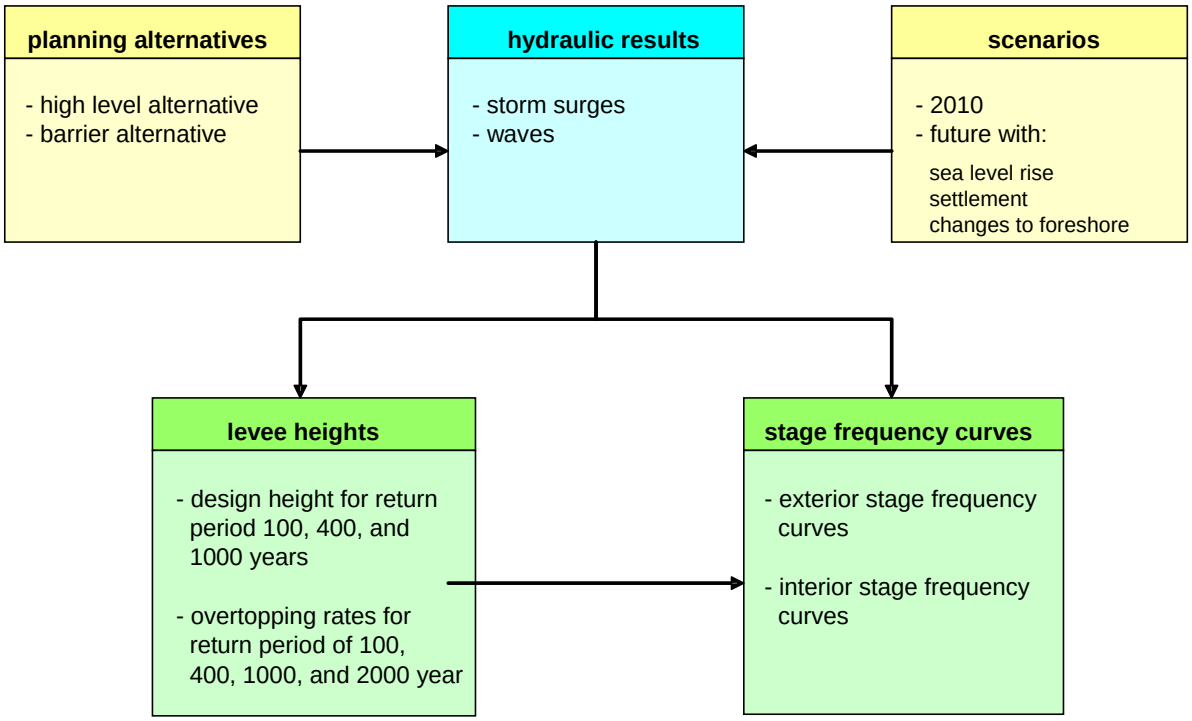


Figure 1.7 - From levee alignments and scenarios to frequency curves for plan evaluation

1.6 Scope and limitations

The work presented in this report has been carried out between June and December 2007 as a combined effort of the United States Army Corps of Engineers, New Orleans District, and Haskoning Inc. The methods and results as described in this report are limited to the technical aspects only and do not include the economic evaluation.

The main deliverables of the hydraulic evaluation of the LACPR work are the design levee heights and the stage frequency curves for both interior and exterior areas. These are meant as input for the economic evaluations and the damage studies.

Note that the results described in this report were developed to enable the relative comparison of various design alternatives. More detailed studies will be needed before doing actual design.

1.7 Report outline

This report describes the results of the processes carried out for determination of the levee heights and stage frequency curves for the five Planning Units. In Chapter 2 the Hydrodynamic modeling

(surge and waves) is discussed, being the primary input for deriving the levee heights and stage frequencies. Chapter 3 describes the process to come up with stage frequency curves for the planning subunits. The Chapters 4 to 8 describe the results for each planning unit respectively. The report ends with conclusions and recommendations in Chapter 9.

2 HYDRODYNAMIC RESULTS

2.1 Introduction

The purpose of the hydrodynamic modeling is to provide input on extreme surge and wave heights for the evaluation of both existing (base) and alternative future conditions to the levee design and stage frequency analysis required for the evaluation of alternatives within the LACPR project. The modeling utilized the 152 storms from the “Joint Probability Method with Optimal Sampling” (JPM-OS) suite so that the method could be used to establish the statistical extremes of surge levels and waves. Two sets of storms were used, one for the eastern part of southern Louisiana (primarily Planning Units 1 and 2) and a second set for the west (Planning Units 3a, 3b and 4). In particular Planning Unit 3a (the Morganza area) fell within both of the storm sets and model runs. The modeling used the ADCIRC and STWAVE models, and the modeling was split into a number of sections for evaluation purposes.

The reader is referred to Volume 1 for a full description of the applied methodology, the underlying models and assumptions. An important issue regarding the wave results from STWAVE is that only the no friction results has been used ultimately in the framework of LACPR. The results from the independent analysis suggest that compared with the STWAVE results with friction, the no friction STWAVE results provide the more appropriate wave conditions for levee design (see also Annex A). Uncertainty in future location and density of coastal marshes, in part due to local subsidence and lack of appropriated funding for marsh restoration, provides additional rationale for excluding the effects of friction in the near shore wave results.

In the post processing of the model results the maximum surge values were established by looking at each time step and developing the maximum value at each point within the model over time. This returns the maximum envelope of surge values for a particular storm event. In addition a peak of peaks surface was produced which took the highest value at each point from the range of storms computed. The ensemble of maximum values (from the suite of storms) was used to determine the expected return periods for the surge elevations. A similar process was undertaken from the STWAVE results for wave height and wave period.

The following sections give a brief overview of the hydraulic modeling results. Section 2.3 describes the 2007 base condition modeling. The chapter continues describe the models developed for the east and west part of the State, including changes to the marsh over 50 years. It briefly presents the processes undertaken to turn the model results into event data, before describing the selection of particular model grids for use in the further analysis. More detailed information about the modeling is provided in Annex A.

All figures presented in the following sections represent the peak of peaks surfaces for all storms simulated, and for the east the results from the southeast STWAVE grid (which covers the east of

New Orleans, the Mississippi Delta, Lake Borgne and the Barrier Islands) have been used to demonstrate the wave effects.

2.2 2007 Base Condition

The 2007 base model has been built to cover the whole of southern Louisiana and represents the situation at the start of the 2007 hurricane season. It includes post Hurricane Katrina and Rita bathymetry together with levee heights and extents which match with the current state of repaired and upgraded levees. A full set of 152 storms was run for each of the east and west parts of the model to determine water levels and corresponding wave heights to use as base conditions for the comparison of future alternatives.

Figure 2.1 and Figure 2.2 represent the maximum surge level recorded for the 152 storms simulated for each of the east and west grids for Southeastern Louisiana. These plots do not represent a single return period surge event, but are representations of the maximum recorded value at each location from all the 152 storms run through the models. The maximum results show significant surge elevations within the existing Hurricane Protection system in the east, but this would be expected as the range of storms considered include storms in excess of the 1000 year return period.

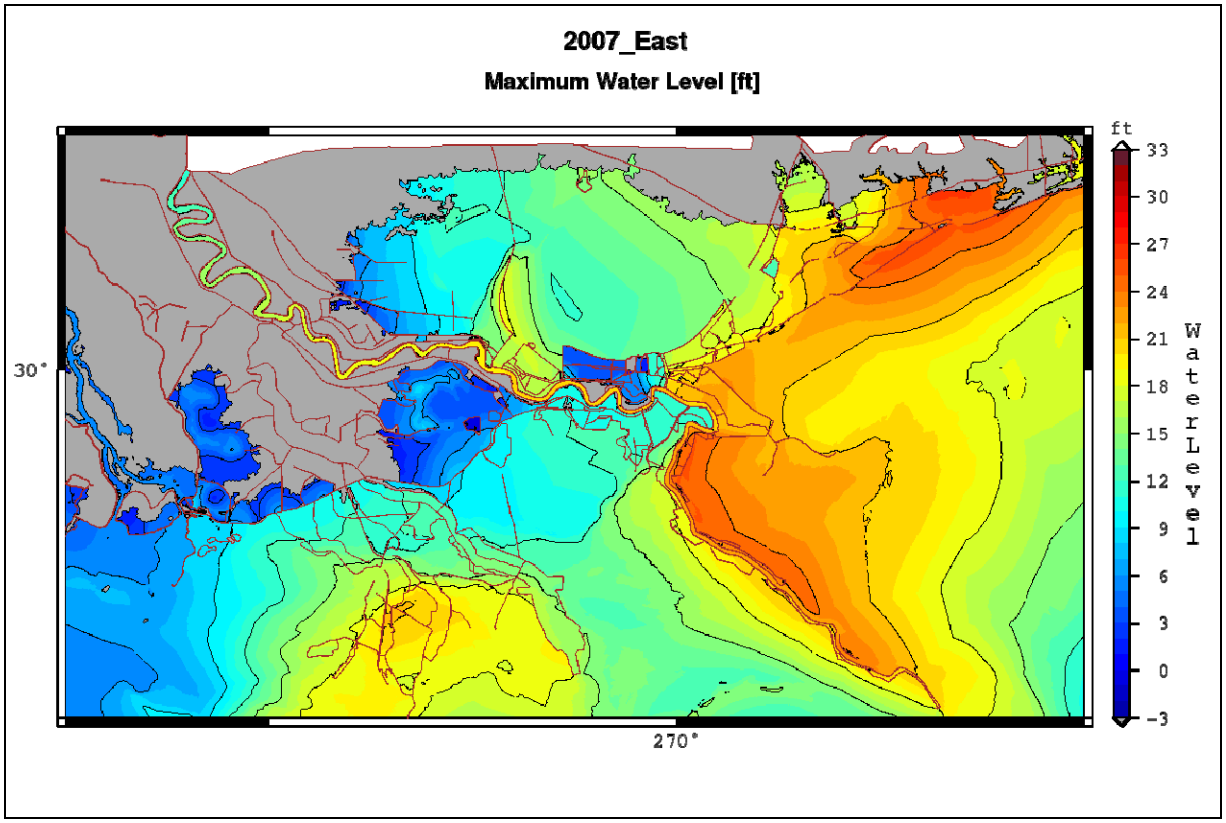


Figure 2.1 - Maximum surge level (ft) for the 2007 base case for all East 152 storms

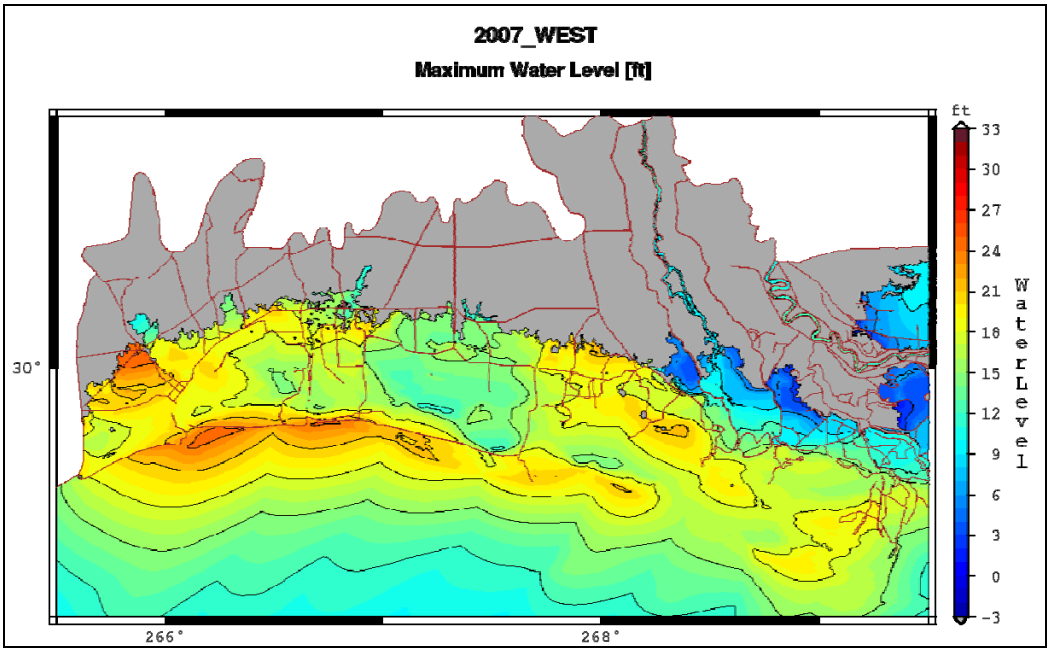


Figure 2.2 - Maximum surge level (ft) for the 2007 base case for all West 152 storms

Figure 2.3 and Figure 2.4 show the maximum wave heights predicted from the range of storms run within the model for the southeastern STWAVE grid (with no friction) and the west STWAVE grid. These show the reduction in wave height as the water depth rapidly decreases at the Barrier Islands and in the east shows maximum heights around the existing levee system of 6 to 8 feet.

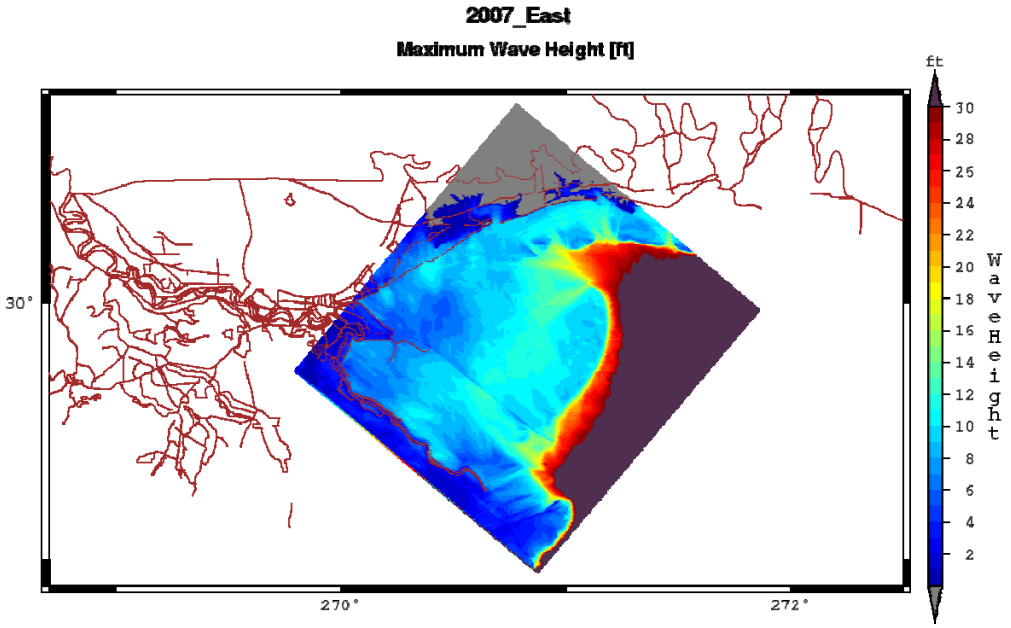


Figure 2.3 - Maximum wave height (ft) for the 2007 base case for all 152 storms - southeast STWAVE grid

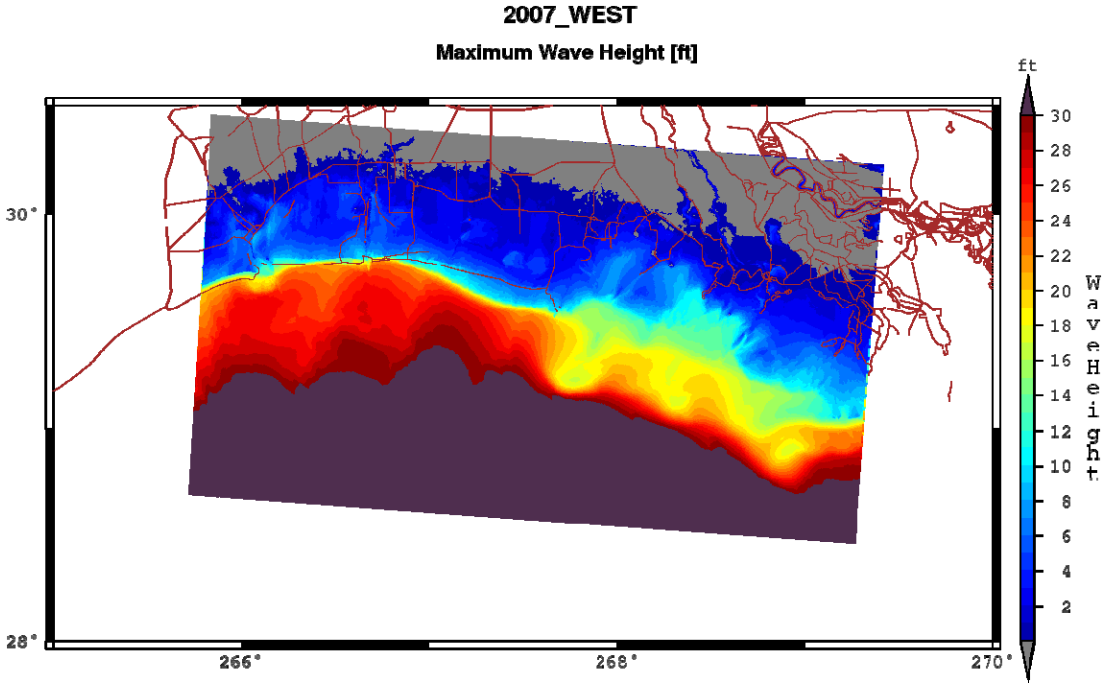


Figure 2.4 - Maximum wave height (ft) for the 2007 base case for all 152 storms - West STWAVE grid

2.3 East Models

2.3.1 2010 Base Condition

The 2010 base condition in the east represents the proposed improvements to the system that are expected to be completed by 2010. These include restoring the levees to their authorized levels and, in and around the metropolitan area of New Orleans, raising the levee heights to provide a 100 year level of protection. Around the Morganza area (to the west of Bayou Lafouche) the model included a non overtopping levee to represent the proposed new levee around the Morganza area.

Figure 2.5 shows the differences in maximum water level between the existing (2007) model and the 2010 base condition. This shows the dramatic reduction in surge elevations within the levee systems where the improved levees reduce surge elevations. However it also indicates the increase in maximum surge levels outside the levee system (generally 1 to 3 feet, but with localized hot spots). The changes in maximum wave height are much less marked, other than within the levee system where the dramatic reduction in water depths reduces the wave heights to also nil. Plots of the wave height change are included in the Annex A.

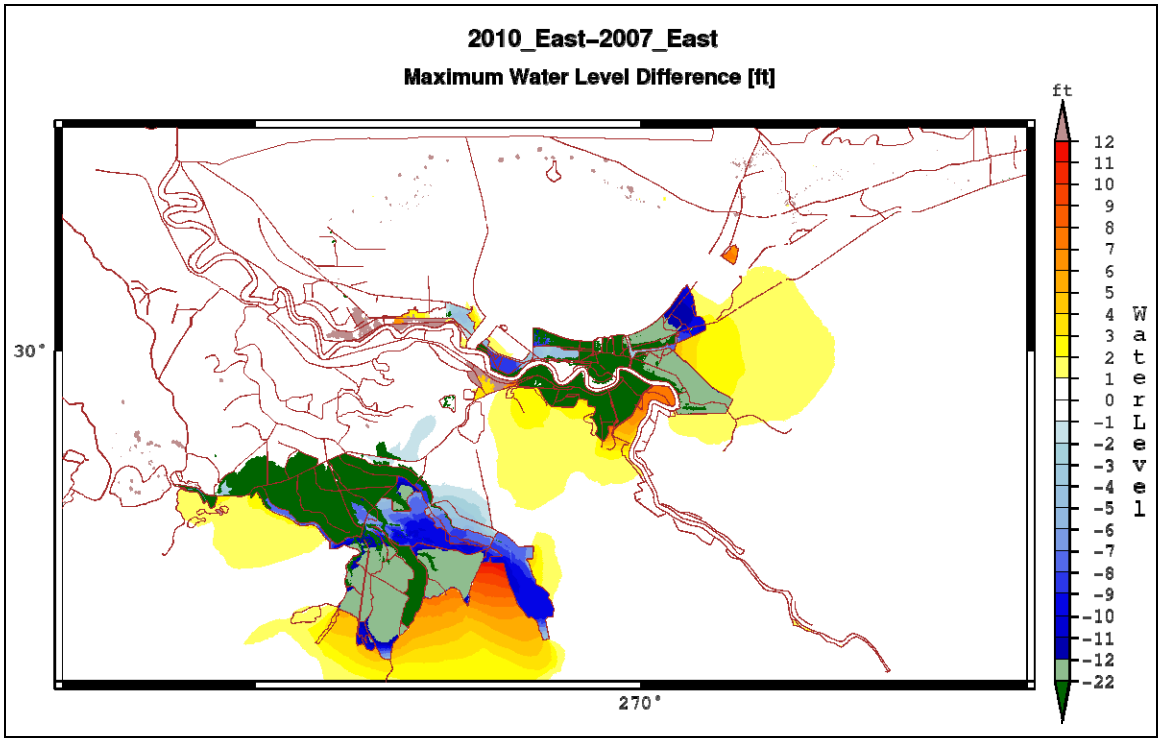


Figure 2.5 Difference in maximum surge level between the 2010 levee configuration and the 2007 base case for the 2010 storm suite

2.3.2 Closure Options of Lake Pontchartrain and the Barataria Basin

Four different model grids have been constructed representing four alternatives for closing the mouth of Lake Pontchartrain (Planning Unit 1), together with three alternative closures of the Barataria Basin area (Planning Unit 2). Note that two of the model grids used the same closure in the Barataria basin. Of these four models, one was used for the main calculations whilst the remainders were used for screening. All four models are considered below, but more detail is given on weir closure alternative which was used for the main comparison of closure alternatives to non closure alternatives. All the models used the 2010 base model as the starting point. More details of the model set ups are given in Volume I.

Full Closure along US90 and GIWW (Model grid EA) For Lake Pontchartrain area this model represents the closure of Lake Pontchartrain along the US90 corridor with a non overtopping levee. This alternative prevents filling of Lake Pontchartrain from Lake Borgne, but it still shows elevated water levels within the Lake as a result of the high wind speeds in this area. It also includes moving the primary levee alignment to around the edge of Lake Borgne, closing the Gulf Intracoastal Waterway (GIWW) and the Mississippi River-Gulf Outlet (MRGO).

For the Barataria Basin the model includes a non-overtopping levee which follows the line of the GIWW from Belle Chase across to the northern end of the Larose to Golden Meadow levee system. It also includes non-overtopping levees around the Larose to Golden Meadow area.

The results of this model are discussed in the Discussion on the East model grids (see Section 2.6).

Weir Closure along US90 and GIWW (Model grid EB) For the Lake Pontchartrain closure this model is the same as the previous alternative albeit that the levee across the mouth of Lake Pontchartrain has been lowered to 12 feet. This blocks the flow of water during small events and act as a weir in extreme events allowing a reduced amount of water into the Lake. Figure 2.6 shows the difference in maximum water levels for all storms between the EB model and the 2007 base case. Reductions of the maximum surges within the Lake are in the order of 2 to 3 feet in the south and 3 to 4 feet in the north. The maximum values do increase on the outside of the weirs, particularly near the closure of the GIWW/MRGO, where the maximum levels go up by 5 to 6 feet. The potential impact of this weir on the Mississippi coastline is discussed in Section 2.6.

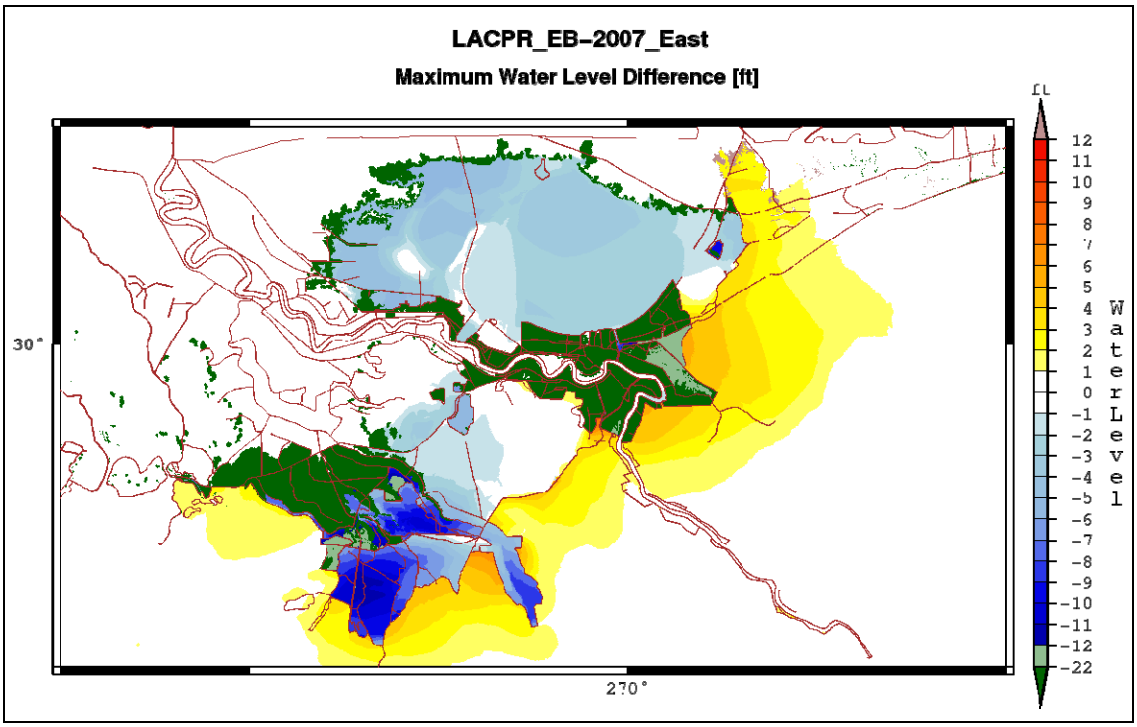


Figure 2.6 Difference in maximum surge level between alternative EB and the base case for the EB storm suite

In the Barataria Basin area the model replaces the non-overtopping levee in model EA with a 12' weir. This weir reduces the maximum water levels in the areas further from the weir, but appears to have little impact on the maximums in the Mississippi west bank areas. Offshore of the weir levels increase by up to 4 feet adjacent to the weir.

Partial closure along US90 and Weir along US90 (Model grid EC) The EC model uses a non overtopping levee similar to EA across the mouth of the Barataria Basin, but in addition allows for openings through the levees at the Chef Menteur Pass and the Rigolets. These opening allow water to flow between Lake Borgne and Lake Pontchartrain during storm events.

Within the Barataria Basin the EC model adopts a 12' weir along the alignment of US90, joining the levees around the Sunset Drainage District with a levee running along the east bank of Bayou Lafouche.

The results of this model are discussed in the Discussion on the East model grids (see Section 2.6).

Full Closure through Lake Borgne (Model grid ED) This alternative considers a non-overtopping levee built across Lake Borgne, connecting the southeastern tip of the St Bernard Parish defenses with Slidell. This alternative results in noticeable increases in maximum water level on the outside

of the levee and along the Mississippi coastline, but has a marked reduction in maximum levels within the Lake Pontchartrain and within the areas to the south and east of New Orleans east and St Bernard Parish.

Figure 2.7 shows the differences in maximum water level between the ED model grid and the 2007 base model.

The model in the Barataria Basin is the same as model grid with the full closure (East A) and is not considered further.

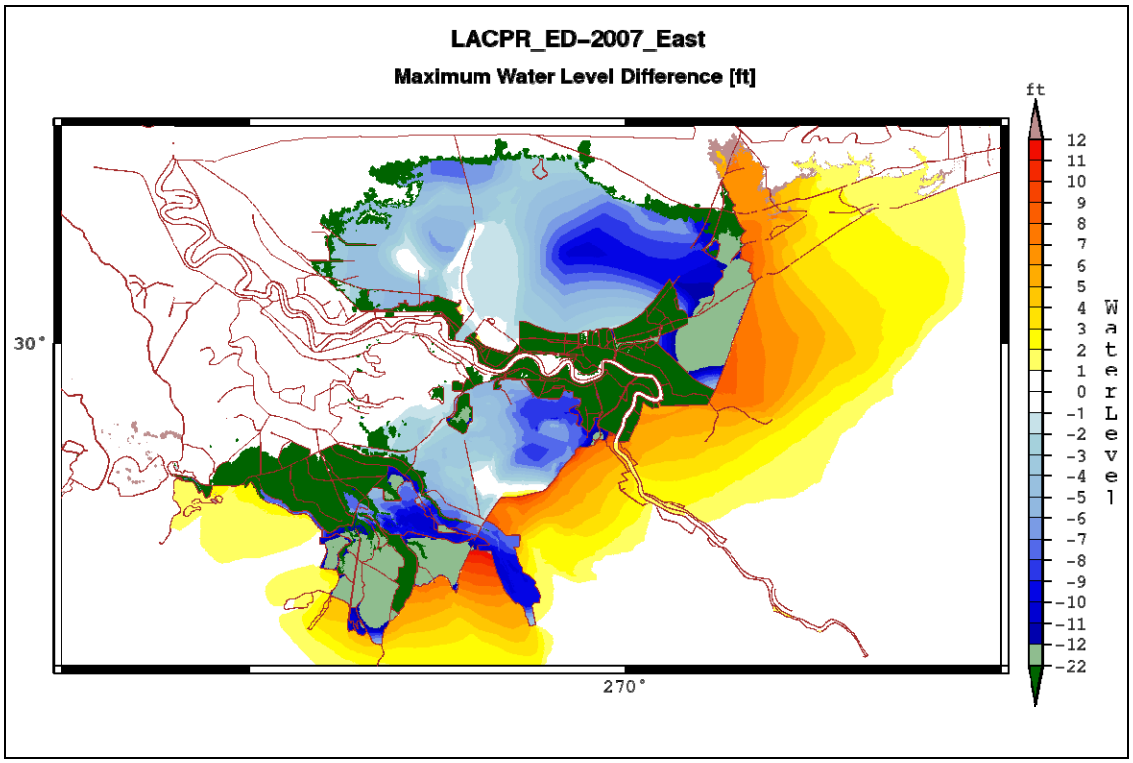


Figure 2.7 Difference in maximum surge level between alternative ED and the base case for the ED storm suite

2.3.3 Other Alternative Models Considered

In addition to the four major alignment alternatives, the following other models have been developed and run to test the impacts of changes to the system:

- Plaquemines 1 - models the introduction of three spillways across the lower Mississippi River within Plaquemines parish;
- Plaquemines 2 - models the removal of all levees along the Mississippi River within the delta which allows the relatively free flow of water across the Mississippi;
- Barrier Islands - five different models were run for a selected storm set which represented the post Katrina conditions and 4 different restored island conditions;

- Marsh Alternative - No Increased action (NIA) or CLEAR model - this is described in more detail below;
- Marsh Alternative - Restored/improved marsh conditions;
- Sea level rise - based on 9 storms using the 2010 model grid and increasing water level by 1', 2' and 3'. The 9 storms were selected to represent the 100 year storm event in various locations.

Apart from the NIA or CLEAR model the other models and their results are described in more detail in Annex A.

Marsh alternative - NIA or CLEAR model This model is also known as the Future Degraded (FD) model. It represents a prediction of the landscape in 50 year time and although referred to as a degraded coast may also include accretion. The prediction has been developed as part of the Coastal Louisiana Ecosystem Assessment and Restoration (CLEAR) program. Figure 2.8 gives an indication of the landscape changes within this model. The levees used within the model are as the 2010 base model, apart from those in the area to the west of Bayou Lafourche where the 2007 model has been used.

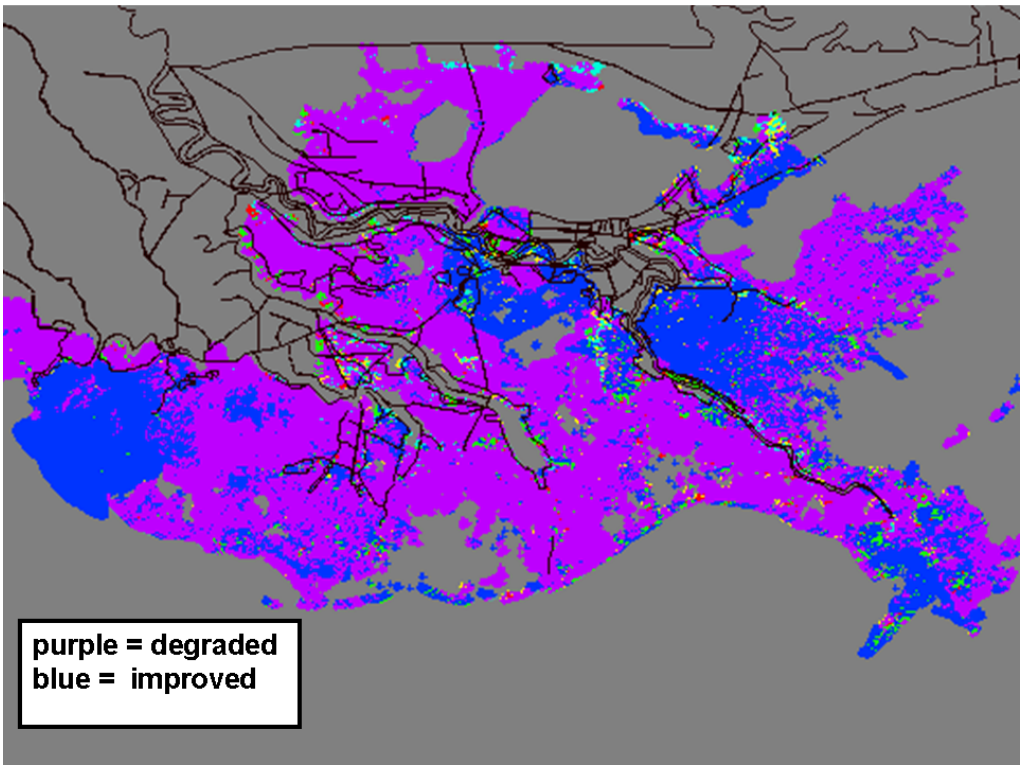


Figure 2.8 Outline of CLEAR/NIA landscape changes

Comparison of the maximum water elevations between the CLEAR model and the 2007/2010 models shows small changes in water level in and around the New Orleans and Lake

Pontchartrain areas, but much larger changes in the Barataria basin and Morganza areas. These changes are shown in Figure 2.9.

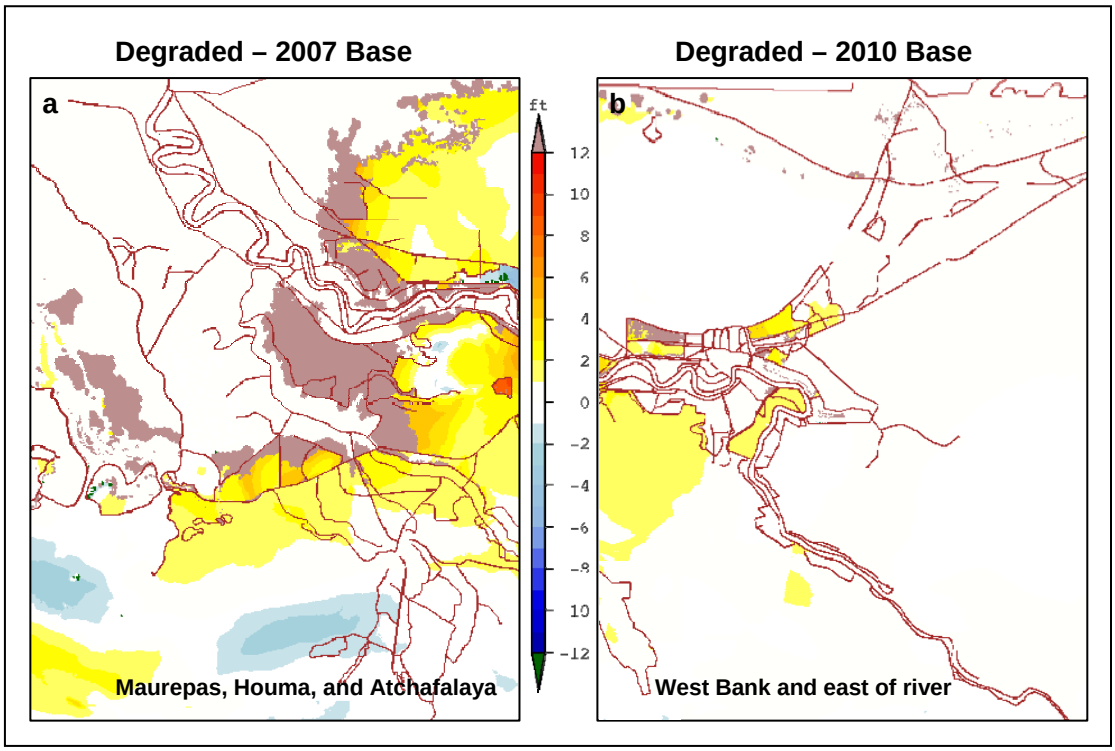


Figure 2.9 Difference in maximum surge level (ft) between the CLEAR/NIA configuration and the 2007 and 2010 base cases for the NIA marsh storm suite

2.4 West Models

In addition to the 2007 baseline model, for the west three models have been developed to represent three potential levee alignments. These models are described briefly below.

Morganza and GIWW alignment (Alternative WA) This model includes a non-overtopping levee which followed the proposed Morganza alignment to the west of Bayou Lafouche, connecting with the existing levee system around Morgan City and Patterson before following a line to the seawards of the GIWW to Lake Charles, and then tying into high ground just before the Louisiana / Texas border.

Figure 2.10 shows the differences in maximum water level between the WA model grid and the 2007 base model

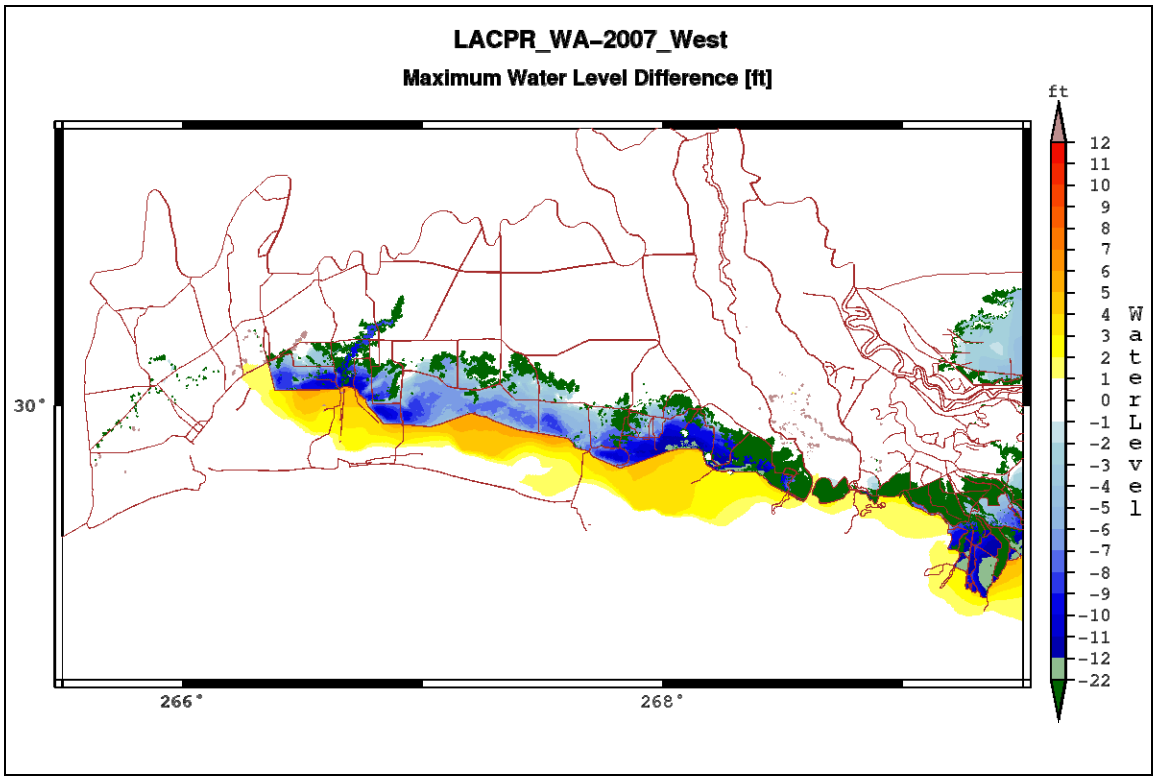


Figure 2.10 Difference in maximum surge level between alternative WA and the 2007 base case for the WA storm suite

Morganza and Retired Levee Alignment, plus ring levees (Alternative WB) This model includes an incomplete levee system around Morganza, with two lines of defense, a non-overtopping levee from Morgan City to Abbeville, following a line between the GIWW and the higher ground, with the levee returning to higher ground around the Vermillion River. To the west of the Vermillion the model included small ring levees around a couple of areas of population and a larger ring around Lake Charles.

Figure 2.11 shows the differences in maximum water level between the WB model grid and the 2007 base model

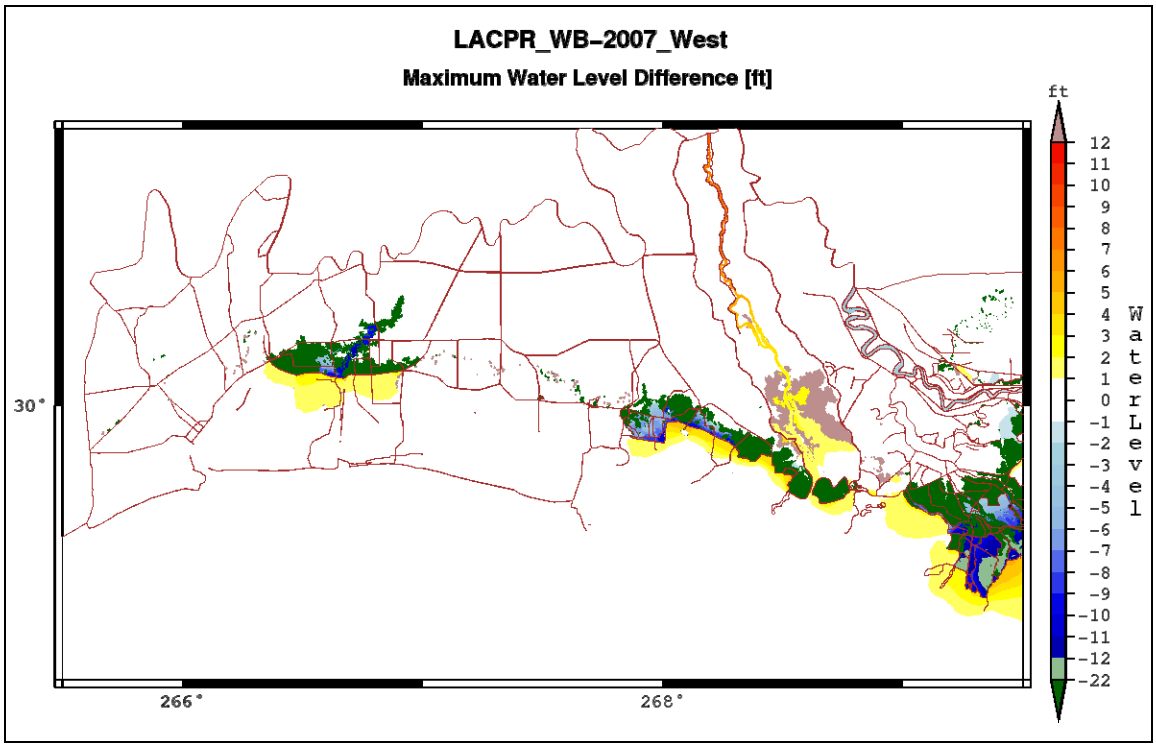


Figure 2.11 Difference in maximum surge level between alternative WB and the 2007 base case for the WB storm suite

Combined Alignments (Alternative WC) This model considers a twin line of defense within Morganza, with a 100 year defense round the outer line and a non-overtopping levee on the inside, a lower level of protection between Houma and Morgan City. Between Patterson and Abbeville the same alignment as WB has been used. From Abbeville to Lake Charles a 100 year levee was modeled along the GIWW alignment, eventually tying into a ring levee around Lake Charles.

Figure 2.12 shows the differences in maximum water level between the WC model grid and the 2007 base model

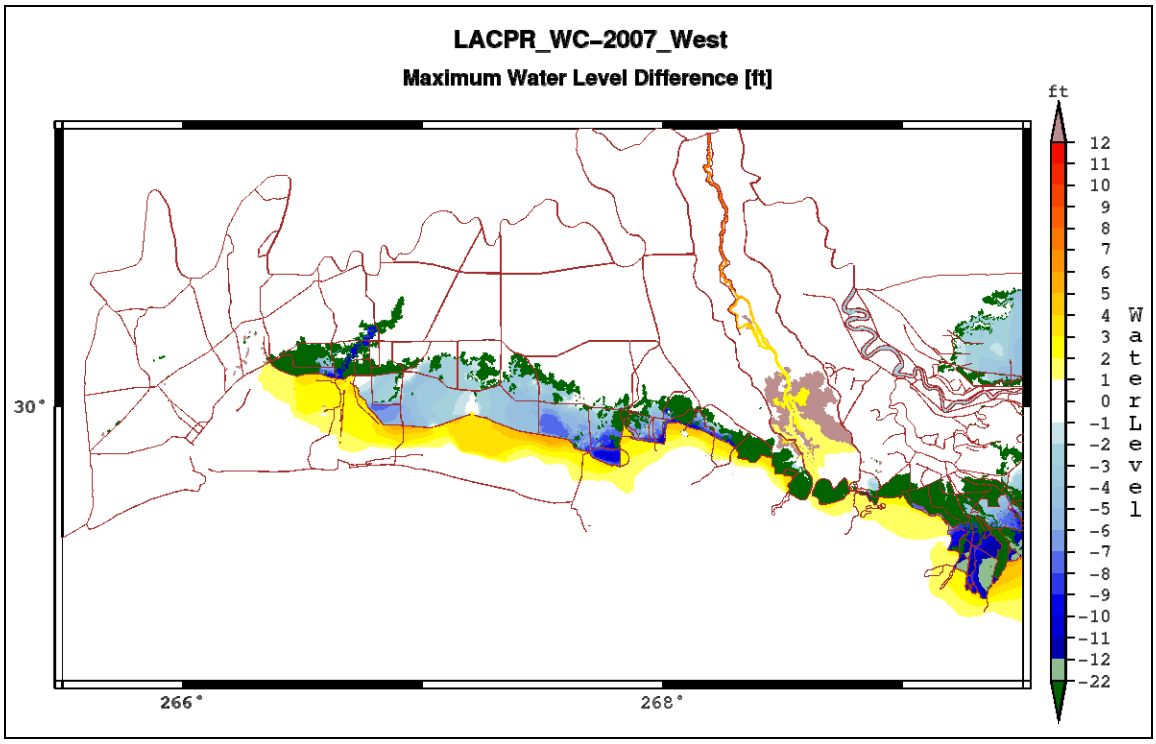


Figure 2.12 Difference in maximum surge level between alternative WC and the 2007 base case for the WC storm suite

Future Degraded In the same way as for the east, a model has been developed based on the projected changes in marsh etc over the next 50 years. This prediction has been made as part of the CLEAR program. The model uses the basic 2007 grid as a starting point.

Figure 2.13 shows the differences in maximum water level between the CLEAR/NIA model grid and the 2007 base model. The degraded landscape generally results in around a 1 to 2 ft increase in peak surges across western Louisiana with the exception of the Atchafalaya area. This is suggested to equate to possible marsh growth as a result of discharges from the Atchafalaya River.

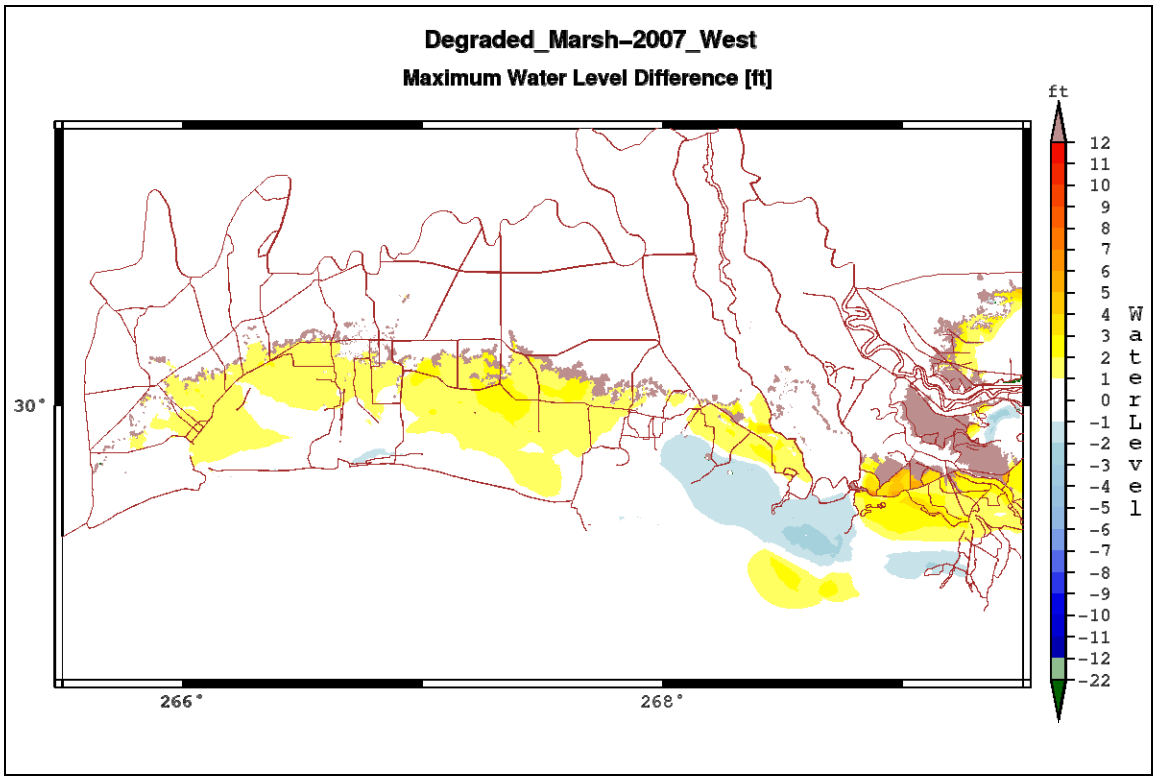


Figure 2.13 Difference in maximum surge level (ft) between the CLEAR/NIA configuration and the 2007 base case for the LAWEST NIA marsh storm suite

2.5 Statistics of Storm Surges and Wave Conditions

The previous sections of this chapter have described the storm surge and wave models developed for LACPR. The results from these models represent specific storms and only the peak values were extracted from the full suite of storms. For use within the derivation of levee heights and economic damage calculations based on flood depths the results need to be translated into stage frequency relationships. This is done using the JPM-OS methodology described in volume I.

The JPM-OS methodology uses the results from the models and statistically obtains the water level or wave conditions relating to a particular return period of event. This has been done for all models at selected points (discussed further below), and for some model (the base models) for all points. Undertaking the analysis at all points within the model allows for the creation of water level and wave height surfaces for display, which cannot be easily created from the reduced point sets used for the main calculations.

The created surge and wave values do not represent a single storm event with a particular frequency. Rather they represent the water level or wave condition that could occur with that frequency. For example if the 100 year surge level occurs along the South shore of Lake

Pontchartrain then it is very unlikely that at the same time the 100 year surge level occurs in the Barataria Basin (as the values could be higher or lower depending on the track of the storm).

Surfaces of extreme water level have been prepared for some of the models for a range of event frequencies. The following figures show the 100 year and 400 year frequency water levels for the 2010 base model for Planning Units 1 and 2, and the 2007 base model for Planning Units 3a, 3b and 4.

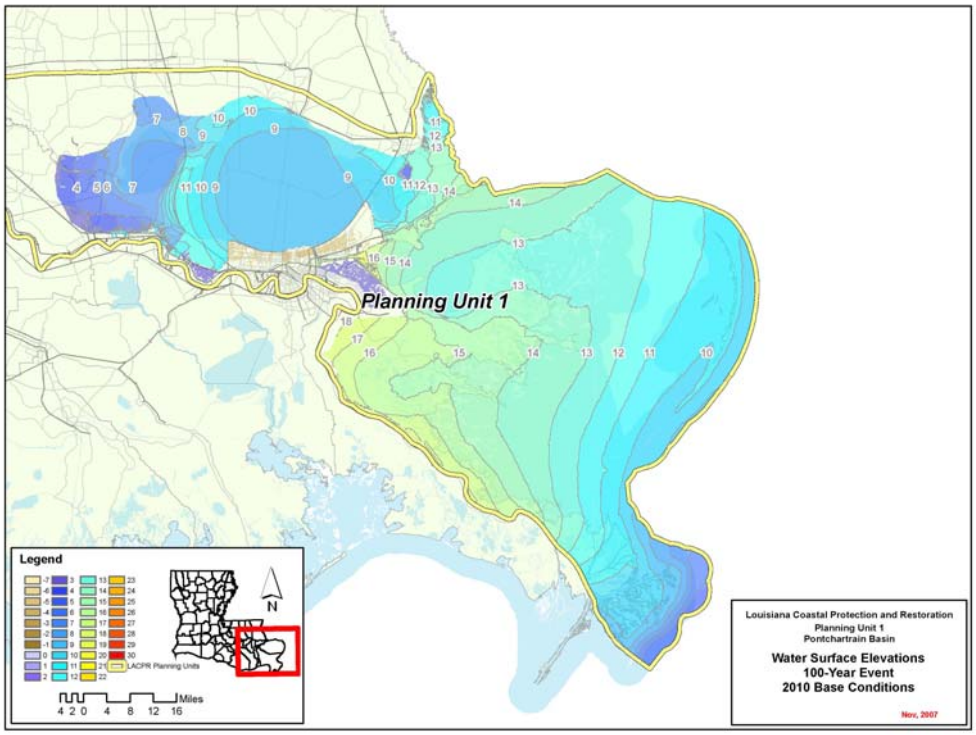


Figure 2.14 Statistical Water Surface for the 100 year event, Planning Unit 1

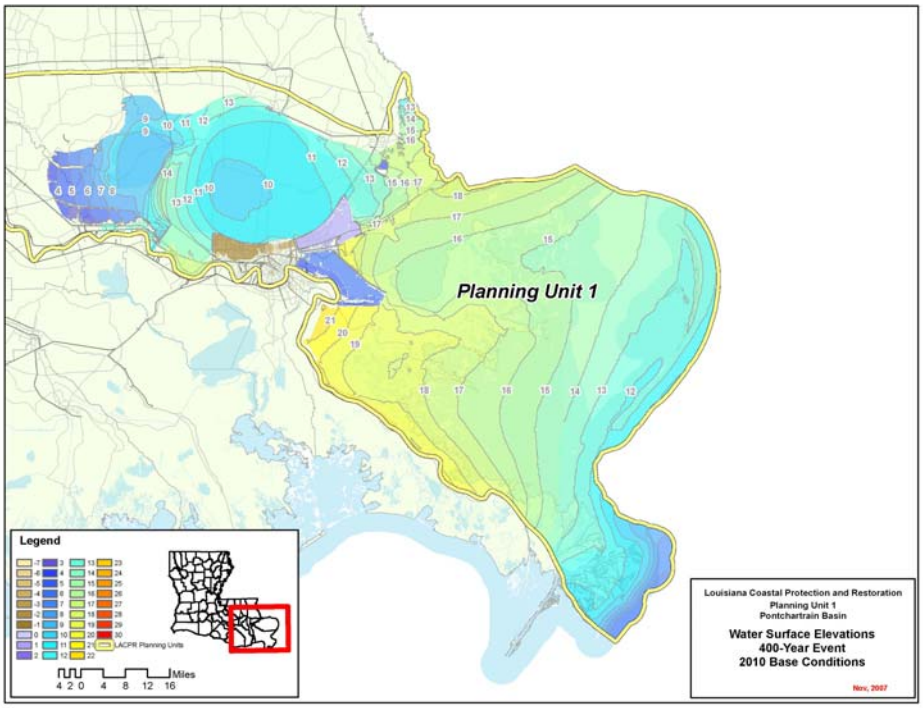


Figure 2.15 Statistical Water Surface for the 400 year event, Planning Unit 1

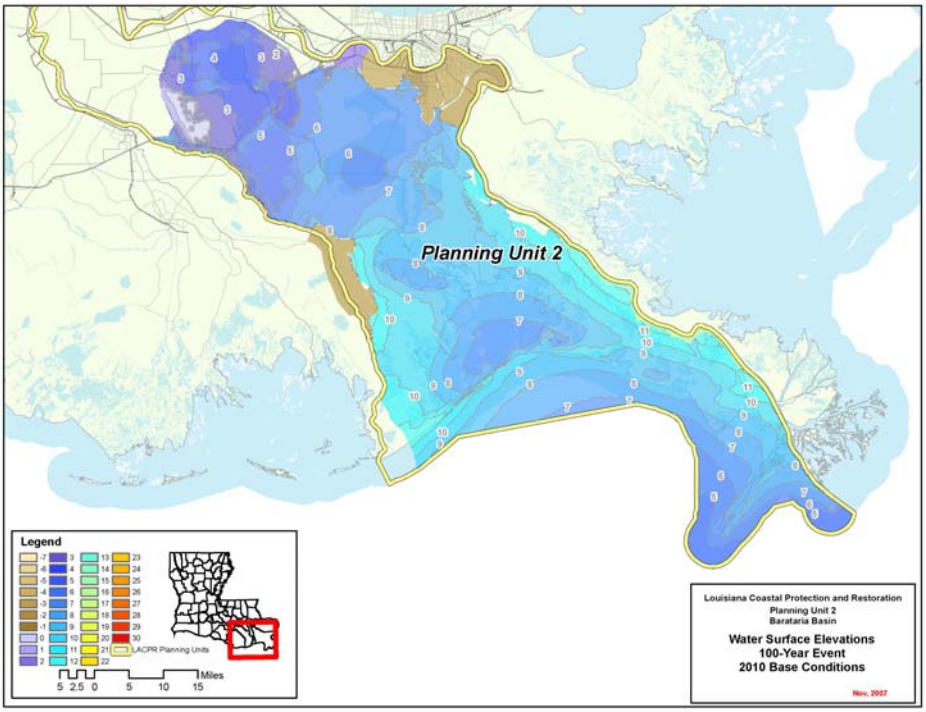


Figure 2.16 Statistical Water Surface for the 100 year event, Planning Unit 2

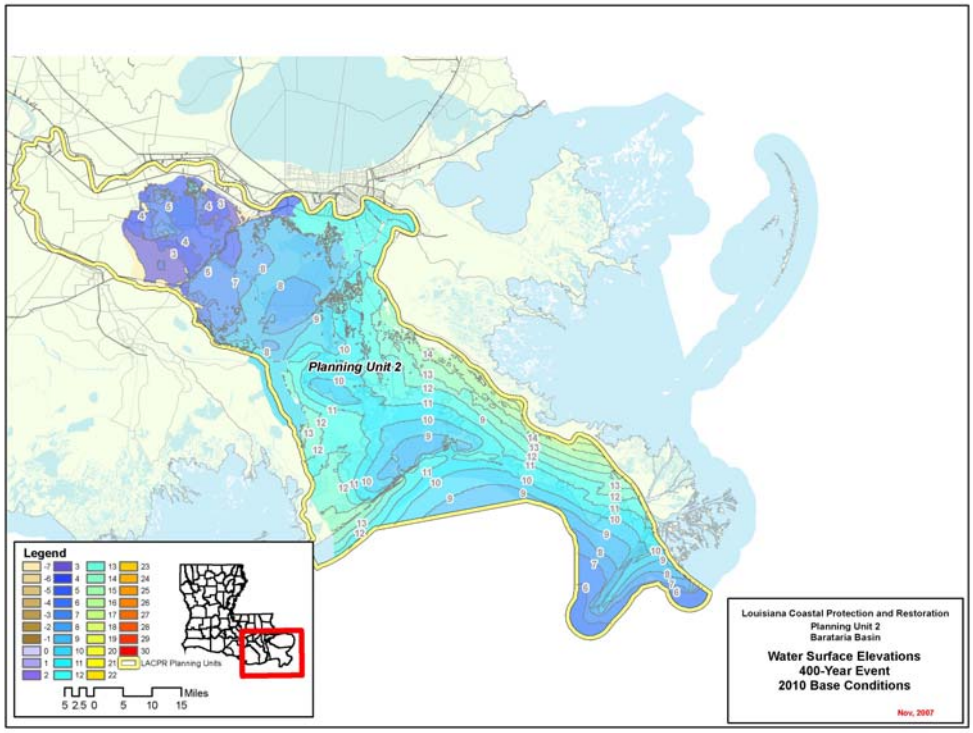


Figure 2.17 Statistical Water Surface for the 400 year event, Planning Unit 2

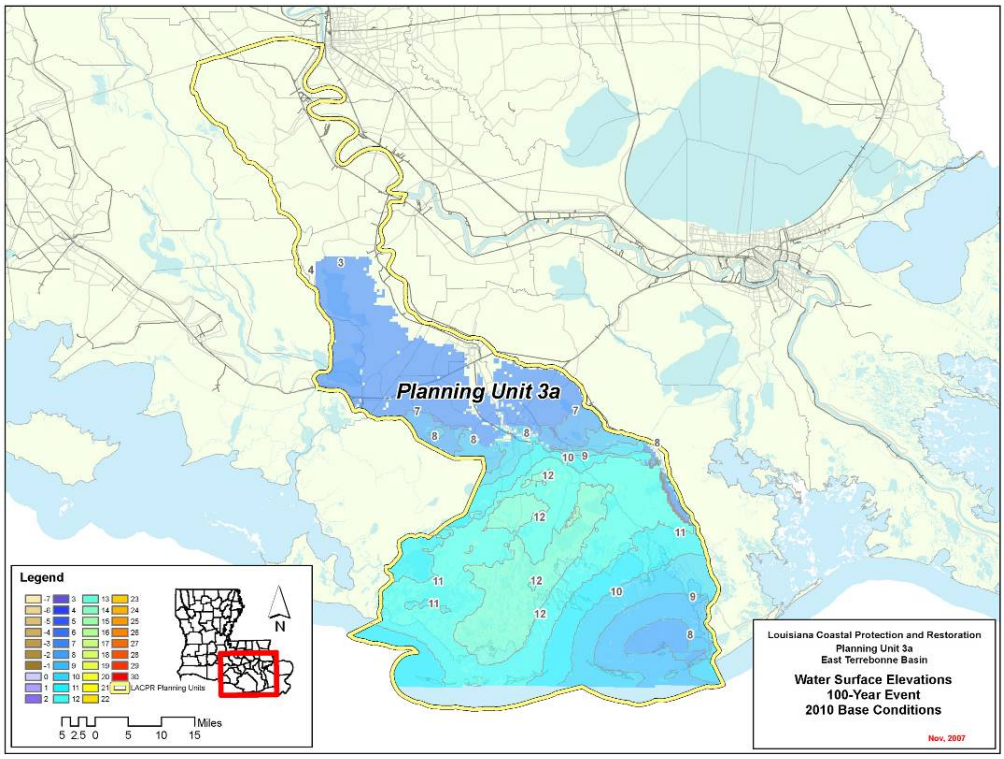


Figure 2.18 Statistical Water Surface for the 100 year event, Planning Unit 3a

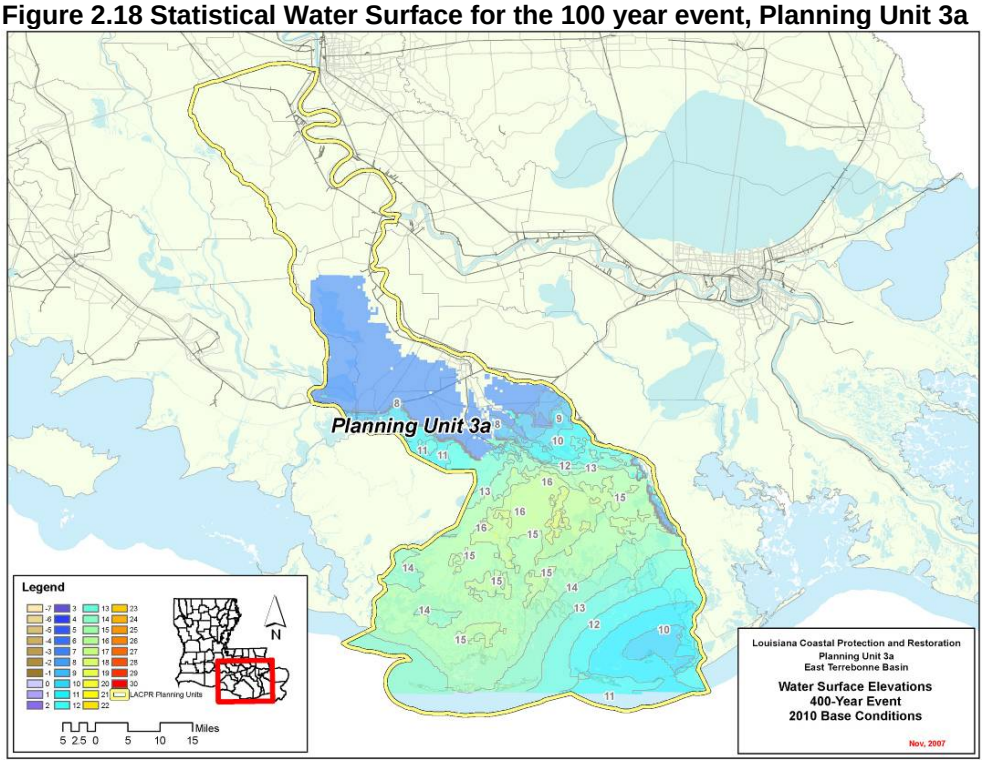


Figure 2.19 Statistical Water Surface for the 400 year event, Planning Unit 3a

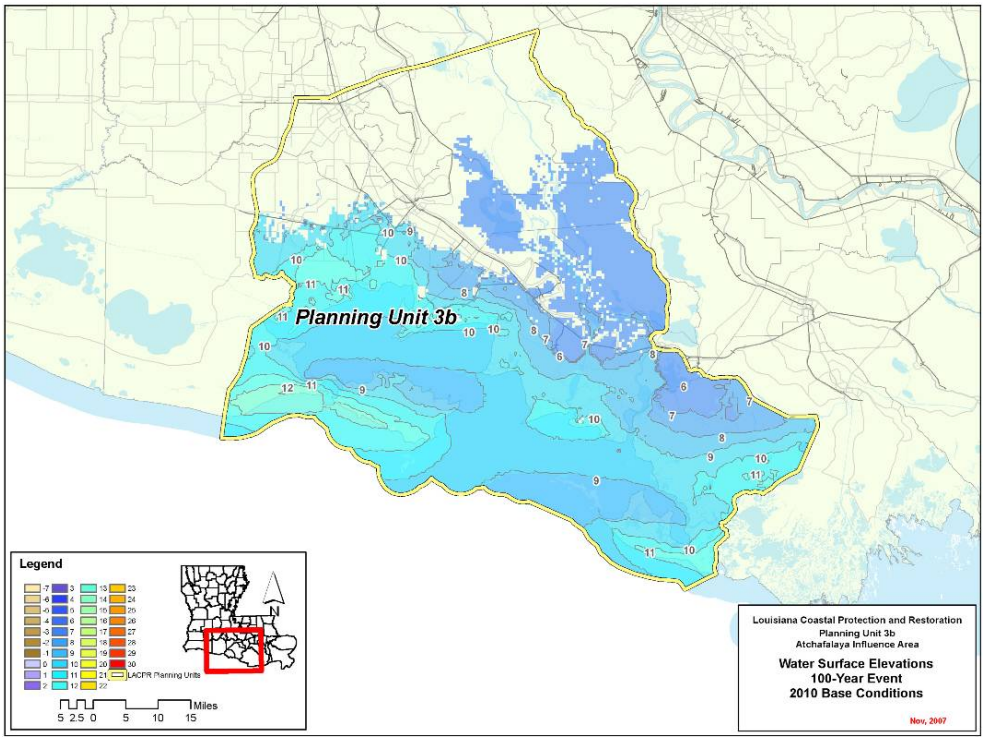


Figure 2.20 Statistical Water Surface for the 100 year event, Planning Unit 3b

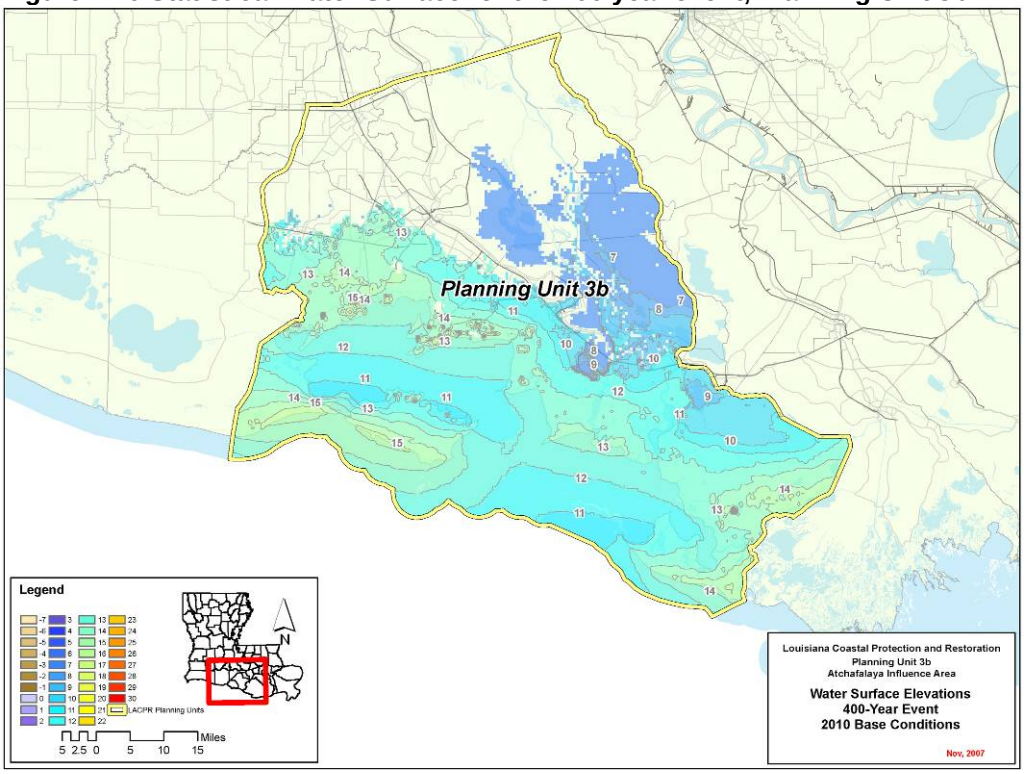


Figure 2.21 Statistical Water Surface for the 400 year event, Planning Unit 3b

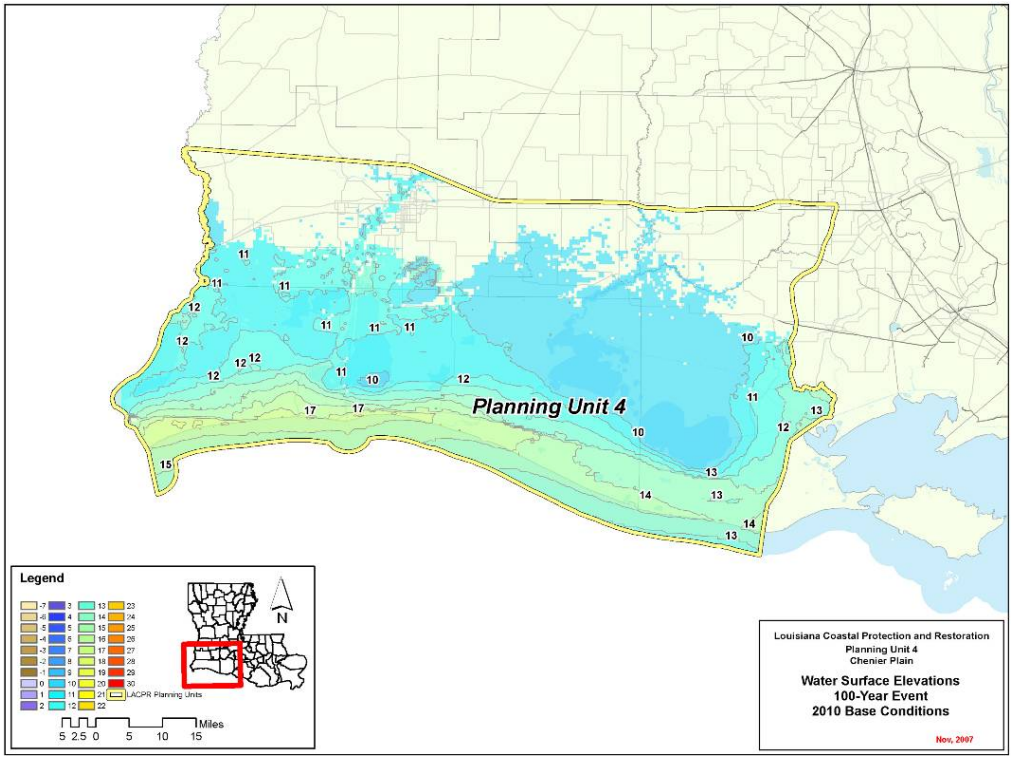


Figure 2.22 Statistical Water Surface for the 100 year event, Planning Unit 4

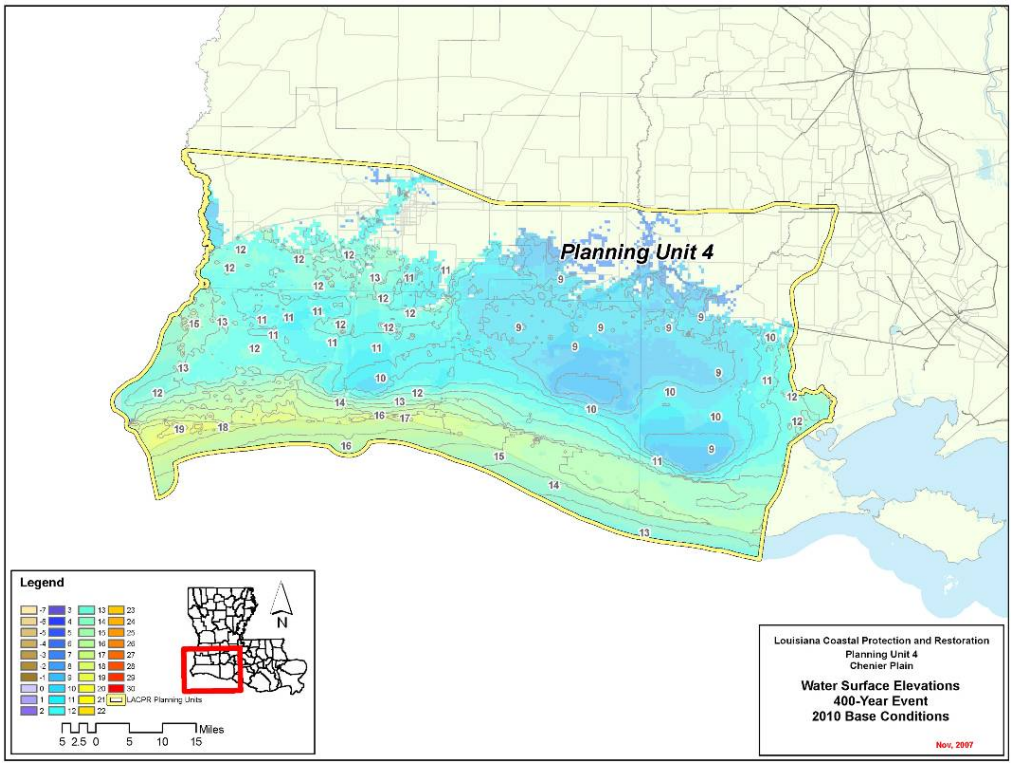


Figure 2.23 Statistical Water Surface for the 400 year event, Planning Unit 4

To establish the stage frequencies for surge levels a series of points were developed that represented the planning subunits. For these points data was extracted from the models to obtain values for the 100, 400, 1000 and 2000 year events. The 10 year surge levels have been obtained from other studies or gauge records.

In the west some problems occurred with the inland parts of the model where the statistical values of surge decayed faster than expected. The low values were adjusted to ensure that the 100 year or higher events were not lower than the 10 year value. This was achieved by raising the 100 year and higher values to be the same as the 10 year values. In addition the values were checked to ensure a progression from the 10 year to the 2000 year, and values were adjusted if required. The process of adjustment always took the level at the higher return period and used this for lower return period events - i.e. if the 1000 year level was greater than the 2000 year level then the 1000 year level was reduced to match the 2000 year level.

The wave heights and surge levels have been extracted for a series of point files. The following three sets of points have been used:

L274 - representing a set of points in the East selected for the purposes of levee design in Planning Units 1 and 2;
W177 - representing a set of points in the west selected for the purposes of levee design in Planning Units 3a, 3b and 4;
Q835 - covering the whole model areas and used for quality control and comparison of results outside of the key design areas.

The spatial extent of these three data sets is given in the following three figures.

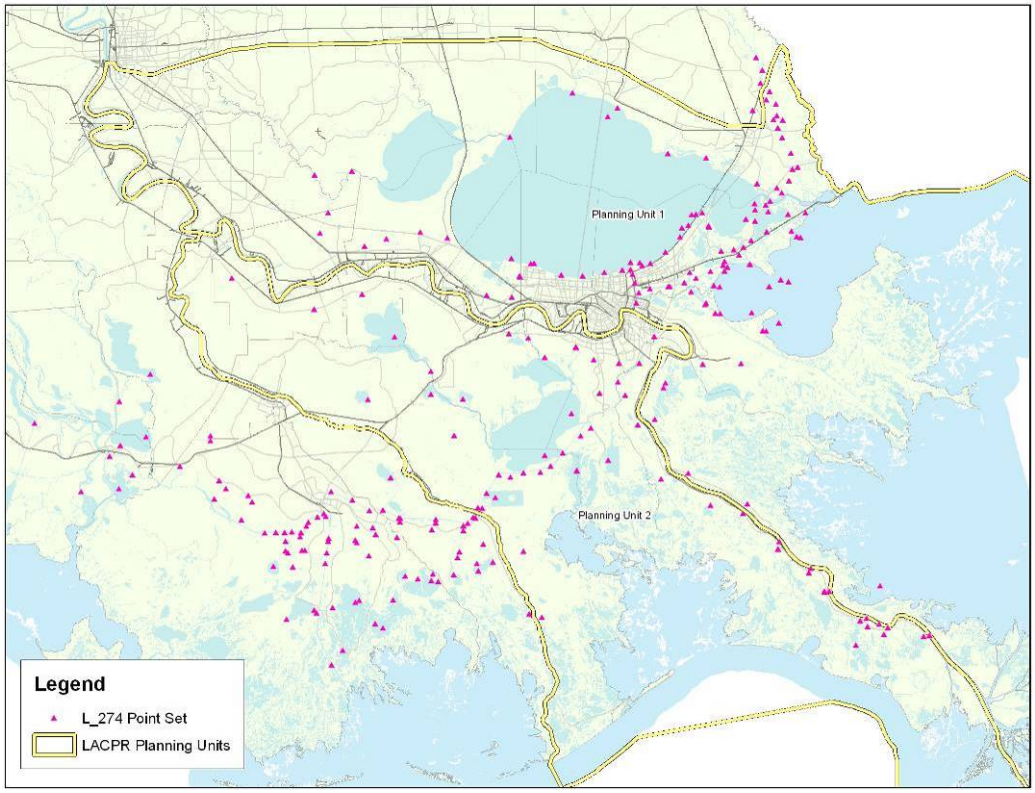


Figure 2.24 L 274 point set locations in Planning Units 1 and 2

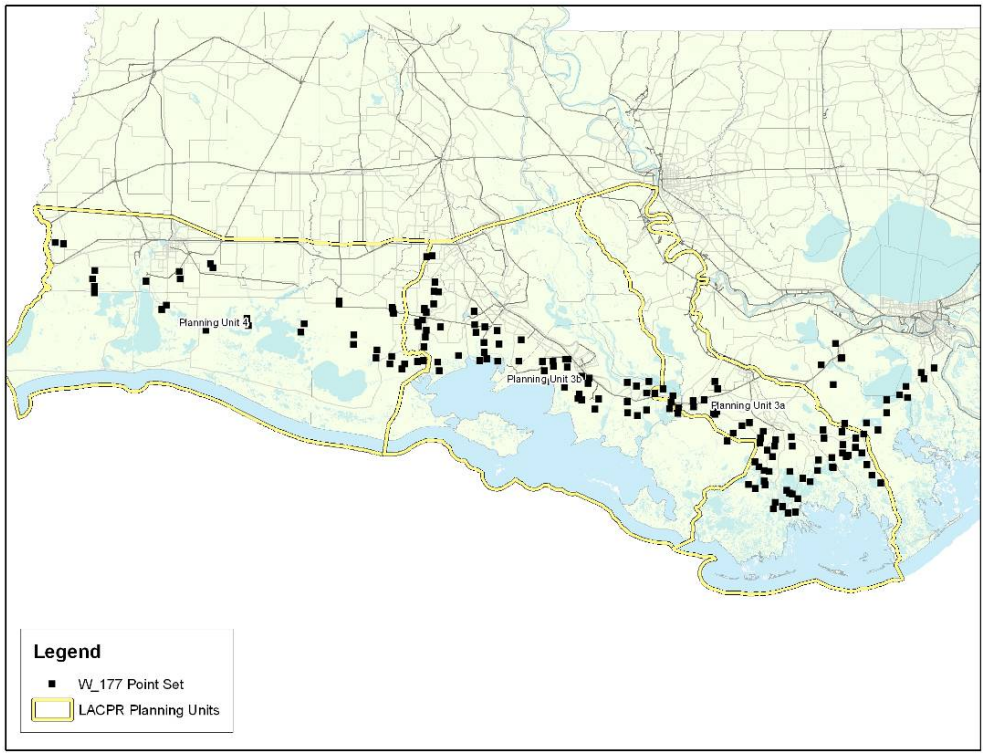


Figure 2.25 W 177 point set locations in Planning Units 3a, 3b and 4

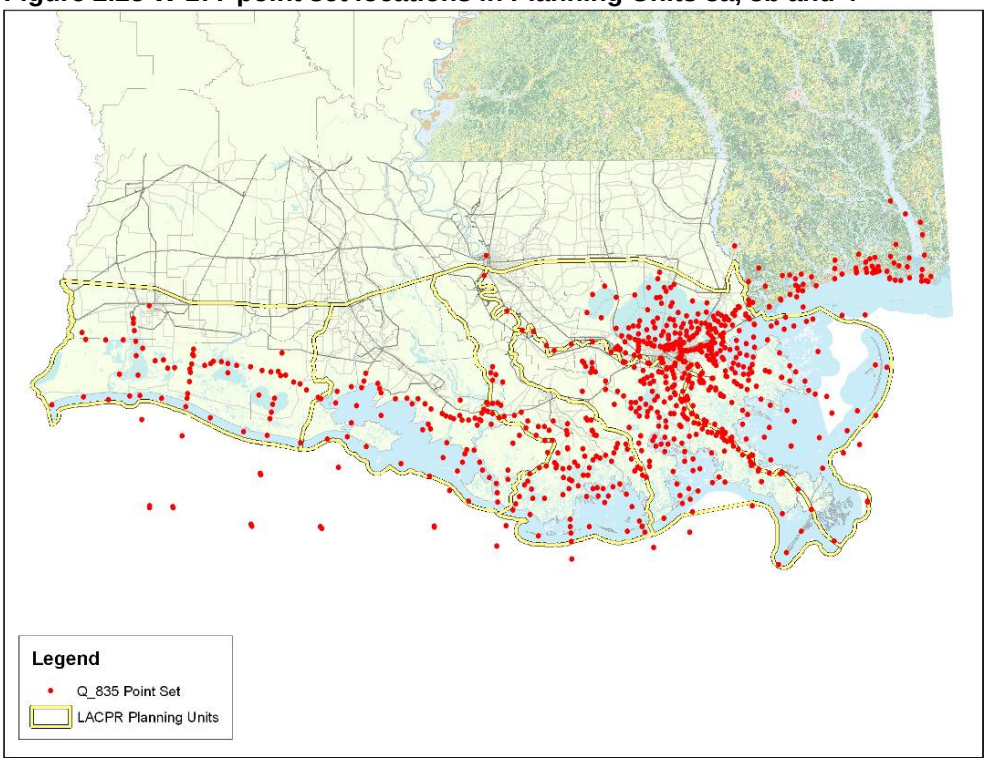


Figure 2.26 Q 835 point set locations for whole coastline

2.6 Discussion on East Models

There are four basic model grids for the Lake Pontchartrain area that model some form of closure of the Lake Pontchartrain. These four models represent the full (impenetrable) barrier (EA), the approximately 100year surge level weir (EB), a full barrier with openings at Chef Menteur and the Rigoletes (EC) and a weir alignment across the Lake Borgne.

Below, the four alternatives are compared in order to investigate their relative impacts on surge levels within Lake Pontchartrain, outside Lake Pontchartrain and along the Mississippi coastline. In addition the EB grid has been compared to the 2010 base grid to investigate particularly the potential impacts on the Mississippi coast.

2.6.1 Comparison of weir with full barrier (EB with EA)

The setup and results of the full closure (East A) and weir plan (East B) have been described separately in Section 2.3.2.

Comparison of changes on Mississippi coast

The weir plan results in maximum changes on the Mississippi coast of up to 3.2 ft and beyond St Louis Bay the maximum drops to 0.8ft and to 0.5ft by Gulf Port. The average change is a maximum of 2.3 ft adjacent to the Louisiana border, dropping to 0.5 ft beyond St Louis Bay and 0.2ft at Gulf Port. For the full barrier the maximum values are 5.4ft, 1.8ft and 1.3ft at the same points and the averages are 3.6ft, 0.9ft and 0.4ft.

The differences have been made by comparing the results of 36 hurricanes with different tracks and intensities that had been run for the 2010 baseline, EA and EB model grids. The maximum difference values arose from hurricanes of frequency > 400 year (i.e. similar or greater than Hurricane Katrina) with a track passing from south to north and making landfall around the end of the Barataria Bay.

These results are shown in Figure 2.27 and Figure 2.28

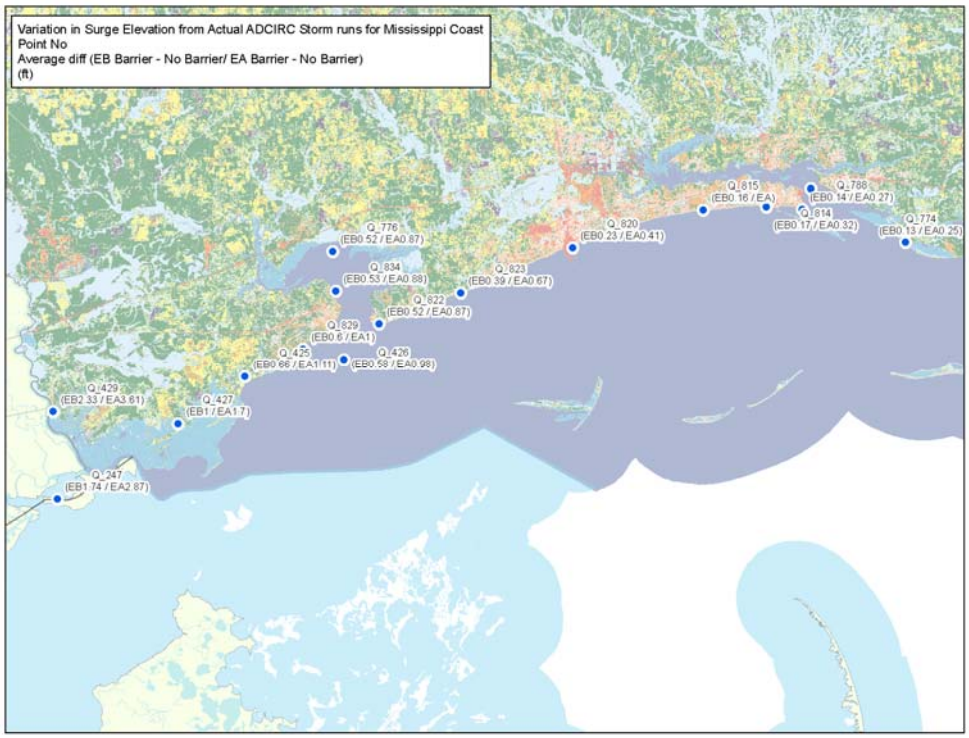


Figure 2.27 Average Differences in Surge between EA and EB models on Mississippi Coast

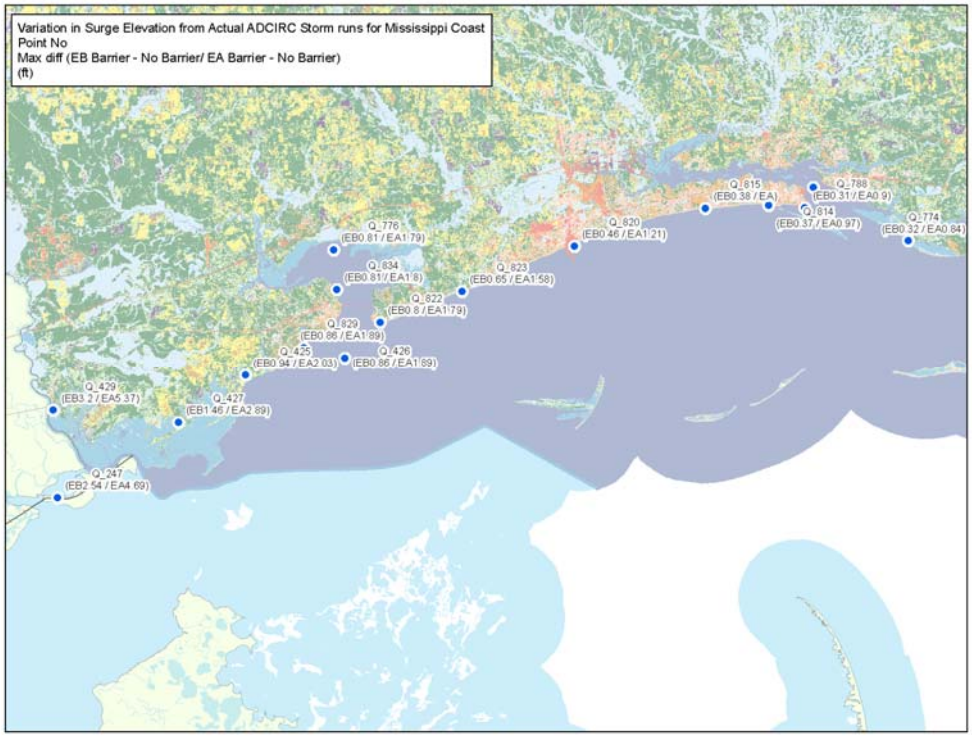


Figure 2.28 Maximum Differences in Surge between EA and EB models on Mississippi Coast

Comparison of changes inside and outside Lake Pontchartrain

Full blockage (EA) when compared to a 100 year surge level weir (EB) shows additional reductions in 100 year surge level within the lake of between 3.1 ft close to the weir to 0.1-0.2 ft on the far side of the lake. The differences are shown on Figure 2.29. Outside of the barrier levels are raised by at least 1 ft for an area from St Bernard Parish across to the Mississippi coast. Differences are greater for the 1000 year storm where the full closure makes a larger impact on levels in the lake, reducing maximum surge levels by up to 7 ft over the weir alternative, shown in Figure 2.30.

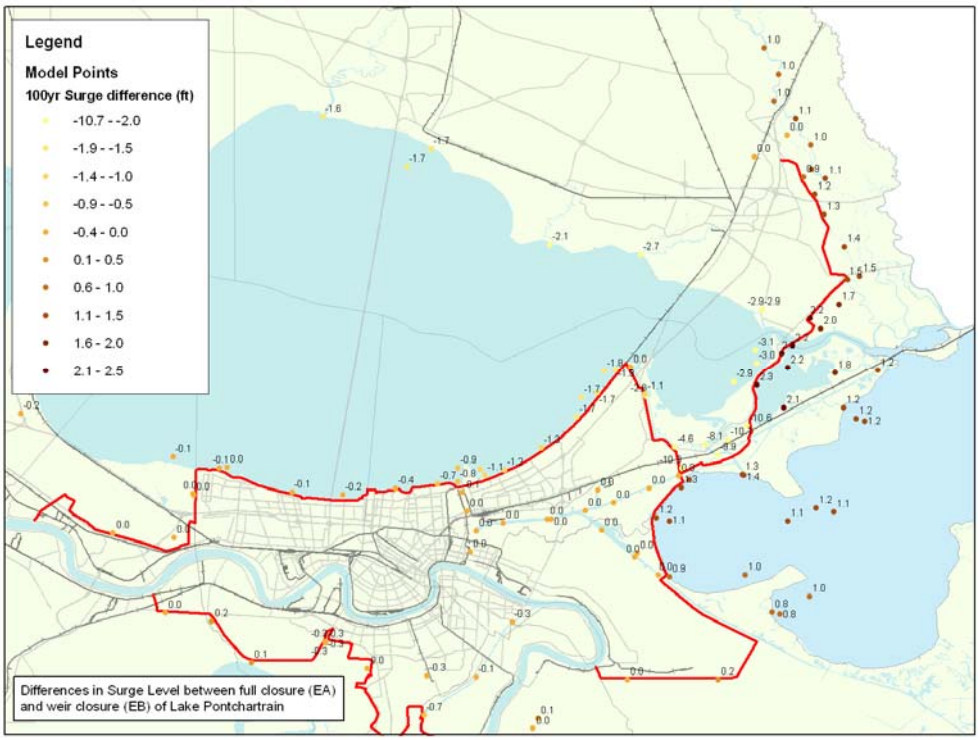


Figure 2.29 Differences in 100 year Surge Level between EA and EB Model Grids

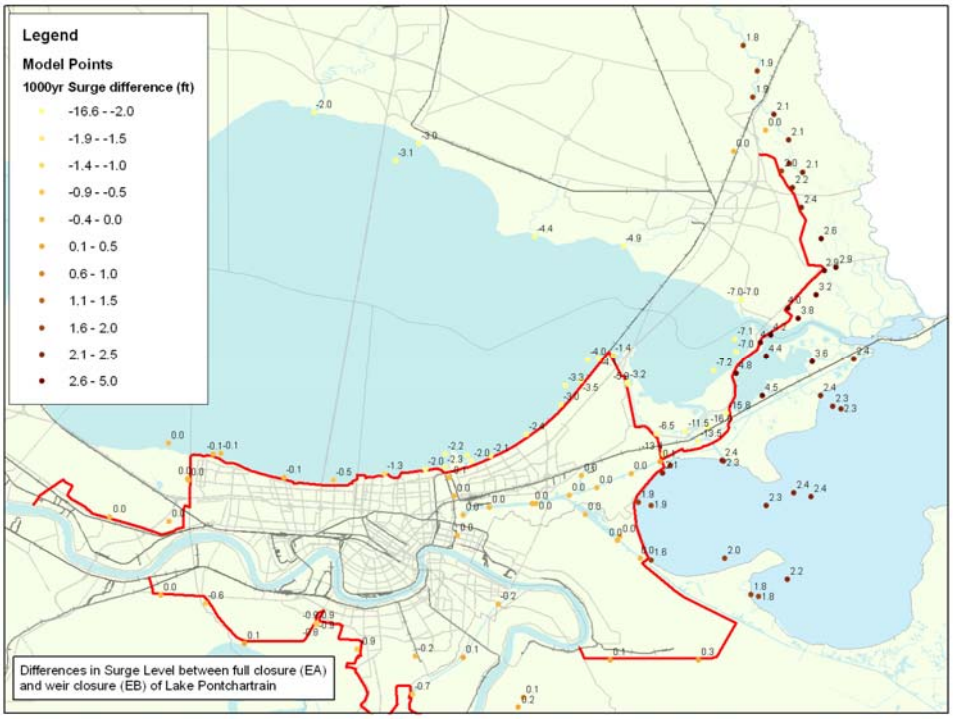


Figure 2.30 Differences in 1000 year Surge Level between EA and EB Model Grids

2.6.2 Comparison of closure with openings and no closure (EC with BS)

The results of the base condition 2010 and the partial closure (East C) are described separately in Section 2.3.2. Comparison of the two model grids (2010 baseline and East model C) shows a limited reduction in surge levels within Lake Pontchartrain. Apart from in the area between New Orleans East and Slidell the reduction in 100 year surge with the closure with openings is less than 1ft, and it induces increases of up to 1 ft on the outside of the closure. For the 1000 year the changes are around the 1 to 1.2 ft range for the main part of the Lake, with increases of 1.5 to 2 ft outside the closure. The differences between EC and baseline are shown in Figure 2.31 and Figure 2.32.

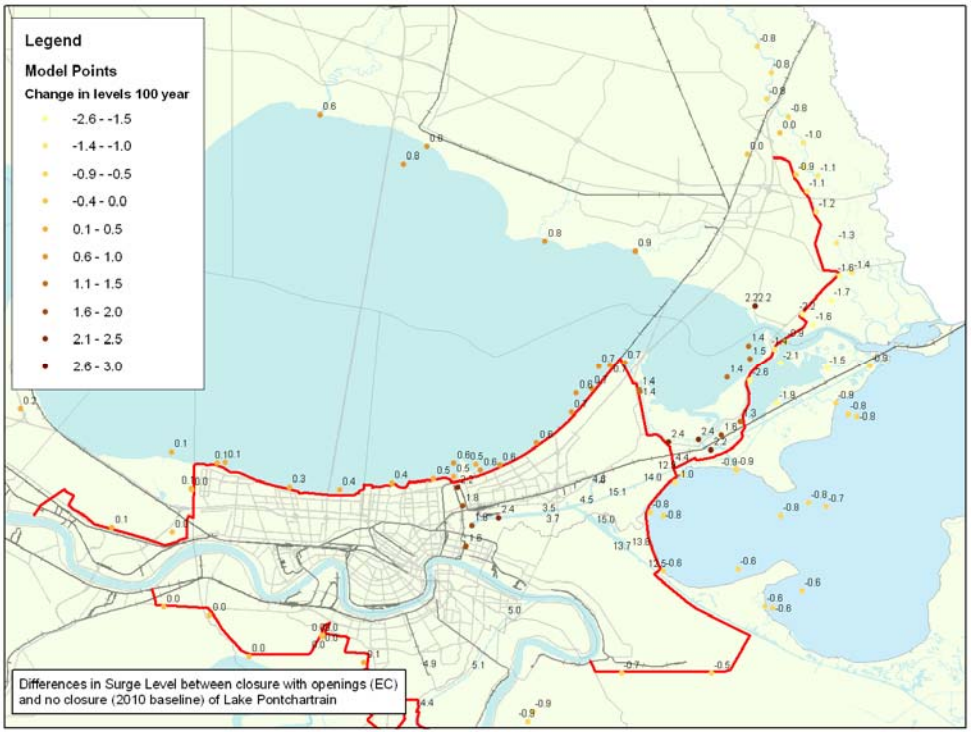


Figure 2.31 Difference in 100 year Surge Level between the EC and 2010 Base Model Grids

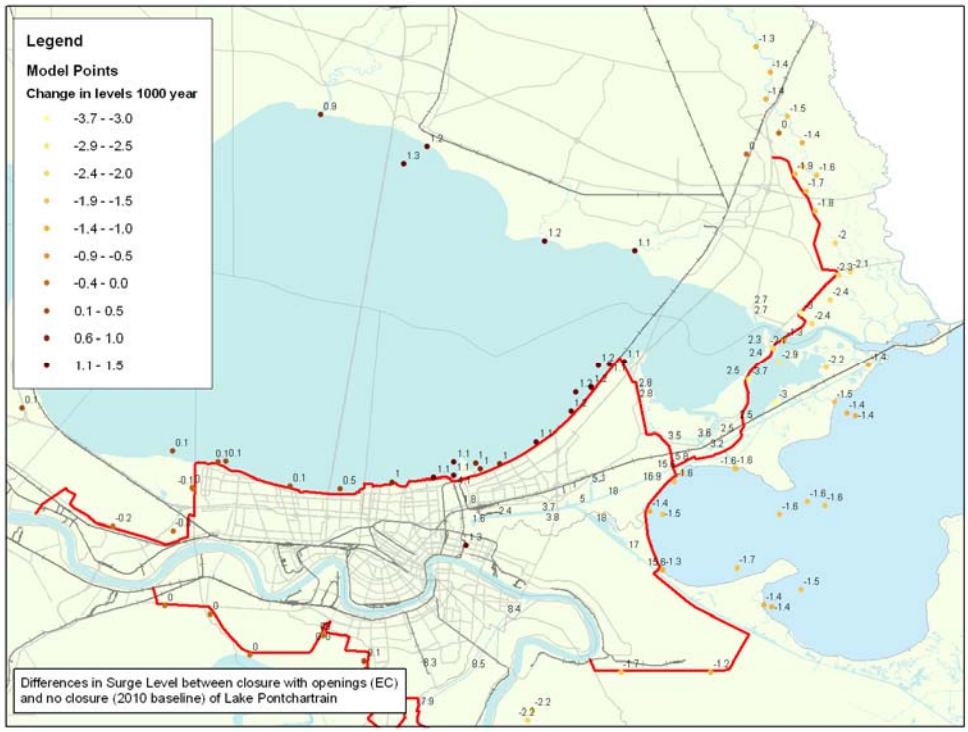


Figure 2.32 Difference in 1000 year Surge Level between the EC and 2010 Base Model Grids

2.6.3 Comparison of full block more seaward with weir closure (ED with EB)

The ED grid represents a full block of Lake Pontchartrain, similar to EA but at a location further towards the Gulf, on a line across Lake Borgne. For the 100 year surge the differences between ED and EB show increases in surge on the outside of the barrier of around 2 feet, and increased reductions within Lake Pontchartrain of up to 3 feet. It shows very large surge reductions within the Golden Triangle area of up to 13 feet, as this is an area which before was on the outside of the weir, and now is inside.

For the 1000 year surges the differences increase, with increases of up to 3.5 feet on the outside of the barrier. This is most noticeable at the north eastern end of the barrier, adjacent to the Mississippi coast where the surge is some 3.3 feet higher.

Figure 2.33 and Figure 2.34 show the surge differences between ED and EB for the 100 and 1000 surge levels. The key issue with the ED model would be the constructability of the barrier. To provide the degree of protection given in the model the levee would need to be in excess of 26 feet at 100 year and 37 feet at 1000 year (these figures are those developed for the Golden Triangle alignment along the edge of Lake Borgne. Lake Borgne is the order of 8-10 feet deep along the alignment.

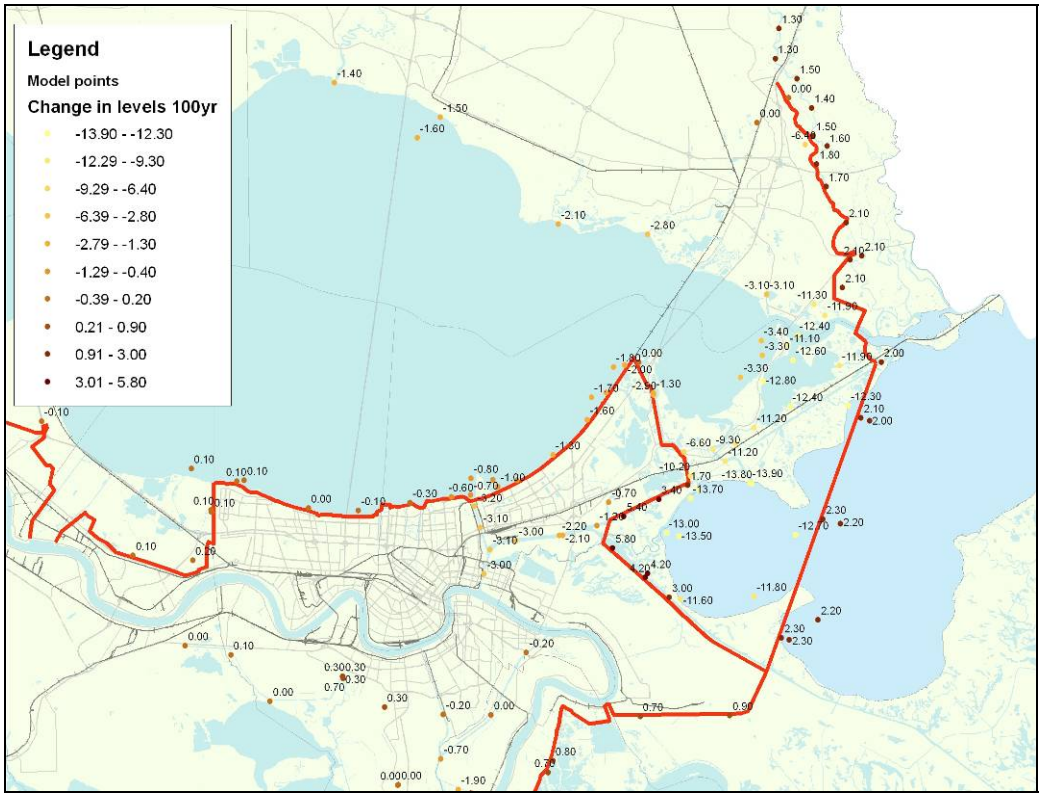


Figure 2.33 Differences in 100 year Surge Level between the ED and EB model grids

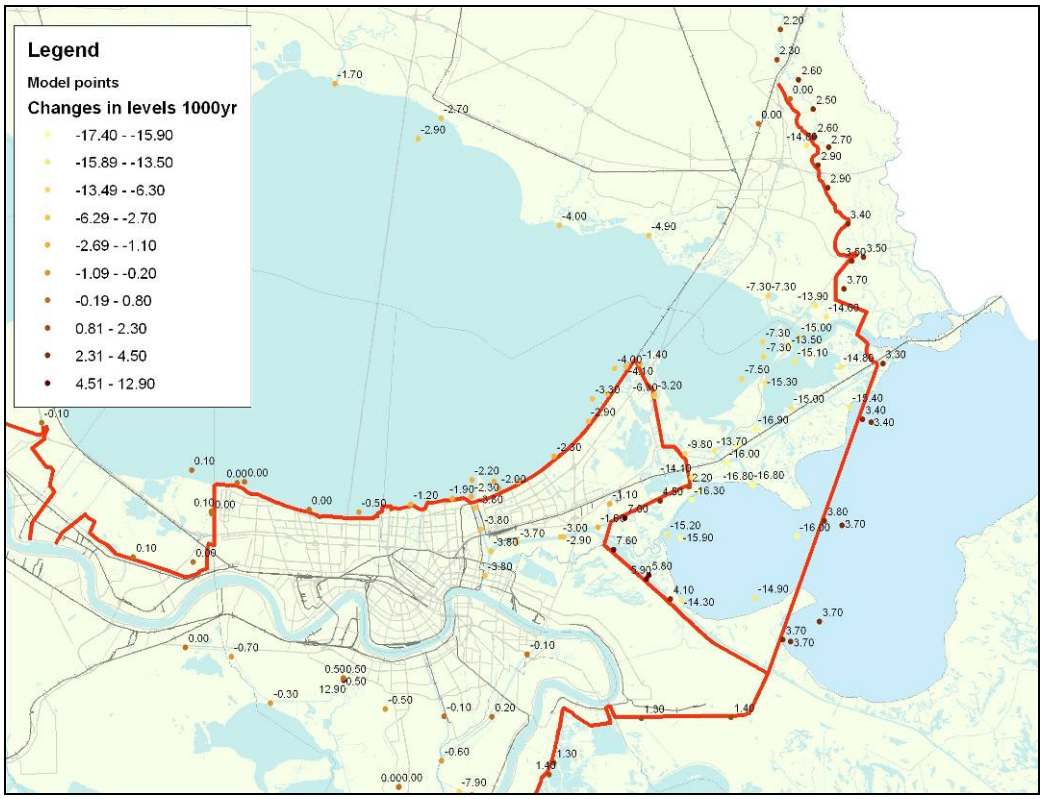


Figure 2.34 Differences in 1000 year Surge Level between the ED and EB model grids

2.6.4 Weir alternative (EB) to Base - Impacts on Mississippi

There is a potential that any changes to the hurricane protection system may have an impact on the surrounding areas. Of particular interest for LACPR is the potential impact that partially closing Lake Pontchartrain may have on the adjacent Mississippi State coastline. Specific work has been carried out to look at the differences between the surge frequency surfaces for the 2010 base conditions and the 12' weir across Lake Pontchartrain.

The following three plots show the difference in the 100, 400 and 1000 year still water levels outside of the barrier system

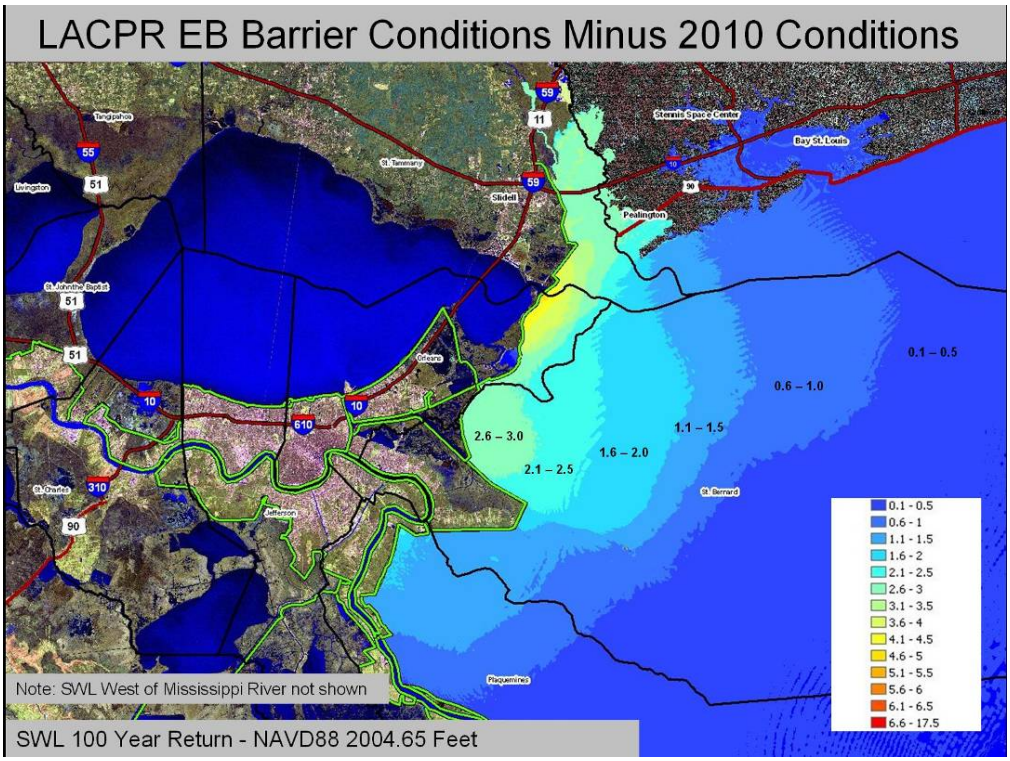


Figure 2.35 Difference in 100 year Surge Level between EB and 2010 Base Model Grids

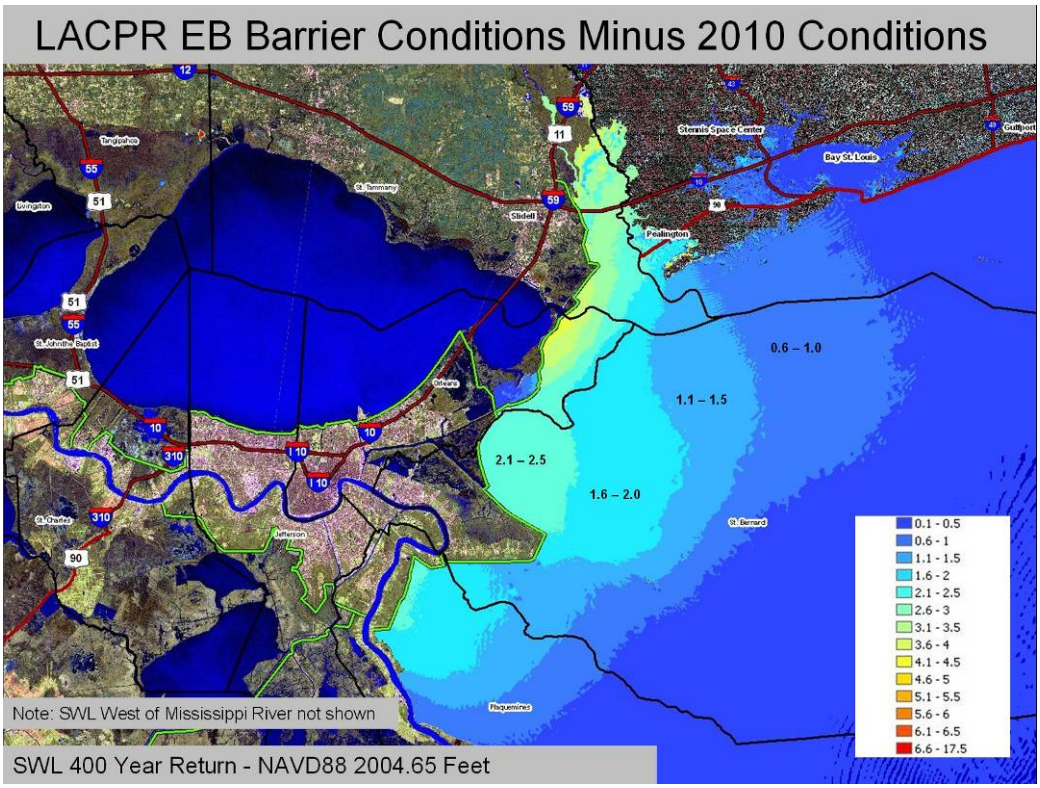


Figure 2.36 Difference in 400 year Surge Level between EB and 2010 Base Model Grids

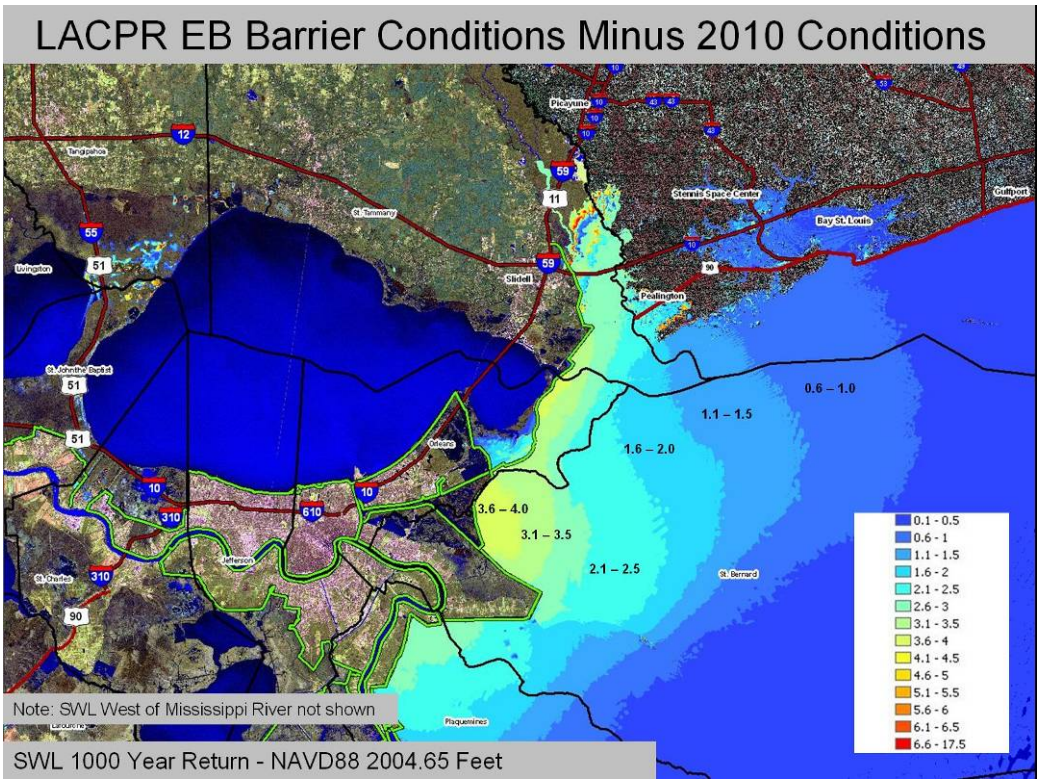


Figure 2.37 Difference in 1000 year Surge Level between EB and 2010 Base Model Grids

2.6.5 Conclusion

In conclusion only the EB grid has been taken forward as an alternative to the baseline model in the analysis of differing structural alignments. This is because the impacts of the full closure on both the Mississippi coast and on constriction heights and the limited beneficial effects of the un-gated openings suggest that neither of these alternatives will provide a more sustainable and costs effective alternative in hydraulic terms.

2.7 Discussion on West Models

There are four primary model grids for the west:

- 2007 base condition
- WA : Morganza and GIWW alignment
- WB : Morganza and Retired Levee Alignment, plus ring levees
- WC : Combined alignment with twin lines of defence

Whereas in the east the model grids were developed to test a number of possible alternatives so that the most appropriate one could be selected, in the west the grids were developed to specifically model significantly different levee alignments. As such the 2007 base, the WA and WB grids were required to represent planning alternatives proposed.

The WC grid, however, was proposed to investigate the twin lines of defence, and also the potential increase in general protection that could be achieved by introducing a 100 year levee along the GIWW. The levee was taken at a nominal 12' to represent the 100 year levee, which may be too low. As the modeling did not account for wave overtopping, and as the number of storms that created flooding within the levees was small, the internal stages derived from the statistics were not taken as being appropriate to use in the alternative with the 12' levee along the GIWW and the normal interior stage frequency calculations were carried out instead.

3 COMPUTATION PROCESS FOR STAGE FREQUENCIES

3.1 Introduction

This chapter describes the general process applied to the hydrodynamic model results in order for them to be translated into the data required for hydraulic evaluation in the framework of LACPR. Section 3.2 describes the general process for the entire planning area. On some aspects the approach as applied to the Planning Units in the West (3a, 3b, and 4) differs from that applied in the East (Planning Units 1 and 2). Therefore, first the common approach is described, with specific attention for the deviations in East and West where applicable. In Section 3.3 the approach and values used to establish hydraulic values for the future scenarios (2060) are outlined.

3.2 Overview of approach

3.2.1 Typology of planning subunits based on their relative location

The planning subunits that make up the planning units, are the level on which the evaluation of the various planning alternatives has taken place. Based on their relative location with respect to the levee system, planning subunits can be identified in three categories:

A External - the area is always outside of the levee system;
B Internal - the area is within a current levee system and will remain inside a levee system;
C Semi-internal - the area is currently outside of the levee system, but may become inside the levee system in the future.

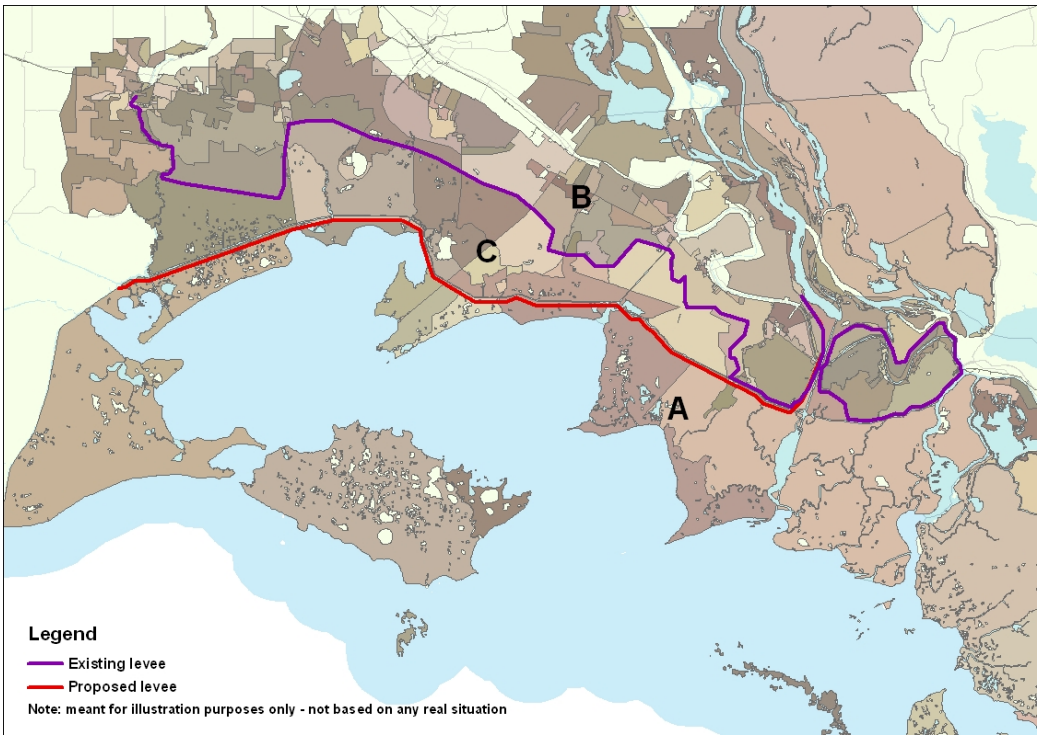


Figure 3.1 Illustration of categories of planning subunits, relative to the levee system

The determination of the stage frequency curves for the planning subunits in these categories is discussed below:

A A stage frequency relationship has been established representing the effects outside the levee systems for differing hydraulic models, as the levee alignments within the model can have an impact on conditions outside of the levees. The outside surge levels for different frequencies originate from the statistical analysis of the hydrodynamic model results. For more information about these models and the statistical method, the reader is referred to Chapter 3 and 4 in Volume I.

B The stage frequency curve has been determined representing the effects of wave/surge overtopping, rainfall and pumping. In these calculations the wave/surge overtopping volumes have been determined using the exterior waves and surge levels, and the levee characteristics. Rainfall and pumping have been included to compute the total water volume in either one or a connected series of planning subunits. The stage has been established using this volume and a single stage-storage relationship. For more information about this procedure, the reader is referred to Chapter 6 in Volume I.

C Per planning subunit, both a stage frequency for the exterior and stage frequencies from interior drainage have been developed. This category combines Category A and B.

The stage frequency curves for the planning subunits have been developed based on the evaluation of the 10-year, 100-year, 400-year, 1000-year and 2000-year hydraulic event. They have been computed for the hydraulic model alternatives (e.g. Base, EB etc), and for areas with new levees this procedure is repeated for the different levels of protection (100, 400, and 1000 year).

East
Since in the East a levee system already exists, all three categories as described above are present in Planning Units 1 and 2. In addition, a number of special cases result in another set of internal stage frequencies. Examples of these are the introduction of the Golden Triangle alignment along the edge of Lake Borgne, or the closure of the Algiers and Harvey Canals.

West
In the West there is no current levee system. Thus, no internal areas exist in these Planning Units, and all planning subunits (and drainage areas) are external (Category A) or semi-internal (Category B).

3.2.2 Hydraulic coding system

Various Planning Alternatives have been assessed using the results from the modeling efforts (see Chapter 2). These Planning Alternatives consider new levees, different levee alignments, and a range of flood protection standards. The modeling grids that were evaluated with the surge and wave models do not always match exactly with the Planning Alternatives in terms of levee

alignments. Hence, combinations of various modeling grids have often been applied to specify the conditions for a specific planning subunit in a specific Planning Alternative.

To ensure consistency in the approach, a coding system has been developed to specify which modeling results apply to the planning subunit for each planning alternative. As the models that have been used for the planning units in the East and the West differ, the hydraulic coding systems differ accordingly. These coding systems are described below:

East
The model grids that were used in the East were:

- 2010 Base model grid (BS), used for:
  - PU 1: the “High Level” alternatives (HL);
  - PU 2: the West Bank Improvements and Ridge alignments;
- East Model Grid B (EB), used for:
  - PU1: the Lake Pontchartrain Barrier alternatives (LP);
  - PU2: the GIWW weir alternatives.

Results from the models were used to develop results for stage frequencies as indicated in the following table.

Table 3.1 Hydraulic Coding System for the East

Hydraulic Code	Model	Description
BS-ext	BS (baseline)	Stage frequency developed from ADCIRC for areas outside of levees
EB-ext	EB (grid B)	Stage frequency developed from ADCIRC for areas outside of levees
BS-xxxxa	BS	Stage Frequency developed from internal drainage for areas inside levees protected to the xxxx level of protection - alternative ‘a’
BS-xxxxb	BS	Stage Frequency developed from internal drainage for areas inside levees protected to the xxxx level of protection - alternative ‘b’
EB-xxxxa	EB	Stage Frequency developed from internal drainage for areas inside levees protected to the xxxx level of protection - alternative ‘a’
EB-xxxxb	EB	Stage Frequency developed from internal drainage for areas inside levees protected to the xxxx level of protection - alternative ‘b’

In this table the alternatives are as follows:

Table 3.2 Alternatives within Hydraulic Codes (East)

Alternative	Planning Unit 1	Planning Unit 2
a	the inner alignment around Lake Borgne (closure from B. Biennenue to Michoud Canal)	Represents the closure of the Harvey and Algiers Canals
b	The outer alignment around Lake Borgne (closure along Lake Borgne Shoreline)	Represents the Harvey and Algiers Canals being open

The planning alternatives have been coded for straightforward identification. This coding is made up of five elements;

PU1-HL-a-100-1
1 2 3 4 5

Each element for Planning Units 1 and 2 is described below.

Element 1	PU1	Planning Unit 1
	PU2	Planning Unit 2
Element 2	HL	High Level Plan Alternative (PU1)
	LP	Lake Pontchartrain Surge reduction barrier Alternative (PU1)
	WBI	West Bank Levee Alternative (PU2)
	G	GIWW Weir alternatives (PU2)
	R	Ridge alternatives (PU2)
Element 3	a	the inner alignment around Lake Borgne (closure from B. Bienvenue to Michoud Canal)
	b	The outer alignment around Lake Borgne (closure along Lake Borgne Shoreline)
	<blank>	All PU2 alternatives
Element 4	100	Alternative provides a 100 year level of protection
	400	Alternative provides a 400 year level of protection
	1000	Alternative provides a 1000 year level of protection
Element 5	Planning Unit 1	
	1	Existing defenses including Oakville extension
	2	As 1 plus Laplace and all of the North Shore
	3	As 1 lpus Laplace and Slidell only
	Planning Unit 2	
	1	Existing defenses - plus closure of Harvey and Algiers canals and Larose to Golden Meadow
	2	As 1 plus levees to Luling and Highway 90
	3	As 2 plus levees to Sunset Drainage District
	4	As 3 plus levees along Bayou Lafouche (Lockport)

An example of the system for linking the hydraulic codes to the planning alternatives for the East is shown below for some of the planning subunits in Planning Unit 1:

Table 3.3 Example of the coding of the stage frequency results per planning subunit per alternative

Planning Sub Unit	Planning Alternative				
	PU1-HL-a-400-1	PU1-HL-b-400-1	PU1-LP-a-400-1	PU1-LP-b-400-1	…
St Bernard Wet	**BS-0400a**	**BS-0400b**	**EB-0400a**	**EB-0400b**	**…**
St Bernard Dev	**BS-0400a**	**BS-0400b**	**EB-0400a**	**EB-0400b**	**…**
STBE_17a	**BS-ext**	**BS-0400b**	**EB-ext**	**EB-0400b**	**…**
ORLE_16b	**BS-ext**	**BS-0400b**	**EB-ext**	**EB-0400b**	**…**
STBE_14a	**BS-ext**	**BS-ext**	**EB-ext**	**EB-ext**	**…**
…	**…**	**…**	**…**	**…**	**…**

West

The models grids that were used in the West were:

- Baseline model grid, referred to as WT;
- West Model Grid A (WA), used for:
  Planning Units 3a, 3b, and 4;
- West Model Grid B (WB), used for:
  Planning Units 3a and 3b.

At the onset of the modeling the planning alternatives in the west were less well defined. This resulted in the levee alignments within the model grids not matching single planning alternatives. Therefore some combining of results from different models has been required in order to represent the planning alternatives.

Results from the models were used to develop results for stage frequencies as indicated in the following table.

Table 3.4 Hydraulic Coding System for the West

Hydraulic Code	Model	Description
WT-ext	WT (baseline)	Stage frequency developed from ADCIRC for all areas
WA-ext	WA (grid A)	Stage frequency developed from ADCIRC for areas outside of levees included in model
WB-ext	WB (grid B)	Stage frequency developed from ADCIRC for areas outside of levees included in model
WT-xxxx	WT	Stage Frequency developed from internal drainage for areas inside levees protected to the xxxx level of protection
WA-xxxxa	WA	Stage Frequency developed from internal drainage for areas inside levees protected to the xxxx level of protection – alternative ‘a’
WA-xxxxb	WA	Stage Frequency developed from internal drainage for areas inside levees protected to the xxxx level of protection - alternative ‘b’
WA-xxxxc	WA	Stage Frequency developed from internal drainage for areas inside levees protected to the xxxx level of protection - alternative ‘c’

WBxxxx	WB	Stage Frequency developed from internal drainage for areas inside levees protected to the xxxx level of protection

In this table the alternatives are as follows:

Table 3.5 Alternatives within Hydraulic Codes (West)

Alternative	Planning Unit 3a	Planning Unit 3b	Planning Unit 4
a	Continuous levee from Larose to Morgan City	Not Used	Full levee along GIWW alignment - connecting into Pu3b
b	Levee from Larose, returning to high ground to the west of Houma, plus Morgan City ring	Not Used	12' levee along GIWW together with localized ring levees
c	As a but with a 100 year defense around Morganza and a secondary defense line	Not Used	Levee along GIWW, returning to high ground to the west of the Vermillion rRver

The planning alternatives have been coded for straightforward identification. This coding is made up of four elements;

PU3a-M-0100-1
1 2 3 4

Each element for Planning Units 3a, 3b and 4 is described below.

Element 1 PU3a Planning Unit 3a
PU3b Planning Unit 3b
PU4 Planning Unit 4

Element 2 M Morganza Levee - from Larose to Morgan City (PU3a)
RL Ring Levees - used in PU3b and 4
G GIWW alignment - used in 3a for the secondary alignment alternatives and for the alignment along the GIWW in PU3b and 4
F Franklin alignment - used in PU3b for alignment which extends between the GIWW and the areas of risk.

Element 3 100 Alternative designed to provide a 100 year level of protection
400 Alternative designed to provide a 400 year level of protection
1000 Alternative designed to provide a 1000 year level of protection

Element 4 1 PU3a Continuous levee from Larose to Morgan City
PU3b All alternatives
PU4 Continuous GIWW levee from PU3b to the west of Lake Charles (G) and ring levees (RL)

2	PU3a	Levee from Larose which returns to the west of Houma to higher ground
	PU3b	Not used
	PU4	GIWW levee which returns to the west of the Vermillion River
3	PU3a	Not Used
	PU3b	Not Used
	PU4	GIWW levee at 12' with a return and isolated ring levees

The full combinations of these elements, together with maps are presented in the …..

An example of the system for linking the hydraulic codes to the Planning Alternatives for the West is shown below for some of the planning subunits in Planning Unit 4:

Table 3.6 Example of the coding of the stage frequency results per planning subunit per alternative

Planning Sub Unit	**Planning Alternative**		
	Base2007	PU4-G-0100-1	…
CALC_ 11i	WT-ext	WT-0100	…
CALC_ 5e	WT-ext	WT-0100	…
VMLN_ 10f	WT-ext	WA-0100a	…
VMLN_ 12d	WT-ext	WA-0100a	…
CALC_ 10g	WT-ext	WT-0100	…
CALC_ 10h	WT-ext	WT-0100	…
…	…	…	…

3.3 Future Scenarios

3.3.1 Factors affecting the future conditions

Part of the hydraulic evaluation of the planning alternatives is to consider the performance in the future (2060). A number of factors affect the hydraulic performance in the future. The following factors have been taken into account:

1. Sea level rise;
2. Global subsidence or subsidence;
3. Changes to the foreshore (marshes).

These factors are visualized schematically in Figure 3.2.

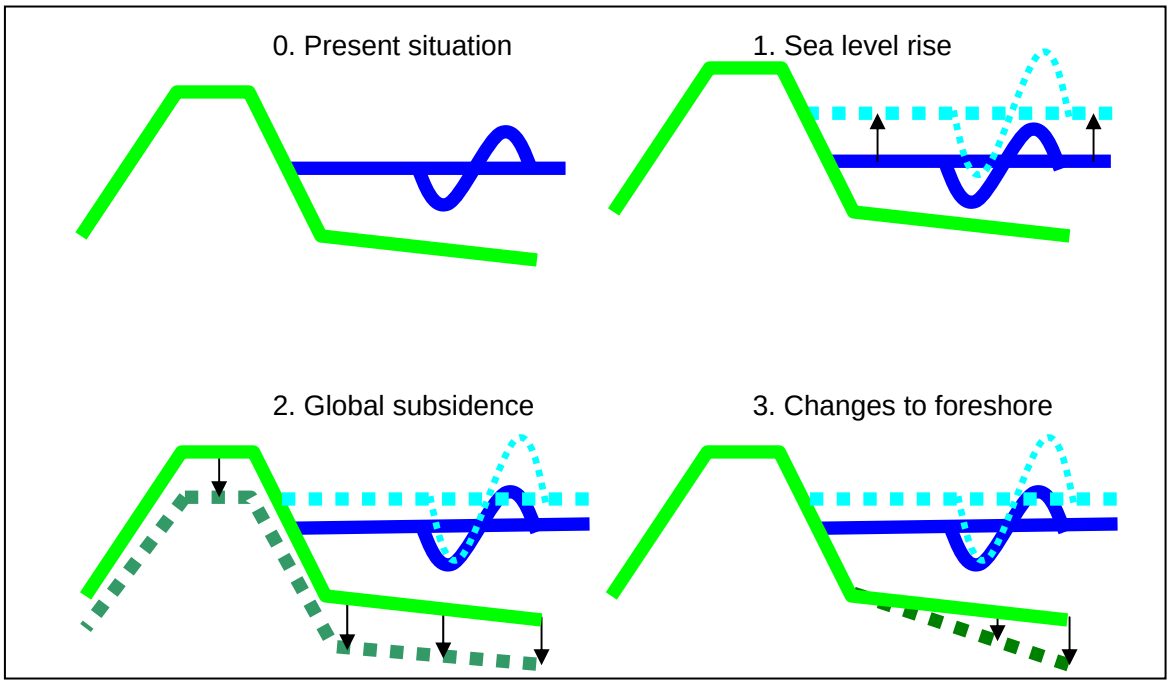


Figure 3.2 Future factors in the framework of LACPR

These factors result in higher surges and wave heights, and also affect the levee heights that are required to provide a specific level of protection. In the framework of LACPR the following approach has been chosen to account for these future factors:

Ad. 1,2) Sea level rise and subsidence has been allowed for in a combined value added to the surge levels. Three scenarios have been evaluated for the relative sea level rise (sea level rise + subsidence): no sea level rise, a mid range sea level rise value and a high sea level rise value. The values used for these scenarios are given in Table 3.7.

The magnitude of the effects of sea level rise on the surge levels has been derived from model runs with different sea level rise scenarios using the 2010 Base Condition as reference case. Notice that the effect of the surge level is more than proportional, i.e. 1ft of sea level rise gives more than 1ft of surge level rise. For more information, the reader is referred to Chapter 2.

Table 3.7 Sea level rise

Planning Unit	No sea level rise	Mid Range (SLR1 = +1ft in 2060)	High Range (SLR2 = +2ft in 2060)
1 - Pontchartrain Basin	+ 0 ft	+ 1.3 ft	+ 2.6 ft
2 - Barataria Basin	+ 0 ft	+ 1.9 ft	+ 3.2 ft
3a – Terrebonne	+ 0 ft	+ 1.9 ft	+ 3.2 ft
3b - Teche/Vermillion	+ 0 ft	+ 1.9 ft	+ 3.2 ft
4 - Mermentau	+ 0 ft	+ 1.3 ft	+ 2.6 ft

Ad. 3) Two future developments of the foreshore conditions have been evaluated. The first is the “maintain coast” condition which has been represented by the existing (2010) bathymetry assuming that the coastline will be maintained. In fact, the surge levels and the waves do not change in this foreshore condition. The second is the “degraded coastal features” condition which has been represented by the bathymetry computed by the CLEAR model. The degraded coastal features model has only been run for the 2010 Base Condition but with a changed bathymetry. Based on these runs, the effect of a degraded foreshore on the surge levels and the waves has been quantified.

Considering the 3 values for sea level rise and 2 future coastlines, this gives 6 possible alternatives for the future with a range of results.

3.3.2 Effects on levee heights and stages

The table below summarizes how the future scenarios have been incorporated in the levee heights, and the exterior and interior stages. These effects are discussed below:

Table 3.8 Effects on levee heights and exterior and interior stages for different future scenarios

Future coastline scenarios	**Future sea level rise scenarios**	**Levee heights**	**Exterior Stages**	**Interior stages**	
				No action	**Maintain levee heights**
Maintain coastline	Sea Level rise 0 Sea Level rise 1 Sea Level rise 2	Present situation + effect of sea level rise scenario	Present situation + effect of sea level rise scenario	Based on present heights with increased overtopping due to sea level rise scenario	No change with present situation
Degraded coastline	Sea Level rise 0 Sea Level rise 1 Sea Level rise 2	Present situation + effect sea level rise scenario + effect degraded coastline	Present situation + effect sea level rise scenario + effect degraded coastline	Based on present heights with increased overtopping due to sea level rise scenario + effect degraded coastline	No change with present situation

The levee heights for 2060 were established as described below (see also Table 3.8):

Maintain coastal features.
For the maintained coast alternatives, the design heights were taken from the Base case which represents the current situation. These heights were increased based on the sea level rise values given in Table 3.7. for all Planning Units to determine the 2060 levee heights.

East - degraded coastal features
For the degraded coastal features the future degraded model results were used to compute design heights for the 'without barrier' alignments. For the 'with barrier' option the difference in levee height between the without and with barrier alternatives was computed. This value was then added to the levee heights calculated for the future degraded model to give a 'with barrier' levee height for the 2060 situation. In all cases sea level rise was applied by adding the values from Table 3.7.

West - degraded coastal features
For the degraded coastal features the model results were used to compute design heights for the same levee alignments as the baseline model. For the other modeled alternatives the change in levee height from the baseline model results to alternative model results was applied to the levee heights calculated for the degraded coastal features model. In all cases sea level rise was applied by adding the values from Table 3.7 to the levee heights.

The stages for 2060 have been computed as follows (see also Table 3.8):

Exterior – Maintained coast
Exterior stage frequency values for the "maintained coast" were obtained by adding the sea level rise values to the external stage frequencies established for the current conditions.

Exterior – Degraded coast
For the degraded coastal features, the exterior stage frequencies have been developed from the degraded coastal model results and then increased by sea level rise. This could only be done directly for the baseline situations, because the degraded coastal features only have been evaluated for this situation. Therefore, the various alternative geometries (e.g. barrier alignment in the East or different levee alignments in the West) are treated differently. For these alternatives, the difference between the current geometry and the alternative geometry results have been applied to the degraded coastal features exterior stage frequencies of the baseline situation, and these are then adjusted for sea level rise.

Interior (East only)
For interior stage frequencies, two options have been considered: "No Action" (this is used as a baseline for the economic evaluation) and with any alternative in place. In the "No Action" plan, the levee heights are kept at a constant elevation and new overtopping rates are calculated using the degraded coastal features model, and calculating the effects on overtopping of the three sea level rise alternatives. These overtopping rates are then used to develop new stage frequency tables for those planning subunits. For the alternatives, the overtopping rate is assumed to be constant as

the degree of protection by the levees is maintained over time, and therefore the stage frequencies did not change.

4 PLANNING UNIT 1

4.1 Introduction

This chapter presents the results of the calculations of the levee heights and the stage frequency curves for the Planning Sub Units of Planning Unit 1 (see Figure 4.1).

Section 4.2 describes the results of the levee heights being computed for the levee system in 2010 for the two different situations. The first is a levee system with a barrier at MRGO (called the High Level Plan, modeled in the 2010 Base Model Grid); the second a levee system with closure of Lake Portchartrain along US90, full closure of IHNC/GIWW along west shore of Lake Borgne, and a weir closure West Bank from Bell Chasse to Larose along GIWW (called the Barrier Plan, modeled in the East Model Grid B).

In section 4.3 the stage frequency curves for Planning Unit 1 are determined. For the economic evaluation both the High Level plan and the Barrier plan have bee evaluated in more detail. For each, four return periods have been considered for the outside surge level and wave characteristics (100-year, 400-year, 1000-year, and 2000-year). In addition, there are a number of special cases that result in additional internal stage frequencies. These are dealt with by determining a second set of internal stage frequency curves.

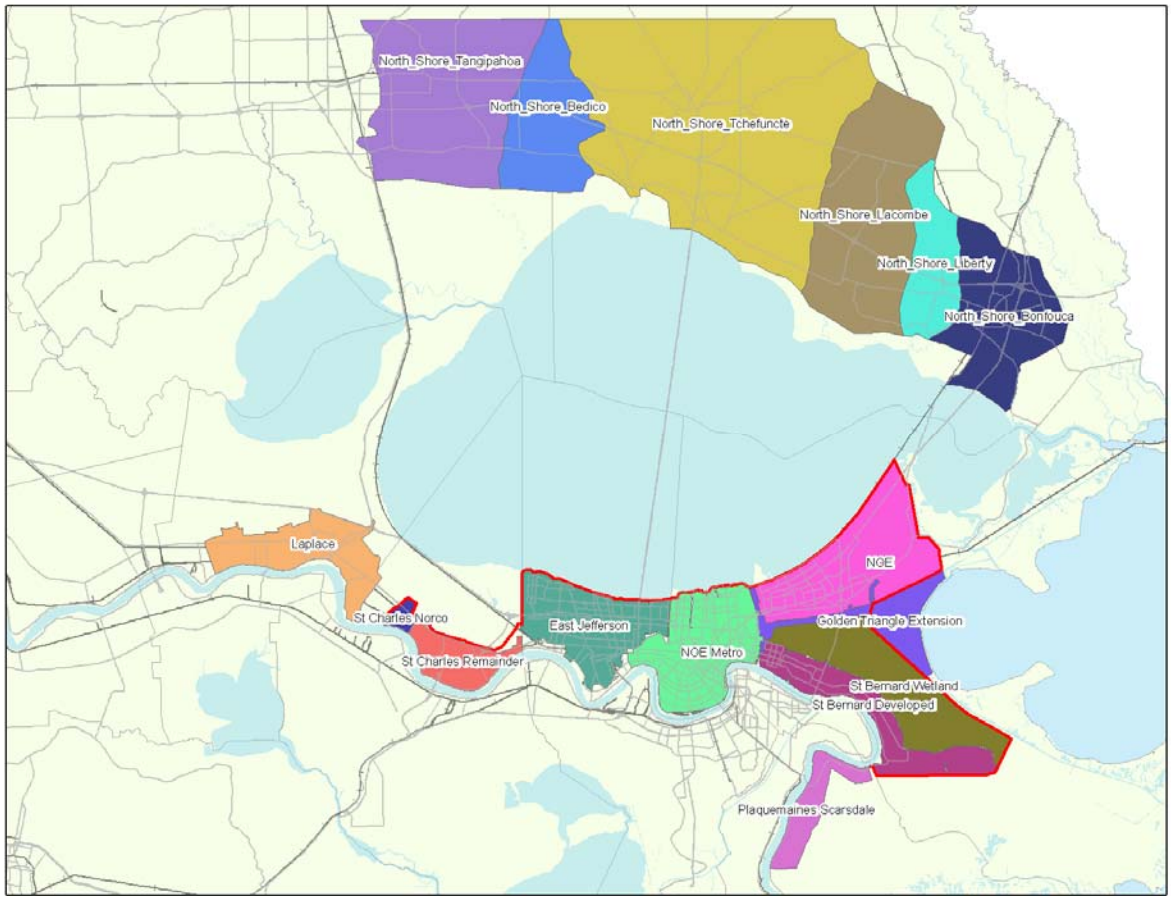


Figure 4.1 Planning Unit 1

4.2 Levee height

The levee height design followed the methodologies described in Volume I of this report. Levee heights were computed for both the High Level Plan and the Barrier Plan for three design standards (100 year, 400 year, and 1000 year) for all levees included in the modeling. Using both the waves developed from the no bed friction model and waves from the with bed friction model has resulted in two sets of levee heights. Below, only the results of the no friction wave model are presented, thus giving the more conservative design heights.

Figure 4.2 to Figure 4.7 show the 100 year, 400 year, and 1000 year design heights in feet for the levees in Planning Unit 1 for the High Level Plan and the Barrier Plan. The design height values have been adjusted to include any adjustments made to increase the levee heights to match the authorized levee heights. In some instances the heights were also adjusted because the results from the hydrodynamic models were not considered to be representative of the lcoations. A detailed overview of the design height is given in the fact sheets in Annex B.

The resulting height values have been used as input for costing design options and for establishing overtopping rates.

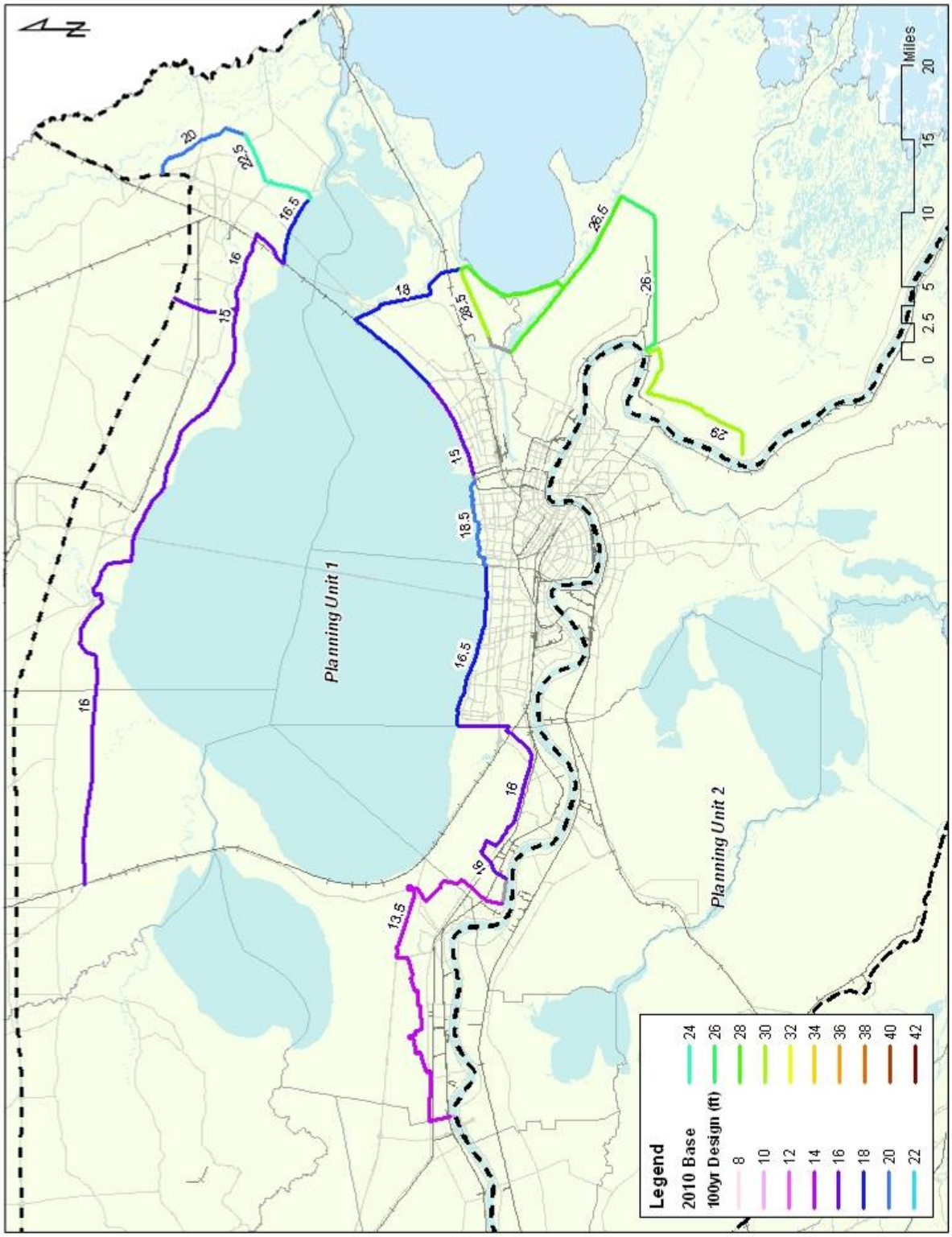


Figure 4.2 2010 Base Model Grid, 100 year design heights

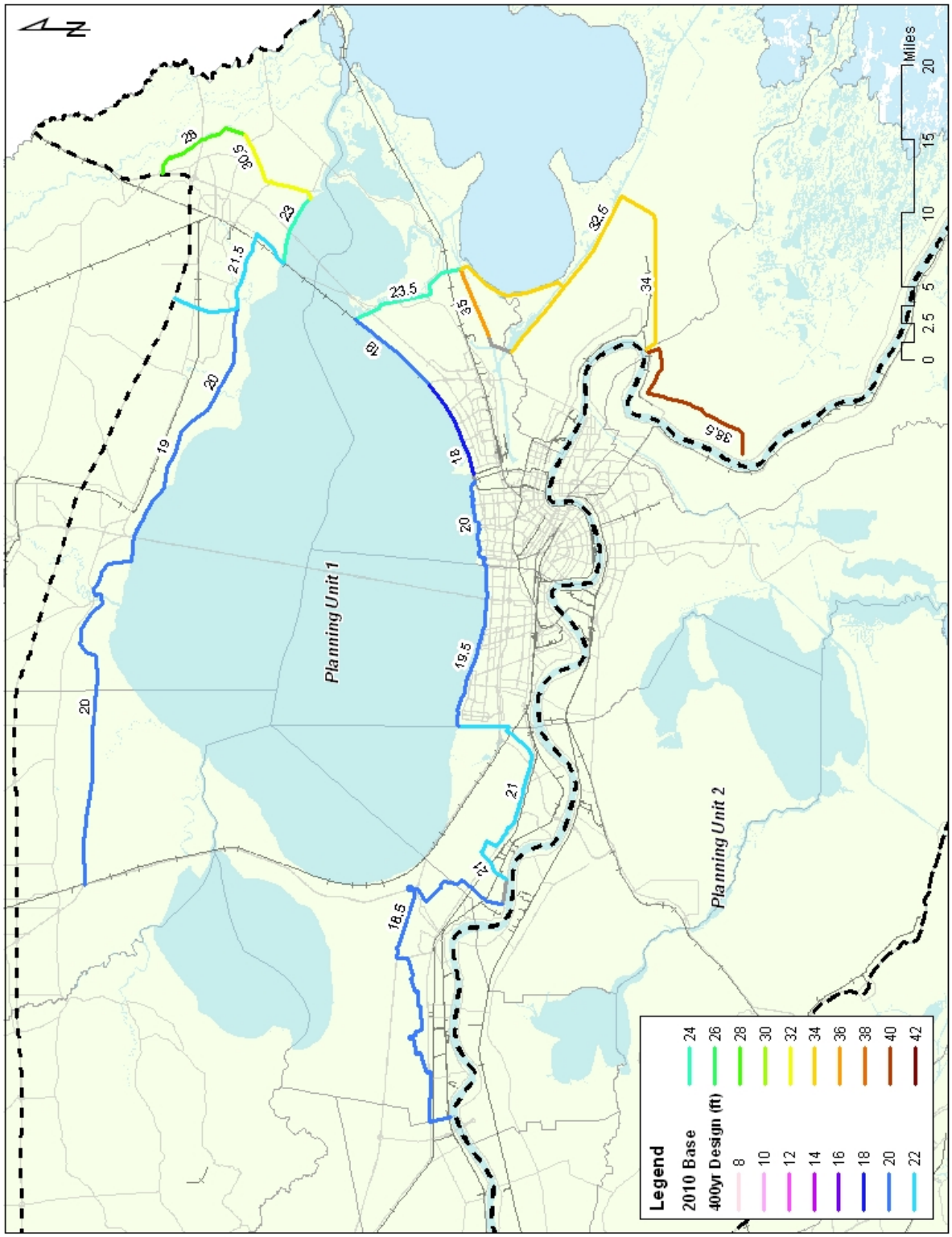


Figure 4.3 2010 Base Model Grid, 400 year design heights

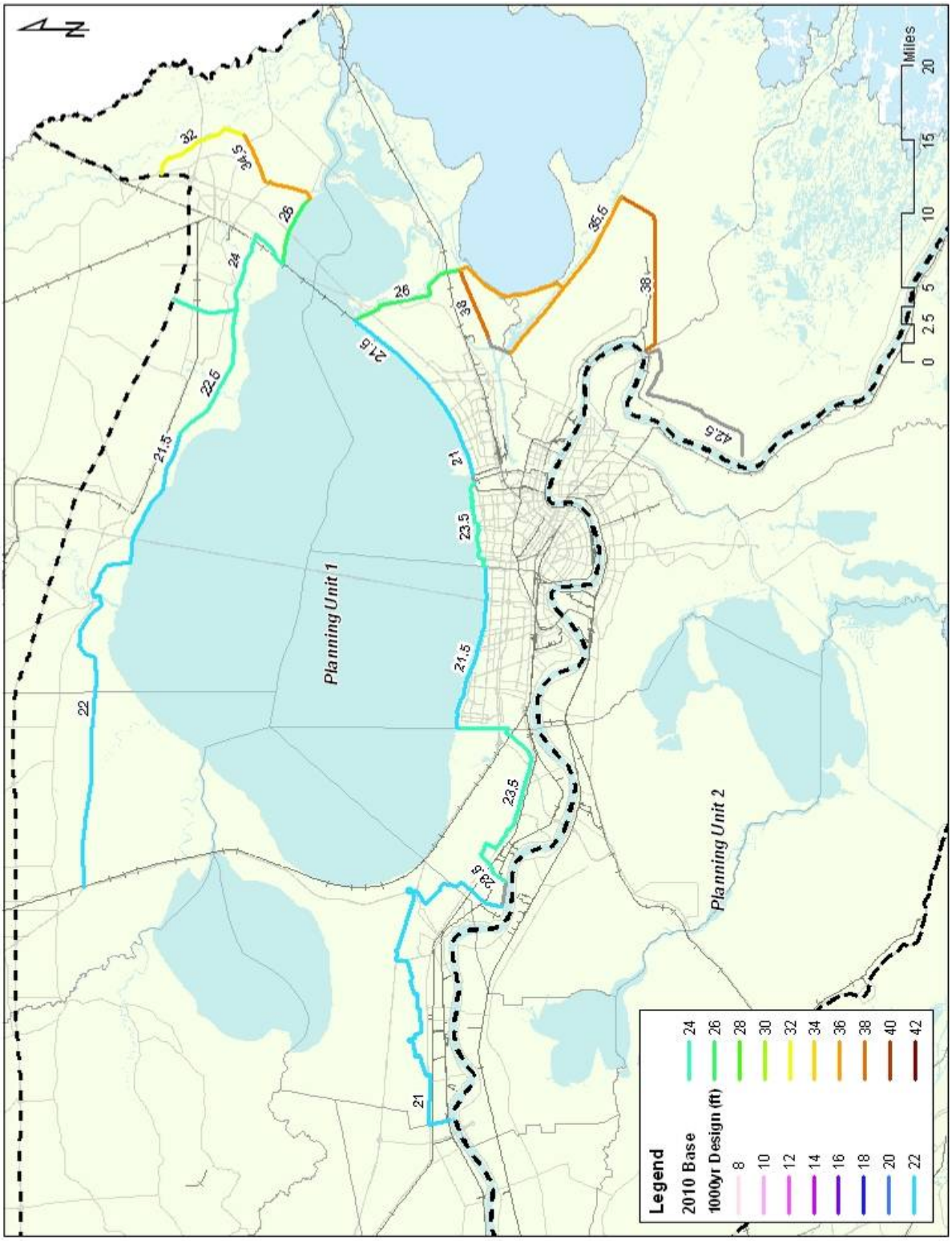


Figure 4.4 2010 Base Model Grid, 1000 year design heights

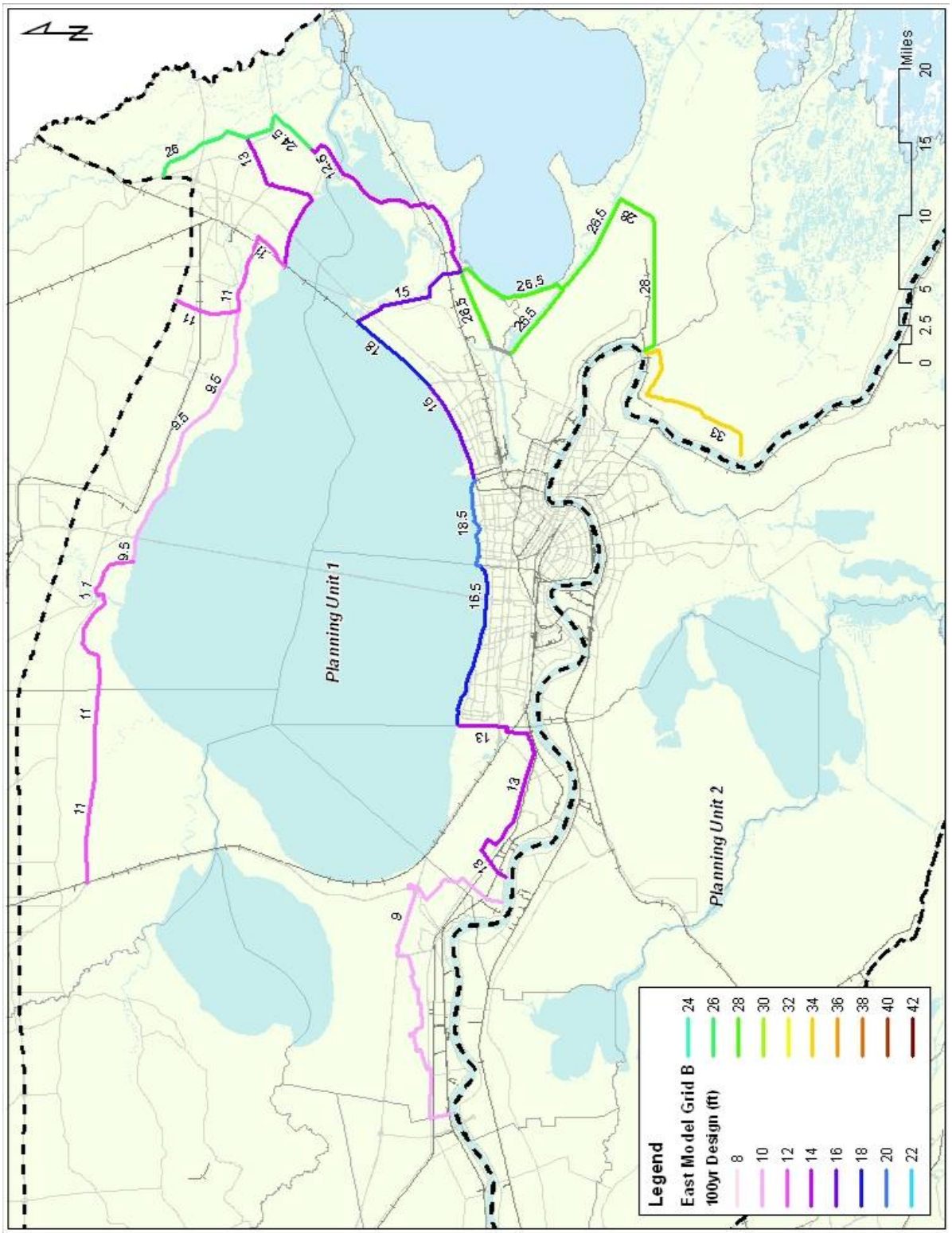


Figure 4.5 East Model Grid B, 100 year design heights

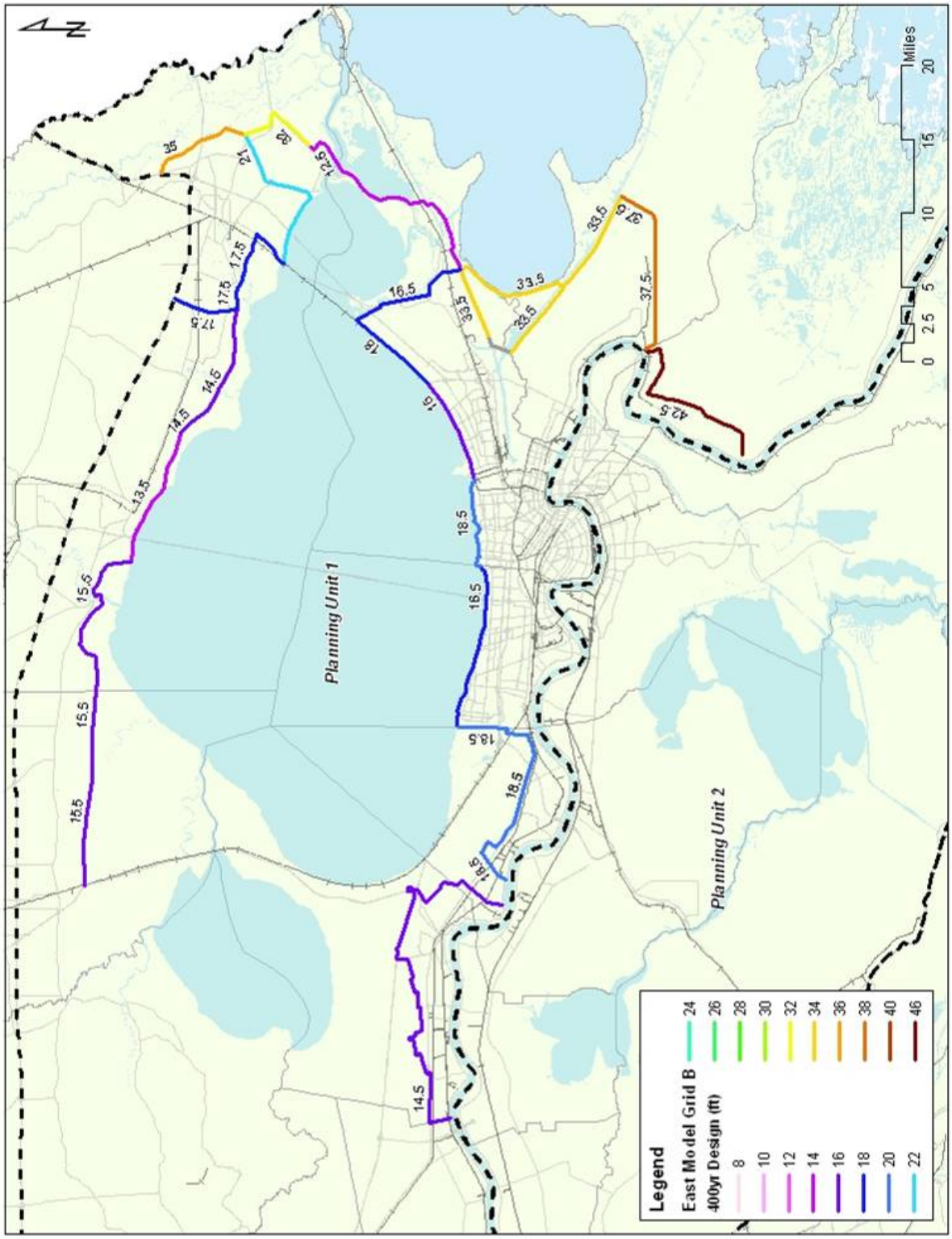


Figure 4.6 East Model Grid B, 400 year design heights

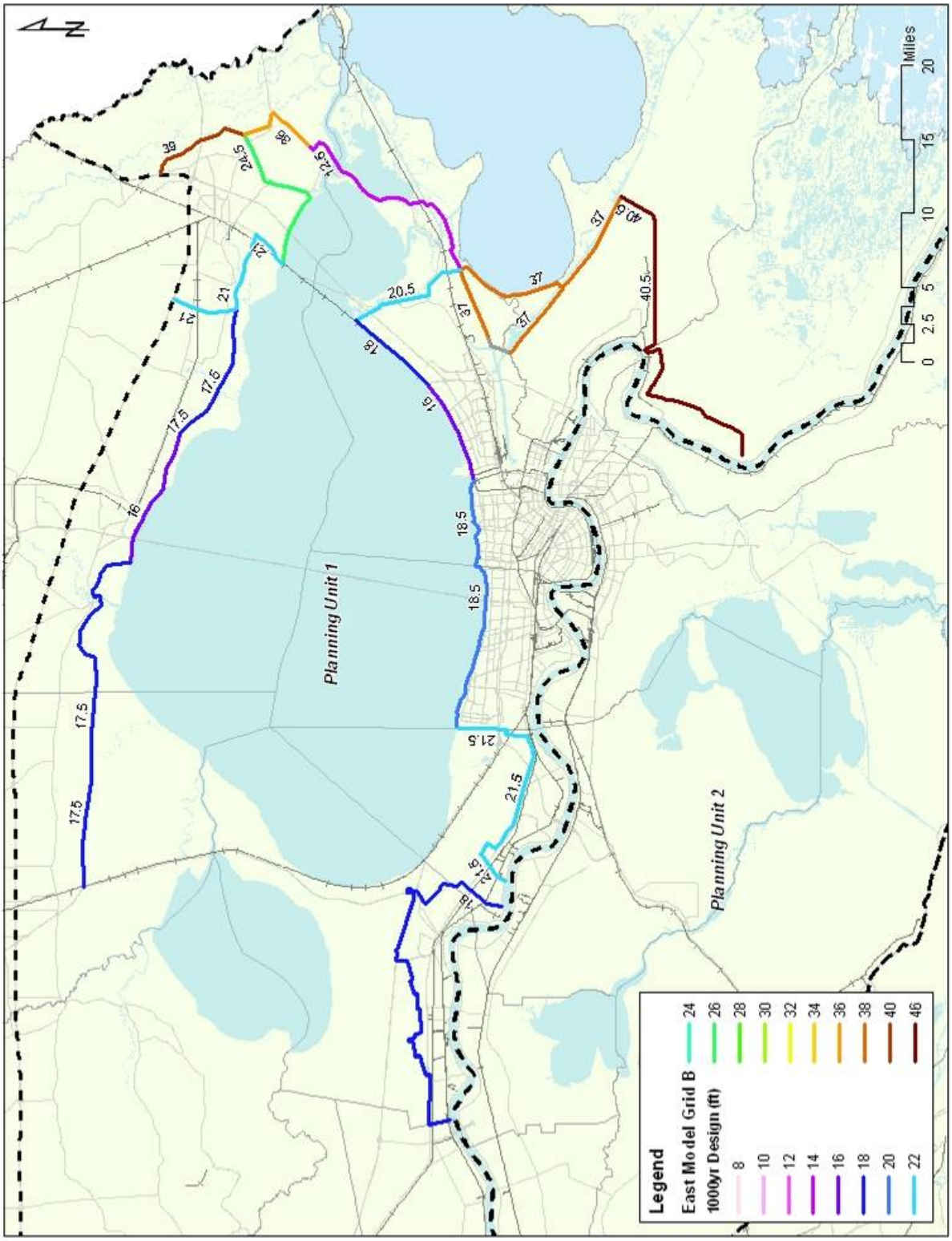


Figure 4.7 East Model Grid B, 1000 year design heights

4.3 Interior and exterior frequency curves

Given the above described levee heights, the overtopping volumes were computed for four return periods of the outside surge level and wave characteristics (100-year, 400-year, 1000-year, and 2000-year). The overtopping volumes are an important input for determination of the interior stage frequency curves per planning subunit.

Of the 100 planning subunits in Planning Unit 1, nine are protected by levees and it is proposed that these continue to be protected in the future. Another 36 are semi-interior, which means they are currently being outside the levee system, but may fall within a levee in one of the future alternatives. The interior and semi-interior planning subunits are listed in Table 4.1.

Table 4.1. Interior and Semi-interior Planning Subunits

Name	Type
New Orleans East	Interior
New Orleans - Metropolitan	Interior
East Jefferson	Interior
St Charles - Norco	Interior
St Charles - remainder	Interior
St Bernard - wetland	Interior
St Bernard - Developed	Interior
PLAQ_14s	Semi-interior (Plaquemines - Scarsdale) (requires improved levee for interior)
PLAQ_15s	Semi-interior (Plaquemines - Scarsdale) (requires improved levee for interior)
PLAQ_16s	Semi-interior (Plaquemines - Scarsdale) (requires improved levee for interior)
PLAQ_17s	Semi-interior (Plaquemines - Scarsdale) (requires improved levee for interior)
Laplace 1	Interior (no flooding when exterior)
Laplace 2	Interior (no flooding when exterior)
STTA_11a	Semi-interior (Bedico) new levee
TANG_10a	Semi-interior (Bedico) new levee
TANG_11	Semi-interior (Bedico) new levee
STTA_10e	Semi-interior (Bonfouca) new levee
STTA_11d	Semi-interior (Bonfouca) new levee
STTA_12b	Semi-interior (Bonfouca) new levee
STTA_12c	Semi-interior (Bonfouca) new levee
STTA_13b	Semi-interior (Bonfouca) new levee
STTA_10i	Semi-interior (Bonfouca) new levee
STTA_7	Semi-interior (Bonfouca) new levee
STTA_10d	Semi-interior (Lacombe) new levee
STTA_9d	Semi-interior (Lacombe) new levee
STCH_11b	Semi-interior (Laplace) new levee
STJO_11b	Semi-interior (Laplace) new levee
STJO_4b	Semi-interior (Laplace) new levee
STJO_5b	Semi-interior (Laplace) new levee
STJO_6b	Semi-interior (Laplace) new levee
STJO_7b	Semi-interior (Laplace) new levee

Name	Type
STJO_8c	Semi-interior (Laplace) new levee
STJO_9d	Semi-interior (Laplace) new levee
STTA_10h	Semi-interior (Liberty) new levee
TANG_8a	Semi-interior (Tangipahoa) new levee
TANG_8c	Semi-interior (Tangipahoa) new levee
TANG_9a	Semi-interior (Tangipahoa) new levee
STTA_10b	Semi-interior (Tchefuncte) new levee
STTA_10c	Semi-interior (Tchefuncte) new levee
STTA_9a	Semi-interior (Tchefuncte) new levee
ORLE_15a	Semi-interior (Golden Triangle) only interior with new levee alignment
ORLE_16b	Semi-interior (Golden Triangle) only interior with new levee alignment
ORLE_17b	Semi-interior (Golden Triangle) only interior with new levee alignment
STBE_16a	Semi-interior (Golden Triangle) only interior with new levee alignment
STBE_17a	Semi-interior (Golden Triangle) only interior with new levee alignment

For each planning subunit,

Table 4.2 lists the model grids that have been used, as well as the application of the special cases. The special cases are described below. For those cases where several planning subunits are located within a single drainage area the name of the drainage area is listed.

Table 4.2. Planning subunit to Hydraulic Alternative Matrix

Planning Subunit	BS-ext	BS-0100a	BS-0100b	BS-0400a	BS-0400b	BS-1000a	BS-1000b	EB-ext	EB-0100a	EB-0100b	EB-0400a	EB-0400b	EB-1000a	EB-1000b
Laplace	X	x		x		x		x	x		x		x	
St Charles Norco		x		x		x			x		x		x	
St Charles - rest		x		x		x			x		x		x	
East Jefferson		x	x	x	x	x	X		x	x	x	x	x	x
New Orleans Metro		x	x	x	x	x	X		x	x	x	x	x	x
New Orleans East		x	x	x	x	x	X		x	x	x	x	x	x
St Bernard Wetland		x	x	x	x	x	X		x	x	x	x	x	x
St Bernard developed		x	x	x	x	x	X		x	x	x	x	x	x
Plaquemines - Scarsdale	X	x		x		x		x	x		x		x	
Golden Triangle	X		x		x		X	x						
Bonfouca	X	x		x		x		x	x		x		x	
Liberty	X	x	x	x	x	x	X	x	x	x	x	x	x	x
Lacombe	X	x		x		x		x	x		x		x	
Tchefuncte	X	x		x		x		x	x		x		x	
Tangipahoa	X	x		x		x		x	x		x		x	
Bedico	X	x		x		x		x	x		x		x	
Other External areas	X							x						
	x = stage frequency calculated													

The hydraulic codes at the top line of the table relate to the various layout alternatives and corresponding sources of information; below these are listed for the 100 year design options:

BS-ext - exterior stage frequency results from the ADCIRC modeling for grid BS;
EB-ext - exterior stage frequency results from the ADCIRC modeling for grid EB;
BS-0100a - interior stage frequency results developed for a 100 year design option - alternative a (see

Table 4.3 below) based on the BS model grid;

BS-0100b - interior stage frequency results developed for a 100 year design option - alternative b (see

Table 4.3 below) based on the BS model grid;

EB-0100a - interior stage frequency results developed for a 100 year design option - alternative a (see

Table 4.3 below) based on the BS model grid;

EB-0100b - interior stage frequency results developed for a 100 year design option - alternative b (see

Table 4.3 below) based on the BS model grid.

The 0400 and 1000 codes refer to the 400 year and 1000 year design options.

Table 4.3. Planning Subunit Interior Stage Frequency Alternatives

Planning Subunit	Alternative 'a'	Alternative 'b'
Laplace	with levee	N/A
St Charles Norco	baseline	N/A
St Charles – rest	baseline	N/A
East Jefferson	baseline	effects of Golden Triangle alignment
New Orleans Metro	baseline	effects of Golden Triangle alignment
New Orleans East	baseline	effects of Golden Triangle alignment
St Bernard Wetland	baseline	effects of Golden Triangle alignment
St Bernard developed	baseline	effects of Golden Triangle alignment
Plaquemines - Scarsdale	with levee	N/A
Golden Triangle	N/A	with levee along Lake Borgne
Bonfouca	with levee	N/A
Liberty	with levee	with ring levee return
Lacombe	with levee	N/A
Tchefuncte	with levee	N/A
Tangipahoa	with levee	N/A
Bedico	with levee	N/A
Other External areas	N/A	N/A

Comments on the specific planning subunits are given in Table 4.4. Additional area specific information is given in Annex B.

Table 4.4. Specific Planning Subunit Comments

Planning Subunit	Comment
Laplace	This is considered as initially without a levee system and therefore exterior. Several of the options (both without and with the Lake Pontchartrain barrier) consider the construction of a levee and so the effect on stage frequency has been calculated with a range of different design standards of a levee protecting Laplace.
St Charles - east bank	The two planning subunits within St Charles Parish on the east bank are within an existing levee system and have been considered as interconnected above a flood level of 4.5'.
East Jefferson New Orleans Metro New Orleans East St Bernard Wetland St Bernard Developed	The central area of New Orleans has been considered as an interconnected system. The following assumptions have been made in developing the stage frequency results in this area. St Bernard wetland and St Bernard Developed are inter-linked at 10.5'. For flood levels greater than 12.5' water flows from St Bernard into New Orleans Metro. Similarly if flooding in New Orleans East exceeds 12.5' then water flows into New Orleans Metro. Water flows between New Orleans Metro and East Jefferson at flood levels greater than 5'. A maximum level of 16' has generally been used within the central New Orleans area. In addition, the effects of creating a levee along the edge of Lake Borgne (the Golden Triangle alignment) were considered by increasing the storage in St Bernard wetland and reducing the overtopping lengths to New Orleans East. Also the design height of this levee, together with overtopping rates, was evaluated. The evaluation of this option resulted in the 'b' alternatives in the matrix above.
Golden triangle	There are a number of areas that have an interior stage frequency when the Golden Triangle alignment is implemented. These areas have the same stage frequency as St Bernard Wetland and are presented in the 'b' alternatives.
Plaquemines - Scarsdale	There are a number of areas within the existing low levee system south of St Bernard Parish that have been included using exterior stage frequency values for the baseline case, and have then been analyzed with improved levee systems at a range of design standards to provide interior stage frequency results.
Bonfouca Liberty	These two areas cover the Slidell part of the North Shore. The existing levee system has not been modeled and the results from the hydrodynamic modeling have been used for when no levee are proposed. The 'a' alternatives consider the creation of a new levee around the areas which then links up with a further levee to the west (see below). The 'b' option for Liberty considers the change in interior stage frequency when a ring levee is included and there is no continuation of the levee along the north shore. No interconnection of levels has been considered within these areas.
Lacombe Tchefuncte Tangipahoa Bedico	These areas cover the North Shore to the west of Slidell and use the exterior stage frequency results from the hydrodynamic modeling for the current no levee situation. Interior stage frequencies have been developed as 'a' alternatives using both the BS and EB grids and with a range of design standards.

4.4 Interconnected Drainage Areas

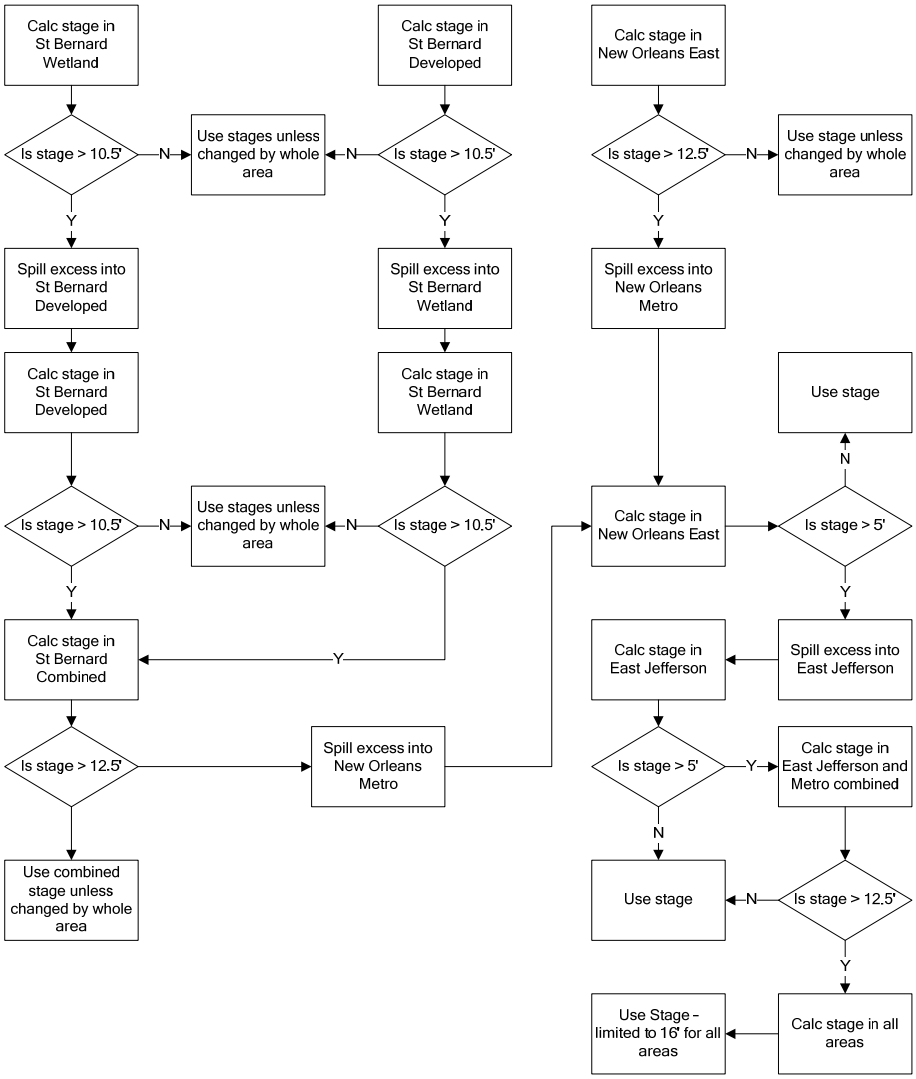
Two groups of planning subunits have been considered as interconnected during severe flood events. Details on how these areas have been linked are given below.

4.4.1 St Charles

The planning subunits St Charles Norco and St Charles-rest are considered as connected, with the link being at 4.5 feet. If both areas have a stage of less than 4.5 feet, then the stages are used from the system. If one is greater than 4.5 feet, then the excess flood volume is added to the other and a new stage is computed. If both stages then reach a level higher than 4.5 feet, the total volume is used with the total stage storage to give a single value of stage. This value is then limited to the higher of the authorized height (13 feet), the design height (32) or the surge (32).

4.4.2 New Orleans

There are five areas that are considered linking within the New Orleans area. These are two in St Bernard, New Orleans East, New Orleans Metro, and East Jefferson. A flow chart of this linking is given below.



The key points for this system are that there is no connection between New Orleans East and St Bernard until the New Orleans Metro/East Jefferson areas have filled to 12.5 feet as well.

4.5 Hydraulic Results to Planning Alternatives

At the initial planning stage, a large number of planning alternatives have been considered. These cover the two basic alternatives:

- High Level plan: raising and extending the existing levee system;
- Barrier plan: construction of a barrier of some sort across the entrance to Lake Pontchartrain together with levee improvements.

In addition, three design standards have been considered (100 year, 400 year, and 1000 year) as well as a range of variations in alignments and areas. All of these alternatives are used for the

determination of the interior and exterior stage frequencies, thus providing results that are the input for the economic evaluation. Following the screening process carried out by the project planning team (based on a basic economic evaluation), eight alternatives and the baseline situation have been considered in more detail.

The relationship between hydraulic alternative (as discussed above in section 4.2) and the selected planning alternatives is given in Table 4.5.

Table 4.5. Planning Subunit to Planning Alternative Matrix

Planning Subunit	2010_base	HL-1a-100-3	HL-1b-400-3	LP-1a-100-1	LP-1a-100-3	LP-1b-400-1	LP-1b-400-3	LP-1b-1000-1	LP-1b-1000-2
Laplace	BS-ext	BS-0100a	BS-0400a	EB-ext	EB-0100a	EB-ext	EB-0400a	EB-ext	EB-1000a
St Charles Norco	BS-0100a	BS-0100a	BS-0400a	EB-0100a	EB-0100a	EB-0400a	EB-0400a	EB-1000a	EB-1000a
St Charles – rest	BS-0100a	BS-0100a	BS-0400a	EB-0100a	EB-0100a	EB-0400a	EB-0400a	EB-1000a	EB-1000a
East Jefferson	BS-0100a	BS-0100a	BS-0400b	EB-0100a	EB-0100a	EB-0400b	EB-0400b	EB-1000b	EB-1000b
New Orleans Metro	BS-0100a	BS-0100a	BS-0400b	EB-0100a	EB-0100a	EB-0400b	EB-0400b	EB-1000b	EB-1000b
New Orleans East	BS-0100a	BS-0100a	BS-0400b	EB-0100a	EB-0100a	EB-0400b	EB-0400b	EB-1000b	EB-1000b
St Bernard Wetland	BS-0100a	BS-0100a	BS-0400b	EB-0100a	EB-0100a	EB-0400b	EB-0400b	EB-1000b	EB-1000b
St Bernard developed	BS-0100a	BS-0100a	BS-0400b	EB-0100a	EB-0100a	EB-0400b	EB-0400b	EB-1000b	EB-1000b
Plaquemines - Scarsdale	BS-ext	BS-0100a	BS-0400a	EB-ext	EB-0100a	EB-ext	EB-0400a	EB-ext	EB-1000a
Golden Triangle	BS-ext	BS-ext	BS-0400b	EB-ext	EB-ext	EB-0400b	EB-0400b	EB-1000b	EB-1000b
Bonfouca	BS-ext	BS-0100a	BS-0400a	EB-ext	EB-0100a	EB-ext	EB-0400a	EB-ext	EB-1000a
Liberty	BS-ext	BS-0100b	BS-0400b	EB-ext	EB-0100b	EB-ext	EB-0400b	EB-ext	EB-1000a
Lacombe	BS-ext	BS-0100a	BS-0400a	EB-ext	EB-0100a	EB-ext	EB-0400a	EB-ext	EB-1000a
Tchefuncte	BS-ext	BS-0100a	BS-0400a	EB-ext	EB-0100a	EB-ext	EB-0400a	EB-ext	EB-1000a
Tangipahoa	BS-ext	BS-0100a	BS-0400a	EB-ext	EB-0100a	EB-ext	EB-0400a	EB-ext	EB-1000a
Bedico	BS-ext	BS-0100a	BS-0400a	EB-ext	EB-0100a	EB-ext	EB-0400a	EB-ext	EB-1000a
Other External areas	BS-ext	BS-ext	BS-ext	EB-ext	EB-ext	EB-ext	EB-ext	EB-ext	EB-ext

The alignments and levee heights for each of the alternatives are shown on the Planning Subunit Key maps in the Evaluation Results Appendix. These maps have an accompanying table showing stage frequency comparisons (baseline to alternative) for a selection of planning subunits.

4.6 Plaquemines

The existing levees from Oakville to Venice (the Plaquemines area) were originally not included in the levee improvements. However as the potential alternatives may affect the standard of protection afforded to this area then the heights of the levees and stage frequencies needed to be established,

An overview of the levees and storage areas is shown in the map below. The existing levee heights (authorized as well as non-federal) as shown in the map and in Table 4.6 were obtained from the design reports for the works.

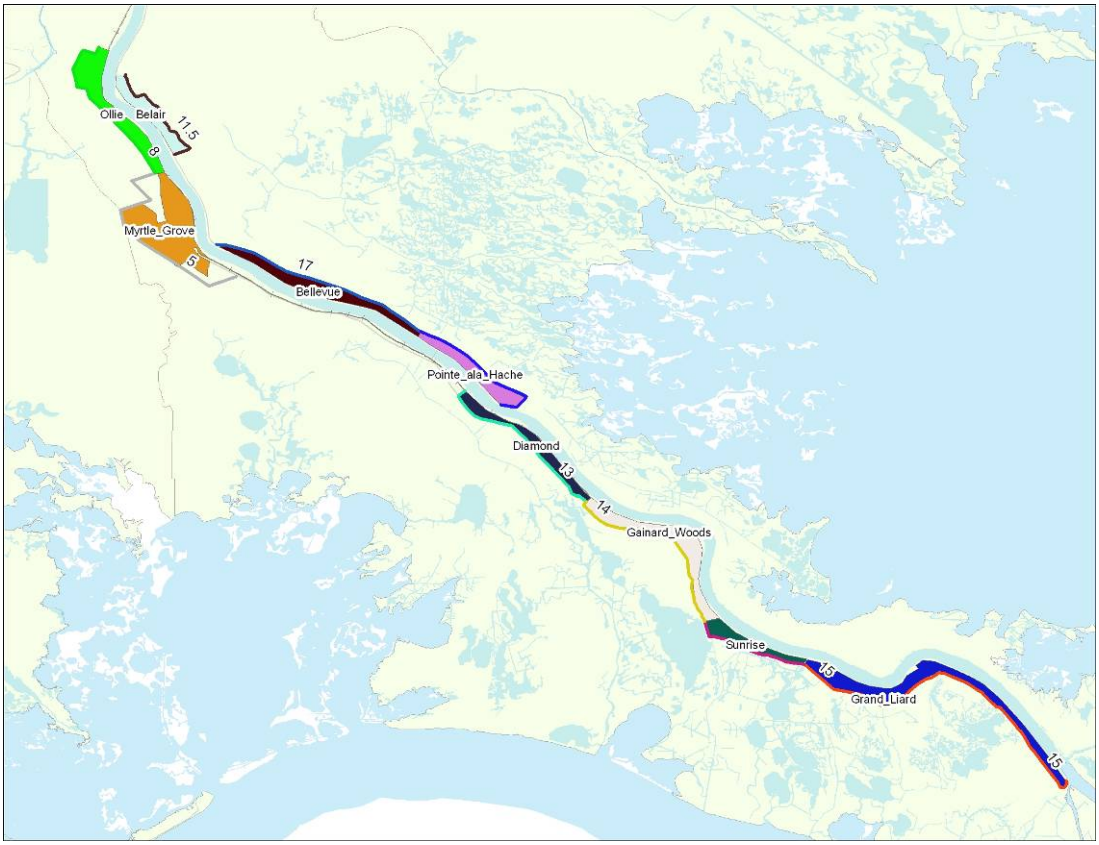


Figure 4.8 Plaquemines - Storage Areas and Existing Levee Heights

Table 4.6. Authorized levee heights

Location	Height in feet	Notes
Belair	11.5	Non-federal
Ollie	8	Non-federal
Myrtle Grove	5	Non-federal
Bellevue	17	Authorized - Reach C
Point ala Hache	17	Authorized - Reach C
Diamond - upper	12.8	Authorized - Reach A
Diamond - lower	13	Authorized - Reach A
Diamond - Mississippi	17	Authorized
Gainard Woods - west	13.5 – 14.5	Authorized - Reach A
Gainard Woods - Mississippi	17	Authorized
Sunrise - west	15	Authorized - Reach B1
Sunrise - Mississippi	17	Authorized
Grand Liard - west	15	Authorized - Reach B1 and B2
Grand Liard - Mississippi	17 – 16	Authorized

To obtain overtopping rates the levees were linked to model output points. The 2010 base model was used, here.

For each storage area the stage storage values have been obtained from the previous modeling of the area. Rainfall was taken as the standard 6.5 inch in 6 hours, as used for the main internal storage areas.

Using the overtopping rates calculated for the points together with the rainfall, flood volumes for the 10 year, 50 year, and 100 year flood events have been calculated. These have then been converted to flood levels using the stage storage volumes. The range of events considered (10,50 and 100) is different from the normal set (10,100,400,1000,2000) as it was considered that over the 100 year event the storage areas would be totally overwhelmed, but that having the 50 year value may enable some conclusions to be drawn as to the vulnerability of the area.

For the 100 year event the majority of the areas were flooded to significant depths. The stage values (for the 50% confidence level) are listed in the table below:

Table 4.7. Stage values in feet for Plaquemines Storage Areas - based on 50% confidence level results

Area	10 yr event (ft)	50yr event (ft)	100yr event (ft)
Bellevue	1.0	1.9	Full to levee
Pointe ala Hache	1.6	2.6	Full to levee
Diamond	0.1	0.1	Full to levee
Gainard Woods	-1.1	-1.1	9.4
Sunrise	-2.3	-1.9	9.7
Grand Liard	-4.7	-4.6	1.9
Ollie	1.4	1.4	Full to levee

The values for 400, 1000, and 2000 year events have been taken from the adjacent exterior stage frequency curves as it was assumed that the levees have only a minor effect on flood levels at these frequencies. For the 'with barrier' option changes in exterior stage frequency were applied for the higher return period events using the east model B results.

To take into account the impacts of implementing the barrier across Lake Pontchartrain and the Barrataria Basin, the increase in surge levels along the Plaquemines was investigated.

The differences in surge heights along the levees was obtained for the without and with barrier options across Lake Pontchartrain and along the GIWW in the Barataria Basin (in Planning Unit 2) by comparing the surge levels from the High Level Plan and east model B results. The differences in surge level were taken as the changes required to increase the levee height to maintain the same standard of protection.

The analysis suggested the following changes to levee heights:

- Ollie - increase levee heights by 2.6 feet to accommodate the maximum change in surge seen at 100 year;
- Bellevue - increase levee heights by 0.6 feet to accommodate the increase in surge level;
- Pointe a la Hache - increase levee heights by 0.3 feet to accommodate the increase in surge level;
- Diamond - Mississippi Levee - increase levee heights by 0.3 feet to accommodate the increase in surge level;
- Gainard Woods - Mississippi Levee - increase levee heights by 0.2 feet to accommodate the increase in surge level;
- Belair - at Belair the increase is around 2 feet, but the non-federal levee is overtopped at less than once in 50 years (1.8 feet still water over levee at 1 in 50 year event). Because of this low defense standard, no allowance was made for increases in this levee.
- Myrtle Grove - no allowances have been investigated for Myrtle Grove as the levee height has been taken as around 5 feet and assumed to be overtopped regularly.

No changes were made to the stage frequency values for the Plaquemines in the future to take into account changes in marsh or for sea level rise as the changes in stage were deemed to be small and only having a minor impact on the final results.

5 PLANNING UNIT 2

5.1 Introduction

Following the same structure as the previous chapter on Planning Unit 1, this chapter presents the levee heights and the stage frequency curves resulting from the calculations for the planning subunits of Planning Unit 2 (see Figure 5.1).

Section 5.2 describes the results of the levee heights being computed for both the 2010 base model grid and the east hydro model grid B, for three design standards (100 year, 400 year, and 1000 year), over all levees included in the modeling.

In section 5.3 the stage frequency curves for Planning Unit 2 are determined.

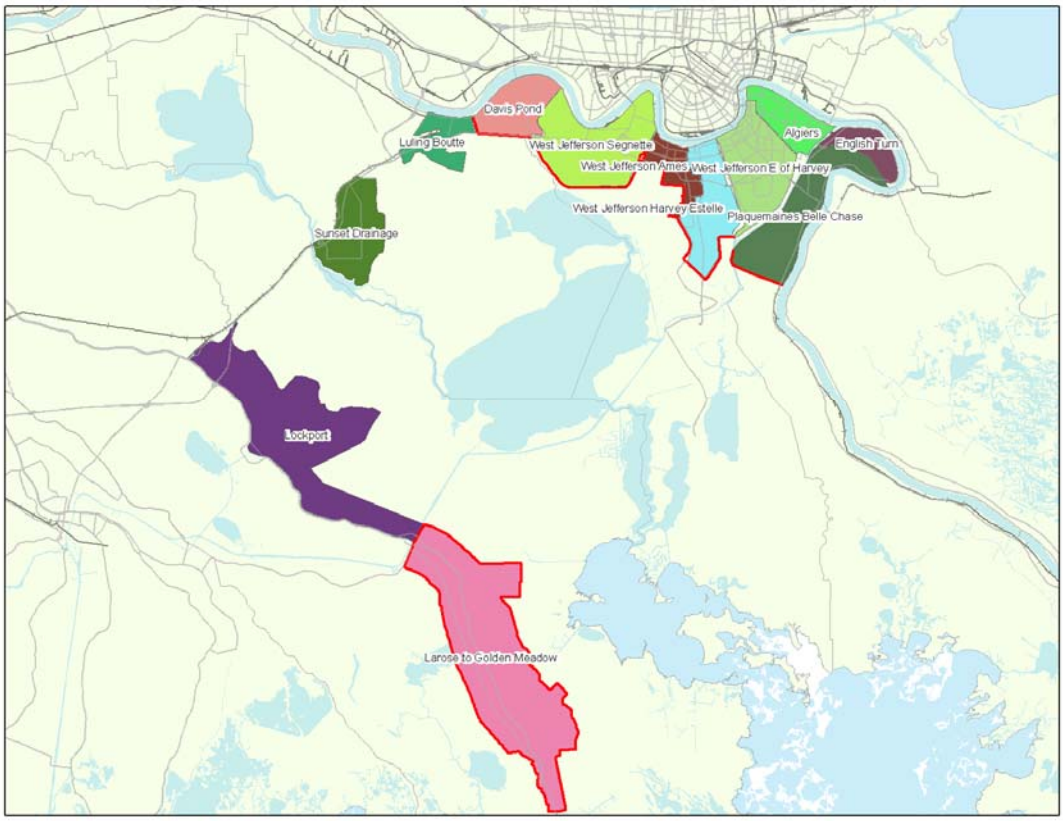


Figure 5.1 Planning Unit 2

5.2 Levee heights

The levee height design was carried out using the methodologies described in Volume 1 of this report. Levee heights were computed for both the 2010 Base model grid and the east model B, for

three separate design standards (100 year, 400 year, and 1000 year) for all levees included within the modeling.

The next six figures show the 100 year, 400 year, and 1000 year design heights in feet for the levees within Planning Unit 2 for the 2010 base grid and the east hydro model B grid. These values have been adjusted to include any changes made for authorized heights or because of issues with specific modeling results. A detailed overview of the design heights is given in the fact sheets in Annex B.

The heights are again used for the purposes of costing design options and for establishing overtopping rates.

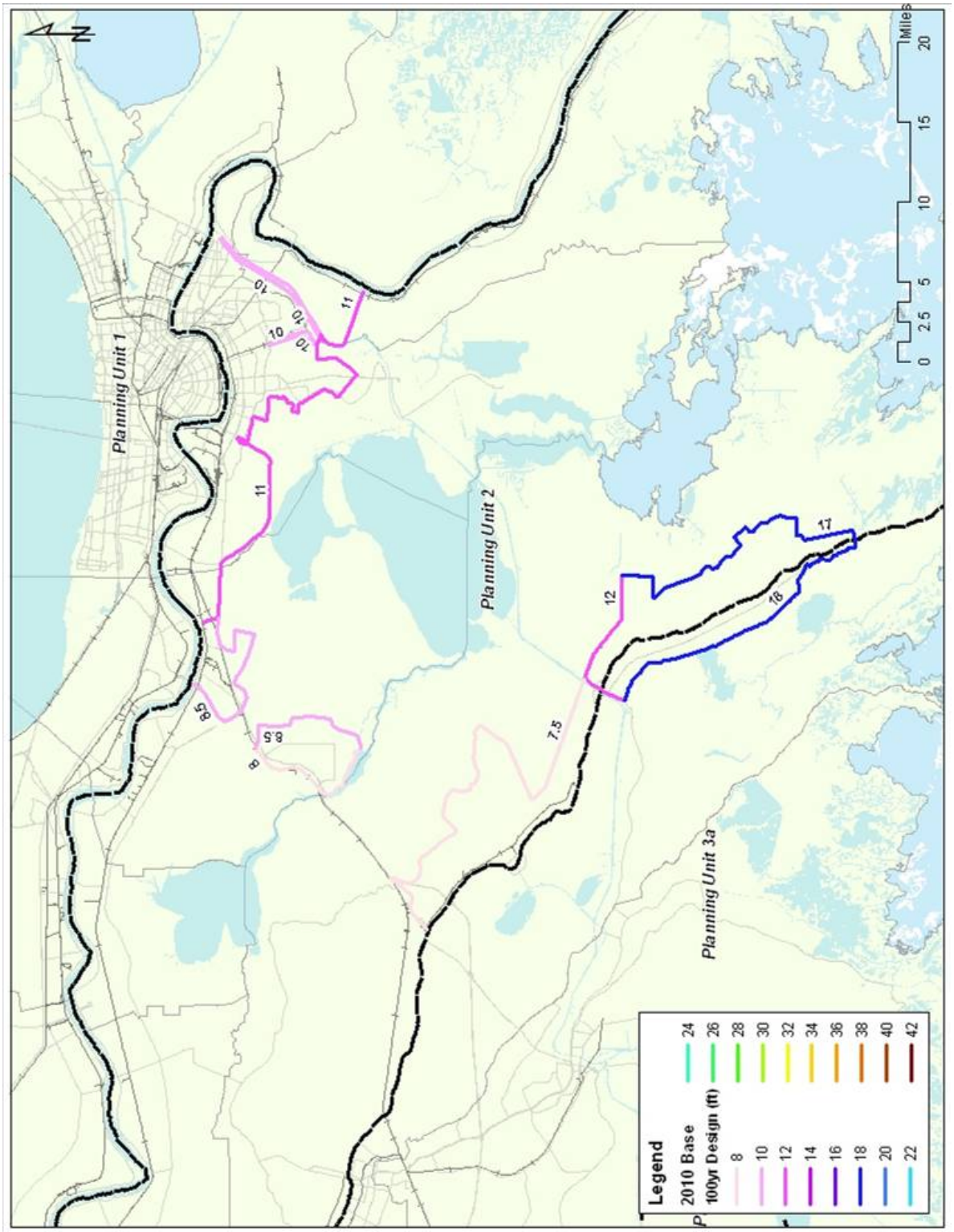


Figure 5.2 2010 base model, 100 year design heights

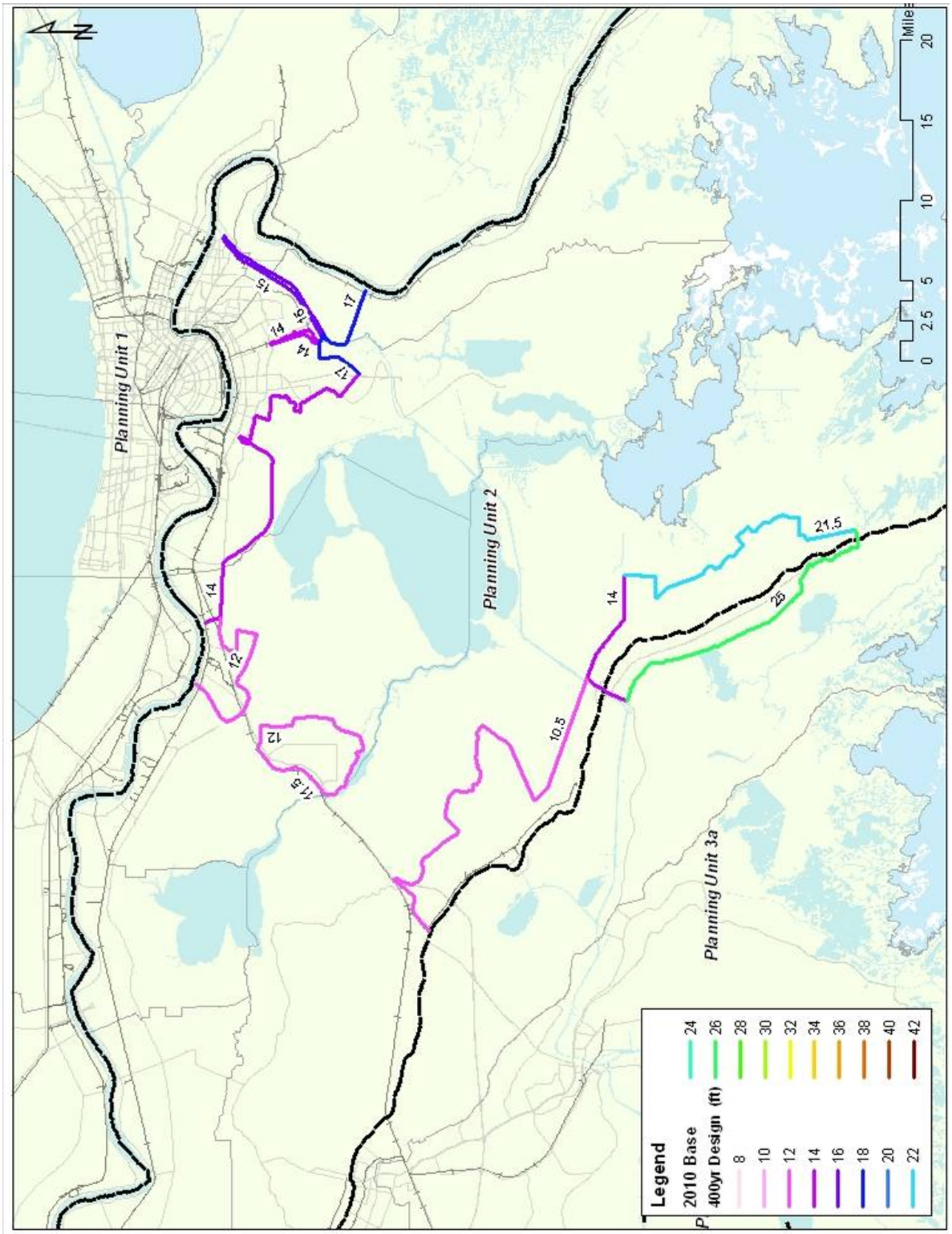


Figure 5.3 2010 base model, 400 year design heights

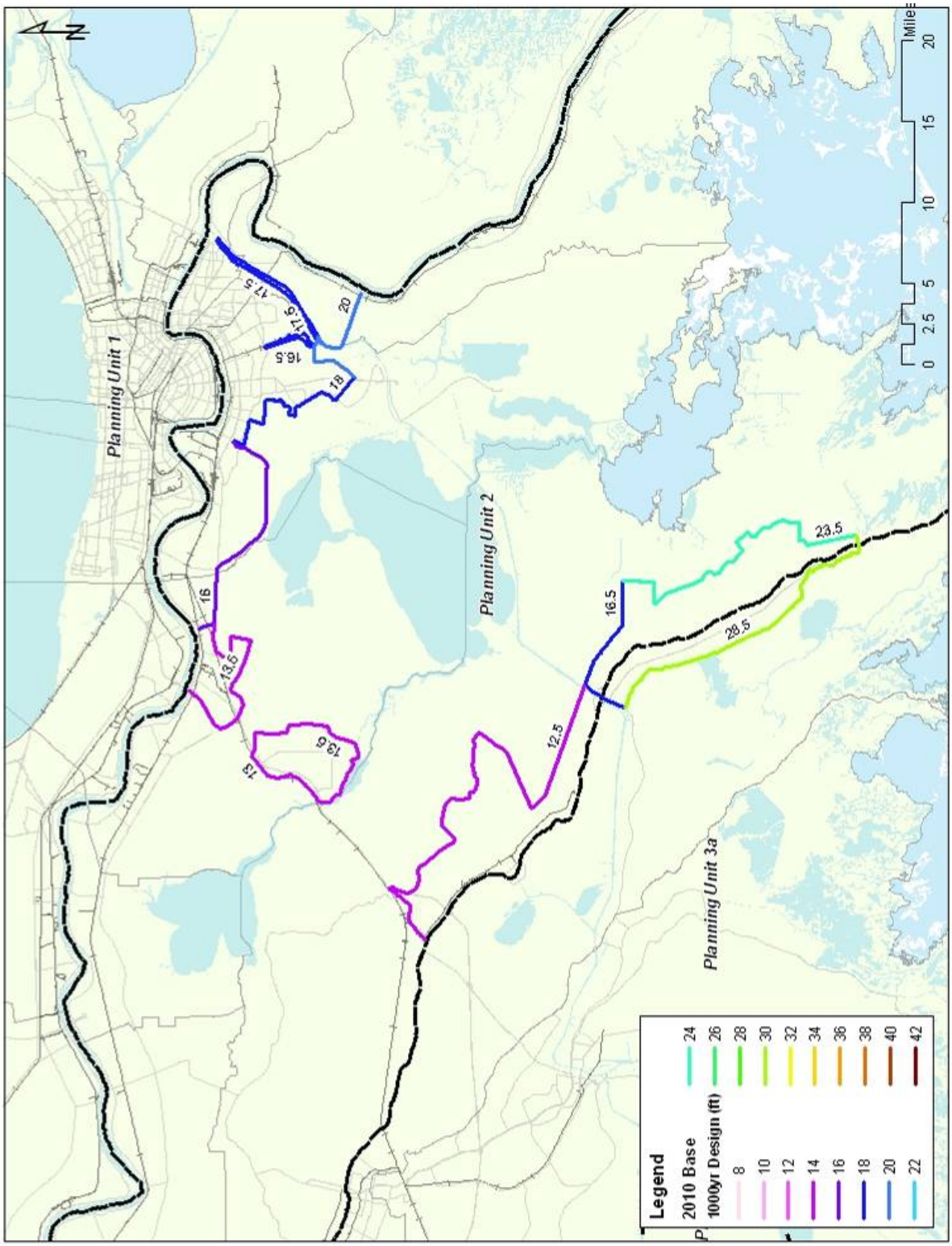


Figure 5.4 2010 base model, 1000 year design heights

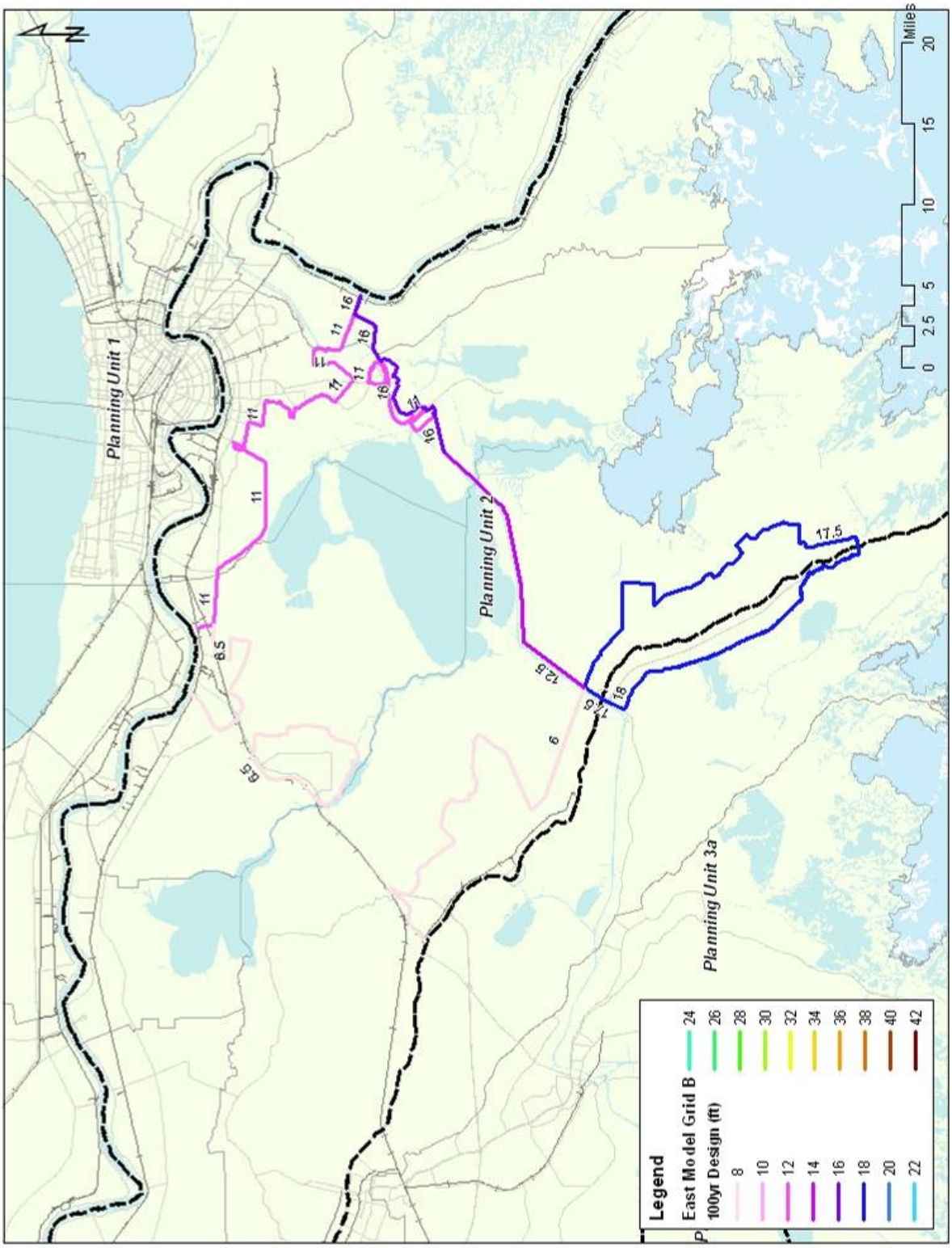


Figure 5.5 East Hydro Model grid B, 100 year design heights

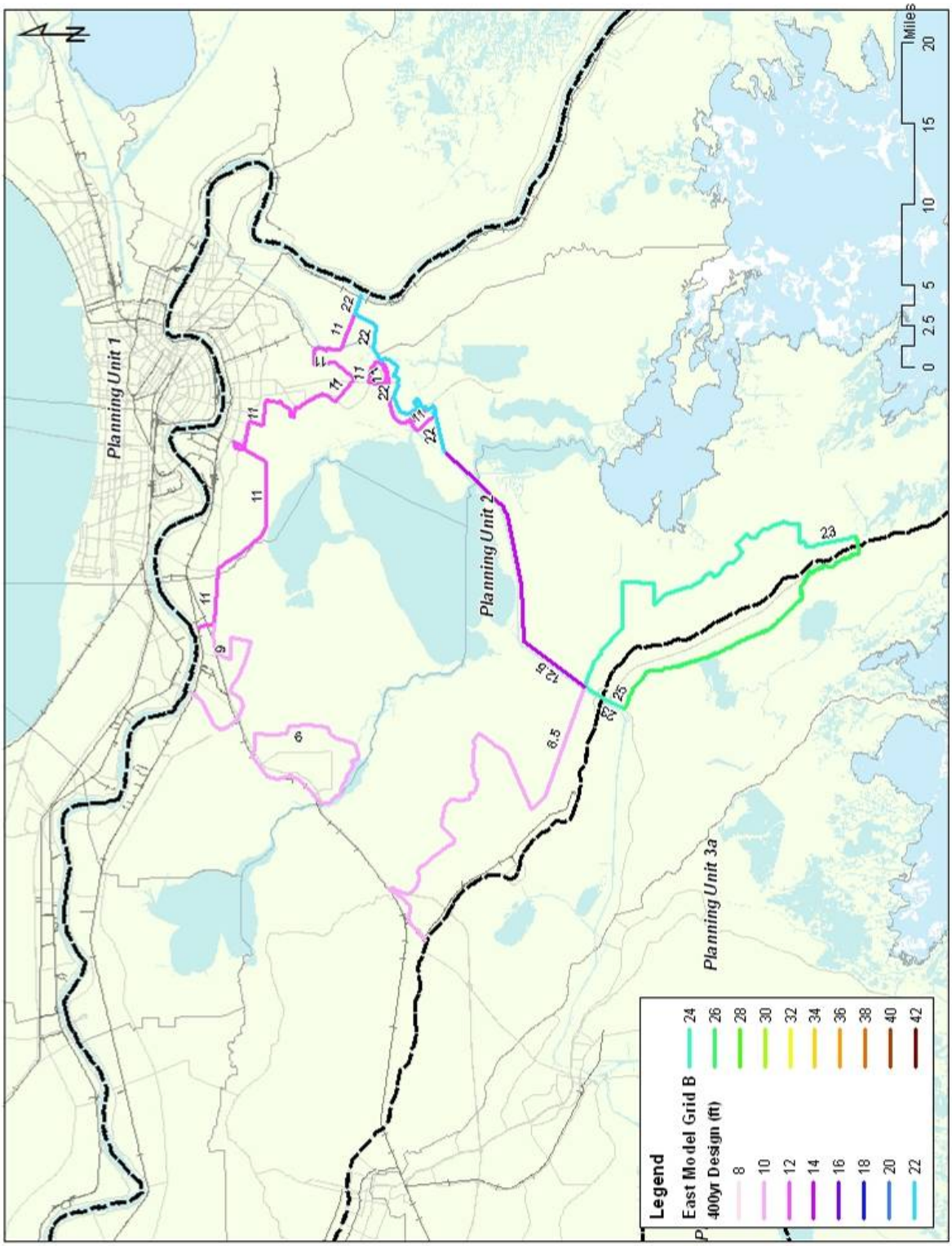


Figure 5.6 East Hydro Model grid B, 400 year design heights

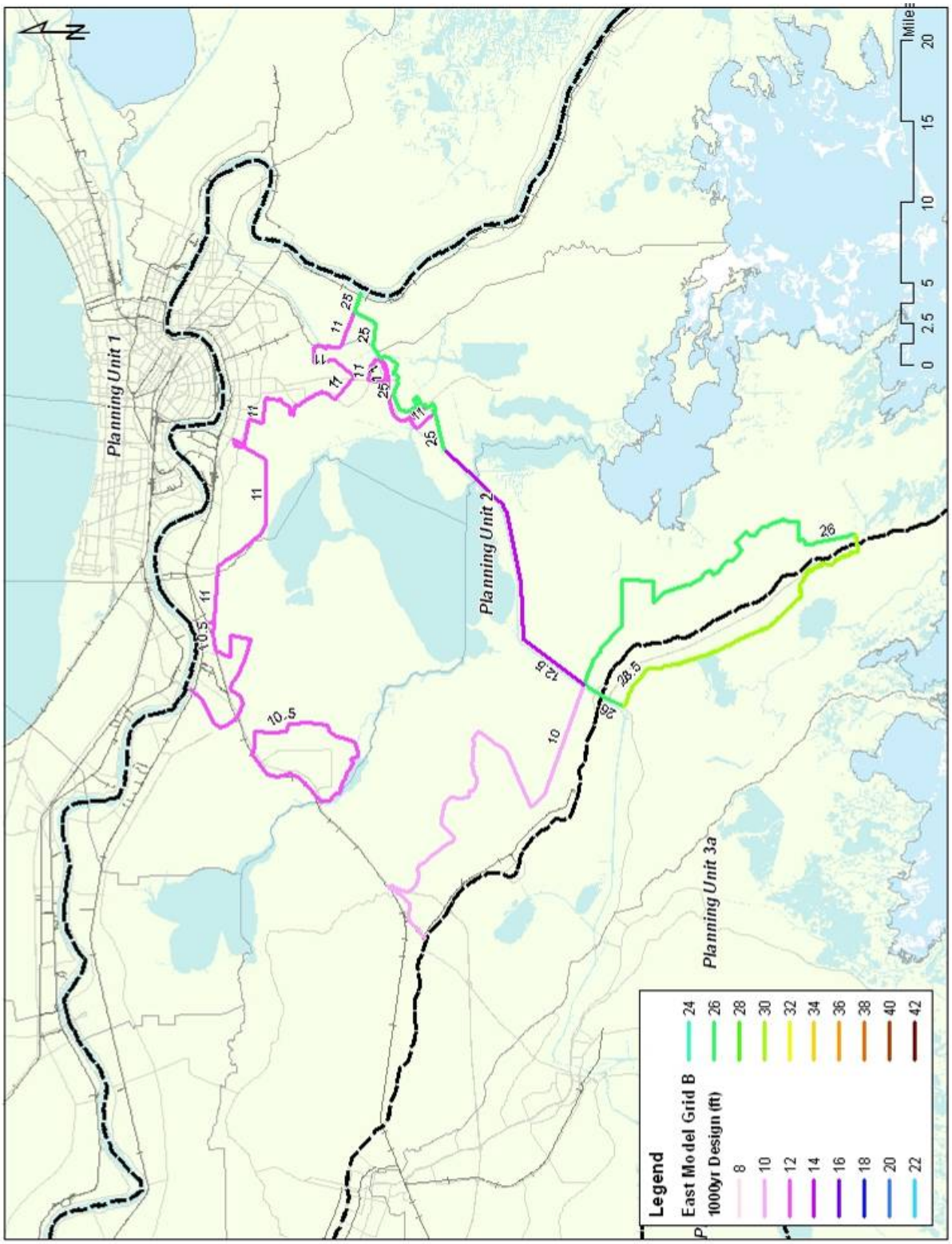


Figure 5.7 East Hydro Model grid B, 1000 year design heights

5.3 Interior and exterior frequency curves

Given the above described levee heights, the overtopping volumes were computed for four return periods of the outside surge level and wave characteristics (100-year, 400-year, 1000-year, and 2000-year). The overtopping volumes are an important input for determination of the interior stage frequency curves per planning subunit.

Planning Unit 2 consists of over 100 planning subunits. Of these, nine are protected by levees and it is proposed that they continue to be protected in the future, and 21 fall in the category of currently being outside the levee system, but may fall within a levee in one of the future alternatives (semi-interior). A list of these is given in Table 5.1.

Table 5.1. Interior and Semi-interior Planning Subunits

Name	Type
Algiers	Interior
English Turn	Interior
West Jefferson - East of Harvey	Interior
West Jefferson - Harvey Estelle	Interior
West Jefferson - Ames	Interior
West Jefferson - Segnette	Interior
St Charles - Davis Pond	Interior
St Charles - Luling Boutte	Semi-interior - new levee
STCH_3c	Semi-interior (Luling) - new levee
STCH_5a	Semi-interior (Luling) - new levee
STCH_6a	Semi-interior (Luling) - new levee
St Charles - Sunset	Semi-interior - non federal levee
STCH_1c	Semi-interior (Sunset) - non federal levee
STCH_1d	Semi-interior (Sunset) - non federal levee
STCH_2c	Semi-interior (Sunset) - non federal levee
Larose to Golden Meadow	Interior
Plaquemines - Belle Chase	Interior
LAFO_2c	Semi-interior (Lockport) - new levee
LAFO_3b	Semi-interior (Lockport) - new levee
LAFO_3c	Semi-interior (Lockport) - new levee
LAFO_4c	Semi-interior (Lockport) - new levee
LAFO_5d	Semi-interior (Lockport) - new levee
LAFO_6b	Semi-interior (Lockport) - new levee
LAFO_6c	Semi-interior (Lockport) - new levee
LAFO_7e	Semi-interior (Lockport) - new levee
LAFO_8e	Semi-interior (Lockport) - new levee
LAFO_9a	Semi-interior (Lockport) - new levee

The stage storage relationships for these planning subunits are based on the results from two of the hydraulic modeling grids: the 2010 East base model (BS) and the East hydro model grid B (EB). Per planning subunit, the grids that have been used and the variations are given in the table

below. After that, specific variations are described. In those cases where several planning subunits are located within a single drainage area, the name of the drainage area has been used. The hydraulic codes at the top line of the table relate to the various layout alternatives and corresponding sources of information; as listed in Chapter 3.

6 PLANNING UNIT 3A

6.1 Introduction

This chapter presents the results of the calculations of the levee heights and stage frequency curves for Planning Unit 3a. It addresses the development of the 100 year, 400 year, and 1000 year design heights in feet for the potential levee alignments within Planning Unit 3a for the '2007 Base model West', 'West model grid A' and the 'West model grid B'.

In section 6.2 computation of the levee heights is described for the different alternatives in Planning Unit 3a in 2007.

As for the other planning units, the resulting heights are used for the purposes of costing design options and for establishing overtopping rates. The combination of the heights to given planning alternatives is coupled with the stage frequency analysis as is described in section 6.3.

Figure 6.1 shows the planning subunits in Planning Unit 3a. For evaluation purposes the planning subunits were grouped into Drainage Areas. These areas are named on the map and outlined in red.

For Planning Unit 3a all alternatives were evaluated in more detail.

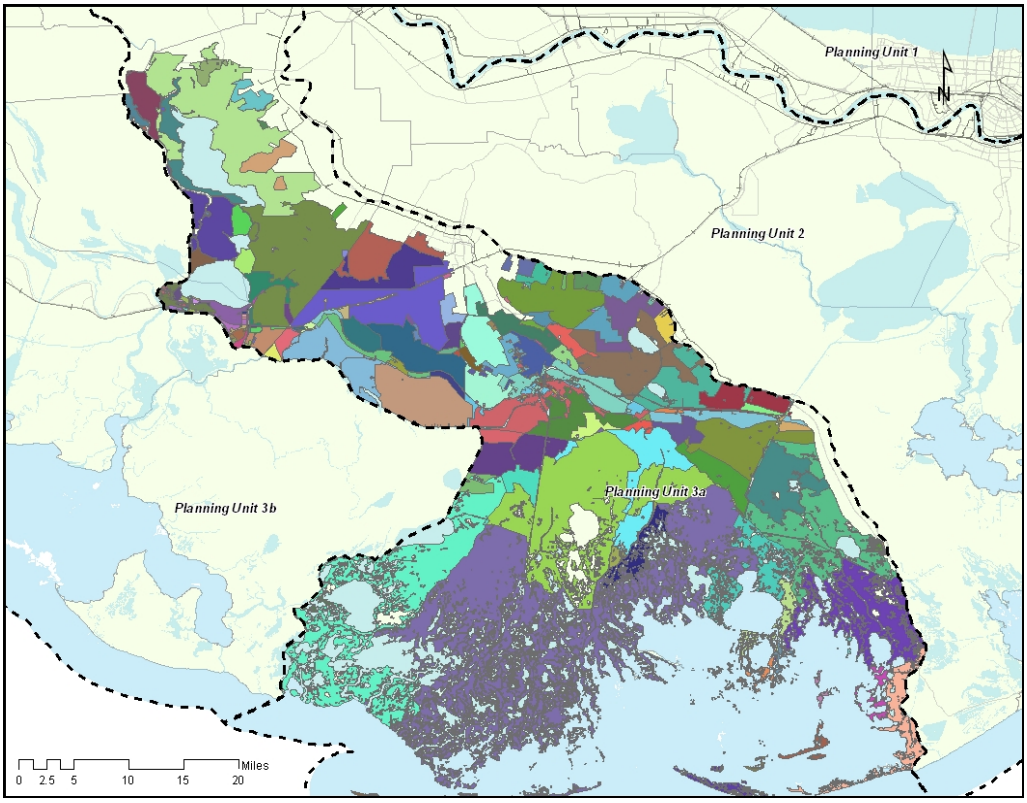


Figure 6.1 Planning Subunits in Planning Unit 3a

6.2 Levee height

6.2.1 General

The levee height design has been carried out using the methodologies described in Volume I of this report. Levee heights have been computed for the '2007 model West A' (WA) and the '2007 model West B' (WB), for three separate design standards (100 year, 400 year, and 1000 year) for all levees included in the alternatives. The design elevations are based on the wave heights and periods obtained from the no bed friction STWAVE models for the west.

The next six figures show the levees designed for Planning Unit 3a using the WA and WB model grids for the 100 year, 400 year, and 1000 year levels of protection. As the WB grid was only used only for the area of Morgan City, only the results for that area are shown with the WB grid.

The levee heights north of Morgan City run along the edge of the Atchafalaya Basin. This is an area where the effects of the extreme conditions are lesser than on the southern side of Morgan City, as the surge has to propogate through the narrowing's around Patterson (to the west of Morgan City). As the levels within the basin, and more significantly the wave heights, are not well modeled, particularly in the hydrodynamic models with high levees, the levee heights within the basin have been derived by using the levee heights outside the basin but reducing their height by the apparent reduction in surge level obtained from the 2007 base grid, for which base values were available within the model results. A detailed overview of the design heights is also given in the fact sheets in Annex B.

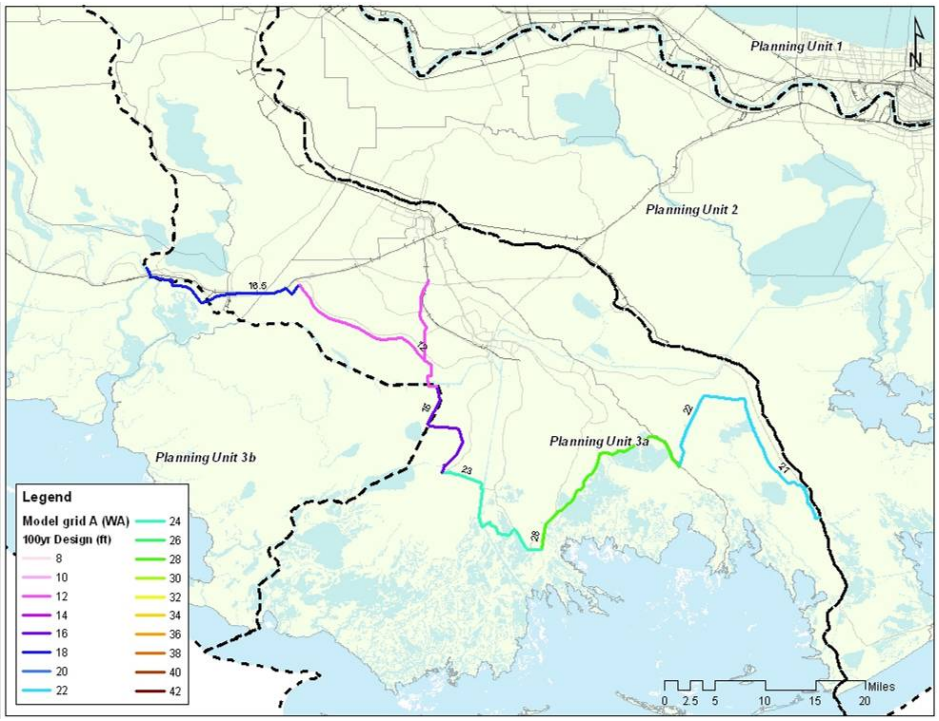


Figure 6.2 West model grid A (WA), 100 year design heights

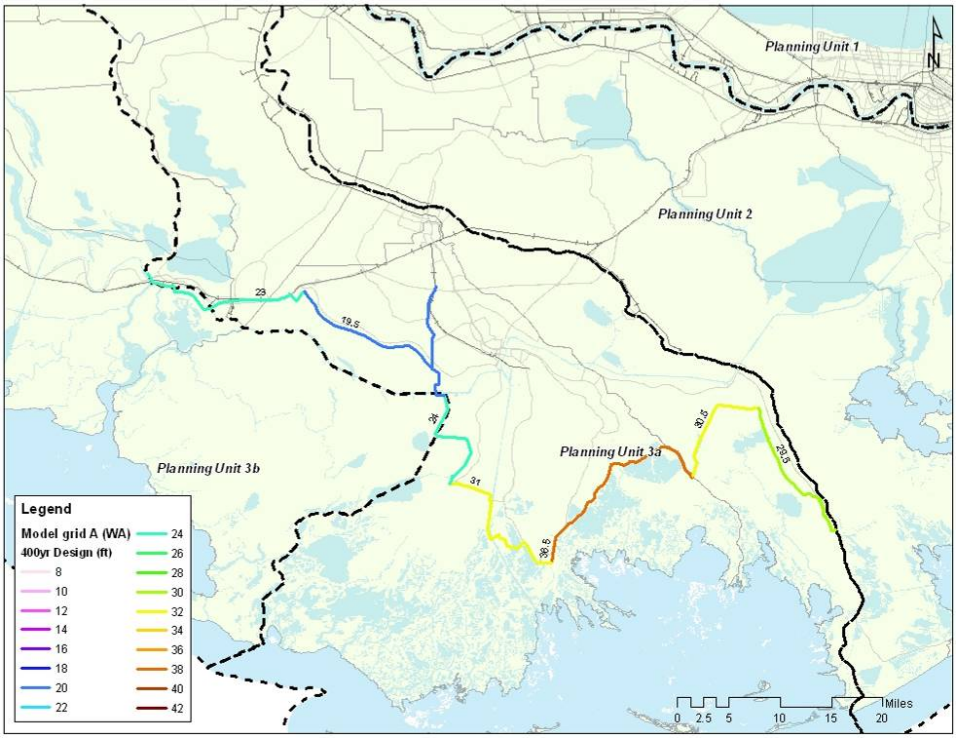


Figure 6.3 West model grid A (WA), 400 year design heights

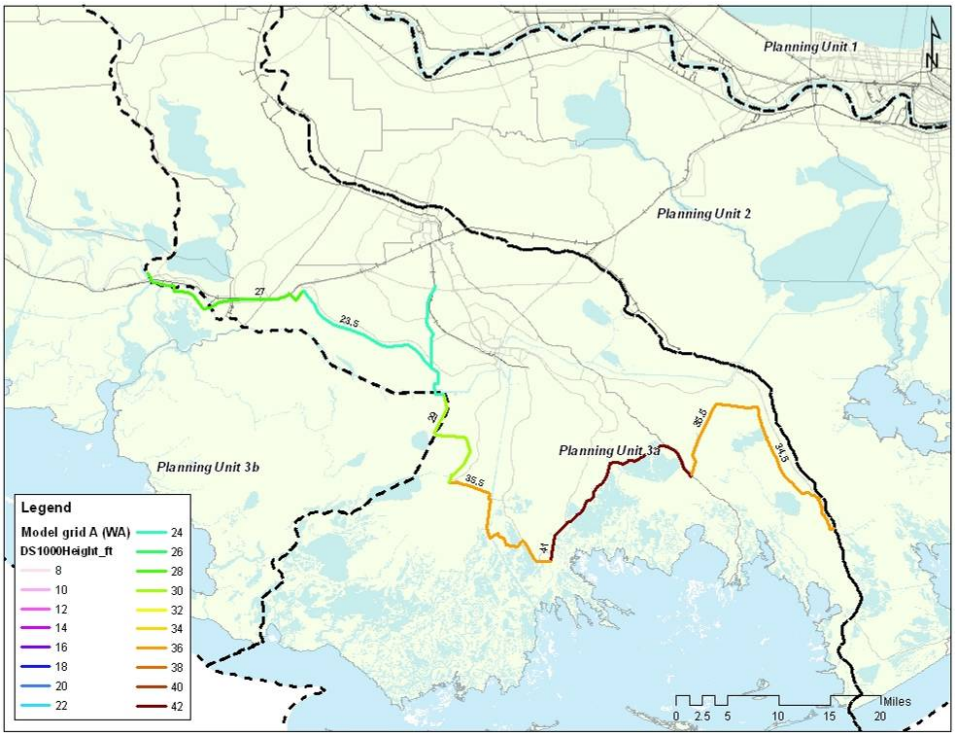


Figure 6.4 West model grid A (WA), 1000 year design heights

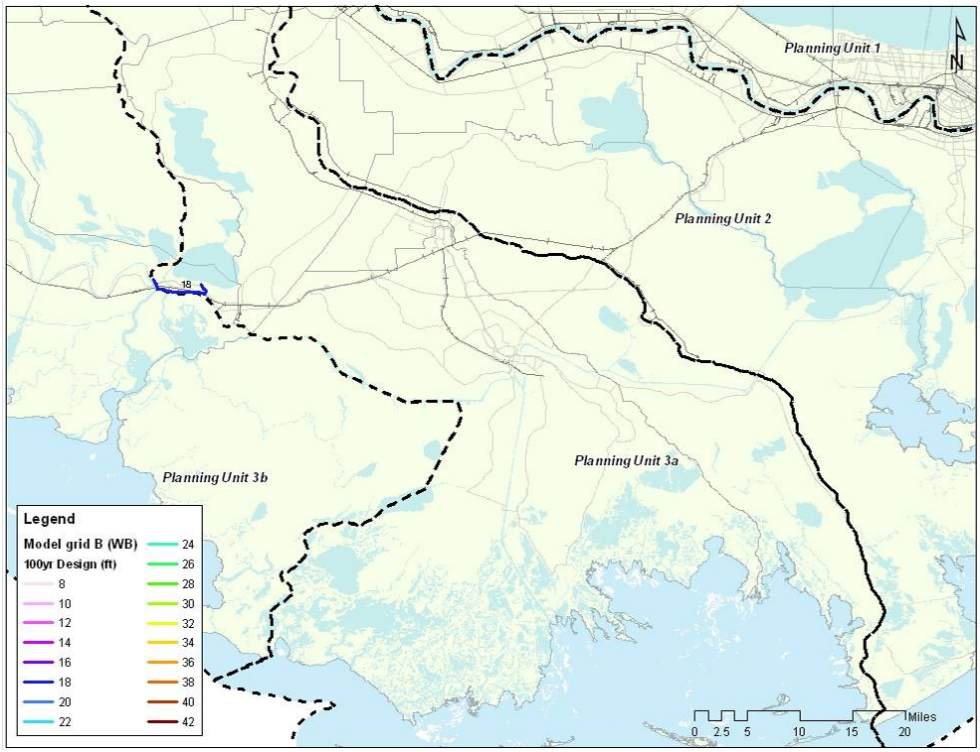


Figure 6.5 West model grid B (WB), 100 year design heights - Morgan City

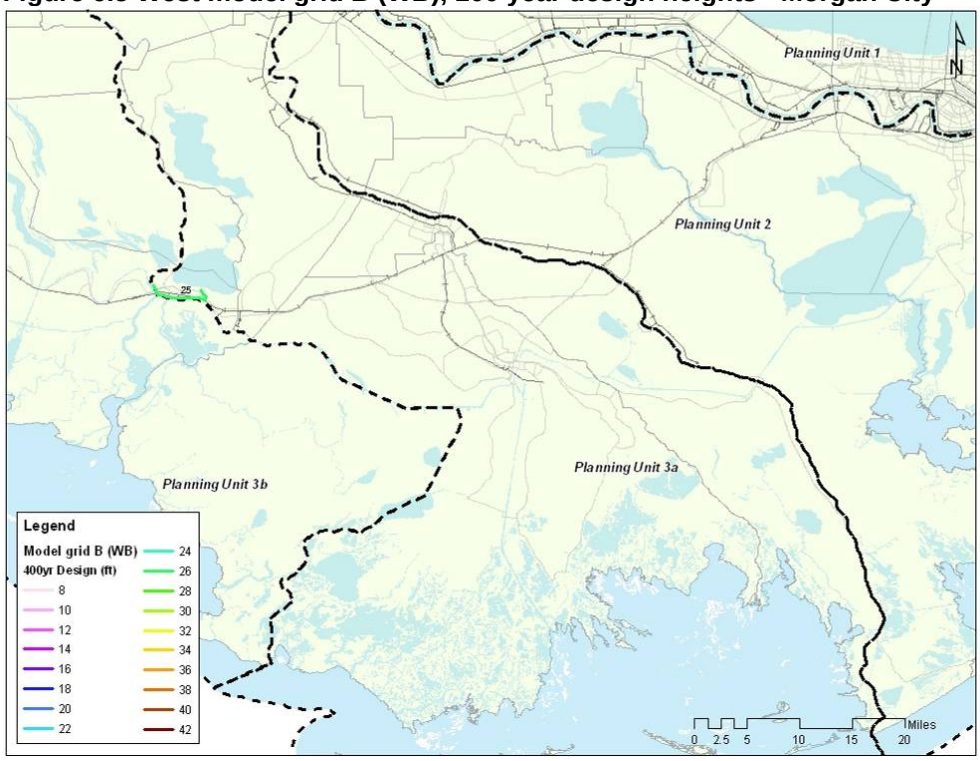


Figure 6.6 West model grid B (WB), 400 year design heights - Morgan City

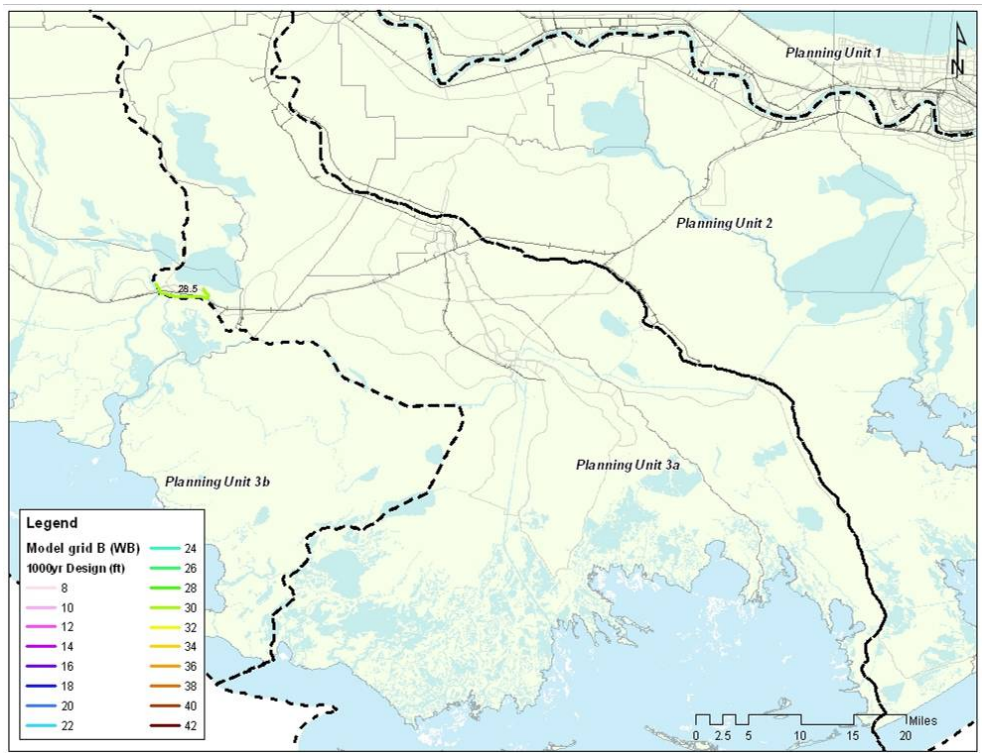


Figure 6.7 West model grid B (WB), 1000 year design heights - Morgan City

6.2.2 Ring levee alignment with secondary defense

This alternative in Planning Unit 3a protects the main Morganza area with a levee based on the 100 year design, while the higher grounds more inland of Morganza are protected by a secondary levee (only 400 and 1000 year design), thus providing it a 400 or 1000 year level of protection. The 100 year design height of the levee at the perimeter of Morganza uses the same design heights derived from the WA grid for the 100 year design. The levee design height of the back levee is based on the interior stages in the Morganza area instead of the surge elevation of the 400 and 100 year conditions in front of this levee. The stage values were obtained by considering the overtopping of the outer levee line for the 400 and 1000 year events to provide a starting water level within the inner area.

Given the 100 year design height at the outer rim of Morganza in combination with a storm event with a return period of 400 years, an interior stage of 6.6 feet results for the Morganza Polder (90% confidence level). To determine the wave height and period, first the return period of a 6.6 feet stage is derived for a point in the data set that is close to the levee alignment. The wave height and period have then been set, matching with the found figures. This results in a new set of input parameters based on which the levee height is calculated (see Table 6.1). For the 1000 year design height a similar procedure has been followed (see also Table 6-1).

Table 6.1 Input parameters used for design height of the Morganza back levee (stages taken from interior frequency curves)

Design standard	Stage (ft) (90%)	Significant wave height (ft)	Peak wave period (s)	Levee Height (ft)
400 year	6.6	2	4.51	9.5
1000 year	15	4.1	7.48	24

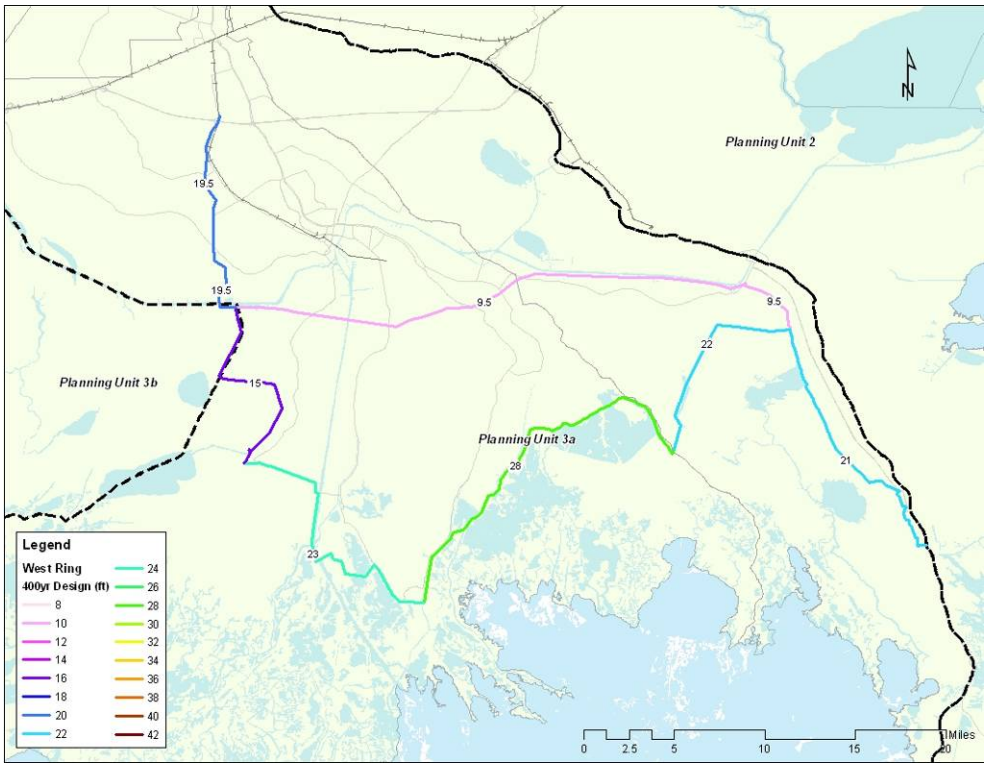


Figure 6.8 Ring Levee alignment with secondary defence, 400 year design heights

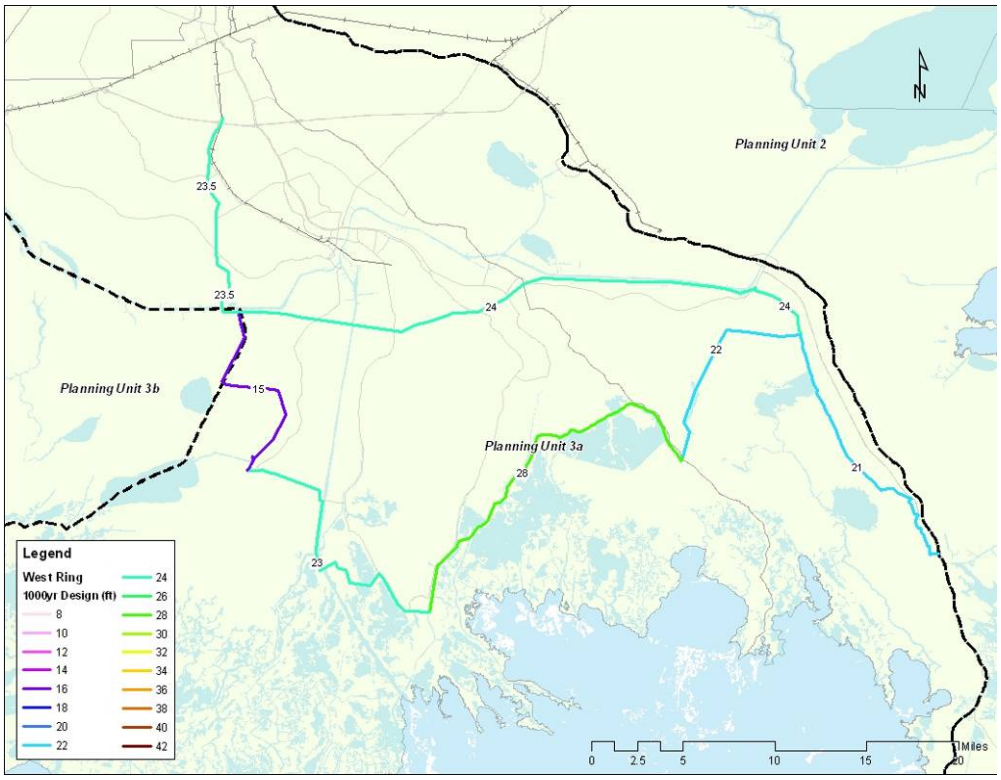


Figure 6.9 Ring Levee alignment with secondary defense, 1000 year design heights

6.3 Interior and exterior frequency curves

Over 200 planning subunits are defined in Planning Unit 3a. These fall into two groups, those which are always outside of the levees and those which fall inside the levees in one of the proposed alignments.

The planning subunits are grouped together to form areas considered for interior drainage (see the areas outlined in red in Figure 6-1). This grouping is based on the level of risk reduction being provided to the area by a particular levee alignment. Thus, the planning subunits are grouped into six internal drainage areas. These are listed below:

Name	Used in	Model
Morgan_City	Ring alternatives	WB
Morganza_with_ret_ring	Ring alternatives	WA
East_of_Morgan_City_ring	Morganza alternative	WA
Morganza_no_ret_ring	Morganza alternative	WA
Morganza_with_ret_ring_m_only	Ring Alternative (100yr levee)	WA
Morganza_back_levee	Ring Alternative (100yr levee)	Hand calculation

Given the levee height as described above in section 6.2, the overtopping volumes were calculated for four return periods of the outside surge level and wave characteristics (100-year, 400-year, 1000-year, and 2000-year).

The grids that are used for each of the drainage areas are listed in Table 6-2 below, followed by a description of the specific variations. The hydraulic codes at the top line of the table relate to the various layout alternatives and corresponding sources of information; as listed in Chapter 3.

Table 6-2 Interior drainage Area to Hydraulic Alternative Matrix

Interior Drainage Area	WT_ext	WA-ext	WA-0100a	WA-0400a	WA-1000a	WA-0100b	WA-0400b	WA-1000b	WA-0100c	WA-0400c	WA-1000c
Morgan_City	x					x	x	x			
Morganza_with_ret_ring	x					x	x	x			
East_of_Morgan_City_ring	x	x	x	x	x						
Morganza_no_ret_ring	x		x	x	x						
Morganza_with_ret_ring_m_only	x								x	x	x
Morganza_back_levee	x								x	x	x
Other External Areas	x	x									

Note - as there are no levees in the Base model, all interior drainage areas also have a WT-ext value.

Whereas in Planning Units 1 and 2 the interior drainage areas are separate (i.e. they don't overlap) in Planning Unit 3a the interior drainage areas may nest or intersect, depending on the respective planning alternatives.

Specific comments with respect to the internal drainage areas in Planning Unit 3a are given in Table 6.2. Additional area specific information is given in Annex B.

Table 6.2 - Specific Planning Unit Comments

Polder Ring	Polder(s)	Comment
Morganza_with_ret_ring_m_only	Morganza	For the alternative "Ring levee alignment with secondary defense" stages in Morganza are only analyzed given the 100 year design and the 100, 400, 1000 and 2000 year return period
Morganza_back_levee	North_of_Houma Houma West_of_Houma	For the alternative "Ring levee alignment with secondary defense" stages behind the secondary defense are calculated based upon overtopping from the flooded polder Morganza. An exception is made for the 2000 year event where stages are equal to the base surge conditions

6.4 Hydraulic Results of Planning Alternatives

A number of planning alternatives have been considered. They cover a range of design standards (100 year, 400 year, and 1000 year) together with a of range of variations in alignment. All of these alternatives are used for the determination of interior and exterior stage frequencies, thus providing results that are used as the input for the economic evaluation. For the West, all the alternatives and the baseline have been considered in more detail.

The key alternatives are as follows:

- Morganza plan
- Morganza/ring levee plan
- GIWW/Morganz/Ring levee plan

These three basic alternatives use levee height designs and interior drainage results from different model runs, and different internal drainage areas (because of the nesting/intersecting of drainage areas). Table 6.3 shows the linkage between the six interior drainage areas and the planning alternatives. The codes are expalined in Chapter 3.

Table 6.3 Internal Drainage Area to Planning Alternative Sets

		Planning Alternative Set			
		Baseline	**Morganza plan**	**Morganza/ring levee plan**	**GIWW/Morganza/Ring levee plan**
Intertnal Drainage Area	Morgan_City			WA-xxxxb	WA-xxxxb
	Morganza_with_ret_ring			WA-xxxxb	
	East_of_Morgan_City_ring		WA-xxxxa		
	Morganza_no_ret_ring		WA-xxxxa		
	Morganza_with_ret_ring_m_only				WA-0100c
	Morganza_back_levee				WA-xxxxc
	Other External Areas	WT-ext	WA-ext	WA-ext	WA-ext

The alignments and levee heights for each of the alternatives are shown on the Planning Subunit Key Maps in the Evaluation Results Appendix. These maps have an accompanying table showing stage frequency comparisons (baseline to alternative) for a selection of planning subunits.

7 PLANNING UNIT 3B

7.1 Introduction

This chapter presents the details of the calculations of the levee heights and stage frequency curves for Planning Unit 3b.

Section 7.2 addresses the development of the 100 year, 400 year, and 1000 year design heights in feet for the potential levee alignments in Planning Unit 3b for the '2007 Base model West', 'West model A' and the 'West model B'.

The heights computed during the process are used for costing design options and for establishing overtopping rates. The combination of the heights to given planning alternatives is coupled with the stage frequency analysis as described in section 7.3. Figure 7.1 shows the planning subunits in Planning Unit 3b. For evaluation purposes the planning subunits have been grouped into interior drainage areas (outlined in red).

For Planning Unit 3b all alternatives were evaluated in more detail.

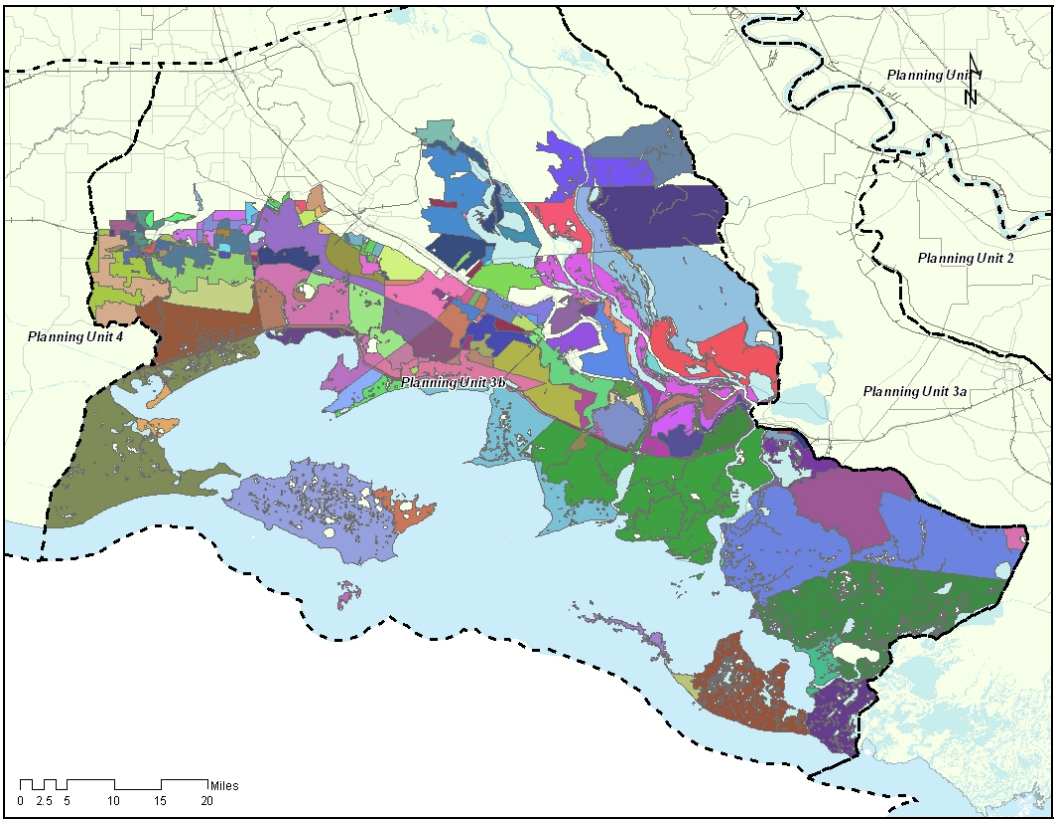


Figure 7.1 Planning Subunits in Planning Unit 3b

7.2 Levee height

The levee height design has been carried out using the methodologies described in Volume I of this report.

Levee heights have been computed using three models, for three separate design standards (100 year, 400 year, and 1000 year) for all levees included within the alternatives. The design elevations are based on the wave heights and periods obtained from the no bed friction STWAVE models for the west.

The '2007 Base model West' (WT, containing no levees) has been used for designing a series of localized ring levees. The 'West model A' (WA) has been used to design levee heights along the GIWW alignment, while the 'West model B' (WB) has been used to design levee heights along a defense line between the GIWW and the higher ground, extending from Franklin to Abbeville.

The results of levee height designs from these three models for the 100, 400, and 1000 year levels of protection are given in the figures below. A detailed overview of the design heights is given in the fact sheets in Annex B.

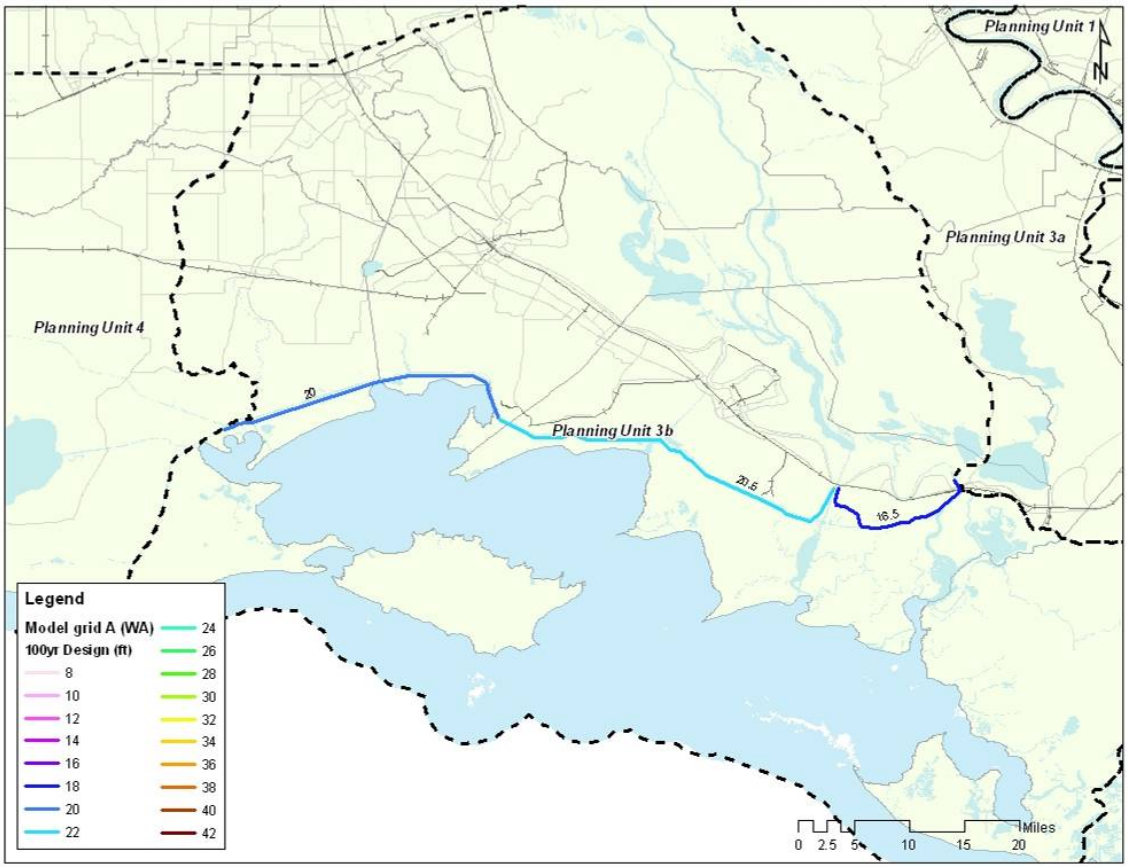


Figure 7.2 West model grid A (WA), 100 year design heights

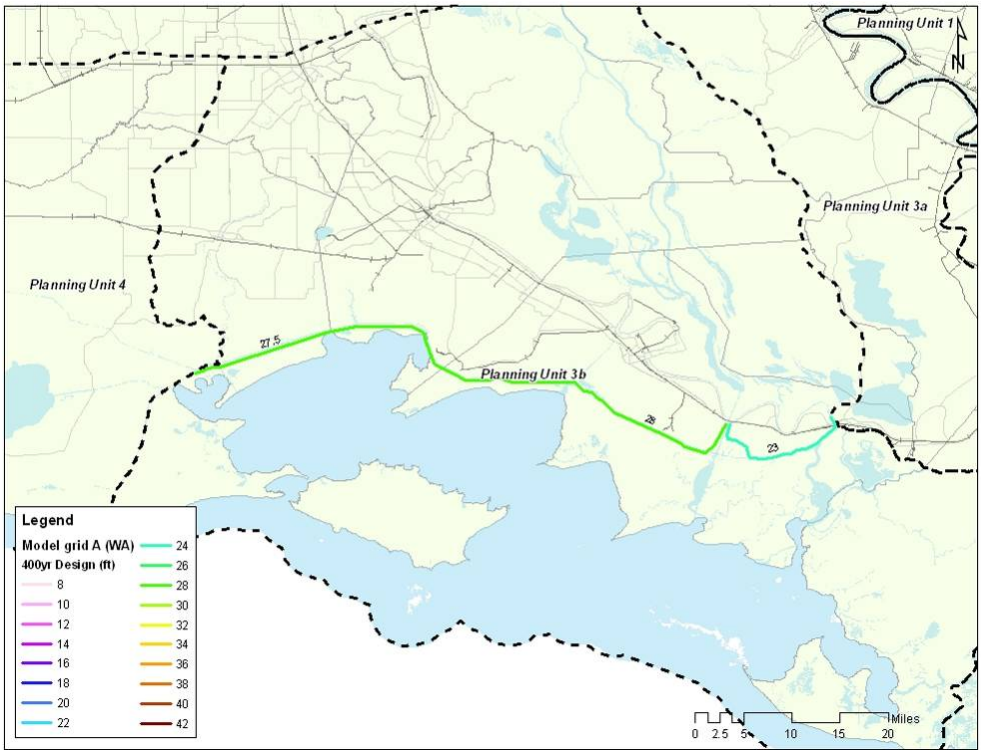


Figure 7.3 West model grid A (WA), 400 year design heights

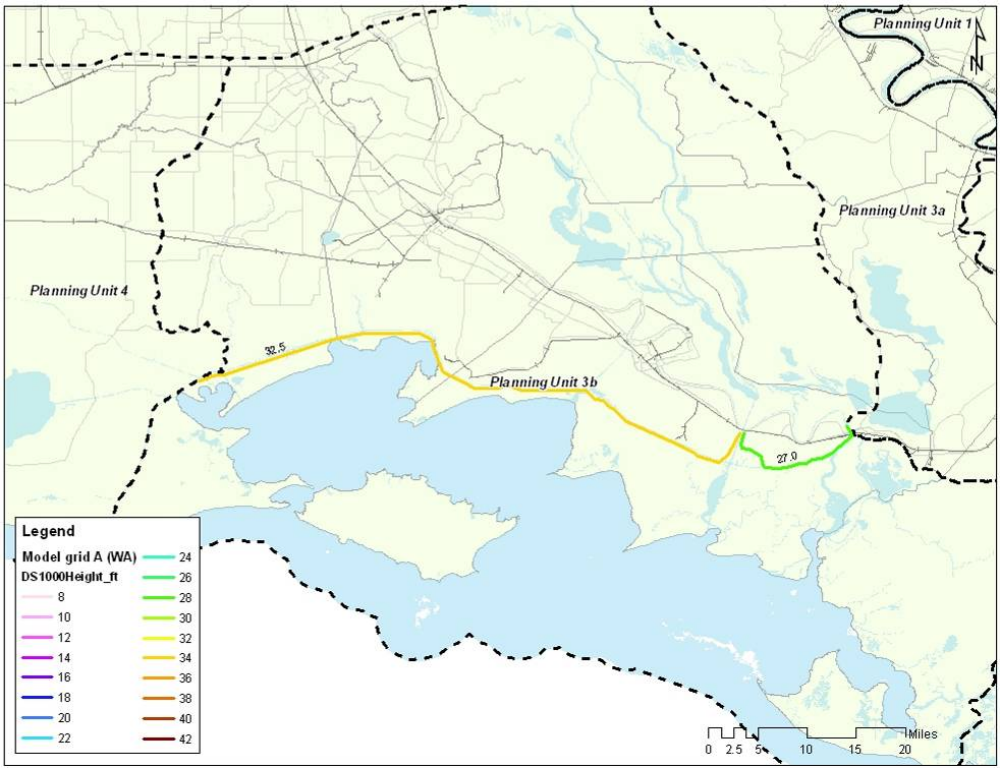


Figure 7.4 West model grid A (WA), 1000 year design heights

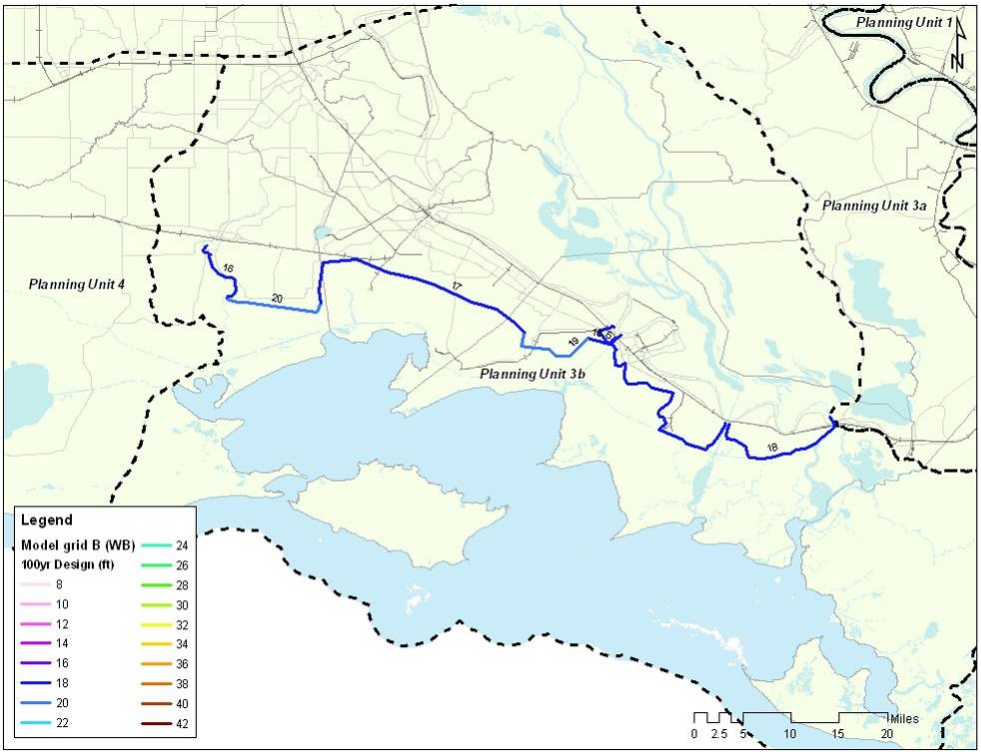


Figure 7.5 West model grid B (WB), 100 year design heights

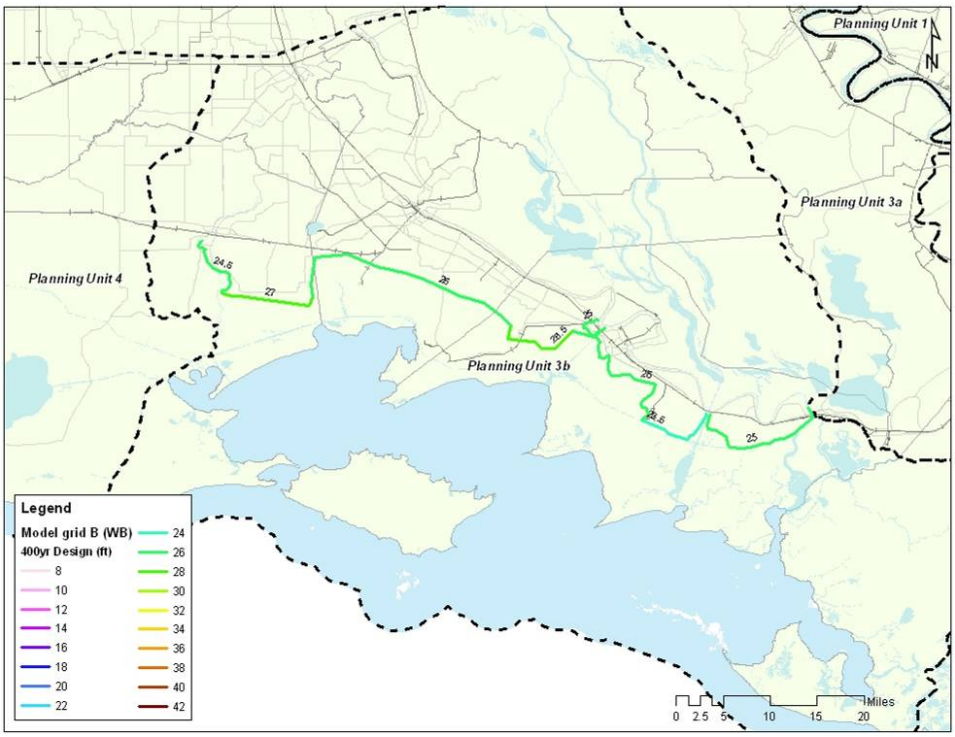


Figure 7.6 West model grid B (WB), 400 year design heights

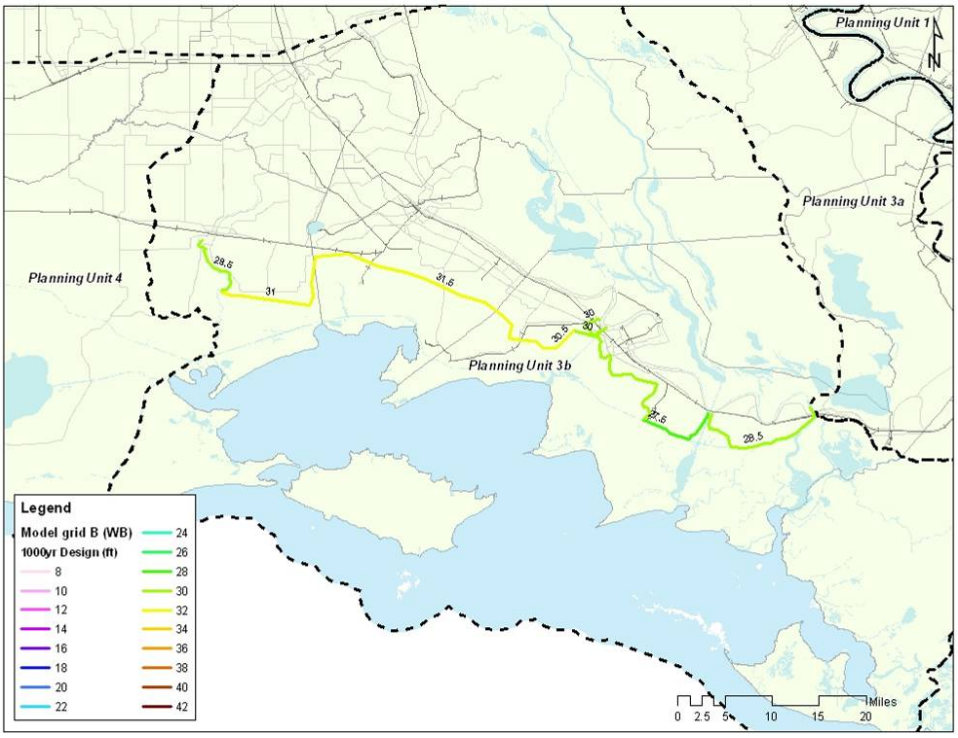


Figure 7.7 West model grid B (WB), 1000 year design heights

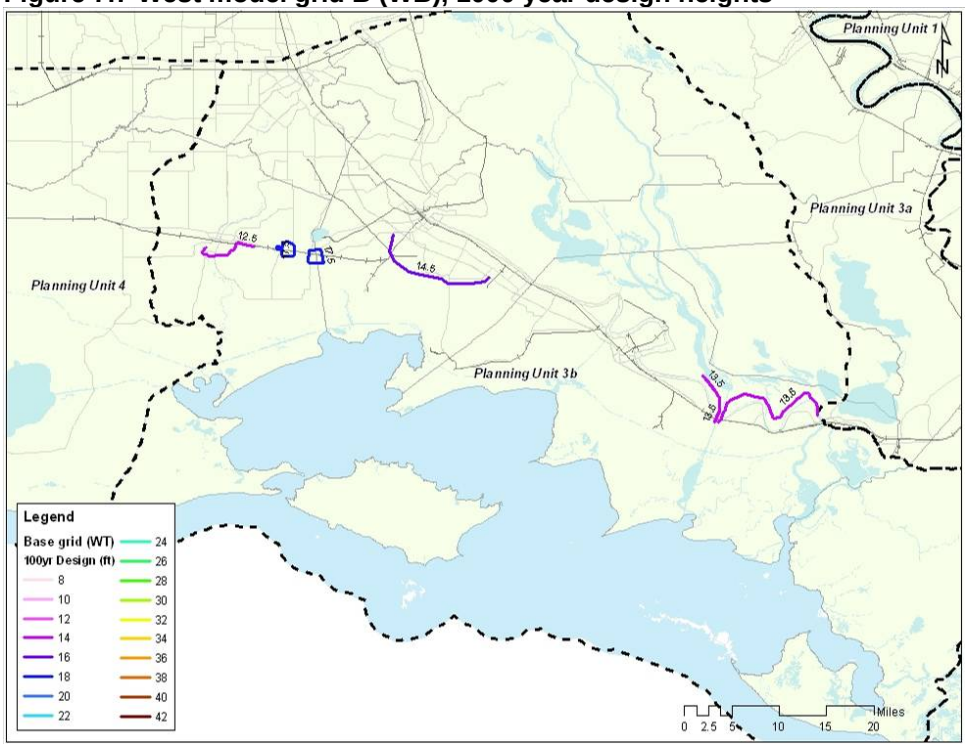


Figure 7.8 2007 model grid (WT), 100 year design heights

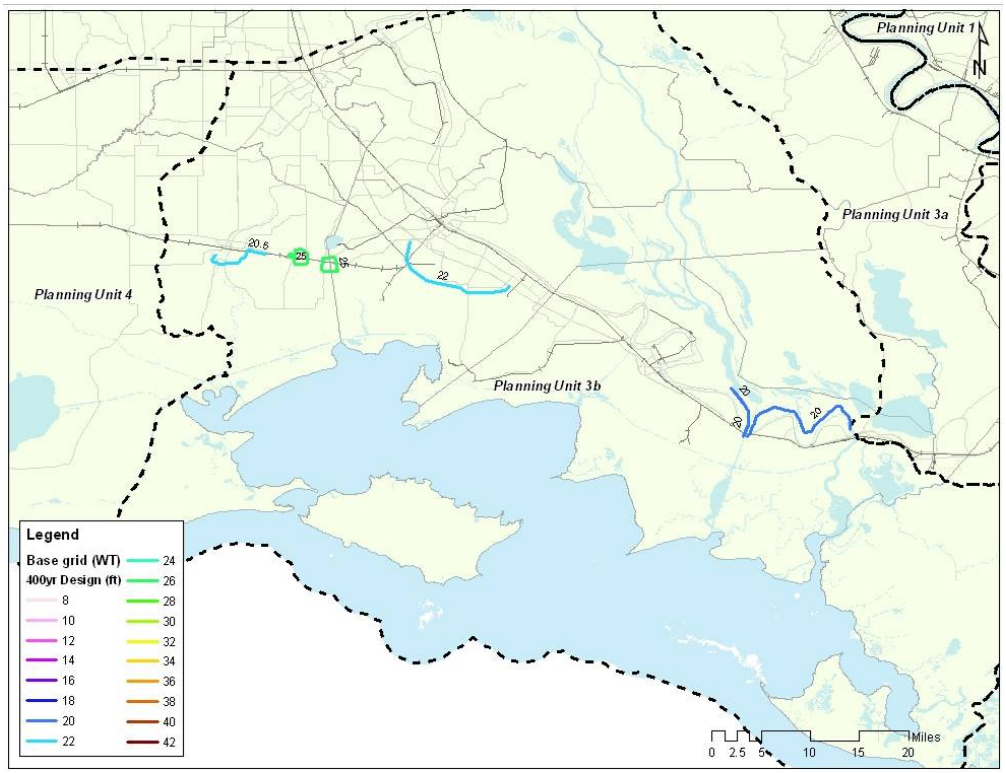


Figure 7.9 2007 model grid (WT), 400 year design heights

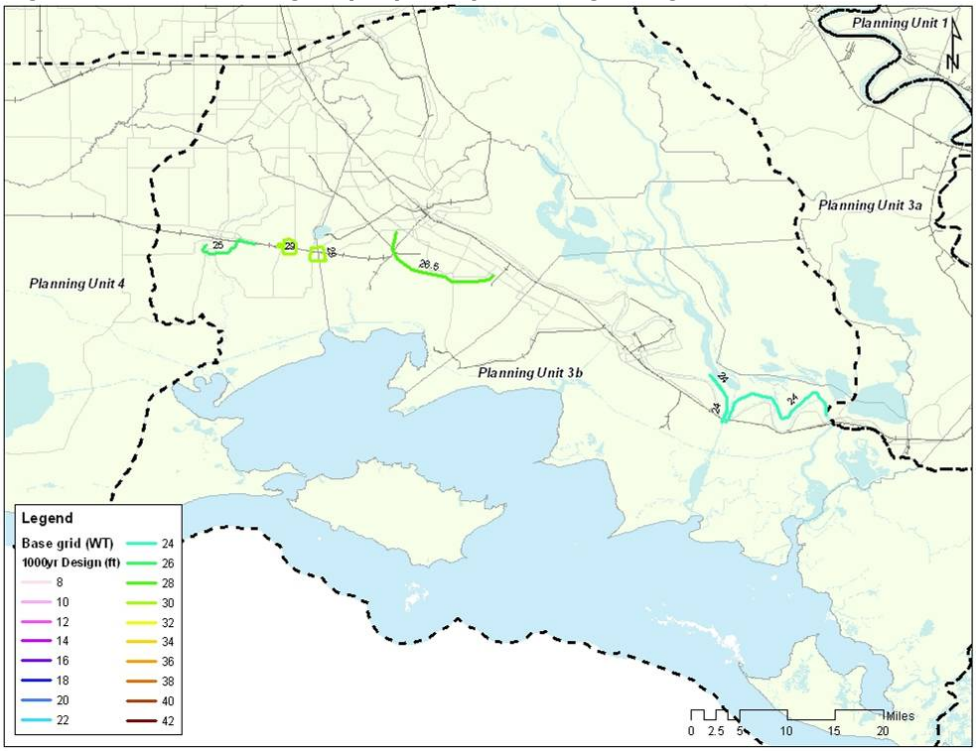


Figure 7.10 2007 model grid (WT), 1000 year design heights

7.3 Interior and exterior frequency curves

Over 200 planning subunits are identified in Planning Unit 3b. These fall into two categories: those being always outside of the levees, and those falling inside the levees in one of the proposed alignments.

The planning subunits have been grouped together to form areas considered for interior drainage. This grouping was based on the protection being provided to the area by a particular levee alignment. A list of the Drainage Areas is given in Table 7.1.

Table 7.1 Drainage areas - relationship to alternative sets and Hydrodynamic Models

Name	Used in	Model
Abbeville	Ring levee alignment	WT
Abbeville_to_Delcambre_ring	Franklin to Abbeville Alignment	WB
Baldwin	Ring levee alignment	WB
Charenton_ring	Franklin to Abbeville Alignment	WB
Delcambre	Ring levee alignment	WT
Erath	Ring levee alignment	WT
Franklin	Ring levee alignment	WB
New_Iberia	Ring levee alignment	WT
New_Iberia_ring	Franklin to Abbeville Alignment	WT
Patterson	GIWW alternative	WA
South_of_Franklin_ring	GIWW alternative	WA
GIWW_PU3b_ring	GIWW alternative	WA

Given the levee height described above in section 7.2, the overtopping volumes have been computed for four return periods of the outside surge level and wave characteristics (100-year, 400-year, 1000-year, and 2000-year). The overtopping volumes are used as input to establish the interior stage frequency curve for the planning subunits.

The grids that are used for each of the drainage areas are listed in Table 7.2 below, followed by a description of the specific variations. In those cases where several planning subunits are located within a single interior drainage area, the name of the drainage area is given. The hydraulic codes at the top line of the table relate to the various layout alternatives and corresponding sources of information; as listed in Chapter 3.

Table 7.2 Interior drainage Area to Hydraulic Alternative Matrix

Interior Drainage Area	WT_ext	WA-ext	WT-0100	WT-0400	WT-01000	WB-0100	WB-0400	WB-1000	WA-0100	WA-0400	WA-1000
Abbeville	x		x	x	x						
Abbeville_to_Delcambre_ring	x					x	x	x			
Baldwin	x					x	x	x			
Charenton_ring	x					x	x	x			
Delcambre	x		x	x	x						
Erath	x		x	x	x						
Franklin	x					x	x	x			
New_Iberia	x		x	x	x						
New_Iberia_ring	x					x	x	x			
Patterson	x								X	x	x
South_of_Franklin_ring	x								X	x	x
GIWW_PU3b_ring	x								X	x	x
Other External Areas	x	x									

Note - as there are no levees in the Base model, all interior drainagae areas also have a WT-ext value.

Whereas in Planning Units 1 and 2 the interior drainage areas are separate (i.e. they don't overlap) in Planning Unit 3b the interior drainage areas may nest or intersect.

Specific comments with respect to the polders in Planning Unit 3b are given in Table 7.3. Additional area specific information is given in Annex B.

Table 7.3 Specific Planning Unit Comments

Polder Ring	Polder(s)	Comment
Patterson	Patterson	For the WA model the back levees at Patterson are 3 feet lower than the levee at the front/sea side. For the WB model the difference is slightly larger (4.5 to 5'), but the levels were adopted at the lower levels for consistency.The overtopping calculations are based upon the assumption that overtopping takes place only from the front/sea side.
GIWW alignment	GIWW_PU3b	The discharge of the river Vermillion is not included in the stored volume, pumps have been assumed to be installed to handle this additional volume.

7.4 Hydraulic Results of Planning Alternatives

A number of planning alternatives have been considered for Planning Unit 3b. They consider a range of design standards (100 year, 400 year, and 1000 year) together with a of range of variations in alignment and in the areas included within the protected areas. All of these

alternatives are considered for interior stage frequency and results have been developed to be used as input for the economic evaluation. For the West, all the alternatives and the baseline have been considered in more detail.

The key alternatives are as follows:

- GIWW plan
- Franklin to Abbeville Alignment plan
- Ring levee plan

These alternatives use a different combination of levee height designs and interior drainage results. Table 7.4 shows the linkage of the interior drainage areas to the planning alternatives, codes are explained in Chapter 3:

Table 7.4 Internal Drainage Area to Planning Alternative Sets

	Baseline	**GIWW Plan**	**Franklin to Abbeville Alignment**	**Ring levee Plan**
Abbeville				WT-xxxx
Abbeville_to_Delcambre_ring			WB-xxxx	
Baldwin				WT-xxxx
Charenton_ring			WB-xxxx	
Delcambre				WT-xxxx
Erath				WT-xxxx
Franklin				WT-xxxx
New_Iberia				WT-xxxx
New_Iberia_ring			WB-xxxx	
Patterson		WA-xxxx	WA-xxxx	WT-xxxx
South_of_Franklin_ring		WA-xxxx		
GIWW_PU3b_ring		WA-xxxx		
Other External Areas	WT-ext	WA-ext	WB-ext	WT-ext

The alignments and levee heights for each of the alternatives are shown on the Planning Subunit Key Maps in the Evaluation Results Appendix. These maps have an accompanying table showing stage frequency comparisons (baseline to alternative) for a selection of planning subunits.

8 PLANNING UNIT 4

8.1 Introduction

This chapter presents the results of the calculations of the levee heights and stage frequency curves for Planning Unit 4,

Section 8.2 describes the development of the 100 year, 400 year, and 1000 year design heights in feet for the potential levee alignments in Planning Unit 4. These have been developed for the '2007 Base model West' (WT), 'West model A' (WA) and the 'West model B' (WB).

The heights computed during the process are used as input for costing design options and for establishing overtopping rates. The combination of the heights to given planning alternatives is coupled with the stage frequency analysis as is described in section 8.3. Figure 8.1 gives the Planning Sub Units of Planning Unit 4. For evaluation purposes the Planning SubUnits are grouped into Drainage Areas. These are outlined in red in the map below.

For Planning Unit 4 all alternatives are evaluated in more detail.

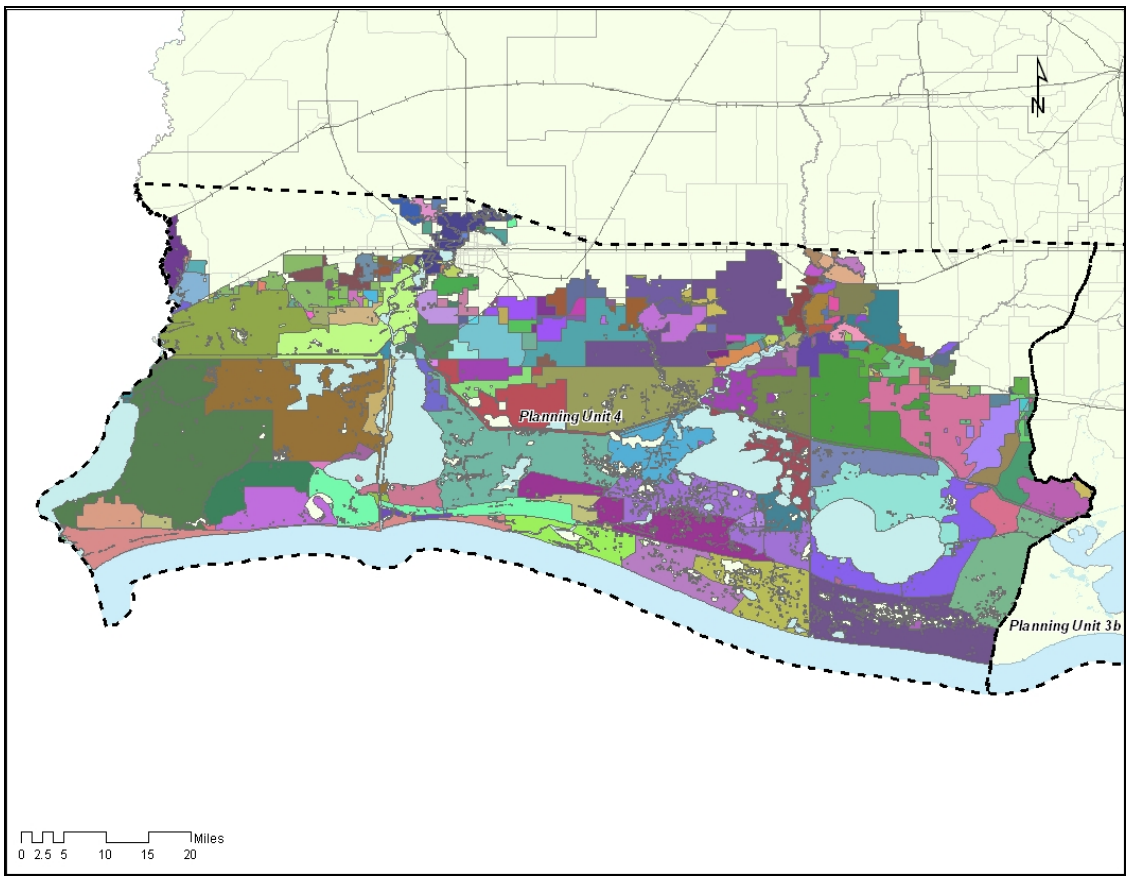


Figure 8.1 Planning Subunits in Planning Unit 4

8.2 Levee height

8.2.1 General

The levee height design has been carried out using the methodologies described in Volume I of this report. Levee heights were computed for the '2007 Base model West' (WT) and 'West model A' (WA), for three separate design standards (100 year, 400 year, and 1000 year) for all levees included in the alternatives. The design elevations are based on the wave heights and periods obtained from the no bed friction STWAVE models for the west.

The '2007 Base model West' (WT, containing no levees) has been used for designing a series of localized ring levees, while the 'West model A' (WA) has been used to design levee heights along the GIWW alignment.

The results of levee height designs from these two models for the 100, 400 and 1000 year levels of protection are given in the following figures. In addition levees were designed considering a low (12 feet high) levee along the GIWW together with ring levees further inland. Heights for these levee were based on hand calculations using the interior stages based on overtopping of the levees using the WA model.

The Calcasieu River flows through Lake Charles on its way to the sea. Within the town there are a number of lower spots which may be at risk of flooding in extreme hurricane events. The heights of the proposed levees located along the Calcasieu River are based upon the modeled sea water elevations and a 3 feet wave height. A moderate wave of 3 feet is chosen as the levees do not face the sea.

A detailed overview of the design heights is given in the fact sheets in Annex B.

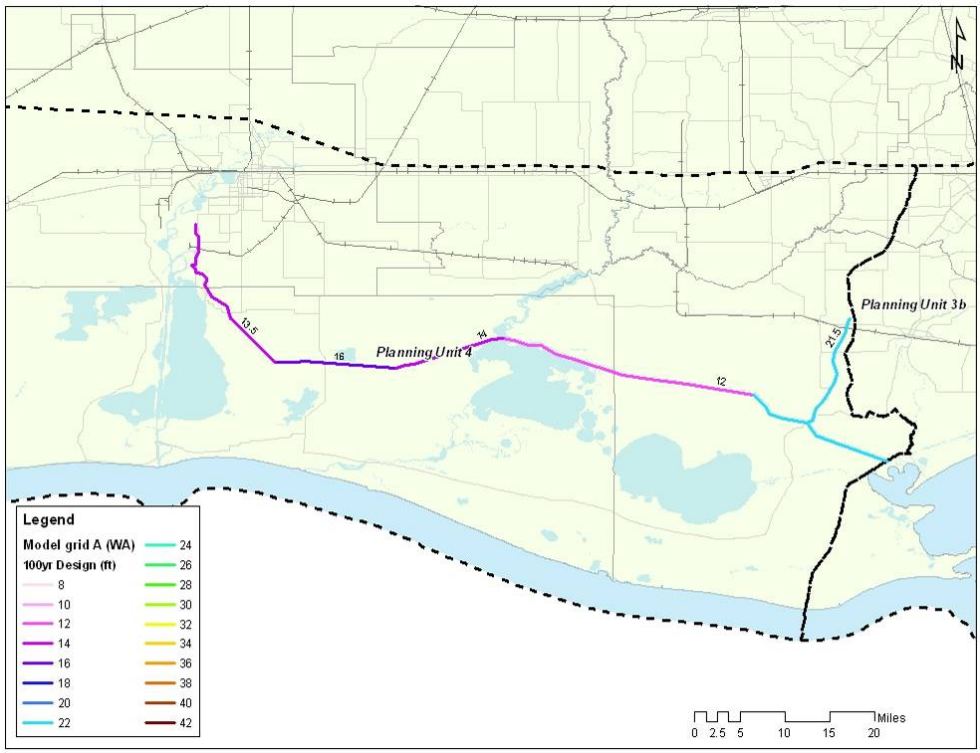


Figure 8.2 West model grid A (WA), 100 year design heights

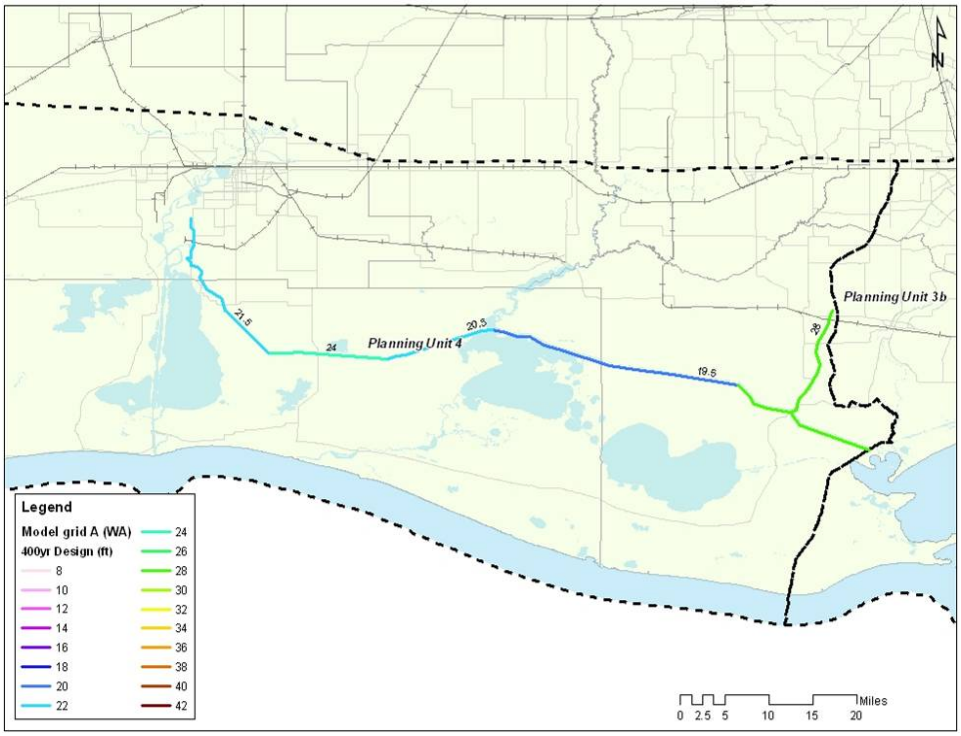


Figure 8.3 West model grid A (WA), 400 year design heights

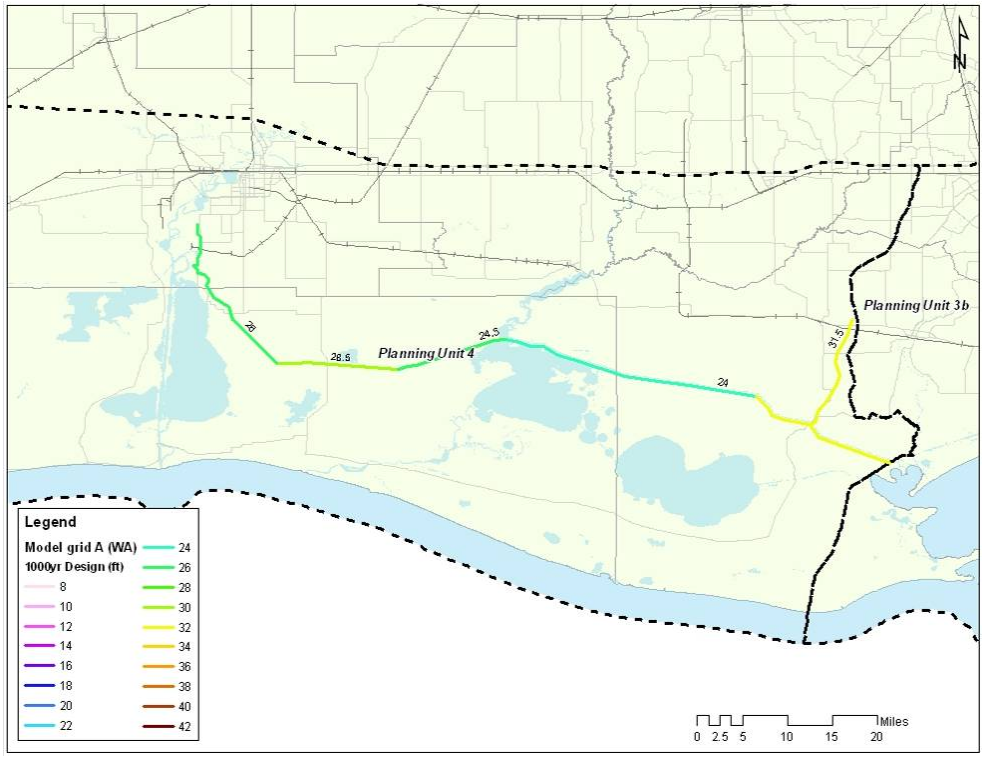


Figure 8.4 West model grid A (WA), 1000 year design heights

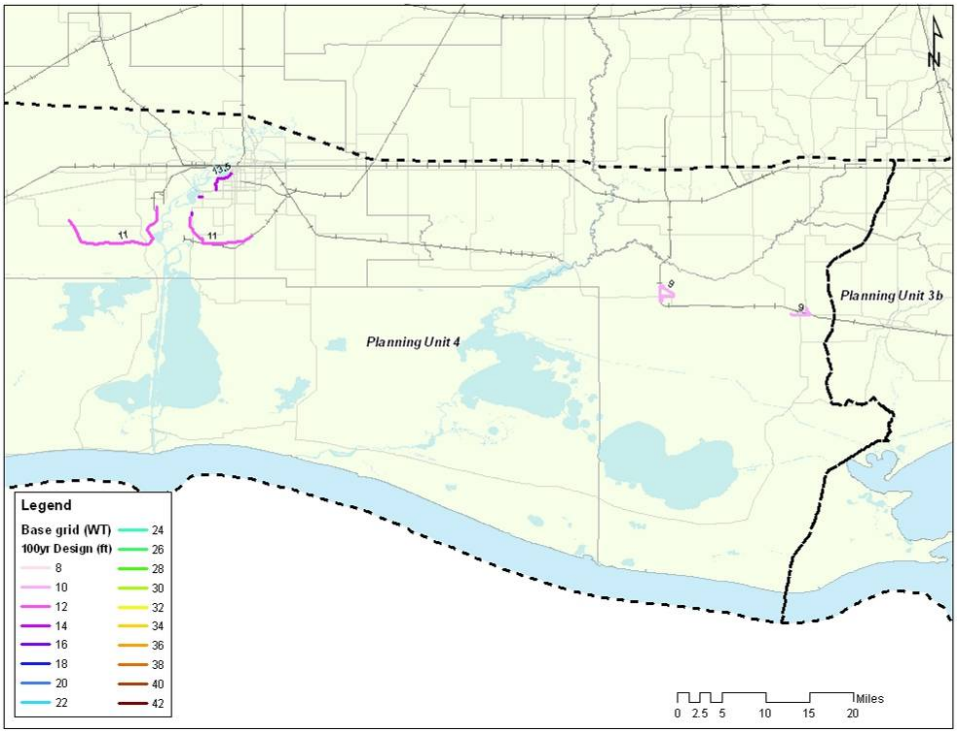


Figure 8.5 2007 model grid (WT), 100 year design heights

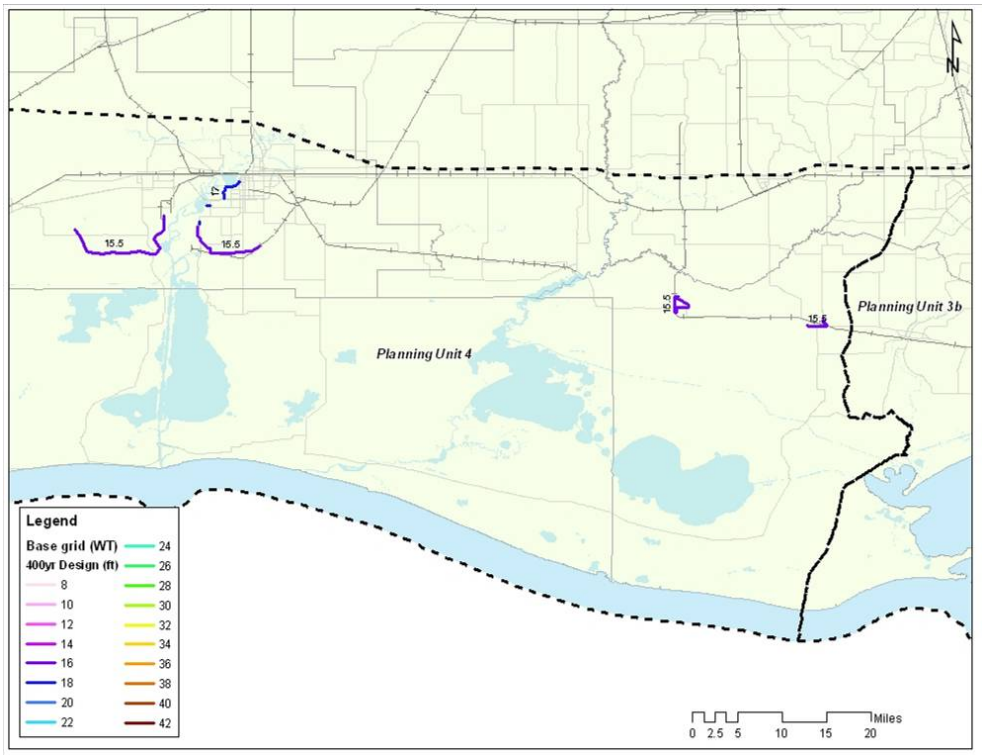


Figure 8.6 2007 model grid (WT), 400 year design heights

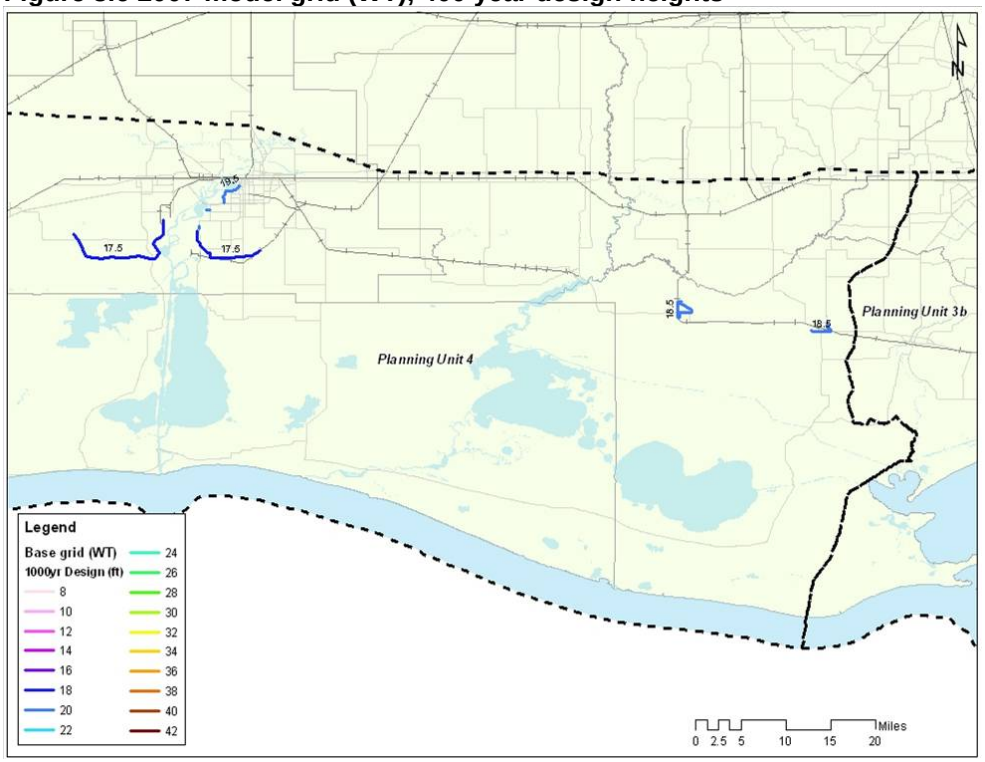


Figure 8.7 2007 model grid (WT), 1000 year design heights

8.2.2 12 feet GIWW levee alignment with return

The concept of the 12' levee alternative was to look at whether a lower level defence relatively close to the sea could improve the level of protection for a large proportion of the population at risk, without the need to introduce extreme levees near the populace.

The 12 feet GIWW levee alignment alternative consists of a 12 feet levee along the GIWW. Behind this alignment there are three areas of significant population which may still be at risk of flooding in extreme events. Therefore three levees have been proposed which can provide either a 400 year or 1000 year level of protection to these areas. The areas are Kaplan, Gueydan and East Lake Charles.

Levee height design for the 400 and 1000 year level of protection is based on interior stages behind the 12 feet levee. Original (WT) designs for the ring levees are reduced in height equal to the decrease in water level in front of the levee that occurs as a consequence of the presence of the 12 feet levee. In these cases interior stages are used instead of surge levels, except the those cases where the surge level exceeds levee height and stage level.

For the levees bordering the Calcasieu River, a similar approach has been used. Levee design heights are given in the two figures below.

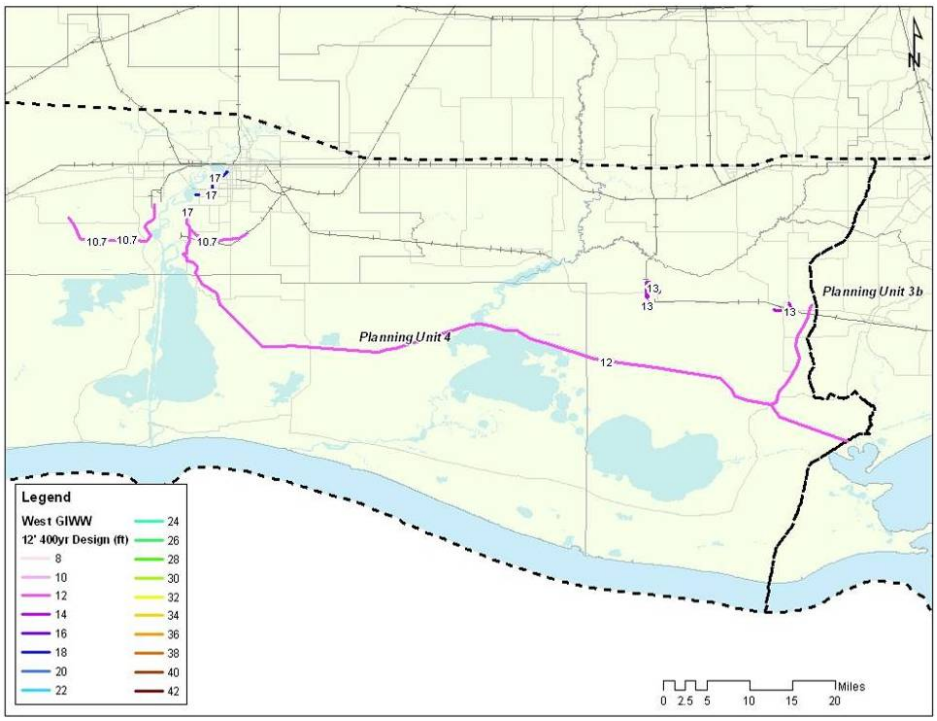


Figure 8.8 12 feet GIWW levee alignment with return, 2007 model grid A (WA), 400 year design heights

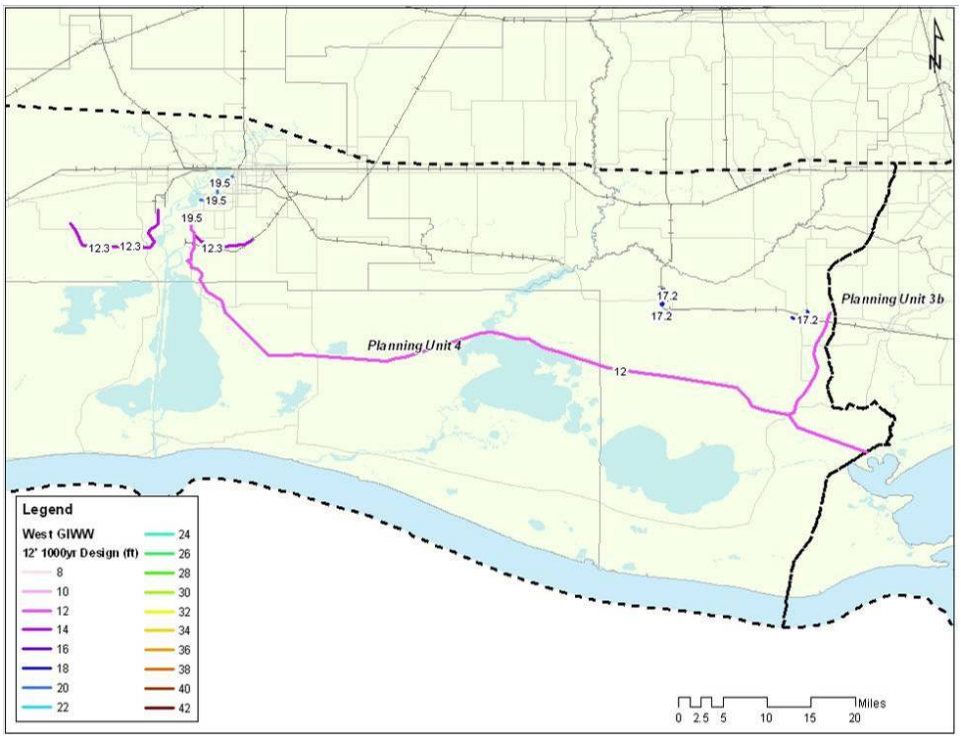


Figure 8.9 12 feet GIWW levee alignment with return, 2007 model grid A (WA), 1000 year design heights

8.3 Interior and exterior frequency curves

There are over 200 Planning Sub Units defined in Planning Unit 4. These fall into 2 groups, those being always outside of the levees and those falling inside the levees in one of the proposed alignments.

Similar to Planning Unit 3a and 3b the Planning Sub Units are grouped together to form areas considered for interior drainage. This grouping is based on the protection being afforded to the area from a particular levee alignment.

The Planning sub units are grouped into twelve internal drainage areas.

Table 8.1 Drainage areas - relationship to alternative sets and Hydrodynamic Models

Name	Used in	Model
West_Lake_Charles	GIWW levee alignment 12 feet GIWW levee alignment Ring levee alternative	WT
East_Lake_Charles	12 feet GIWW levee alignment Ring levee alternative	WT
Gueydan	12 feet GIWW levee alignment Ring levee alternative	WT
Kaplan	12 feet GIWW levee alignment Ring levee alternative	WT
South_of_Lake_Charles_ring	GIWW levee alignment (with return)	WA
Central_PU4_ring	GIWW levee alignment (with return)	WA
GIWW_to_Veterans_ring	GIWW levee alignment (with return)	WA
South_of_Lake_Charles_ring_12	12 feet GIWW levee alignment	WA
Central_PU4_ring_large_12	12 feet GIWW levee alignment	WA
GIWW_to_Veterans_ring_large_12	12 feet GIWW levee alignment	WA
Prien	GIWW levee alignment 12 feet GIWW levee alignment Ring levee alternative	WT
Inner_Lake_Charles	GIWW levee alignment 12 feet GIWW levee alignment Ring levee alternative	WT

Given the levee height (see section 8.2) the overtopping volumes are computed for four return periods of the outside surge level and wave characteristics (100-year, 400-year, 1000-year, and 2000-year).

The grids that are used for each of the drainage areas are listed in

Table 8.2 below, followed by a description of the specific variations. In those cases where several Planning Sub Units are located within a single drainage area, the name of the drainage area is given. The hydraulic codes at the top line of the table relate to the various layout alternatives and corresponding sources of information; as listed in Chapter 3.

Table 8.2 Interior Drainage Area to Hydraulic Alternative Matrix

Interior Drainage Area	WT_ext	WA-ext	WT-0100	WT-0400	WT-01000	WA-0100a	WA-0400a	WA-1000a	WA-0100c	WA-0400c	WA-1000c	WA-0100b	WA-0400b	WA-01000b
West_Lake_Charles	x		x	x	x									
East_Lake_Charles	x		x	x	x								x	x
Gueydan	x		x	x	x								x	x
Kaplan	x		x	x	x								x	x
South_of_Lake_Charles_ring	x	x				x	x	x						
Central_PU4_ring	x	x				x	x	x						
GIWW_to_Veterans_ring	x	x				x	x	x						
GIWW_to_Veterans_inc_ret_ring	x	x							x	x	x			
GIWW_PU3b_ring (PU4-ext)	x	x				x	x	x						
South_of_Lake_Charles_ring_12	x											x		
Central_PU4_ring_large_12	x											x		
GIWW_to_Veterans_ring_large_12	x											x		
Prien	x		x	x	x									
Inner_Lake_Charles	x		x	x	x									
Other External Areas	x	x												

Note - as there are no levees in the Base model, all interior drainage areas also have a WT-ext value.

Whereas in Planning Units 1 and 2 the interior drainage areas are separate (i.e. they don't overlap) in Planning Unit 3b the interior drainage areas may nest or intersect.

Because of the large areas of potential flooding and that these areas may be reaching the maximum potential length of coastaline affected by a single hurricane approaching the GIWW levee, the area behind the GIWW levee has been split into three drainagae areas even though they might act together. To evaluate the flooding in these areas they have been modelled as both independent, and as linked. When linked, the overtopping has been considered as coming from just one of the three sections (representing an extreme hurricane), but the volume has been distributed between all three areas.

For the GIWW as a primary defence, where it was required to ensure that the potential highest residual flood levels were recorded, the drainage areas are considered as acting independently, while when the levee was set at 12' and a more conservative approach could be considered, the areas were considered interlinked. These alternatives are described as the "large" internal drainage areas.

Specific comments with respect to the polders in Planning Unit 4 are given in

Table 8.3. Additional area specific information is given in Annex B.

Table 8.3 Specific Planning Unit Comments

Polder Ring	Drainage area(s)	Comment
GIWW alignment	North of Veterans	The discharge of the river Mermentau is not included in the stored volume, pumps will handle this additional volume.
12 feet GIWW alignment	North of Veterans and Central PU4 ring	For the 12 feet alignment the stages within the polders are calculated based upon large Polder Rings.
12 feet GIWW alignment	South of Lake Charles	The stages for South of Lake Charles are based on overtopping of the levee protecting the Polder South of Lake Charles or based on flooding spreading form the Central PU4 polder. Due to higher grounds between Central PU4 and the South of Lake Charles polder (higher ridge at 8 feet) stages are set to a minimum of 8 feet when overtopping occurs from the South of Lake Charles side. Otherwise, stages within South of Lake Charles follow the stages caused by the flooding of Central PU4 if these stages exceed the threshold of 8 feet.

8.4 Hydraulic Results of Planning Alternatives

A number of planning alternatives have been considered. They considered a range of design standards (100 year, 400 year, and 1000 year) together with a of range of variations in alignment and in the areas included within the protected areas. All of these alternatives are considered for interior stage frequency and results developed for inclusion in the economic evaluation. For the West all the alternatives, plus the baseline were taken forward for more detailed consideration.

The key alternatives are as follows:

- GIWW plan;
- 12 feet GIWW plan;
- Ring levee plan.

These alternatives use different combinations of levee height designs and interior drainage results to produce sets of stage frequency results. Table 8-4 shows the linkage of the interior drainage areas to the planning alternatives:

Table 8.4 Internal Drainage Area to Planning Alternative Sets

	Baseline	GIWW Plan	12' GIWW Plan	Ring levee Plan
West_Lake_Charles		WA-xxxxa		WT-xxxx
East_Lake_Charles			WA-xxxxb	WT-xxxx
Gueydan			WA-xxxxb	WT-xxxx
Kaplan			WA-xxxxb	WT-xxxx
South_of_Lake_Charles_ring		WA-xxxxa		
Central_PU4_ring		WA-xxxxa		
GIWW_to_Veterans_ring		WA-xxxxa		
GIWW_to_Veterans_inc_ret_ring				
South_of_Lake_Charles_ring_12			WA-0100b	
Central_PU4_ring_large_12			WA-0100b	
GIWW_to_Veterans_ring_large_12			WA-0100b	
Prien		WA-xxxxa		WT-xxxx
Inner_Lake_Charles		WA-xxxxa		WT-xxxx
Other External Areas	WT-ext			

The alignments and levee heights for each of the alternatives are shown on the Planning Subunit Key Maps in the Evaluation Results Appendix. These maps have an accompanying table showing stage frequency comparisons (baseline to alternative) for a selection of planning subunits.

9 CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

The hydraulic analysis for each planning alternative in LACPR consisted of the following consecutive steps:

1. Numerical computations of surge levels and wave characteristics using ADCIRC, WAM, and STWAVE;
2. Frequency analysis using the JPM-OS method and determination of exterior stage frequency;
3. Determination of the levee heights and overtopping volumes;
4. Determination of the interior stages including rainfall.

To provide a range of alternatives for evaluation and to enable the economic evaluation, it has been decided to evaluate each levee alignment alternative for different protection levels and event frequencies. A levee design has been made for three levels of protection (100-year, 400-year, 1000-year). Given the level of protection, the overtopping volumes have been computed for four return periods of the outside surge level and wave characteristics (100-year, 400-year, 1000-year, and 2000-year). For all alternatives, the 10-year rainfall was added to the overtopping volume to establish the interior stage frequency curve, while also pumping has been taken into account.

The ADCIRC model results and the “without friction” STWAVE results in combination with the JPM-OS method have been used for determination of levee design and overtopping quantities. This dataset has also been used for the calculation of interior and exterior stages. The method was adopted as being a robust approach for the purpose of comparison for the selection of the levee alignment plans presented in this report.

9.2 Discussion

From the onset of LACPR the scale of the work, both in terms of geographic area and the range of alternatives to be considered, has dictated the selection of methods and procedures used to determine results. The processes described in this report do represent a compromise - one of absolute accuracy over delivery.

This compromise has been realized in various parts of the process, and its main components are described below.

Hydraulic Modeling and Frequency Analysis

- *Model alignments* - what has been modeled does not necessarily represent the final alternatives; this would have required an iterative process to review the results and then modify the models to optimize the levee layouts.

- *Range of storms* - for some models the suite of storms has been reduced so that the models could be completed within a practical time frame. The selection of the storms may have skewed the statistical results for the higher extremes.
- *Result presentation* - only for selected points results have been prepared for all models rather than for all model points, which would have enabled a more accurate view of the spatial variation in variables and the identification of problem areas within the model grids.
- *Wave computations with and without friction* - at present all calculations have been made using wave heights derived from a without-friction model. The with-friction models have been developed, but the results have not been used in the analysis to date. Validation of the wave models is also required.

Levee Design

- *Use of a single point to define a long length of levee* - some of the variations in surge elevation and wave height have not been considered as the levee height design has been based on a single result point - in some cases extending some tens of miles.
- *Fixed design criteria* - the design process has only considered earthen embankments, and all levees have been designed to the same design criteria. No consideration has been made to other forms of construction, to the area at risk, or to the consequences of failure.

Stage Frequency Calculations

- *Simple stage storage approach* - no allowance has been made in the stage frequency analysis for the flow of water within areas and the time taken for areas to fill and empty.
- *Large storage areas* - the size of the storage areas has generally been large and the areas have been considered to act primarily in isolation. Only in critical areas interconnection has been considered and then only in a very simple “overflowing bucket” process.
- *No breaching of defenses* - the levees have been assumed to withstand all ranges of overtopping without breaching. This may potentially lead to higher flood depths inside a levee as the water can “pump up” due to the influences of waves.
- *Simplified pumping* - pumping has been included at the existing capacity where known. In other areas a simple relationship of 0.5 cfs/acre has been adopted without any consideration of any potential storage areas, the time for the water to reach the pumps or the distances over which pumping needed to take place. In some areas the area used for computing the pumping capacity has been fixed as there was no upper limit because of normal catchment drainage.
- *Pre-event storage*. No allowance has been made for water trapped inside areas once flood defenses have been shut prior to a hurricane.
- *Rainfall* - the rainfall rates have been taken as a synthetic distribution based on a fixed 10 year rainfall event. This has been used for all events, whereas in reality the rates of rainfall are likely to change for different return periods of event, and the distribution is unlikely to follow the uniform distribution assumed for this project.
- *Joint probability of high river levels and high surges* - no consideration has been given to the potential for increased levels at the interface between tidal and fluvial flows. River flows and levels have been taken as nominal.

Many of the above issues can easily be dealt with for small areas or if sufficient time and resources are available. Within the constraints of LACPR, they have been adopted as a pragmatic approach.

However, as the project progresses and the range of alternatives decreases then some of these issues should be reviewed and changes to the methodology made. It is not easy to quantify the effect that addressing these issues will have on the final results, but as alternatives progress towards more detailed design then addressing the issues will improve confidence on the absolute values obtained.

In addition it will be difficult to improve all of the issues to the same degree for all of the Planning Units. As such, care should be taken in improving issues if the approach cannot be applied to all Planning Units as this may make comparing alternatives difficult, whereas at present the consistent approach adopted across all units makes alternatives comparable not only within a Planning Unit but also across Planning Units.

9.3 Recommendations

As LACPR progresses there will be a number of opportunities to refine the work carried out to date. These refinements will follow the route defined by the project and some may not be required depending of the direction of that route. In addition, the timing of any refinements also needs to follow the project route.

Suggested key refinements are as follows:

- Model in ADCIRC and STWAVE the actual proposed defense alignments at their proposed heights and for the full suite of storms. Extract data for locations required for design and overtopping purposes for the proposed alignments. Ensure that a larger range of values are available for checking of the results.
- Validate the STWAVE results for the actual areas with a field measurement program of wave propagation over marshes so that the issue of no friction or with friction wave modeling can be resolved. It is without doubt that more insight and more predictive capabilities in this regard could save huge amounts of money considering the differences in design heights when waves with and without friction are applied.
- Undertake levee design specific to more localized areas and consider walls as well as embankments if necessary.
- Compute wave overtopping over shorter lengths to give variable inflow into flood areas.
- Use 2D modeling of flood flow to establish residual flood areas and depths and use the results of this modeling to site and design pump stations. 2D models should consider their interaction with adjacent areas so sequential flooding of drainage areas can be undertaken.
- In the 2D modeling consider varying rainfall and establishing relationships between rainfall and hurricane events so that the shape of the rainfall hydrograph more closely matches that which would be expected within an extreme event.

- Carry out further research to look at the parameters for defense breaching and determine if in extreme events levees should be assumed to breach. Investigate the impact of breaching on peak water levels within drainage areas.

10 REFERENCES

1. Plan Formulation Atlas, April 16 2007, http://lacpr.usace.army.mil/default.aspx?p=atlas
2. Resio et al., 2007. White paper on estimating Hurricane Inundation Probabilities, USACE, ERDC-CHL.
3. TAW, 2003. Technische Adviescommissie voor de Waterkeringen, Leidraad kunstwerken (In Dutch), May 2003.
4. TAW, 2002: Wave runup and overtopping at Dikes, Technical Report, Delft, 2002. See also: www.tawinfo.nl.
5. USACE, 2007. Elevations for design of hurricane protection levees and structures, Lake Pontchartrain, Louisana and vicinity hurricane protection project, west bank and vicinity. Draft report, Final report, Prepared by New Orleans District, 15 October 2007.
6. TAW, 2002. Technical Report Wave Run-up and Wave Overtopping at Dikes, Delft, The Netherlands.
7. IPET, 2007. Performance Evaluation of the New Orleans and Southeast Louisiana Hurricane Protection System, L.E. Link (editor).
8. FEMA, 2007. Flood insurance Study: Southeastern Parishes Louisiana, DRAFT, Intermediate Submission 1: Scoping and Data Review. September 19, 2007. FEMA Region 6 and USACE MVN District.
9. R.L. Pfost, 1993. Technical Attachment Rainfall patterns and Hurricane Andrew. A Hydro-meteorological Survey, Lower Mississippi River Forecast Center, Slidell, Louisiana
10. R.W. Shoner and S. Molansky, 1956. Rainfall associated with Hurricanes. National Hurricane Research Project. Report No. 3. Prepared under P.L.71, 84th Congress, 1st Session.
11. Hughes, S.A., 2007: Evaluation of Permissible Wave Overtopping Criteria For Earthen Levees Without Erosion Protection, ERDC-CHL, Vicksburg.
12. U.S. Army Corps of Engineers, 2001: Coastal Engineering Manual. Engineer Manual 1110-2-1100, U.S. Army Corps of Engineers, Washington, D.C. (in 6 volumes).

Annex A
Hydrodynamic Results

ANNEX A. HYDRODYNAMIC RESULTS

A.1 Introduction

The purpose of the hydrodynamic modeling was to estimate the surge and wave conditions for the base conditions and various alternatives for storms in the JPM-OS suite for the calculation of stage-frequency curves. This involved an examination of the entire spatial domain every time step (1 sec) to determine if water levels exceeded the previous time steps maximum water level at any point in the domain. The result of this analysis is a maximum envelope of water level for a given simulation. From the ensemble of results, the expected return periods for those surge and wave conditions is calculated to assist in the quantification of risk. Example output generated from the ADCIRC model results are provided in the figures and discussion below. The results provided in this section are maximum surge elevations for each alternative or base condition for all storms simulated. The results are for illustrative purposes and as presented here do not provide information on levels of protection, which is discussed in subsequent chapters of this report. As discussed in Volume I of this report, five STWAVE grids were utilized. Results from only the southeast grid are presented here as an example of those results.

For each alternative presented herein, results for the suite of storms simulated for each alternative were scanned for peak elevations at each node, from which a “peak of peaks” data file and plot were produced (hereafter referred to as “peak” or “maximum” values/plots). The peak values for the same storm suite run on the 2007 base grid were then subtracted from the alternative maximum surge values to produce difference files and plots. Each figure title indicates the alternatives being compared to the 2007 base. Because the 2007 peak values are always subtracted from the alternative, a positive number indicates that peak surge values for the alternative are higher than the 2007 peaks, while a negative number indicates that peak surge values for the alternative are lower than the 2007 peaks. For surge results, the upper range of the legend ends at +12 feet (except for the Barrier Island cases), the maximum difference observed in any of the comparisons. Areas colored mauve indicate regions that were wet for at least one storm in the alternative simulations but were dry during all storms in the 2007 simulations. The lower range of the legend ends at -12 feet for the Marsh, and Plaquemines alternatives, the lowest observed difference for those scenarios. For the EA-ED levee system options, as well as the 2010 configuration, the lower range of the legend ends at -22 feet, the maximum observed difference for those scenarios. Areas colored dark green indicate regions that were dry during the entire storm suite in the alternative simulations but were wet for at least one storm in the 2007 base case. For these graphs, the range -12 to -22 feet was colored pale green; this color indicates regions that have a small depth of water present for at least one storm for that alternative (e.g., a marsh-like area), and they had a large peak surge value for at least one storm in the 2007 base case. The Barrier Island surge results legend had an upper and lower end of +/- 6 feet, respectively. For the STWAVE results, a legend with an upper range of +6 feet and a lower range of -6 feet was used for all alternatives, except the Barrier Islands, which used +8 feet at the upper end and -8 feet at the lower.

A.2 2007 Base Condition - East

The 2007 Base condition was created to represent South Louisiana as it was projected to exist at the start of the 2007 hurricane season. Post Hurricane Katrina and Rita topographic and bathymetric conditions were combined with levee definitions to reflect the system repairs and upgrades that were implemented as part of the USACE Task Force Guardian and by the USACE HPO and MVN. Simulations were completed for the 152 storms for eastern Louisiana in order to define water levels

and corresponding wave conditions. This information serves as a base condition to which alternative levee systems, barrier island variations, marsh improvements and/or degradation, and sea level rise can be compared. Section 2.4 of Volume 1 of this report (and section A.4 of this Annex) describes the motivation for study and changes to the physical system for each alternative inspected.

Figure A.2-1 represents the maximum surge level recorded for the East 152 storms simulated for Southeastern Louisiana. It is important to note that the displayed water levels are not stochastic representations of the 100-year or other return period water elevations, but rather are the maximum surge levels for all 152 specific storms simulated for the JPM-OS method. The highest surge levels occurred in three locations: along the east side of the Plaquemines Parish levee system from Belle Chasse to Port Sulphur; along the Mississippi coast near Biloxi and Gulfport; and northwest of Terrebonne Bay near Houma.

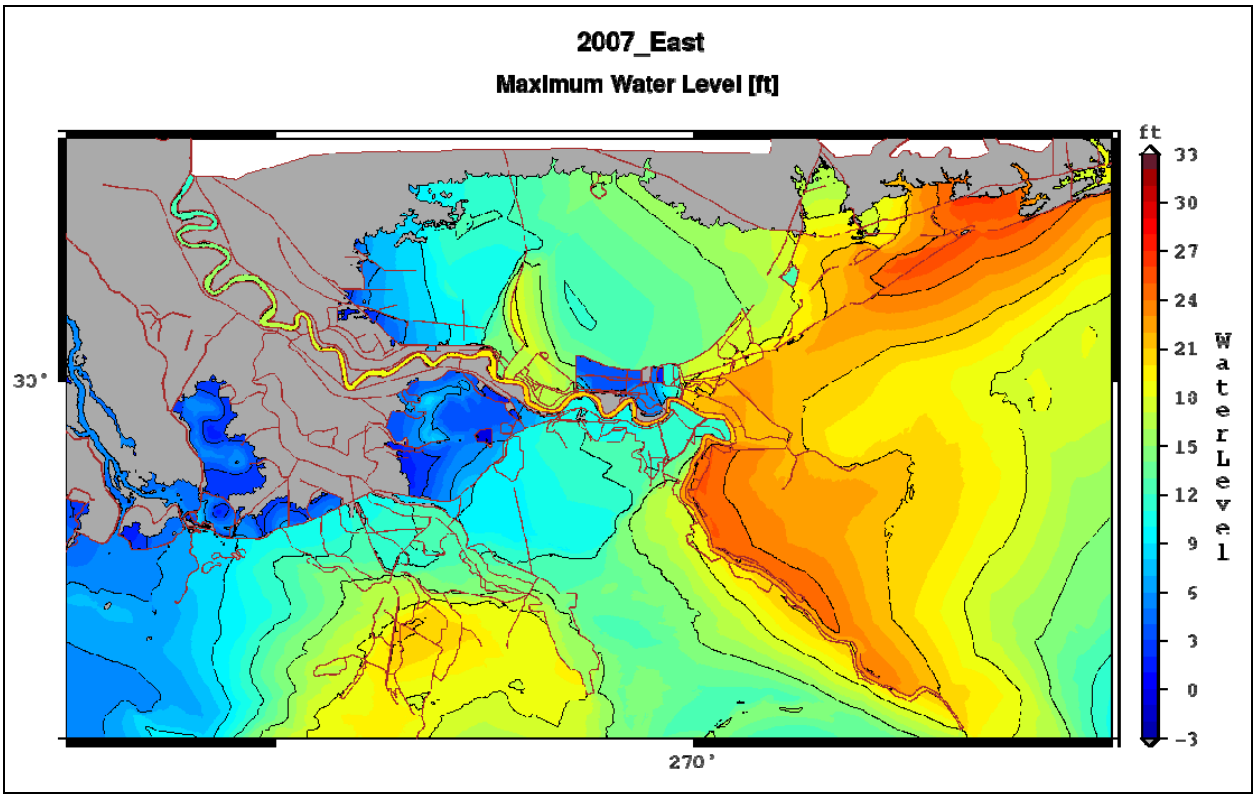


Figure A.2-1. Maximum surge level (ft) for the 2007 base case for all East 152 storms.

East of the Mississippi River, peak surge levels along the Plaquemines Parish levees all the way to the Mississippi Coast are on the order of 25 ft. These high surges develop as water is blown by easterly and then southerly winds onto the shallow Mississippi-Alabama shelf and is then stopped by the Mississippi River delta and levees and the coast of the state of Mississippi. The New Orleans metropolitan region is significantly flooded as the levees of St. Bernard Parish and New Orleans East are overtopped. Mean water levels also rise in in Lake Pontchartrain as water flows via the Rigolets, Chef Menteur Pass and and over the Pontchartrain landbridge, especially in easterly winds. In addition, strong localized set up occurs in this large shallow lake. Maximum surge elevations on the north and south shores of Lake Pontchartrain are approximately 15 to 18 ft. A substantial populace is located in areas directly affected by the water levels in the lake. For this reason, primary alternative levee systems inspected are various closure options for Lake Pontchartrain. Maximum surge values northwest of Terrebonne Bay in the Houma area are over 20 ft due in large part to surge being locally trapped both as it propagates north but also east and west by local levees and roads. Maximum surge elevations along the West Bank levees are more modest

reaching about 12 ft. Much like the regions adjacent to Lake Pontchartrain, a high populace resides in this portion of the state. Maximum 2007 wave heights outside of the east New Orleans levee system, as predicted by STWAVE simulations (Figure A.2-2), are on the order of 6 to 8 feet near Caenarvon, on the order of 6 to 8 feet near the MRGO/GIWW, and on the order of 8 to 10 ft near the Pontchartrain Landbridge.

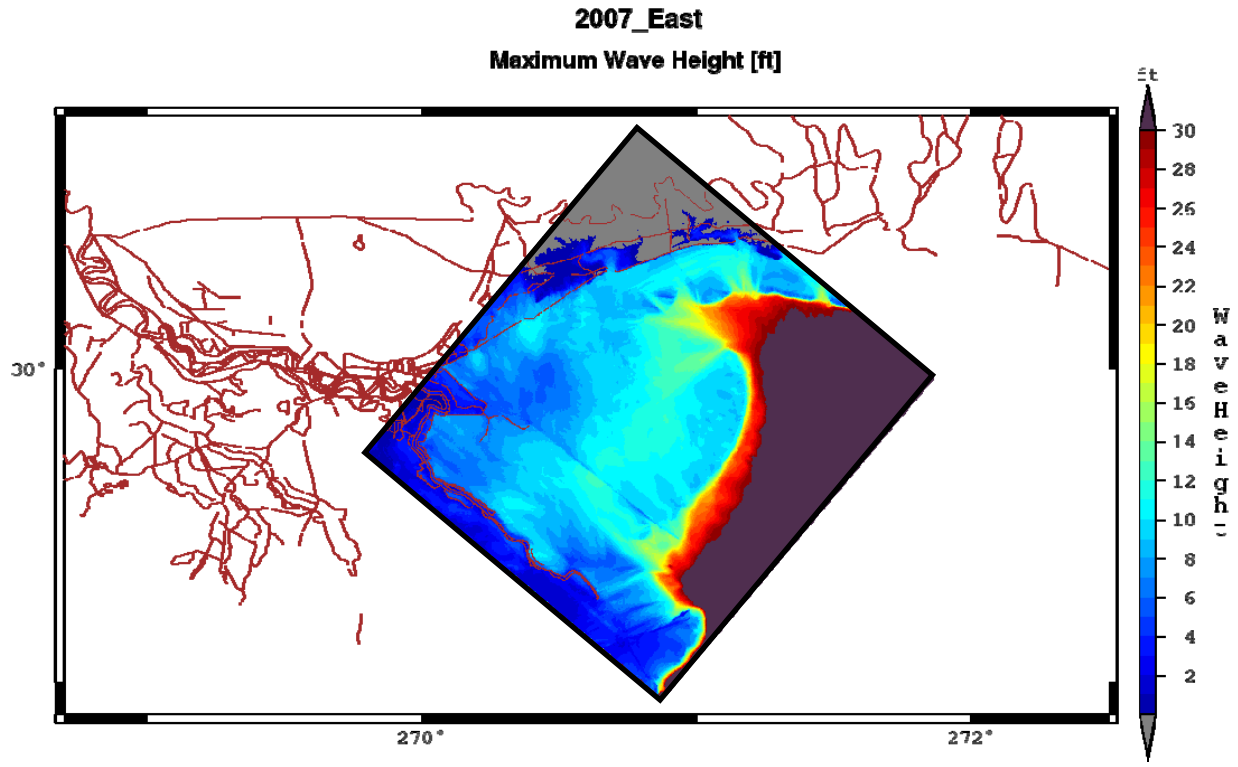


Figure A.2-2. Maximum wave height (ft) for the 2007 base case for all 152 storms.

A.3 2010 Base Condition

The 2010 condition represents the levee configuration that would exist if the proposed hurricane protection system was built to currently-authorized levels and also includes a levee that runs along the proposed Morganza to the Gulf alignment raised so that it does not overtop. The 2010 system also raises levee heights around the existing system in and around metropolitan New Orleans on both the east and west banks (with the exception of the Belle Chase) to approximate 100 year levels. In addition, the system includes a levee to close the MRGO/GIWW east of Paris Road to stop the propagation of surge into the heart of New Orleans. Figure A.3-1 shows the difference in the envelope of maximum water level between the 2010 and 2007 configurations. The inclusion of a non-overtopping barrier around Golden Meadows and from Morganza to the Gulf blocks the incoming surge, raising the peak water levels south of the levees by up to 12 feet near Cut Off and up to 3 feet near Morgan City. Behind the barrier, the peak water levels in most areas are either reduced by 10 to 22 feet (dark blue and pale green areas), or they remain completely dry for all simulated storms, whereas in the 2007 configuration, the area had peaks up to 22 feet. Similar effects are seen in the New Orleans area, i.e., the fortified 2010 system either reduces the peaks by 10 to 22 feet (dark blue and pale green areas), or eliminates the surge entirely (dark green areas). Outside of the fortified New Orleans system, the peak surge increases in most areas about 1 to 3

feet. However, near the MRGO/GIWW closure, the peak surge increases 4 to 5 feet, while the peak surge near the English turn in the Mississippi increases by about 7 to 8 feet, relative to peak 2007 conditions. Maximum surge also increases up to 6 ft in the poorly protected Belle Chase region with effective focusing of surge in this concavity in the system. There was very little change in the maximum wave heights outside the hurricane protection system (Figure A.3-2).

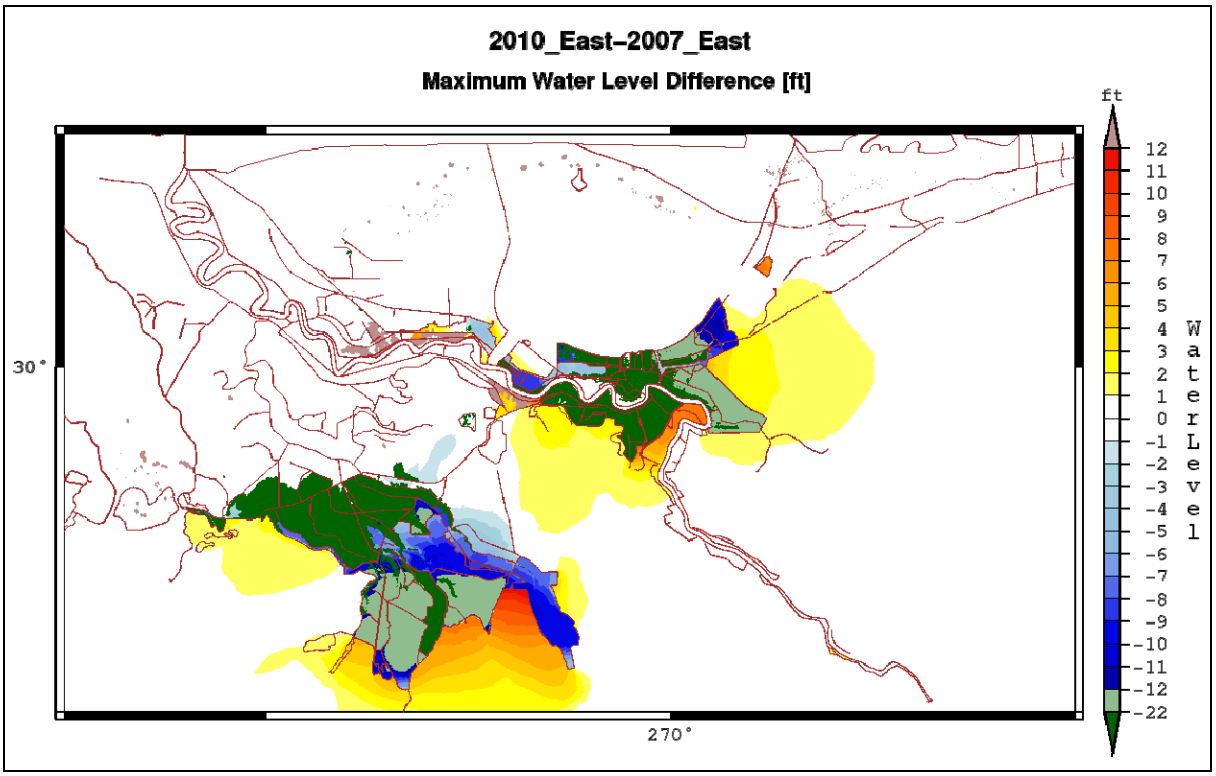


Figure A.3-1. Difference in maximum surge level between the 2010 levee configuration and the 2007 base case for the 2010 storm suite.

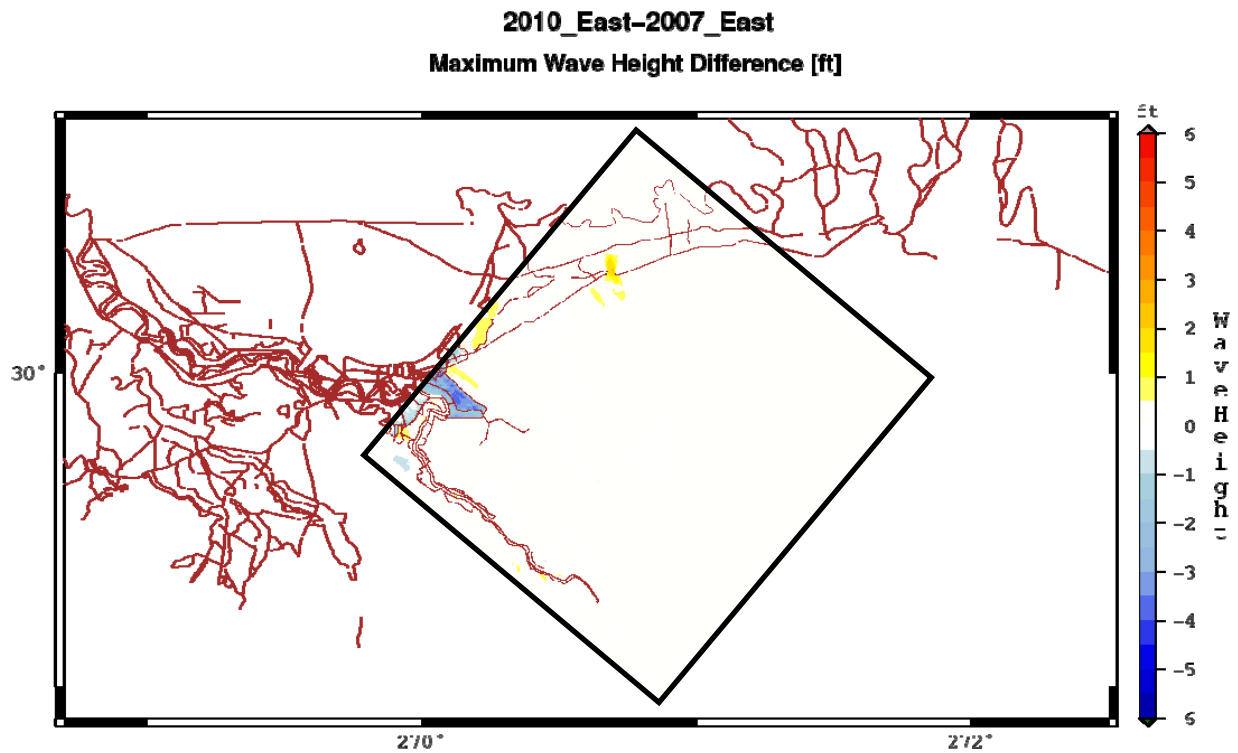


Figure A.3-2. Difference in maximum wave height (ft) between the 2010 levee configuration and the 2007 base case for the 2010 storm suite for the southeast STWAVE grid.

A.4 Closure options of Lake Pontchartrain

Various levee system alternatives were developed to understand the performance and implications of a variety of levee system improvements. A more detailed description and the suite of storms simulated for each alternative is provided in Volume I of this report, Background and Methodology. Four east levee configurations included closure options of Lake Pontchartrain. This section documents results for east alternatives A through D as they relate to the proposed closures of Lake Pontchartrain.

A.4.1 Full closure along US90 (Alternative EA)

Alternative EA involves complete closure of Lake Ponchartrain through a 30-mile non-overtopping levee extending from the junction of US11 and US90 to a point just north of Slidell near I-59. The levee generally follows the US90 corridor, extending along the west bank of Lake Borgne, the west boundary of Lake Saint Catherine, and crossing through the Chef Menteur and Rigolets Passes. Both the passes would be entirely closed during storms with gates. At the intersection of US90 and US190, the levee stretches northwestward, ultimately terminating at a point approximately one mile north of the I-10/I-12/I-59 interchange near Slidell, LA. Another feature of the alternative EA configuration is a non-overtopping levee extending along the west shore of Lake Borgne, providing full closure at the funnel for the Inner Harbor Navigation Channel and the Gulf Intracoastal Waterway.

Figure A.4-1 depicts the difference in maximum water level between the alternative EA and 2007 base case. Non-overtopping levees and channel closures prevent the filling of Lake Pontchartrain from Lake Borgne and the Mississippi Sound and thus prevent the increase in mean lake levels. Local winds still drive a localized set up in the wind direction causing high water levels along the shores of the lake. A 2 to 3 ft decrease is predicted for lakefront areas at the city of New Orleans, with maximum surge levels in the neighborhood of 10 to 12 ft. Along the north shore of Lake Pontchartrain, areas such as Mandeville and Lacombe are expected to experience a maximum surge decrease ranging between 2 and 7 ft. Maximum surge levels along the north shore of Pontchartrain are predicted to be between 9 and 14 ft. At the western shore of Lake Pontchartrain, surge reductions are predicted to be between 3 and 4 ft. In addition, the entire south levee of New Orleans East, about half the north levee of St. Bernard and the southern reach of the IHNC experience vast reductions in surge levels and/or see little or no surge against them as a result of the closure on the west shore of Lake Borgne.

Areas seaward of the levee experience water level increases. As inland surge propagation accumulates along the seaward side of the non-overtopping levee, maximum levels within Lake St. Catherine are predicted to increase by as much as 8 ft in comparison with the 2007 base levels, with a maximum predicted level of approximately as much as 30 ft. Increases in maximum surge levels are expected to be around 4 ft along the mouth of the Pearl River, and 7 ft near Bayou Savage National Wildlife Refuge within Lake Borgne. At the non-overtopping levee that encloses the funnel, surge levels are expected to increase by between 6 and 8 ft from the base 2007 levels. The effects of alternative EA may be felt as far east as Long Beach, MS, with a surge increase of 1 ft, and maximum levels between 22 and 24 ft.

In Figure A.4-2, the difference in maximum wave heights between alternative EA and the base case are presented. Wave heights increase seaward of the full-closure funnel levee between 0.5 and 1 feet. Wave heights increase seaward of the non-overtopping US90 Pontchartrain levee by up to 3 ft.

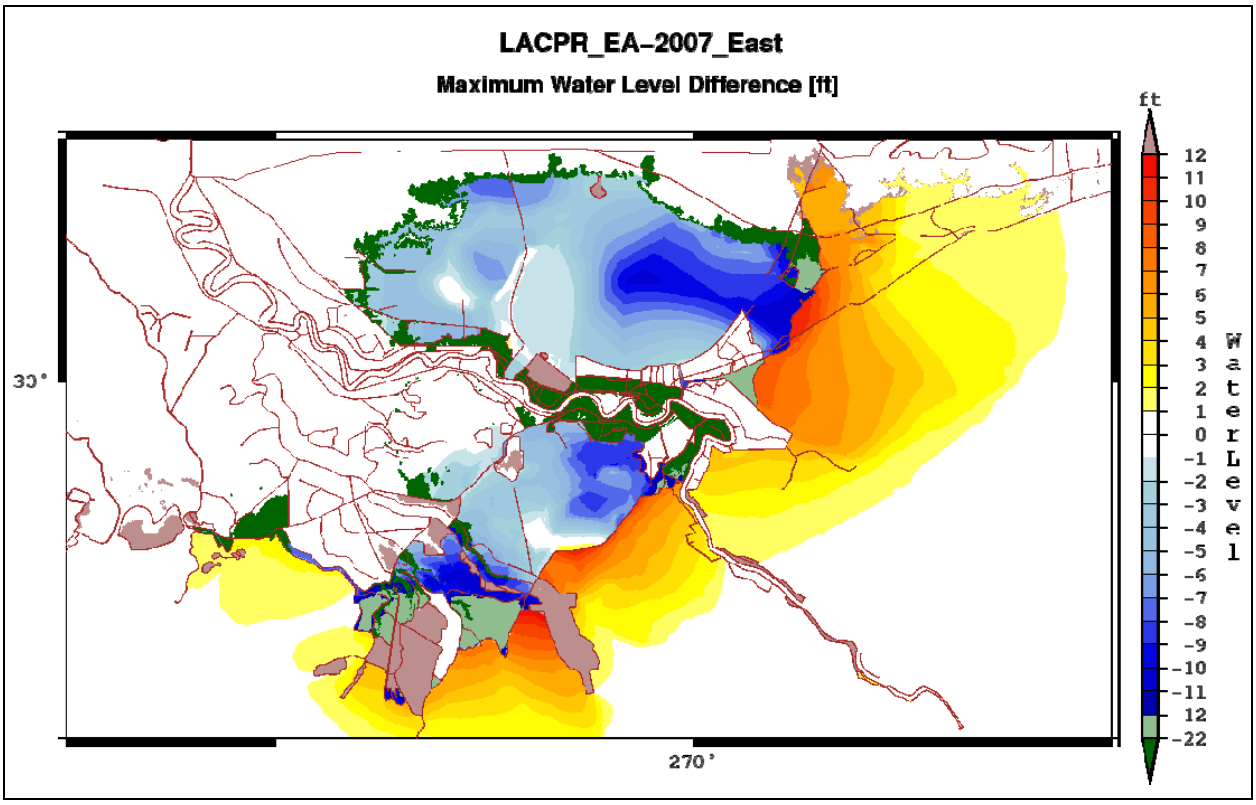


Figure A.4-1. Difference in maximum surge level between alternative EA and the base case for the EA storm suite.

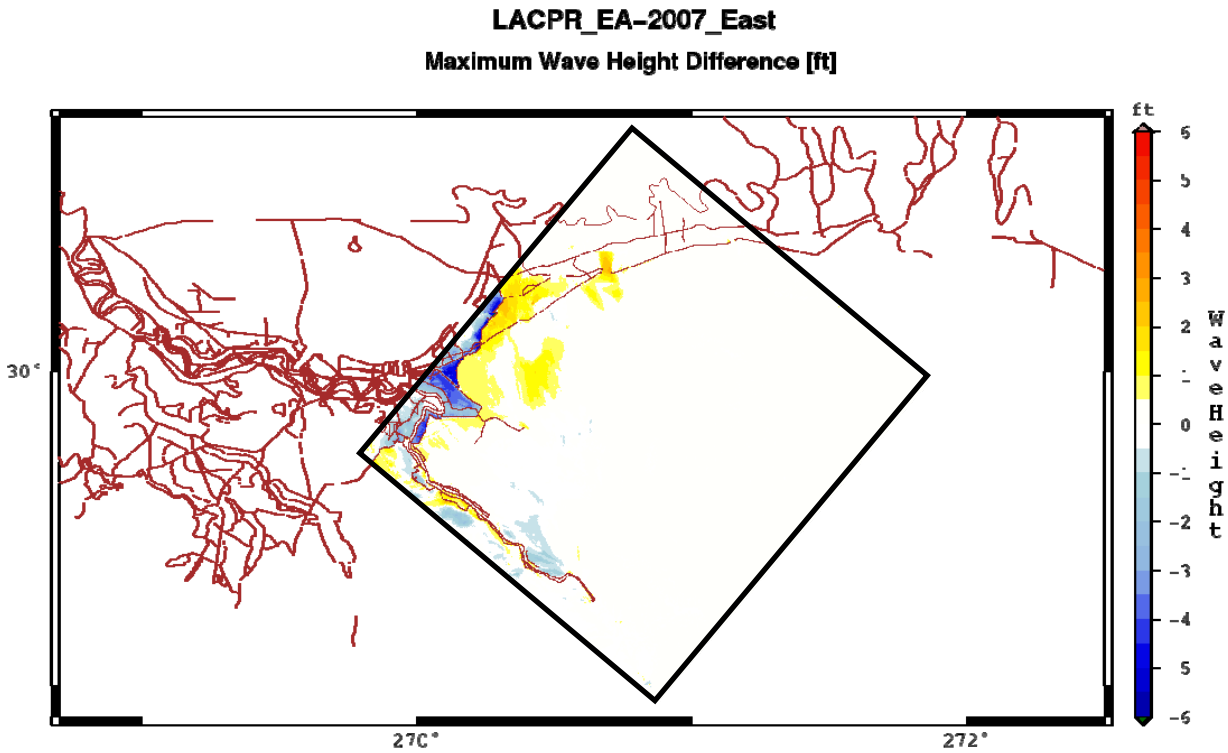


Figure A.4-2. Difference in maximum wave height (ft) between alternative EA and the base case for the EA storm suite for the southeast STWAVE grid.

A.4.2 Weir closure along US90 (Alternative EB)

Alternative EB is identical to EA with the exception that the levee across the Pontchartrain land-bridge from Chef Menteur to the Rigolets was lowered from a height not to be overtopped to 12 ft. Figure A.4-3 is the difference in the envelope of maximum water level between alternative EB and the 2007 base case. The weir levee stops the propagation of the surge into Lake Pontchartrain until its elevation exceeds 12 ft, resulting in lower peak surges in Lake Pontchartrain relative to the base case. However, for large storms on select tracks there will still be considerable infilling of Lake Pontchartrain from Lake Borgne and the Mississippi Sound. The surge on the south shore of Pontchartrain is reduced 2 to 3 ft relative to the 2007 base case and reductions of up to 3 to 4 ft are predicted on the north shore. The maximum surges on the south shore with alternative EB in place range from about 9 to 13 ft, increasing as you move from west to east. On the north shore, the peak surges for alternative EB are greater than 12 ft from about Madisonville to the east. The inclusion of the weir levee across the Pontchartrain landbridge increases water level seaward of the weir 3 to 4 ft and near Slidell 2 to 4 ft. The peak surge at the proposed levee that closes the funnel is increased 5 to 6 ft. In comparison to alternative EA, the surge reductions in Lake Pontchartrain due weir closure are less, however they are not significantly different on the south shore. The surge seaward of the structure is also less, with a maximum increase of 8 ft for alternative EA, compared to an increase of 4 ft for alternative EB. Figure A.4-4 depicts the maximum wave height differences for alternative EB.

Wave height differences for areas seaward of the full-closure funnel levee range between 4 and 5 feet. Wave heights are predicted to increase inland of the US90 Pontchartrain weir by up to about 2 ft.

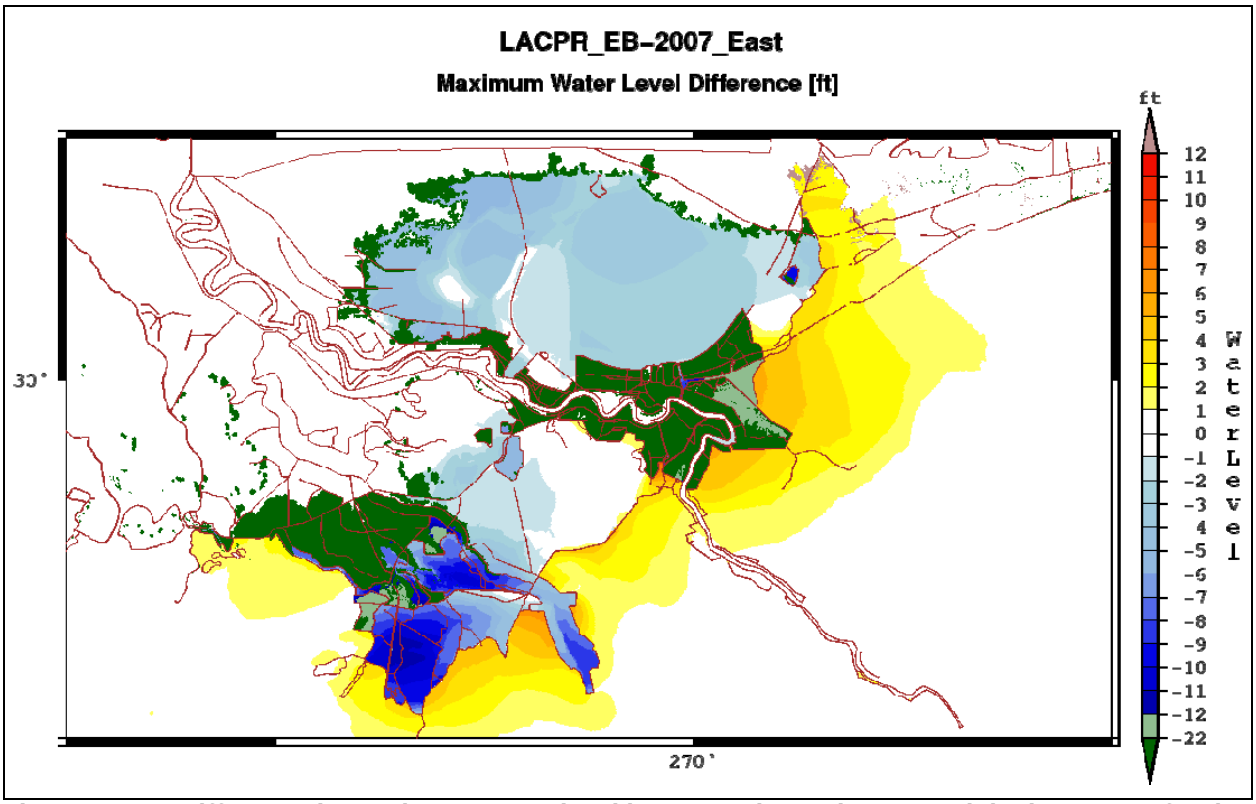


Figure A.4-3. Difference in maximum surge level between alternative EB and the base case for the EB storm suite.

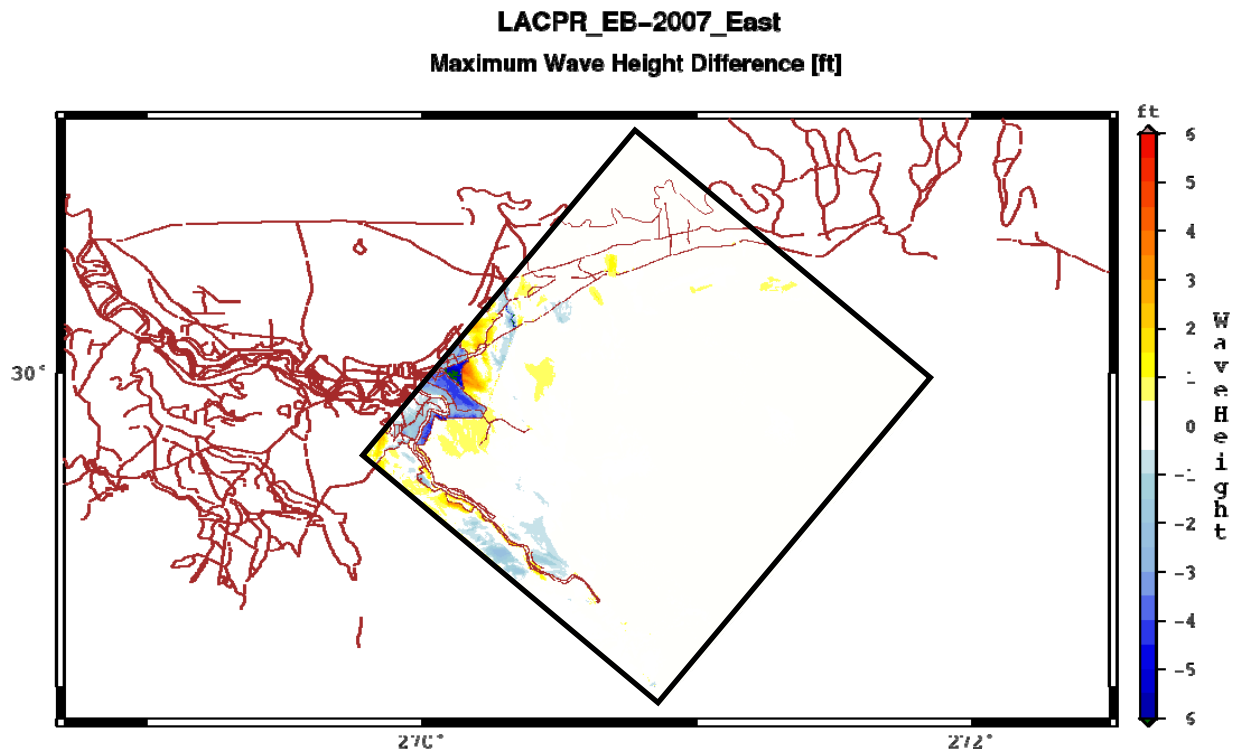


Figure A.4-4. Difference in maximum wave height (ft) between alternative EB and the base case for the EB storm suite for the southeast STWAVE grid.

A.4.3 Partial closure along US90 (Alternative EC)

The levee configuration for alternative EC involves a non-overtopping levee following the same path as alternative EA. Alternative EC differs from alternative EA in that it includes openings at Chef Menteur Pass and the Rigolets. These openings allow water to flow through these deep conveyance channels between Lake Pontchartrain and Lake Borgne. Alternative EC maintains the closure at the funnel through a non-overtopping levee placed along the west bank of Lake Borgne. Figure A.4-5 illustrates the difference between the maximum water level for alternative EC and Base 2007. Alternative EC's partial closure configuration results in a maximum increase within Lake Pontchartrain of less than 3 ft. Areas along Pontchartrain's north shore are predicted to experience a surge reduction of less than 2 ft, with similar reductions in the vicinity of New Orleans. Maximum water levels within Lake Pontchartrain range from 11 to 15 ft along the northern shore from Mandeville, LA to Lacombe, LA. Water levels as high as 18 ft are predicted for areas between Kenner, LA and Frenier, LA. Seaward of the levee, an accumulation of surge forms, resulting in an increase of alternative EC water levels in comparison with the Base 2007 levels. The greatest surge increase due to the EC configuration is 6 ft, occurring within Lake Saint Catherine. Maximum surge level increases range between 5 and 6 ft at points along the seaward side of the levee that provides closure to the funnel. The effects of the levees in alternative EC are confined to areas west of Waveland, MS, where surge increases due to the modified levees are predicted to be less than 1 ft. In comparison with alternatives EA and EB, alternative EC provides less reduction in surge levels within Lake Ponchartrain. For example, Lacombe, LA is predicted to experience only a 1 ft surge reduction due to alternative EC compared to 7 and 3 ft for alternatives EA and EB, respectively. Maximum wave height differences for alternative EC are presented in Figure A.4-5. Wave heights seaward of the full-closure funnel levee are not predicted to increase. Wave heights are predicted to increase at the partial closure US90 Pontchartrain levee by up to 1 ft.

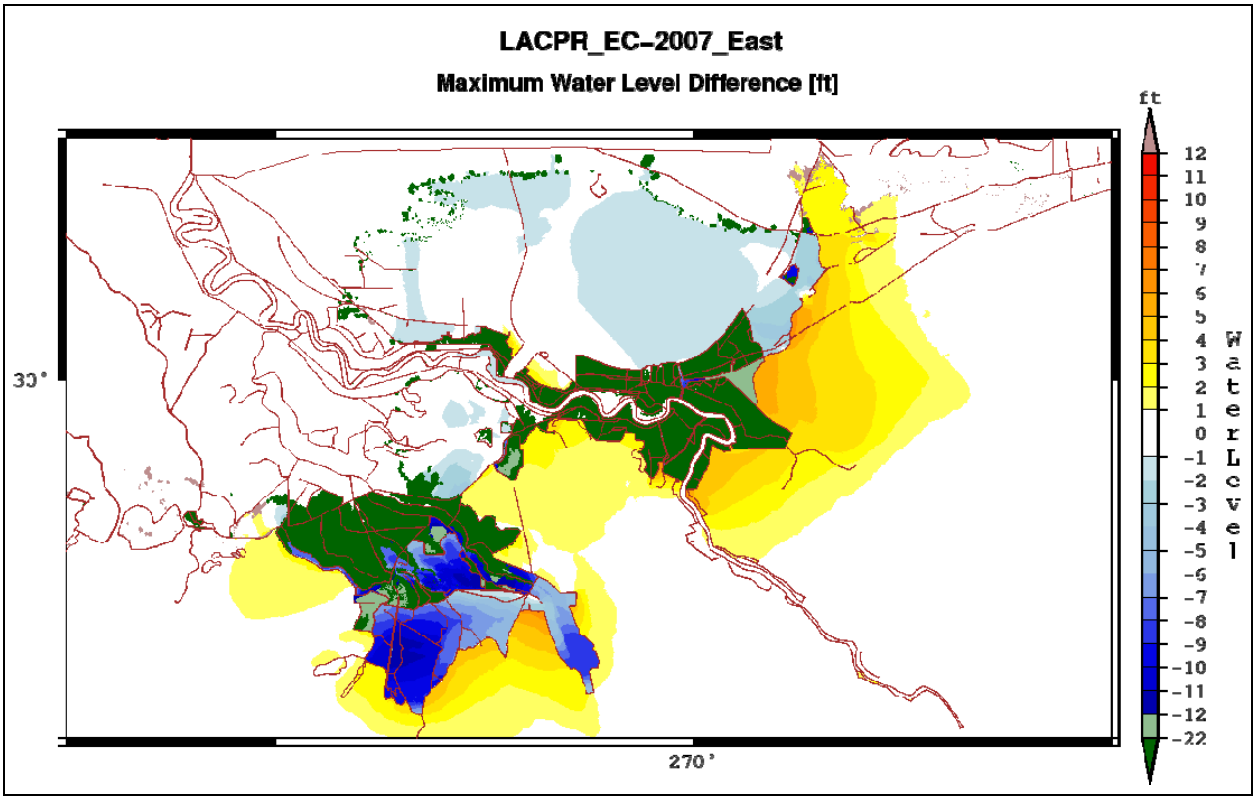


Figure A.4-5. Difference in maximum surge level between alternative EC and the base case for the EC storm suite.

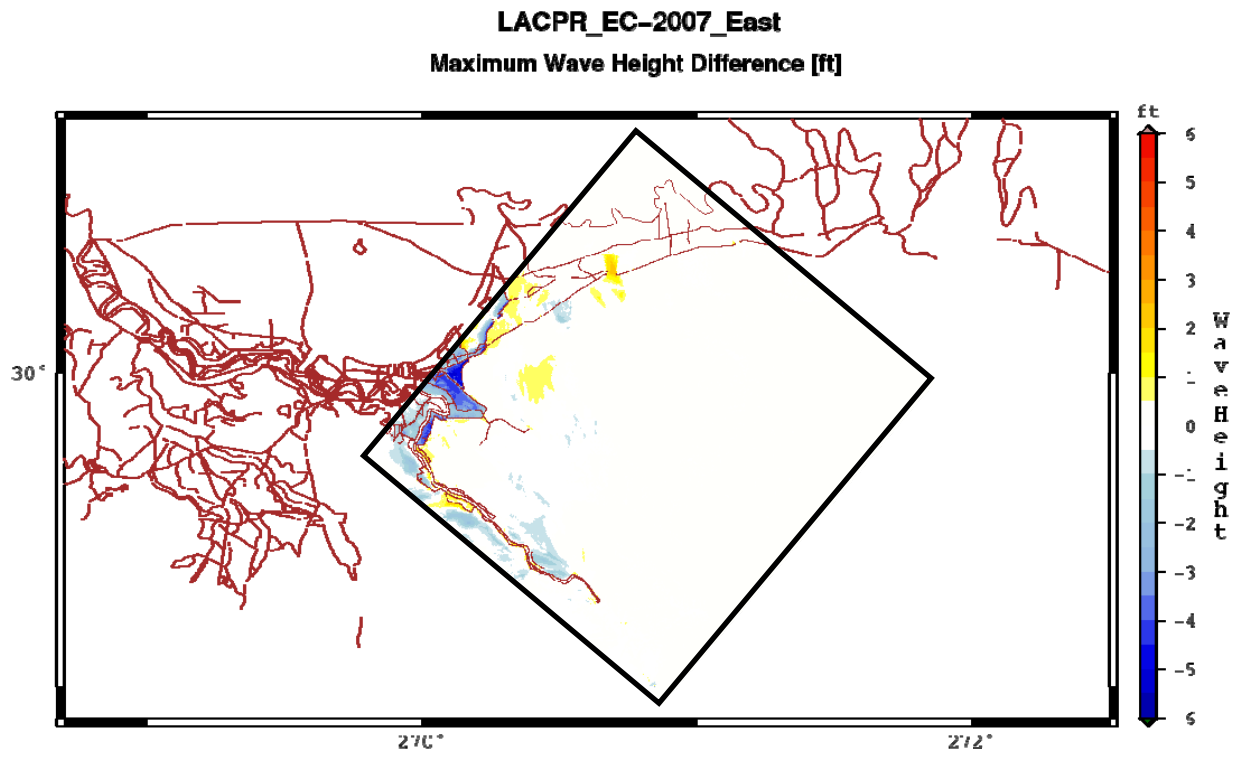


Figure A.4-6. Difference in maximum wave height (ft) between alternative EC and the base case for the EC storm suite for the southeast STWAVE grid.

A.4.4 Full closure through Lake Borgne (Alternative ED)

In alternative ED, a non-overtopping levee isolates Lake Pontchartrain from Lake Borgne. This levee extends from Verret, LA, northward through Lake Borgne along a straight line to a point along the Gulf Intracoastal Waterway just south of Little Lake. At this point, the levee extends northwestward along the Pearl River corridor, crossing I-10, and terminating at a point approximately one mile north of the I-10/I-12/I-59 interchange. This approximately 35 mile levee provides full closure to Lake Pontchartrain, Lake Saint Catherine, the Chef Menteur Pass, the Rigolets, the funnel, and portions of southeastern Lake Borgne. The non-overtopping levee in alternative ED results in an inland surge decrease accompanied by seaward accumulation of water. Figure A.4-7 illustrates the difference between the maximum water level for alternative ED and Base 2007. Maximum surge decreases inland of the non-overtopping levee are predicted to be over 12 ft at areas within Lake Borgne and Lake Saint Catherine. From Mandeville, LA to Lacombe, LA, predicted maximum surge decreases range from 3 to 6 ft along Pontchartrain's north shore. Areas along the southern shore show a 2 to 3 ft decrease from the Base 2007 levels. Maximum water levels within Lake Pontchartrain range from 3 to 15 feet, with the highest levels occurring along Pontchartrain's southwestern shore, between Kenner, LA and Frenier, LA. Maximum levels along Lake Pontchartrain at New Orleans were between 9 and 12 ft. Simulation of the alternative ED configuration depicts the maximum water level occurring seaward of the non-overtopping levees. For areas seaward of the non-overtopping levee within Lake Borgne, maximum water levels are approximately 30 ft. The effects of the alternative ED levee are predicted to be felt as far east as Gulfport, MS, where surge levels increase less than one foot due to levee implementation. In regards to surge reductions within Lake Ponchartrain, alternative ED is comparable to alternative

EA. Alternative ED is unique in that it provides dramatic reductions within Lake Saint Catherine and portions of Lake Borgne, whereas alternative EA increases levels in these areas. Figure A.4-8 depicts maximum wave height differences for alternative ED. Wave heights seaward of the full closure levee dividing lake Ponchartrain and Lake Borgne are predicted to increase up to approximately 2 ft. Wave heights in the Caenarvon area are expected to increase by less than 1 ft.

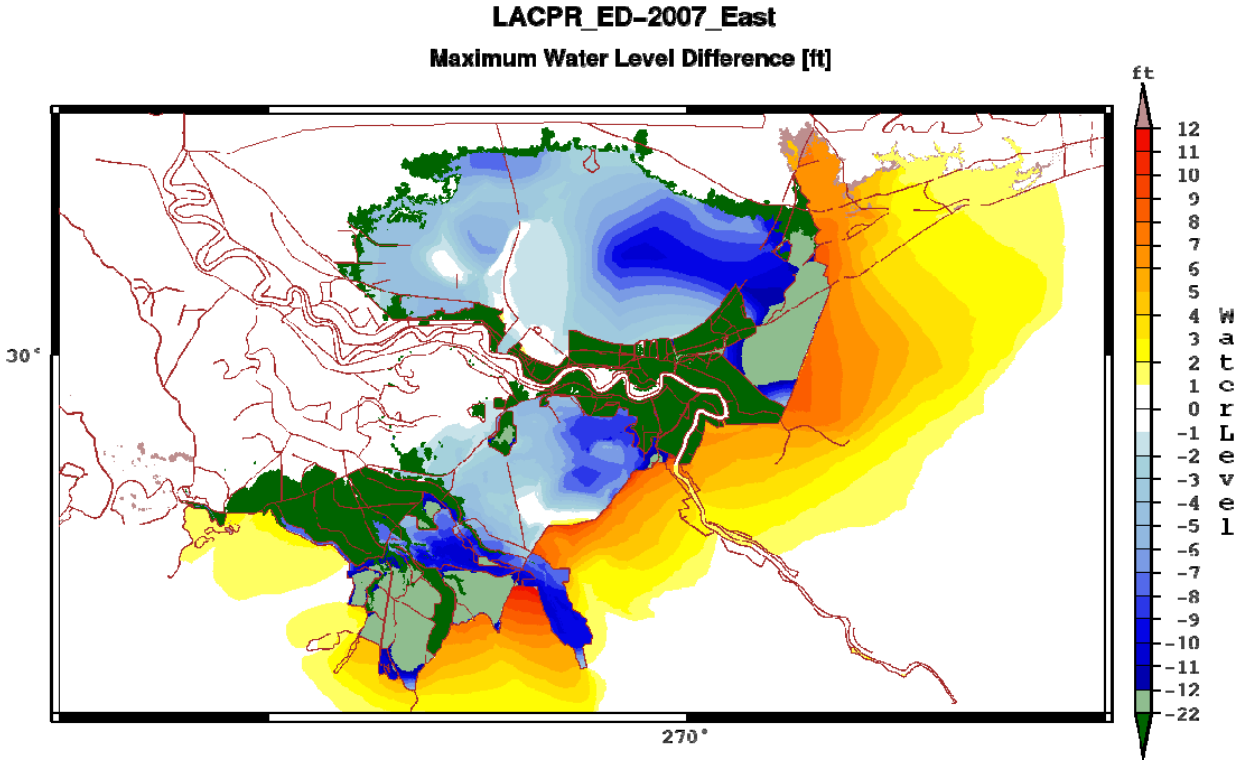


Figure A.4-7. Difference in maximum surge level between alternative ED and the base case for the ED storm suite.

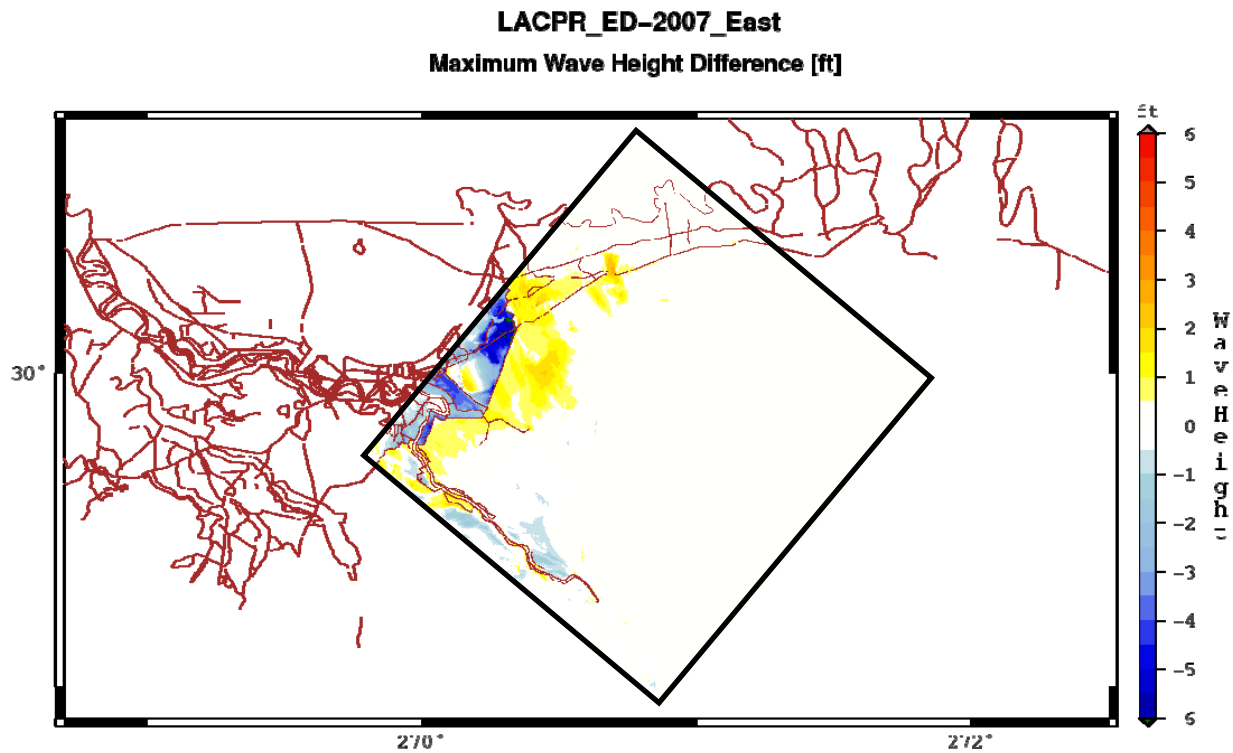


Figure A.4-8. Difference in maximum wave height (ft) between alternative ED and the base case for the ED storm suite for the southeast STWAVE grid.

A.5 Plaquemines

This section documents the results of the study that explored the influences of the lower Plaquemines Parish levee system on storm surge. The height of the levee system range from 16 to 18 ft, the natural floodplains of the Mississippi range from 3 to 8 ft. From Jesuit Bend, the levee system has a length of 24 mi on the eastside and 57 mi on the westside of the river. The total length of the delta is 81 mi from Jesuit Bend to the birds-foot. A suite of 18 hypothetical storms were simulated in order to evaluate three different configurations of the levee system: One represents the 2007 base case and serves as the reference case; the second, Plaquemines 1, introduces three spillways across the levee system with a total length of 9.5 mi; and the last one, Plaquemines 2, represents the situation of having no levees along the delta, 57 mi of levees has been removed.

A.5.1 Plaquemines 1

The purpose of the spillways is to provide a hydrodynamic connection between the west- and eastside of the delta, which should result in reduced surge levels on the upwind side of the delta. Figure A.5-1 shows the difference in peak values between Plaquemines 1 and the 2007 base case. The spillways reduce the maximum water levels 1 to 2 ft on the northeastern part of the delta, around the first spillway. At Pointe a la Hache, at the second spillway, the maximum reduction in peak water levels is about 2 ft. On the westside of the delta, around Barataria, maximum surge levels are increased 1 to 2 ft. Changes in maximum water levels due to the spillways only occur

along the delta. Surge that propagates upriver spills out through the northern spillway, reducing the surge that propagates to New Orleans. Figure A.5-2 shows the difference in maximum wave heights between Plaquemines 1 and the 2007 base case. Waves are predicted to locally increase by less than 3 ft at the spillways while there are some small decreases in waves east of the spillways.

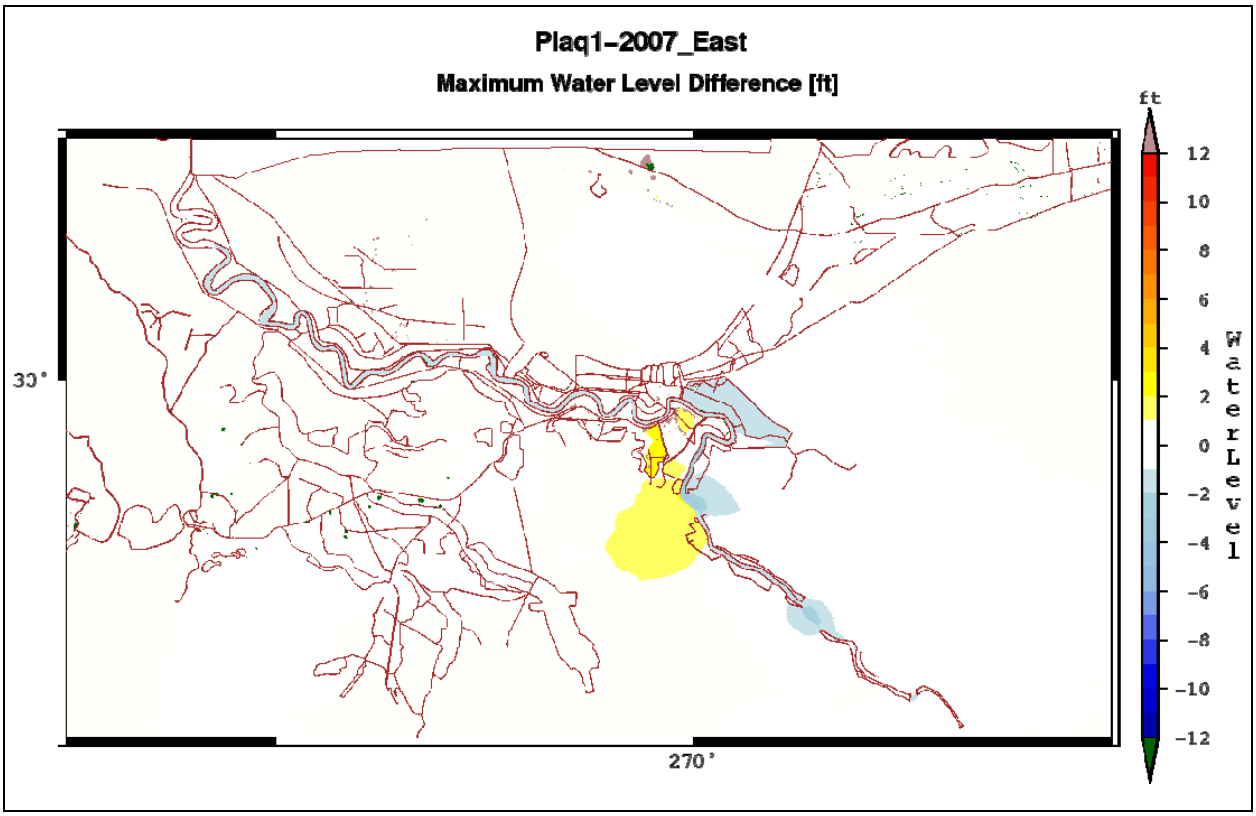


Figure A.5-1. Difference in maximum surge level between Plaquemines 1 and the base case for the Plaquemines storm suite.

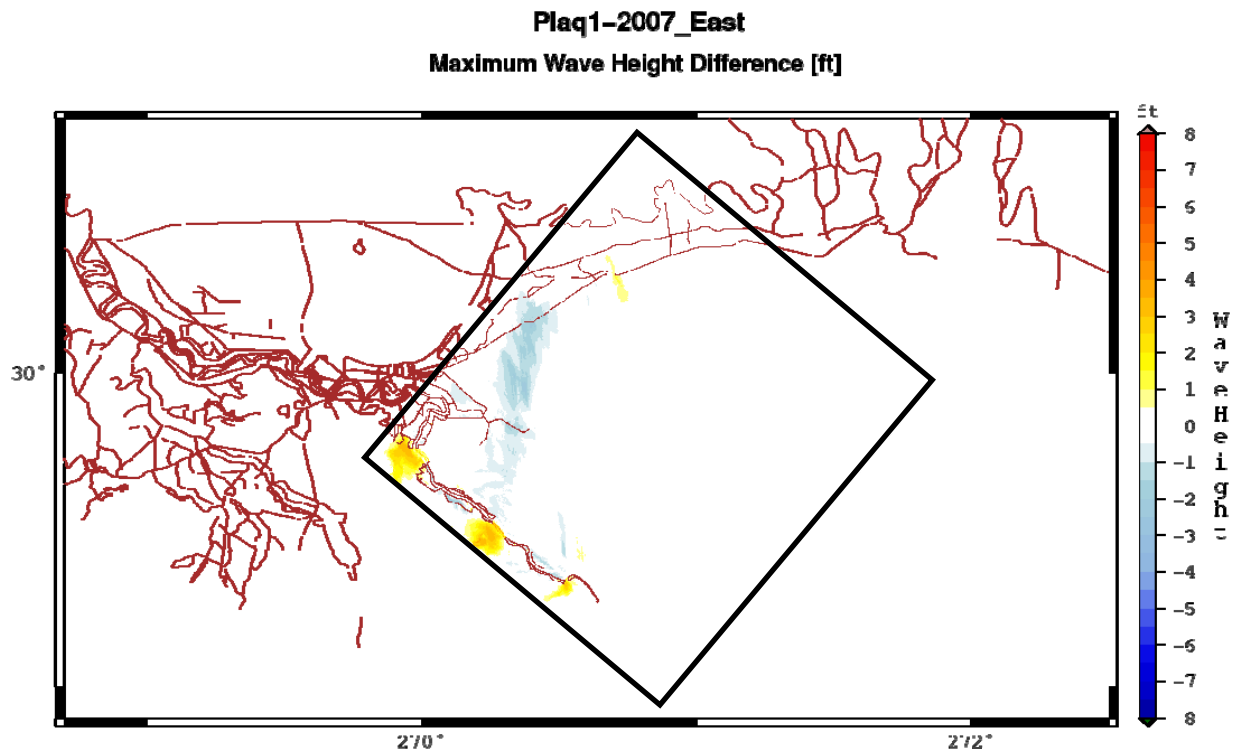


Figure A.5-2. Difference in maximum wave height (ft) between Plaquemines 1 and the base case for the Plaquemines storm suite for the southeast STWAVE grid.

A.5.2 Plaquemines 2

The configuration without having levees along the delta provides an upper limit in creating a hydrodynamic connection between the west- and eastside of the delta and represents a more natural system as well. Figure A.4-3 plots the difference in peak values between Plaquemines 2 and the 2007 base case. Completely removing levees reduces the maximum flood levels 3-8 ft along the levees of St. Bernard and Plaquemines Parish. The flood levels increase less than 1 ft at Barataria, on the westside of the delta, less than in the case with spillways. Surge that propagates upriver towards New Orleans is reduced due to the surge that propagates across the delta; and because the surge moving up the river spills out before reaching Jesuit Bend. Figure A.5-4 shows the difference in maximum wave heights between Plaquemines 2 and the 2007 base case. Waves are predicted to decrease 2 to 3 ft along the levees of St. Bernard and Plaquemines Parish as well as in the Caenarvon and Biloxi Marsh areas. Waves on the east bank of the river are predicted to decrease up to 6 ft.

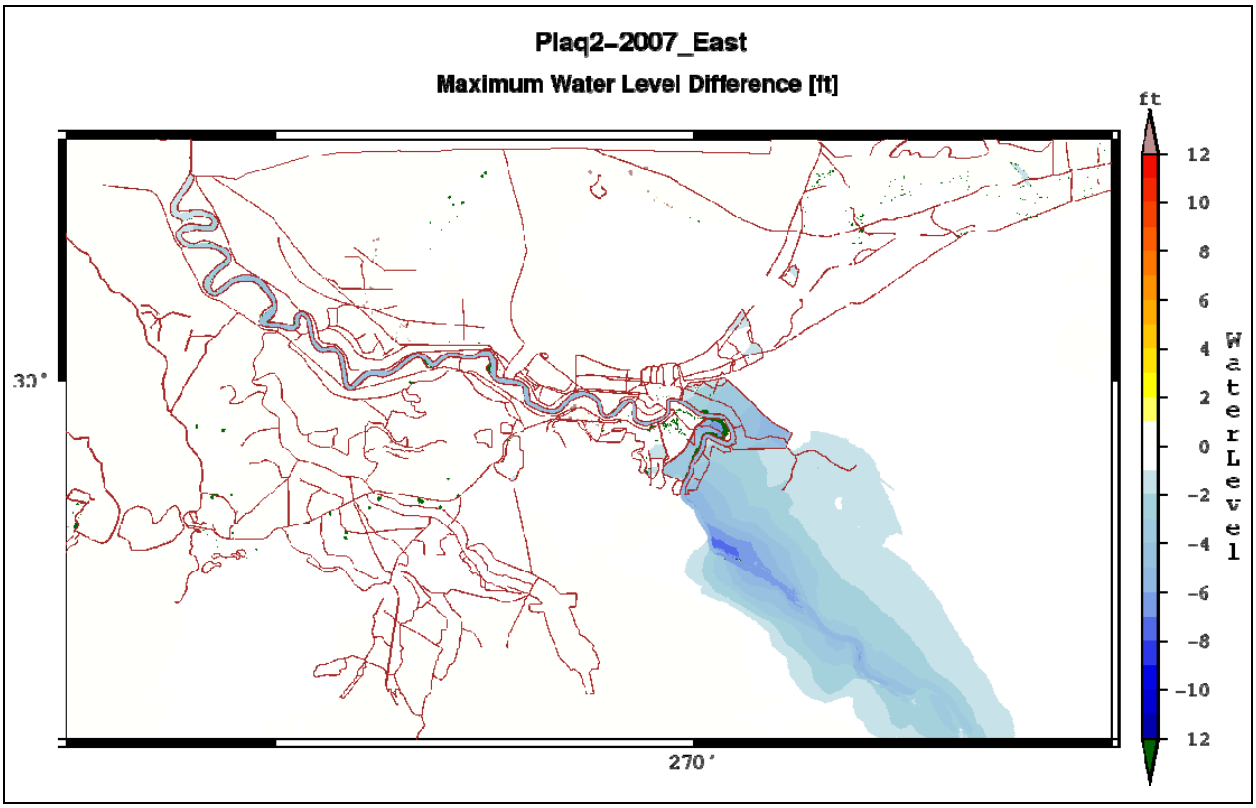


Figure A.5-3. Difference in maximum surge level between Plaquemines 2 and the 2007 base case for the Plaquemines storm suite.

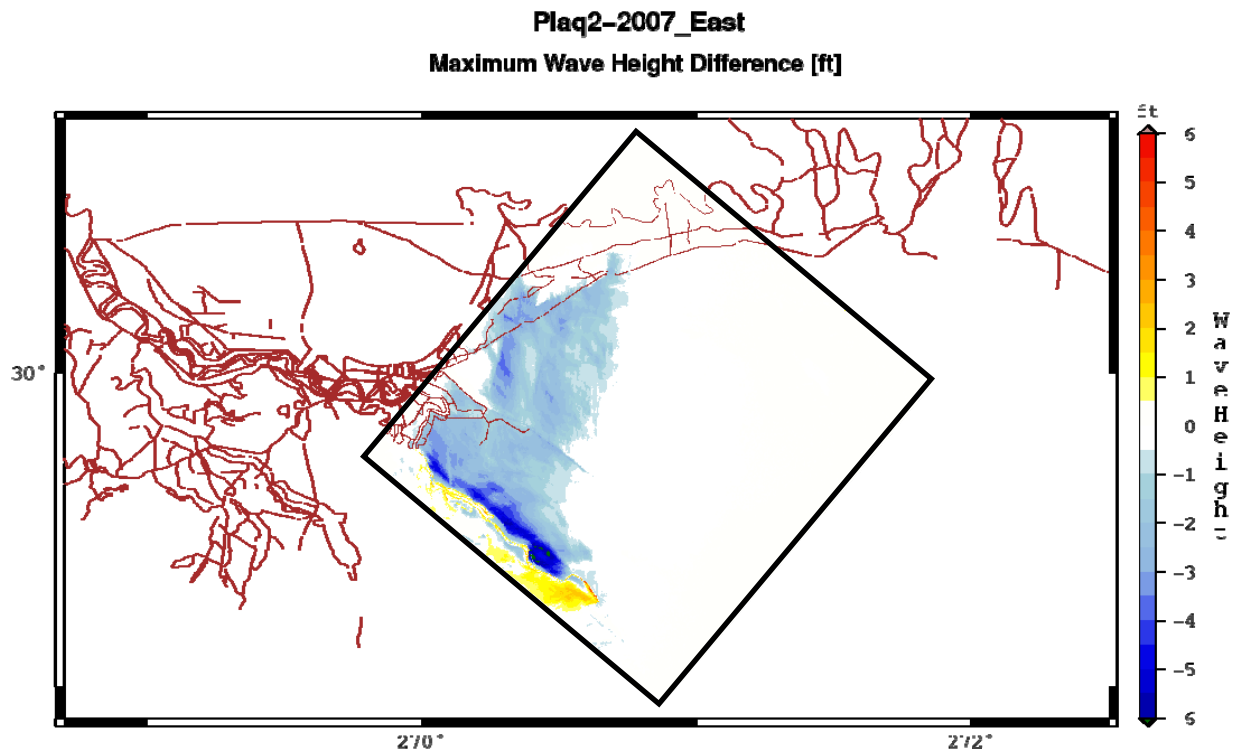


Figure A.5-4. Difference in maximum wave height (ft) between Plaquemines 2 and the base case for the Plaquemines storm suite for the southeast STWAVE grid.

A.6 Closure options for Barataria Basin

Various levee system alternatives were developed to understand the performance and implications of a variety of levee system improvements. A more detailed description and the suite of storms simulated for each alternative is provided in Volume I of this report, Background and Methodology. Two east levee configurations included closure options for the Barataria Basin. This section documents results for east alternatives EA and EB as they relate to the proposed closure of Barataria Basin.

A.6.1 Full closure (Alternative EA)

In this region, alternative EA includes the non over-topping Morganza to the Gulf levee as in the 2010 system and adds a non-overtopping levee from the west bank of the Mississippi River from Belle Chasse to Larose along the alignment of the GIWW. On the east, the closure ties into the Mississippi river levee and on the west, the closure ties into the Larose and Golden Meadow flood protection structure. The difference in the envelope of maximum water level between alternative EA and the 2007 base case is given in Figure A.4-1. The non over-topping levee effectively eliminates the propagation of the surge into the Barataria Basin where water levels in the protected region behind the levee are shown to be reduced by as much as 10 ft in some areas, including along the West Bank. However, the inclusion of the non over-topping levee across the opening of the Barataria Basin does increase water levels seaward of the structure by up to 12 ft because the hurricane wind and waves force the water to pile up against the levee structure. Water surface elevations to the west of Golden Meadow are essentially the same as in the 2010 configuration.

A.6.2 Weir closure (Alternative EB)

Alternative EB includes a lower 20 ft overtopping Morganza to the Gulf levee and in addition lowers the closure across Barataria Basin from a height not to be overtopped to 12 ft. The difference in the envelope of maximum water level between alternative EB and the 2007 base case is given in Figure A.4-3. While the weir reduces the flooding from smaller storms, it is over-topped by larger storm events. The Barataria levee does slow surge propagation northward, but the additional defenses along the west bank increase the surge in this area. Consequently, maximum surge values north of the Barataria closure are not changed much relative to the base case. However, the inclusion of the weir across the opening of Barataria Basin still stops or reduced northerly flows and therefore does increase peak water levels seaward of the weir by up to 4 ft. Surge is also amplified in this region by raising of the Mississippi river levees (see 2010 Base condition) which prevents water from escaping from west bank to the Mississippi River. Without this relief, the water piles up higher against the seaward side of the Barataria Basin levee. Since the weir in this configuration will allow over-topping, some regions immediately landward from the structure show increases in maximum surge levels as a result of the water which piles up on the landward side of the structure. The increases within the protected region are very localized. A benefit that is not revealed by the maximum plots is that many smaller storms will generate significantly less surge behind the weir compared with the base case, for instance a reduction in the 100-yr water level is expected and this is the intent of such a weir structure. Water surface elevations to the west of Golden Meadow are similar to the 2010 configuration although more flow propagates northward behind the lowered system.

A comparison of difference in the envelope of maximum water surface elevations between alternatives EA and EB reveals that Barataria Basin is significantly better protected against large events by the non-overtopping levee. Reducing the crest elevation of the levee to permit over-topping in EB results in minimal protection from large storm events, but does provide protection for storms near and below the 100-year level. On the seaward side of the levee, the higher levee of EA induces a much greater increase in maximum surge along the structure. Conversely, the lower EB weir allows relief during the larger storms that can overtop it, thus its impact seaward of the structure is not as pronounced. In summary, the EA structure is more effective at reducing surge in Barataria Basin but causes greater increase in surge on the seaward side, while the EB structure reduces surge in Barataria Basin from smaller storms.

A.7 West Alignments

Various levee system alternatives were also developed for the western part of the state. A description and the suite of storms simulated for the west and each alternative is provided in Volume I of this report, Background and Methodology. Three west levee configurations were simulated and this section documents results for west alternatives A through C.

2.7.1 2007 Base Condition

The 2007 Base condition was created to represent South Louisiana as it was projected to exist at the start of the 2007 hurricane season. Post Hurricane Katrina and Rita topographic and bathymetric conditions were used. Simulations were completed for the 152 storms for western Louisiana in order to define water levels and corresponding wave conditions. This information serves as a base condition to which alternative levee systems, marsh improvements and/or degradation, and sea level rise can be compared. Section 2.4 of Volume 1 of this report (and section A.4 of this Annex)

describes the motivation for study and changes to the physical system for each alternative inspected.

Figure A.7-1 represents the maximum surge level recorded for the West 152 storms simulated for Southeastern Louisiana. It is important to note that the displayed water levels are not stochastic representations of the 100-year or other return period water elevations, but rather are the maximum surge levels for all 152 specific storms simulated for the JPM-OS method. The highest surge levels in Louisiana occurred along the coast of Cameron Parish. Peak surge levels along the Cameron Parish levees are on the order of 24 ft. South of Lafayette, LA, peak surge levels reach approximately 21 ft. Maximum 2007 wave heights, as predicted by STWAVE simulations (Figure A.7-2), are on the order of 18 feet near the coast but break there and are greatly reduced inland.

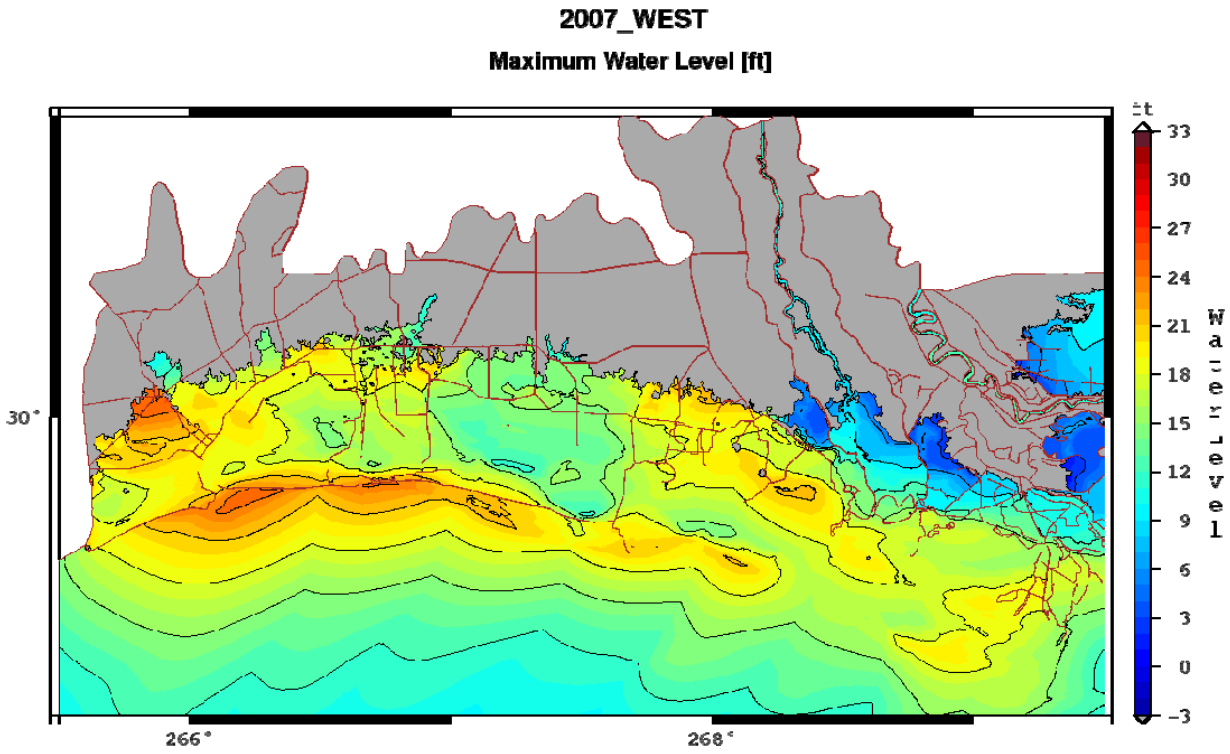


Figure A.7-1. Maximum surge level (ft) for the LAWEST 2007 base case for all West 152 storms.

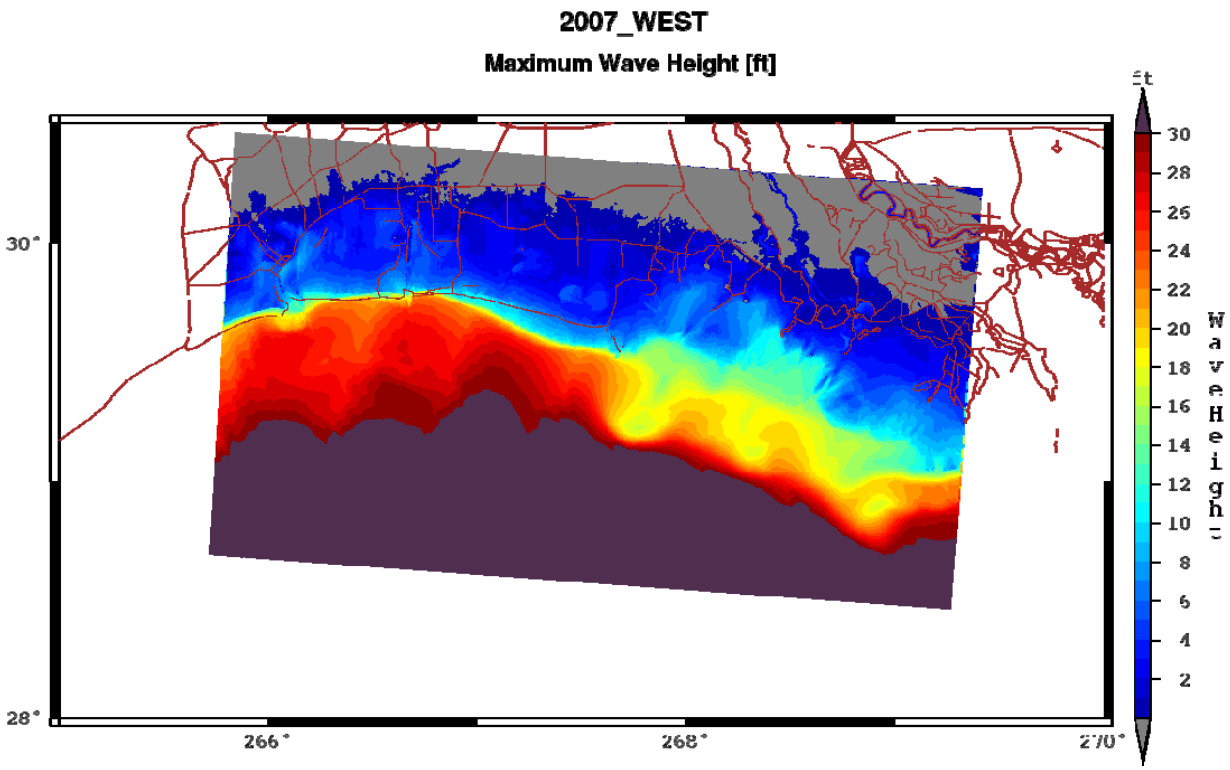


Figure A.7-2. Maximum wave height (ft) for the LAWEST 2007 base case for all 152 storms.

A.7.2 Alternative WA

Alternative WA includes a non-ovetopping levee that runs along the GIWW across all of western Louisiana from the Atchafalaya River to Vinton. West of Vinton, the levee turns north and runs to higher ground. The difference in the envelope of maximum water level between alternative WA and the 2007 base case is given in Figure A.7-3. The non over-topping levee eliminates the propagation of the surge north of the levee where water levels in the protected region behind the levee are shown to be reduced by greater than 10 ft in some areas. However, the inclusion of the non over-topping levee does increase water levels seaward of the structure by up to 6 ft because the hurricane wind and waves force the water to pile up against the levee structure. Maximum wave heights (Figure A.7-4) are reduced by 1 to 3 ft in some areas north of the proposed levee. Less than a 1 ft increase in wave height is predicted seaward of the levee.

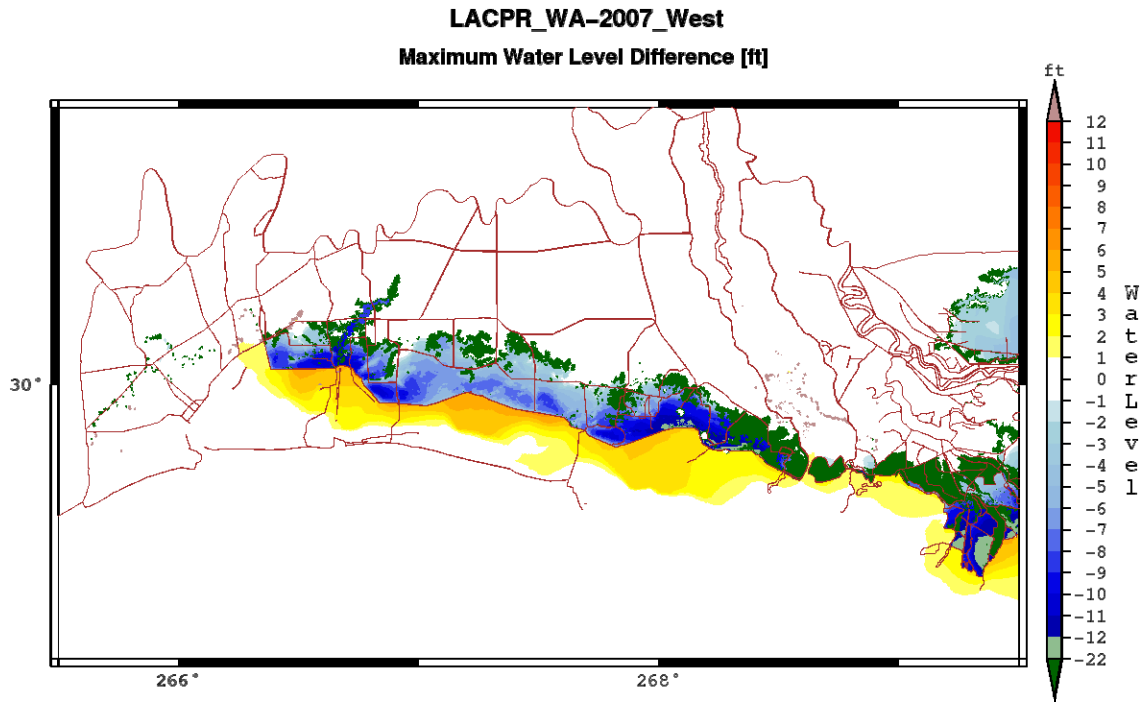


Figure A.7-3. Difference in maximum surge level between alternative WA and the LAWEST base case for the WA storm suite.

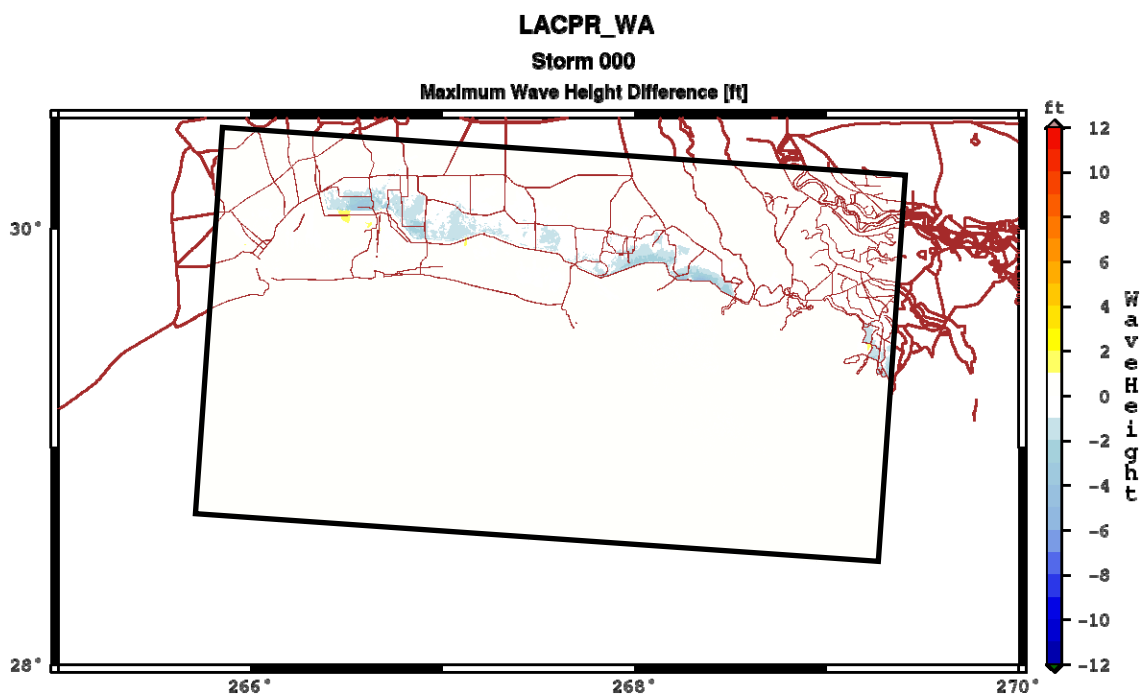


Figure A.7-4. Difference in maximum wave height (ft) between alternative WA and the LAWEST base case for the WA storm suite for the west STWAVE grid.

A.7.3 Alternative WB

Alternative WB includes a non-ovetopping levee that runs from the Atchafalaya River to Abbeyville, north of the GIWW. At Abbeyville, the levee turns north and runs west of Lafayette to higher ground. This alternative also includes small ring levees around Gueydan and Kaplan. Further to the west, a large ring levee extends from east of Lake Charles to west of Vinton protecting these areas. The difference in the envelope of maximum water level between alternative WB and the 2007 base case is given in Figure A.7-5. The non over-topping levees eliminate the propagation of the surge north of the levee where water levels in the protected region behind the levee are shown to be reduced by up to 10 ft in some areas and flooding is eliminated in many areas. The inclusion of the non over-topping levees does increase water levels seaward of the structures. Maximum wave heights (Figure A.7-6) are changed by less than 1 ft.

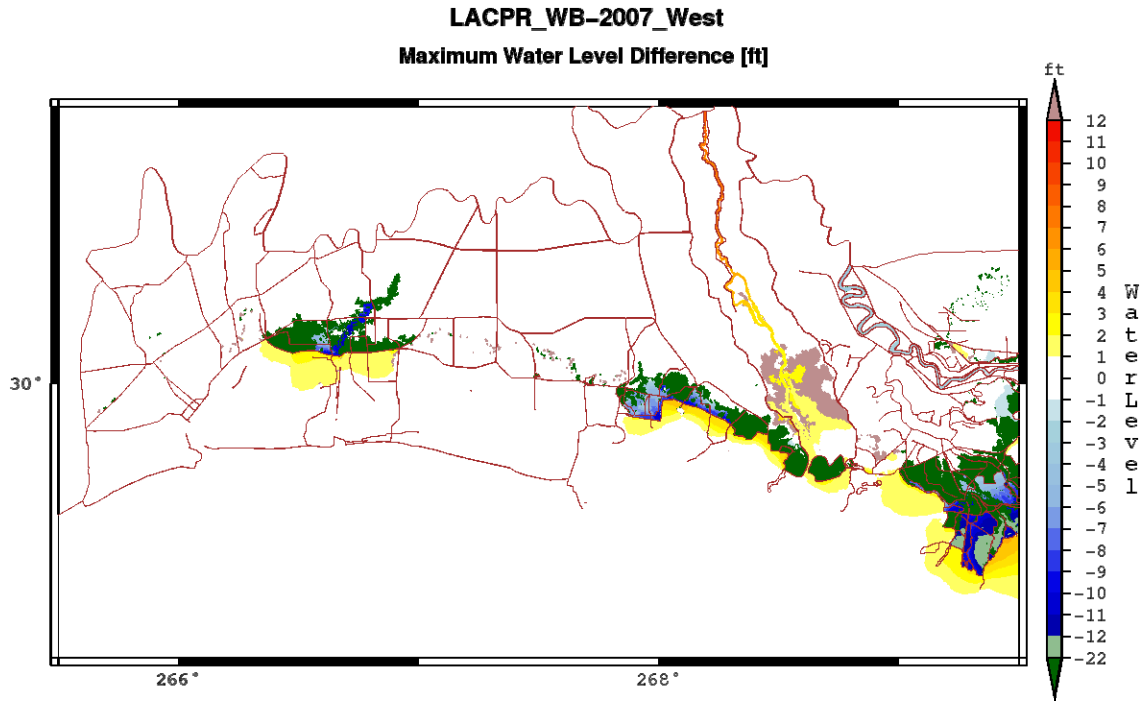


Figure A.7-5. Difference in maximum surge level between alternative WB and the LAWEST base case for the WB storm suite.

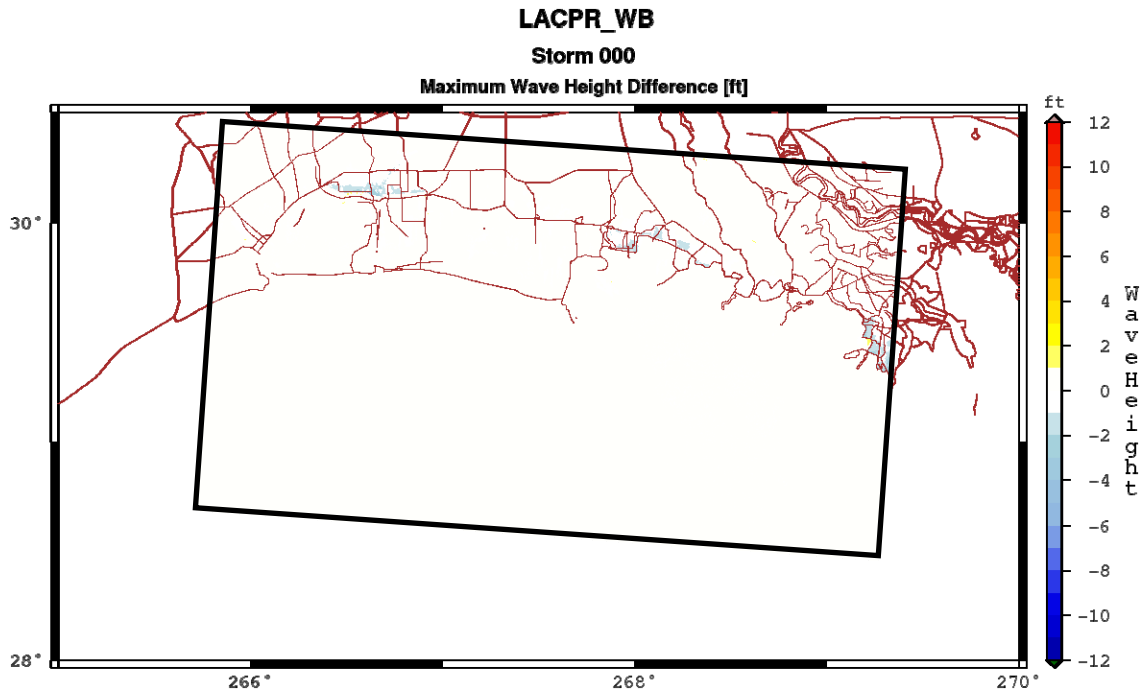


Figure A.7-6. Difference in maximum wave height (ft) between alternative WB and the LAWEST base case for the WB storm suite for the west STWAVE grid.

A.7.4 Alternative WC

Alternative WC is similar to WB except that a 100-year protection levee extends along the GIWW from Vermillion Bay to Calcasieu Lake and there are no ring levees around Gueydan and Kaplan. The difference in the envelope of maximum water level between alternative WC and the 2007 base case is given in Figure A.7-7. The results are similar to the other alternatives. The non over-topping levees eliminate the propagation of the surge north of the levee where water levels in the protected region behind the levee are shown to be reduced by up to 10 ft in some areas and flooding is eliminated in many areas. The 100-year protection levee also greatly reduces surges, with decreases from 1 to 10 ft across the protected area. The inclusion of the levees does increase water levels seaward of the structures. Maximum wave heights (Figure A.7-8) are generally changed by less than 1 ft with 1 to 2 ft reductions in some areas behind the proposed levees.

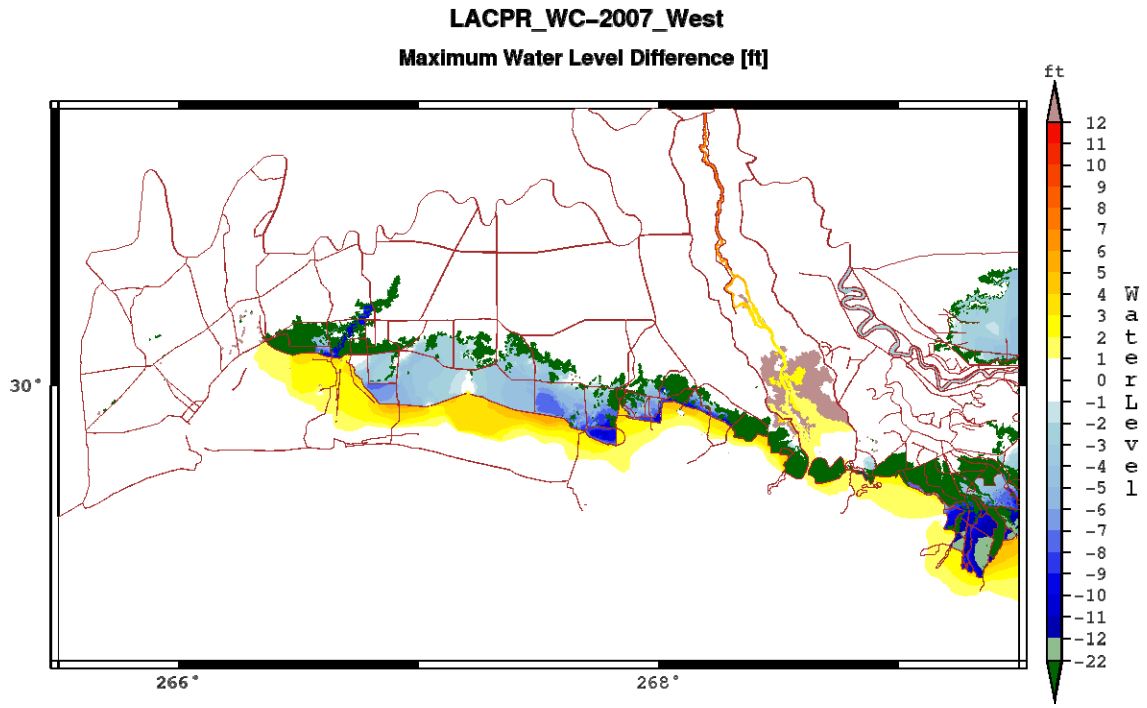


Figure A.7-7. Difference in maximum surge level between alternative WC and the LAWEST base case for the WC storm suite.

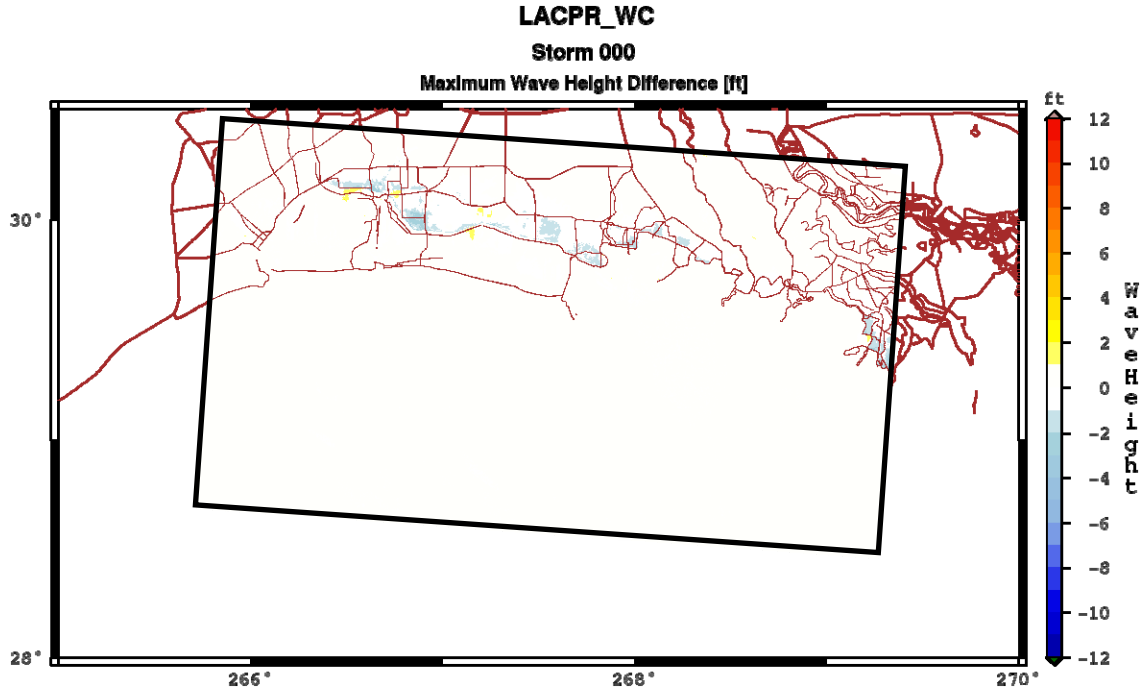


Figure A.7-8. Difference in maximum wave height (ft) between alternative WC and the LAWEST base case for the WC storm suite for the west STWAVE grid.

A.8 Future Conditions

A sensitivity analysis was performed to assess the impact of sea level rise and bathymetric and frictional resistance changes on ADCIRC-simulated peak surge elevations and STWAVE-simulated waves. Topography, landscape features, and vegetation have the potential to reduce storm surge elevations and absorb wave energy. Land elevations greater than the storm surge elevation act as a physical barrier and create bathymetric resistance for the surge and waves. Landscape features such as barrier islands also have the potential to create frictional resistance and affect storm surge and wave energy even when below the surge elevation. The influence of these features is reduced if they are lost or inundated due to sea level rise. This section is used to assess the impact of barrier island and marsh features on storm surge and wave energy at the mainland coast and to evaluate the impact of sea level rise.

A.8.1 Barrier Islands

The barrier island configurations modeled were: 1) the existing 2007 base Post-Katrina degraded condition; 2) no barrier islands with open water Manning's n value = 0.02 (BI-1); and 3) a restored barrier island configuration of 12 ft (NAVD88 2004.65) for Cat Island, Ship Island, Horn Island, Petit Bois Island, and Dauphin Island and 6 ft (NAVD88 2004.65) for the Chandeleur Islands (BI-2), 4) the existing Post-Katrina degraded condition with a forest Manning's n = 0.15 (BI-3), and 5) a restored barrier island configuration with a forest Manning's n = 0.15 (BI-4). The BI-4 configuration is identical to the restored BI-2 configuration except a Manning's n=0.15 friction has been applied to the islands to represent the increased frictional resistance associated with a forest. Results from the extreme cases, BI-1 and BI-4, are presented here.

The difference in the envelope of maximum water level between the BI-1 configuration and the 2007 base case can been seen in Figure A.8-1. The largest increase in surge seen by the removal of the barrier islands is approximately 1.7 ft in Chandeleur Sound. Outside of Chandeleur Sound, the surge increases less than a foot nearly everywhere when compared to the 2007 base case. Lake Borgne demonstrates a rise in surge of approximately 0.7 ft. The removal of the barrier islands also increases surge by as much as 1.5 ft in the Bay St. Louis, MS area. The maximum wave height differences predicted for the BI-1 configuration can be seen in Figure A.8-2. Maximum wave heights are expected to increase outside of the east New Orleans levee system up to 2 feet near Caenarvon and the IHNC/MRGO funnel. Maximum wave heights are predicted to increase by as much as 3 ft in the Bay St. Louis, MS area. The largest increase in maximum wave heights (greater than 8 ft) is observed immediately landward of the barrier islands.

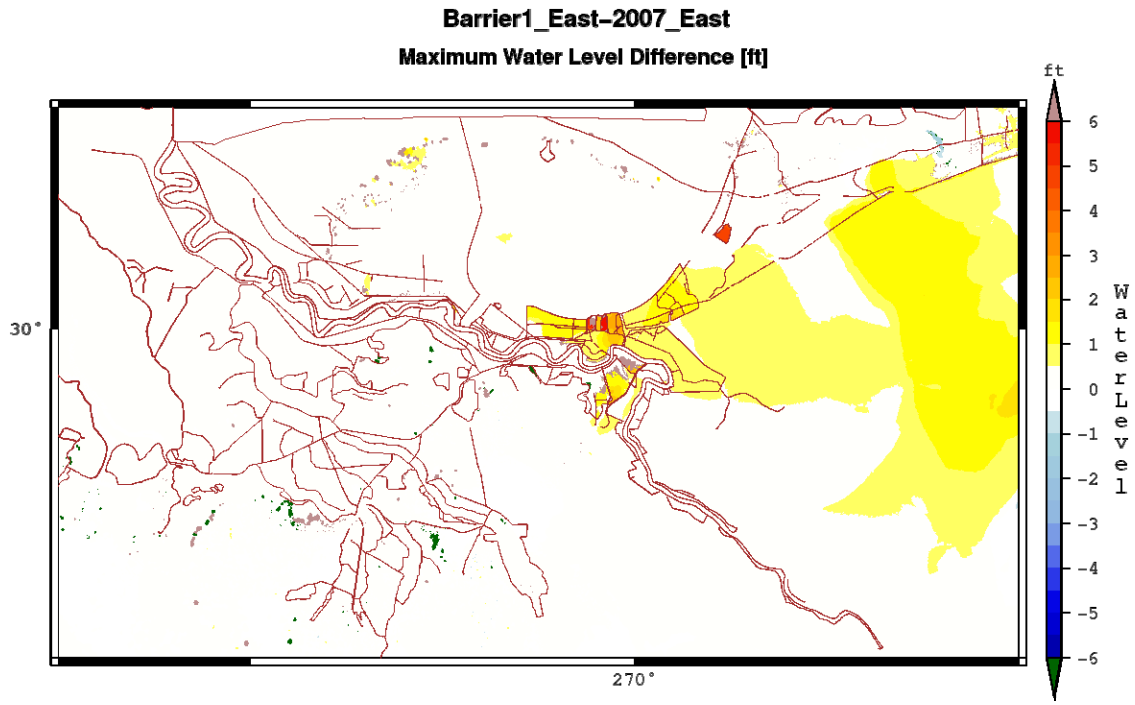


Figure A.8-1. Difference in maximum surge level (ft) between the BI-1 configuration and the base case for the Barrier Islands storm suite.

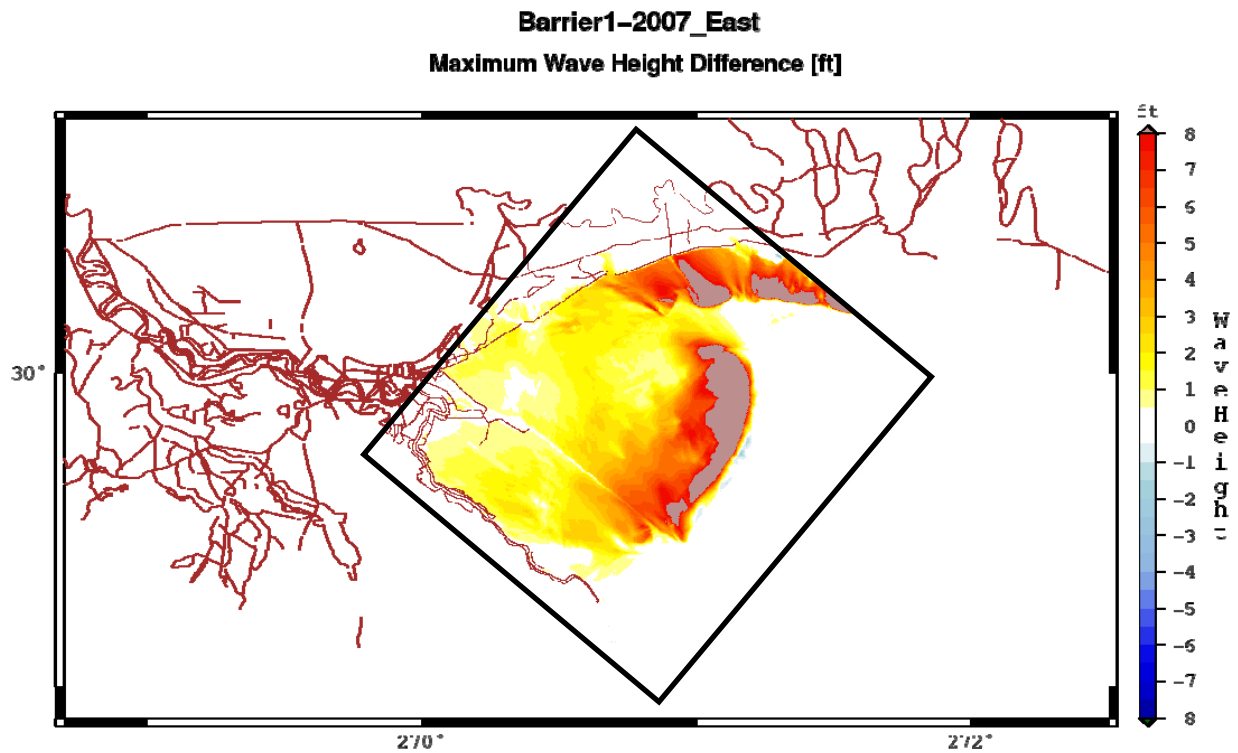


Figure A.8-2. Difference in maximum wave height (ft) between BI-1 and the base case for the Barrier Islands storm suite for the southeast STWAVE grid.

Figure A.8-3 is the difference in the envelope of maximum water level between the BI-4 configuration and the 2007 base case. The figure demonstrates the potential effects of the restored barrier islands configuration with reductions in maximum surge generally 2 ft or less at the levees when compared to the 2007 base case. There is less than 1 ft decrease in surge in Lake Pontchartrain. The restored barrier islands also decrease surge by approximately 2 ft in the Bay St. Louis, MS area. The surge in Chandeleur Sound just behind the island is reduced by as much as 6 ft with for this restoration scenario, but the reduction is less than one foot at the Plaquemines and St. Bernard levees. Figure A.8-4 shows the maximum wave height differences for the BI-4 configuration. Maximum wave heights are expected to decrease outside of the east New Orleans levee system, as predicted by STWAVE simulations, up to 2 feet near Caenarvon and 1 ft near the IHNC/MRGO funnel. Maximum wave heights are predicted to decrease by as much as 1.5 ft in the Bay St. Louis, MS area. The largest decrease in maximum wave heights (greater than 6 ft) is observed immediately landward of the barrier islands. Wave energy dissipates as a result of the restored islands and reduces the landward maximum wave heights when compared to the BI-1 and base configurations.

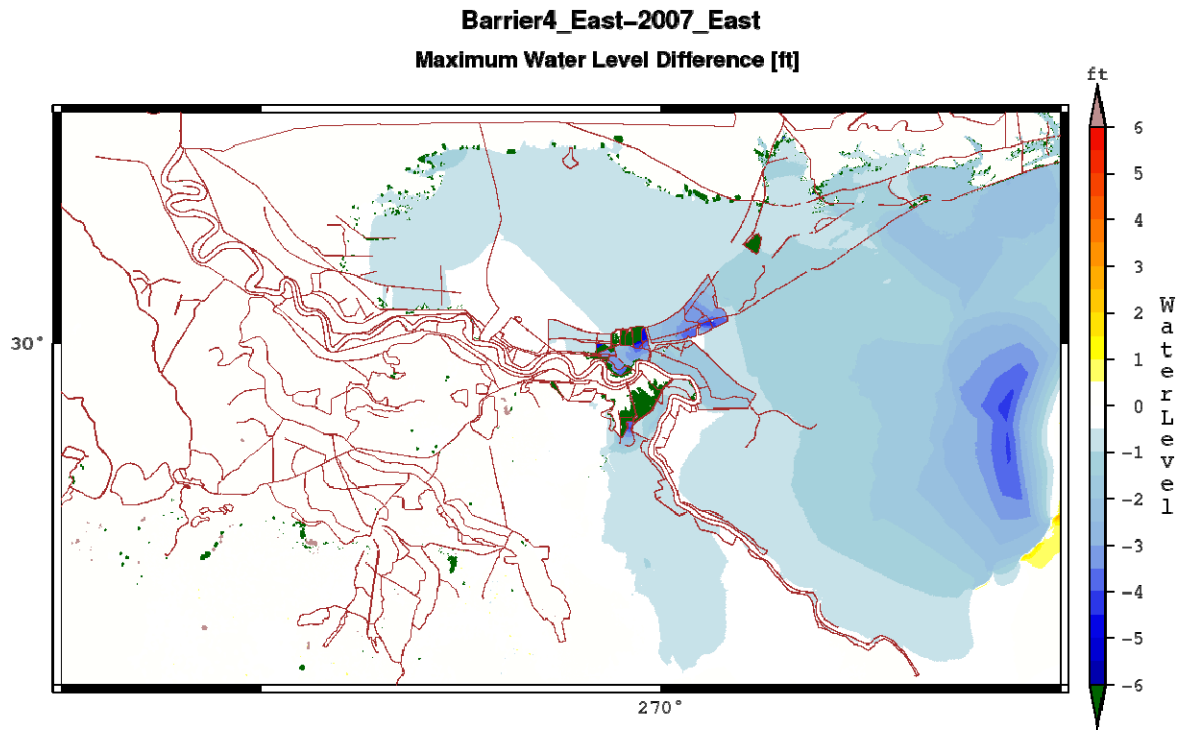


Figure A.8-3. Difference in maximum surge level (ft) between the BI-4 configuration and the base case for the Barrier Islands storm suite.

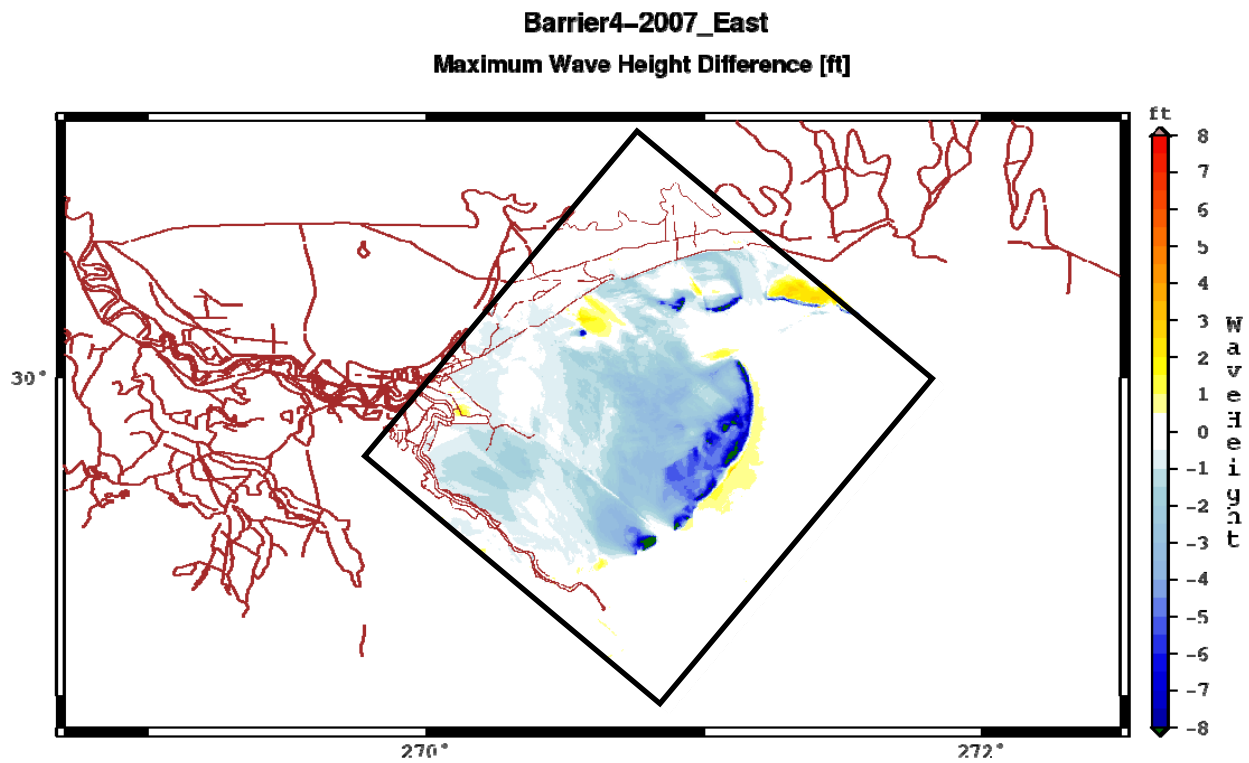


Figure A.8-4. Difference in maximum wave height (ft) between BI-4 and the base case for the Barrier Islands storm suite for the southeast STWAVE grid.

The model results indicate that the barrier islands provide some level of protection as a first line of defense. In general, raising the barrier islands caused a decrease in peak water level and wave energy landward of the barrier islands when compared to the peak water level and wave energy for the baseline 2007 Post-Katrina configuration. Degradation of the barrier islands caused a minimal increase in maximum surge level landward of Chandeleur Sound and increased waves at the hurricane protection system. With less obstruction in the Chandeleur Sound, the modeled wave heights increase, thus heightening the potential for overtopping of levees and inundation of protection areas.

A.8.2 Marsh Alternatives

The marsh alternatives included a predicted wetland definition 50 years into the future with no increased action (NIA) taken and a restored/improved marsh condition. The NIA condition was developed as part of the Coastal Louisiana Ecosystem Assessment and Restoration (CLEAR) Program. The forecasting model developed by CLEAR predicts physical processes, geomorphic features, water quality, and ecological succession. Geomorphic/bathymetric changes are based on the likelihood of discretized regions changing from open water to marsh or marsh to open water. The future condition of Coastal Louisiana predicted by CLEAR, referred to as the degraded condition, in fact does predict degradation in Southern Louisiana, but also predicts growth in the Atchafalaya basin and Breton Sound. The CLEAR future condition bathymetry was applied to the model grids and mesh and a series of storm simulations was made. Figure A.8-5 identifies the CLEAR/NIA landscape changes. Figure A.8-6 is the difference in the envelope of maximum water level between the CLEAR marsh configuration and the 2007 base case for areas to the west and the 2010 base case for the West Bank and areas east of the river. Comparison to two grids is required to isolate the impact of the wetland degradation. The degraded wetlands were incorporated into the

2010 base grid with the Morganza to the Gulf levee removed. For this reason, areas to the west were compared to 2007 which also did not incorporate the Morganza to the Gulf levee. White areas experienced less than 1 ft of increase or decrease. There is a widespread increase in surge up to 6 ft across most of the degraded areas shown in Figure A.8-6a. The surge is increased by 1-3 ft in the Lake Maurepas region, 1-6 ft in St. John/St. Charles Parishes, and 1-3 ft east of Morgan City. Less than 1 ft change in surge occurs east of the MS River and surges are increased at the West Bank 1-2 ft. Figure A.8-7 shows the maximum wave heights differences for the restored configuration. Seaward of the east New Orleans levee system, waves are expected to increase by as much as 2 ft. Maximum wave heights are also expected to increase by up to 2 ft in the Crown Point vicinity. Note that the wave height differences west of the MRGO in St. Bernard Parish are consistent with the differences observed for the 2010 vs 2007 configurations, i.e. the CLEAR/NIA bathymetry is based on the 2010 grid so the predicted differences are due to the increased 2010 levee heights and not a result of the degraded marsh conditions.

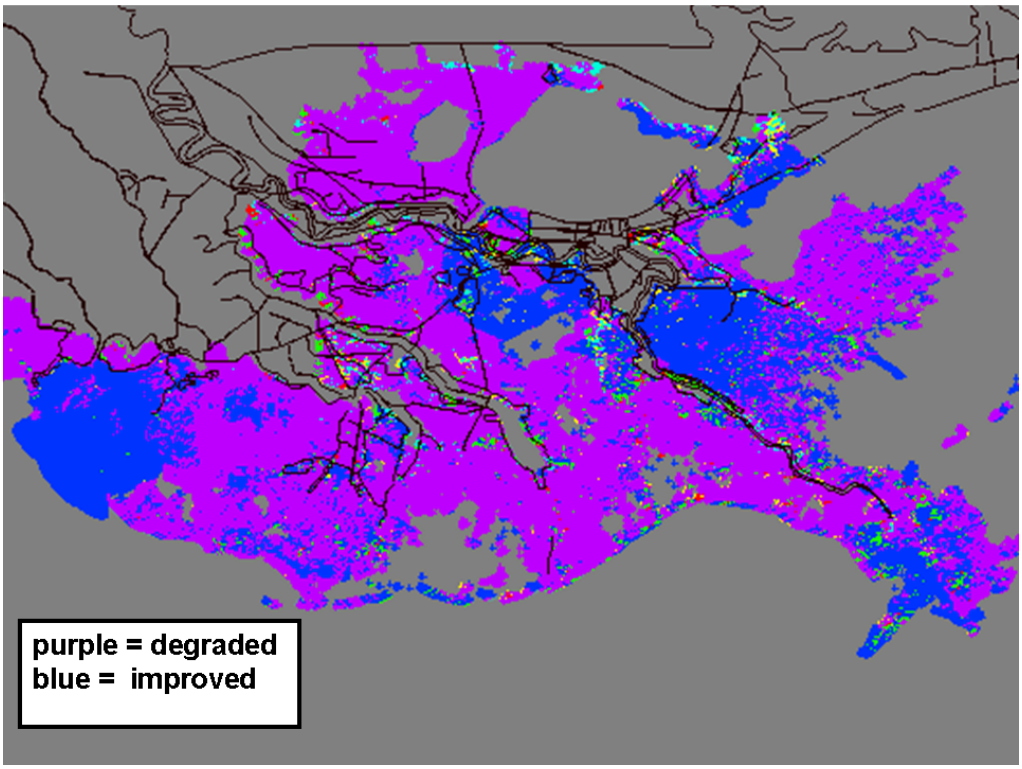


Figure A.8-5. Outline of CLEAR/NIA landscape changes.

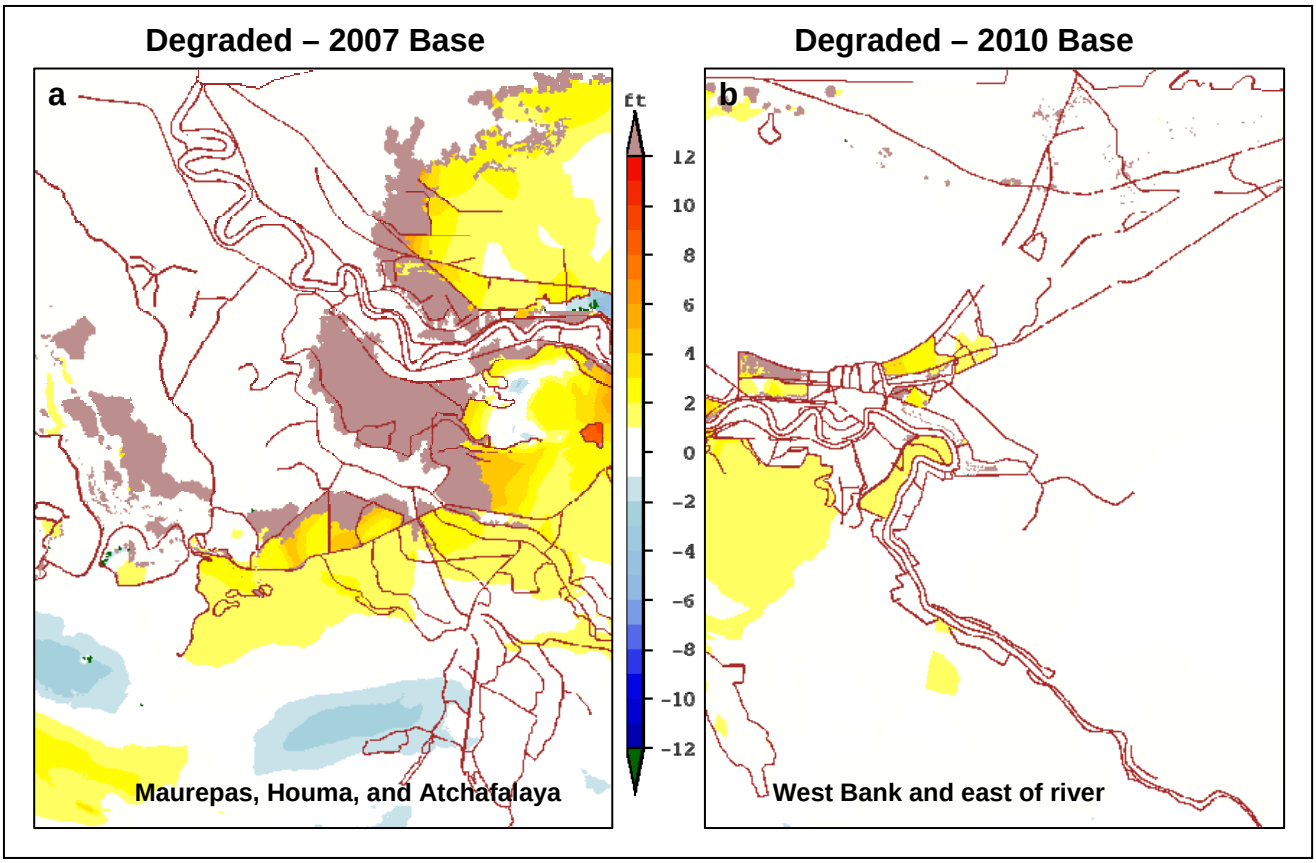


Figure A.8-6. Difference in maximum surge level (ft) between the CLEAR/NIA configuration and the 2007 and 2010 base cases for the NIA marsh storm suite.

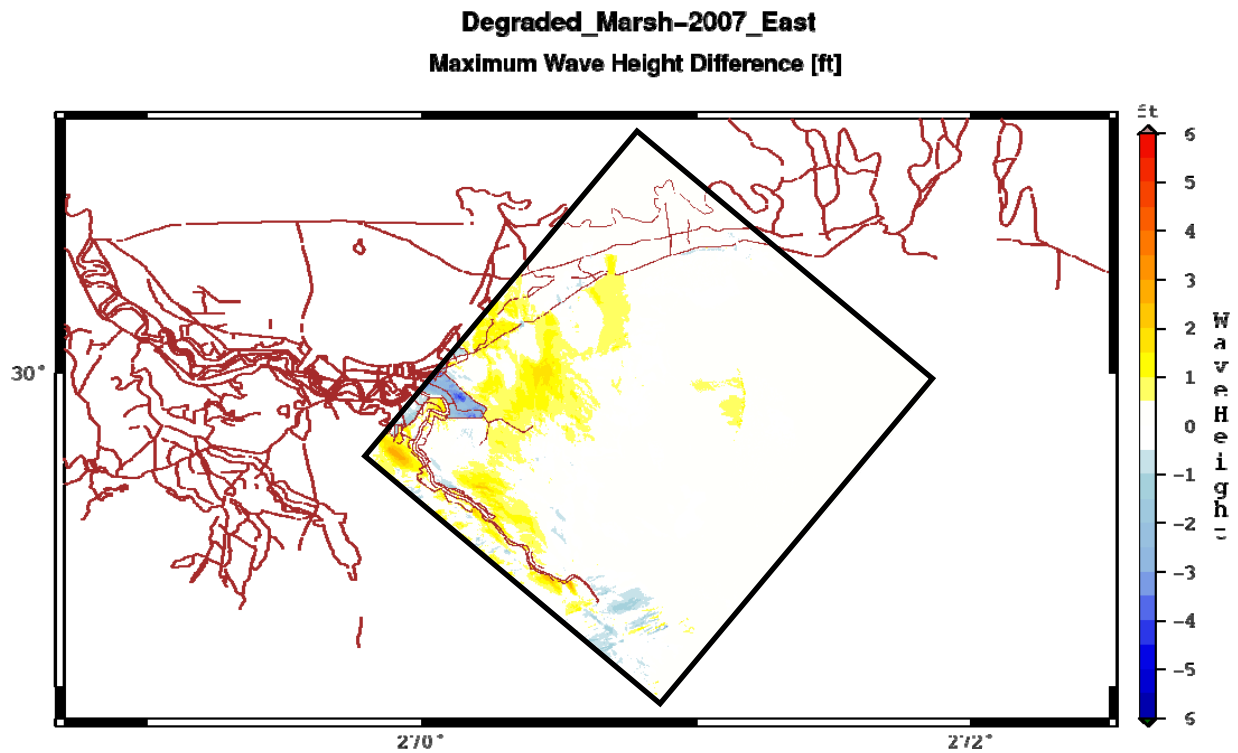


Figure A.8-7. Difference in maximum wave height (ft) between the CLEAR/NIA configuration and the base case for the NIA marsh storm suite for the southeast STWAVE grid.

The restored condition was developed by ERDC-CHL under the direction of the New Orleans District's improved action plan. The District provided CHL with marsh creation locations and type (i.e. freshwater, cypress swamp, saline, etc), freshwater diversion locations, and the volume of sediment diverted. CHL implemented these restoration features into a marsh creation program and modifications were made to the bathymetry, Manning's n values, and directional roughness lengths. These changes were applied to the model grids, mesh, and frictional files and a series of storm simulations was made. Figure A.8-8 shows an outline of the marsh restoration features for eastern Louisiana. Figure A.8-9 is the difference in the envelope of maximum water level between the restored marsh configuration and the 2007 base case and the 2010 base case. As with the degraded case, comparison to two grids is required to isolate the impact of the wetland restoration. There is a reduction in surge west of the MS River bounded by Golden Meadow on the east and mid-Terrebone Parish on the west ranging from 1-3 ft with the largest reduction (greater than 2 ft) east of the Houma Navigation Canal and south of Route 24. This region of attenuated surge corresponds with an area that has many restoration features. There is also an area of 1-3 ft surge reduction on the West Bank east of the GIWW. Less than 1 ft change in maximum surge occurs east of the MS River. Figure A.8-10 shows the maximum wave height differences for the restored configuration. Seaward of the east New Orleans levee system, the waves are not expected to change. Note that the wave height differences west of the MRGO in St. Bernard Parish are generally consistent with the differences observed for the 2010 vs 2007 configurations, i.e. the restored bathymetry is based on the 2010 grid so the predicted differences are likely due to the increased 2010 levee heights and not a result of the restored marsh conditions.

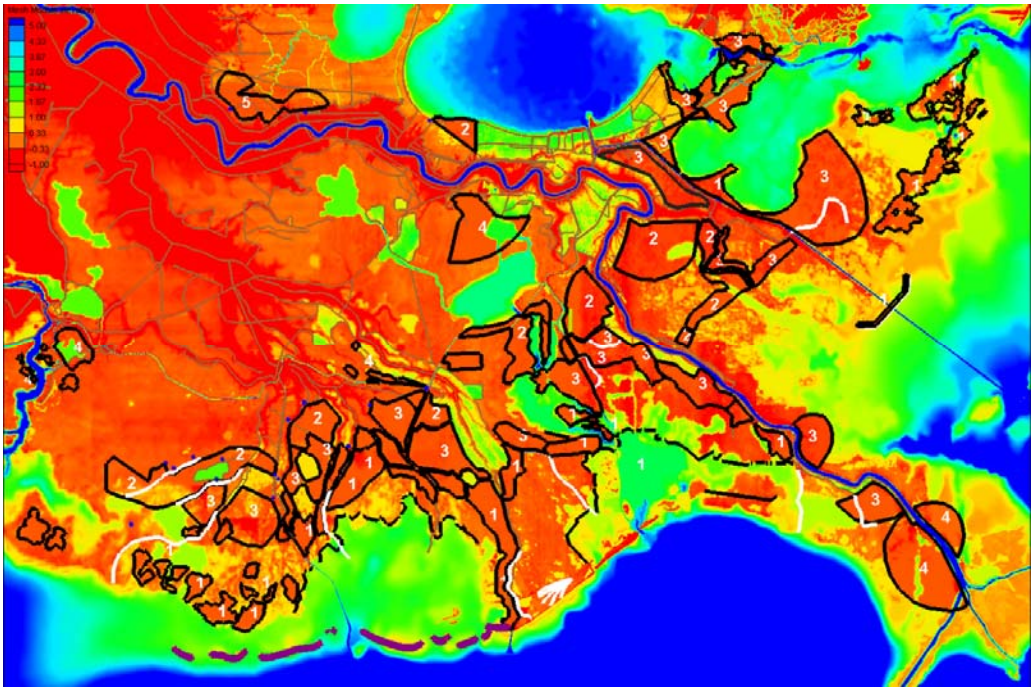


Figure A.8-8. Outline of marsh restoration features. Marsh types are outlined as follows: 1 = saline, 2 = intermediate, 3 = brackish, 4 = fresh, 5 = cypress, white lines = ridges, purple = shrub/scrub for barrier islands.

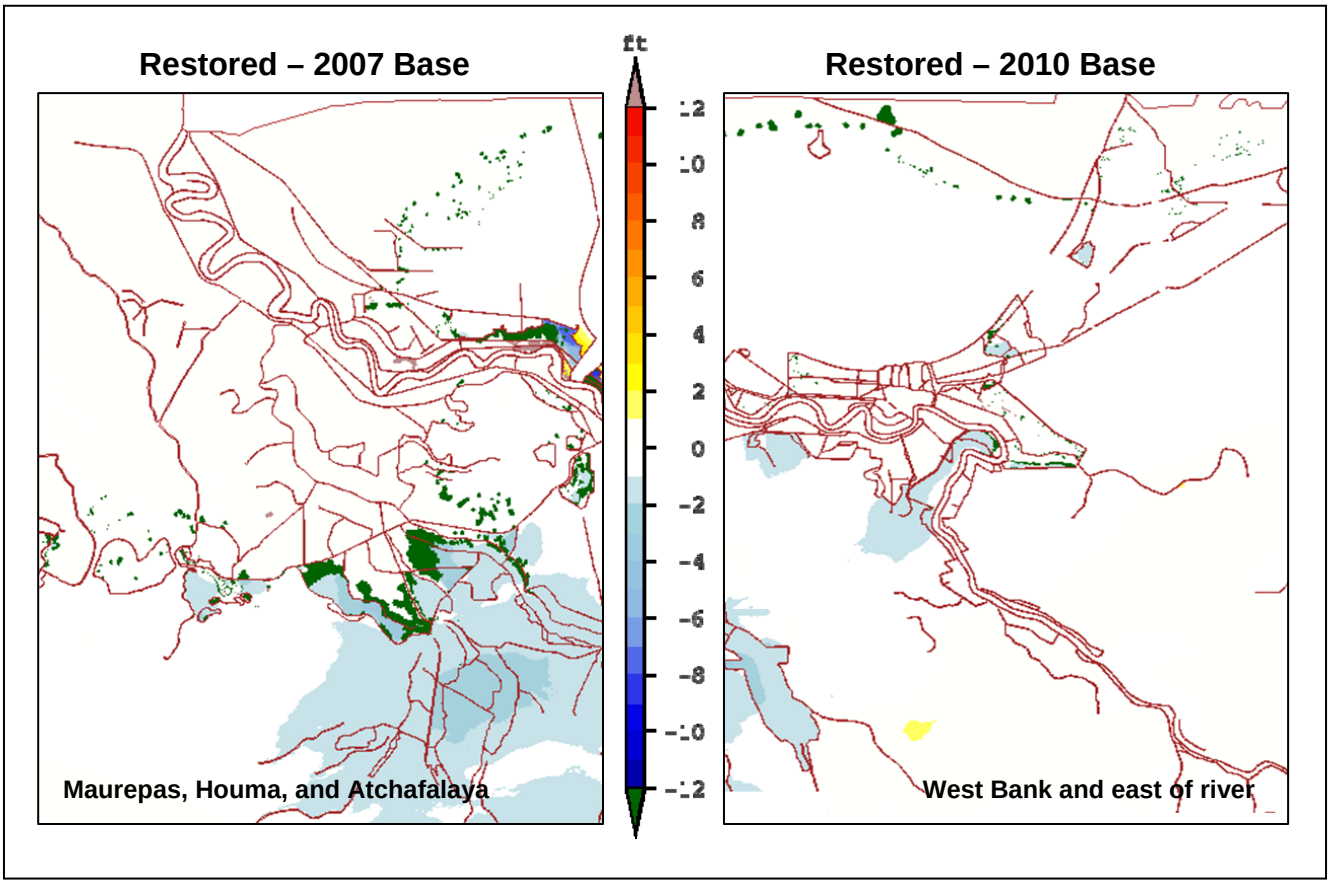


Figure A.8-9. Difference in maximum surge level (ft) between the restored marsh configuration and the 2007 and 2010 base cases for the restored marsh storm suite.

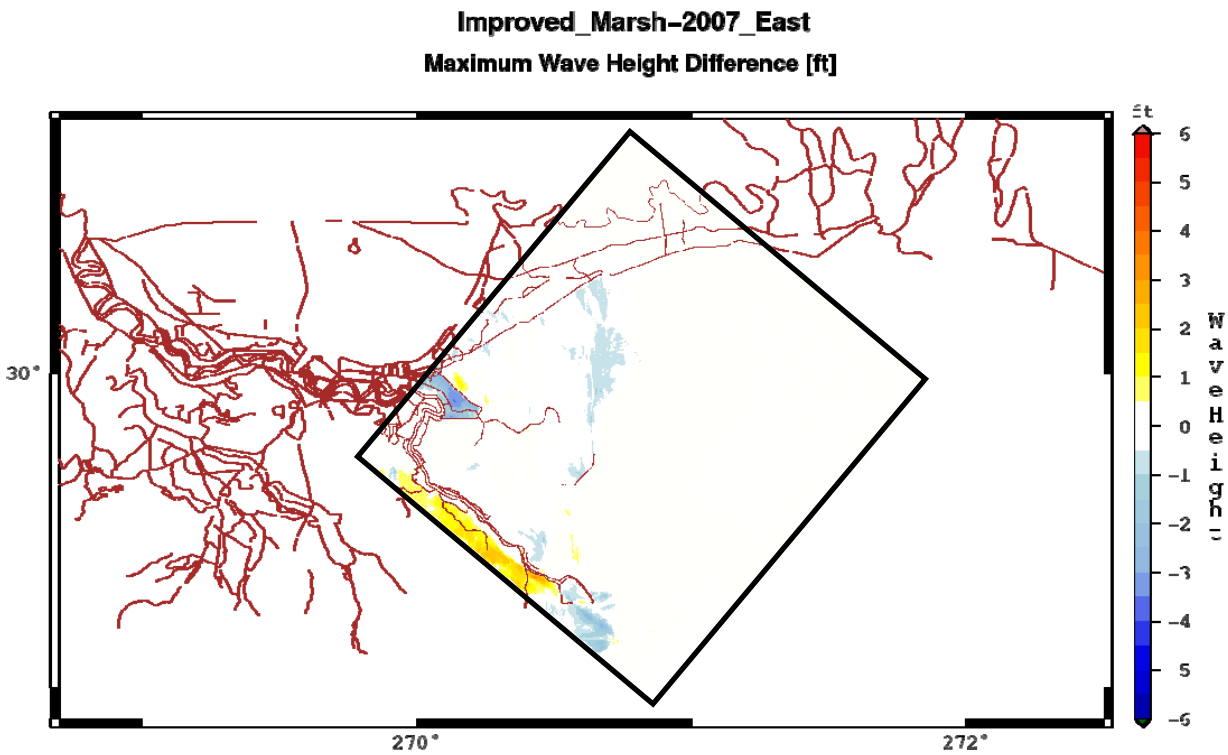


Figure A.8-10. Difference in maximum wave height (ft) between the restored marsh configuration and the base case for the restored marsh storm suite for the southeast STWAVE grid.

A.8.2.1 Marsh Alternatives for LAWEST

The improved marsh scenario for western Louisiana changed maximum surge levels and wave heights by less than 1 ft. See Figures A.8-11 and A.8-12.

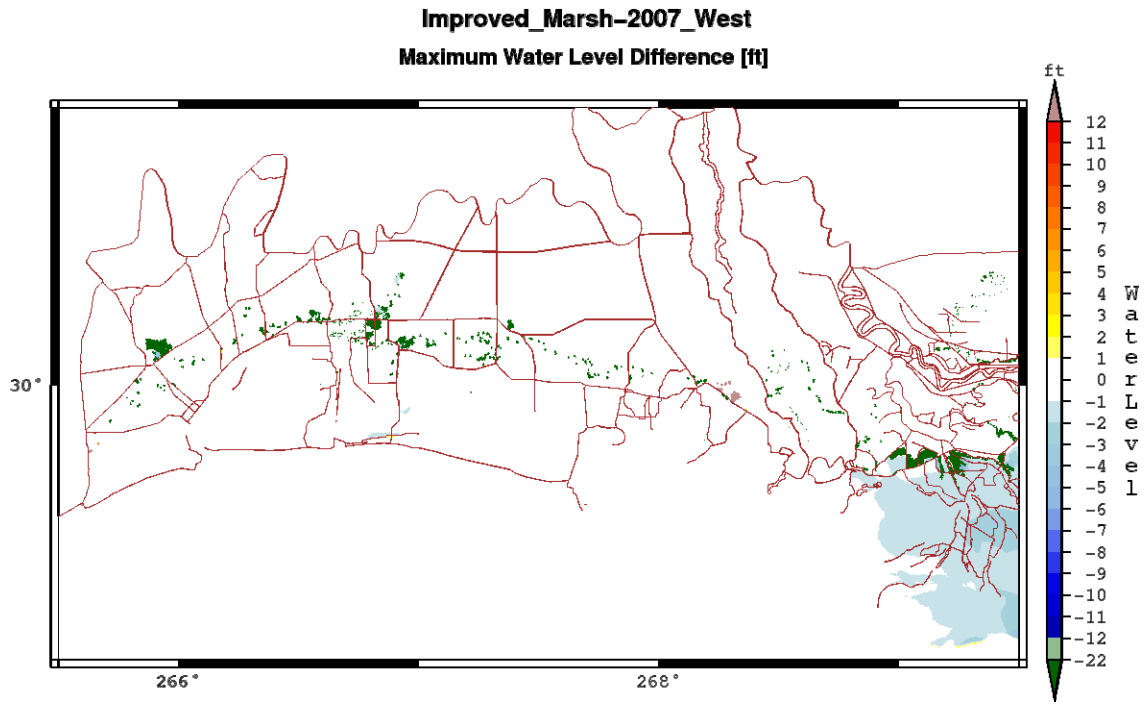


Figure A.8-11. Difference in maximum surge level (ft) between the restored marsh configuration and the LAWEST base cases for the LAWEST restored marsh storm suite.

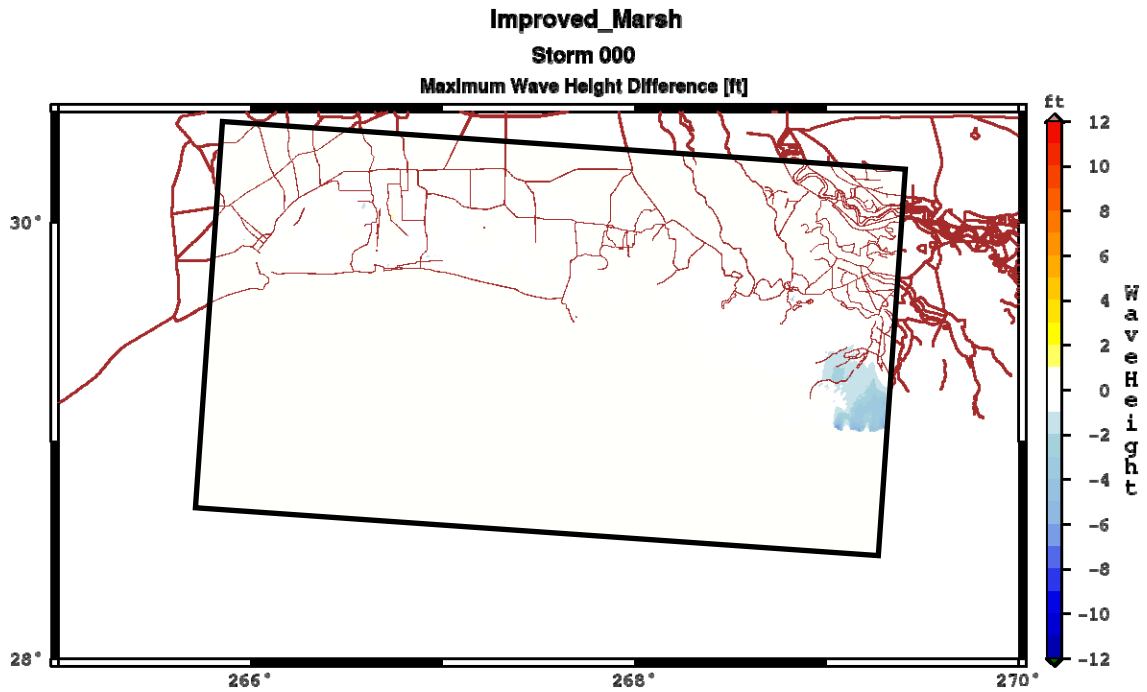


Figure A.8-12. Difference in maximum wave height (ft) between the restored marsh configuration and the LAWEST base case for the LAWEST restored marsh storm suite for the west STWAVE grid.

The impact of the future degraded landscape on peak surge levels and wave heights are given in Figures A.8-13 and A.8-14. The degraded landscape generally results in 1 to 2 ft increases in peak surges across western Louisiana with the exception of the Atchafalaya area. The future condition in this area is an improved landscape due to land building from the Atchafalaya River. Decreases in surges in this area are 1 to 3 ft. Maximum wave heights are also generally increased across west Louisiana. Some areas are greater experience greater than 1 ft change while others are less than a foot. In the Atchafalaya area, maximum wave height decreases are as much as 6 ft.

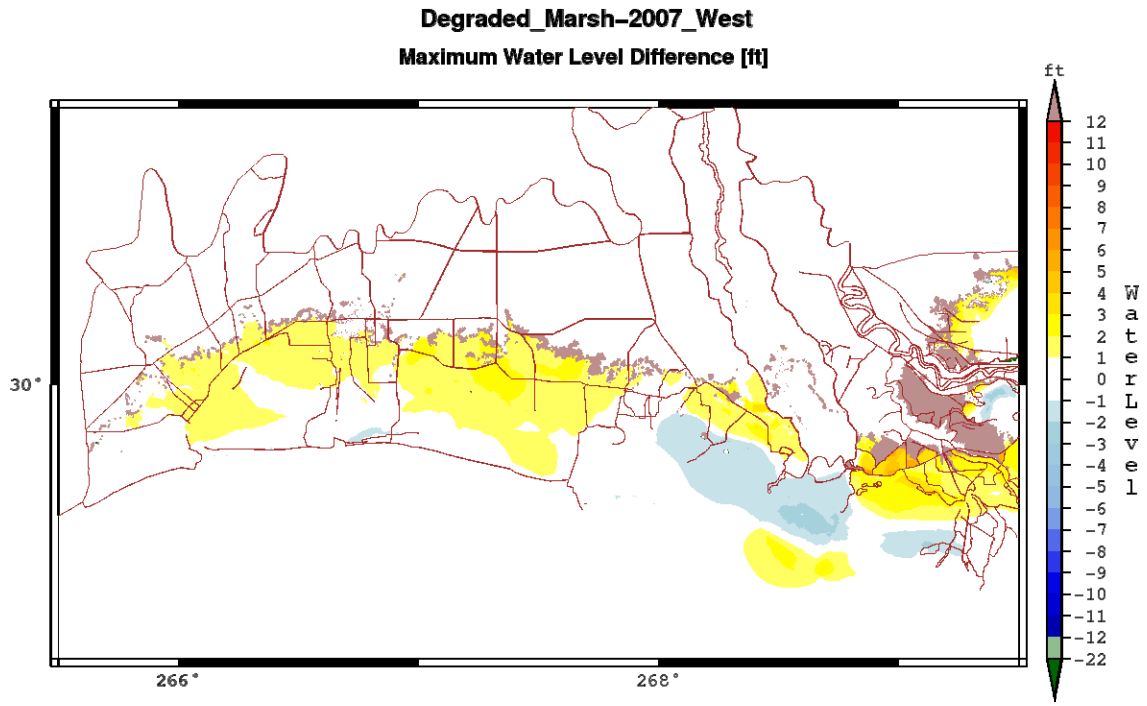


Figure A.8-13. Difference in maximum surge level (ft) between the CLEAR/NIA configuration and the LAWEST base case for the LAWEST NIA marsh storm suite.

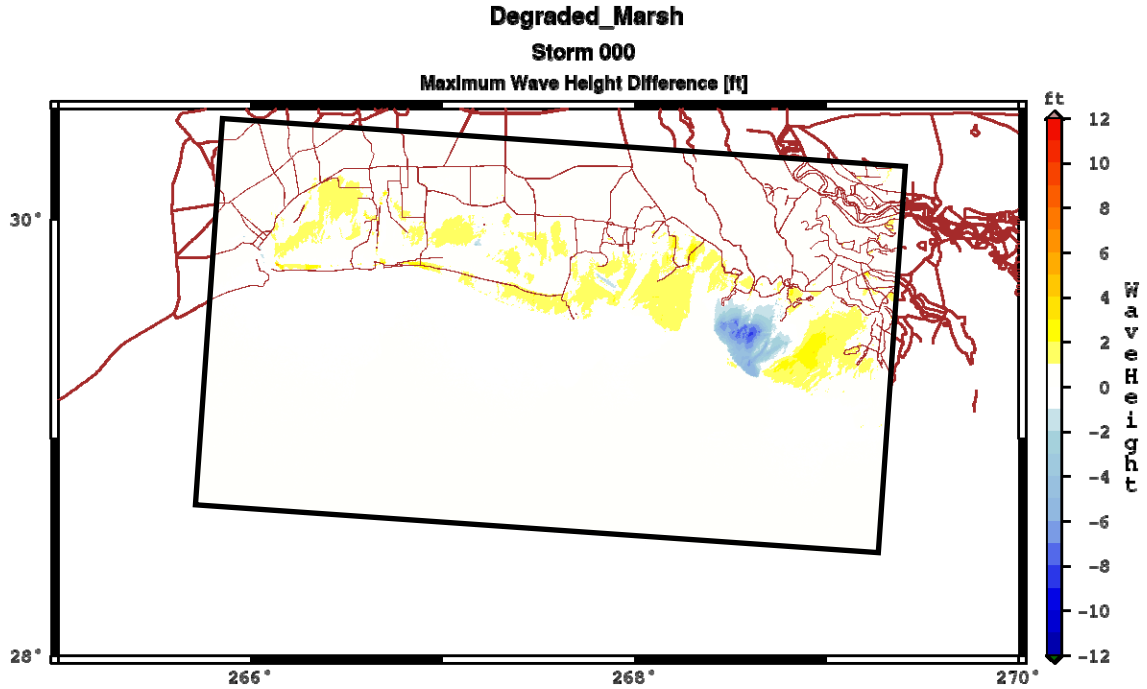


Figure A.8-14. Difference in maximum wave height (ft) between the CLEAR/NIA configuration and the LAWEST base case for the LAWEST NIA marsh storm suite for the west STWAVE grid.

A.8.3 Sea Level Rise

Sea level rise and subsidence are significant issues in the design of flood protection for southeast Louisiana. Flood walls, in particular, can not be easily raised, so future sea level rise must be considered in the initial design. The purpose of this analysis is to estimate the impact of sea level rise on surge and waves for the design of the flood defenses.

The sea level rise analysis consisted of 27 storm simulations. Nine storms were selected from the 2010 simulations and each was run with 1 ft, 2 ft, and 3 ft increase in water level. No other changes to input were made (same offshore waves, same land cover specification, same model parameters, etc.). The storms were chosen to target 100-year water levels in various areas. To summarize the results, eleven reaches are defined: South Shore of Lake Pontchartrain (SSP), East Orleans (EO), St. Bernard North (SBN), St. Bernard South (SBS), Caenarvon (C), Plaquemines East (PE), Plaquemines West (PW), South West Bank (SWB), North West Bank (NWB), Golden Meadow (GM), and Morganza to the Gulf (MtG). These areas are illustrated in Figure A.8-9.

The selection of only nine storms that give approximate 100-yr water levels provides estimates of the impact of sea level rise, but is not a rigorous analysis. For example, land cover classifications were not changed in the analysis. Vegetation types would change as water level increases, but if the increase is slow enough and sediment is available, the marsh elevation may also adjust to the change in water level. Manning-n values were not adjusted in this analysis because of the uncertainty in the values for higher sea level and so the results at each water level could be directly compared. Sea level was increased over the entire domain, which means that local impacts of subsidence are probably over estimated. The impacts of increasing sea level are two fold, the surge wave (which propagates at a speed, $c = \sqrt{gd}$, were g is acceleration of gravity and d is water depth) propagates faster, and the depth-limited wave height increases (also increasing wave setup). In general, it is expected that sea level rise increases water levels more than linearly (water level increase > sea level rise), but the complex, shallow geometry and bathymetry of Southeast Louisiana alters this trend depending on the relative speed of the storm and the surge propagation (and the relative phasing of the two).

The surge increases are calculated as the difference between the maximum water level at each grid point for the sea level rise run and the maximum water level for the base 2007 run. Similarly, the wave increases are calculated as the difference between the maximum wave height at each grid point for the sea level rise run and the maximum wave height for the base 2007 run. Surge increases were normalized by the sea level rise and are presented as multipliers below.

<u>South Shore of Lake Pontchartrain</u>. The SSP reach has the most consistent response to sea level rise. The multiplier is 1.0 to 1.5 (1 would be a linear response, 1 ft sea level rise = 1 ft increase is water level) with an average value of 1.3 for the target storms. The increased depth decreases the friction, allowing more water to pile up on the shore. The SSP reach has fairly consistent increase in wave height for sea level rise: 0.6 ft for 1 ft sea level rise, 1.0 ft for 2 ft sea level rise, and 1.5 ft for 3 ft sea level rise. The ratio of wave height increase to water level increase for the target storms varies from 0.23 to 0.60, with an average value of 0.43. The

values are relatively high because an increase in surge results in a direct increase in depth-limited wave height in most areas.

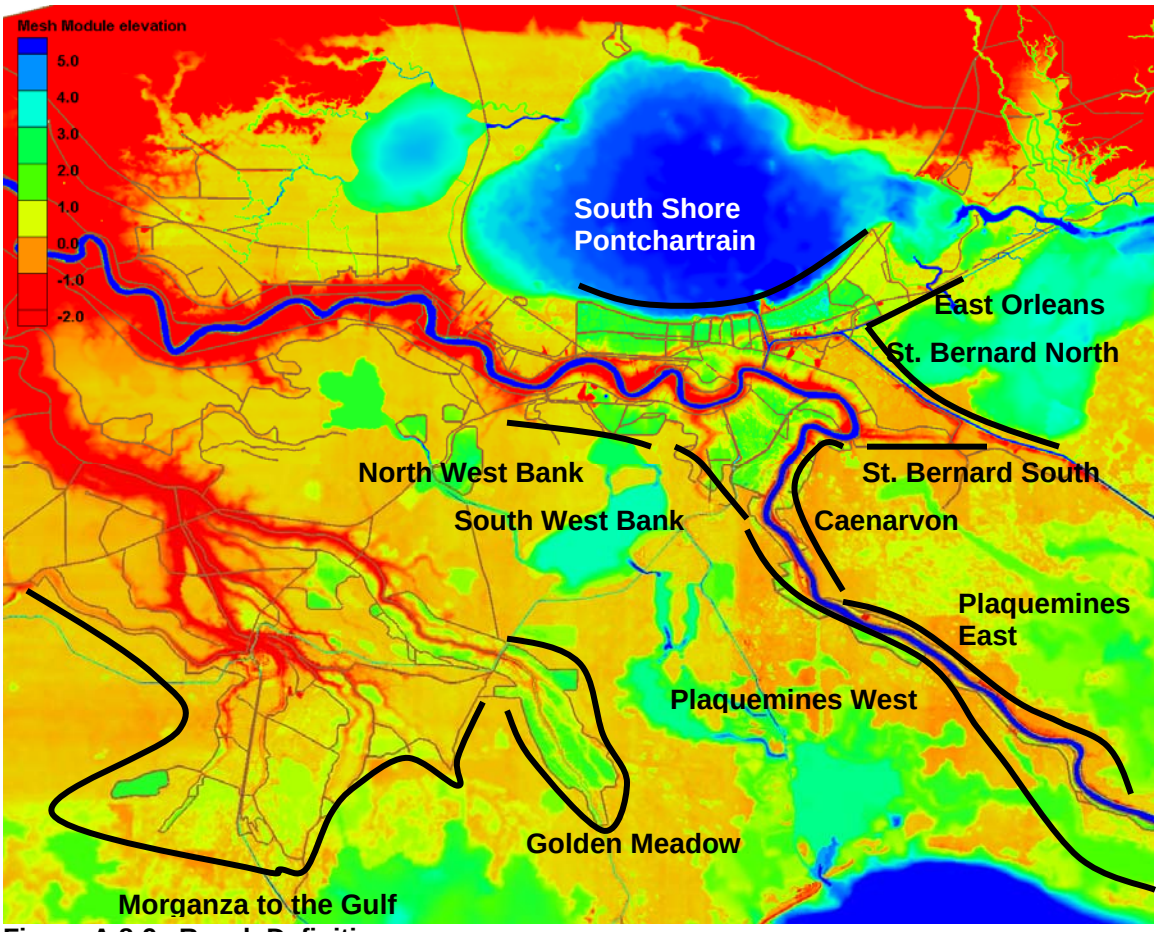


Figure A.8-9. Reach Definitions.

Back Levees of East Orleans and St. Bernard North. The response in EO and SBN has slightly more variation than SSP, with a multiplier of 1.1 to 1.6. This area forms a small pocket in the funnel area, but the reach is not as complex or shallow as areas to the south and west. The multipliers for the storms near the 100-yr water level are 1.1 to 1.6 in EO and 1.2 to 1.6 in SBN, with average values of 1.2 and 1.3, respectively. The EO and SBN behave relatively consistently with increases in wave height of 0.1 to 1.2 ft for EO and 0.1 to 1.0 ft for SBN. The ratios of wave height increase to water level increase are all less than 0.4, with average values for the target storms of 0.13 (range of 0.06 to 0.31) for EO and 0.17 (range of 0.04 to 0.38) for SBN.

St. Bernard South and Caenarvon. This reach is complex and shallow, and the results are highly variable with multipliers of 0.7 to 4.5. The large responses correspond to the storms with some of the smallest maximum surges, which have tracks that cross through Breton Sound, east of this area. As the storms pass, the larger water depth allows the surge to move in faster, as well as decreasing the frictional resistance. The “catchers mitt” of Caenarvon amplifies the surge for these storms. Storms that produce the largest surge in these areas (20-25 ft) have a sea level rise multipler of 0.6 to 1.3 for St. Bernard South and 0.6 to 2.0 for Caenarvon. Storms that produce the 100-yr water levels have multipliers of 0.7 to 2.3 for SBS and 0.7 to 4.5 for C

with average values of 1.4 and 2.1, respectively. The wave height results are highly variable with increases of 0.1 to 2.1 ft for SBS and 0.5 to 3.0 ft for C. The large responses correspond to the storms with the smallest maximum surges with tracks that cross through Breton Sound, east of this area. As the storms pass, the larger water depth allows large waves to propagate into the area, as well as decreases the frictional resistance. The average ratio of wave height increase to water level increase is relatively large in this area, 0.45 (range of 0.4 to 0.5) for SBS and 0.50 (range of 0.42 to 0.63) for C.

Plaquemines East and West. These reaches are large with a lot of spatial variability, but the multipliers are less variable than the adjoining reaches. The multipliers for the target storms are 1.3 to 2.0 for Plaquemines East. For the Plaquemines West reach, the range of multipliers for the target storms is 1.4 to 3, with average values of 1.5 and 1.9, respectively. The wave height increases in these areas are similar to St. Bernard South and Caenarvon. The wave height increases are 0.4 to 2.8 ft for PE and 0.4 to 2.9 ft for PW. The maximum increases in wave height in the Plaquemines East reach were typically at the north end of this reach, between Phoenix and Davant. The average ratio of wave height increase to water level increase is 0.58 (range 0.38 to 0.78) for the target storms for PE. For the Plaquemines West reach, the maximum increases in wave height were typically between Empire and Buras or near Myrtle Grove. The average ratio of wave height increase to water level increase is 0.41 (range 0.23 to 0.69) for the target storms for PE.

West Bank. This reach is also complex and shallow. The multipliers range from 1.0 to 3.6. Storms near the 100-yr level for the West Bank have multipliers ranging from 1.3 to 3.6 for SWB and 1.0 to 2.9 for NWB. The largest numbers tend to be hot spots (small areas) and not large areas of high multipliers. The average multipliers for the target storms are 2.5 for SWB and 2.1 for NWB. The wave height increases are 0.1 to 1.0 ft. The ratio of wave height increase to water level increase is 0.03 to 0.3 for the target storms with average values of 0.11 for SWB and 0.15 for NWB.

Golden Meadow and Morganza to the Gulf. Multipliers in this reach are similar to the West Bank, but not as variable. Multipliers range from 1.0 to 2.5. The surges tend to be most amplified on the northeast corner of Golden Meadow and in the pocket regions. The multipliers for the storms near the 100-yr water level are 1.4 to 2.3 for Golden Meadow and 1.5 to 2.0 for Morganza to the Gulf, with average values of 1.8 and 1.7, respectively. These reaches include complex levee geometries (pockets) and bathymetry, but are more exposed than the west bank. The wave height increases are up to 2.0 ft along Golden Meadow and up to 3.0 ft along Morganza to the Gulf. The average ratio of wave height increase over surge increase for the target storms is 0.27 (range 0.14 to 0.42) for Golden Meadow and 0.37 (range 0.23 to 0.5) for Morganza to the Gulf.

768

Annex B

Fact sheets for sub basins

Planning Unit 1

Laplace

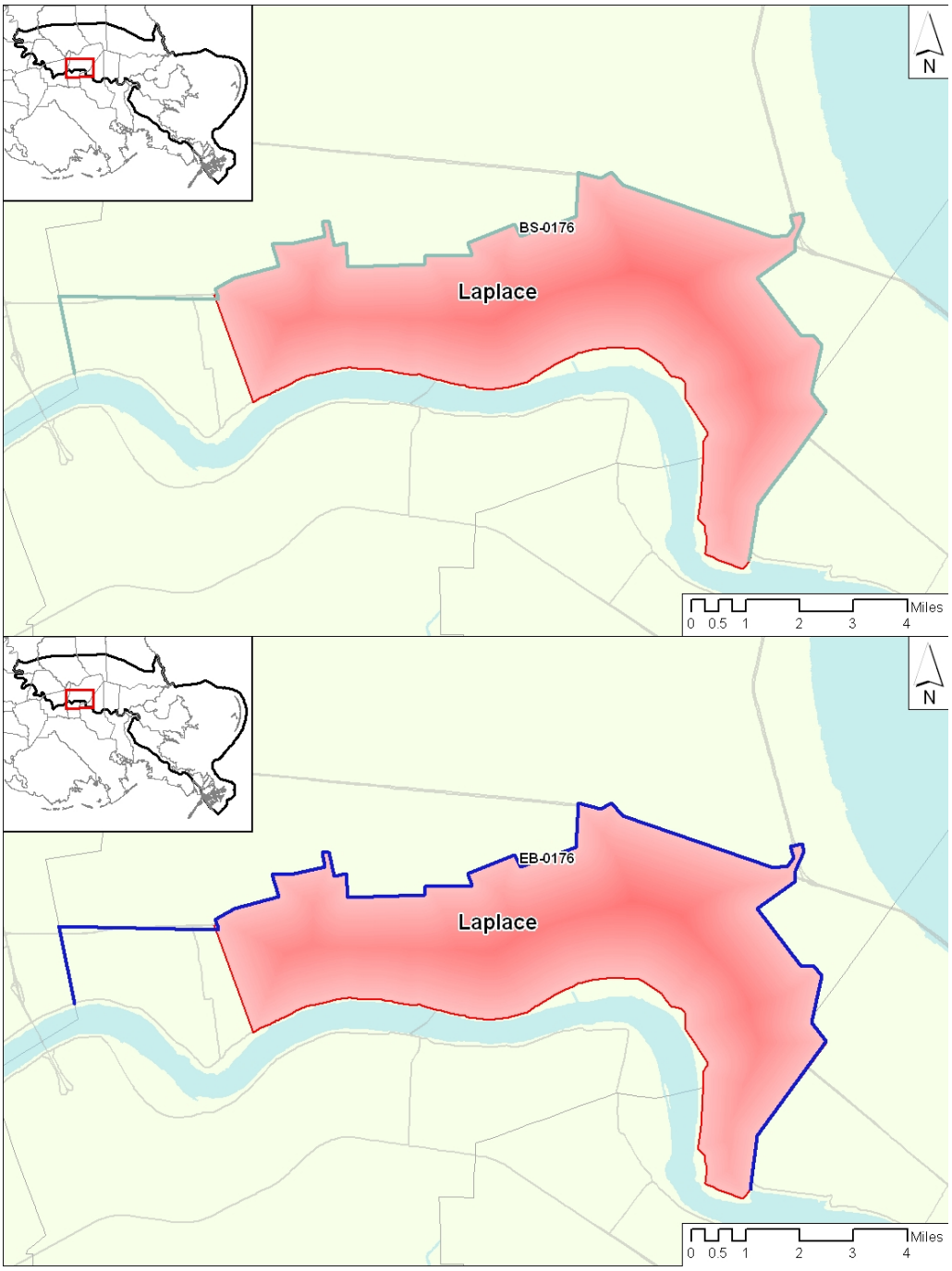


Figure B.1 –Sub-basin and levees Laplace (High Level and Barrier Plan)

Table B-1 – Levee characteristics

High Level Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0176		**n.a.**	**13.5**	**18.5**	**21**	**12.5**	**17**	**19**
-	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
-	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
EB-0176		**n.a.**	**9**	**14.5**	**18**	**8**	**13**	**16**
-	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
-	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	0	10,000	Based on 0.5cfs/acre

Storage Area	**Type**	**Notes**
Laplace	Single area	Max stage is higher of surge (176) or design height (176)

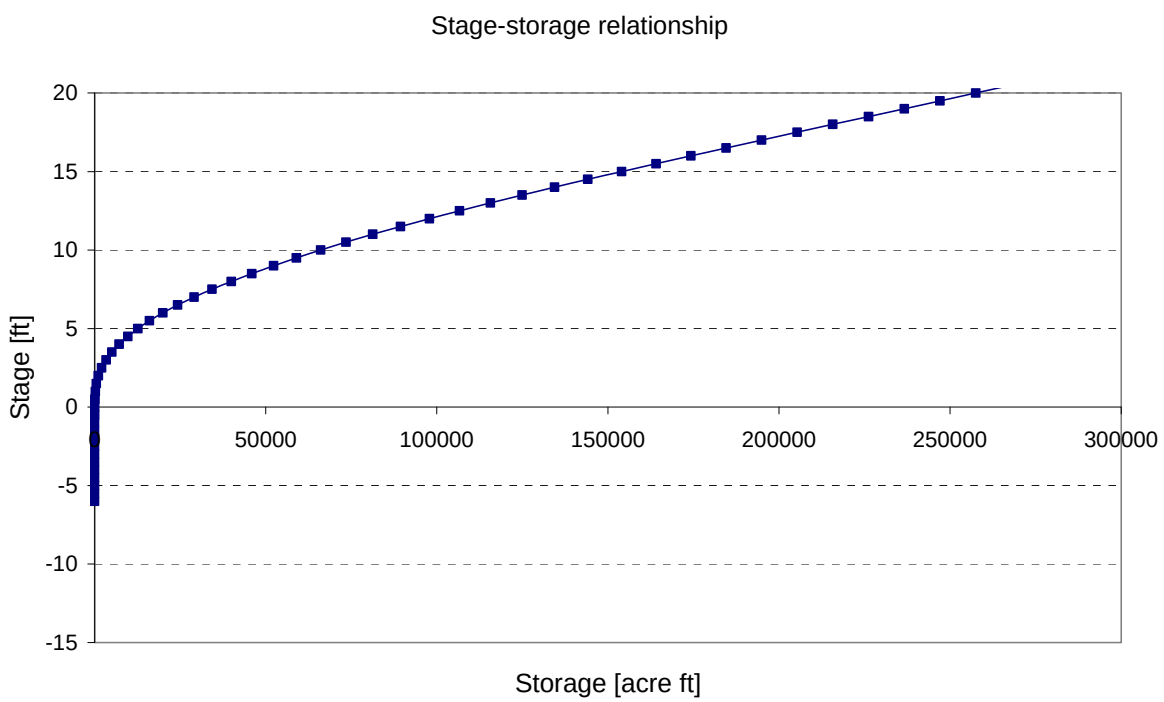


Figure B.2 - Stage storage relationship Laplace

Additional Notes

Pumping needs to be included based on the basis of 0.5cfs/acreas as development is close behind the proposed levee line. Area taken as 21000 acres and therefore assumed 10,000cfs.

A new alignment for the levee in Laplace has been suggested from a different study. At present - for consistency - the original alignment is being maintained, but reference will be made in the final documentation to the new alignments. Pump sizing has also been undertaken for both the existing and new alignments by the other project. For the existing alignment a value of 3500cfs has been developed against the 10,000cfs suggested in above. For consistency the 10,000cfs value has been used.

Initial economic runs suggested that significantly more people were affected with a levee than without. This appears to be a result of the planning sub units finishing short of the actual flood extents, therefore suggesting in the without case that some property is outside the flood extent whereas they are below the extreme surge elevations (for the higher events). To solve this exterior stage frequency values were taken from the existing planning sub units and applied to the interior units in this area. The relationships were:

Laplace 1 - exterior values from SJJO_8c
Laplace 2 - exterior values from STCH_11b

St. Charles Norco

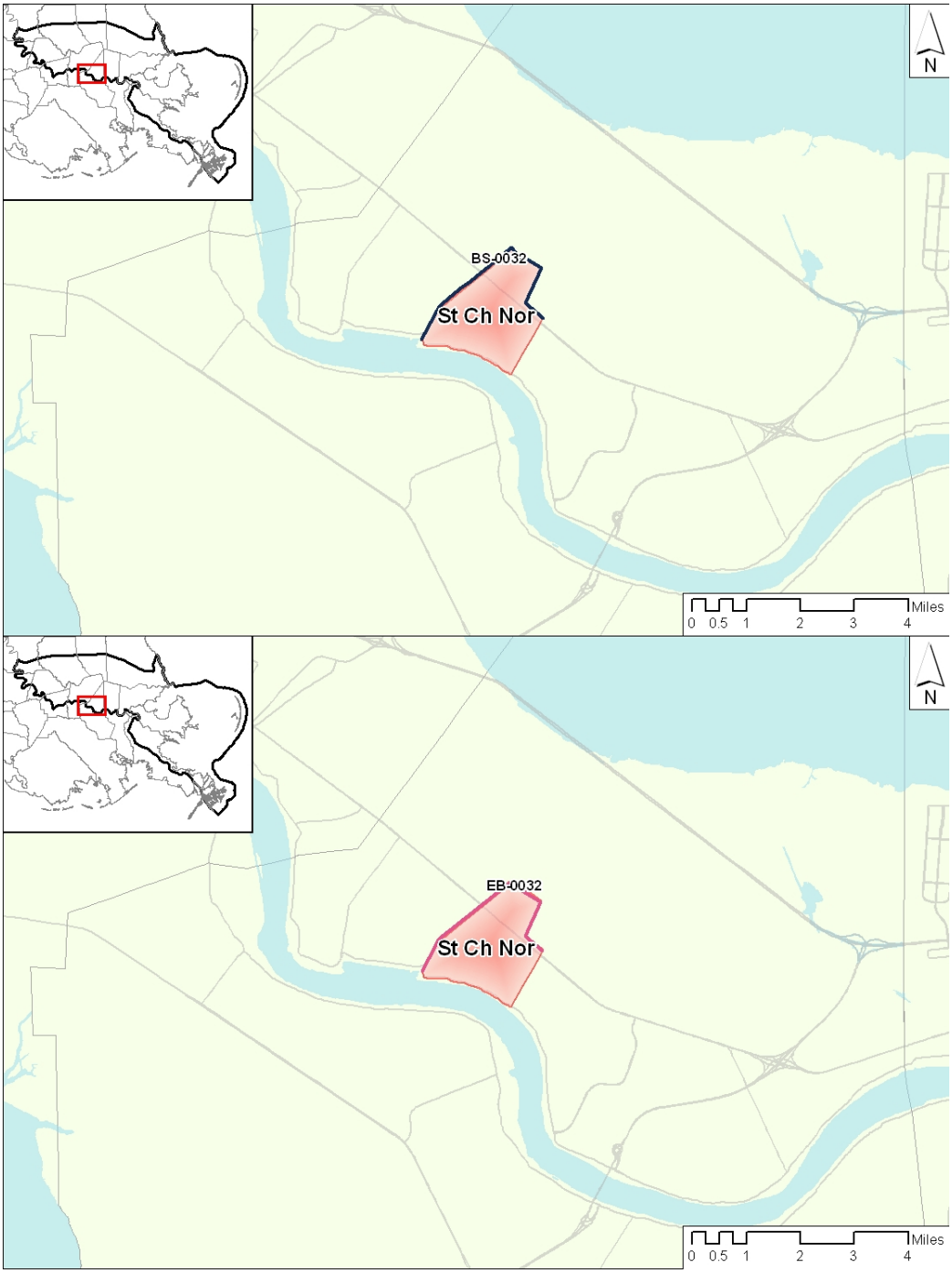


Figure B.3 – Sub-basin and levees St Charles Norco (High Level and Barrier Plan)

Table B-2 – Levee characteristics

High Level Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0032	**22510**	**13**	**16**	**21**	**23.5**	**14.5**	**19.5**	**21.5**
-	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
EB-0032	**22085**	**13**	**13**	**18.5**	**21.5**	**13**	**17**	**19.5**
-	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	800	800	

Storage Area	**Type**	**Notes**
St Charles - Norco	Linked area (St Charles)	Connects to St Charles - rest (4.5'). See description of linked system in chapter 4.

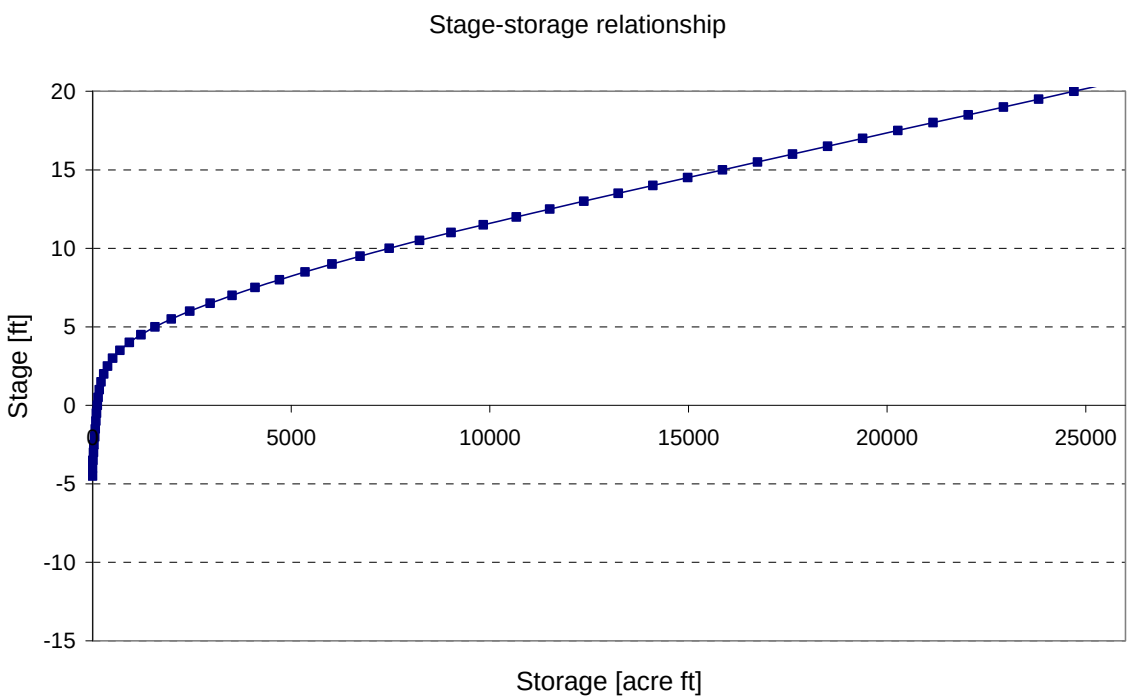


Figure B.4 - Stage storage relationship St Charles Norco

St Charles Remainder

Figure B.5 – Sub-basin and levees St. Charles Remainder (High Level and Barrier Plan)

Table B-3 – Levee characteristics

High Level Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0032	**22510**	**13**	**16**	**21**	**23.5**	**14.5**	**19.5**	**21.5**
-	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
EB-0032	**22085**	**13**	**13**	**18.5**	**21.5**	**13**	**17**	**19.5**
-	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	0	0	

Storage Area	**Type**	**Notes**
St Charles - Rest	Linked area (St Charles)	Connects to St Charles - Norco (4.5'). See description of linked system in chapter 4.

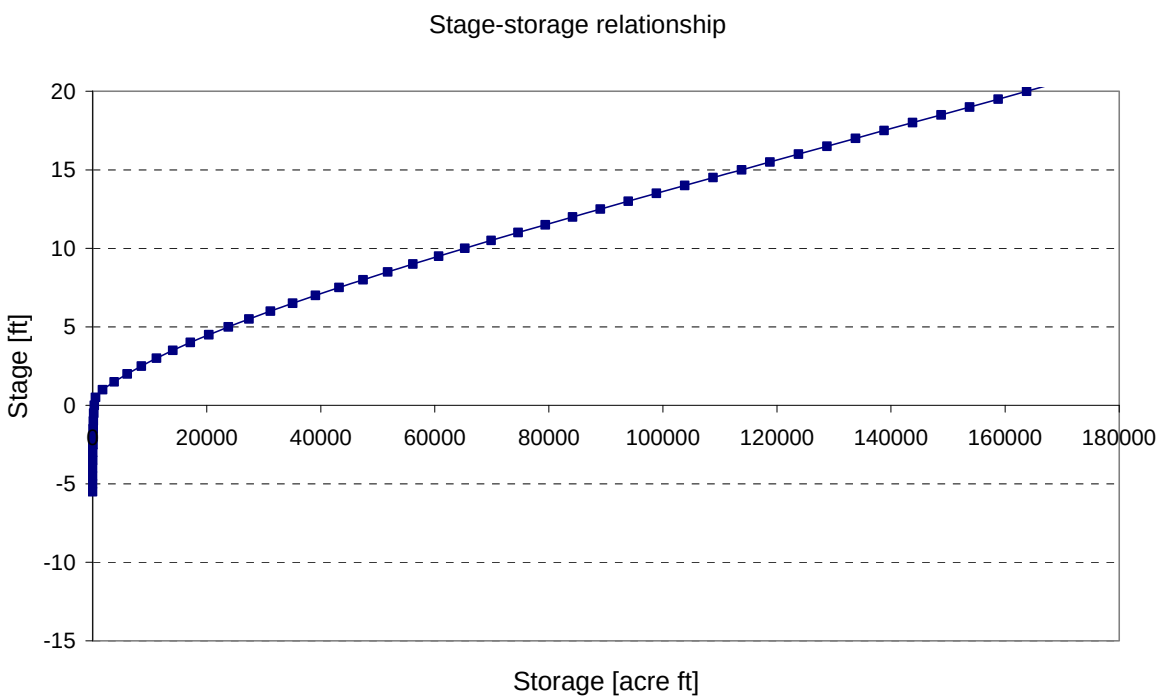


Figure B.6 - Stage storage relationship St Charles Remainder

East Jefferson

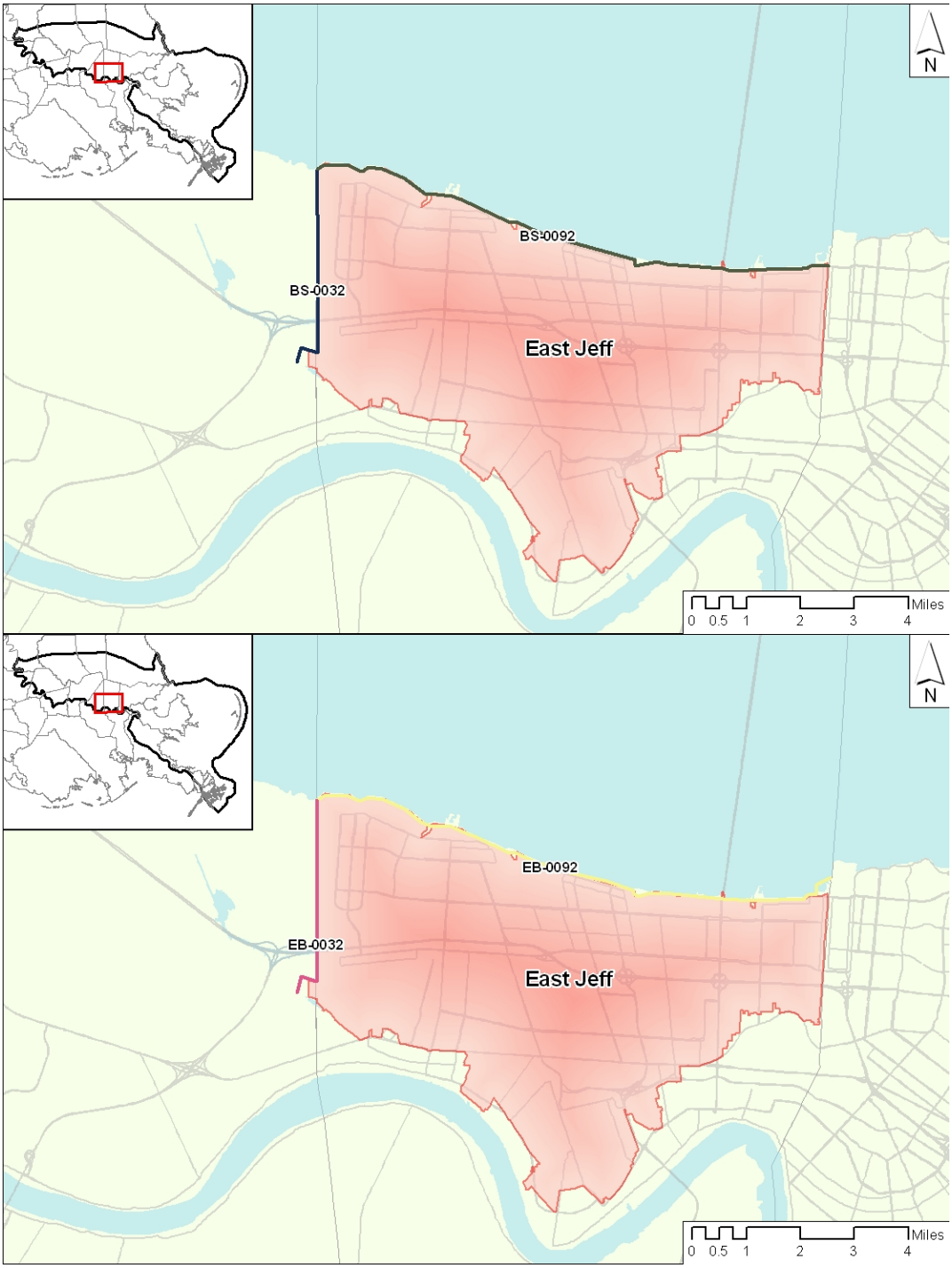


Figure B.7 – Sub-basin and levees East Jefferson (High Level and Barrier Plan)

Table B-4 – Levee characteristics

High Level Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0032	**21089**	**13**	**16**	**21**	**23.5**	**14.5**	**19.5**	**21.5**
BS-0092	**52949**	**16.5**	**16.5**	**19.5**	**21.5**	**16.5**	**19.5**	**21.5**

Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
EB-0032	**21033**	**13**	**13**	**18.5**	**21.5**	**13**	**17**	**19.5**
EB-0092	**54153**	**16.5**	**16.5**	**16.5**	**18.5**	**16.5**	**16.5**	**18.5**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	20,590	20,590	

Storage Area	**Type**	**Notes**
East Jefferson	Linked area (New Orleans)	Connects to NO Metro with a weir at 5'. If stage < 5' then likely only floods to this level. See description of linked system in chapter 4

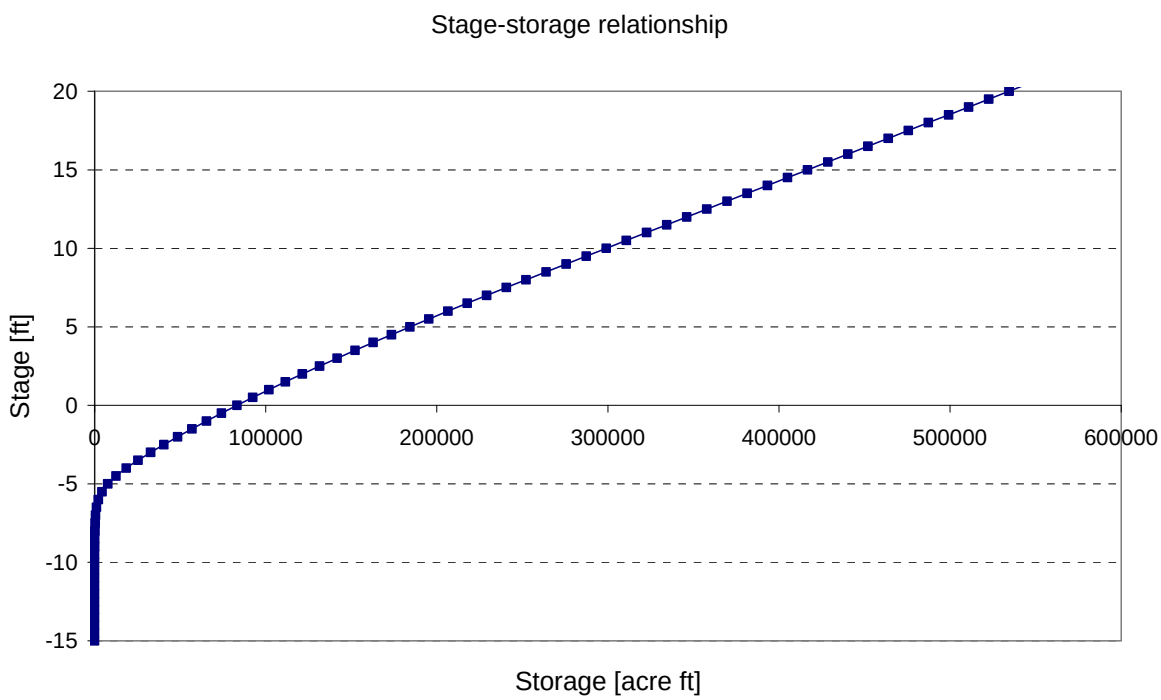


Figure B.8 - Stage storage relationship East Jefferson

New Orleans Metro

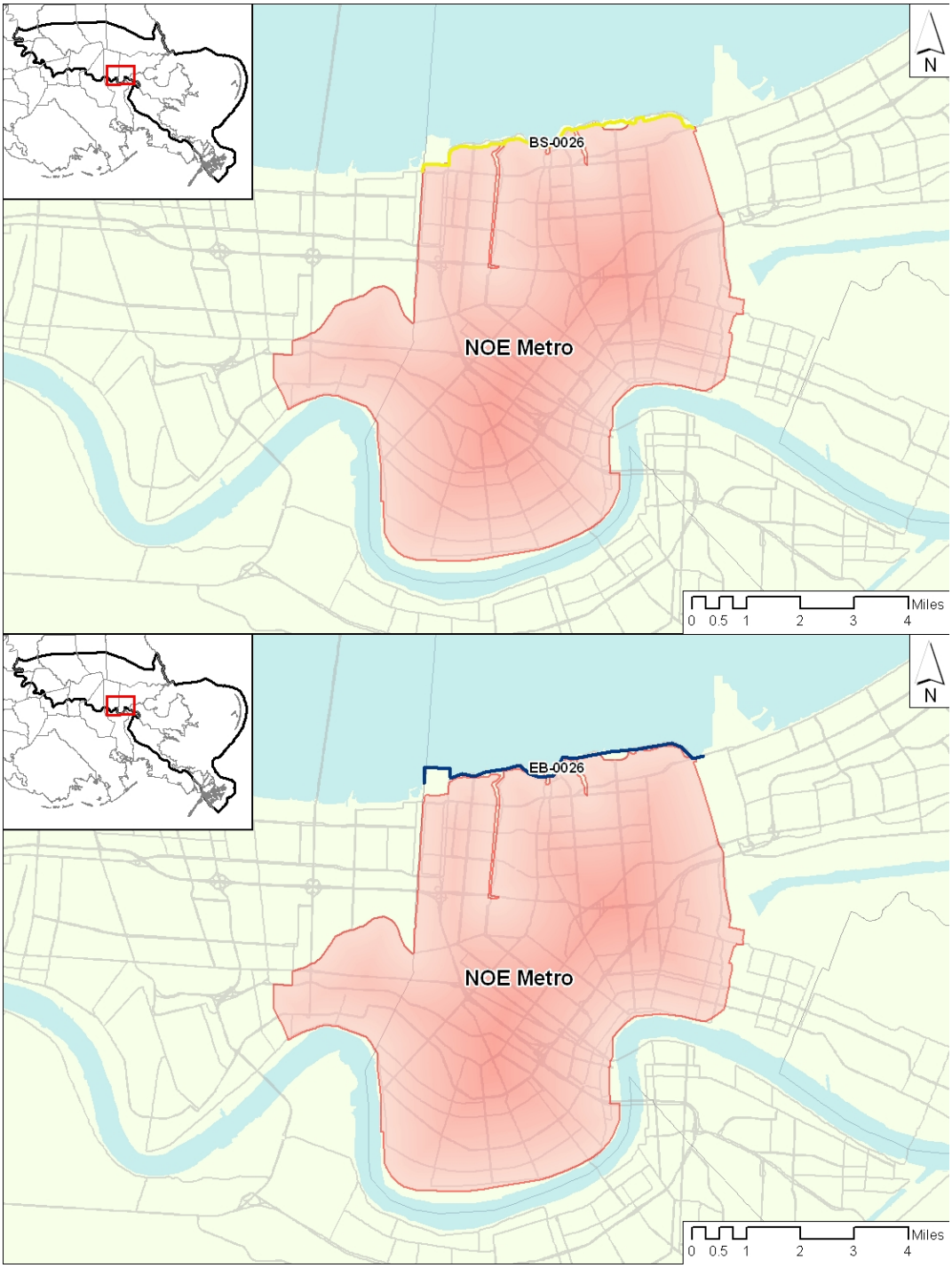


Figure B.9 – Sub-basin and levees New Orleans Metro (High Level and Barrier Plan)

Table B-5 – Levee characteristics

High Level Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0026	**32164**	**18.5**	**18.5**	**20**	**23.5**	**18.5**	**20**	**23.5**

Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
EB-0026	**32158**	**18.5**	**18.5**	**18.5**	**18.5**	**18.5**	**18.5**	**18.5**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	14,420	14,420	This has been identified as in error - value should be 26,160

Storage Area	**Type**	**Notes**
NO Metro	Linked area (New Orleans)	Connects to East Jefferson (5'), St Bernard (12.5') and NOE (12.5'). See description of linked system in chapter 4

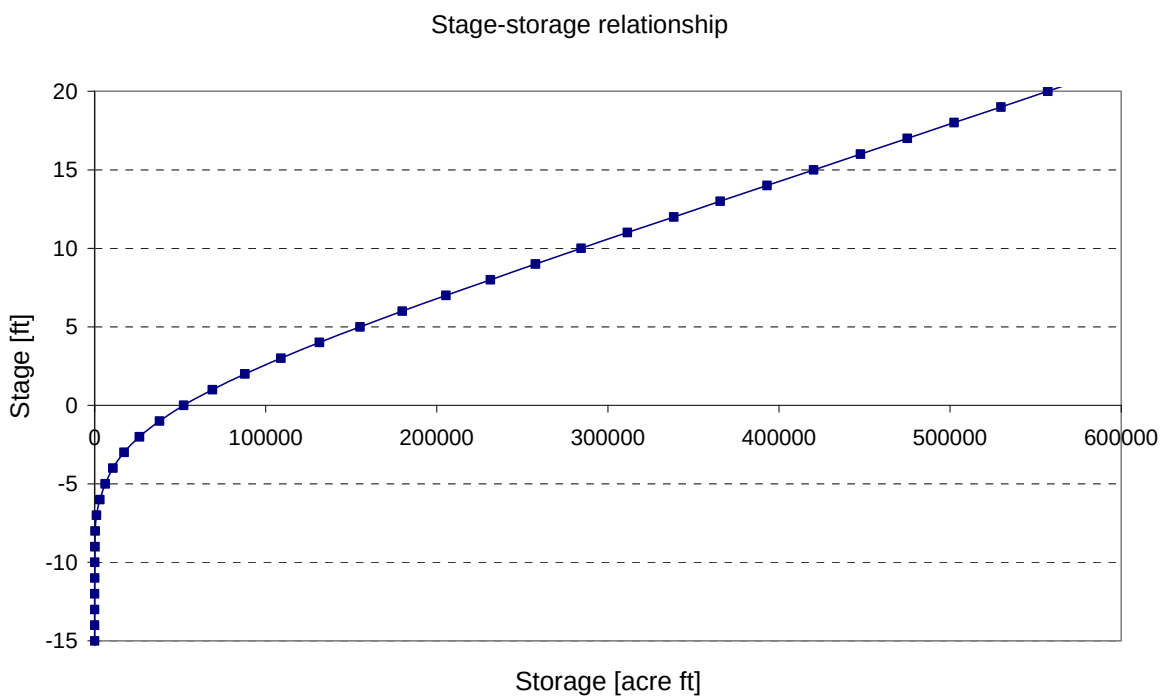


Figure B.10 - Stage storage relationship New Orleans Metro

New Orleans East

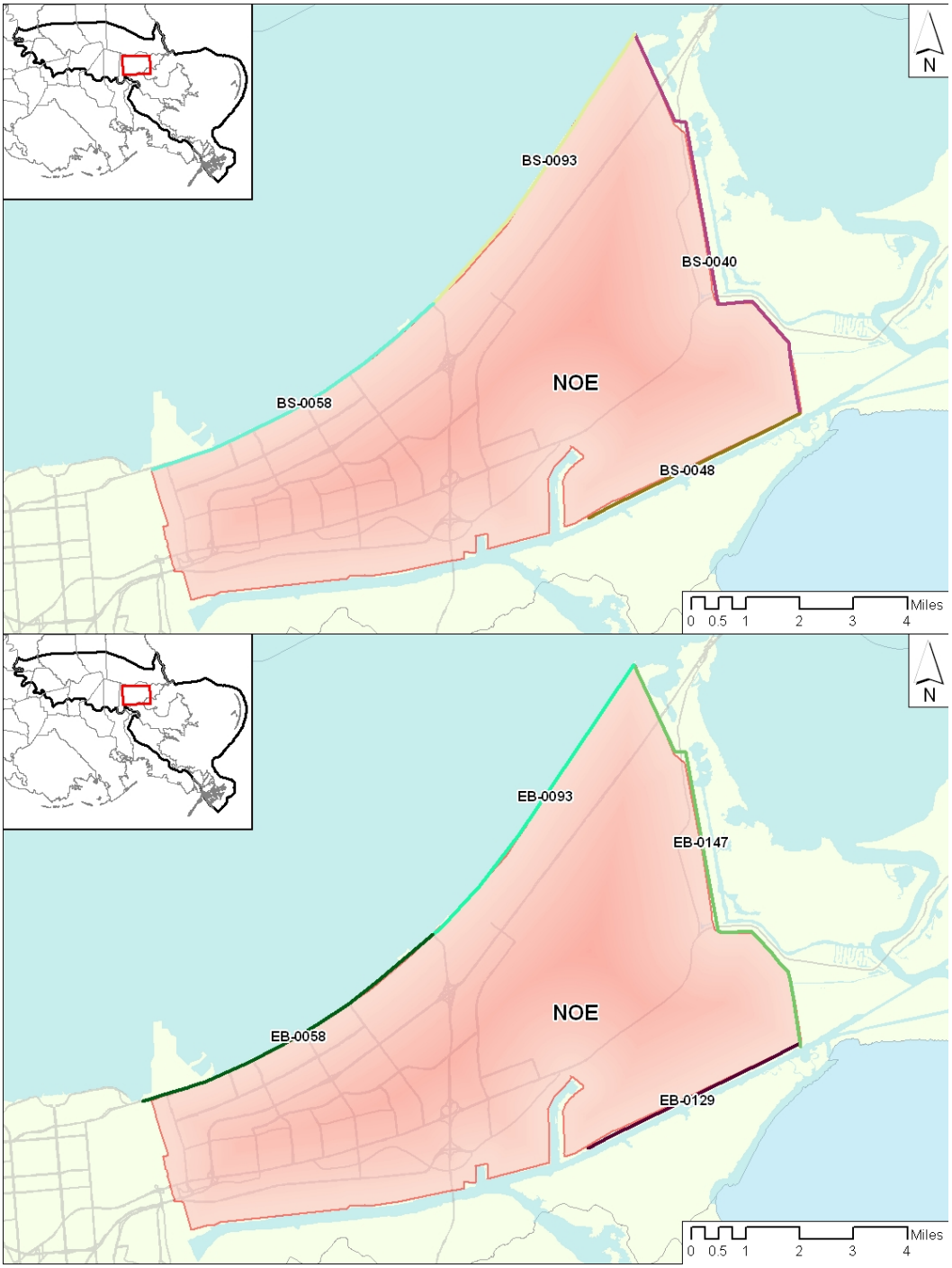


Figure B.11 – Sub-basin and levees New Orleans East (High Level and Barrier Plan)

Table B-6 – Levee characteristics

High Level Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0040	**44308**	**15**	**18**	**23.5**	**26**	**17.5**	**23**	**26**
BS-0048	**23035**	**18**	**28.5**	**35**	**38**	**24**	**30**	**32**
BS-0058	**32286**	**15**	**15**	**18**	**21**	**15**	**18**	**21**
BS-0093	**32997**	**18**	**18**	**19**	**21.5**	**18**	**19**	**21.5**

Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
EB-0058	**33135**	**15**	**15**	**15**	**15**	**15**	**15**	**15**
EB-0093	**32973**	**18**	**18**	**18**	**18**	**18**	**18**	**18**
EB-0129	**23183**	**18**	**26.5**	**33.5**	**37**	**26.5**	**33.5**	**37**
EB-0147	**44370**	**15**	**15**	**16.5**	**20.5**	**15**	**16.5**	**20**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	6,310	6,310	

Storage Area	**Type**	**Notes**
NOE	Linked area (New Orleans)	Connects to NO Metro with a weir at 12.5'. If stage <12.5' then likely floods to this level. See description of linked system in chapter 4

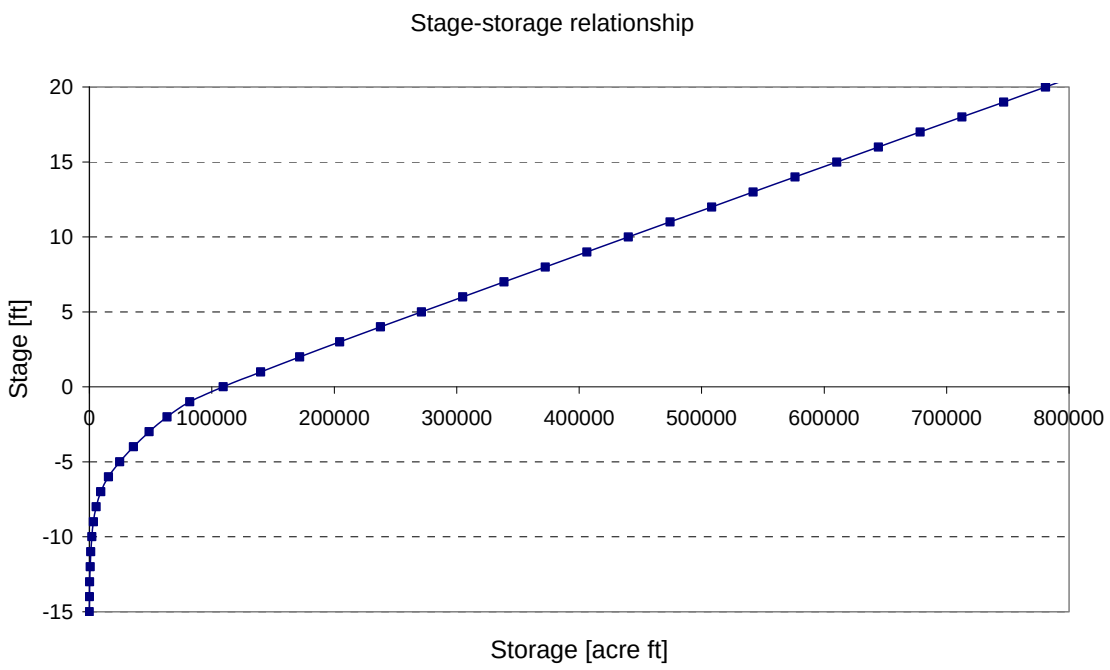


Figure B.12 - Stage storage relationship New Orleans East

St Bernard Wetland

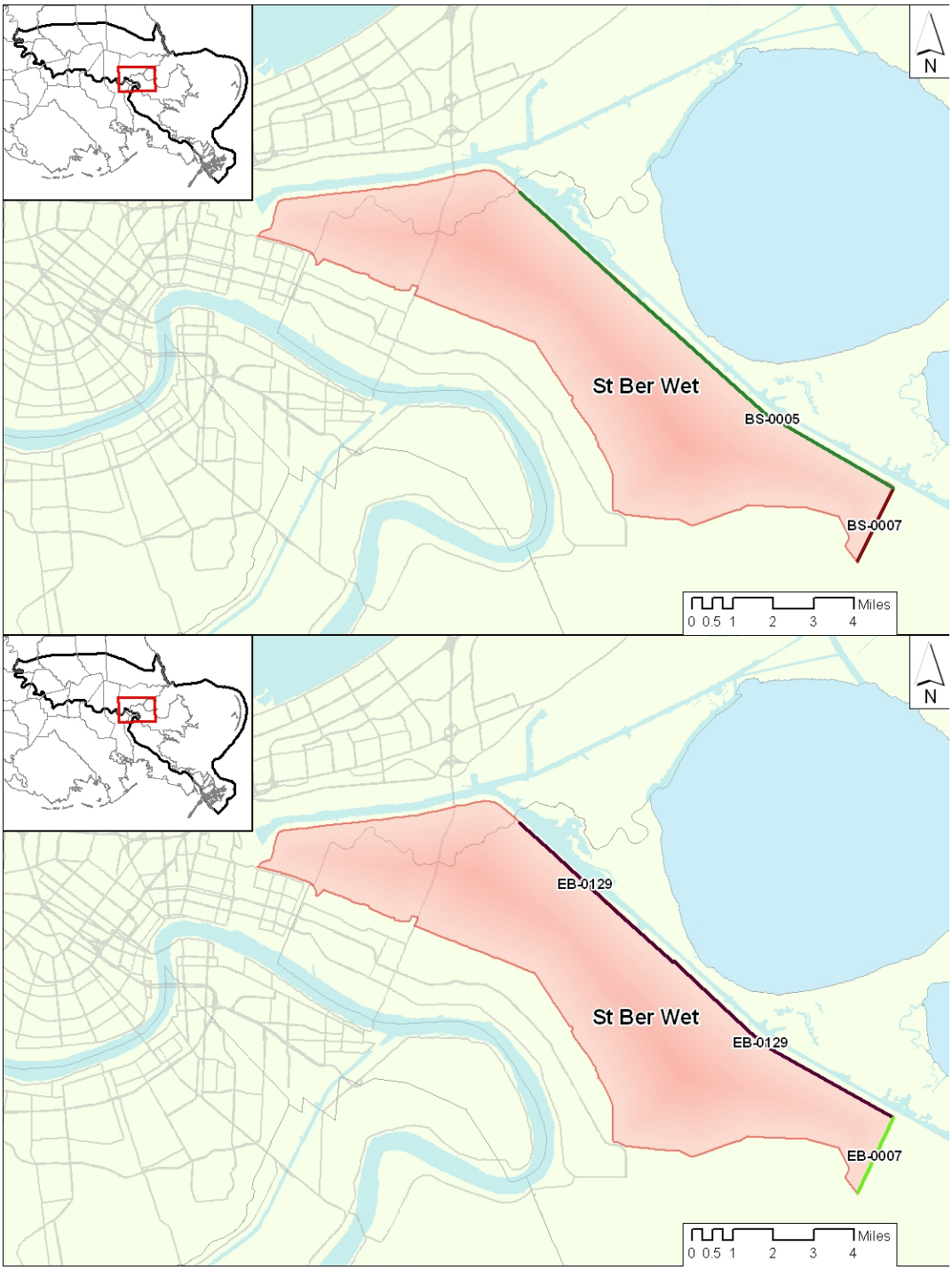


Figure B.13 – Sub-basin and levees St Bernard Wetland (High Level and Barrier Plan)

Table B-7 – Levee characteristics

High Level Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0005	**62502**	**18**	**26.5**	**32.5**	**35.5**	**24**	**29.5**	**32**
BS-0007	**10645**	**17**	**26**	**34**	**38**	**21.5**	**28**	**31.5**

Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
EB-0007	**10816**	**17**	**28**	**37.5**	**40.5**	**23**	**30.5**	**35**
EB-0129	**62430**	**18**	**26.5**	**33.5**	**37**	**26.5**	**33.5**	**37**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	0	0	

Storage Area	**Type**	**Notes**
St Bernard Wetland	Linked area (New Orleans)	Connects to St Bernard Developed at 10.5'. If stage <10.5' then likely only floods to this level. See description of linked system in chapter 4

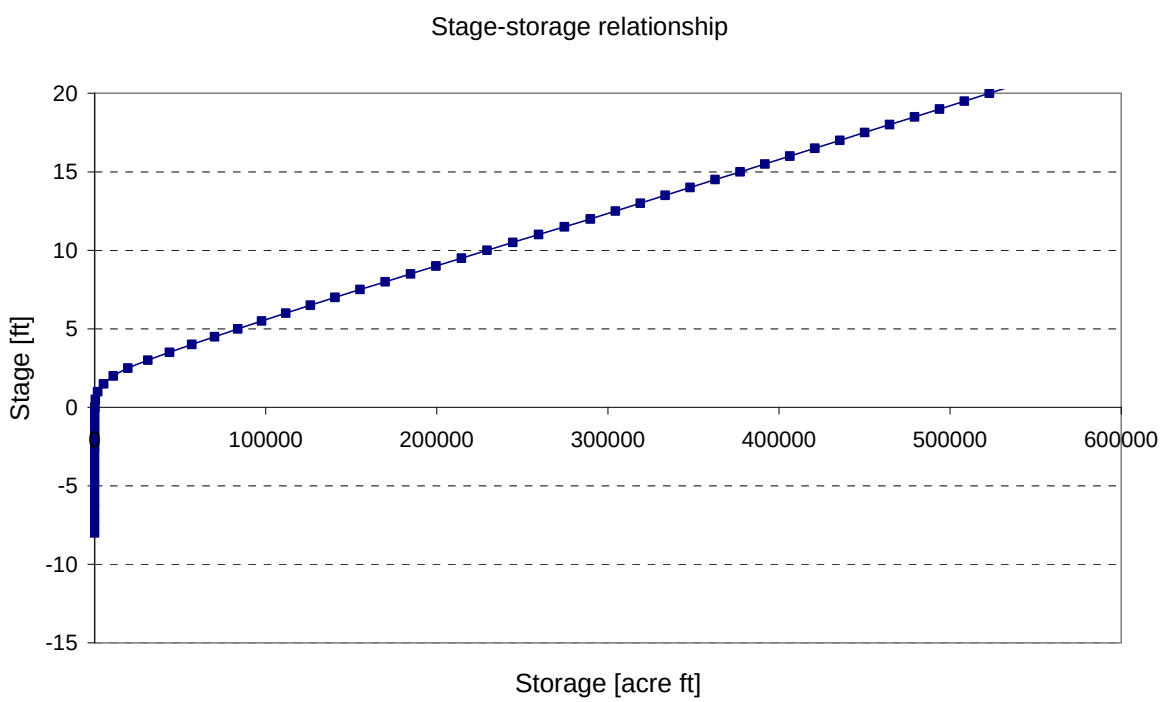


Figure B.14 - Stage storage relationship St Bernard Wetland

St Bernard Developed

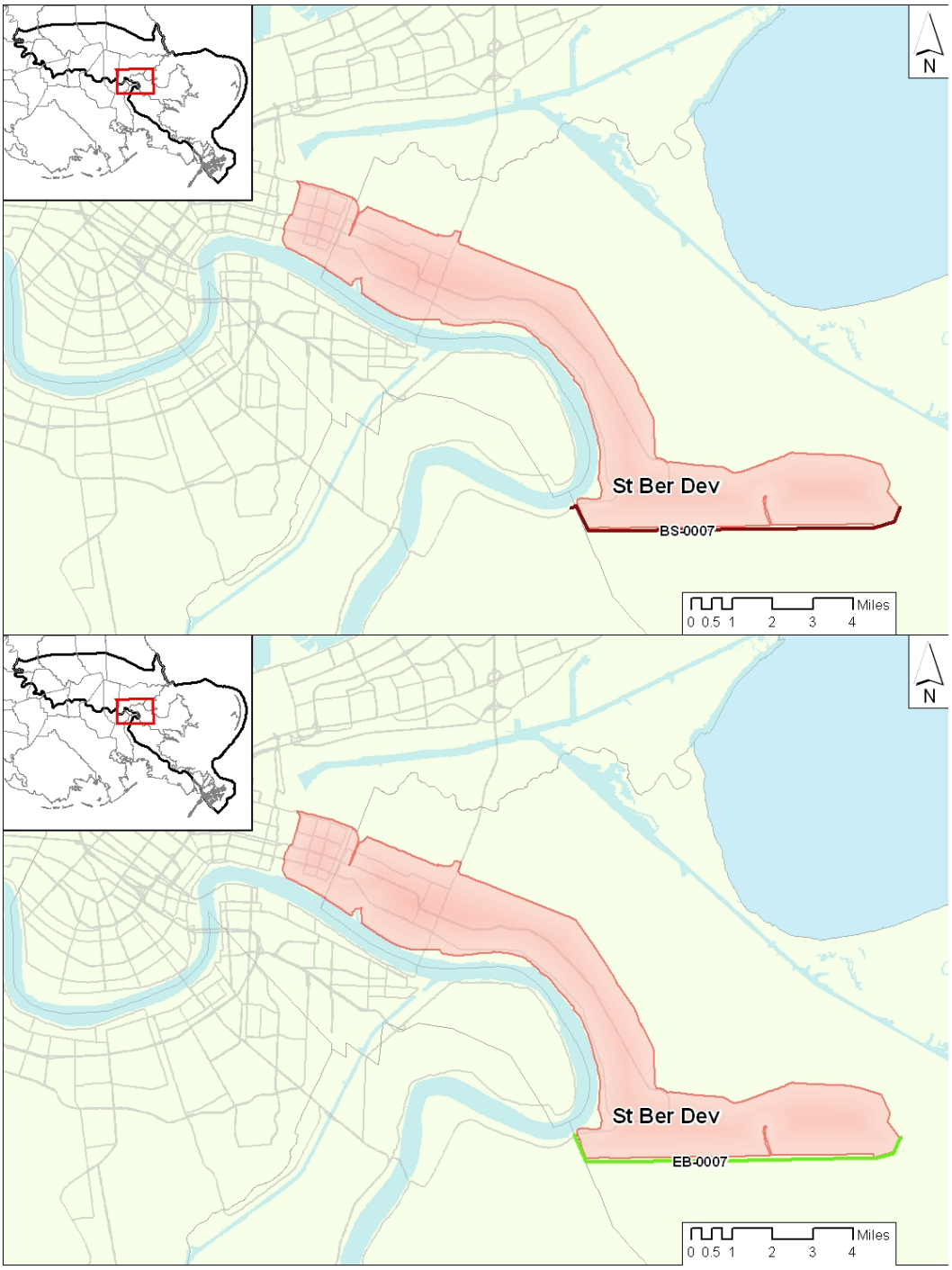


Figure B.15 – Sub-basin and levees St Bernard Developed (High Level and Barrier Plan)

Table B-8 – Levee characteristics

High Level Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0007	**46595**	**17**	**26**	**34**	**38**	**21.5**	**28**	**31.5**

Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
EB-0007	**46319**	**17**	**28**	**37.5**	**40.5**	**23**	**30.5**	**35**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	8,190	8,190	Pumps assumed to pump out of system rather than into St Bernard Wetland

Storage Area	**Type**	**Notes**
St Bernard Developed	Linked area (New Orleans)	Connects to St Bernard Wetland (10.5') and NO Metro (12.5'). See description of linked system in chapter 4.

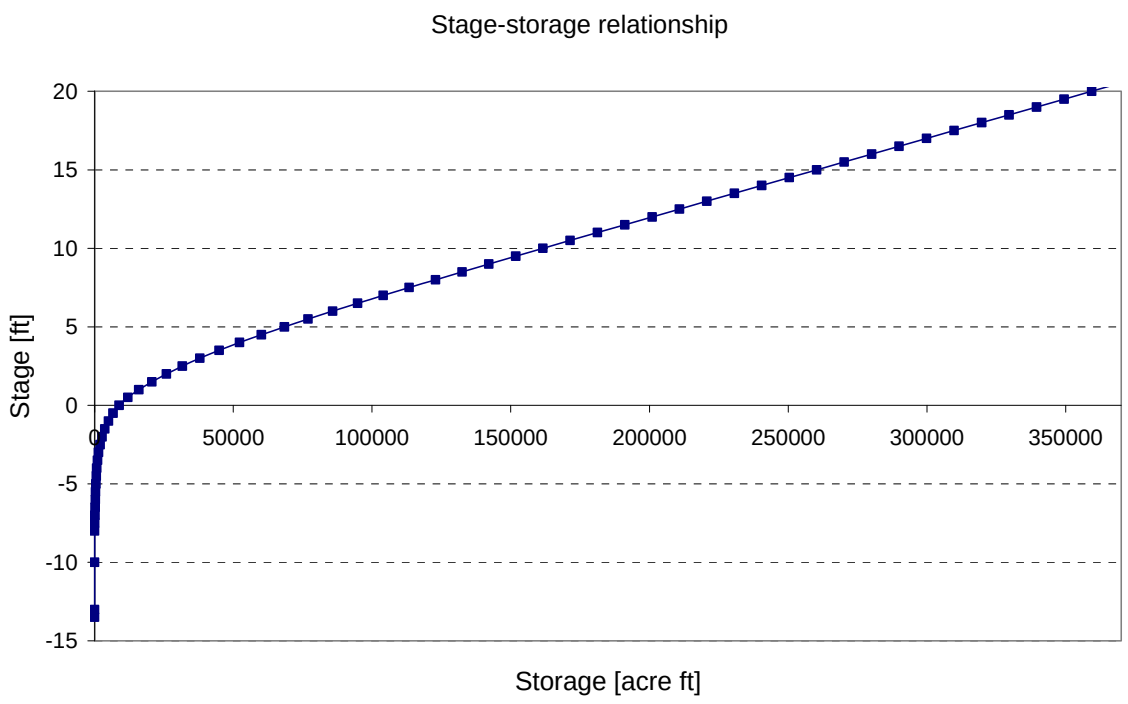


Figure B.16 - Stage storage relationship St Bernard Developed

Plaquemines - Scarsdale

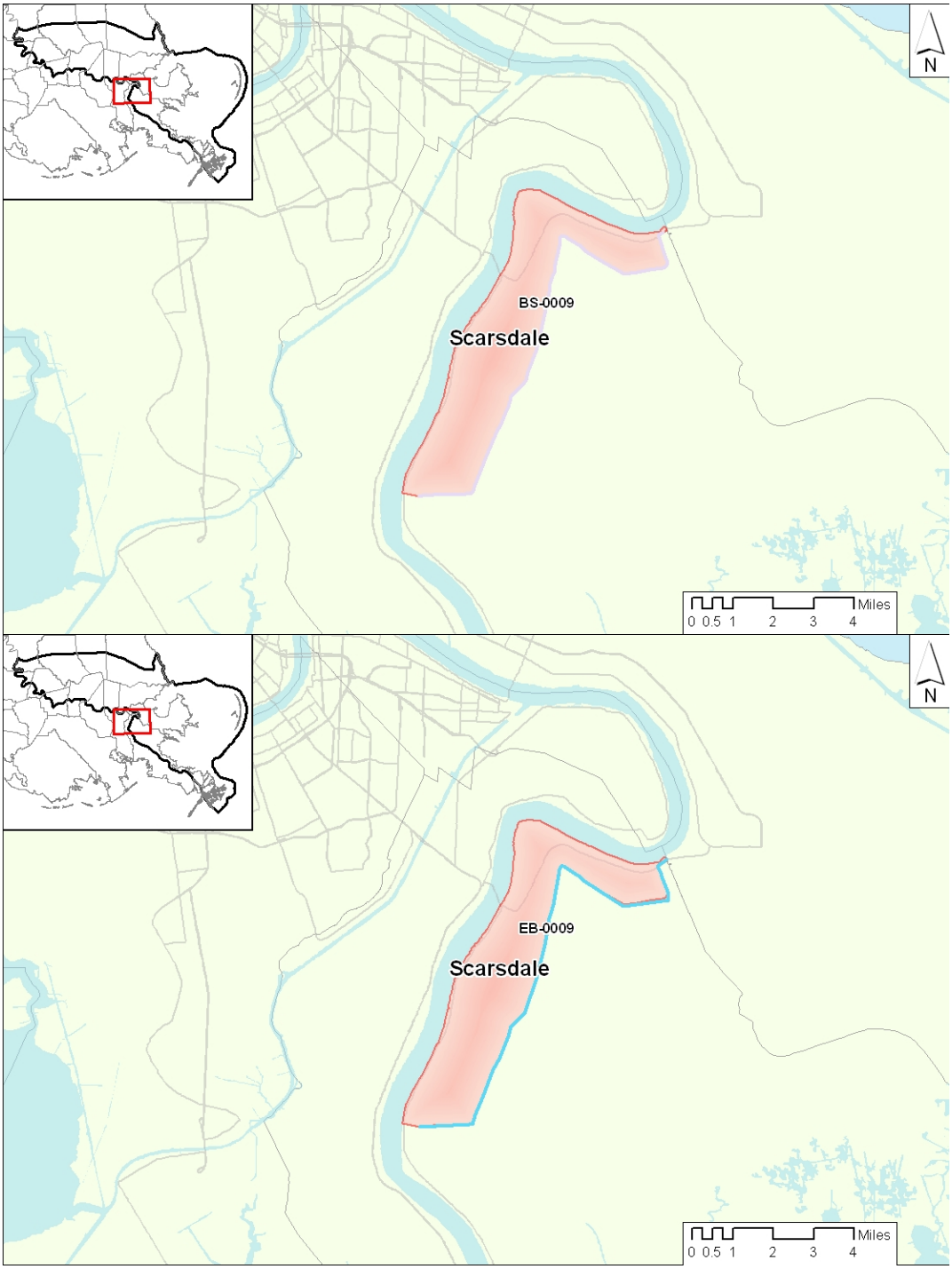


Figure B.17 – Sub-basin and levees Plaquemines - Scarsdale (High Level and Barrier Plan)

Table B-9 – Levee characteristics

High Level Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0009	**631884**	**n.a.**	**29**	**38.5**	**42.5**	**24**	**31**	**35**

Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
EB-0009	**64792**	**n.a.**	**33**	**42.5**	**45.5**	**25.5**	**34.5**	**40**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	1,780	1,780	

Storage Area	**Type**	**Notes**
Plaquemines Scarsdale	Single area	Max height is higher of surge (9) or design height (9) - upper level is also capped at 18' as the outflow level into the Mississippi River

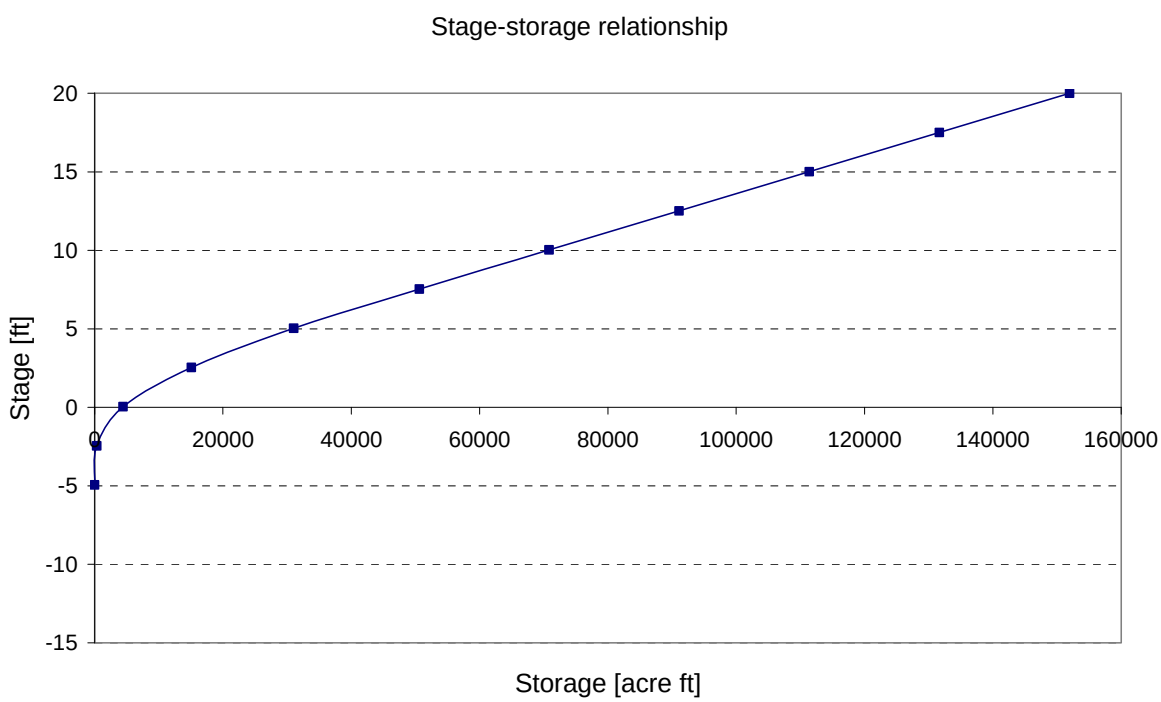


Figure B.18 - Stage storage relationship Plaquemines - Scarsdale

Additional Notes

Limit of flood depth will be based on the MRT levees rather than the hurricane protection - taken as 18’ as an upper limit.

Bonfouca

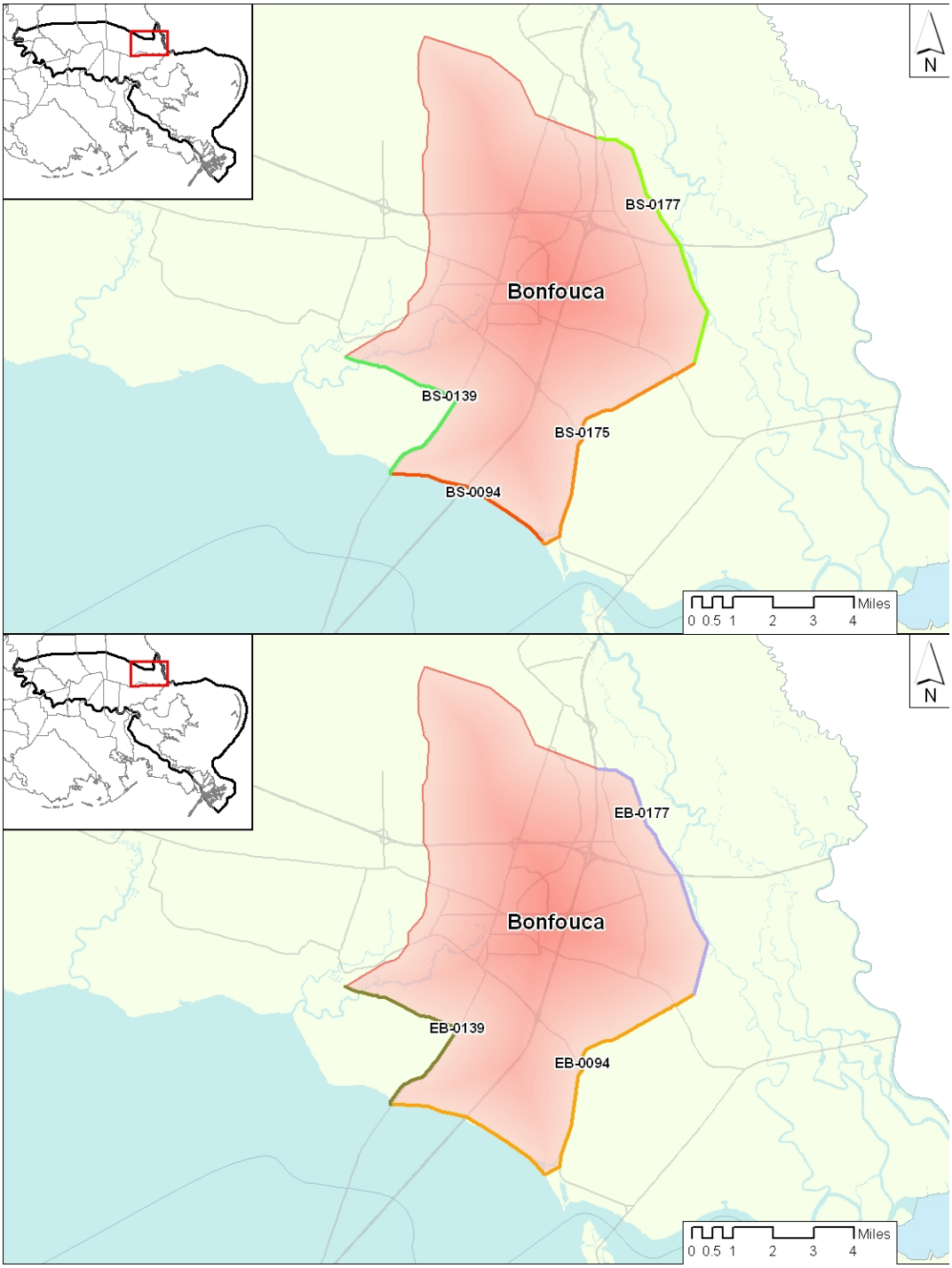


Figure B.19 – Sub-basin and levees Bonfouca (High Level and Barrier Plan)

Table B-10 – Levee characteristics

High Level Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0094	**22404**	**n.a.**	**16.5**	**23**	**26**	**16.5**	**23**	**26**
BS-0139	**29845**	**n.a.**	**16**	**21.5**	**24**	**16**	**21.5**	**24**
BS-0175	**34473**	**n.a.**	**22.5**	**30.5**	**34.5**	**19**	**25.5**	**29**
BS-0177	**36669**	**n.a.**	**20**	**28**	**32**	**17.5**	**23.5**	**26.5**

Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
EB-0094	**56878**	**n.a.**	**13**	**21**	**24.5**	**12.5**	**20.5**	**24.5**
EB-0139	**29924**	**n.a.**	**11**	**17.5**	**21**	**11**	**17.5**	**21**
EB-0177	**25400**	**n.a.**	**26**	**35**	**39**	**20.5**	**27**	**30**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	0	10,000	Based on 0.5cfs/acre - area taken as south of I12

Storage Area	**Type**	**Notes**
Bonfouca	Single area	Max stage is higher of surge (139) or design height (139) - note surges and levee heights are higher to the east and it has been assumed that levels in the west will control max interior flood stage.

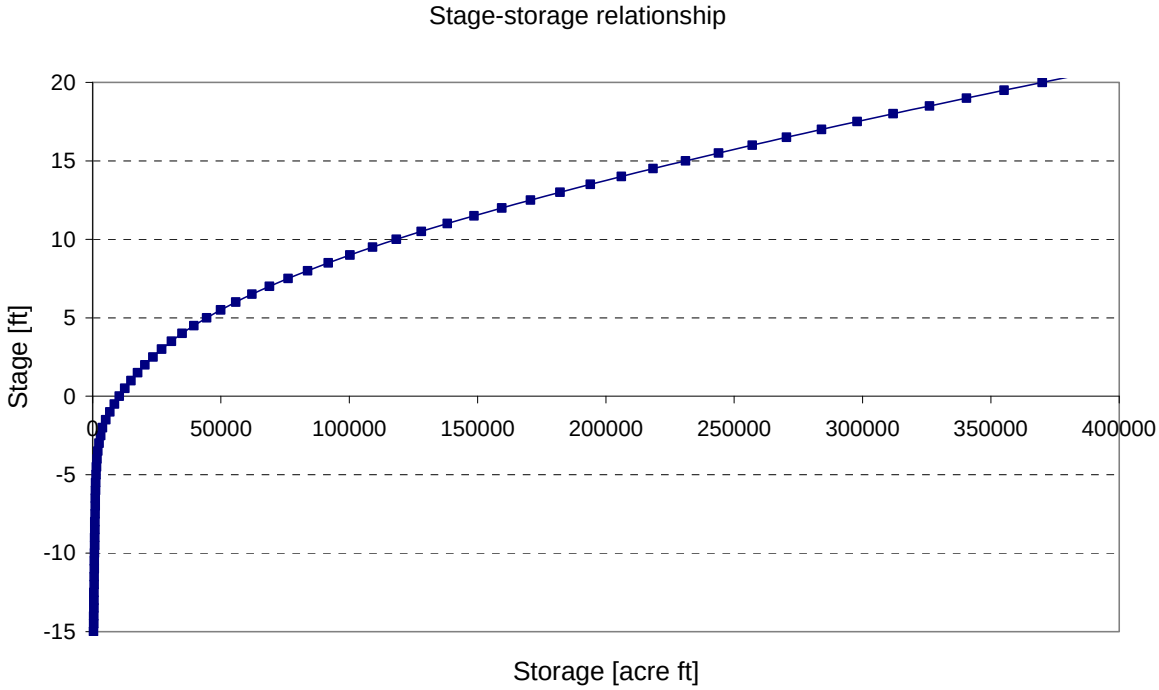


Figure B.20 - Stage storage relationship Bonfouca

Additional Notes

The Lidar levels on the North Shore show very low levels and the storage curves extend to well below 0 datum. It has been decided to assume that there is no storage available below 3' in all areas on the North shore when levees are constructed. The stage storage relationships used in the calculations have been amended to this for both the high level and barrier plans, although the graph above shows the full curve.

For the North Shore (where the new levees are being introduced) pump capacity was established based on 0.5cfs/acre (derived from East Jefferson which has approx 20k cfs of pumping for 30k acres - approx 0.6cfs/acre).

Rainfall rates are based on the local storage behind the levees rather than the total areas used in the stage storage analysis. The following areas were used in sizing the pumps for the North Shore and in establishing rainfall volumes. The table gives the full area and the reduced area used in the calculations.

Area	**Old Area approx(acres)**	**New Area (acres)**
Bedico	30,000	6,000
Bonfouca	37,000	20,000
Lacombe	58,000	13,500
Liberty	20,000	5,000
Tangipahoa	62,000	5,000
Tchefuncte	145,000	20,000

Rainfall quantities based on these areas have been included in the stage storage analysis.

Liberty

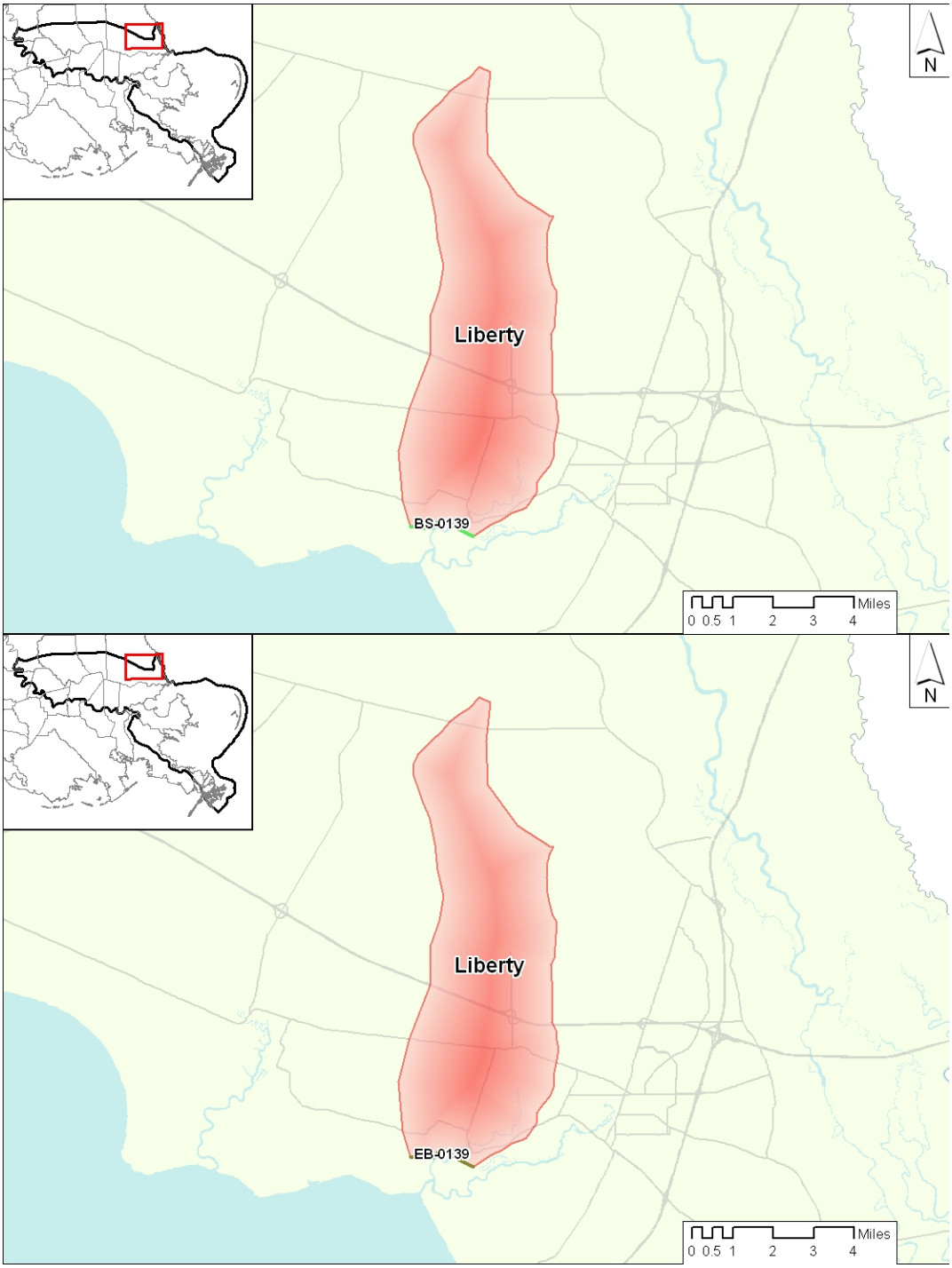


Figure B.21 – Sub-basin and levees Liberty (High Level and Barrier Plan)

Table B-11 – Levee characteristics

High Level Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0139	**9115**	**n.a.**	**16**	**21.5**	**24**	**16**	**21.5**	**24**

Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
EB-0139	**9036**	**n.a.**	**11**	**17.5**	**21**	**11**	**17.5**	**21**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	0	2,500	Based on 0.5cfs/acre - area taken as south of I12

Storage Area	**Type**	**Notes**
Liberty and Liberty_R	Single area	Max height is higher of surge (139) or design height (139)

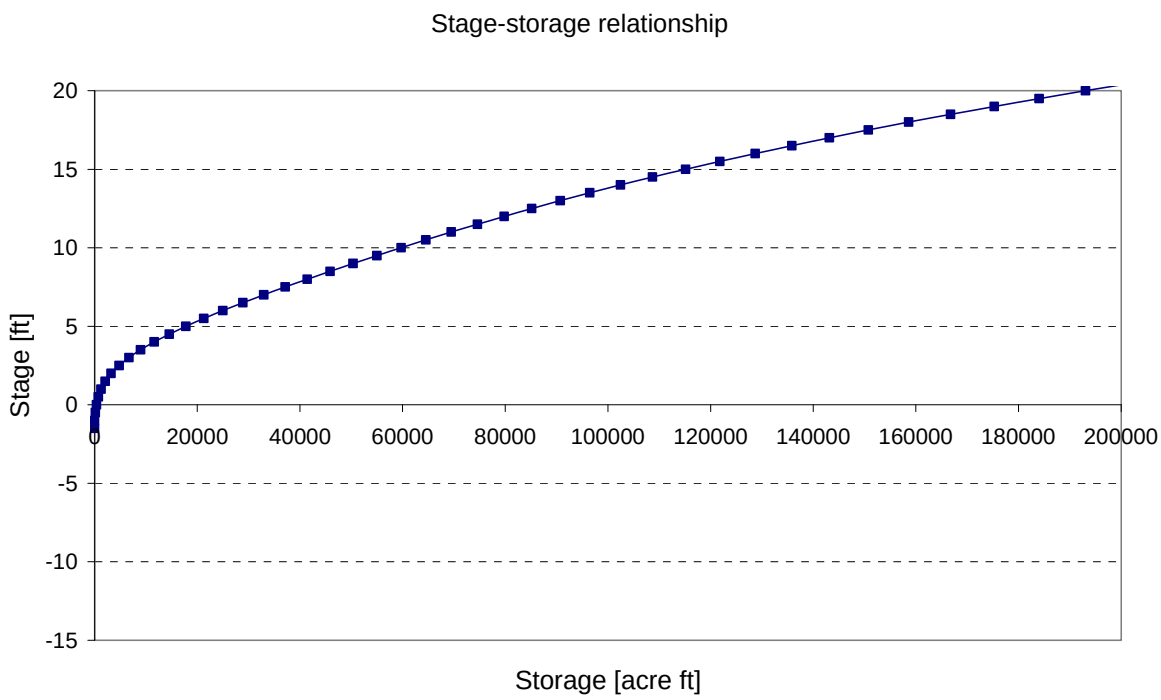


Figure B.22 - Stage storage relationship Liberty

Additional Notes

The Lidar levels on the North Shore show very low levels and the storage curves extend to well below 0 datum. It has been decided to assume that there is no storage available below 3' in all areas on the North shore when levees are constructed. The stage storage relationships used in the calculations have been amended to this for both the high level and barrier plans, although the graph above shows the full curve.

For the North Shore (where the new levees are being introduced) pump capacity was established based on 0.5cfs/acre (derived from East Jefferson which has approx 20k cfs of pumping for 30k acres - approx 0.6cfs/acre).

Rainfall rates are based on the local storage behind the levees rather than the total areas used in the stage storage analysis. The following areas were used in sizing the pumps for the North Shore and in establishing rainfall volumes. The table gives the full area and the reduced area used in the calculations

Area	**Old Area approx(acres)**	**New Area (acres)**
Bedico	30,000	6,000
Bonfouca	37,000	20,000
Lacombe	58,000	13,500
Liberty	20,000	5,000
Tangipahoa	62,000	5,000
Tchefuncte	145,000	20,000

Rainfall quantities based on these areas have been included in the stage storage analysis.

Lacombe

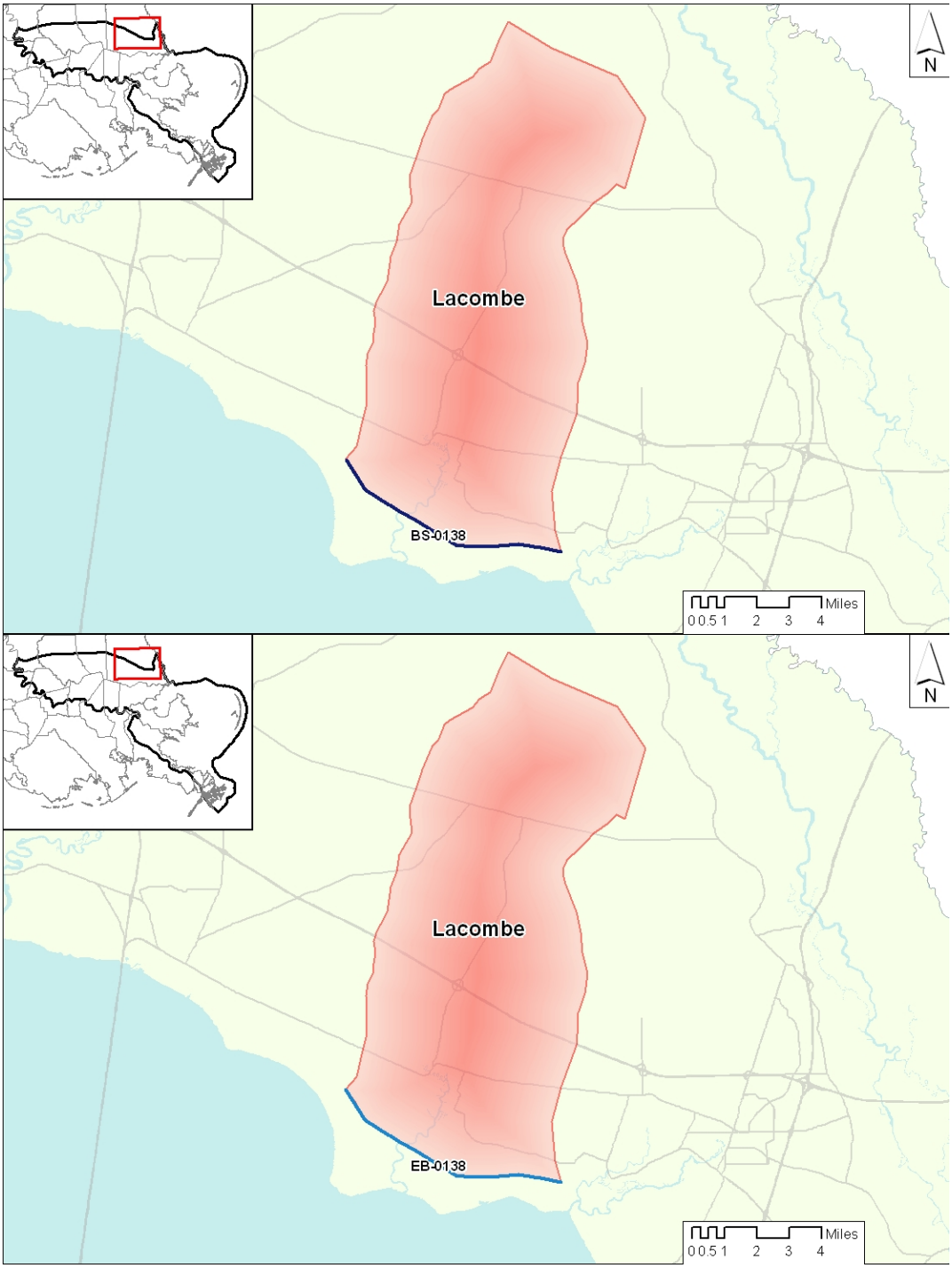


Figure B.23 – Sub-basin and levees Lacombe (High Level and Barrier Plan)

Table B-12 – Levee characteristics

High Level Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0138	**40380**	**n.a.**	**15**	**20**	**22.5**	**15**	**20**	**22.5**

Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
EB-0138	**40598**	**n.a.**	**9.5**	**14.5**	**17.5**	**9.5**	**14.5**	**17.5**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	0	7,000	Based on 0.5cfs/acre - area taken as south of I12

Storage Area	**Type**	**Notes**
Lacombe	Single area	Max stage is higher of surge (138) or design height (138)

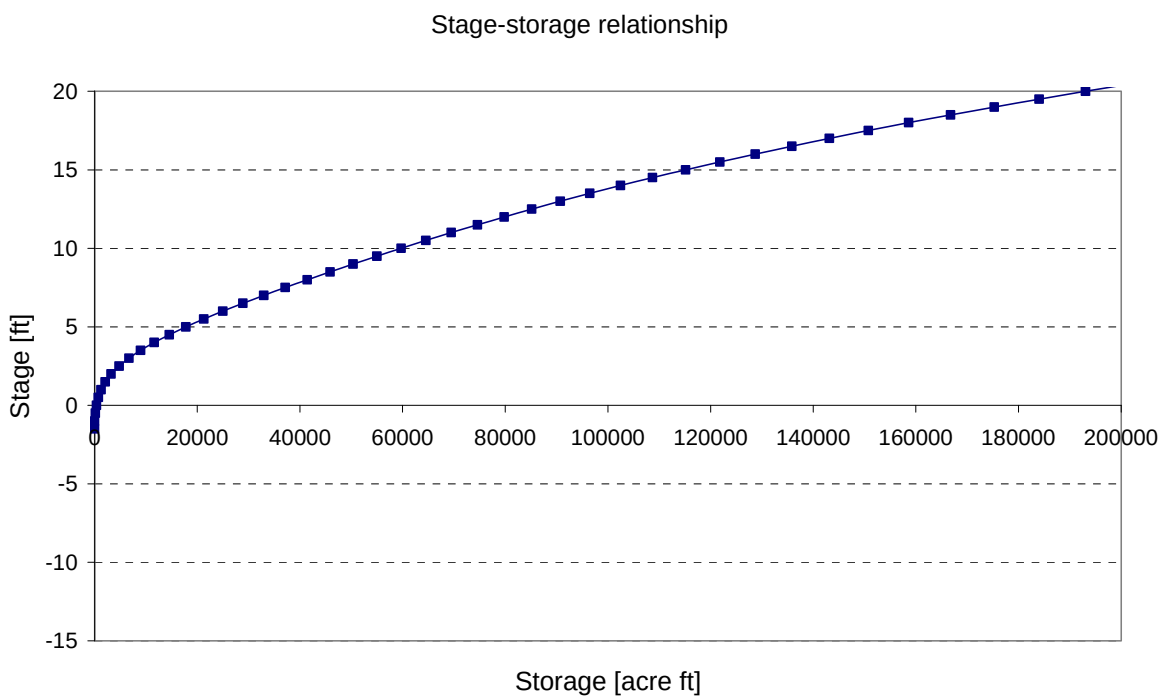


Figure B.24 - Stage storage relationship Lacombe

Additional Notes

The Lidar levels on the North Shore show very low levels and the storage curves extend to well below 0 datum. It has been decided to assume that there is no storage available below 3' in all areas on the North shore when levees are constructed. The stage storage relationships used in the calculations have been amended to this for both the high level and barrier plans, although the graph above shows the full curve.

For the North Shore (where the new levees are being introduced) pump capacity was established based on 0.5cfs/acre (derived from East Jefferson which has approx 20k cfs of pumping for 30k acres - approx 0.6cfs/acre).

Rainfall rates are based on the local storage behind the levees rather than the total areas used in the stage storage analysis. The following areas were used in sizing the pumps for the North Shore and in establishing rainfall volumes. The table gives the full area and the reduced area used in the calculations

Area	**Old Area approx(acres)**	**New Area (acres)**
Bedico	30,000	6,000
Bonfouca	37,000	20,000
Lacombe	58,000	13,500
Liberty	20,000	5,000
Tangipahoa	62,000	5,000
Tchefuncte	145,000	20,000

Rainfall quantities based on these areas have been included in the stage storage analysis.

Tchefuncte

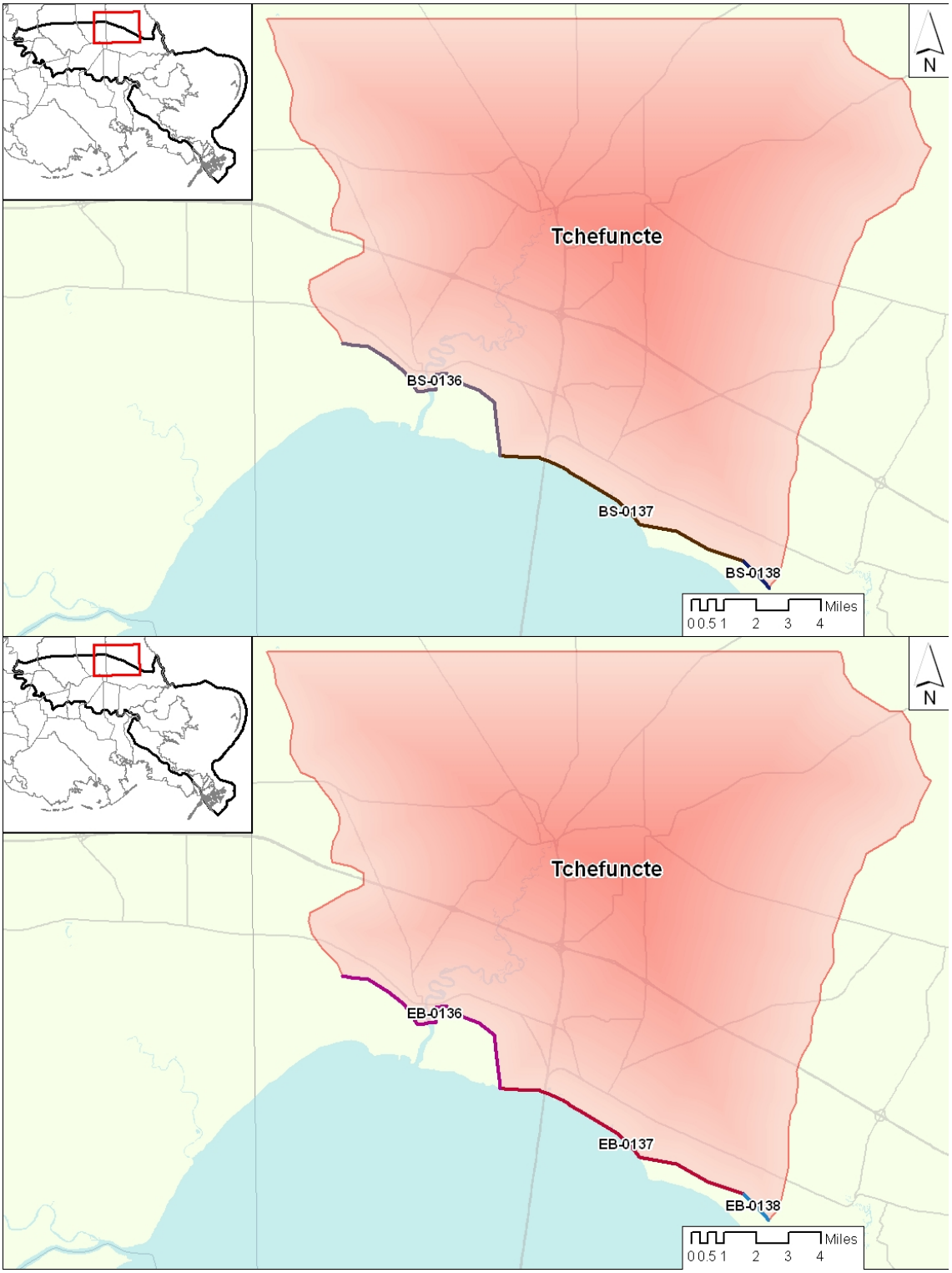


Figure B.25 – Sub-basin and levees Tchefuncte (High Level and Barrier Plan)

Table B-13 – Levee characteristics

High Level Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0136	**40570**	**n.a.**	**16**	**20**	**22**	**16**	**20**	**22**
BS-0137	**44328**	**n.a.**	**15**	**19**	**21.5**	**15**	**19**	**21.5**
BS-0138	**6143**	**n.a.**	**15**	**20**	**22.5**	**15**	**20**	**22.5**

Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
EB-0136	**40581**	**n.a.**	**11**	**15.5**	**17.5**	**11**	**15.5**	**17.5**
EB-0137	**44328**	**n.a.**	**9.5**	**13.5**	**16**	**9.5**	**13.5**	**16**
EB-0138	**5925**	**n.a.**	**9.5**	**14.5**	**17.5**	**9.5**	**14.5**	**17.5**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	0	10,000	Based on 0.5cfs/acre - area taken as south of I12

Storage Area	**Type**	**Notes**
Tchefuncte	Single area	Max stage is higher of surge (139) or design height (139)

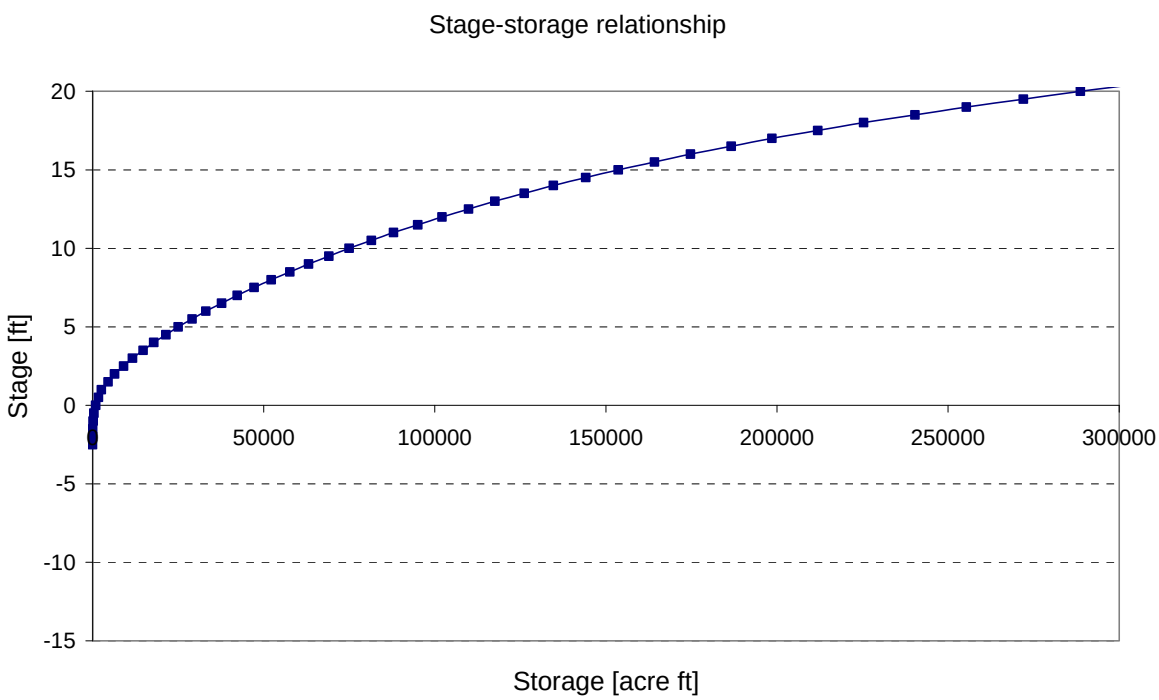


Figure B.26 - Stage storage relationship Tchefuncte

Additional Notes

The Lidar levels on the North Shore show very low levels and the storage curves extend to well below 0 datum. It has been decided to assume that there is no storage available below 3' in all areas on the North shore when levees are constructed. The stage storage relationships used in the calculations have been amended to this for both the high level and barrier plans, although the graph above shows the full curve.

For the North Shore (where the new levees are being introduced) pump capacity was established based on 0.5cfs/acre (derived from East Jefferson which has approx 20k cfs of pumping for 30k acres - approx 0.6cfs/acre).

Rainfall rates are based on the local storage behind the levees rather than the total areas used in the stage storage analysis. The following areas were used in sizing the pumps for the North Shore and in establishing rainfall volumes. The table gives the full area and the reduced area used in the calculations

Area	**Old Area approx(acres)**	**New Area (acres)**
Bedico	30,000	6,000
Bonfouca	37,000	20,000
Lacombe	58,000	13,500
Liberty	20,000	5,000
Tangipahoa	62,000	5,000
Tchefuncte	145,000	20,000

Rainfall quantities based on these areas have been included in the stage storage analysis.

Tangipahoa

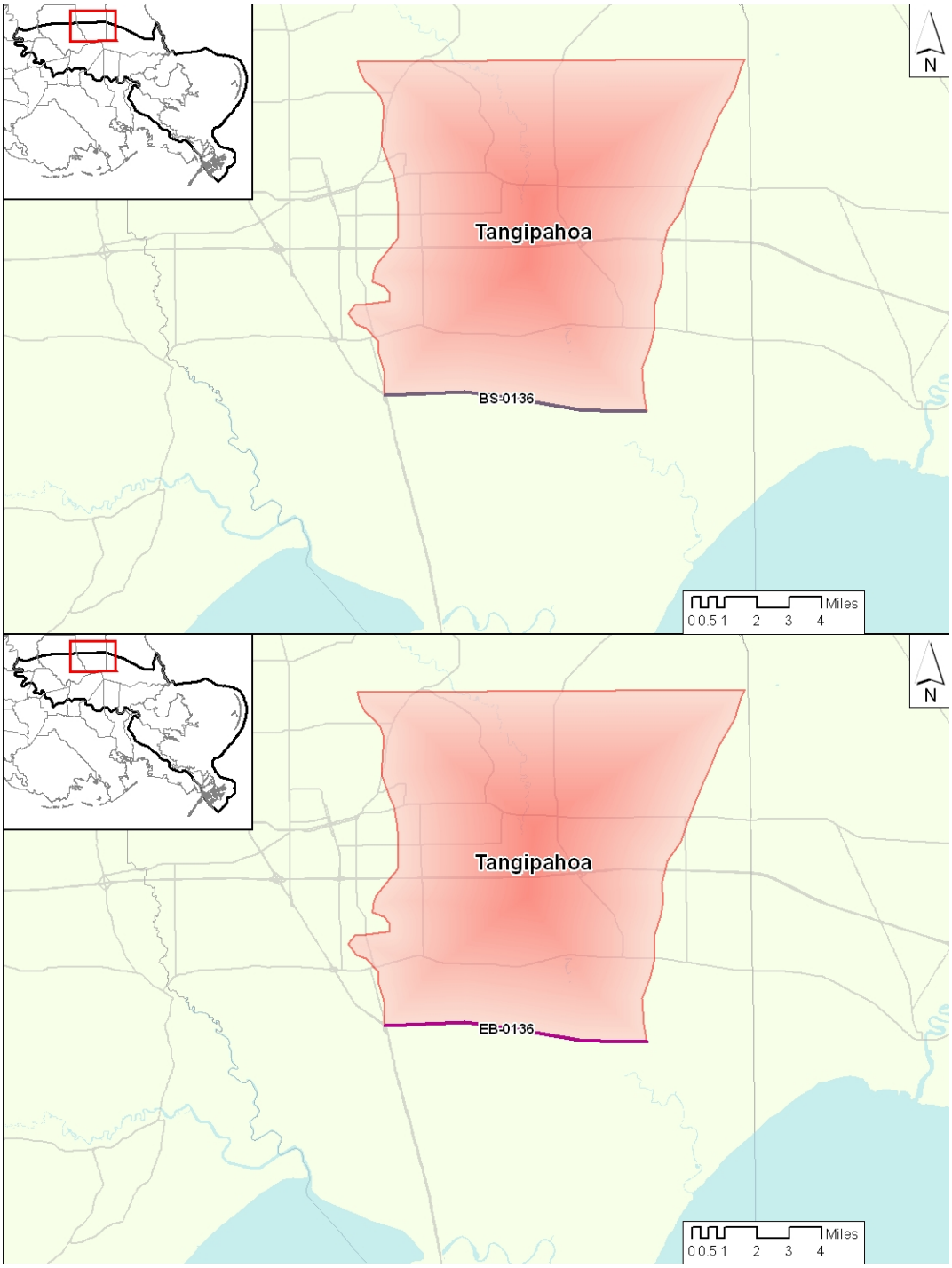


Figure B.27 – Sub-basin and levees Tangipahoa (High Level and Barrier Plan)

Table B-14 – Levee characteristics

High Level Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0136	**35756**	**n.a.**	**16**	**20**	**22**	**16**	**20**	**22**

Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
EB-0136	**35577**	**n.a.**	**11**	**15.5**	**17.5**	**11**	**15.5**	**17.5**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	0	2,500	Based on 0.5cfs/acre - area taken as south of I12

Storage Area	**Type**	**Notes**
Tangipahoa	Single area	Max stage is higher of surge (136) or design height (136)

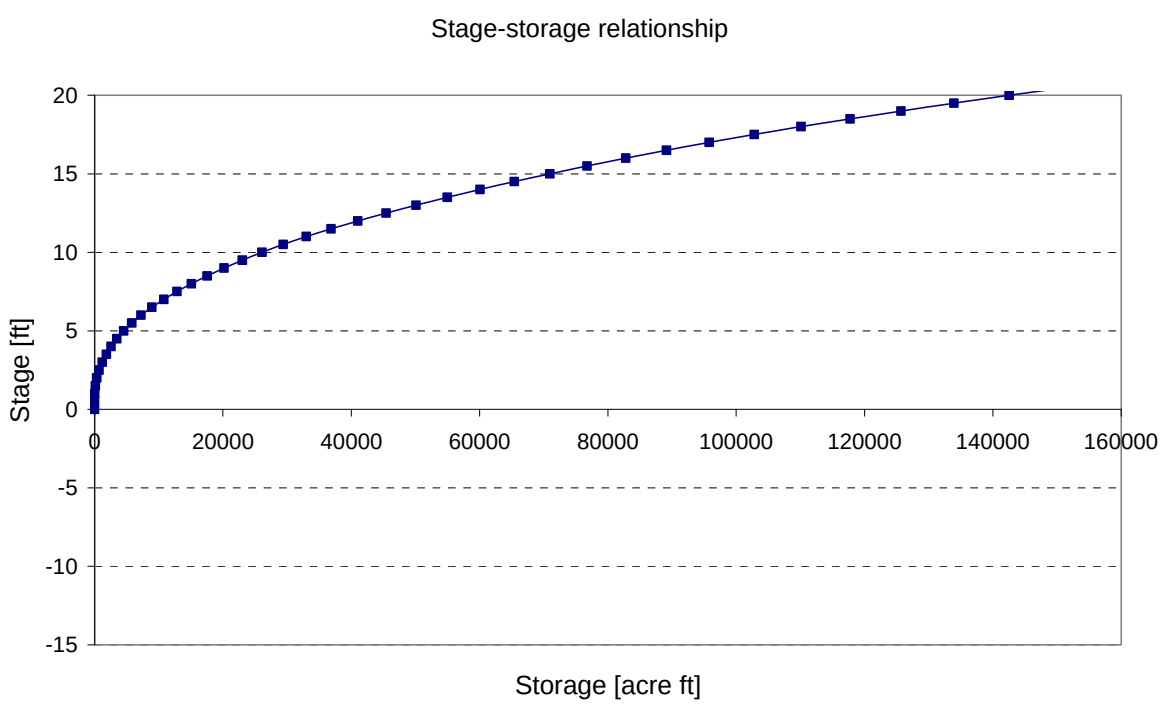


Figure B.28 - Stage storage relationship Tangipahoa

Additional Notes

The Lidar levels on the North Shore show very low levels and the storage curves extend to well below 0 datum. It has been decided to assume that there is no storage available below 3' in all areas on the North shore when levees are constructed. The stage storage relationships used in the calculations have been amended to this for both the high level and barrier plans, although the graph above shows the full curve.

For the North Shore (where the new levees are being introduced) pump capacity was established based on 0.5cfs/acre (derived from East Jefferson which has approx 20k cfs of pumping for 30k acres - approx 0.6cfs/acre).

Rainfall rates are based on the local storage behind the levees rather than the total areas used in the stage storage analysis. The following areas were used in sizing the pumps for the North Shore and in establishing rainfall volumes. The table gives the full area and the reduced area used in the calculations

Area	**Old Area approx(acres)**	**New Area (acres)**
Bedico	30,000	6,000
Bonfouca	37,000	20,000
Lacombe	58,000	13,500
Liberty	20,000	5,000
Tangipahoa	62,000	5,000
Tchefuncte	145,000	20,000

Rainfall quantities based on these areas have been included in the stage storage analysis.

Bedico

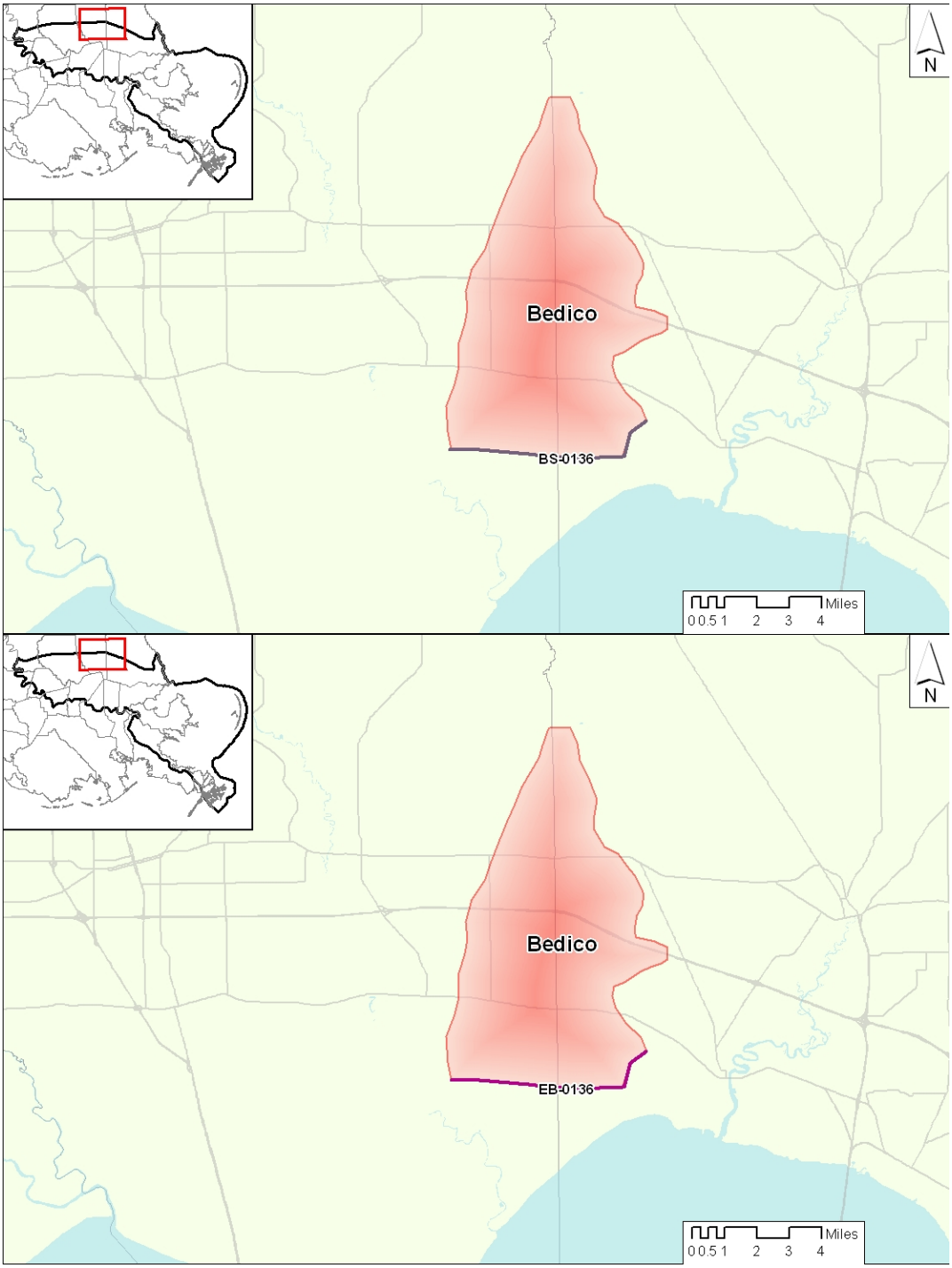


Figure B.29 – Sub-basin and levees Bedico (High Level and Barrier Plan)

Table B-15 – Levee characteristics

High Level Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0136	**35756**	**n.a.**	**16**	**20**	**22**	**16**	**20**	**22**

Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
EB-0136	**35577**	**n.a.**	**11**	**15.5**	**17.5**	**11**	**15.5**	**17.5**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	0	3,000	Based on 0.5cfs/acre - area taken as south of I12

Storage Area	**Type**	**Notes**
Bedico	Single area	Max stage is higher of surge (136) or design height (136)

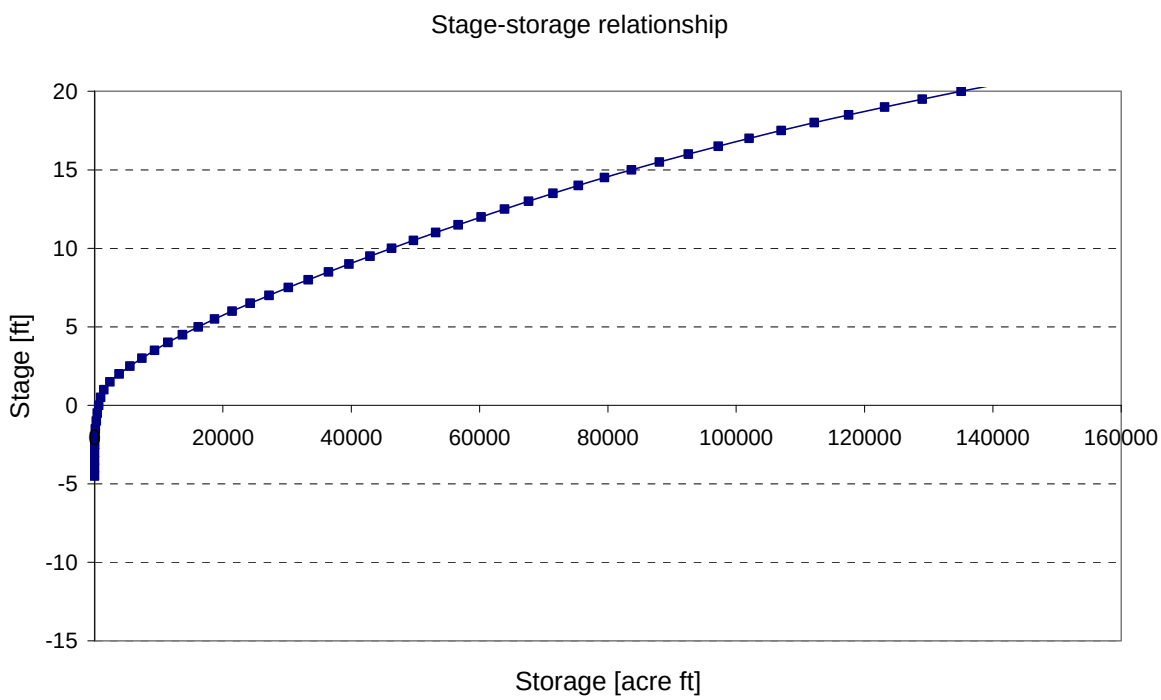


Figure B.30 - Stage storage relationship Bedico

Additional Notes

The Lidar levels on the North Shore show very low levels and the storage curves extend to well below 0 datum. It has been decided to assume that there is no storage available below 3' in all areas on the North shore when levees are constructed. The stage storage relationships used in the calculations have been amended to this for both the high level and barrier plans, although the graph above shows the full curve.

For the North Shore (where the new levees are being introduced) pump capacity was established based on 0.5cfs/acre (derived from East Jefferson which has approx 20k cfs of pumping for 30k acres - approx 0.6cfs/acre).

Rainfall rates are based on the local storage behind the levees rather than the total areas used in the stage storage analysis. The following areas were used in sizing the pumps for the North Shore and in establishing rainfall volumes. The table gives the full area and the reduced area used in the calculations

Area	**Old Area approx(acres)**	**New Area (acres)**
Bedico	30,000	6,000
Bonfouca	37,000	20,000
Lacombe	58,000	13,500
Liberty	20,000	5,000
Tangipahoa	62,000	5,000
Tchefuncte	145,000	20,000

Rainfall quantities based on these areas have been included in the stage storage analysis.

Planning unit 2 – Barataria Basin

Algiers

Figure B.31 – Sub-basin and levees Algiers (High Level and Barrier Plan)

Table B-16 – Levee characteristics

High Level Plan/ Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0158	**10519**	**10**	**10**	**15**	**17.5**	**10**	**15**	**17.5**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	4,650	4,650	

Storage Area	**Type**	**Notes**
Algiers	Single area	Max stage is higher of surge (158) or authorized (10') or design height (158)

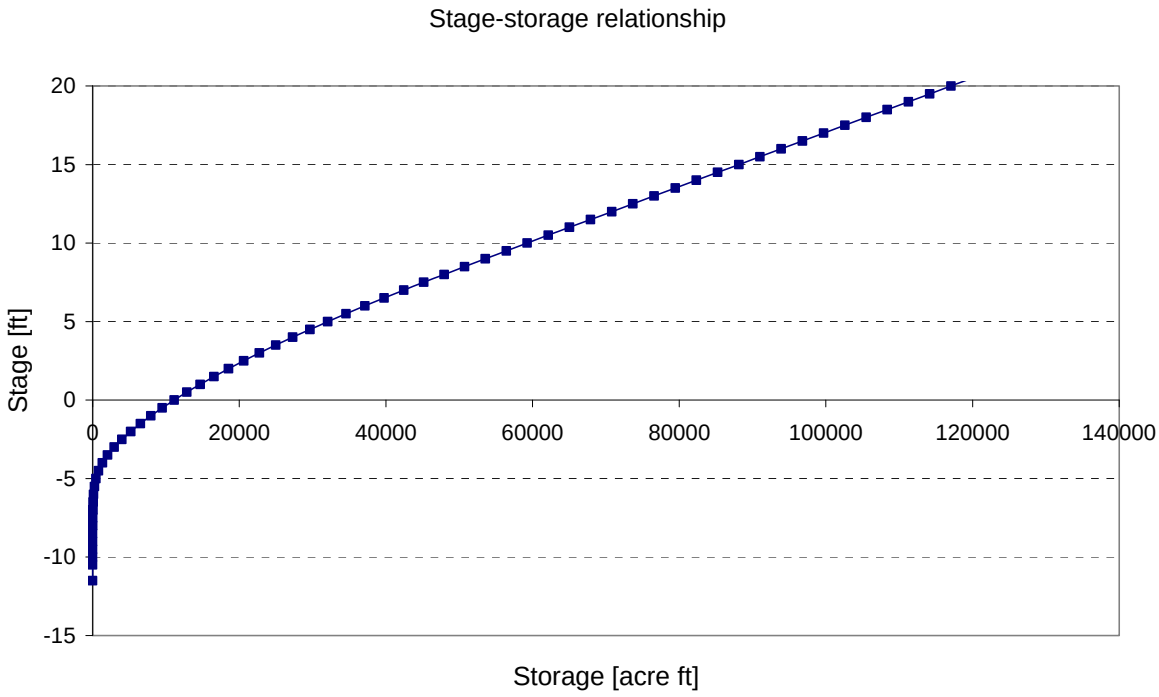


Figure B.32 - Stage storage relationship Algiers

English Turn

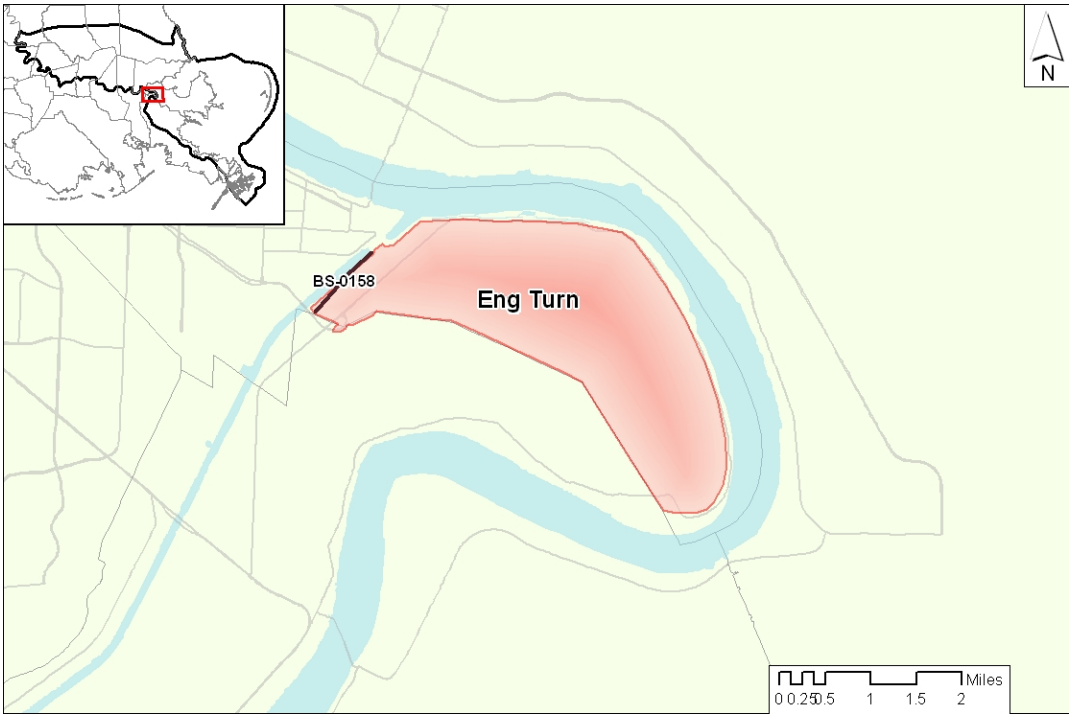


Figure B.33 – Sub-basin and levees English Turn (High Level and Barrier Plan)

Table B-17 – Levee characteristics

High Level Plan/ Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0158	**4842**	**10**	**10**	**15**	**17.5**	**10**	**15**	**17.5**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	1,670	1,670	

Storage Area	**Type**	**Notes**
English Turn	Single area	Max stage is higher of surge (158) or authorized (10') or design height (158)

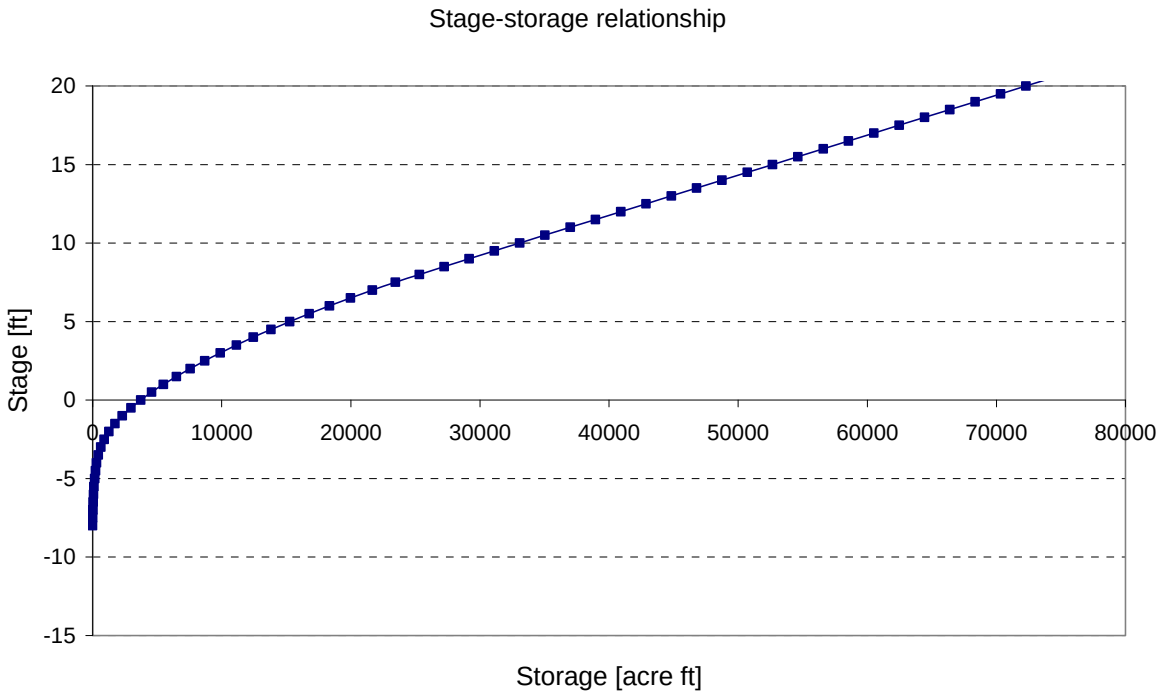


Figure B.34 - Stage storage relationship English Turn

Plaquemaines Belle Chase

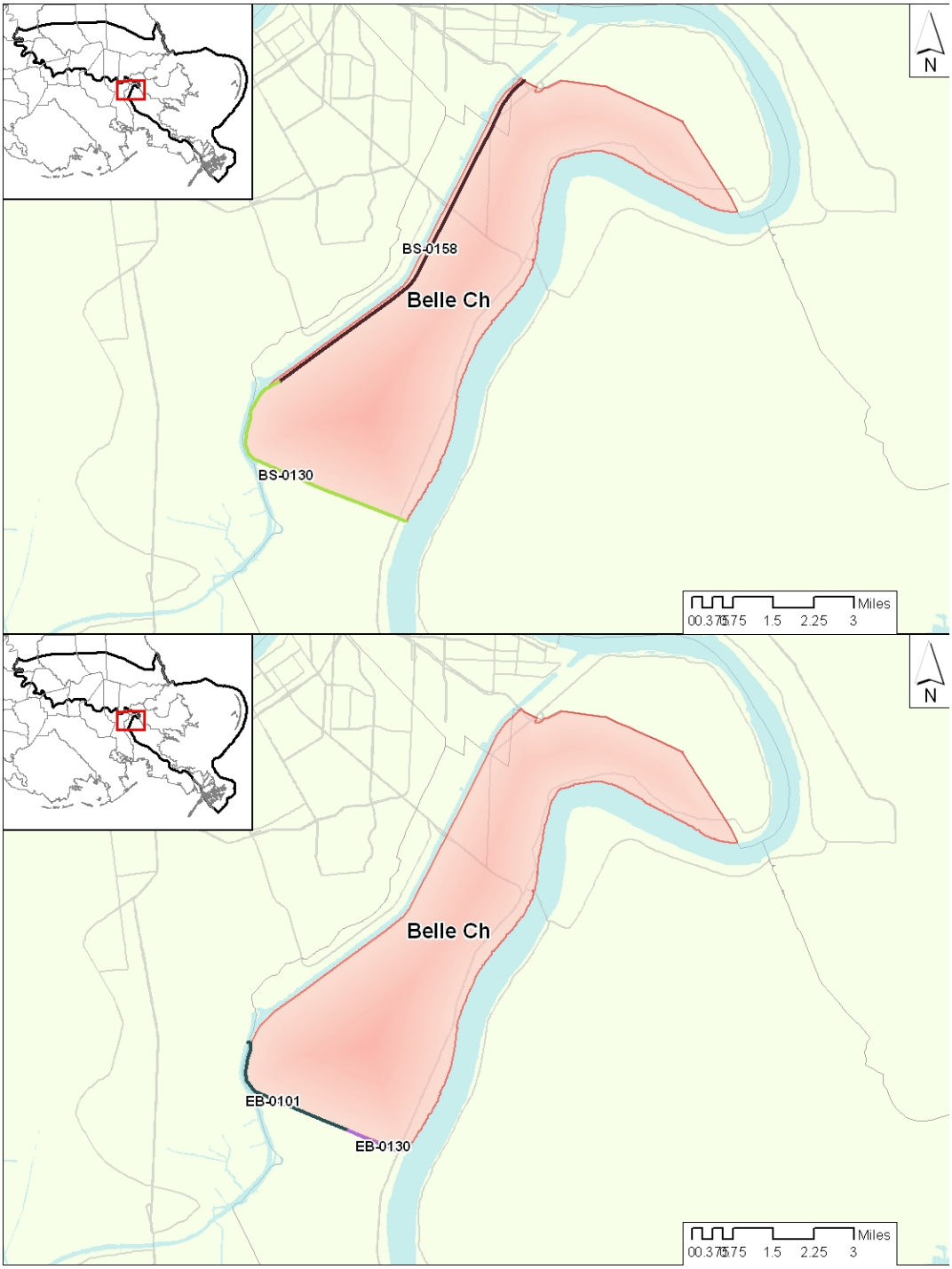


Figure B.35 – Sub-basin and levees Plaquemaines Belle Chase (High Level and Barrier Plan)

Table B-18 – Levee characteristics

High Level Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0130	**25271**	**11**	**11**	**17**	**20**	**11**	**15**	**17**
BS-0158	**38978**	**10**	**10**	**15**	**17.5**	**10**	**15**	**17.5**

Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
EB-0101	**15425**	**11**	**11**	**11**	**11**	**11**	**11**	**11**
EB-0130		**11**	**16**	**22**	**25**	**14**	**19**	**22**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	4,650	4,650	

Storage Area	**Type**	**Notes**
Plaquemines Belle Chase	Single area	Max height is higher of authorized (11'), surge (130) or design height (130)

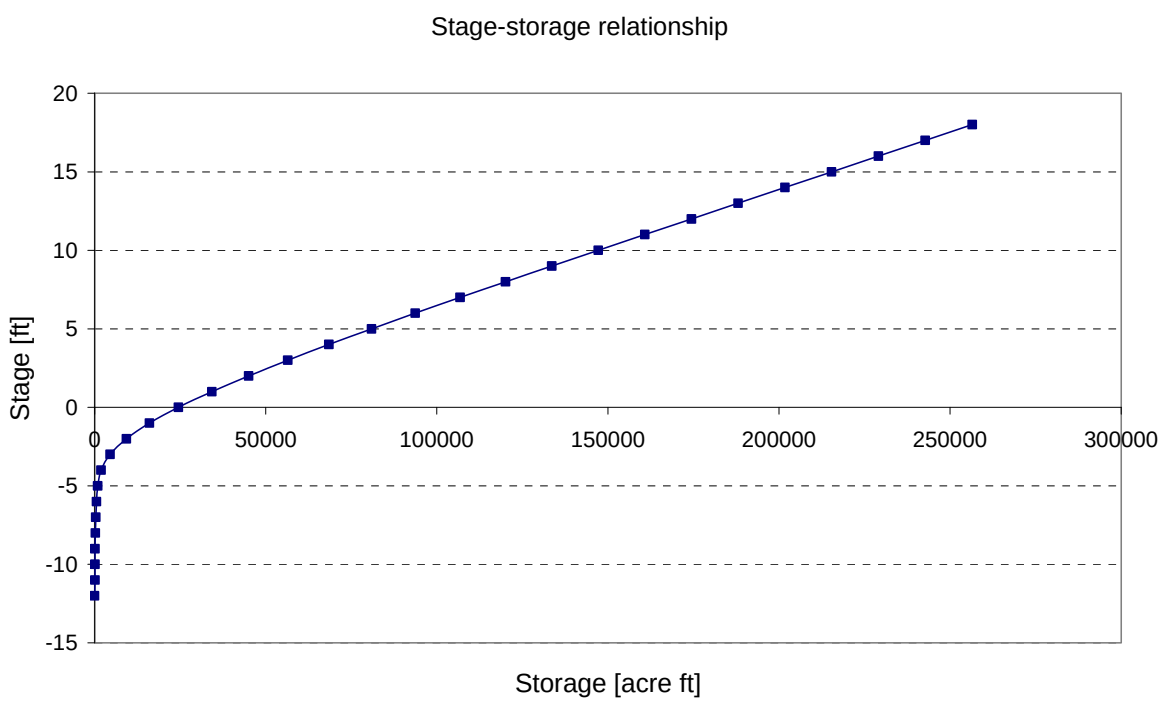


Figure B.36 - Stage storage relationship Plaquemaines Belle Chase

West Jefferson – East of Harvey

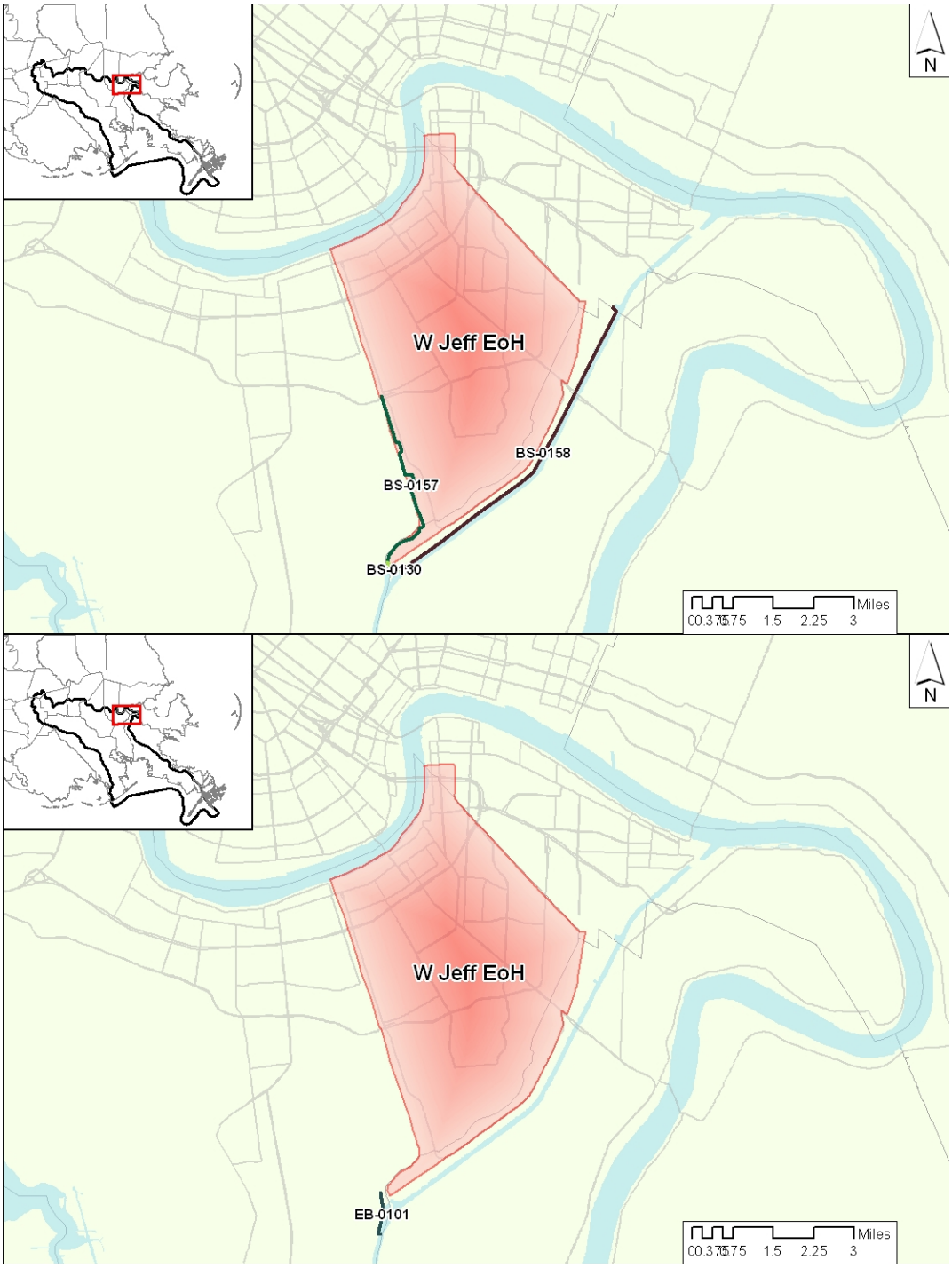


Figure B.37 – Sub-basin and levees West Jefferson – East of Harvey (High Level and Barrier Plan)

Table B-19 – Levee characteristics

High Level Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0130	**1694**	**11**	**11**	**17**	**20**	**11**	**15**	**17**
BS-0157	**20352**	**10**	**10**	**14**	**16.5**	**10**	**14**	**16**
BS-0158	**34327**	**10**	**10**	**15**	**17.5**	**10**	**15**	**17.5**

Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
EB-0101	**4489**	**11**	**11**	**11**	**11**	**11**	**11**	**11**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	10,430	10,430	

Storage Area	**Type**	**Notes**
West Jeff - East of Harvey	Linked area (West Jeff)	Connects to Harvey (5'). See description of linked system in chapter 5

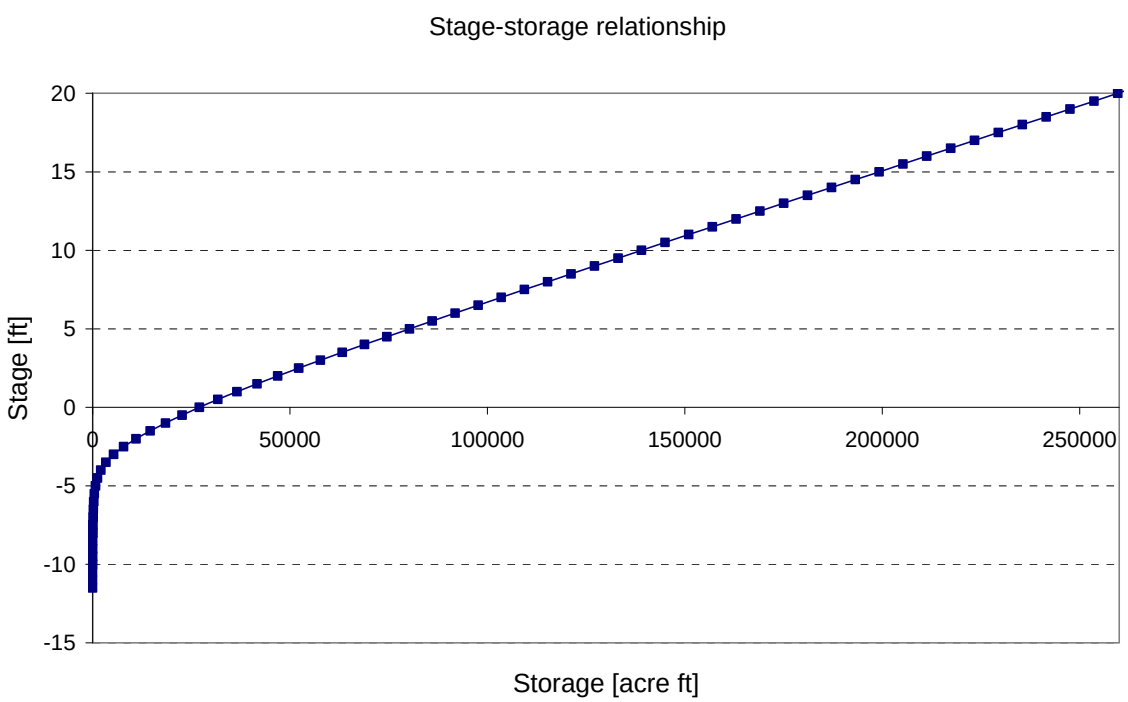


Figure B.38 - Stage storage relationship West Jefferson – East of Harvey

West Jefferson – Harvey

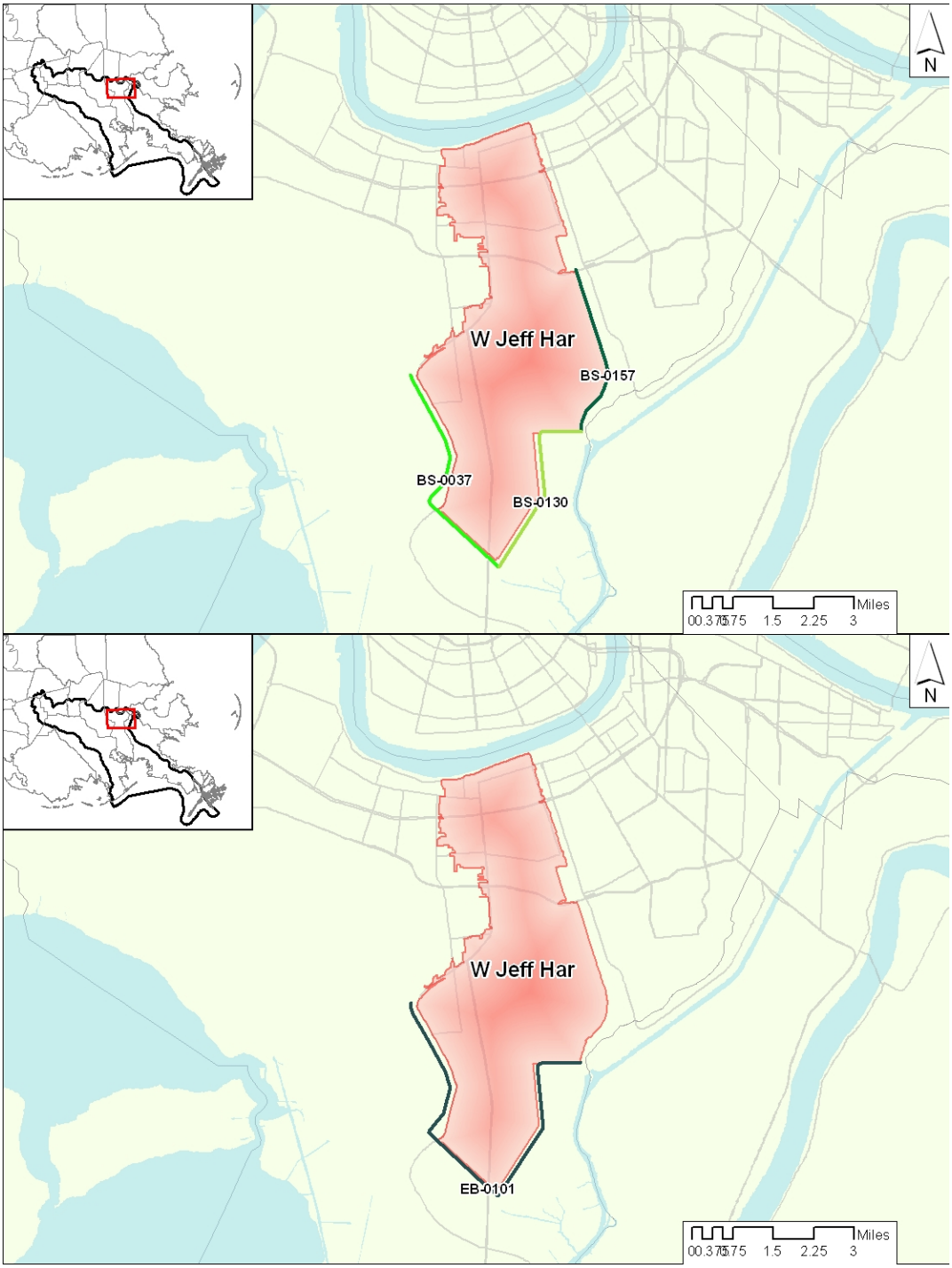


Figure B.39 – Sub-basin and levees West Jefferson – Harvey (High Level and Barrier Plan)

Table B-20 – Levee characteristics

High Level Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0037	**23358**	**11**	**11**	**14**	**18**	**11**	**12.5**	**16**
BS-0130	**18623**	**11**	**11**	**17**	**20**	**11**	**15**	**17**
BS-0157	**17231**	**10**	**10**	**14**	**16.5**	**10**	**14**	**16**

Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
EB-0101	**18449**	**11**	**11**	**11**	**11**	**11**	**11**	**11**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	7,930	7,930	

Storage Area	**Type**	**Notes**
West Jeff - Harvey	Linked area (West Jeff)	Connects to EoH (5') and Ames (5'). See description of linked system in chapter 5.

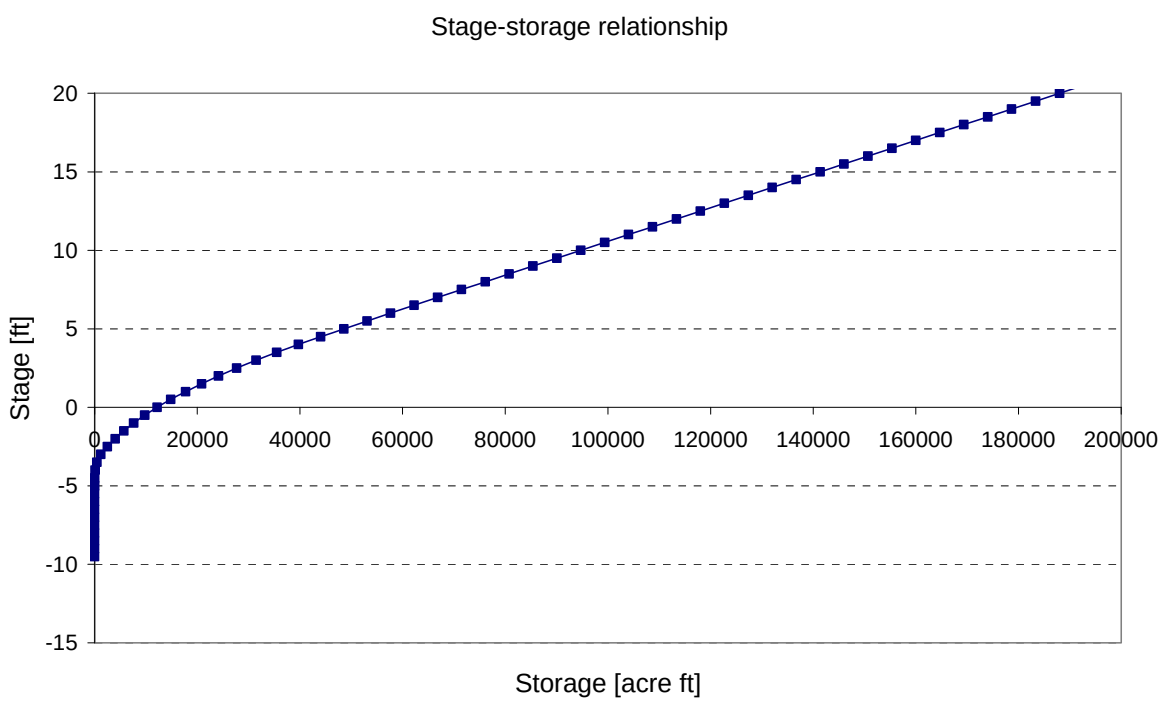


Figure B.40 - Stage storage relationship West Jefferson – Harvey

West Jefferson – Ames

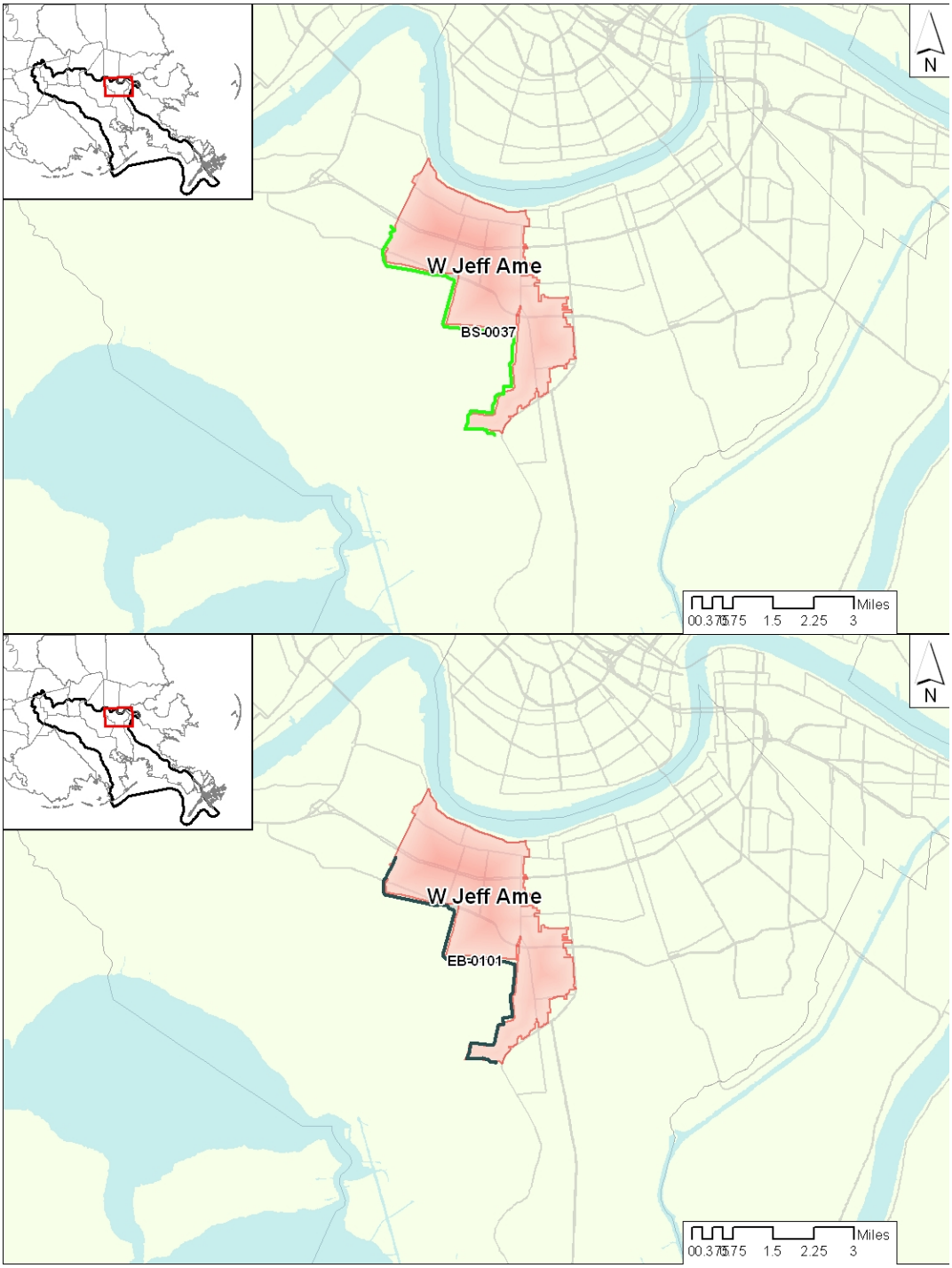


Figure B.41 – Sub-basin and levees West Jefferson – Ames (High Level and Barrier Plan)

Table B-21 – Levee characteristics

High Level Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0037	**40145**	**11**	**11**	**14**	**18**	**11**	**12.5**	**16**

Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
EB-0101	**39179**	**11**	**11**	**11**	**11**	**11**	**11**	**11**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	4,760	4,760	

Storage Area	**Type**	**Notes**
West Jeff - Ames	Linked area (West Jeff)	Connects to Segnette (5') and fed from Harvey (5'). See description of linked system in chapter 5

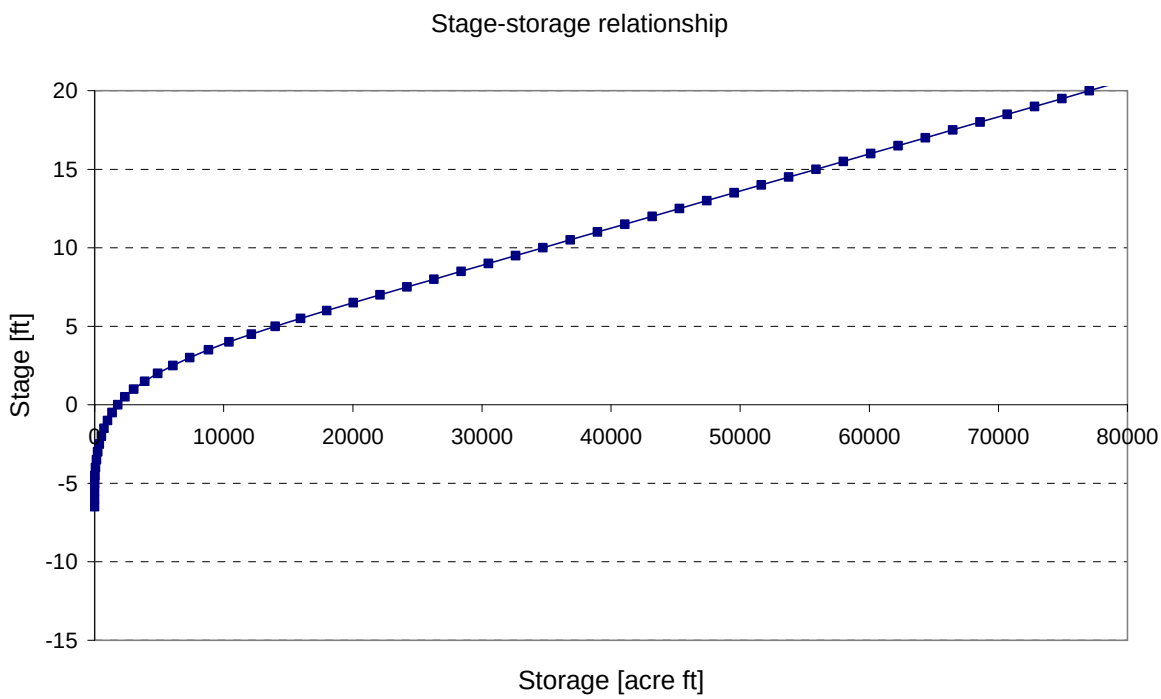


Figure B.42 - Stage storage relationship West Jefferson – Ames

West Jefferson – Segnette

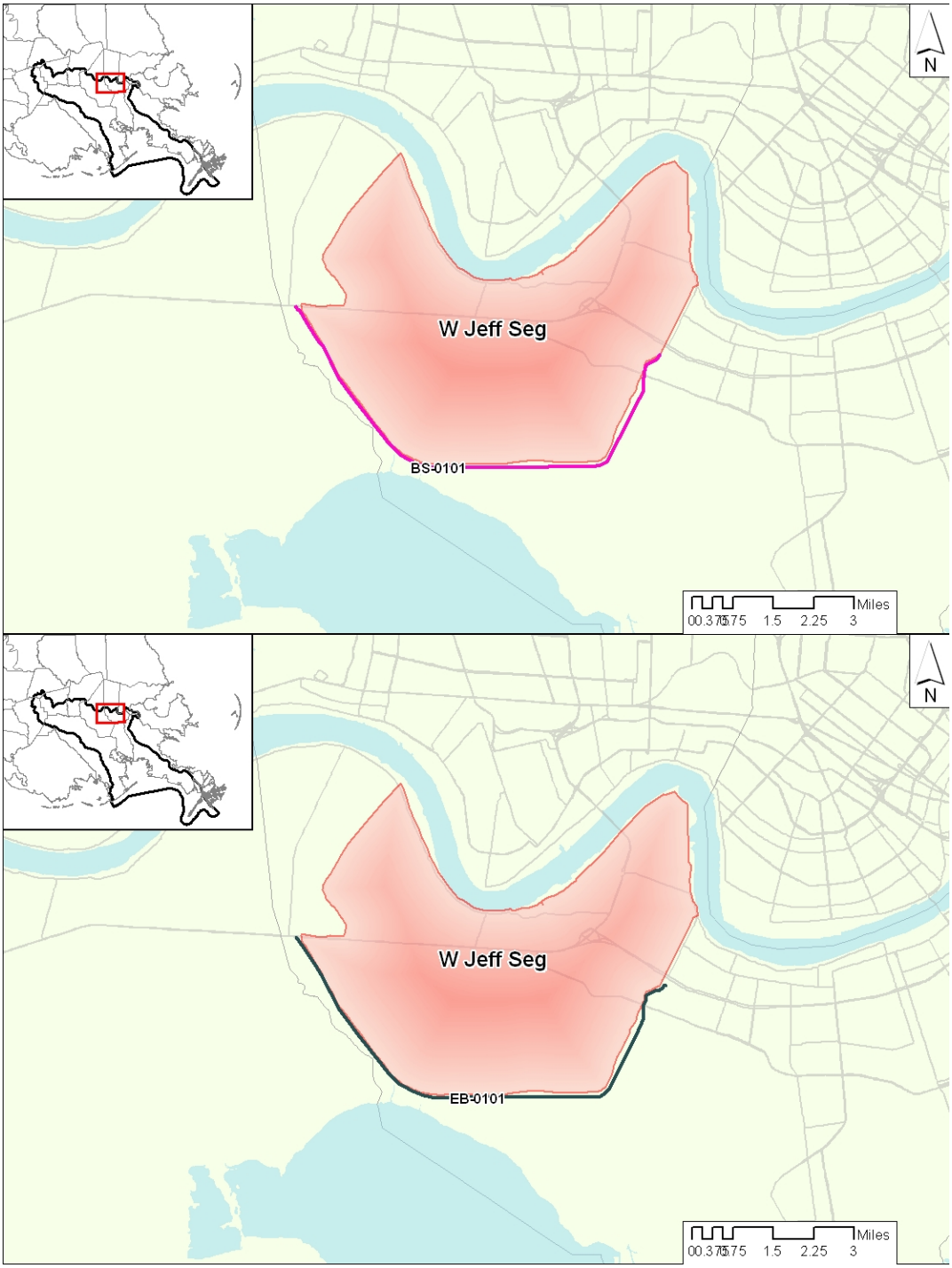


Figure B.43 – Sub-basin and levees West Jefferson – Segnette (High Level and Barrier Plan)

Table B-22 – Levee characteristics

High Level Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0101	**50660**	**11**	**11**	**14**	**16**	**11**	**14**	**16**

Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
EB-0101	**50957**	**11**	**11**	**11**	**11**	**11**	**11**	**11**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	2,000	2,000	

Storage Area	**Type**	**Notes**
West Jeff - Segnette	Linked area (West Jeff)	Connects to Ames (5'). See description of linked system in chapter 5.

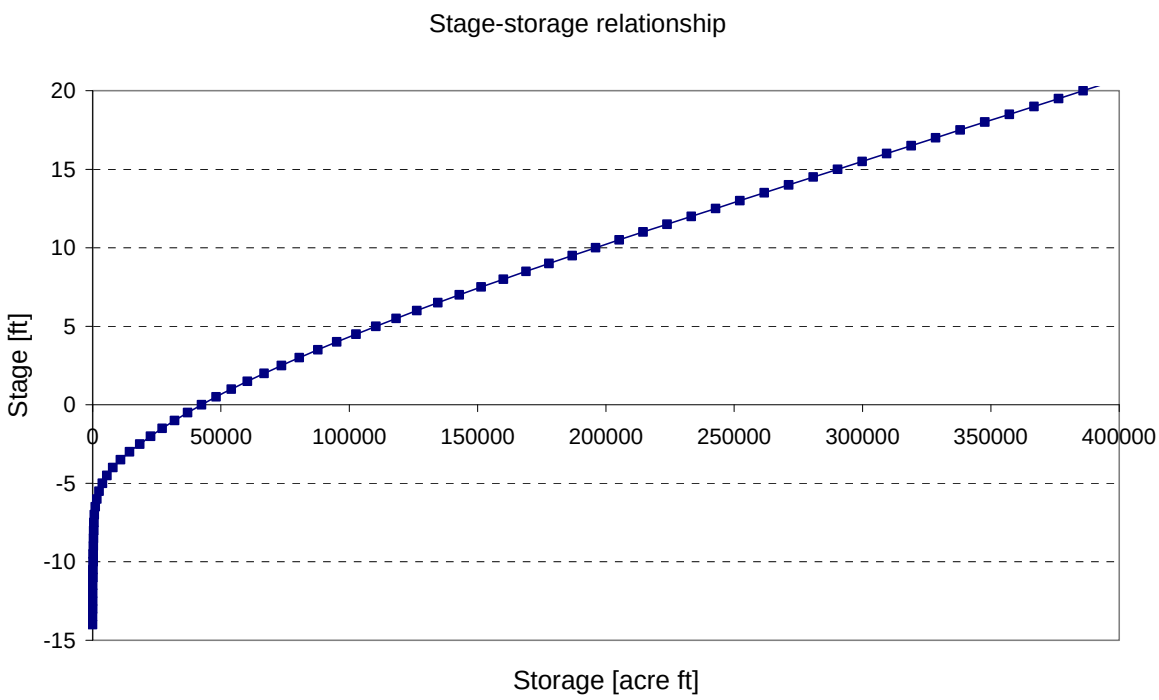


Figure B.44 - Stage storage relationship West Jefferson – Segnette

St Charles – Davis Pond

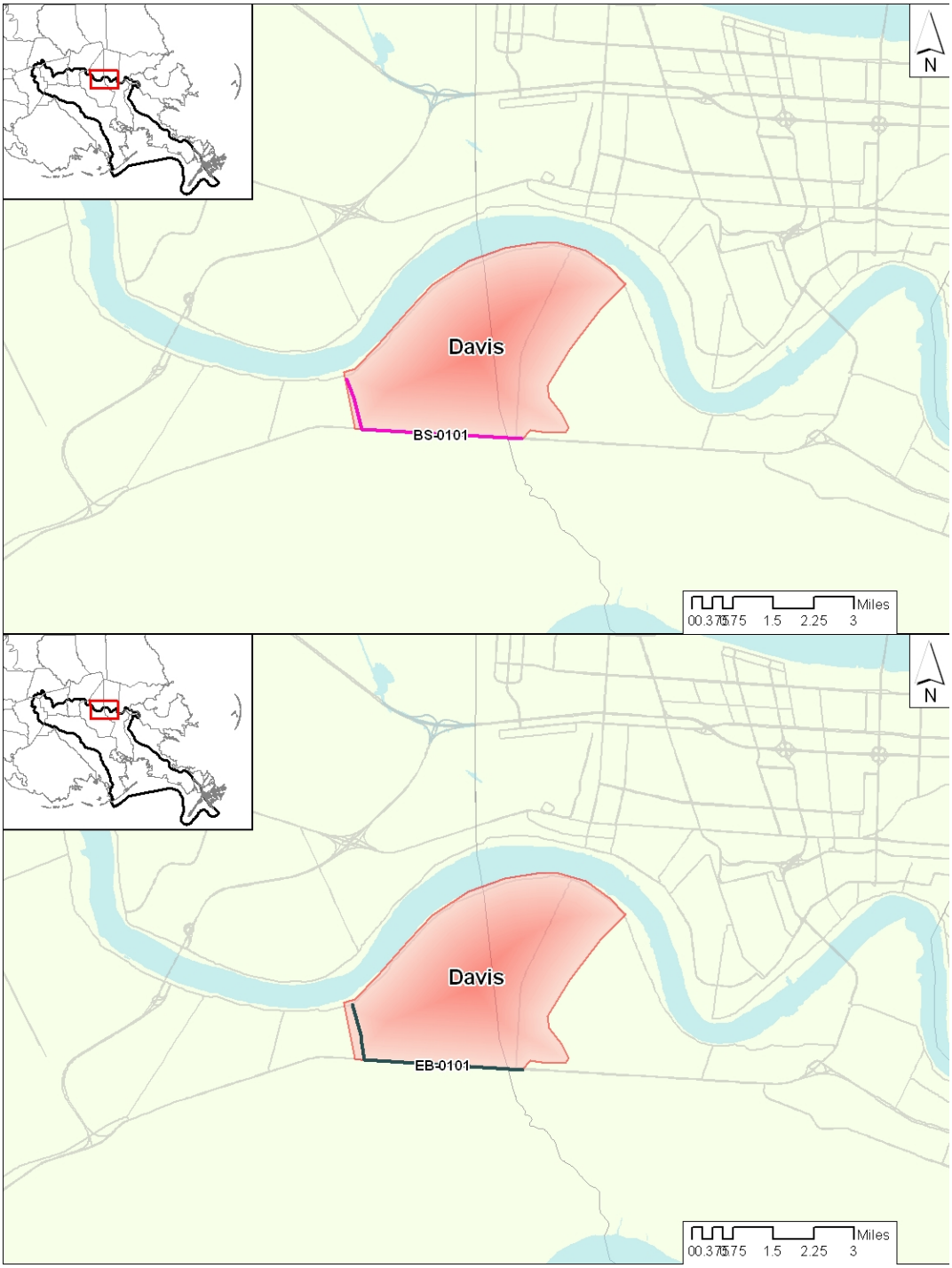


Figure B.45 – Sub-basin and levees St Charles – Davis Pond (High Level and Barrier Plan)

Table B-23 – Levee characteristics

High Level Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0101	**20835**	**11**	**11**	**14**	**16**	**11**	**14**	**16**

Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
EB-0101	**21099**	**11**	**11**	**11**	**11**	**11**	**11**	**11**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	0	0	

Storage Area	**Type**	**Notes**
St Charles - Davis pond	Single area	Max stage is higher of surge (101) or authorized (11') or design height (101)

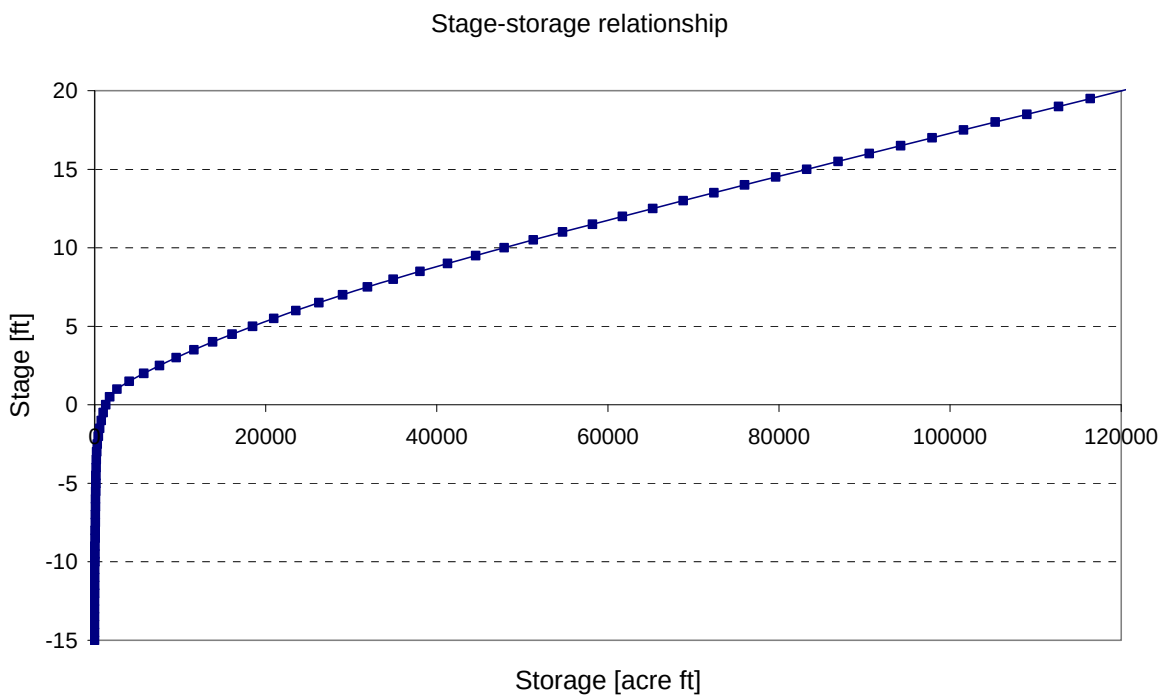


Figure B.46 - Stage storage relationship St Charles – Davis Pond

St Charles – Lulling

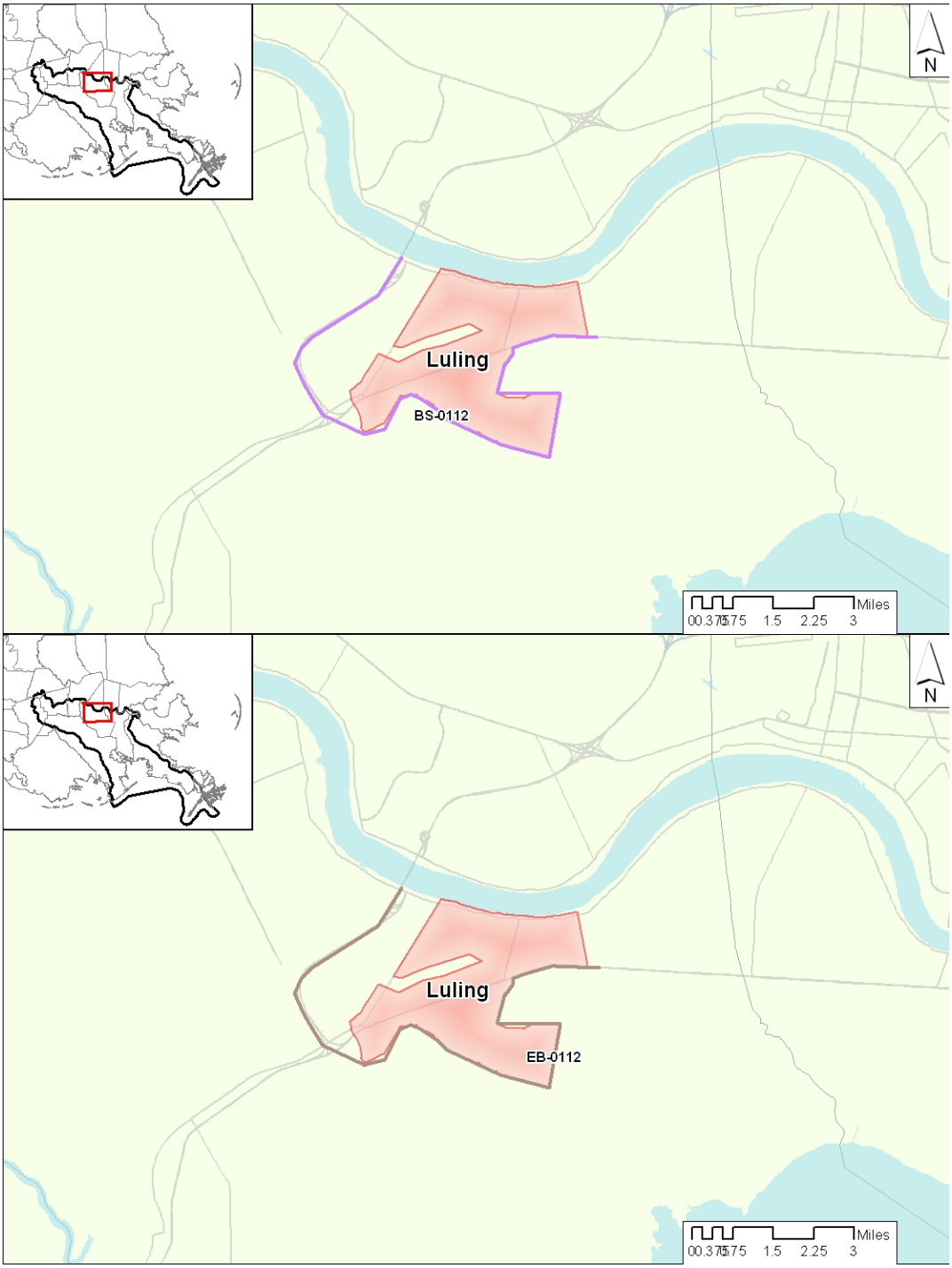


Figure B.47 – Sub-basin and levees St Charles - Lulling (High Level and Barrier Plan)

Table B-24 – Levee characteristics

High Level Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0112	**72665**	**n.a.**	**8.5**	**12**	**13.5**	**8**	**11**	**13**

Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
EB-0112	**72980**	**n.a.**	**6.5**	**9**	**10.5**	**6**	**9**	**10**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	3,150	3,150	

Storage Area	**Type**	**Notes**
St Charles - Luling	Single area	Max stage is higher of surge (112) or design height (112)

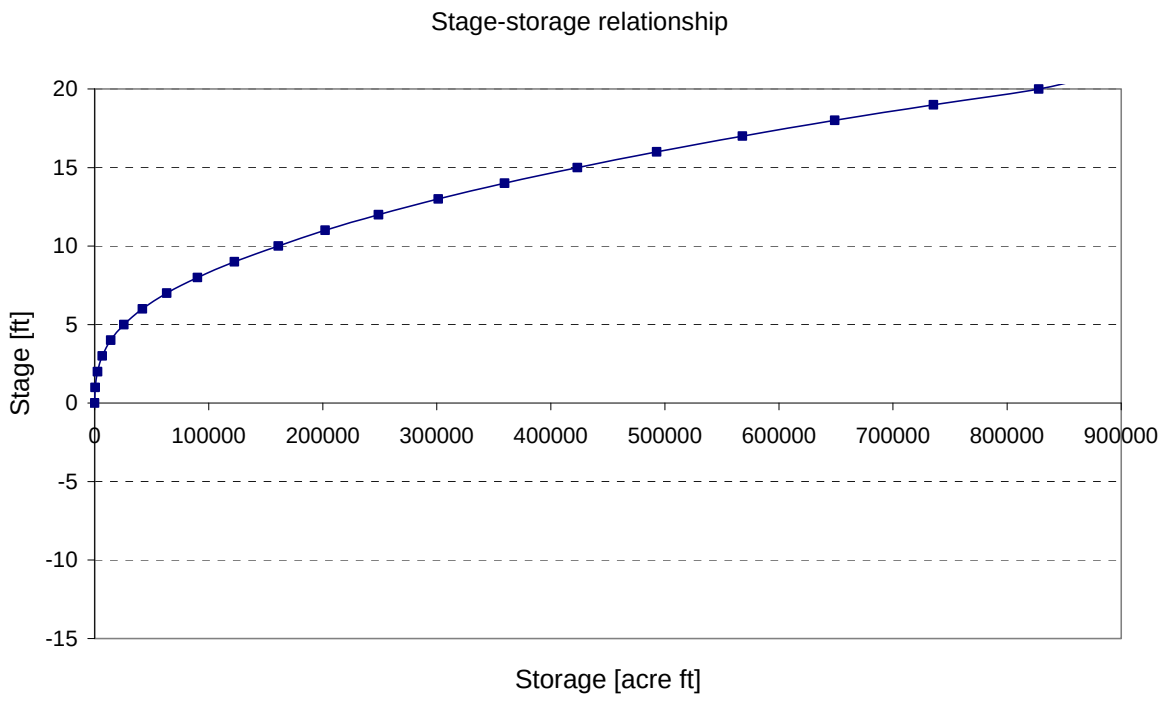


Figure B.48 - Stage storage relationship St Charles - Lulling

St Charles – Sunset

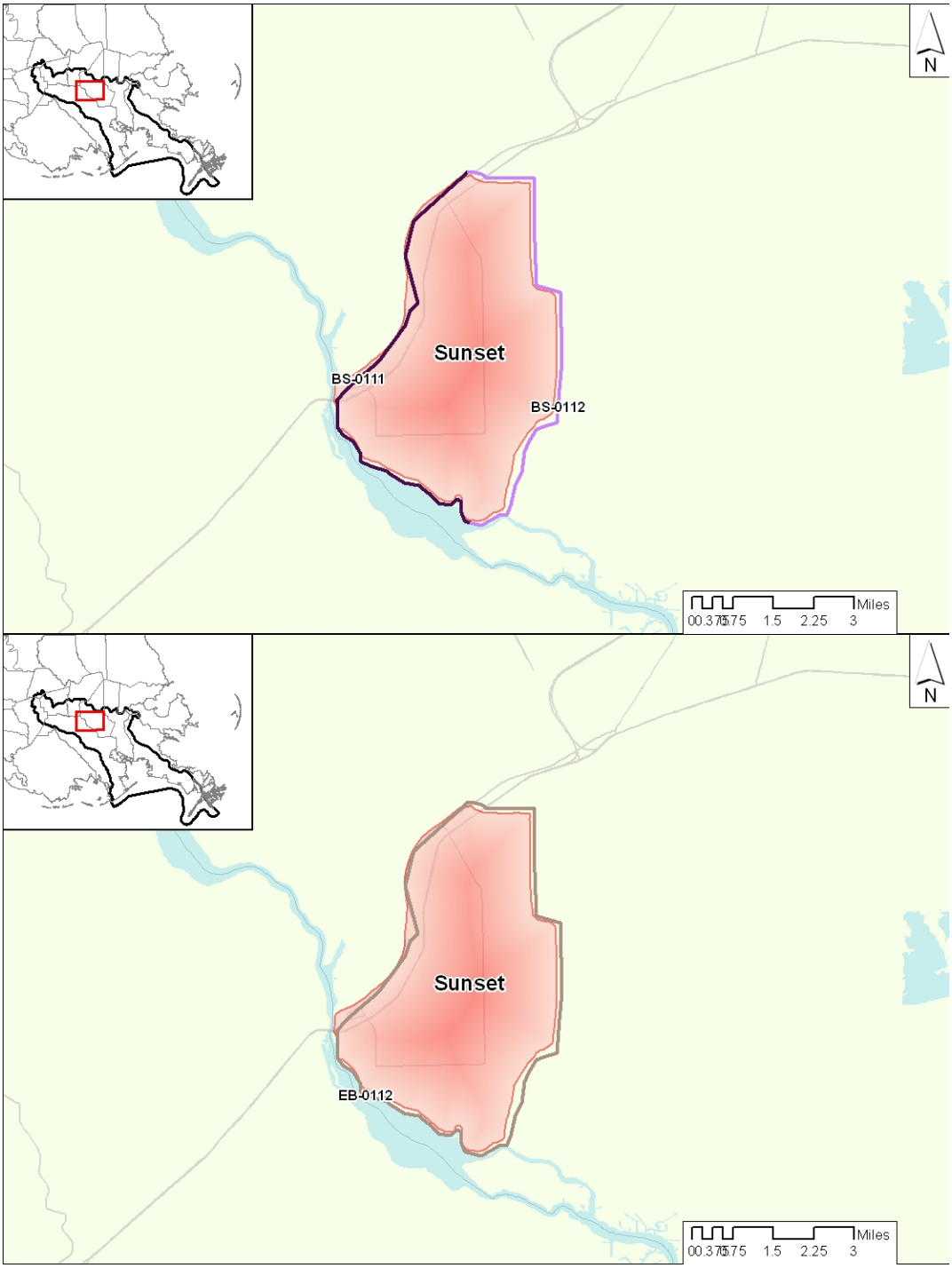


Figure B.49 – Sub-basin and levees St Charles - Sunset (High Level and Barrier Plan)

Table B-25 – Levee characteristics

High Level Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0111	**49237**	**n.a.**	**8**	**11.5**	**13**	**8**	**11.5**	**13**
BS-0112	**47170**	**n.a.**	**8.5**	**12**	**13.5**	**8**	**11**	**13**

Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
EB-0112	**96407**	**n.a.**	**6.5**	**9**	**10.5**	**6**	**9**	**10**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	800	800	

Storage Area	**Type**	**Notes**
St Charles - Sunset	Single area	Max stage is higher of surge (112) or design height (112)

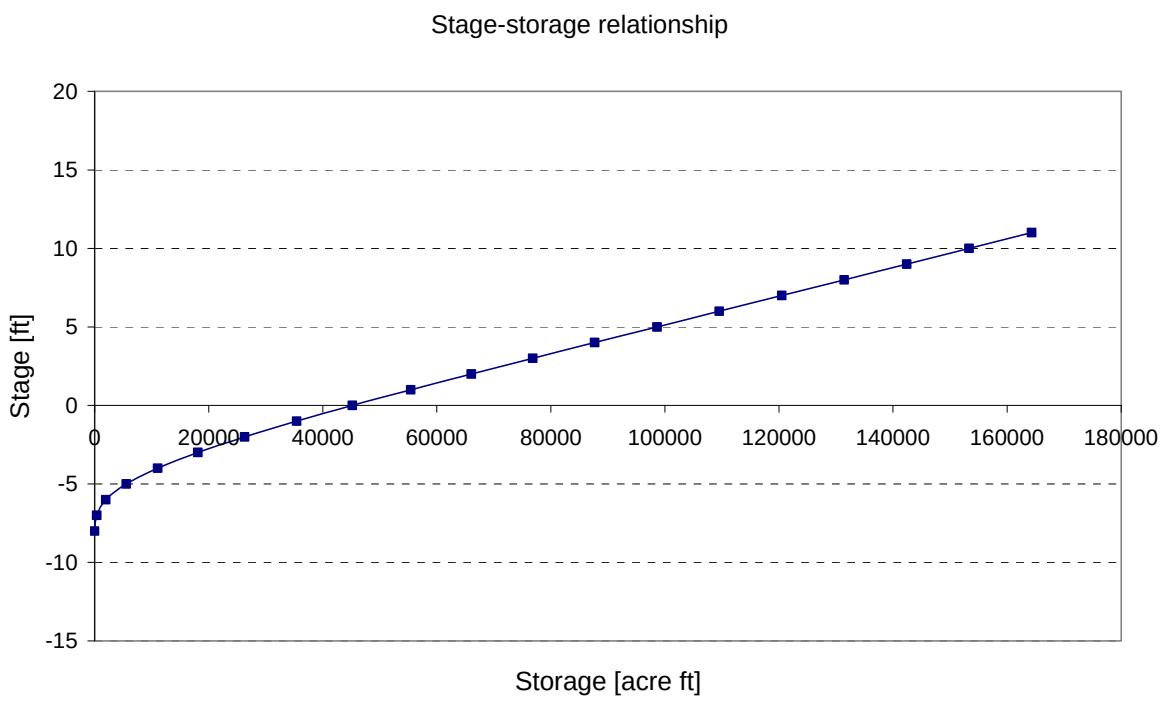


Figure B.50 - Stage storage relationship St Charles - Sunset

Lockport

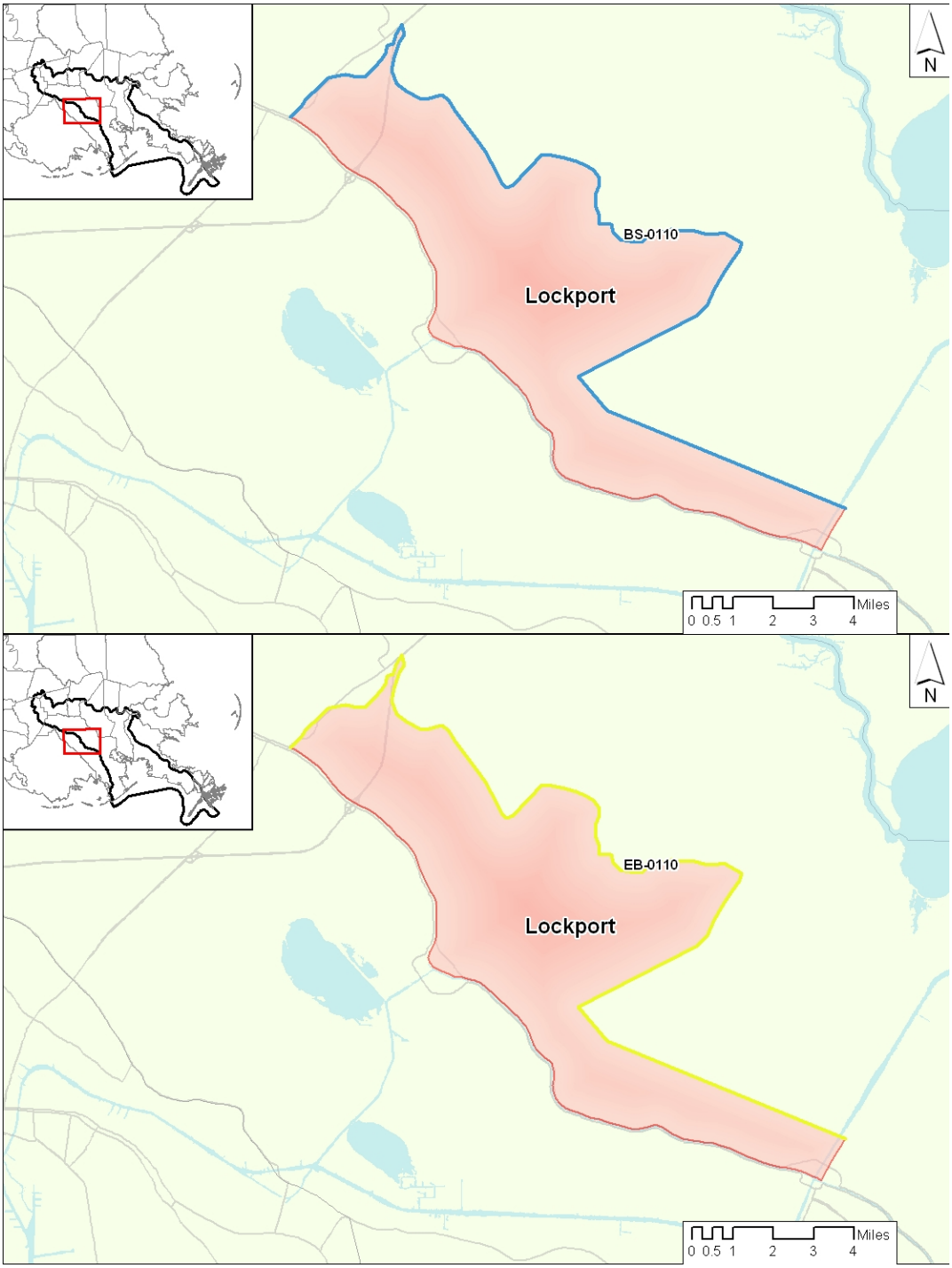


Figure B.51 – Sub-basin and levees Lockport (High Level and Barrier Plan)

Table B-26 – Levee characteristics

High Level Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0112	**160546**	**n.a.**	**8.5**	**12**	**13.5**	**8**	**11**	**13**

Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
EB-0500	**160546**	**n.a.**	**6**	**8.5**	**10**	**6**	**8**	**10**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	0	0	

Storage Area	**Type**	**Notes**
Lockport	Single area	Max stage is higher of surge (110BS or 101EB) or design height (110BS or 101EB)

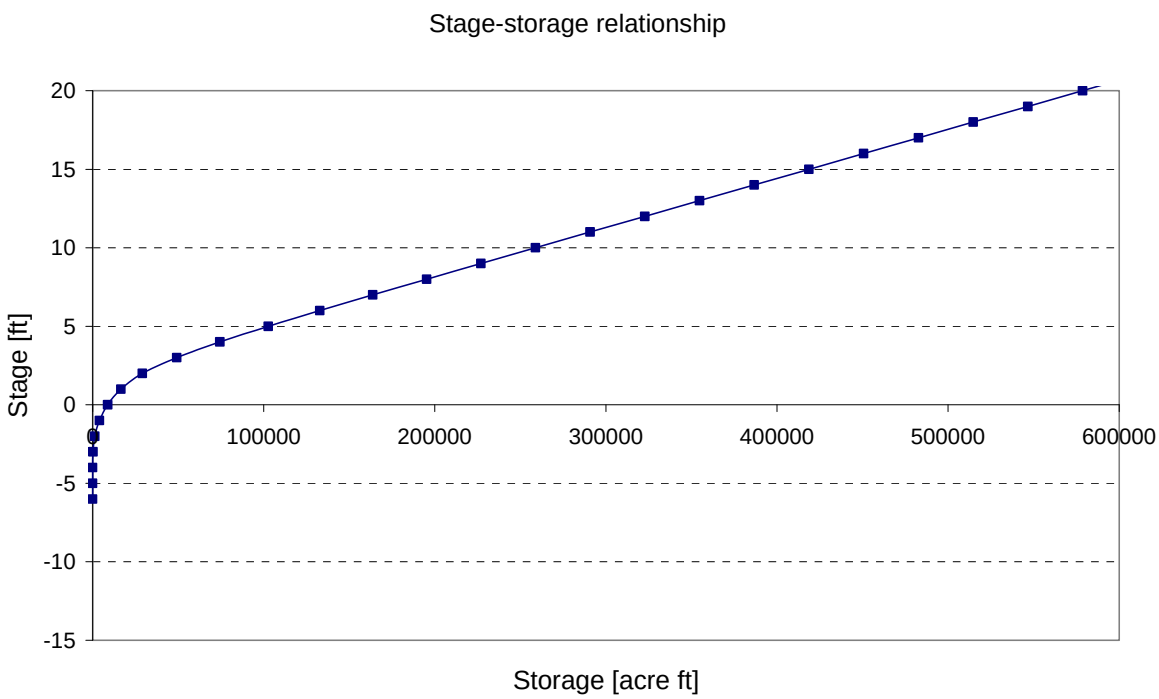


Figure B.52 - Stage storage relationship Lockport

Larose to Golden Meadow

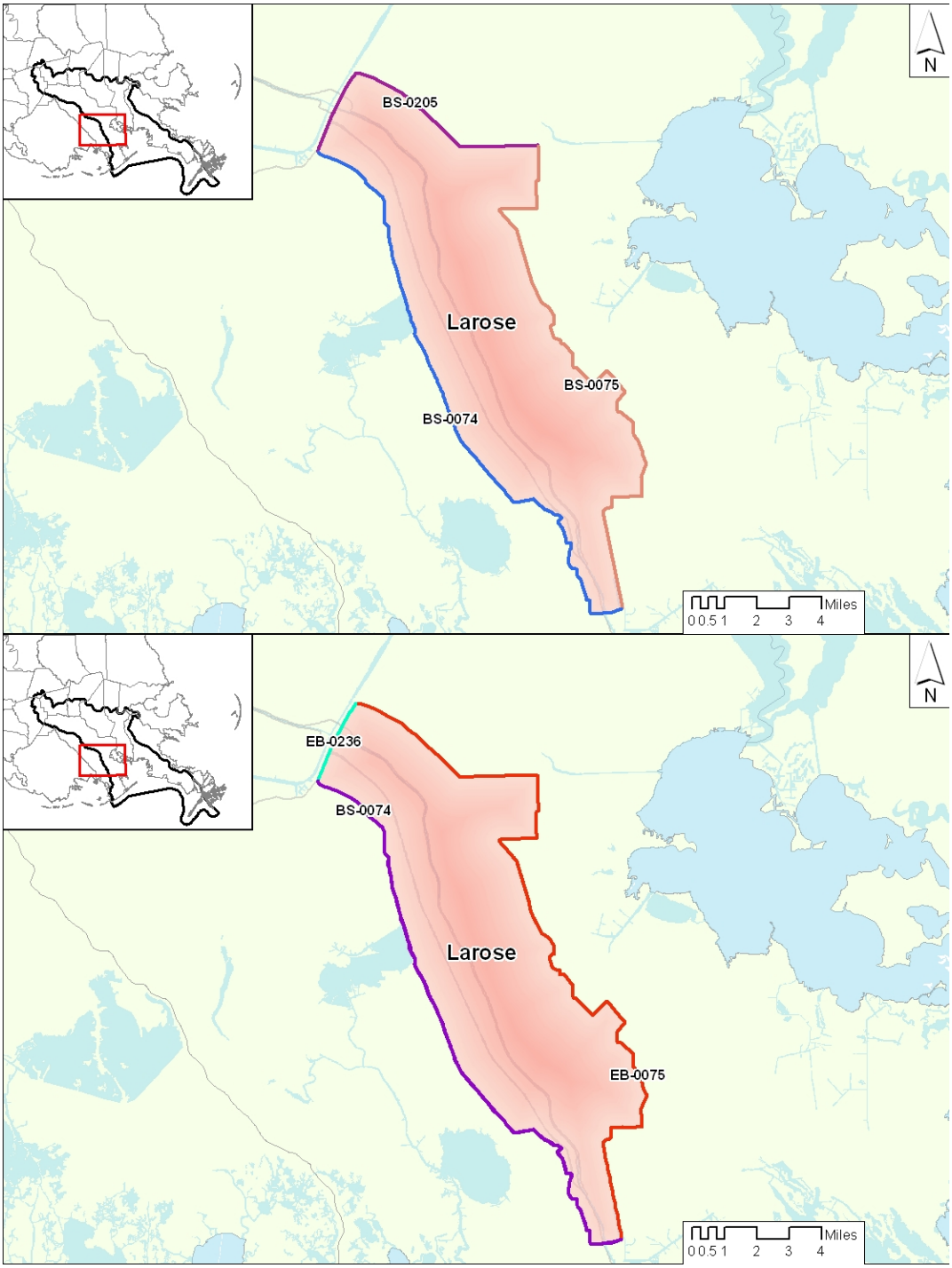


Figure B.53 – Sub-basin and levees Larose to Golden Meadow (High Level and Barrier Plan)

Table B-27 – Levee characteristics

High Level Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
BS-0074	**101609**	**12**	**18**	**25**	**28.5**	**15.5**	**21.5**	**25**
BS-0075	**103345**	**12**	**17**	**21.5**	**23.5**	**16**	**20.5**	**22.5**
BS-0205	**48492**	**12**	**12**	**14**	**16.5**	**11**	**14**	**16.5**

Barrier Plan			Design Height (waves modeled without friction)			Design Height (waves modeled with friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**	**100 year**	**400 year**	**1000 year**
[-]	**[miles]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
EB-0074	**184704**	**12**	**18.5**	**26.5**	**30.5**	**15.5**	**22**	**25.5**
EB-0075	**138274**	**12**	**17.5**	**23**	**26**	**16.5**	**22**	**24.5**
EB-0236	**14096**	**12**	**17.5**	**23**	**26**	**16.5**	**22**	**24.5**

	Existing	**Proposed**	**Notes**
Pump Capacity (cfs)	0	0	

Storage Area	**Type**	**Notes**
Larose	Single area	This is a ring levee system with a varying level of levee because of a rapidly changing elevation of surge. Max surge is the higher of surge (75), authorized (13.5') or design height (75), but capped at 15' as the damages don't increase beyond this point. (see additional note below)

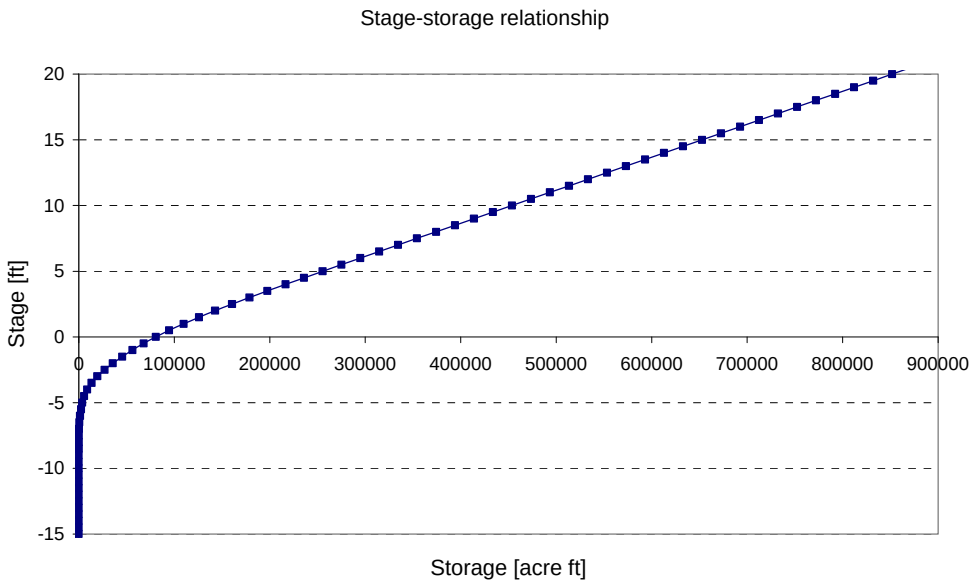


Figure B.54 - Stage storage relationship Larose to Golden Meadow

Additional Notes

Two authorized heights have been used, 13.5' for the southern end of the ring and 10' for the northern end. A review of the stage damage curves has suggested that damages tail off dramatically at 15'.

The Larose to Golden Meadow area is considered as a single interior stage storage area with the potential for overtopping from both the east and west. The western side falls within Planning Unit 3a, which has not been fully investigated yet. If the results from the EB model grid are used for the west it results in higher design heights than with the base case. This is because of the effects of the closure across the Morganza region in the EB model. As the alternatives for this area have yet to be evaluated it has been decided to use the values from the base grid for both the without and with GIWW weir alternatives so the rates of overtopping are constant into the Larose areas from the west. (i.e. BS-0074 is to be used for all alternatives in Planning Unit 2.

As there will be no 100 year level of protection levee system in place before 2010 the base case internal stage frequency should be based on the existing authorized heights rather than the 100 year design heights. For this study three sections are used, BS-0074, BS-0075 and BS-0205. Using the original study reports the authorized heights vary from 13.5' in the south to 10' in the north. For analysis the 13.5' levels have been used for points BS-0074 and BS-0075 whilst 10' has been used for BS-0205.

Planning Unit 3a

Polder Ring: Morganza_no_ret_ring

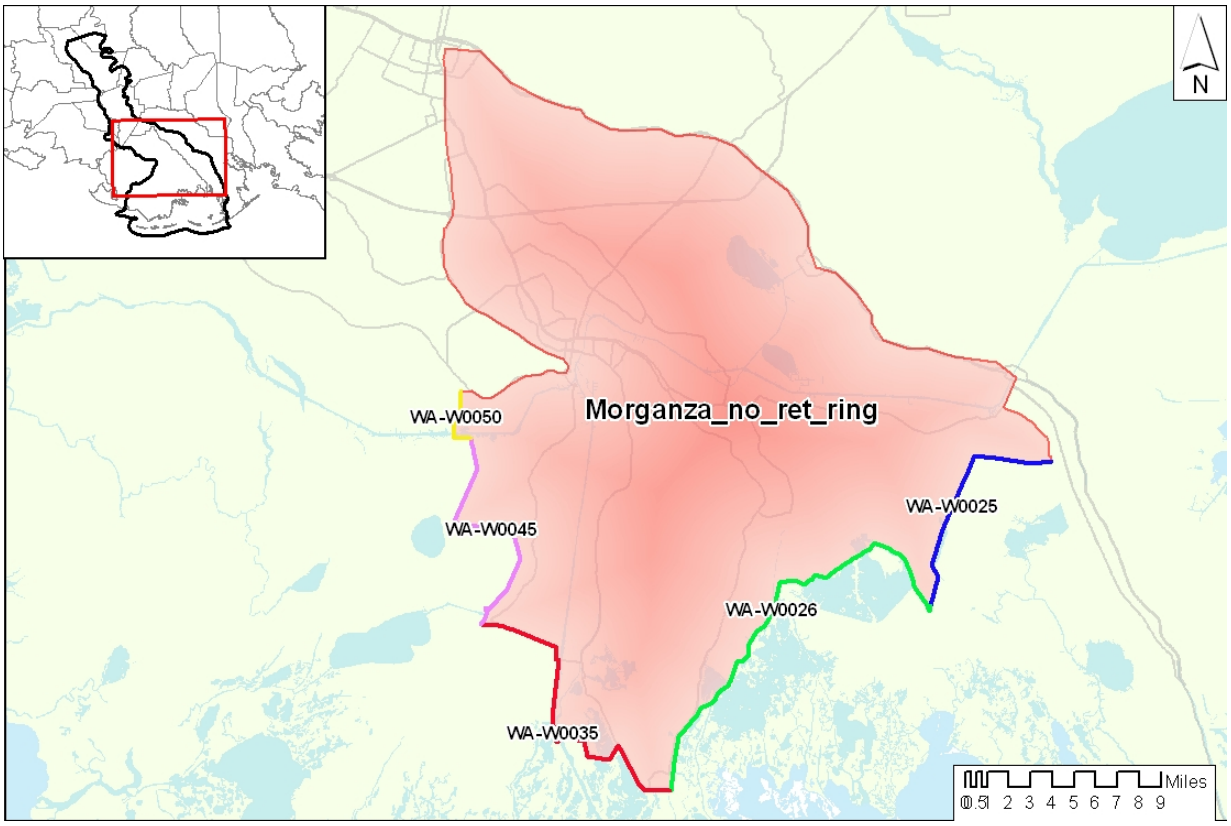


Figure E. 1 **–Sub-basin and levees Morganza_no_ret_ring**

Table E-28 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WA-W0050	**17395**	**n.a.**	**12**	**19.5**	**23.5**
WA-W0045	**63223**	**n.a.**	**15**	**24**	**29**
WA-W0035	**83975**	**n.a.**	**23**	**31**	**35.5**
WA-W0026	**110857**	**n.a.**	**28**	**36.5**	**41**
WA-W0025	**57759**	**n.a.**	**22**	**30.5**	**35.5**

Storage Area	**pumping rate [cfs]**	**Type**	**Notes**
Morganza_no_ret_ring	36581	Single area	

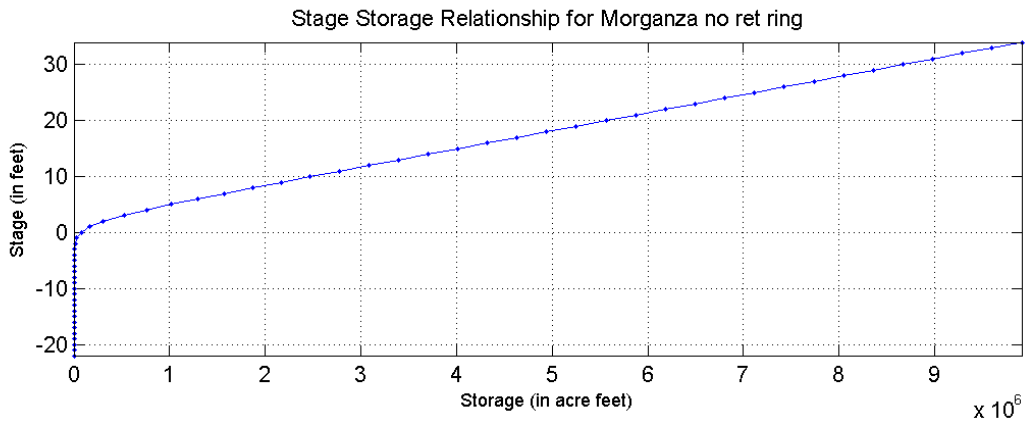


Figure B.54 - Stage storage relationship for Morganza no ret ring

Polder Ring: East_of_Morgan_City_ring

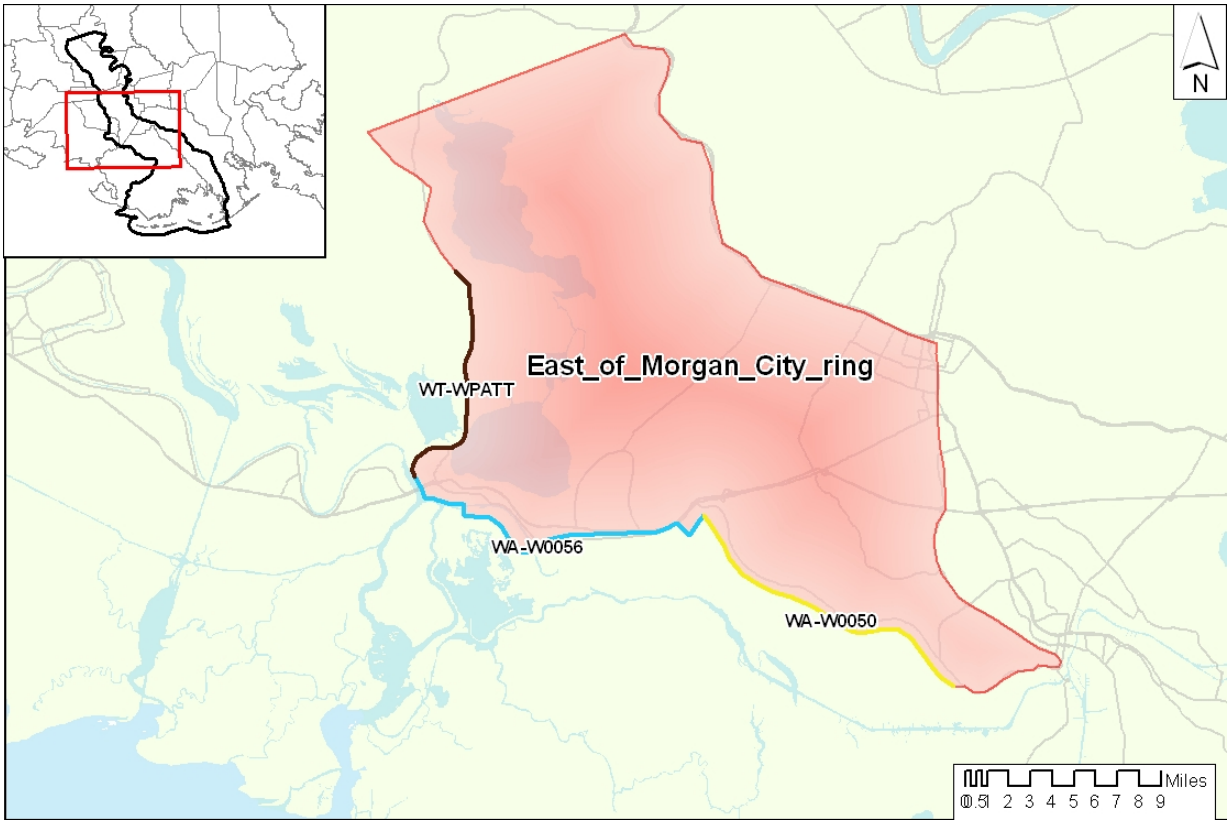


Figure E. 2 **–Sub-basin and levees East_of_Morgan_City_ring**

Table E-29 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WA-W0056	**86276**	**n.a.**	**16.5**	**23**	**27**
WA-W0050	**78062**	**n.a.**	**12**	**19.5**	**23.5**
WT-WPATT		**n.a.**	**13.5**	**20**	**24**

Storage Area	**pumping rate [cfs]**	**Type**	**Notes**
East_of_Morgan_City_ring	400	Single area	

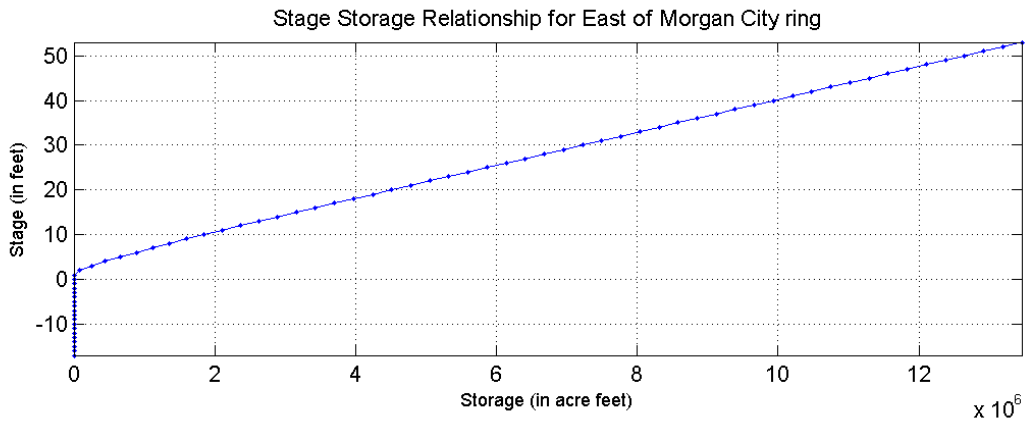


Figure B.54 - Stage storage relationship for East_of_Morgan_City_ring

Polder Ring: Morganza_with_ret_ring

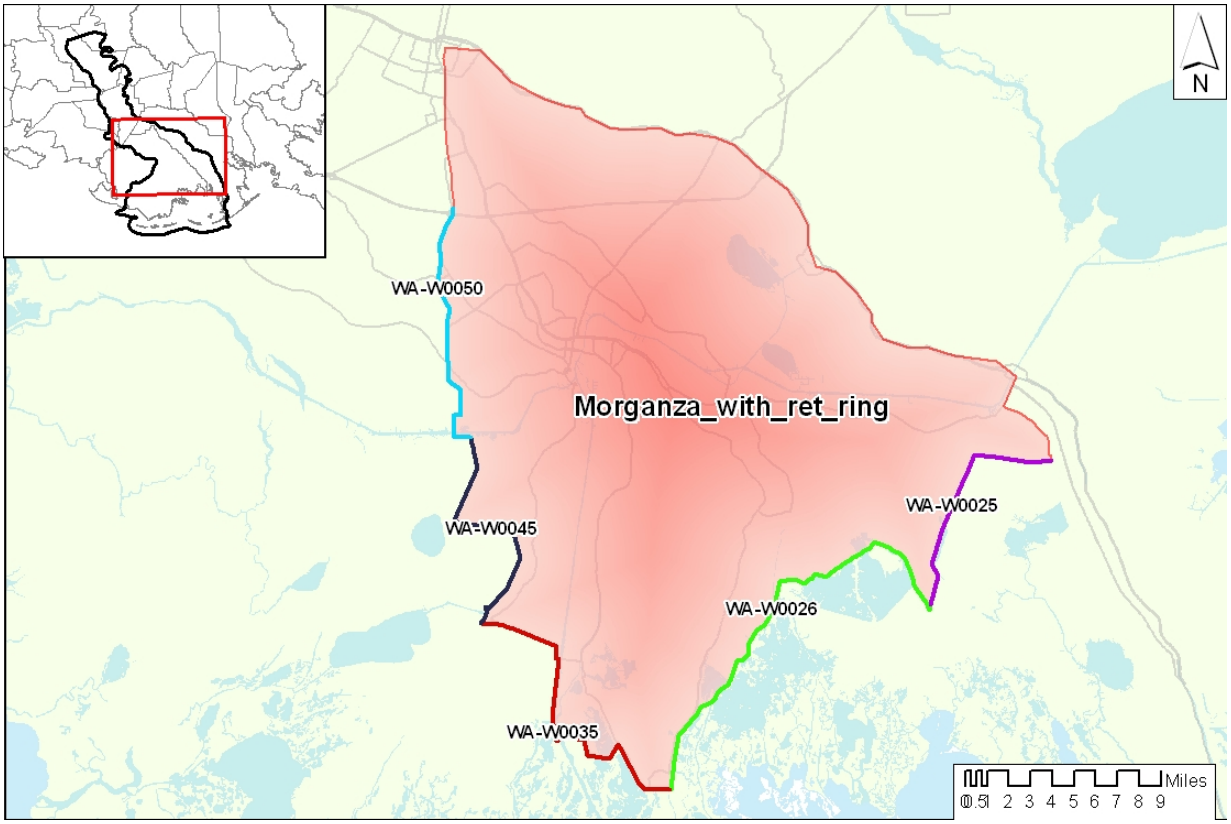


Figure E. 3 ––Sub-basin and levees Morganza_with_ret_ring

Table E-30 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WA-W0050	**43663**	**n.a.**	**12**	**19.5**	**23.5**
WA-W0050	**21006**	**n.a.**	**12**	**19.5**	**23.5**
WA-W0045	**63223**	**n.a.**	**15**	**24**	**29**
WA-W0035	**83975**	**n.a.**	**23**	**31**	**35.5**
WA-W0026	**110857**	**n.a.**	**28**	**36.5**	**41**
WA-W0025	**57759**	**n.a.**	**22**	**30.5**	**35.5**

Storage Area	**Pumping rate [cfs]**	**Type**	**Notes**
Morganza_with_ret_ring	55151	Single area	

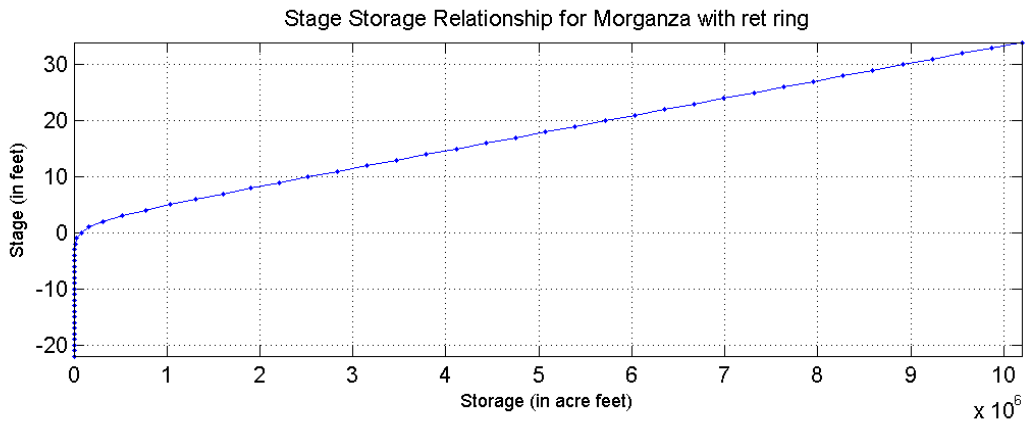


Figure B.54 - Stage storage relationship for Morganza with ret ring

Polder Ring: Morganza_with_ret_ring_m_only

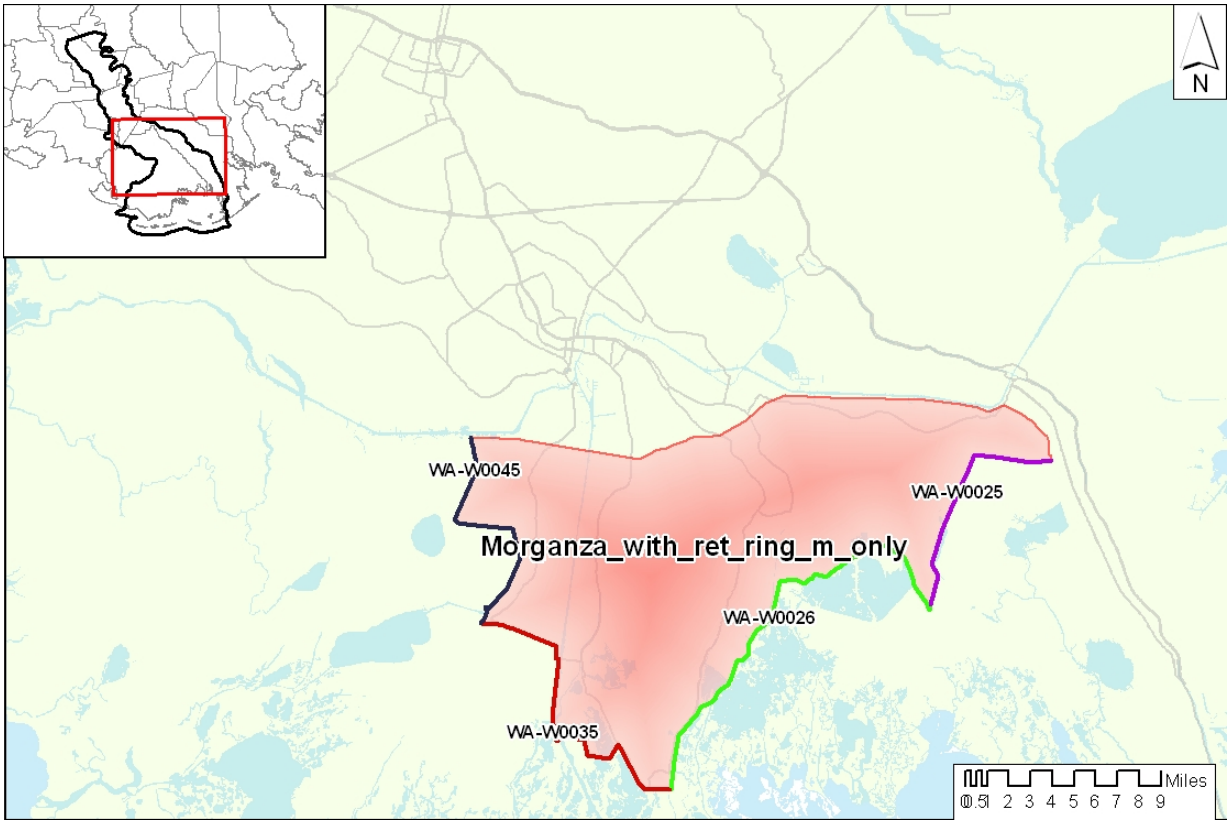


Figure E. 4 ––Sub-basin and levees Morganza_with_ret_ring_m_only

Table E-31 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WA-W0045	**63223**	**n.a.**	**15**	**24**	**29**
WA-W0035	**83975**	**n.a.**	**23**	**31**	**35.5**
WA-W0026	**110857**	**n.a.**	**28**	**36.5**	**41**
WA-W0025	**57759**	**n.a.**	**22**	**30.5**	**35.5**

Storage Area	**Pumping rate [cfs]**	**Type**	**Notes**
Morganza_with_ret_ring_m_only	2042	Single area	

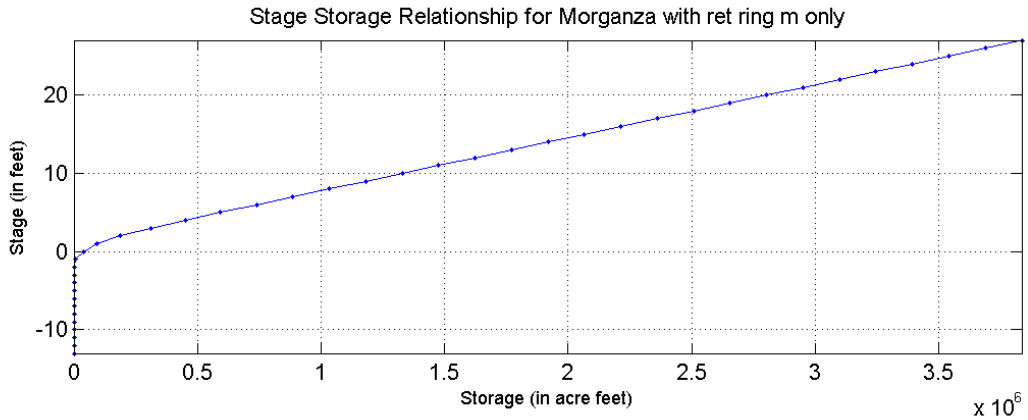


Figure B.54 - Stage storage relationship for Morganza_with_ret_ring_m_only

Polder Ring: Morganza_back_levee

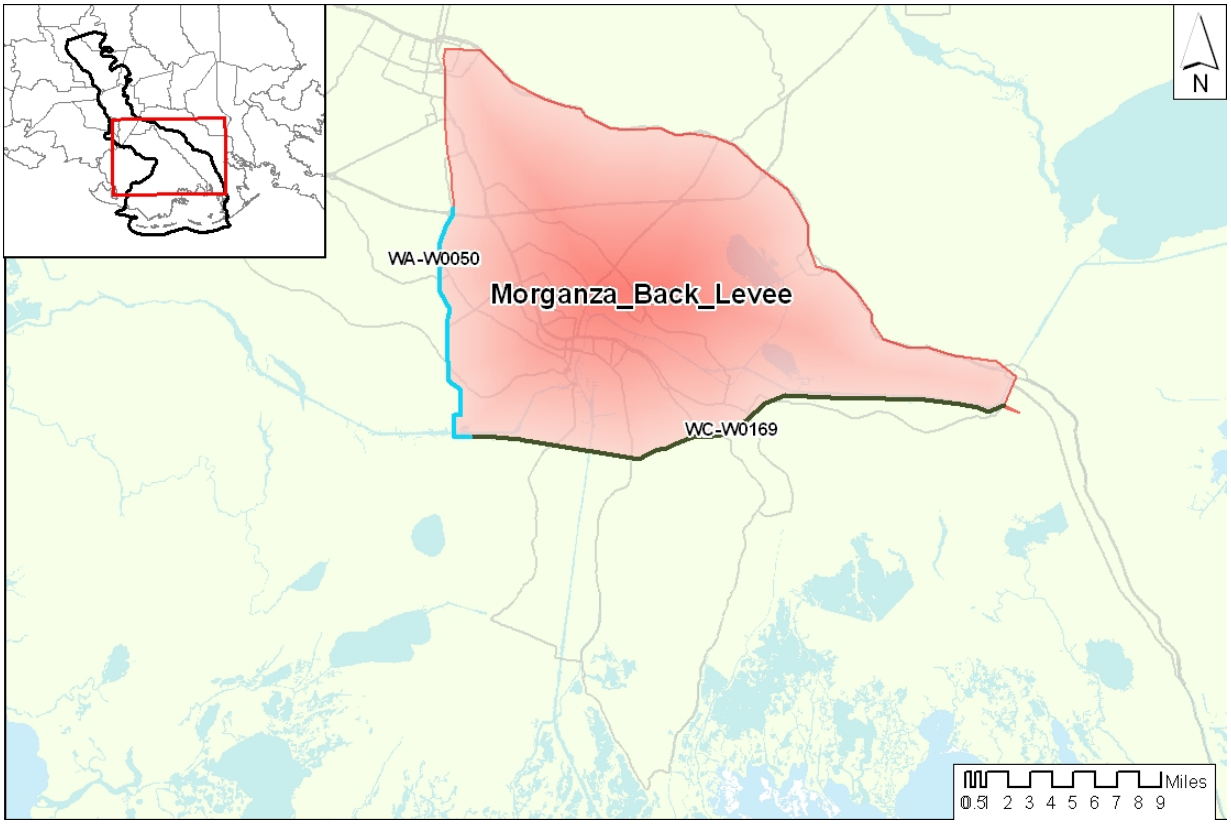


Figure E. 5 ––Sub-basin and levees Morganza_back_levee

Table E-32 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WA-W0050	**43663**	**n.a.**	**12**	**19.5**	**23.5**
WA-W0050	**21006**	**n.a.**	**12**	**19.5**	**23.5**
WC-W0169	**154153**	**n.a.**	**-**	**9.5**	**24**

Storage Area	**Pumping rate [cfs]**	**Type**	**Notes**
Morganza_back_levee	53109	Single area	**Stages behind the secondary defense (Morganza back levee) are calculated based upon overtopping from the flooded polder Morganza. An exception is made for the 2000 year event where stages are equal to the base surge conditions**

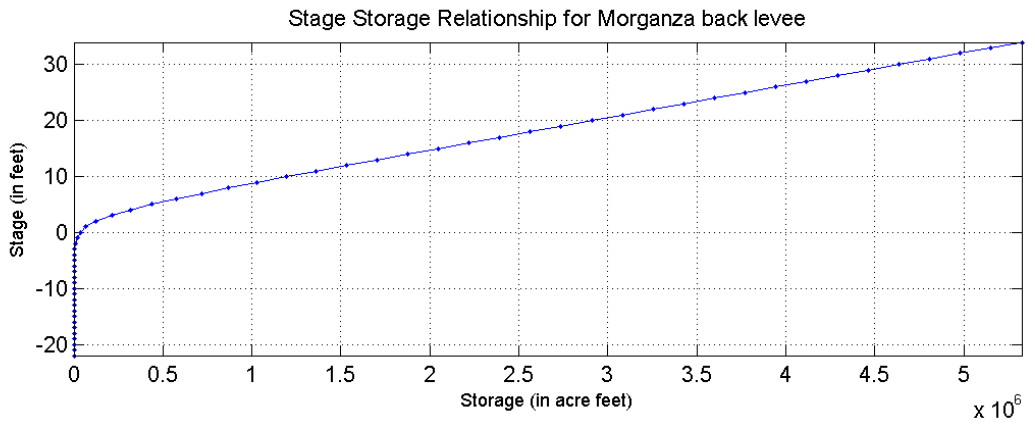


Figure B.54 - Stage storage relationship for Morganza_back_levee

Morgan_City

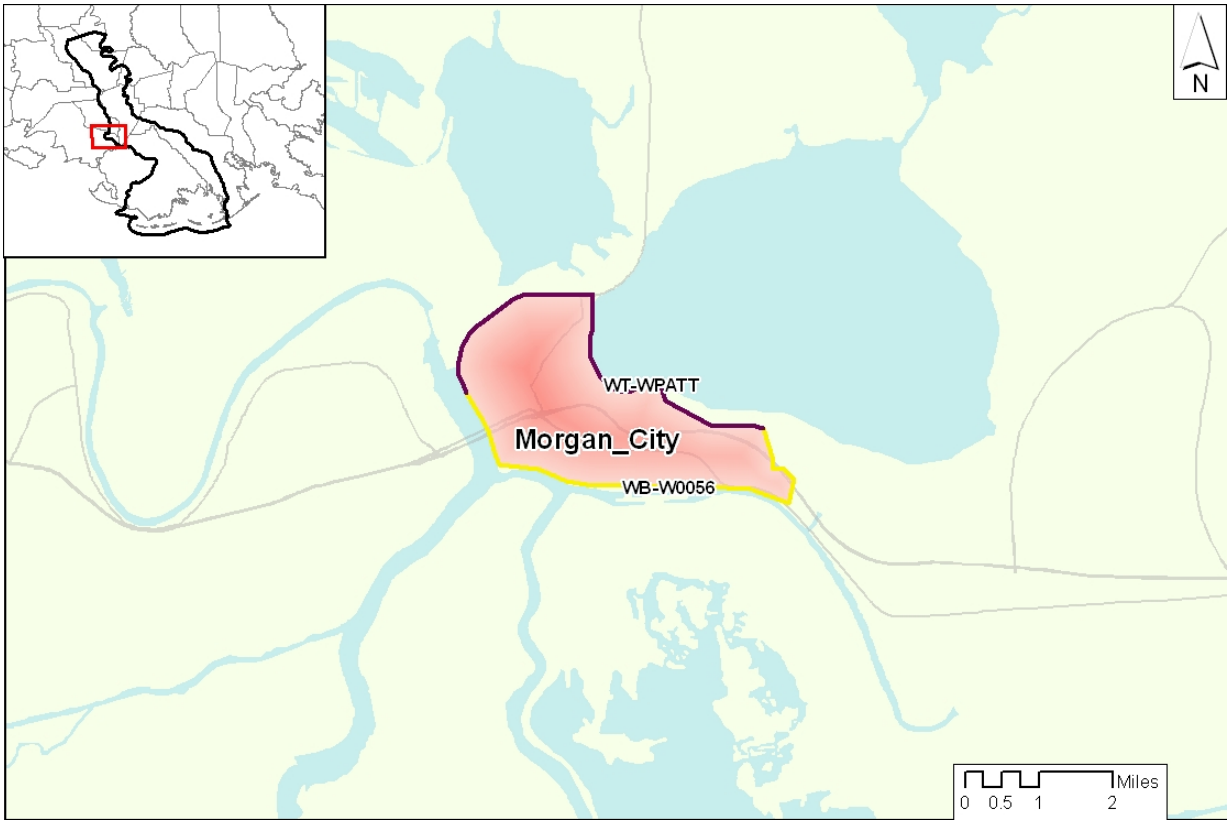
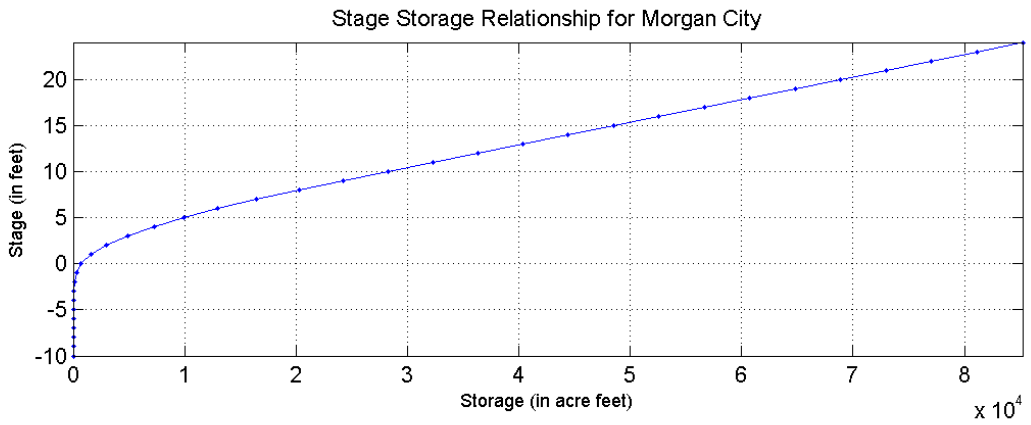


Figure E. 6 ––Sub-basin and levees Morgan_City_ring

Table E-33 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WB-W0056	**33243**	**n.a.**	**18**	**25**	**28.5**
WT-WPATT		**n.a.**	**13.5**	**20**	**24**

Storage Area	**Pumping Rate [cfs]**	**Type**	**Notes**
Morgan_City_ring	400	Single area	For small ring levees overtopping is assumed only to occur from the sea side levee. In this case that is levee 56


Stage Storage Relationship for Morgan City
Stage (in feet)
20
15
10
5
0
-5
-10
0
1
2
3
4
5
6
7
8
Storage (in acre feet)
x 10^4

Planning Unit 3b

Polder Ring: South_of_Franklin_ring

Figure E. 7 ––Sub-basin and levees South_of_Franklin_ring

Table E-34 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WA-W0079	**151872**	**n.a.**	**20.5**	**28**	**32.5**
WT-WPATT		**n.a.**	**13.5**	**20**	**24**

Storage Area	**Pumping Rate [cfs]**	**Type**	**Notes**
South_of_Franklin_ring	311	Single area	

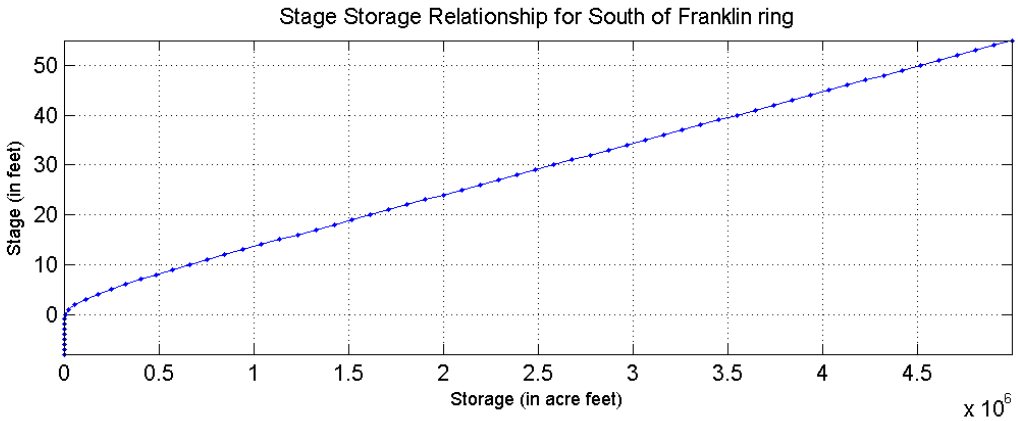


Figure B.54 - Stage storage relationship for South_of_Franklin_ring

Polder Ring: GIWW_PU3b_ring

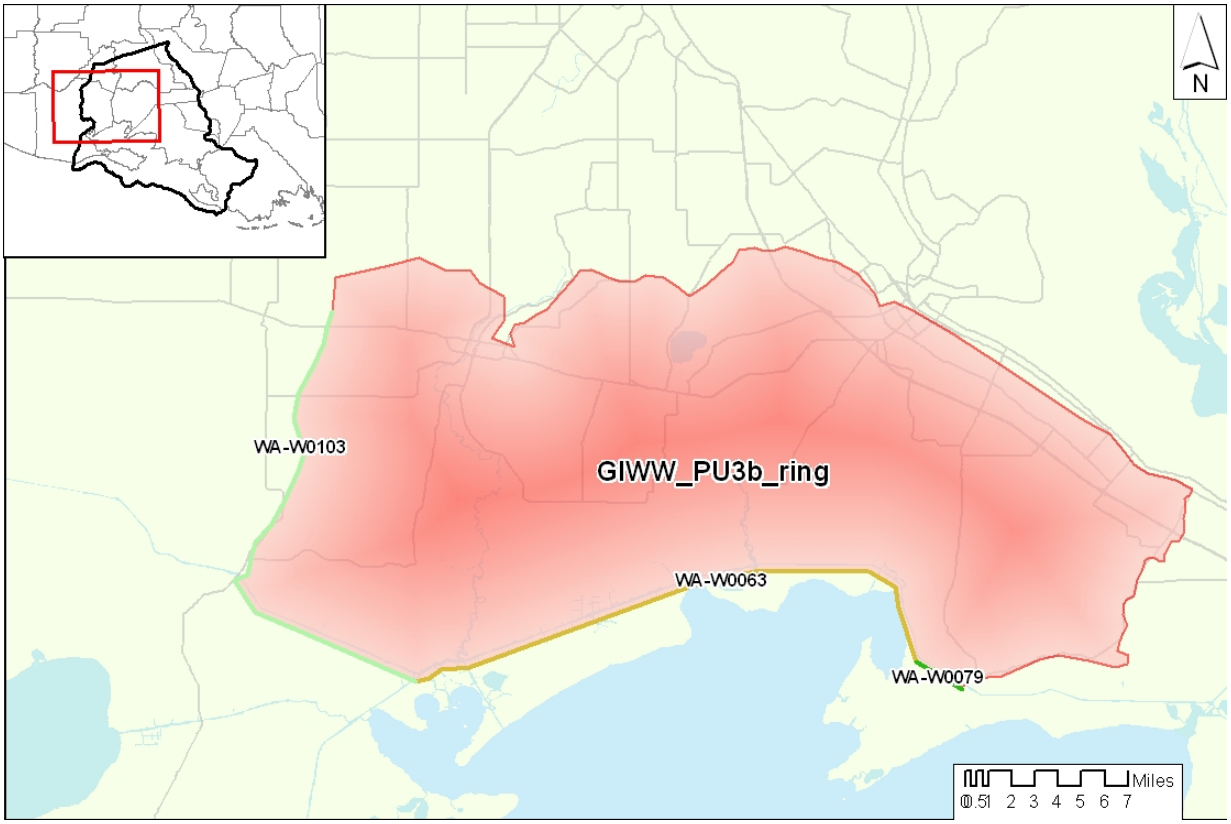


Figure E. 8 ––Sub-basin and levees GIWW_PU3b_ring

Table E-35 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WA-W0103	**48316**	**n.a.**	**21.5**	**28**	**31.5**
WA-W0063	**131984**	**n.a.**	**20**	**27.5**	**32.5**
WA-W0079	**12102**	**n.a.**	**20.5**	**28**	**32.5**

Storage Area	**Pumping Rate [cfs]**	**Type**	**Notes**
GIWW_PU3b_ring	19046	Single area	

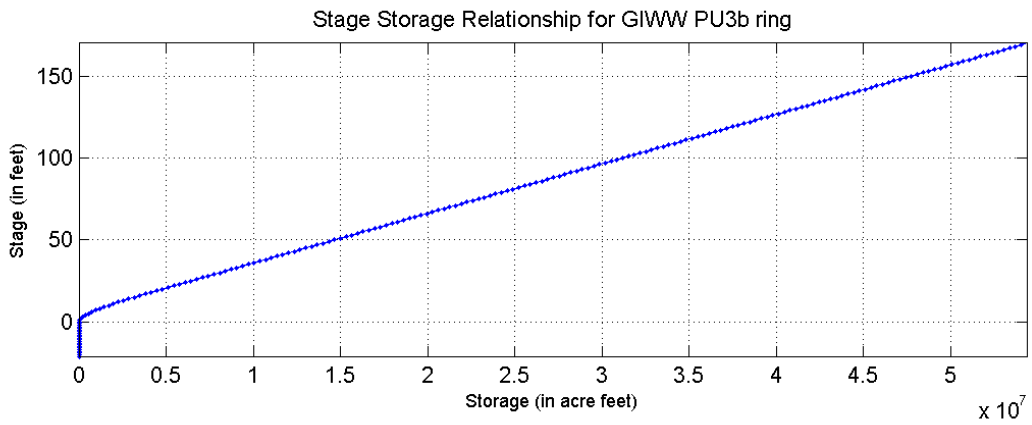


Figure B.54 - Stage storage relationship for GIWW_PU3b_ring

Polder Ring: Patterson

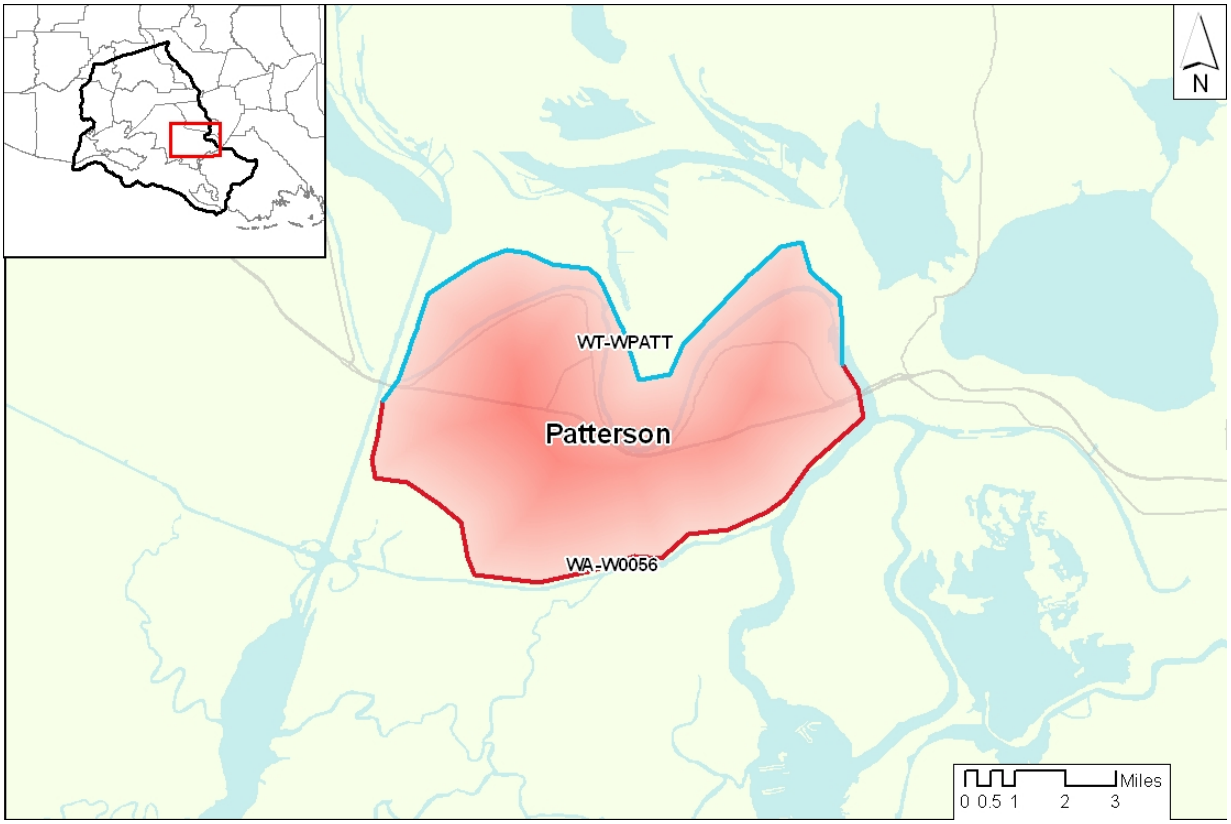


Figure E. 9 ––Sub-basin and levees Patterson

Table E-36 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WB-W0056	**77285**	**n.a.**	**18**	**25**	**28.5**
WT-WPATT		**n.a.**	**13.5**	**20**	**24**

Storage Area	**Pumping Rate [cfs]**	**Type**	**Notes**
Patterson	29853	Single area	For the Patterson ring levee overtopping is assumed to only occur over the levee facing the sea.

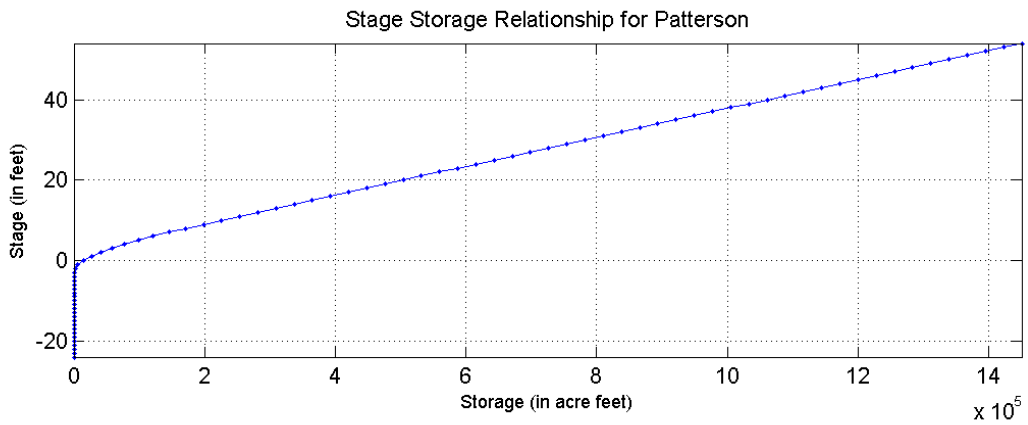


Figure B.54 - Stage storage relationship for Patterson

Polder Ring: Abbeville_to_Delcambre_ring

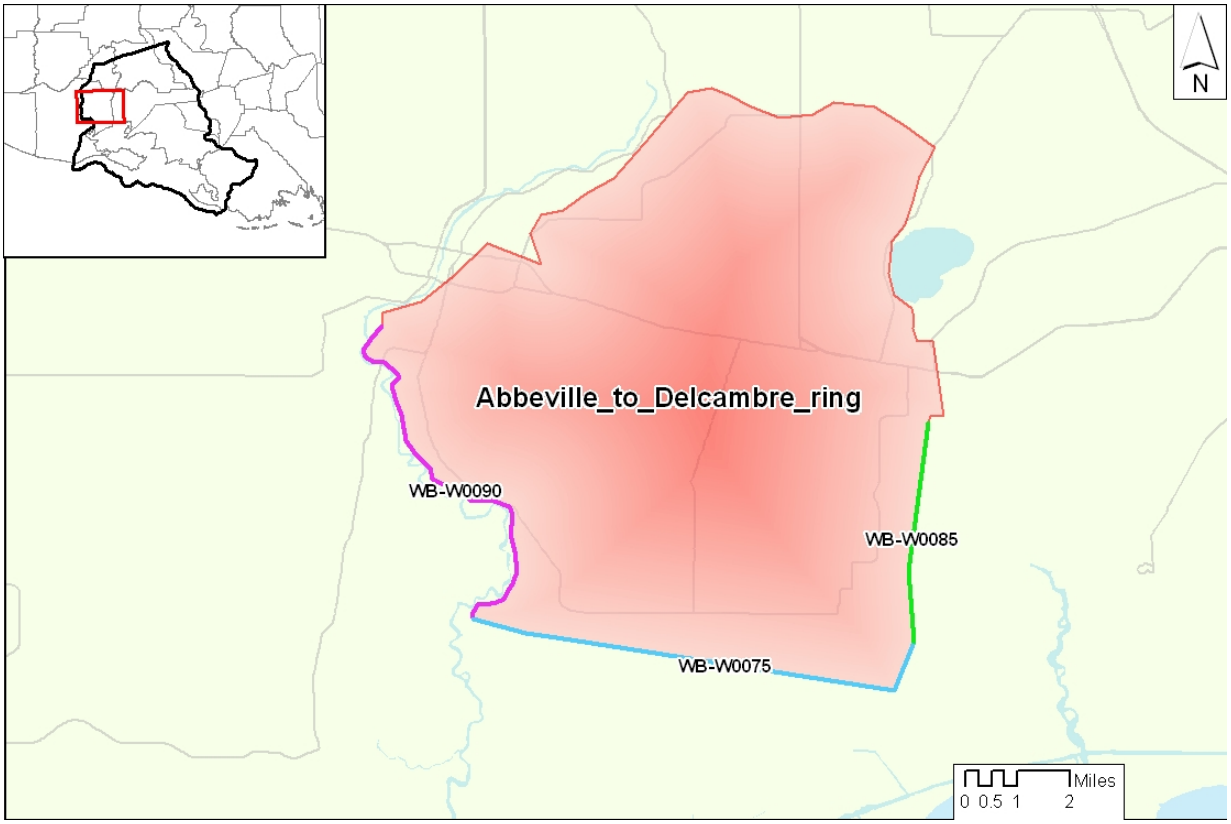


Figure E. 10 ––Sub-basin and levees Abbeville_to_Delcambre_ring

Table E-37 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WB-W0090	**42402**	**n.a.**	**18**	**24.5**	**28.5**
WB-W0075	**48469**	**n.a.**	**20**	**27**	**31**
WB-W0085	**22333**	**n.a.**	**17**	**26**	**31.5**

Storage Area	**Pumping Rate [cfs]**	**Type**	**Notes**
Abbeville_to_Delcambre_ring	27617	Single area	

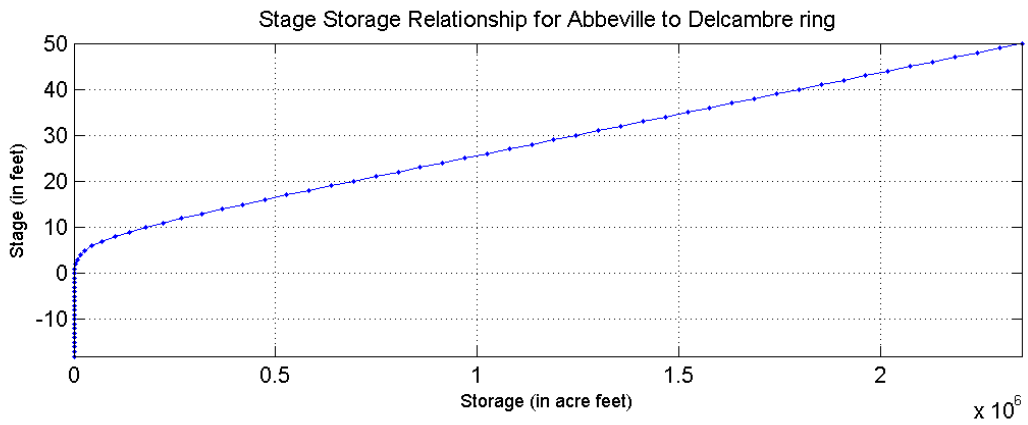


Figure B.54 - Stage storage relationship for Abeville_to_Delcambre_ring

Polder Ring: New_Iberia_ring

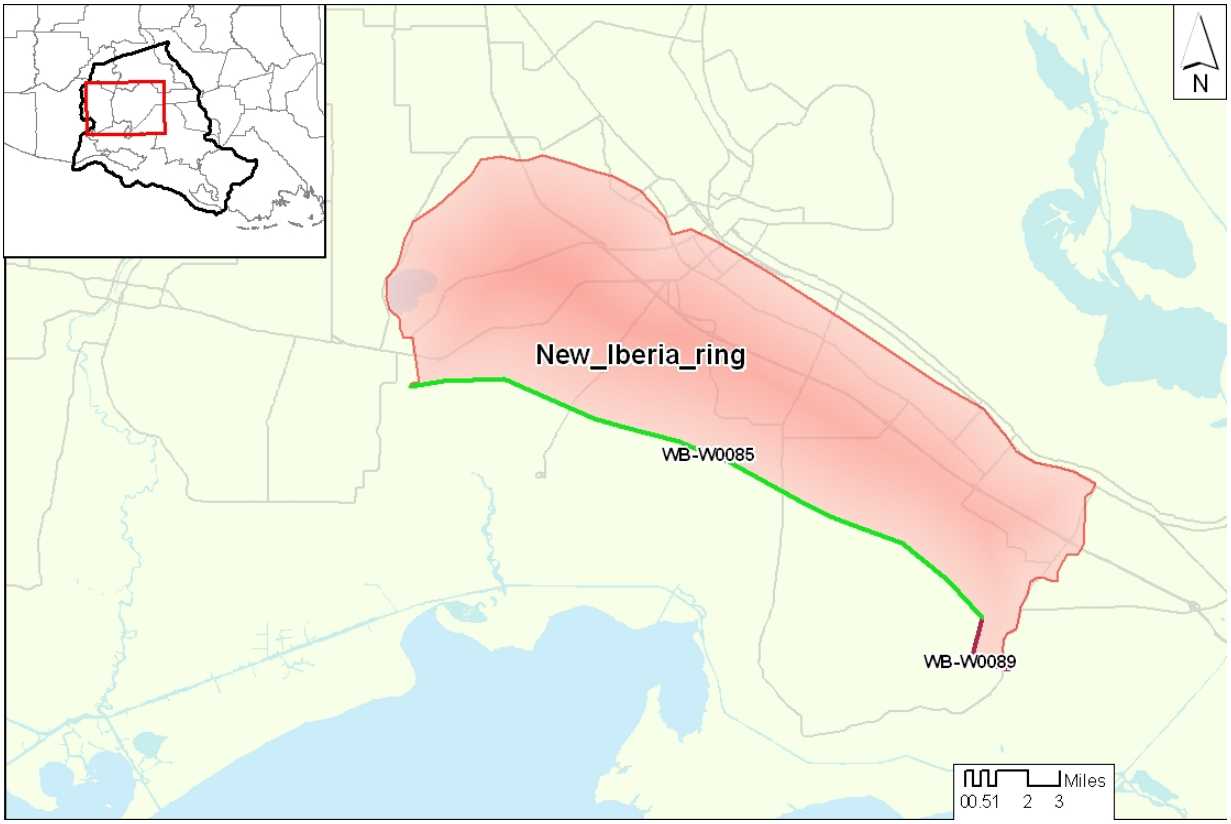


Figure E. 11 ––Sub-basin and levees New_Iberia_ring

Table E-38 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WB-W0085	**106523**	**n.a.**	**17**	**26**	**31.5**
WB-W0089	**13927**	**n.a.**	**19**	**26.5**	**30.5**

Storage Area	**Pumping Rate [cfs]**	**Type**	**Notes**
New_Iberia_ring	0	Single area	For large storage areas pumping capacities are set to zero as it is assumed that enough “natural storage” is available inside these drainage basins.

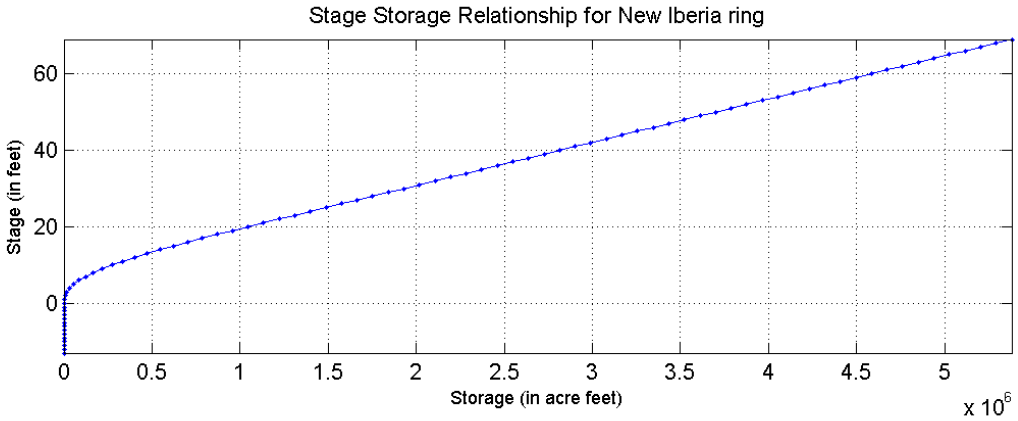


Figure B.54 - Stage storage relationship for New_Iberia_ring

Polder Ring: Charenton_ring

Figure E. 12 ––Sub-basin and levees Charenton_ring

Table E-39 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WB-W0089	**31581**	**n.a.**	**19**	**26.5**	**30.5**
WB-W0094	**11259**	**n.a.**	**16.5**	**25**	**30**

Storage Area	**Pumping Rate [cfs]**	**Type**	**Notes**
Charenton_ring	10472	Single area	

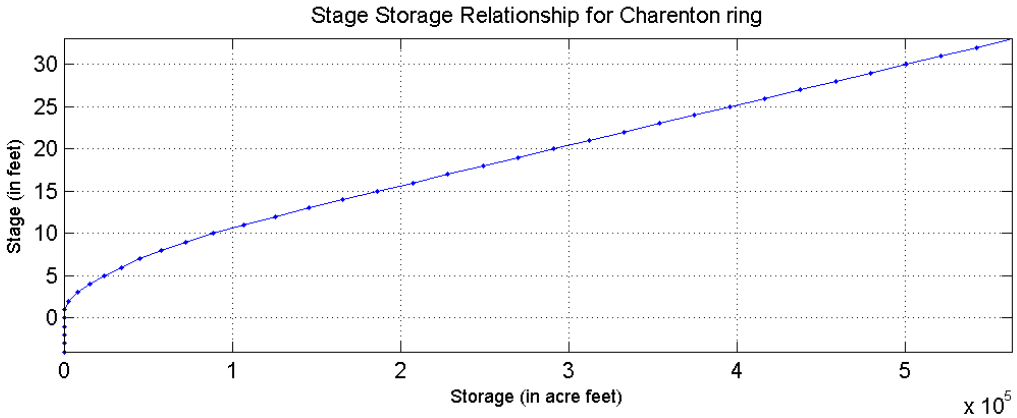


Figure B.54 - Stage storage relationship for Charenton_ring

Polder Ring: Abbeville

Figure E. 13 ––Sub-basin and levees Abbeville

Table E-40 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WT-W0110	**33797**	**n.a.**	**12.5**	**20.5**	**25**

Storage Area	**Pumping Rate [cfs]**	**Type**	**Notes**
Abbeville	1836	Single area	

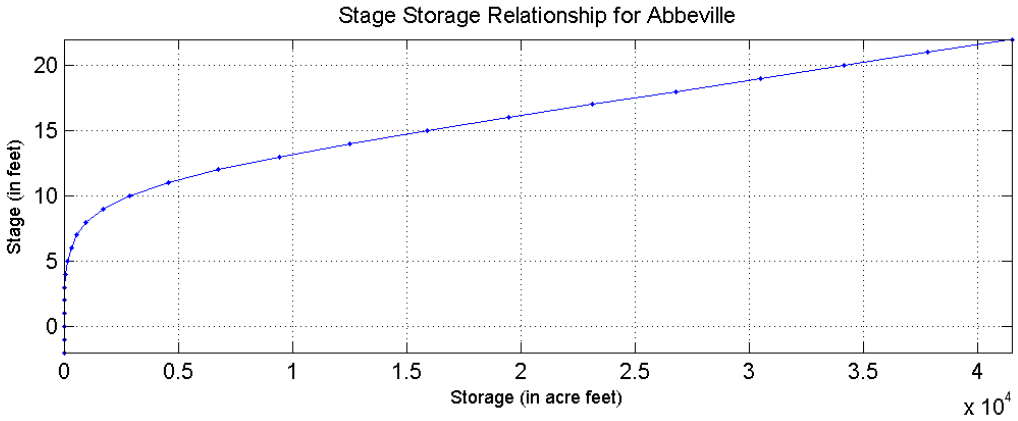


Figure B.54 - Stage storage relationship for Abbeville

Polder Ring: Erath

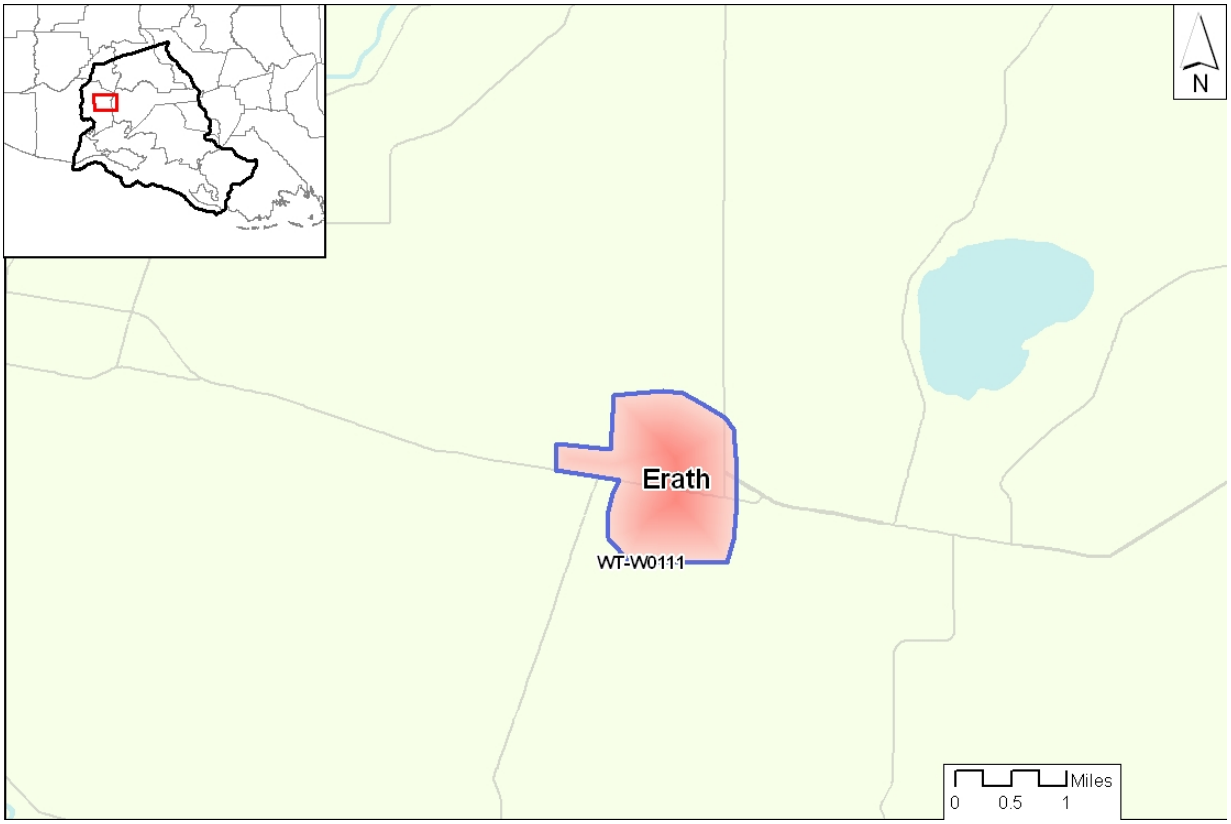


Figure E. 14 ––Sub-basin and levees Erath

Table E-41 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WT-W0111	**19667**	**n.a.**	**17.5**	**25**	**29**

Storage Area	**Pumping Rate [cfs]**	**Type**	**Notes**
Erath	553	Single area	Erath is amongst the ring levees for which overtopping is only included for the seaward side of the levee

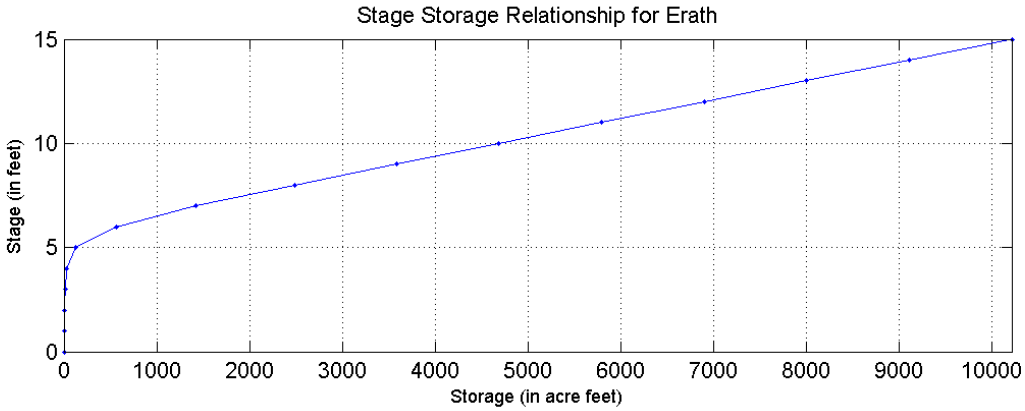


Figure B.54 - Stage storage relationship for Erath

Polder Ring: Delcambre

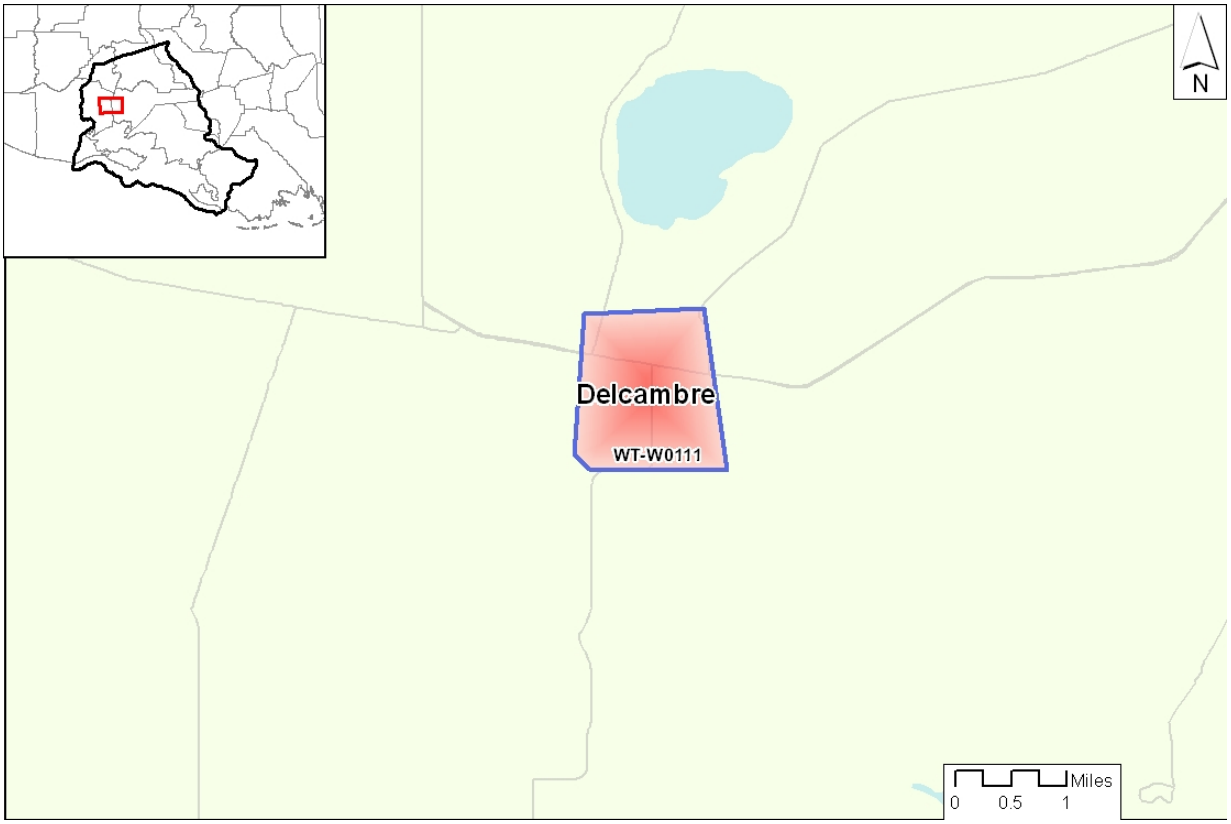


Figure E. 15 ––Sub-basin and levees Delcambre

Table E-42 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WT-W0111	**21979**	**n.a.**	**17.5**	**25**	**29**

Storage Area	**Pumping Rate [cfs]**	**Type**	**Notes**
Delcambre	555	Single area	

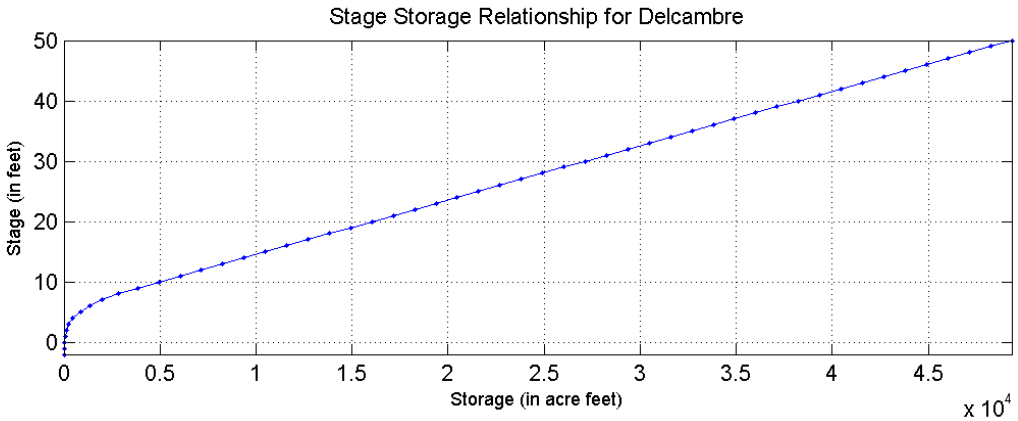


Figure B.54 - Stage storage relationship for Delcambre

Polder Ring: New_Iberia

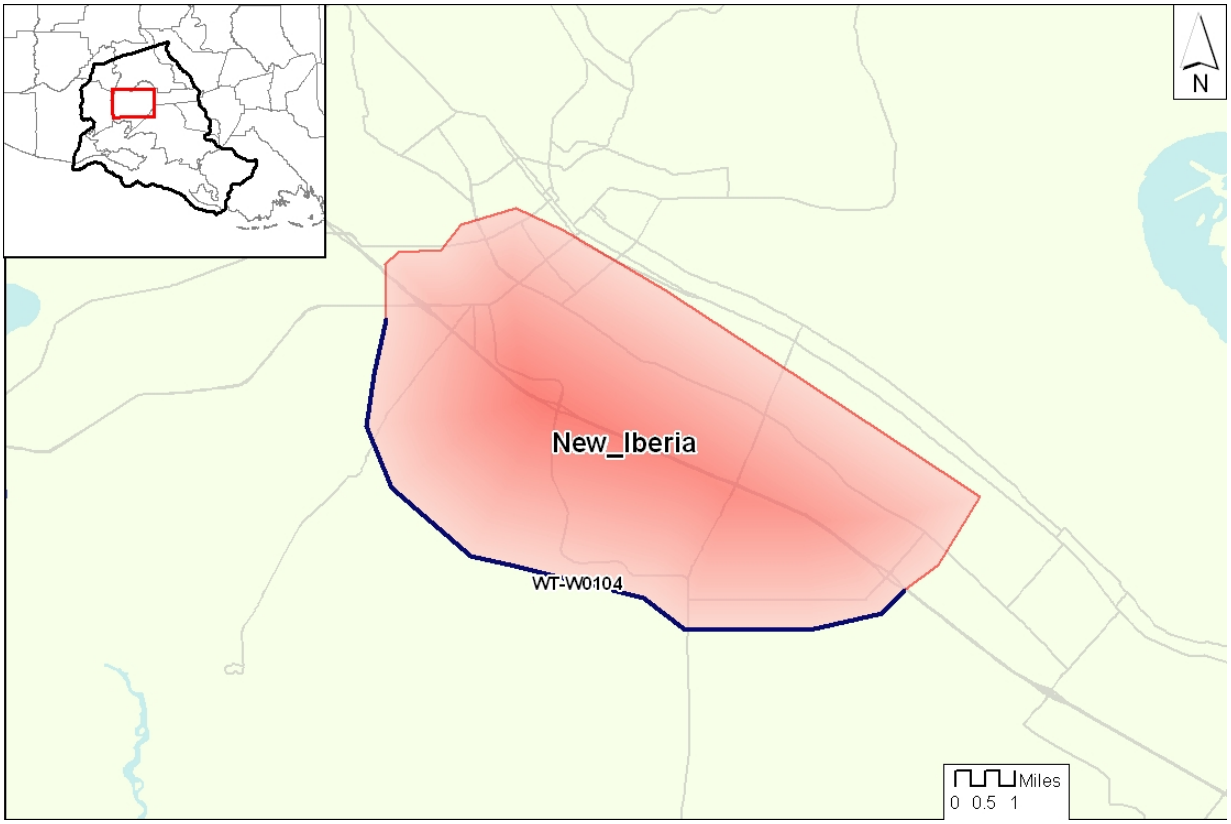


Figure E. 16 ––Sub-basin and levees New_Iberia

Table E-43 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WT-W0104	**66021**	**n.a.**	**14.5**	**22**	**26.5**

Storage Area	**Pumping Rate [cfs]**	**Type**	**Notes**
New_Iberia	0	Single area	

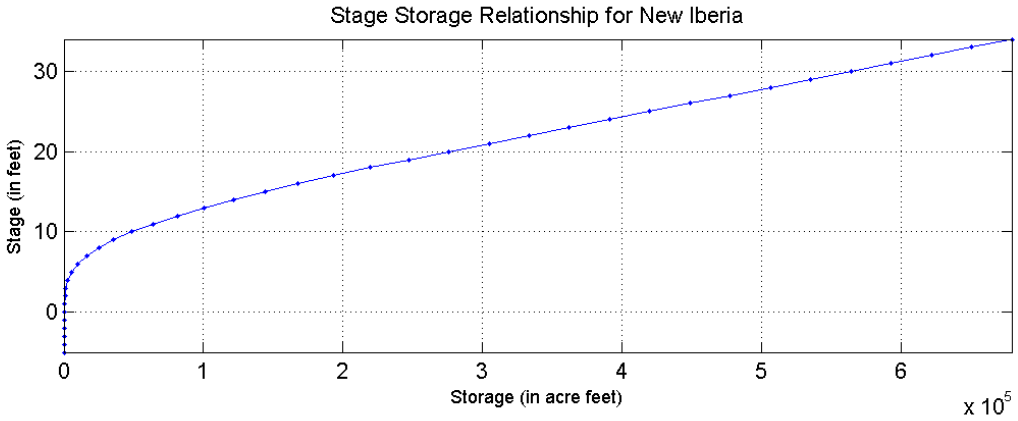


Figure B.54 - Stage storage relationship for New_Iberia

Polder Ring: Baldwin

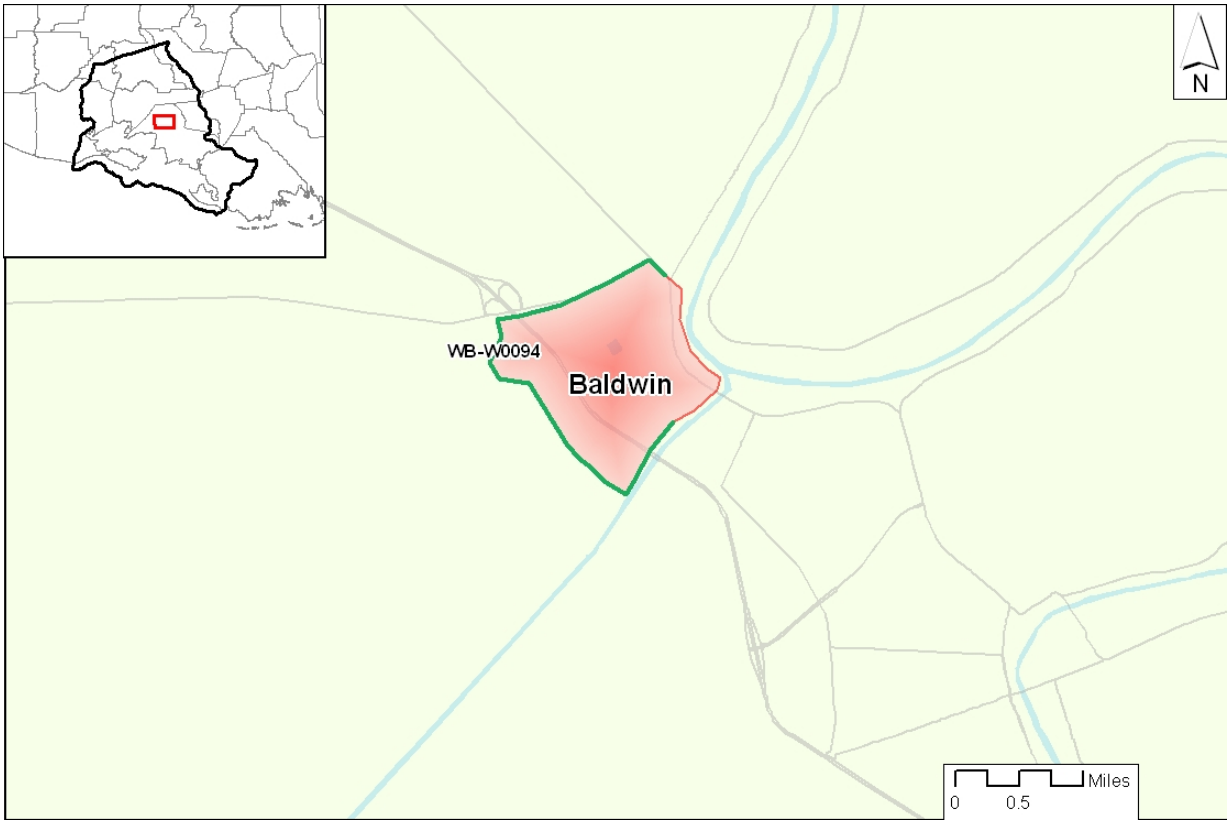


Figure E. 17 ––Sub-basin and levees Baldwin

Table E-44 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WB-W0094	**17831**	**n.a.**	**16.5**	**25**	**30**

Storage Area	**Pumping Rate [cfs]**	**Type**	**Notes**
Baldwin	554	Single area	

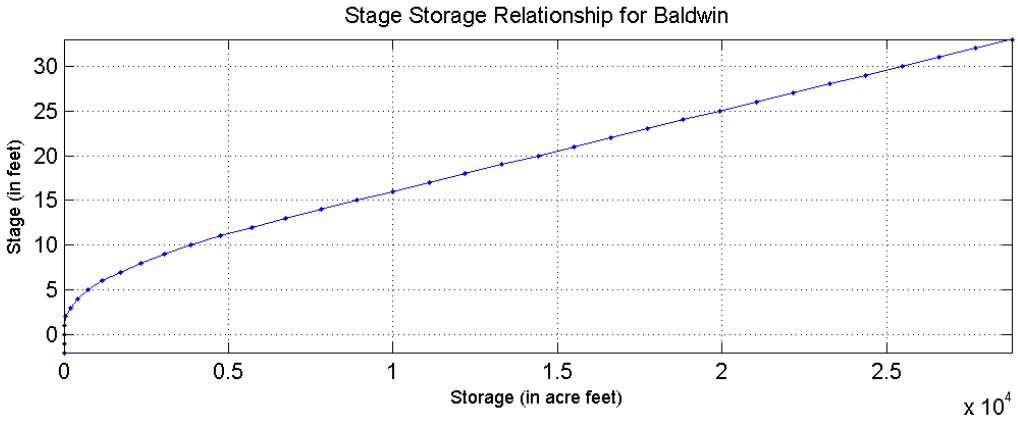


Figure B.54 - Stage storage relationship for Baldwin

Polder Ring: Franklin

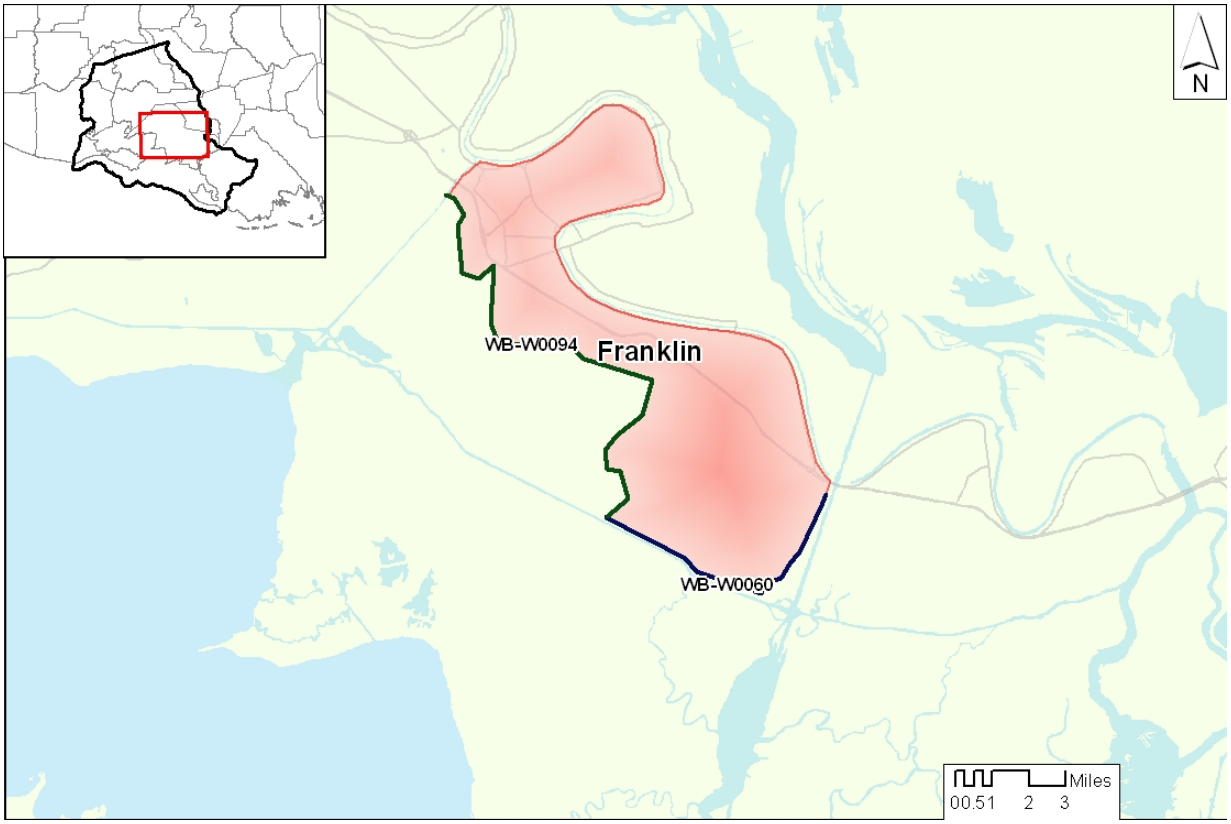


Figure E. 18 ––Sub-basin and levees Franklin

Table E-45 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WB-W0094	**78444**	**n.a.**	**16.5**	**25**	**30**
WB-W0060	**42760**	**n.a.**	**16.5**	**23.5**	**27.5**

Storage Area	**Pumping Rate [cfs]**	**Type**	**Notes**
Franklin	17125	Single area	

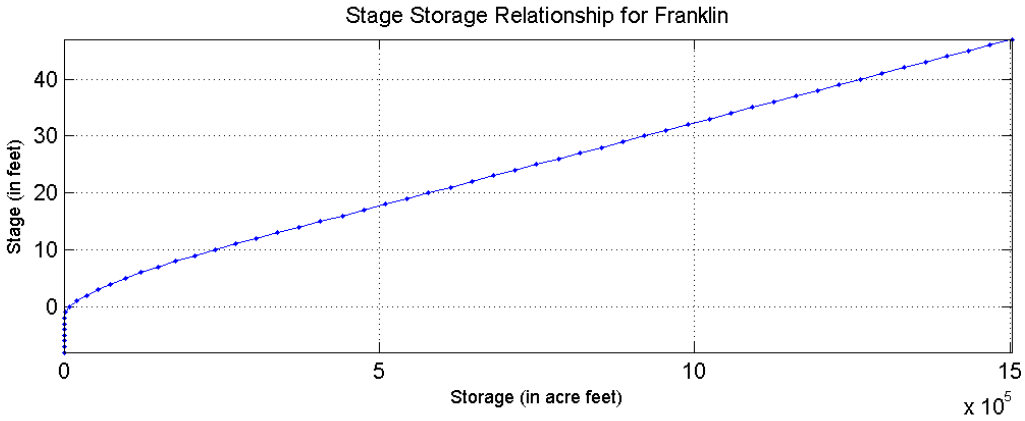


Figure B.54 - Stage storage relationship for Franklin

Planning Unit 4

Polder Ring: Central_PU4_ring

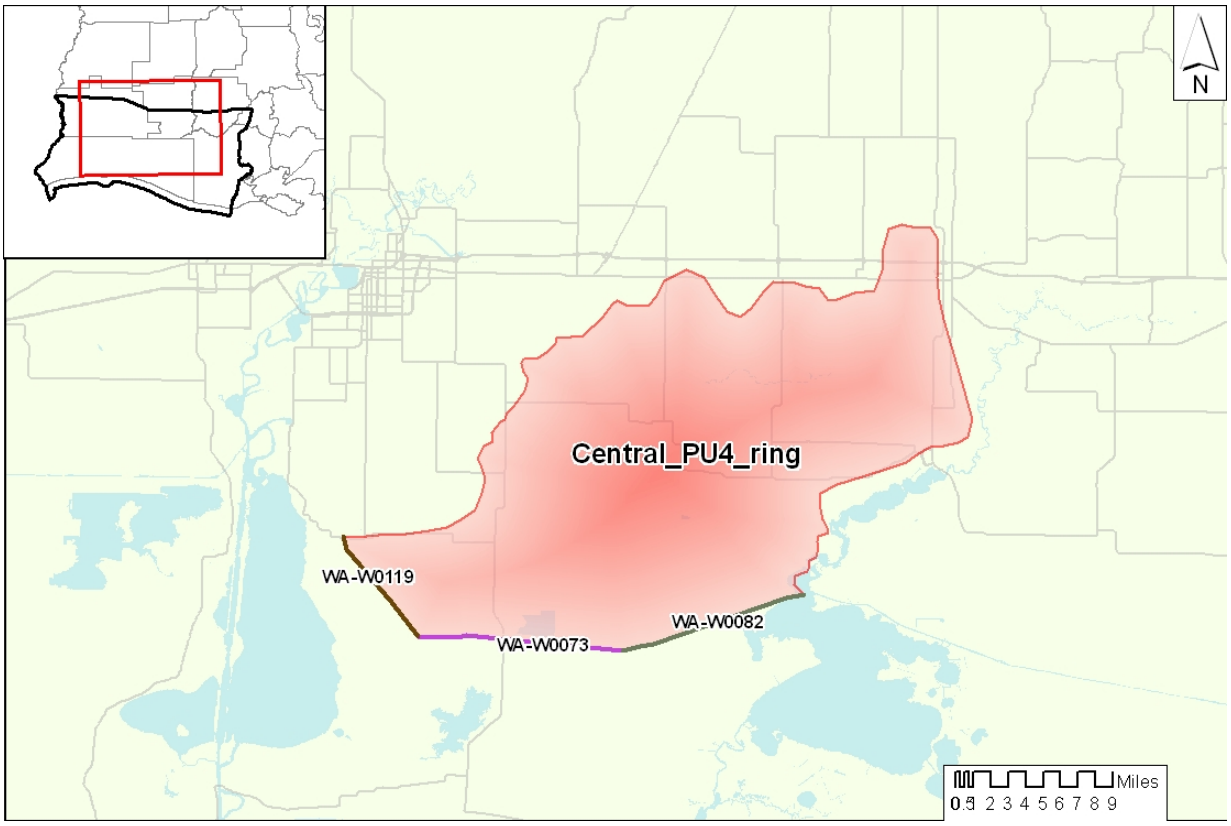


Figure E. 19 ––Sub-basin and levees Central_PU4_ring

Table E-46 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WA-W0119	**38332**	**n.a.**	**13.5**	**21.5**	**26**
WA-W0073	**62206**	**n.a.**	**16**	**24**	**28.5**
WA-W0082	**57523**	**n.a.**	**14**	**20.5**	**24.5**

Storage Area	**Pumping Rate [cfs]**	**Type**	**Notes**
Central_PU4_ring	0	Single area	

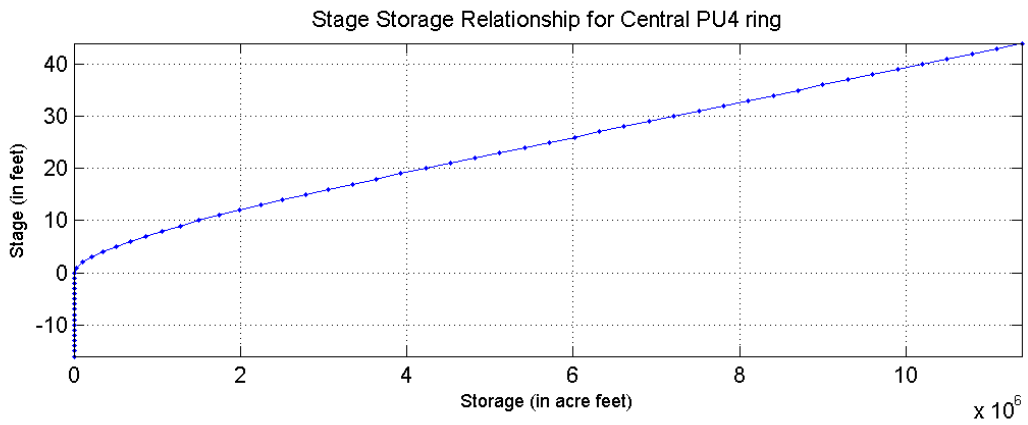


Figure B.54 - Stage storage relationship for Central_PU4_ring

Polder Ring: GIWW_to_Veterans_ring

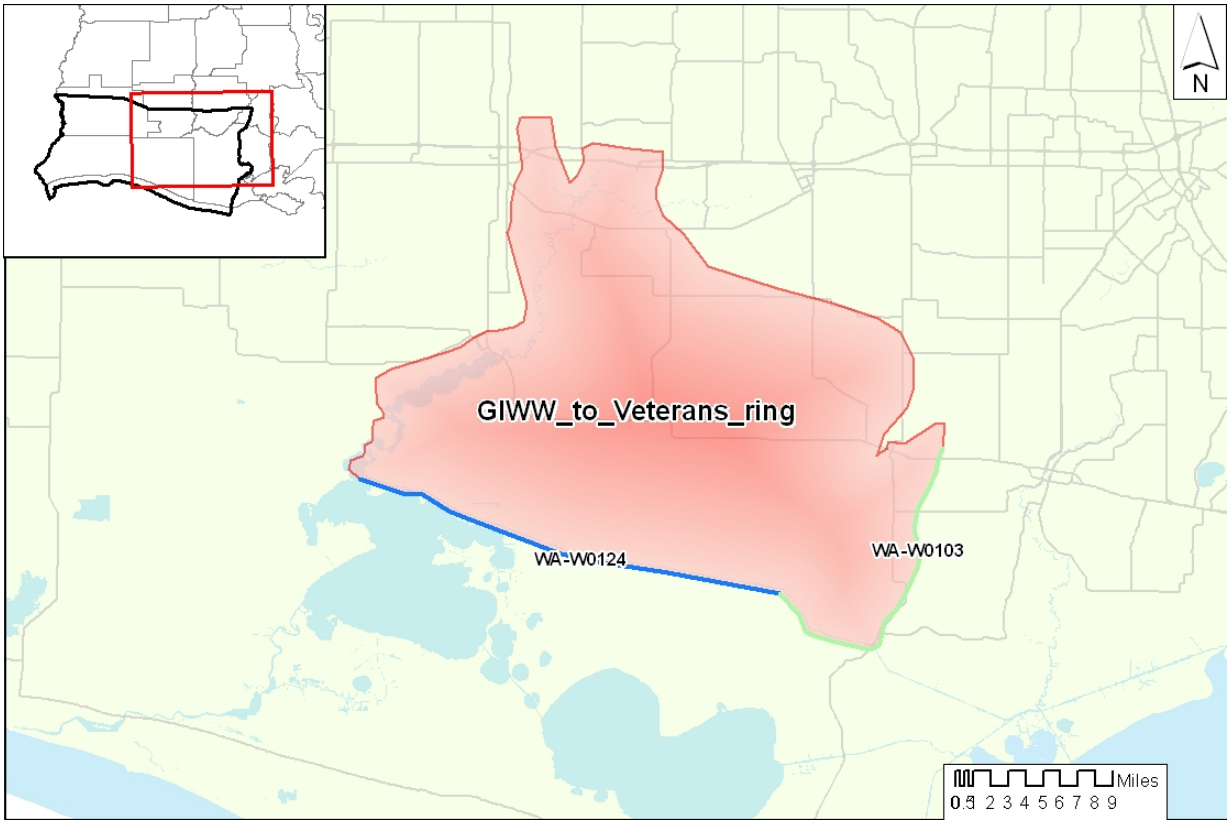


Figure E. 20 ––Sub-basin and levees GIWW_to_Veterans_ring

Table E-47 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WA-W0124	**132503**	**n.a.**	**12**	**19.5**	**24**
WA-W0103	**33981**	**n.a.**	**21.5**	**28**	**31.5**

Storage Area	**Pumping Rate [cfs]**	**Type**	**Notes**
GIWW_to_Veterans_ring	366	Single area	

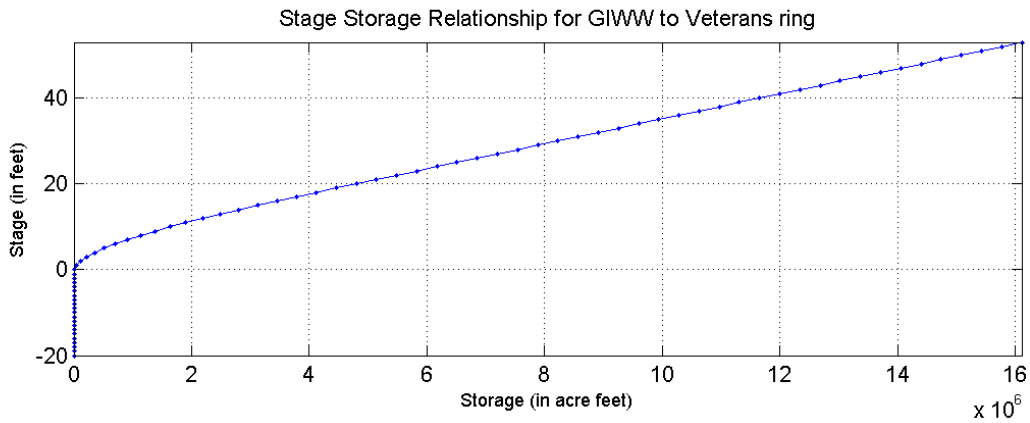


Figure B.54 - Stage storage relationship for GIWW_to_Veterans_ring

Polder Ring: South_of_Lake_Charles_ring

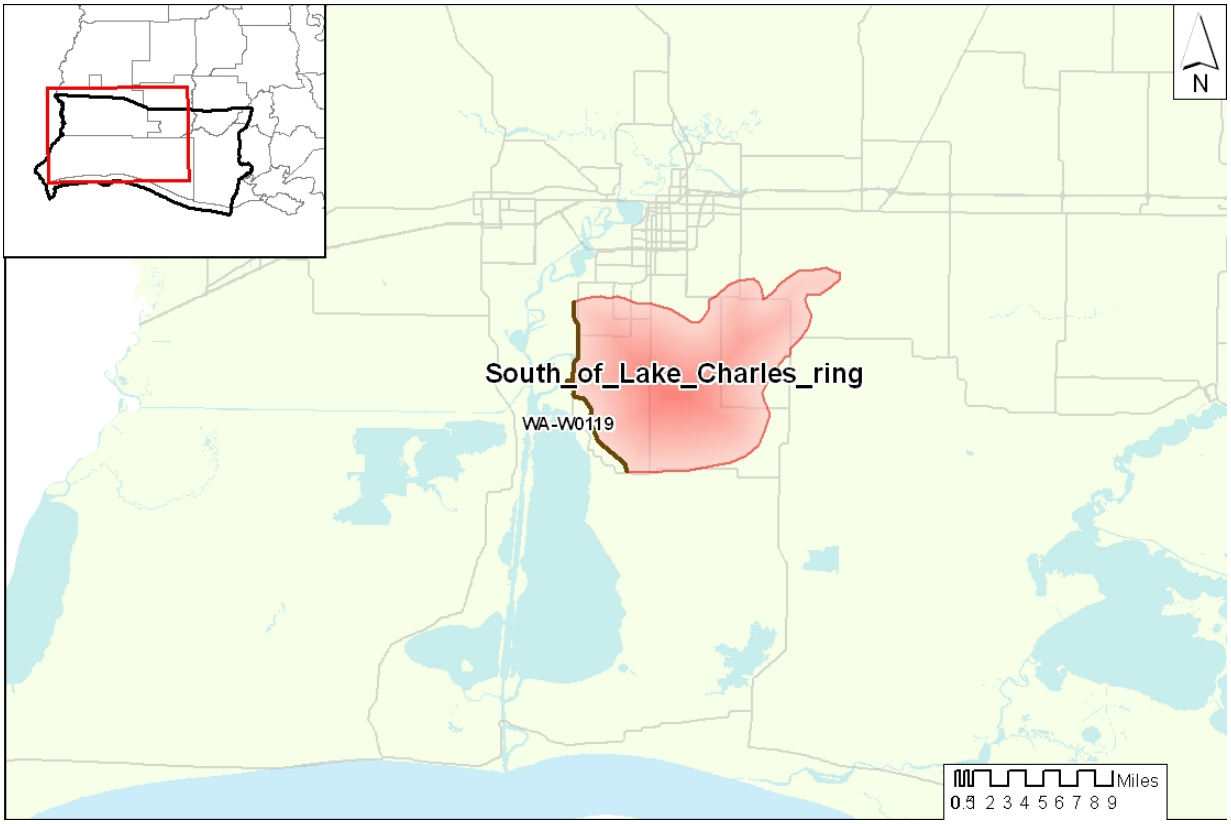


Figure E. 21 ––Sub-basin and levees South_of_Lake_Charles_ring

Table E-48 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WA-W0119	**62456**	**n.a.**	**13.5**	**21.5**	**26**

Storage Area	**Pumping Rate [cfs]**	**Type**	**Notes**
South_of_Lake_Charles_ring	29761	Single area	

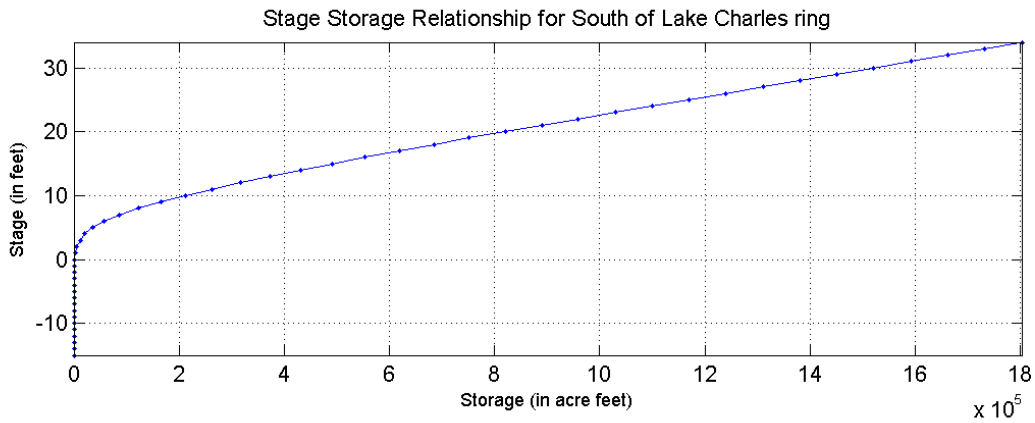


Figure B.54 - Stage storage relationship for South_of_Lake_Charles_ring

Polder Ring: West_Lake_Charles

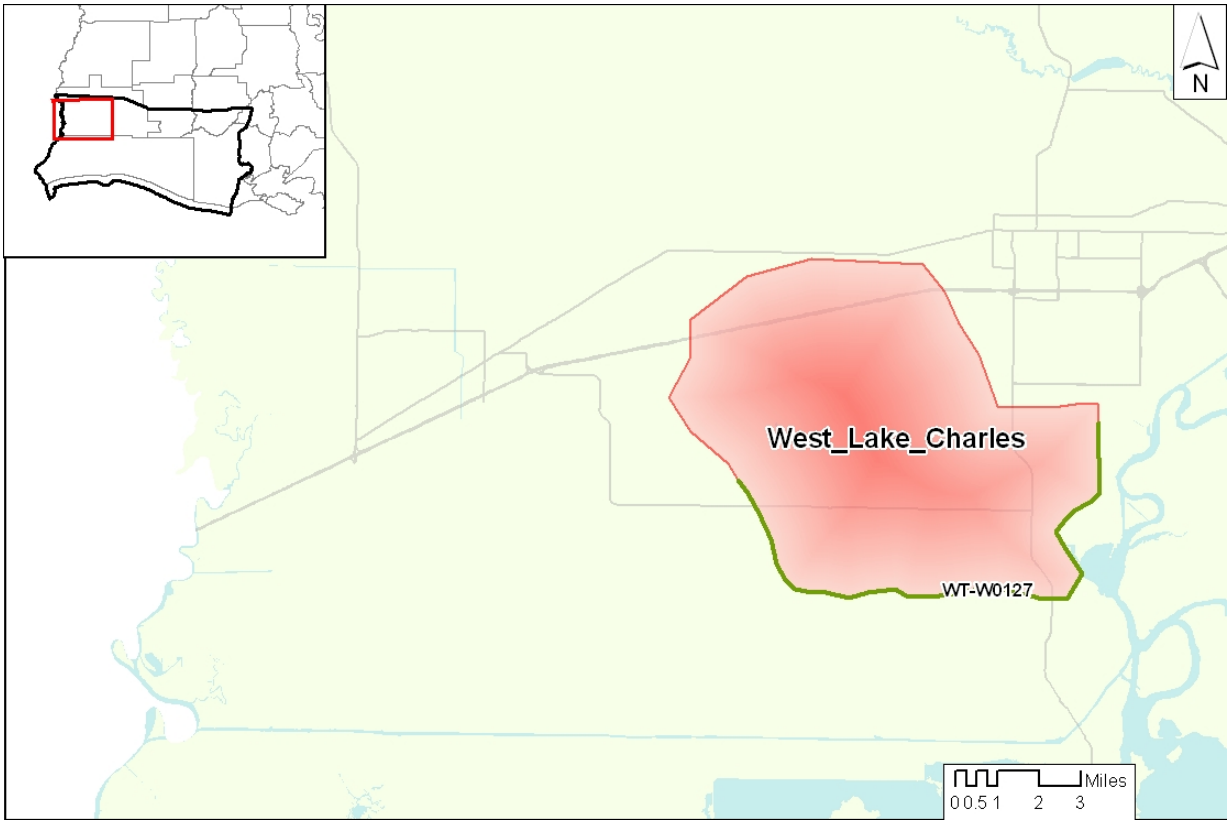


Figure E. 22 ––Sub-basin and levees West_Lake_Charles

Table E-49 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WT-W0127	**77095**	**n.a.**	**11**	**15.5**	**17.5**

Storage Area	**Pumping Rate [cfs]**	**Type**	**Notes**
West_Lake_Charles	29761	Single area	

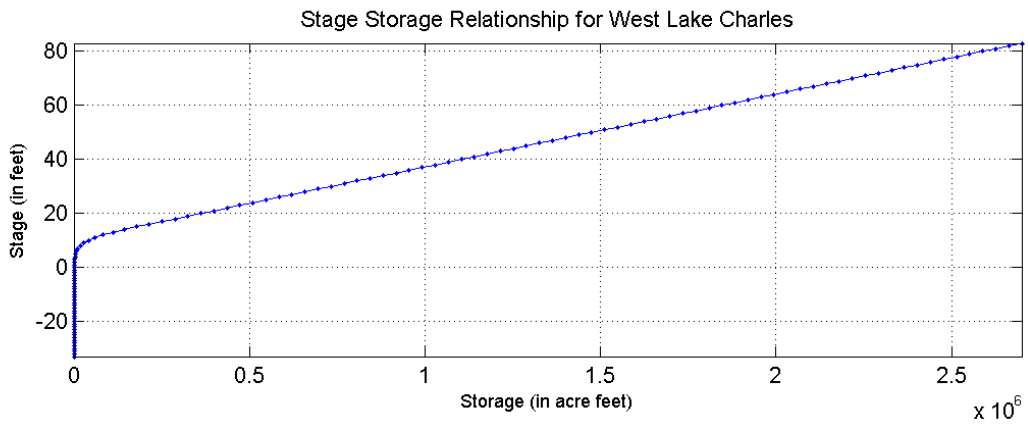


Figure B.54 - Stage storage relationship for West_Lake_Charles

Polder Ring: Prien

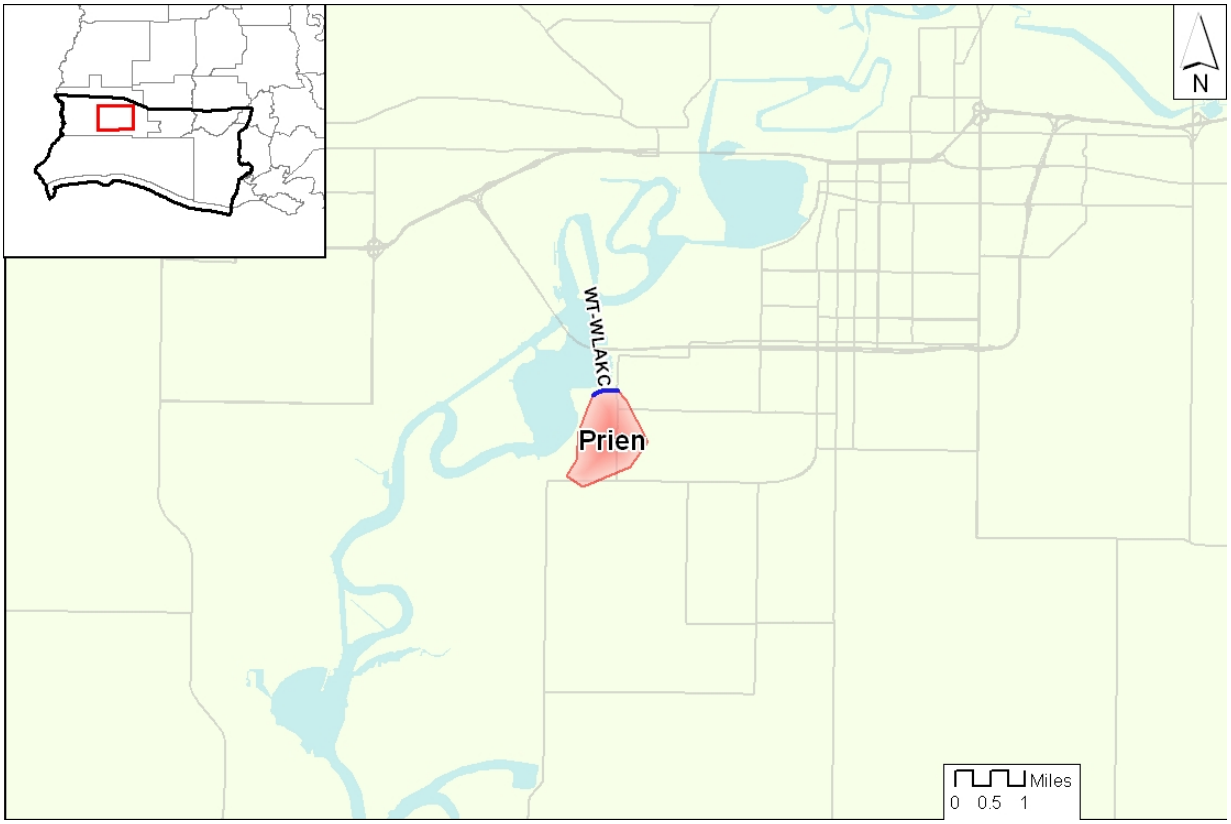


Figure E. 23 ––Sub-basin and levees Prien

Table E-50 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WT-W0999	**1918**	**n.a.**	**13.5**	**17**	**19.5**

Storage Area	**Pumping Rate [cfs]**	**Type**	**Notes**
Prien	13927	Single area	The Prien area is more prone to flooding from the river side instead of the sea side while sea surge penetrate up the river. Due to lack of wave data a 3ft wave is applied to come to overtopping rates for this levee.

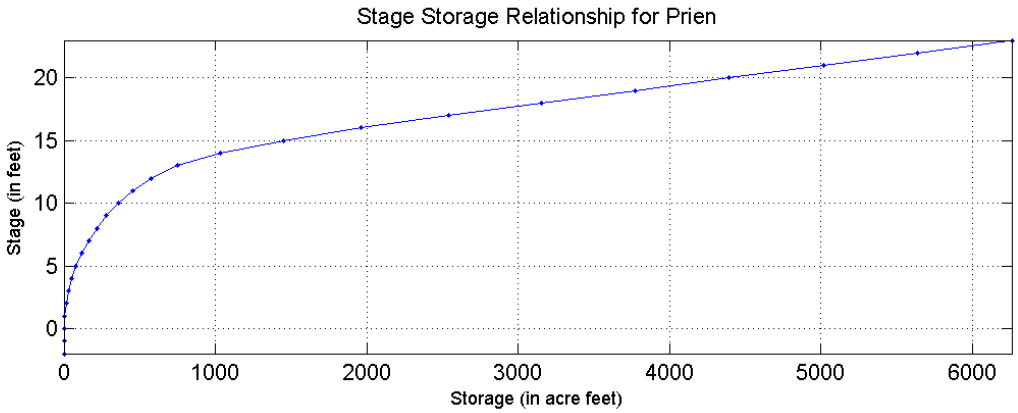


Figure B.54 - Stage storage relationship for Prien

Polder Ring: Inner_Lake_Charles

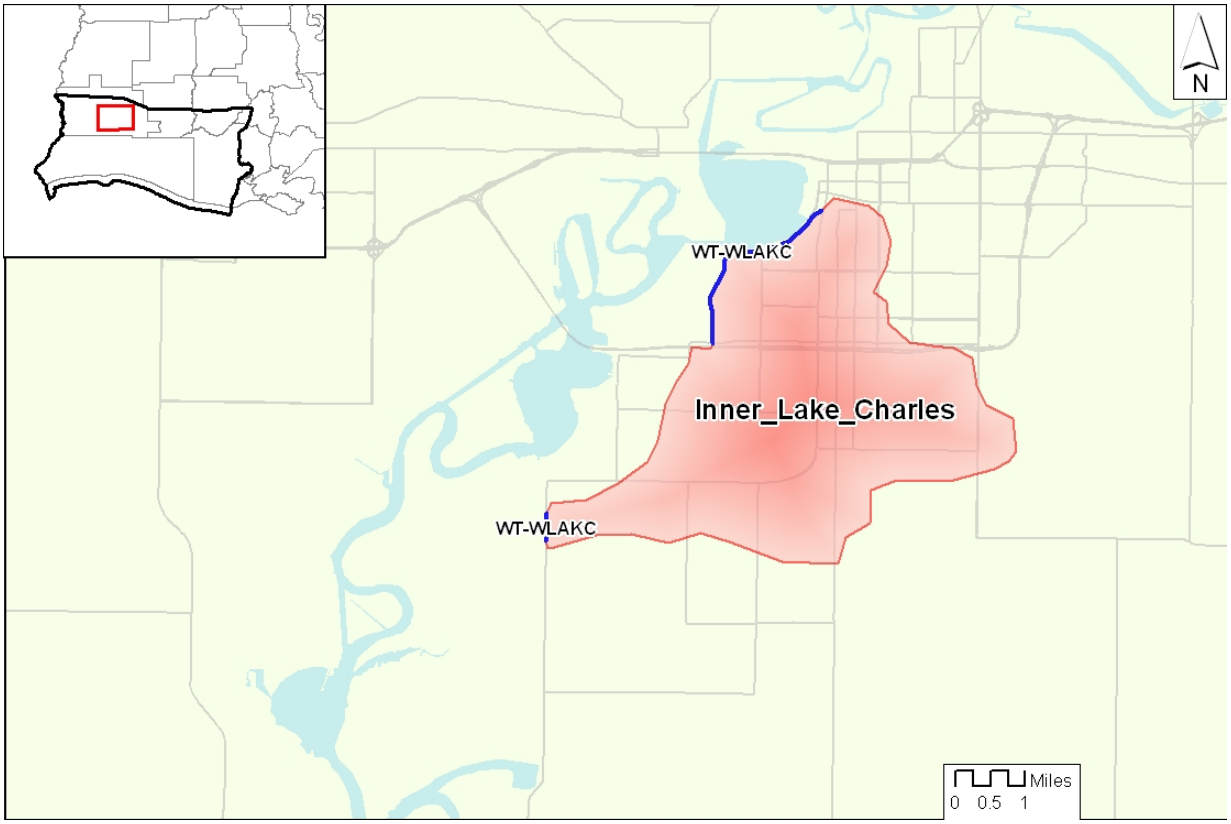


Figure E. 24 ––Sub-basin and levees Inner_Lake_Charles

Table E-51 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WT-W0999	**2103**	**n.a.**	**13.5**	**17**	**19.5**
WT-W0999	**15698**	**n.a.**	**13.5**	**17**	**19.5**

Storage Area	**Pumping Rate [cfs]**	**Type**	**Notes**
Inner_Lake_Charles	13927	Single area	Equally to the Prien area this area is more prone to flooding from the river side instead of the sea side while sea surge penetrates up the river. Due to lack of wave data a 3ft wave is applied to come to overtopping rates for this levee.

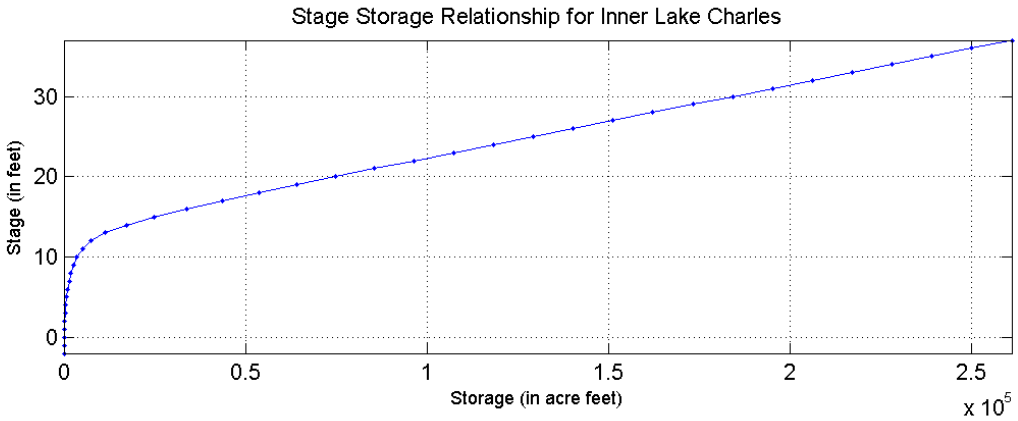


Figure B.54 - Stage storage relationship for Inner_Lake_Charles

Polder Ring: South_of_Lake_Charles_ring_12

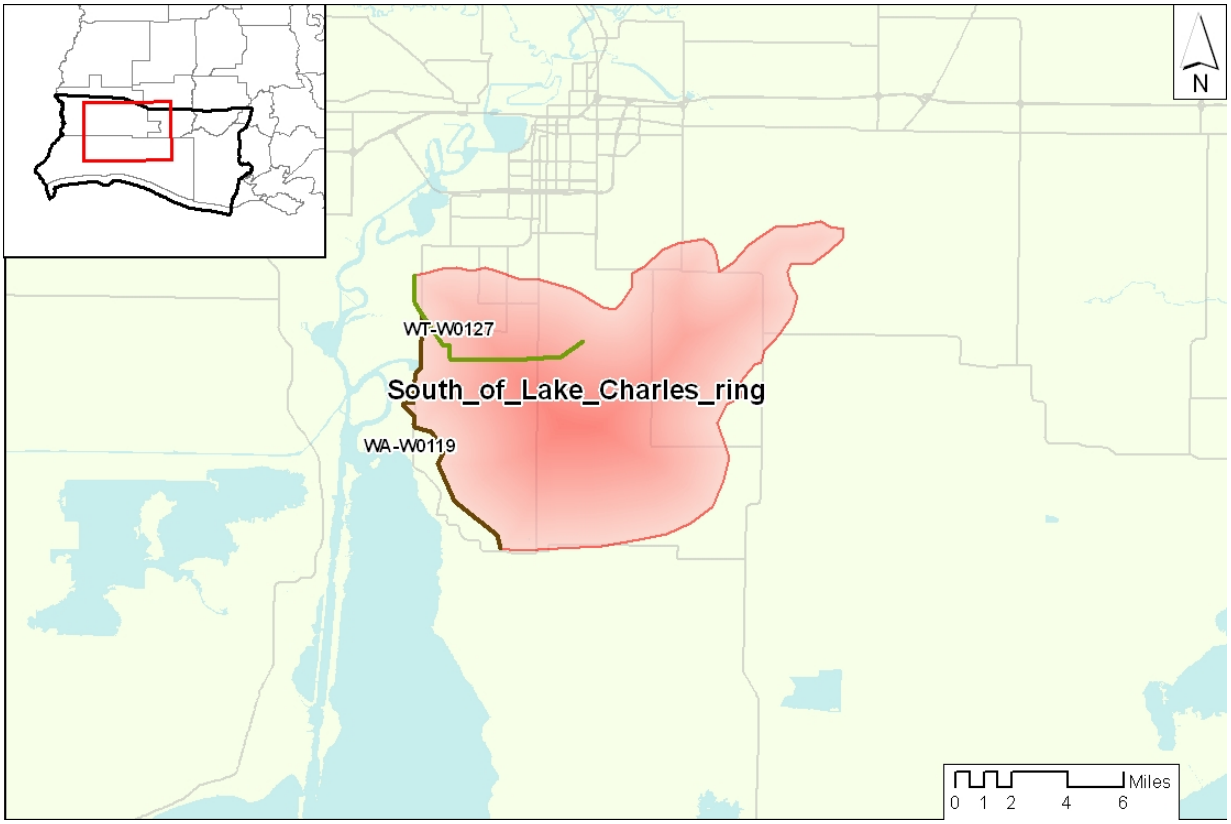


Figure E. 25 ––Sub-basin and levees South_of_Lake_Charles_ring_12

Table E-52 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WA-W0119	**62456**	**n.a.**	**12**	**12**	**12**
WT-W0127	**44374**	**n.a.**	**-**	**10.7**	**12.3**

Storage Area	**Pumping Rate [cfs]**	**Type**	**Notes**
South_of_Lake_Charles_ring_12	311	Single area	

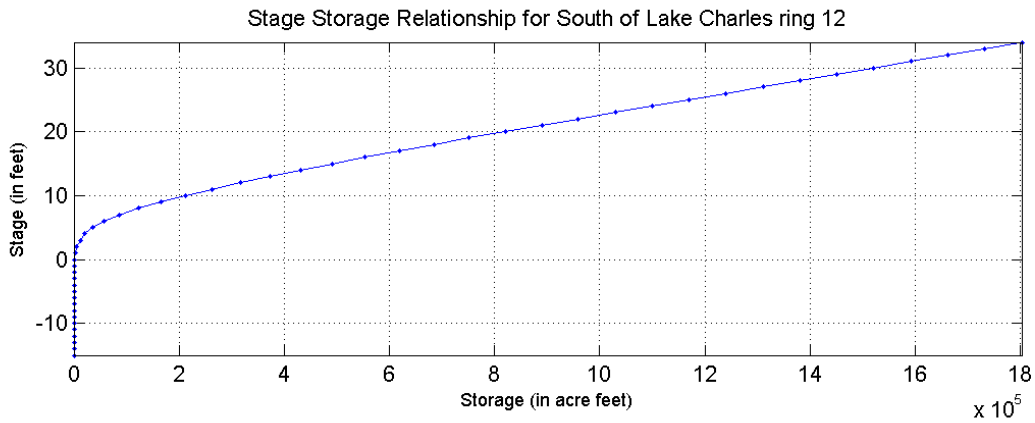


Figure B.54 - Stage storage relationship for South_of_Lake_Charles_ring_12

Polder Ring: Central_PU4_ring_large_12

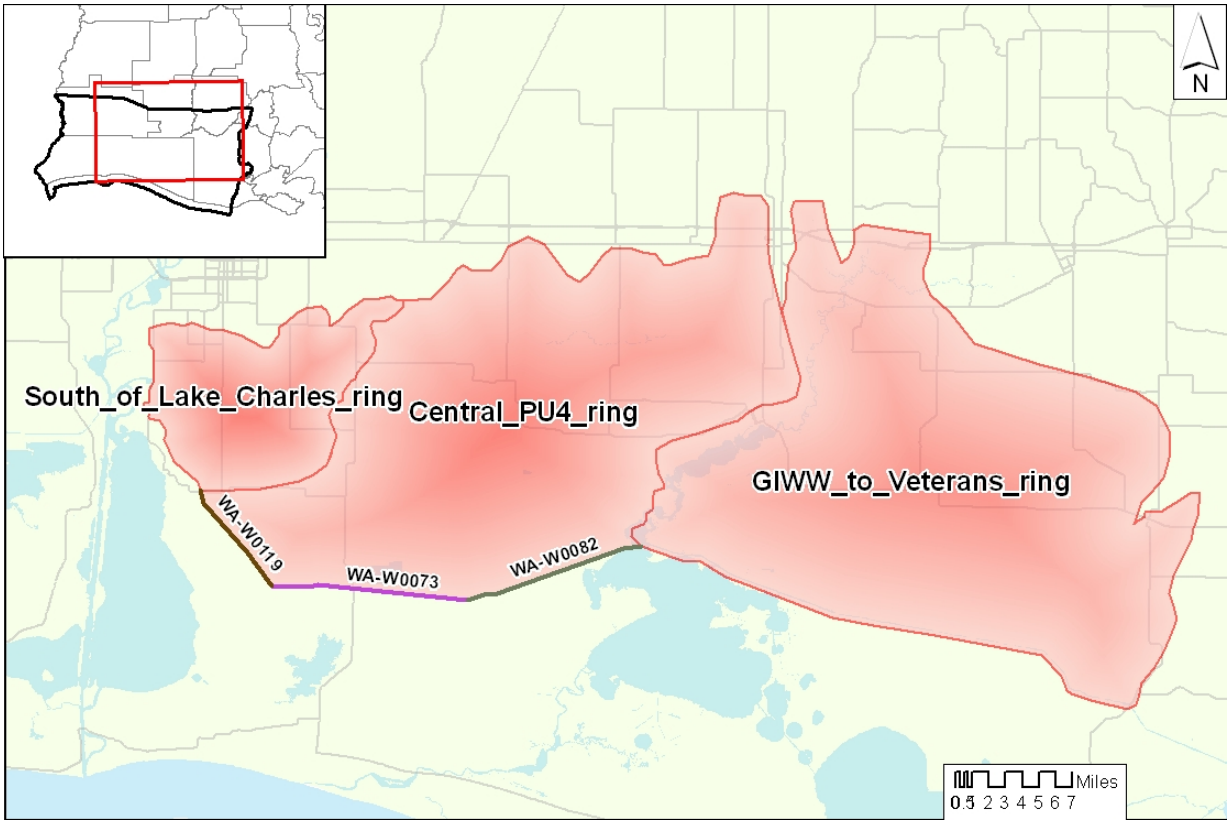


Figure E. 26 ––Sub-basin and levees Central_PU4_ring_large_12

Table E-53 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WA-W0119	**38332**	**n.a.**	**12**	**12**	**12**
WA-W0073	**62206**	**n.a.**	**12**	**12**	**12**
WA-W0082	**57523**	**n.a.**	**12**	**12**	**12**

Storage Area	**Pumping Rate [cfs]**	**Type**	**Notes**
Central_PU4_ring_large_12	29761	multiple areas	For the 12' levee design to be effective areas are combined to let the flooding to spread out over several areas.

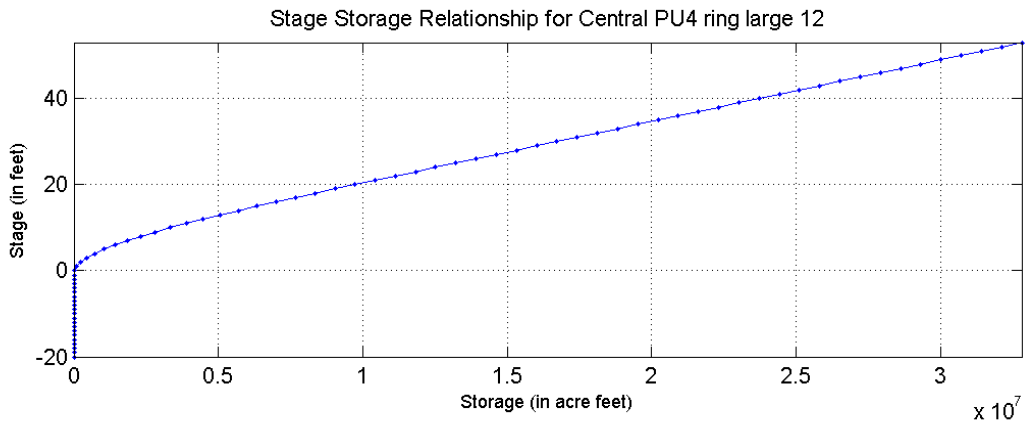


Figure B.54 - Stage storage relationship for Central_PU4_ring_large_12

Polder Ring: GIWW_to_Veterans_ring_large_12

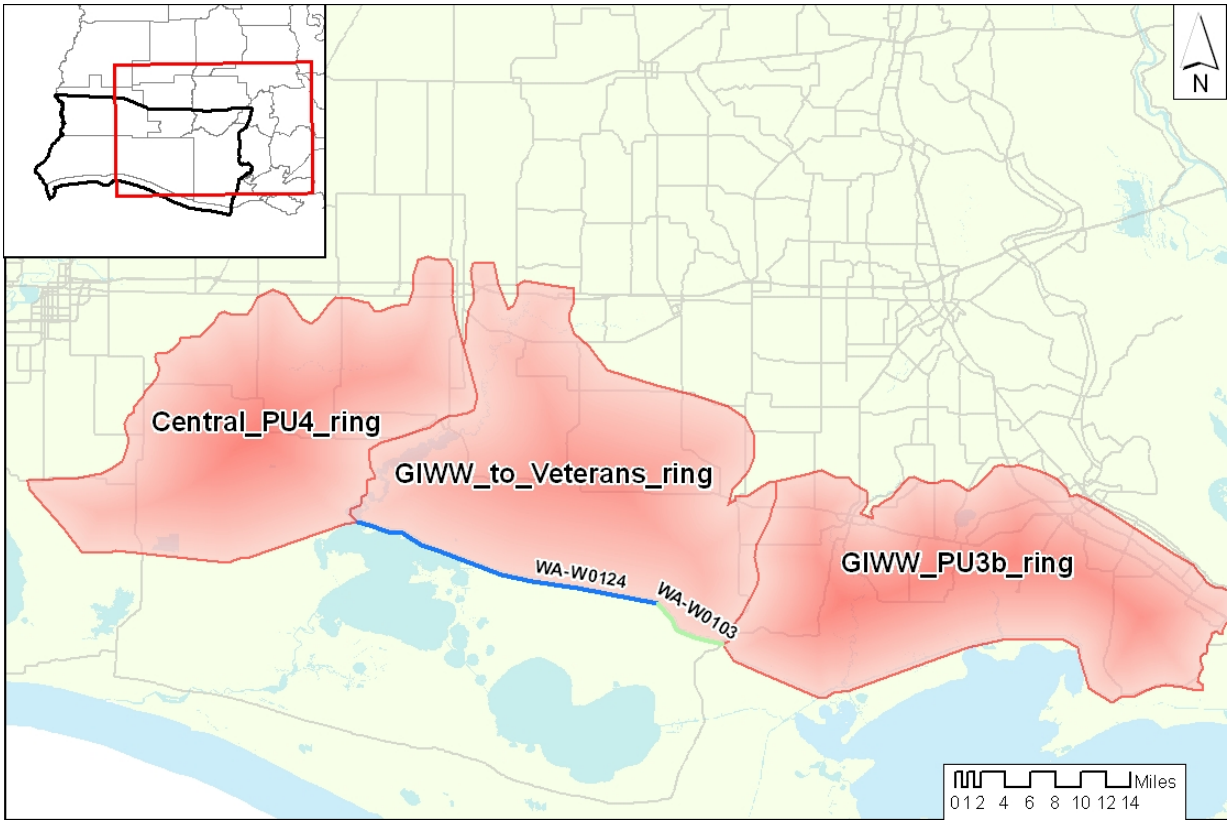


Figure E. 27 ––Sub-basin and levees GIWW_to_Veterans_ring_large_12

Table E-54 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WA-W0124	**132503**	**n.a.**	**12**	**12**	**12**
WA-W0103	**33981**	**n.a.**	**12**	**12**	**12**

Storage Area	**Pumping Rate [cfs]**	**Type**	**Notes**
GIWW_to_Veterans_ring_large_12	366	multiple areas	For the 12' levee design to be effective areas are combined to let the flooding to spread out over several areas.

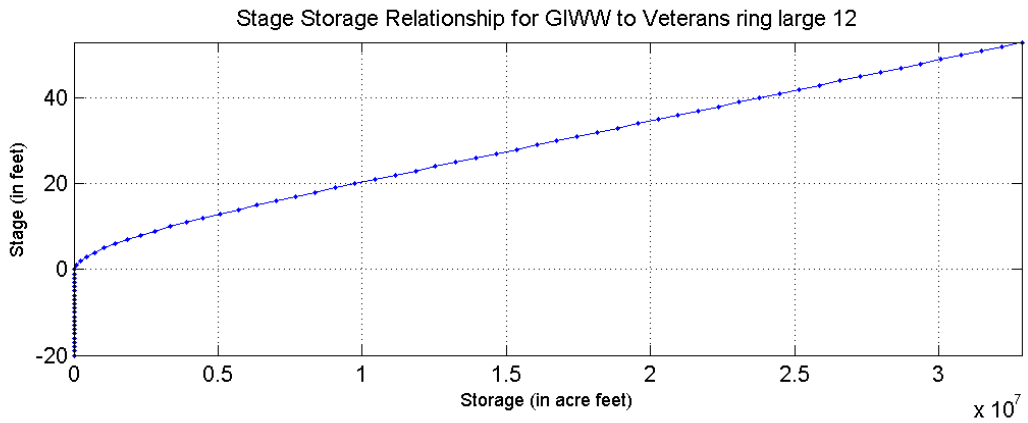


Figure B.54 - Stage storage relationship for GIWW_to_Vetterans_ring_large_12

Polder Ring: East_Lake_Charles

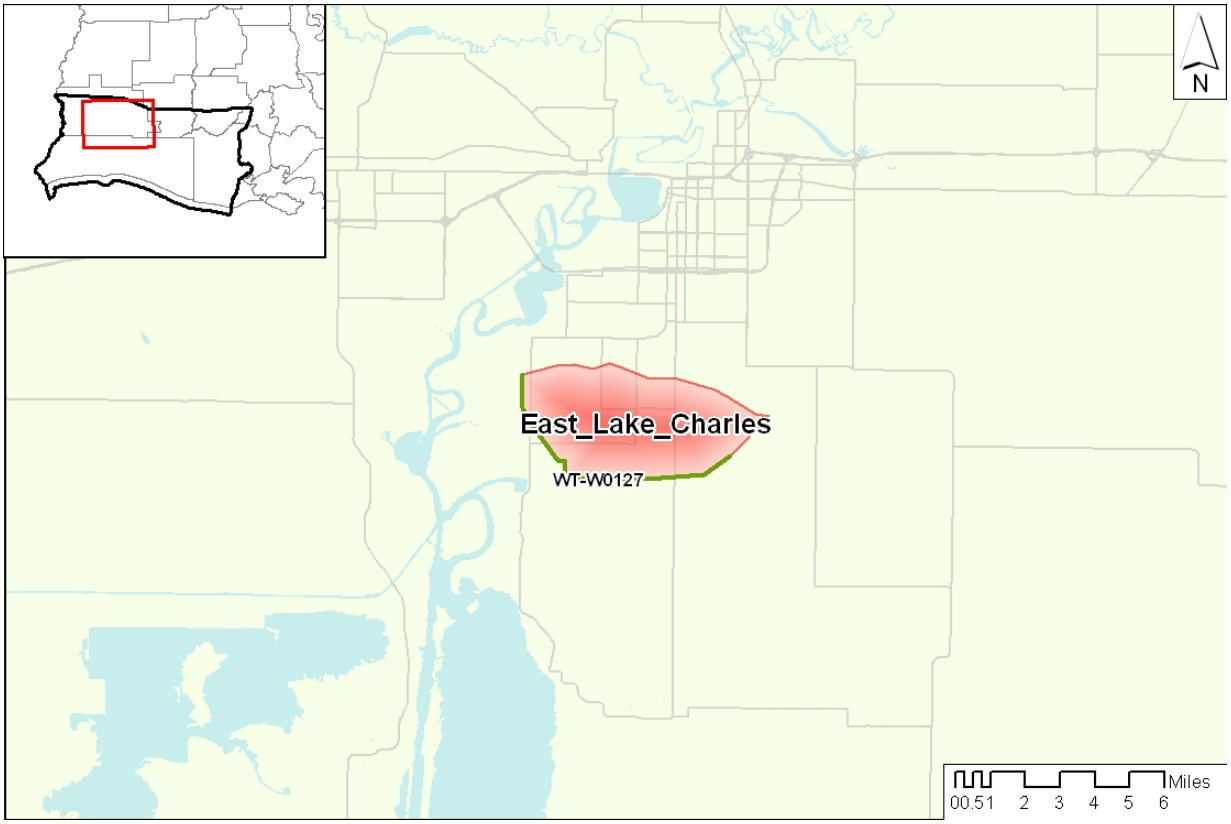


Figure E. 28 ––Sub-basin and levees East_Lake_Charles

Table E-55 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WT-W0127	**77095**	**n.a.**	**11**	**15.5**	**17.5**

Storage Area	**Pumping Rate [cfs]**	**Type**	**Notes**
East_Lake_Charles	5396	single area	

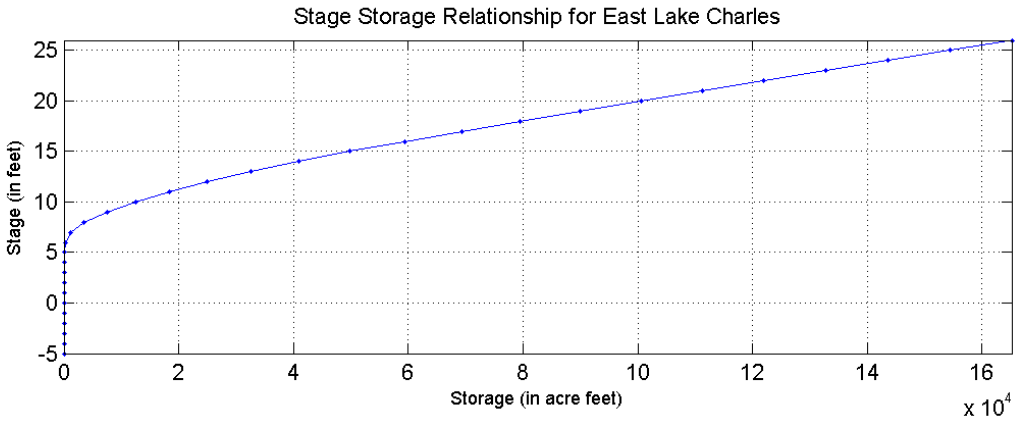


Figure B.54 - Stage storage relationship for East_Lake_Charles

Polder Ring: Gueydan

Figure E. 29 ––Sub-basin and levees Gueydan

Table E-56 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WT-W0153	**21674**	**n.a.**	**9**	**15.5**	**18.5**

Storage Area	**Pumping Rate [cfs]**	**Type**	**Notes**
Gueydan	366	single area	Equally to other smaller ring levees Gueydan is only overtopped from the seawards side

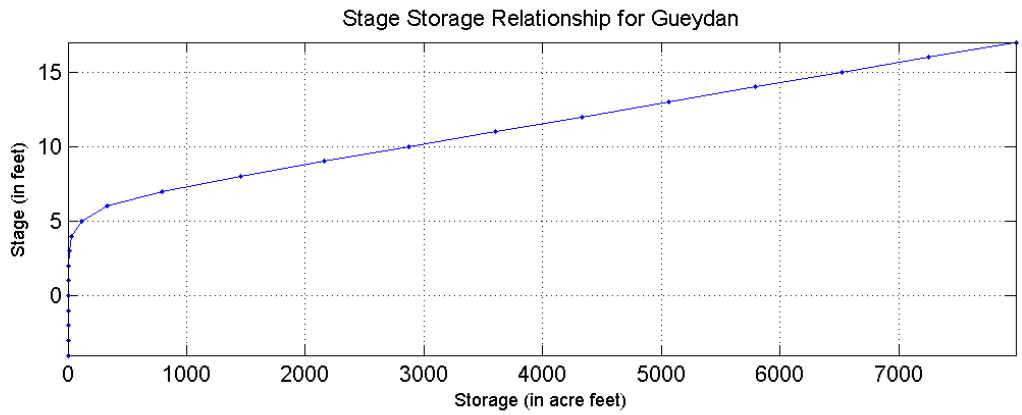


Figure B.54 - Stage storage relationship for Gueydan

Polder Ring: Kaplan

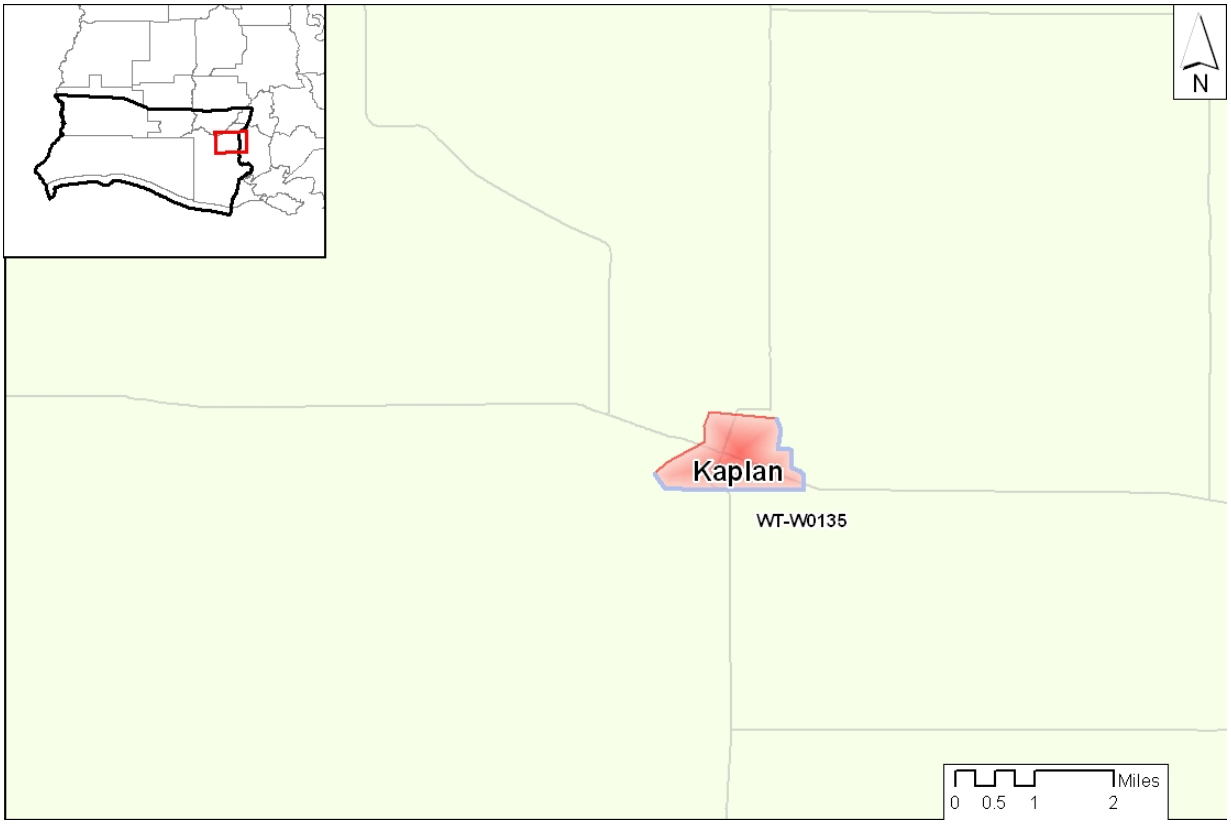


Figure E. 30 ––Sub-basin and levees Kaplan

Table E-57 – Levee characteristics

			Design Height (waves modeled without friction)		
Reach ID	**Length**	**Authorized Height**	**100 year**	**400 year**	**1000 year**
[-]	**[ft]**	**[ft]**	**[ft]**	**[ft]**	**[ft]**
WT-W0135	**16630**	**n.a.**	**9**	**15.5**	**18.5**

Storage Area	**Pumping Rate [cfs]**	**Type**	**Notes**
Kaplan	5496	single area	Equally to other smaller ring levees Kaplan is only overtopped from the seawards side

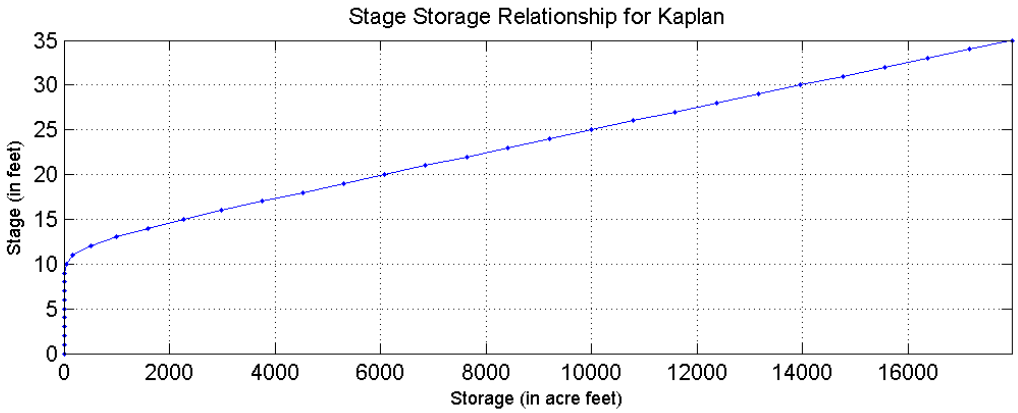


Figure B.54 - Stage storage relationship for Kaplan