ECONOMICS APPENDIX

MIAMI-DADE BACK BAY COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

MIAMI-DADE COUNTY, FLORIDA

APPENDIX C

May 2020

U.S. Army Corps
of Engineers
Norfolk District

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1 ECONOMIC EVALUATION METHODOLOGY

1.1 Introduction

This appendix presents an economic evaluation of the Tentatively Selected Plan for the Miami-Dade Back Bay Coastal Storm Risk Management Feasibility Study. Due to the large geographic scale of the study and the inability to provide a comprehensive recommendation under this study effort, a process was completed to identify the most vulnerable areas based on flooding potential and social vulnerability. The process to identify those areas is fully described in Chapter 3. This analysis was conducted in accordance with Engineer Regulation (ER) 1105-2-100, Planning Guidance Notebook, and ER 1105-2-101, Planning Guidance, Risk Analysis for Flood Damage Reduction Studies. The National Economic Development Procedures Manual for Flood Risk Management and Coastal Storm Risk Management, prepared by the Water Resources Support Center, Institute for Water Resources, was also used as a reference, along with the USACE Engineer Research and Development Center G2CRM Manual. G2CRM was used in this study since the model is designed to evaluate inundation of areas in a coastal environment wherein the effect of wave action contributes to the damage. The G2CRM analysis is covered in Chapter 2 of this appendix.

The economic appendix consists of a description of the methodology used to determine National Economic Development (NED) damage under existing and future conditions and projects costs. The damage and costs were originally calculated using October 2018 (FY19) price levels and were then indexed to reflect October 2019 (FY20) price levels. Damage was converted to equivalent average annual values using the FY20 Federal discount rate of 2.75 percent and a period of analysis of 50 years. The year 2030 was identified as the base year for each of the alternatives as the basis for plan comparison.

1.1.1 *NED Benefit Categories Considered*

The NED procedure manuals for coastal and urban areas recognize four primary categories of benefits for flood risk management measures: inundation reduction, intensification, location, and employment benefits. The majority of the benefits attributable to a project alternative, generally, result from the reduction of actual or potential damage to structure and/or its contents caused by inundation.

Physical Flood *Damage Reduction*. Physical flood damage reduction benefits include the decrease in potential damage to residential, commercial, industrial or public structures and their contents. While future population growth was projected for the study area, a future development structure inventory was not included in the damage calculations due to the limited remaining available land and the expectation that future growth will more likely be accomplished through redevelopment.

Emergency Cost Reduction Benefits. Emergency costs are those incurred by the community during and immediately following a major storm. They include the costs of emergency measures, such as evacuation and reoccupation activities conducted by local governments and homeowners, repair of streets, highways, and railroad tracks, and the subsequent cleanup and restoration of private, commercial, and public properties.

1.1.2 *Regional Economic Development.*

When the economic activity lost in the flooded region can be transferred to another area or region in the national economy, these losses cannot be included in the NED account. However, the impacts on the employment, income, and output of the regional economy are considered part of the Regional Economic Development (RED) account. The input-output macroeconomic model RECONS was used to address the impacts of the construction spending only associated with the Recommended Plan, since only this alternative provides detailed cost information necessary to prepare a complete and accurate analysis. The RED account is addressed in Section 5.

1.2 Study Area Description

1.2.1 *Geographic Location*

The County is located in the South Miami-Dade watershed approximately 230 miles southeast of Orlando, FL and approximately 120 miles east of Naples, FL. The County is bordered mostly by water with the Biscayne Bay in the center and the Atlantic Ocean to the east. The most populous county in Florida, Miami-Dade County is home to 34 incorporated municipalities, cities, towns and villages, as well as to unincorporated communities and neighborhoods. Additional major water bodies that traverse the County include Miami River, Little River, and a large number of various canals and waterways.

1.2.2 *Land Use*

The U.S. Census totals the number of developed and undeveloped land within Miami-Dade County as 1,899 square miles, with one third of this land area located in Everglades National Park. Miami-Dade County was established in 1836 and has since grown from an original population of 1,000 residents to over 2.7 million today. The County is split up into 34 different municipalities, with the City of Miami being the largest.

The County has established an Urban Development Boundary (UDB) that discourages development outside its bounds. Due to the density of the structures in Miami-Dade County and the very limited vacant land, a future development structure inventory was not included in the damage calculations. In 2008, the UDB contained 269,000 acres (420 square miles), of which approximately six percent was undeveloped. Very little land has been added to the UDB in the last 20 years. It is anticipated that the majority of future development will be the infill of structures on the limited vacant land, or redevelopment.

1.3 Socioeconomic Setting

The impacts of flooding affect local industries, including tourism, commercial shipping/logistics, technology, and education, as well as residents of the peninsula. Business operations are reduced when anticipating a coastal storm, especially if evacuation orders are issued, but if the storm significantly damage property and infrastructure, operations would be impacted for a longer duration of time. Residents may have flood insurance to cover some damage, but they are still financially impacted by storm events.

1.3.1 *Population and Number of Households*

Table 1 displays the population for the County for the years 1980, 1990, 2000, and 2010, as well as projections for the years 2020 and 2040. As shown in Table 1, the County experienced relatively constant population growth between the years 1980 and 2010, and is expected to maintain this growth rate in the next 20 years.

Table 1. Historical and Projected Miami-Dade Population (1,000s)

County	1980	1990	2000	2010	2020	2040
Miami-Dade	1,625	1,937	2,259	2,507	2,861	3,367

Source: U.S. Census Bureau

Table 2 shows the total number of households in the County for the years 1990, 2000, and 2010, and projections for years 2020 and 2040. The projected number of households was based on U.S. Census Bureau data and extended from the year 2030 to the year 2040 based on the compound annual growth rate population growth rate forecasted by U.S Census Bureau.

Table 2. Number of Households in Miami-Dade County

County	1990	2000	2010	2020	2040
Miami-Dade	692,355	776,906	867,352	983,271	1,156,255

Source: U.S. Census Bureau

The County experienced a decline in the rate of increasing total number of households between 1990 through 2010, followed by an increasing growth rate starting in year 2010. From year 2010 to 2040, the total number of households is expected to increase by approximately 33%, with Northern Miami and the Miami Beach area expected to experience the most household growth at a 54% increase and 45% increase respectively. The West Miami area is expected to see the least household growth at a 3% increase. In the year 2010, 58% of households were single-family, 41% were multi-family, and 2% were mobile homes; by 2040 it is projected that only 48% of households will be single-family and only 1% mobile homes, with the largest household category becoming multi-family at 51% (2040 Miami-Dade Transportation Plan)

1.3.2 *Income*

Table 3 shows the median household income levels for Miami-Dade County for the years 1990, 2000, 2005, 2010, 2014, and 2018, the year with the latest available data. As shown in the table and based on Bureau of Economic Analysis data, Miami-Dade County experienced a steady increase in household income between 2000 and 2018. In 2010, 29% of households earned less than $25,000 annually, and 26% earned between $25,000 - $50,000. It is expected in the year 2040 for the annual household income of these two categories to be 31% and 26% respectively. (2040 Miami Transportation Plan)

Table 3. Median Household Income ($)

County	2000	2005	2010	2014	2018
Miami-Dade	33,228	37,142	40,145	42,754	52,043

Source: U.S. Bureau of Economic Analysis

1.3.3 *Employment*

Table 4 shows the total number of employed civilians by industry in Miami-Dade County age 16 and up based on 2018 U.S. Census data. According to this data, approximately 58% of employed civilians in Miami-Dade are white collar workers, while 20% is considered blue collar and 22% is considered service and farm. The unemployment rate of Miami-Dade County in 2018 was 6.33%.

Table 4. 2018 Employed Civilians 16+ by Industry of Miami-Dade County

Category	Total Persons	Percentage of Total
Accommodation/Food Services	124,185	9.41%
Admin/Support/Waste Management	76,308	5.78%
Agriculture/Fishing/Hunting	9,888	0.75%
Entertainment/Recreation Services	28,568	2.16%
Construction	104,232	7.89%
Education Services	94,586	7.16%
Insurance/Real estate/Rent/Lease	98,501	7.46%
Health Care/Social Asst.	165,228	12.51%
Information	25,834	1.96%
Management of Companies	845	0.06%
Total Manufacturing	59,164	4.48%
Other Services	82,481	6.25%
Prof/Sci/Tech/Admin	89,784	6.80%
Public Administration	45,279	3.43%
Retail Trade	162,298	12.29%
Transport/Warehouse/Utils	104,523	7.92%
Wholesale Trade	48,629	3.68%
Total	**1,320,693**	**100.00%**

Source: Bureau of Labor and Statistics

The County's economy is diverse and includes Federal government, higher education, manufacturing, port activity, residential construction, downtown business and residential development, and the medical and health professions. Economic growth within the county is

expected to continue due to proximity to major transportation routes such as Interstate 95, the Port of Miami, Miami International Terminal, and Miami International Airport.

In all portions of the study area, growth is highly dependent upon the major employment sectors. A steady pace in employment in Miami-Dade County is likely the result of the influx of population and businesses that support the Port of Miami and Miami International Airport. From the years 2010 to 2040, growth is expected in all employment industries excluding Agriculture, with the most growth of 68% expected in the health care and restaurant industries and the least growth in the utilities industry at 28%. Due to limited development outside the UDB, the agriculture industry is expected to decline approximately 33% between 2010 and 2040. Miami-Dade County has a gross domestic product (GDP) of approximately $111 billion, with the largest contributing sector being Finance, Insurance and Real Estate at 26%, followed by Wholesale and Retail Trade at 16%.

1.3.4 *Compliance*

Given continued growth in population and employment, it is expected that development or, most likely, redevelopment will continue to occur in the study area with or without a coastal storm risk management system. In general, this will not conflict with PGL 25 and Executive Order 11988, which states that the primary objective of a flood risk reduction project is to protect existing development, rather than to make undeveloped land available for more valuable uses. The overall growth rate is anticipated to be the same with or without the project in place as no new lands will be created but rather measures will reduce the risk of population being displaced. However, it is possible that the construction of structural measures could reduce the perceived necessity for higher flood risk management standards and therefore, redevelopment behind structural measures could occur at lower standards than if the structural measures were never constructed. It is, therefore, recommended that structures with lowest adjacent grades at or below the effective FEMA Base Flood Elevation (BFE) be treated as if it remains within a regulatory floodplain and be subject to the existing floodplain ordinance.

1.4 Scope of Study

The study investigated structural and nonstructural measures that comprise alternative plans. Project alternatives, including the Tentatively Selected Plan, are described in the main report in Chapter 6 and 7.

1.4.1 Structural Measures

Structural measures were screened based on engineering concerns and via non-Federal sponsor (NFS) and agency input at workshops and charrettes. Details on the screening process are described in Chapter 6 of the main report. After thorough screening, the following types of structural measures were considered for this study area:

- Surge barriers (tide gates, miter gates, etc.) at major canals
- Floodwalls

1.4.2 Nonstructural Measures

The areas considered for nonstructural measures were narrowed down to the seven refined focus areas identified through the Hazus and social vulnerability index analysis. It was determined that there are seven socially vulnerable economic damage centers within the study area: Miami River, Little River, and Arch Creek. Aventura, North Beach, South Beach, and Cutler Bay. After thorough screening, the following nonstructural measures are being considered within these areas.

- Elevation of structures
- Acquisition and demolition of structures
- Wet floodproofing
- Dry floodproofing

1.4.3 Natural and Nature-based Measures

Natural and nature-based (NNBF) coastal storm risk management measures work with or restore natural processes with the aim of wave attenuation and storm surge reduction. NNBF measures are designed to work in conjunction with non-structural and structural measures. For this study, mangrove restoration is being considered in the Cutler Bay area. This benefit reduction methodology will be coordinated with the Economics Planning Center of Expertise (ECO-PCX).

1.4.4 Critical Infrastructure

Asset categories were determined through scoping meetings and in-line with Miami-Dade County's Rapid Action Plan, which consists of vulnerable critical infrastructure.

1.5 Study Methodology

In order to develop plans to address water resource problems within a study area, three conditions must be fully analyzed: the "existing" condition, the "future without project" condition, and the "future with project" condition.

In this analysis, the existing condition represents current conditions that is without sea level change. The future without project condition is the condition that would likely exist in the future without the implementation of a Federal project and incorporates sea level change. This condition is evaluated for a 50 year period for coastal storm management projects, and the results are expressed in terms of average annual damage. For this study, the future without project condition is for the years 2030-2079. The future with project condition is the condition that would likely exist in the future with the implementation of a Federal project, using the same 50 year period as in the future without project condition.

The difference in expected annual flood damage to the Miami-Dade County study area assets between the future without and with project conditions represents the flood risk management benefits to the project. Economic and other significant outputs may accrue to the project as well, including recreation benefits, ecosystem restoration benefits, regional economic benefits, and other social effects. Other social effects, which often defy quantification in monetary terms, range from improvement in the quality of life within the study area to community impacts. This analysis attempts to recognize and, where possible, quantify the reduction of damage from coastal storm surge inundation due to the Federal project in the study area (i.e. NED benefits).

1.6 Assumptions Used in Computing Damage

This section of the analysis presents the assumptions used in computing average annual equivalent flood damage for the study area:

- Floodplain residents will react to a floodplain management plan in a rational manner.
- Real property will continue to be repaired to pre-flood conditions subsequent to each flood event given a rebuilding period with a maximum rebuild of 5 times, and not removed from the asset inventory (i.e. cumulative damage threshold not used).
- Residential structures are raised after receiving substantial damage within the period of analysis. This is defined by FEMA as total cost of repairs is 50 percent or more of the structure's market value before the disaster occurred. Once that level is reached, the structure would be raised to the effective FEMA BFE plus one additional foot to account for freeboard.
- Non-residential depth-percent damage relationships for structure and content are from expert elicitation found in the revised 2013 draft report completed by the USACE Institute of Water Resources. Non-residential flood depth-damage functions derived from expert elicitation are assumed to be representative of non-residential structures in the floodplain.
- The present valued damage, first costs, and benefits will be annualized using the FY 2020 Federal discount rate of 2.75% assuming a period of analysis of 50 years.
- All values are equivalent to 2019 dollars.
- All project alternatives are evaluated for a 50 year period of analysis.
- The project construction is scheduled to begin in 2026.
- The project base year, the year in which benefits begin to accrue, is assumed to be 2030.

- The final year of the 50-year period of analysis ends December 31, 2079.
- Unless otherwise stated, elevations are in feet (ft.) North American Vertical Datum of 1988 (NAVD88).
- Sea level change follows the USACE high curve and used a sea level change rate of 0.0126 feet per year.
- Depreciation is calculated for structures during the life cycle analysis by determining the depreciated replacement value.

1.7 Risk and Uncertainty

Risk and uncertainty are inherent in water resources planning and design. These factors arise due to errors in measurement and from the innate variability of complex physical, social, and economic situations. The measured or estimated values of key planning and design variables are rarely known with certainty and can take on a range of possible values. Risk analysis in flood risk management projects is a technical task of balancing risk of design exceedance with reducing the risk from flooding; trading off uncertainty of flood levels with design accommodations; and providing for reasonably predictable project performance. Risk-based analysis is therefore a methodology that enables issues of risk and uncertainty to be included in project formulation.

The U.S. Army Corps of Engineers (USACE or Corps) has a mission to manage flood risks:

"The USACE Flood Risk Management Program (FRMP) works across the agency to focus the policies, programs and expertise of USACE toward reducing overall flood risk. This includes the appropriate use and resiliency of structures such as levees and floodwalls, as well as promoting alternatives when other approaches (e.g., land acquisition, flood proofing, etc.) reduce the risk of loss of life, reduce long-term economic damage to the public and private sector, and improve the natural environment."

As a part of that mission, the Institute for Water Resources (IWR) in cooperation with other Corps groups has developed the Generation II Coastal Risk Model (G2CRM) to support planning-level studies of hurricane protection systems (HPS).

1.8 Model Overview

G2CRM is distinguished from other models currently used for that purpose by virtue of its focus on probabilistic life cycle approaches. This allows for examination of important long-term issues including the impact of climate change and avoidance of repetitive damage. G2CRM is a desktop computer model that implements an object-oriented probabilistic life cycle analysis (PLCA) model using event-driven Monte Carlo simulation (MCS). This allows for incorporation of time-dependent and stochastic event-dependent behaviors such as sea level change, tide, and structure raising and removal. The model is based upon driving forces (storms) that affect a coastal region (study area). The study area is comprised of individual sub-areas (model areas) of different types that interact hydraulically and may be

defended by coastal defense elements that serve to shield the areas and the assets they contain from storm surge flooding. Within the specific terminology of G2CRM, the important modeled components are:

- **Driving forces** - storm hydrographs (surge and waves) at locations, as generated externally from high fidelity storm surge and nearshore wave models such as ADCIRC and STWAVE;
- **Modeled areas** (MAs) - areas of various types (coastal upland, unprotected area) that comprise the overall study area. The water level in the modeled area is used to determine consequences to the assets contained within the area.
- **Protective system elements** (PSEs) - the infrastructure that defines the coastal boundary be it a coastal defense system that protects the modeled areas from flooding (levees, pumps, closure structures, etc.), or a locally developed coastal boundary comprised of bulkheads and/or hardened shoreline.
- **Assets** – spatially located entities that can be affected by storms. Damage to structure and contents is determined using damage functions. For structures, population data at individual structures allows for characterization of loss of life for storm events.

The model deals with the engineering and economic interactions of these elements as storms occur during the life cycle, areas are inundated, protective systems fail, and assets are damaged and lives are lost. A simplified representation of hydraulics and water flow is used. Modeled areas currently include unprotected areas and coastal uplands defended by a seawall or bulkhead. Protective system elements are limited to bulkheads/seawalls.

1.8.1 Modeling Variables

According the USACE Engineering Regulation (ER) 1105-2-101, 7. Variables in Risk Assessment. (b.):

A variety of variables and their associated uncertainties may be incorporated into the risk assessment of a flood risk management study. For example, economic variables in an urban situation may include, but are not necessarily limited to depth-damage curves, structure values, content values, structure first-floor elevations, structure types, flood warning times, and flood evacuation effectiveness. Uncertainties in economic variables include building valuations, inexact knowledge of structure type or of actual contents, method of determining first-floor elevations, or timing of initiation of flood warnings. Other key variables and associated uncertainties include the hydrologic and hydraulic conditions of the system. Uncertainties related to changing climate should be addressed using the current USACE policy and technical guidance.

As previously stated, G2CRM is a desktop computer model that implements an object-oriented probabilistic life cycle analysis (PLCA) model using event-driven Monte Carlo simulation (MCS). Monte Carlo Simulation (MCS) is a method for representing uncertainty by making repeated runs (iterations) of a deterministic simulation, varying the values of the uncertain input variables

according to probability distributions. A triangular distribution is a three-parameter statistical distribution (minimum value, most likely value, maximum value) used throughout G2CRM to characterize uncertainty for inputs in the model. The following sections attempt to characterize the uncertainties for both the economic and engineering inputs that went into the G2CRM for the study area.

1.8.2 Economic Inputs

Uncertainty was quantified for errors in the underlying components of structure values for residential and nonresidential structures, content to structure value ratios for residential and nonresidential structures, depth-percent damage relationship for both residential and nonresidential structures, and first floor elevations for all structures. G2CRM used the uncertainty surrounding these variables to estimate the uncertainty surrounding the storm-damage relationships developed for each in the study area.

The uncertainty surrounding each of the economic and engineering variables is also considered in the model. Either a normal probability distribution, with a mean value and a standard deviation, or a triangular probability distribution, with a most likely, maximum and minimum value, was entered into the models to quantify the uncertainty associated with the key economic variables. A normal probability distribution was entered into the model to quantify the uncertainty surrounding the ground elevations. The number of years that stages were recorded at a given gage was entered for each study area reach to quantify the hydrologic uncertainty or error surrounding the stage-probability relationships.

1.8.2.1 Structure Inventory

Parcel and building boundaries were downloaded from Miami-Dade County's GIS portal site to assist with characterizing residential and nonresidential structures for the economic analysis. Data included addresses, property class description, occupancy type, total value, property use, dwelling year built, number of units, etc. National Structure Inventory 2.0 (NSI2) data was supplemented where information in the data set was missing or lacking and used to determine foundation type. First floor elevations (FFE) were calculated based on the following:

1. An assumed foundation height per foundation type based off of discussions with Miami-Dade County's Floodplain Supervisor as well as a senior building code official which was then added to the building's lowest adjacent grade (LAG) using LiDAR data.

2. Google Earth/Maps were also used to determine the FFE based on counting steps leading up to the FFE (usually one step equals 6 inches). This was also used to verify some of the calculated FFEs.

3. The calculated FFEs were verified against elevation certificates (EC) when available to determine any adjustments that should be made due to any errors.

Table 5 shows the number of elevation certificates that were available and used for comparison.

Table 5. Elevation Certificate Comparison

Refined Focus Area	Number of ECs	% of Structures in Refined Focus Area	Average Difference Between Calculated FFE and EC FFE	Average Difference Between Calculated LAG and EC LAG
Cutler Bay	110	2%	-0.16 feet	-0.016 feet
South Beach	222	11%	-1.06 feet	-0.03 feet
North Beach	33	1%	-0.17 feet	N/A

The difference between the calculated FFE and the FFE from the elevation certificate was only 0.16 and 0.17 feet for the Cutler Bay and North Beach areas respectively. It was off by 1.06 feet for South Beach due to the typical foundation type in this refined focus area being different from the rest of the study area. Modifications to foundation heights were made to this area to address the difference.

G2CRM also uses a minimum, most likely, and maximum FFE for triangulation. The calculated FFE was used for the most likely and a 0.5' was subtracted and added to the calculated FFE for the minimum and maximum respectively to account for error adjustments.

Table 6 shows the occupancy types used in this study and their descriptions.

Table 6. Occupancy Types and Descriptions

Occupancy Type	Occupancy Type Description
COM1	Average Retail
COM2	Average wholesale
COM3	Average Personal & Repair Services
COM4	Average Prof/Tech Services
COM5	Bank
COM6	Hospital
COM7	Average Medical Office
COM8	Average Entertainment/Recreation
COM9	Average Theatre
COM10	Garage
EDU1	Average school
EDU2	Average college/university

Occupancy Type	Occupancy Type Description
GOV1	Average government services
GOV2	Average emergency response
IND1	Average heave industrial
IND2	Average light industrial
IND3	Average Food/Drug/Chem
IND4	Average Metals/Minerals processing
IND5	Average High Technology
IND6	Average Construction
REL1	Church
RES1-1SNB	Res 1, 1 Story no Basement
RES1-2SNB	Res 1, 2 Story no Basement
RES1-3SNB	Res 1, 3 Story no Basement
RES2	Mobile home
RES3A	Condominium, 1 Story
RES3B	Condominium, 2-3 Stories
RES4	Average Hotel, & Motel
RES5	Nursing Home
RES6	Nursing Home
HRISE	High-rise structure, 4 stories and above, commercial and residential

1.8.2.2 Structure Values

Depreciated replacement value per square foot was calculated for residential and non-residential structures using values from Gordian's 40th edition of "Square Foot Costs with RSMeans Data." RSMeans assumed an average age of construction materials and average effective age of 30 years.

Since square footage was not available for all structures, to determine a square footage per building, the following methodology was used. The polygon area of the building footprint was calculated in ArcGIS and multiplied by 0.9 to allow for unusable space such as doors, walls, etc. This area was multiplied by the number of floors, not to exceed the number of floors within the depth-damage function for the occupancy type of the structure. An average square footage was calculated for three construction classes (economy, average, and luxury) within each residential occupancy category reflecting the quality of the materials used in the construction of the buildings. An average replacement cost per square foot was calculated for four exterior walls types (wood frame, brick veneer, stucco, or masonry) within each construction class.

According to the RSMeans depreciation schedule, structures were depreciated based on the effective age, and then, depreciated an additional percentage to equal a regional adjustment of 80 percent for residential, as determined by RSMeans for the Miami-Dade County area. This

process was used to calculate a most-likely cost per square foot for each construction class within each residential occupancy category. The most-likely depreciated cost per square foot was then multiplied by the square footage calculated for individual structures in each occupancy to obtain a total depreciated cost or value for each structure in an occupancy. Finally, the Marshall and Swift Valuation Service was used to calculate a depreciated replacement cost per square foot for the manufactured or mobile homes.

An average square footage was calculated for each non-residential category or occupancy, and an average replacement cost per square foot was calculated for six exterior wall types (decorative concrete with steel frame and bearing walls frame, face brick with concrete block back-up with steel frame and bearing walls frame, metal sandwich panel with steel frame, an precast concrete panel with bearing walls frame) within each occupancy. Based on Miami-Dade County Assessor's data, it was determined that the average non-residential structure in the study area was approximately 30 years old. The RSMeans depreciation schedule for non-residential structures provides three depreciation percentages for structures based on their exterior wall type: wood frame exterior walls; masonry on wood frame; and masonry on steel frame. The masonry on wood exterior wall depreciation percentage was used as the most-likely value and applied to all of the non-residential structures in the structure inventory. An additional regional adjustment of 84 percent, or a 6% decrease in value, for the Miami-Dade area was applied to the depreciated cost per square foot. This process was used to calculate a most-likely cost per square foot for each structure within a non-residential category or occupancy. The most-likely depreciated cost per square foot was then multiplied by the actual square footage of the individual structures in each occupancy to obtain a total depreciated cost.

The residential and non-residential structures included in the economic analysis were classified into distinct damage categories (residential, apartment, commercial, industrial, and public) and structure occupancies.

1.8.2.3 Structure Value Uncertainty

A triangular probability distribution based on the depreciated replacement costs derived for the three construction classes (economy, average, and luxury) was used to represent the uncertainty surrounding the residential structure values in each occupancy category for the back-bay structures. The most-likely depreciated value was based on the average construction class, the minimum value was based on the economy construction class, and the maximum value was based on the luxury construction class. These values were then converted to a percentage of the most-likely value with the most-likely value equal to 100 percent of the average value for each occupancy category and the economy and luxury class values equal to a percentage of these values. The triangular probability distributions were entered into the G2CRM model to represent the uncertainty surrounding the structure values in each residential occupancy category in the back-bay.

A triangular probability distribution based on the depreciation percentage associated with the three exterior wall types (wood frame, masonry on wood frame, and masonry on masonry or steel) was used to represent the uncertainty surrounding the non-residential structure values in

each occupancy category. The most-likely depreciated value was based on the depreciation percentage assigned to a masonry exterior wall construction, the minimum value was based on the depreciation percentage assigned to a wood frame exterior wall construction, and the maximum value was based on the on the depreciation percentage assigned to a masonry on masonry/steel exterior wall construction. These values were then converted to a percentage of the most-likely value with the most-likely value being equal to 100 percent and the minimum and maximum values equal to percentages of the most-likely value. The triangular probability distributions were entered into the economic models to represent the uncertainty surrounding the structure values for each non-residential occupancy category.

1.8.2.4 Future Development Inventory

Due to the density of structures in the County and limited vacant land, a future development structure inventory was not included in the damage calculations. It is anticipated that the majority of future development will be the infill of structures on the limited vacant land, or, most likely, redevelopment. Moreover, existing floodplain ordinance requires new or substantially improved structures in FEMA's Special Flood Hazard Area, or the 1% annual chance floodplain, to be constructed at BFE plus three feet of additional elevation. In addition, structures within FEMA's Zone X, or the 0.2% annual chance floodplain to be elevated 18 inches above the highest adjacent grade. Therefore, the percentage of infill or new development is anticipated to have a negligible impact on the growth of the structure inventory and future damages.

1.8.2.5 Content-to-Structure Value Ratios

Site-specific Content-to-Structure Value Ratios (CSVR) information was not available for the study area. Residential and non-residential CSVRs used in this feasibility study were obtained from North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk, Physical Depth Damage Function Summary Report and the Non-residential Flood Depth-Damage Functions Derived from Expert Elicitation Draft Report, revised 2013. As shown in Table 7. Content-to-Structure Value Ratios (CSVRs) and Triangular Distribution, a CSVR was computed for each residential and non-residential structure in the study as a percentage of the total depreciated replacement value. A triangular distribution was used to estimate the error.

Table 7. Content-to-Structure Value Ratios (CSVRs) and Triangular Distribution

Structure Category		CSVR Percent Min	Most Likely	Max	Source
Residential	1 Story no Basement	25	50	75	NACCS, Prototype 5A
	2 or 3 Story no Basement	25	50	75	NACCS, Prototype 5B
	Mobile home	68	142	209	Marshall & Swift Residential Valuation Service
	Apartment				
	Condominium, 1, 2, or 3 stories	8	10	14	NACCS, Prototype 1A-1, 1A-3
Non-residential	**Commercial**				
	Average Retail	37	45	53	2013 Prototype 12
	Garage	31	37	44	NACCS, Prototype 3
	Average wholesale	31	37	43	NACCS, Prototype 2
	Average Personal & Repair Services	56	66	74	2013 Prototype 13
	Average Prof/Tech Services	14	18	24	NACCS, Prototype 2
	Bank	14	18	24	2013 Prototype 7
	Hospital	35	44	50	2013 Prototype 6
	Average Medical Office	53	60	66	2013 Prototype 5
	Average Hotel, & Motel	20	26	33	2013 Prototype 4
	Nursing Home	14	18	24	NACCS, Prototype 2
	High-rise structure, 4 stories and above, commercial and residential	14	18	24	NACCS, Prototype 4A
	Average government services	14	18	24	NACCS, Prototype 2
	Industrial				
	Average heavy / light industrial	32	38	44	2013 Prototype 14
	Average Food/Drug/Chem	14	18	24	NACCS, Prototype 2
	Average Metals/Minerals processing	14	18	24	NACCS, Prototype 2
	Average High Technology / Theater	14	18	24	NACCS, Prototype 2
	Average Construction	32	38	44	2013 Prototype 14
	Public				
	Average school / university	5	7	9	2013 Prototype 21
	Church	5	7	11	2013 Prototype 20
	Average emergency response	60	70	75	2013 Prototype 18
	Average Entertainment / Recreation	20	25	31	2013 Prototype 19

2013 = Nonresidential Flood Depth-Damage Functions Derived from Expert Elicitation, Revised 2013
NACCS = NACCS Physical Depth Damage Function Summary Report

1.8.2.6 Content to Structure Value Uncertainty

A triangular probability distribution was used to represent the uncertainty surrounding the contents-to-structure value ratios (CSVRs) for residential structures. The minimum CSVR value, 25 percent, was obtained from the Willoughby GRR, an evaluation completed in Norfolk, Virginia, while the maximum CSVR value, 70 percent, was based on a survey of homes in coastal Louisiana. This survey was produced for the USACE New Orleans District and is the product of a very thorough and extremely detailed expert panel elicitation. A triangular probability distribution was also used to represent the uncertainty surrounding the CSVRs for the non-residential occupancies. The minimum, maximum and most-likely values were based on data obtained from either the Physical Depth Damage Function Summary Report published as a part of NACCS study or the 2013 Draft Non-residential Flood Depth-Damage Functions Derived from Expert Elicitation, depending on the type of non-residential occupancy.

1.8.2.7 Debris Removal

In addition to structural damage, a flooded community typically incurs a variety of other flood related costs including debris removal. The cost of the debris removal can vary according to the residential or nonresidential occupancy type of the structure. The content-related debris includes white goods (refrigerators, stoves, dishwashers, etc.), electronics, and hazardous waste (paints, oil, household chemicals, poisons, etc.).

Interviews were conducted with experts in the fields of debris collection, processing, and disposal following Hurricanes Katrina and Rita. The experts were asked to provide a minimum, most likely, and maximum estimate for the cleanup costs associated with the 2 feet, 5 feet, and 12 feet depths of flooding. A prototypical structure size in square feet was used for the residential occupancy categories and for the nonresidential occupancy categories. The experts were asked to estimate the percentage of the total cleanup caused by floodwater and to exclude any cleanup that was required by high winds.

In order to account for the cost/damage surrounding debris cleanup, values for debris removal would need to be incorporated into the structure inventory for each record according to its occupancy type. These values would then be assigned a corresponding depth-damage function with uncertainty in the economic models. For all structure occupancy types, an assumption would need to be made as to when 100% damage would be reached. All values and depth-damage functions would be selected according to the short-duration flooding data specified in a report titled “Development of Depth-Emergency Cost and Infrastructure Damage Relationships for Selected South Louisiana Parishes.” This analysis was not performed during the Tentatively Selected Plan selection, but the team may consider it prior to the Agency Decision Milestone if needed.

1.8.2.8 First Floor Elevations

Ground elevations were obtained from Light Detection and Ranging (LiDAR) digital elevation model (DEM), developed in support of new FEMA coastal Flood Insurance Rate Map update, using NAVD88. Parcel data from the 2019 real estate assessment tables provided by the County included type of foundation for some structures, but was supplemented with foundation type data from the National Structure Inventory 2.0 (NSI2). The team determined the average height above ground for each foundation type and validated with FEMA Elevation Certificates provided by the County. Google Street View was used to estimate foundation heights for structures that did not have data in the provided database. Steps were assumed to have a height of 6 inches. The foundation height (sum of the number of stairs) was added to the ground elevation to determine the first floor elevation of each structure in NAVD88.

1.8.2.8.1 First Floor Elevation Uncertainty

There are two sources of uncertainty surrounding the first floor elevations: the use of the 2015 Light Detection and Ranging (LIDAR) data to estimate the ground elevation, and the use of parcel data to determine the foundation heights above ground elevation. The error implicit in using LIDAR data is normally distributed with a mean of zero and a standard deviation of 0.377 feet. The error implicit in the use of parcel data is also normally distributed with a mean of zero and a standard deviation of 0.51 feet for residential structures and 0.31 feet for non-residential structures at the 95 percent level of confidence. There was less uncertainty surrounding the commercial structures relative to the residential structures because there was less variation in foundation types. The combination of the two uncertainties yielded a standard deviation of 0.63 for residential structures and 0.49 for non-residential structures.

1.8.2.9 Depth-Damage Relationships

Various depth damage functions (DDFs) were considered for use in the study. However, given that no geographically specific curves were available for the Florida coastal region, a broader geographic collection of curves was considered. Given the high amount of multi-family and high rise condominiums in the study area, combined with the salt-water environment associated with the location, the DDFs established within the NACCS Physical Depth Damage Function Summary Report were determined to be the most appropriate for use on the study. The NACCS curves were used to model damage for all residential structures and the majority of nonresidential structures, unless curves for more specific non-residential structure types were developed as part of the Nonresidential Flood Depth-Damage Functions Derived from Expert Elicitation Report in 2013 (2013). These curves were used in lieu of the NACCS curves for non-residential inundation to more closely match specific non-residential occupancy types within the structure inventory. Several examples of depth damage functions are shown in the figures below. NACCS was used for residential structures, while 2013 IWR Elicitation was used for non-residential structures.

1.8.2.9.1 Depth Damage Relationships Uncertainty

A triangular probability density function was used to determine the uncertainty surrounding the damage percentages associated with each depth of flooding for the various residential and non-residential occupancy categories. A minimum, maximum, and most-likely damage estimate for each depth of flooding was obtained from the Physical Depth Damage Function Summary Report published as a part of NACCS study and the 2013 Draft Nonresidential Flood Depth-Damage Functions Derived from Expert Elicitation. A national panel of building, construction, insurance, and restoration experts was used to develop the data contained in these reports. Moreover, both contained a normal distribution function with an associated standard deviation of damage to account for uncertainty surrounding the damage percentage associated with each depth of flooding. This distribution was then converted into a triangular distribution for input into the model.

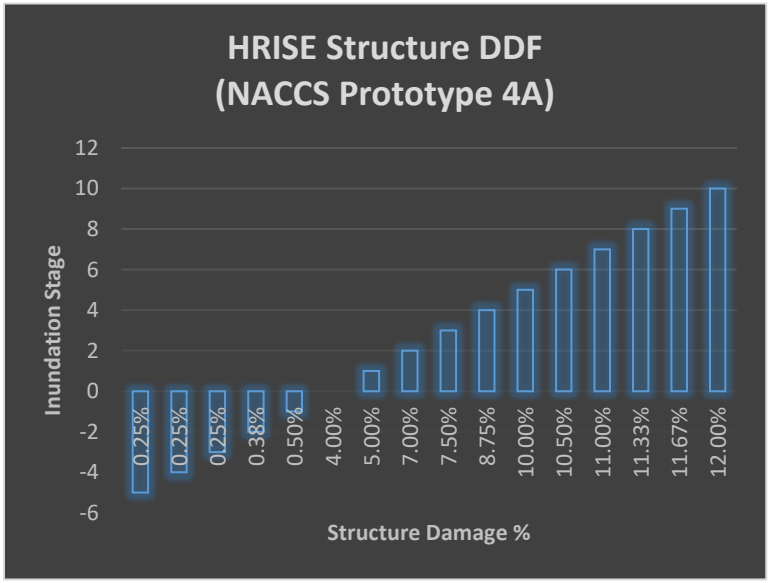

Figure 1. High Rise Structure DDF

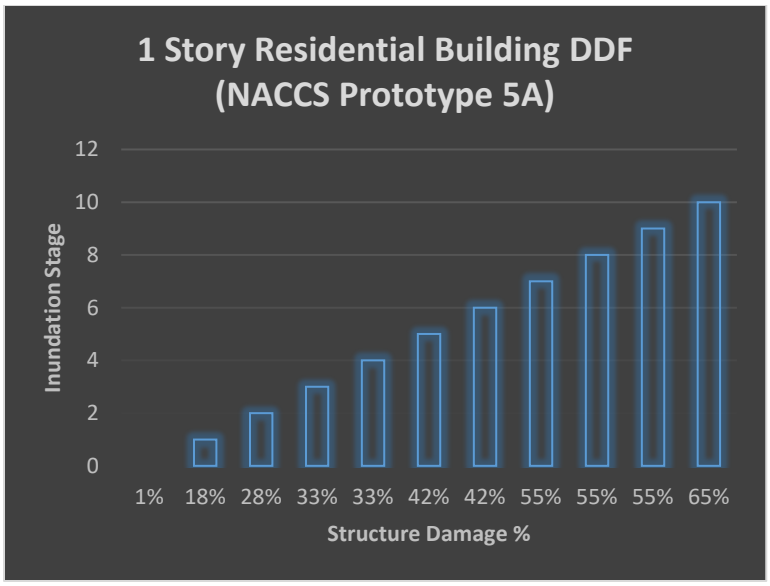

Figure 2. 1 Story Residential DDF

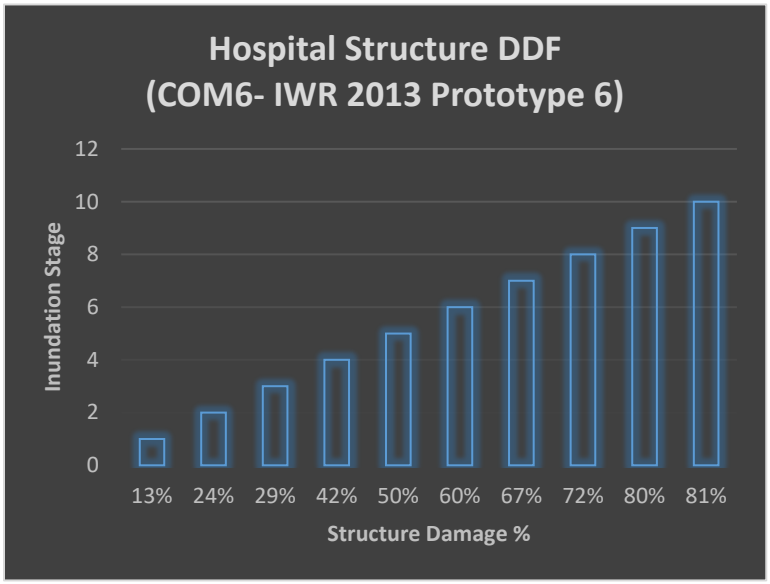

Figure 3. Hospital DDF

1.8.3 Engineering Inputs to the Model

1.8.3.1 Storms

For the study area, a reduced storm set was selected. The number of storm selected was driven by schedule and budget constraints, and by knowledge gathered from other previous and ongoing USACE feasibility studies about the minimum number of storms required to adequately capture the storm surge hazard. The goal of storm selection was to find the optimal combination of storms given a predetermined number of storms to be sampled, referred to as reduced storm

set. In the process of selecting the number for the study area, it was determined that a reduced storm set of this size adequately captured the storm surge hazard for the range of probabilities covered by the full storm set.

The storm selection process was performed using the design of experiments (DoE) .The DoE compares still water level, hazard curves derived from the reduced storm set to “benchmark” hazard curves corresponding to the full storm set at a given number of save points within the study area. The difference between the reduced storm set hazard curves and full storm set benchmark curves is minimized in an iterative process considering multiple subsets of cyclones. In summary, the general steps in this DoE approach for selecting a subset of storms are:

1. Identify a set of save points critical to a project or study area, where optimization will be performed.

2. Develop hazard curves for the full storm set.

3. Select number of storms to be sampled.

4. Develop hazard curves for the reduced storm set.

5. Choose the range of probabilities for which hazard curves will be compared. The reduced storm set versus full storm set differences can be computed along the entire hazard curve, or by prioritizing a specific segment of the curves, for example, 50 to 500 years.

6. Compute differences between reduced storm set and full storm set hazard curves.

7. An iterative sensitivity analysis is performed to determine the optimal combination of storms constituting the reduced storm set.

8. Once the optimal combination of storms is determined, an optional analysis can be performed to evaluate the benefits of increasing storm subset size; finalize storm selection.

1.8.3.2 Save Points

The numerical modeling aspect of the study area is to provide estimates of waves and water levels for existing condition, future without project condition, and future with project condition. A save point is a point of interest in the study area. From a dataset of over 1000 points, 12 save points were selected. These save points contained the water elevations and wave heights for each of the storms in the reduced storm set to be used in the model and eventually used to represent the final model areas. These water elevations will be applied to the model areas along with economic inputs to derive flood damage in the existing condition, future without project condition, and future with project condition for the Miami-Dade County Study Area.

1.8.3.3 Stage-Probability Relationships – H5 Files

Stage-probability relationships were provided for the existing (2030) without-project condition and future without (2079) project conditions. Water surface profiles were provided for 9 annual chance exceedance (ACE) events: 50% (2-year), 20% (5-year), 10% (10-year), 5% (20-year), 2% (50-year), 1% (100-year), 0.5% (200-year), 0.2% (500-year), and 0.1% (1000-year). The without-project water surface profiles were based on 12 Save Points

For each of these ACE events, the water surface profiles for the years 2030 and 2079 were calculated by adding relative sea level rise, as determined by the USACE Sea Level Rise Calculator using the USACE High Curve to the Save Point elevations. The mean sea level trend of 0.012 ft./yr. (Vaca Key, FL) was used as the sea level change rate. Additional information regarding water surface elevation calculations can be found in the Engineering Appendix.

1.8.3.3.1 Uncertainty Surrounding the Engineering Inputs

The uncertainty surrounding the key engineering parameters was quantified and entered into G2CRM. The model is based upon driving forces (i.e. storms) that affect a study area. The study area is comprised of individual sub-areas of different types, defined as model areas, which do interact hydraulically, and may be defended by coastal defense elements, such as protective system elements, that serve to shield the areas and the assets they contain from storm surge. The model used the uncertainty surrounding the storm information to account for uncertainty surrounding the elevation of the storm surges for the study area. The Engineering Appendix contains more information regarding G2CRM engineering inputs.

2 EXISTING CONDITION

There are thousands of structures in the FEMA 1% annual chance exceedance (ACE), or 100 year floodplain, in the Miami-Dade County Study Area. These property owners are technically required to purchase flood insurance, although flood insurance has eligibility requirements and numerous exclusions. The FEMA National Flood Insurance Program does not cover additional living expenses, such as temporary housing, while the building is being repaired or is unable to be occupied; loss of use or access to the insured property; financial losses caused by business interruption; property and belongings outside of an insured building, such as trees, plants, wells, septic systems, walks, decks, patios, fences, seawalls, hot tubs and swimming pools; most self-propelled vehicles, such as cars[1], including their parts; and personal property kept in basements. Federal flood insurance coverage is also capped at $250,000 per building and $100,000 for contents.

Parcel data from the 2019 real estate assessment tables provided by the County included type of foundation for some structures, but was supplemented with foundation type data from the

[1] The PDT has reserved the option to include vehicles as damageable inventory in optimization after TSP, but before ADM.

National Structure Inventory 2.0 (NSI2). The inventoried structures were categorized as residential or nonresidential which were further categorized into occupancy types (reference Structure Inventory section). Table 8 displays the count and the most likely depreciated replacement values (DRV - estimated replacement cost less depreciation) of the structures within the refined focus areas by the main occupancy types.

Table 8. Structure Inventory by Occupancy Types within Refined Focus Areas

Occupancy Type	Description	Count	Most Likely DRV of Structures
COM1	Average Retail	2,517	$2.12 Billion
COM10	Garage	123	$61 Million
COM2	Average Wholesale	3,642	$6.79 Billion
COM3	Average Personal & Repair Services	1,670	$614 Million
COM4	Average Professional / Tech Services	1,535	$1.09 Billion
COM5	Bank	145	$144 Million
COM6	Hospital	27	$164 Million
COM7	Average Medical Office	34	$48 Million
COM8	Average Entertainment / Recreation	988	$408 Million
COM9	Average Theatre	12	$25 Million
EDU1	Average School	415	$365 Million
EDU2	Average College / University	38	$20 Million
GOV1	Average Government Services	2,575	$1.83 Billion
GOV2	Average Emergency Response	702	$1.27 Billion
HRISE	High-rise Structure, 4 stories and above	2682	$44.69 Billion
IND1	Average Heavy Industrial	210	$670 Million
IND2	Average Light Industrial	358	$695 Million
IND3	Average Food / Drug / Chem	1,602	$3.49 Billion
IND4	Average Metals / Minerals processing	56	$32 Million
IND6	Average Construction	1,519	$325 Million
REL1	Church	1,043	$673 Million
RES1-1SNB	Res 1, 1 Story no Basement	123,092	$17.26 Billion
RES1-2SNB	Res 1, 2 Story no Basement	7,450	$2.40 Billion
RES1-3SNB	Res 1, 3 Story no Basement	1,555	$619 Million
RES2	Mobile Home	3,481	$139 Million
RES3A	Condominium, 1 Story	28,303	$8.03 Billion
RES3B	Condominium, 2-3 Stories	10,055	$8.47 Billion
RES4	Average Hotel, & Motel	397	$356 Million
RES5	Nursing Home	1	$2.6 Million
RES6	Nursing Home	216	$192 Million
Grand Total		**196,443**	**$103 Billion**

2.1 Modeled Areas

The term “modeled areas” describes various geographic units that may exist within the study area. Flood elevations are uniform within a modeled area (MA). A storm event is processed to determine the peak stage in each defined MA and it is this peak stage that is used to estimate consequences to assets within the MA. Therefore, MA boundaries tend to correspond to the drainage divides separating local-scale watersheds. The seven refined focus areas, Arch Creek, Aventura, Cutler Bay, Little River, Miami River, North Beach, and South Beach, were divided into 12 MAs. Figure 4 shows the refined focus areas, the associated save points used, and how they were split into further MAs when applicable.

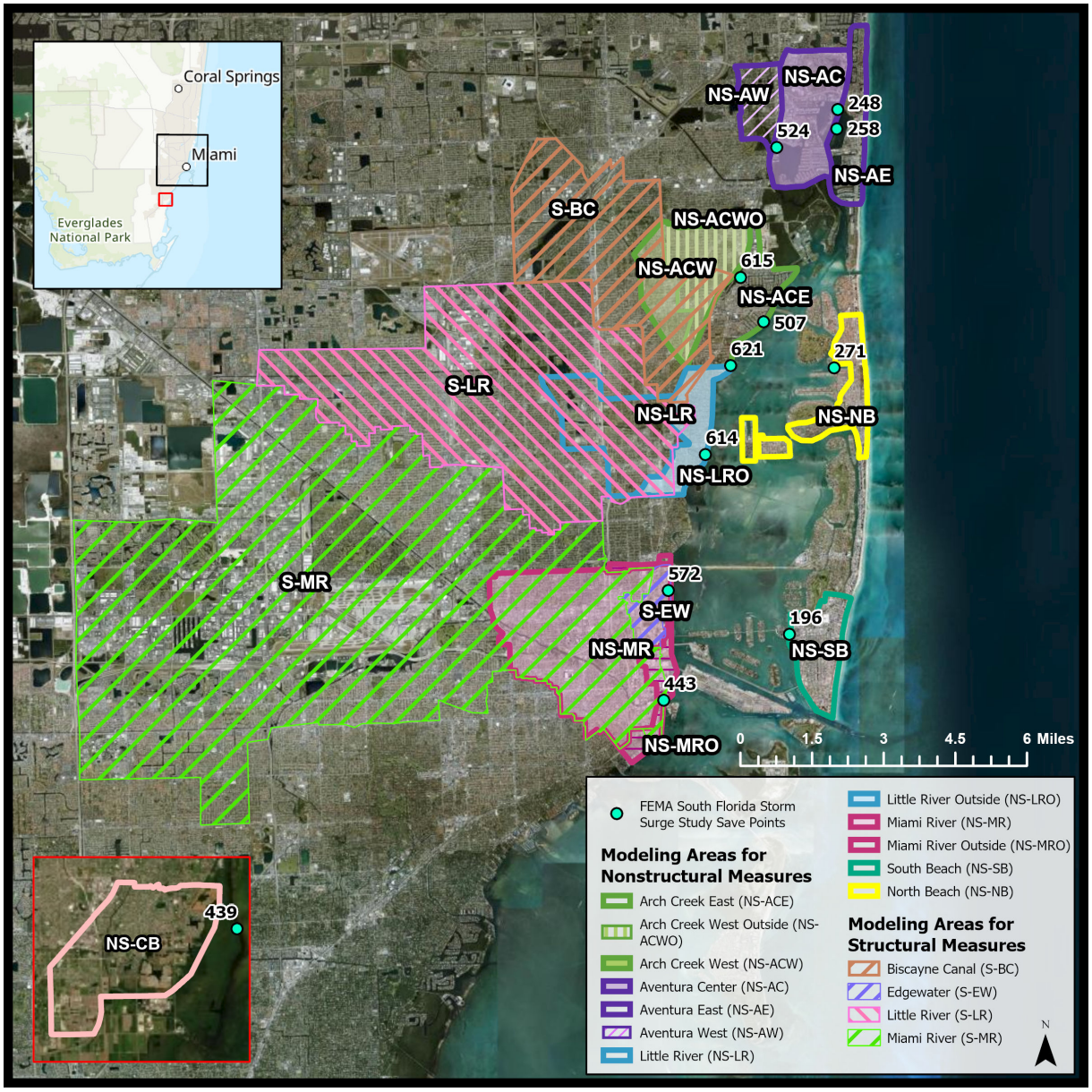

Figure 4. Modeled Areas with Save Points within Refined Focus Areas

Considerable professional judgment was used in defining MA boundaries including taking into account natural or built topological features such as high ground, ridges, highways, etc. Originally, the SWFWMD water basins were used as the initial MAs. The team then used HEC-RAS to perform analysis using the water levels from the save points to determine inundation areas. These inundation areas were based on the USACE derived 2079 1% annual exceedance probability stillwater level from the FEMA SFSSS which includes storm surge and USACE high curve sea level rise. This data was used to define the MAs for the refined focus areas where structural measures were recommended as shown in Figure 4.

The refined focus areas were used as the MAs where nonstructural measures were being recommended. Data from save points was used to identify changes in water levels and wave heights to determine where MAs could be broken down even further. The following describes how the MAs were broken down for these areas:

- The Aventura refined focus area was broken down into three MAs: Aventura West (NS-AW), Aventura Center (NS-AC), and Aventura East (NS-AE) as shown in Figure 4 via the purple outline. NS represents nonstructural.
- The Arch Creek refined focus area was broken down into Arch Creek West (NS-ACW) and Arch creek East (NS-ACE). Arch Creek West was also split into two categories: Arch Creek West Outside (NS-ACWO) and Arch Creek West (NS-ACW). NS-ACWO represents areas of Arch Creek West that are on the outside of any risk reduction from the Biscayne Canal storm surge barrier structural measures. The goal was to provide a complete coastal storm reduction of the refined focus areas as possible so nonstructural measures were always recommended on the outside (i.e.: bay side) of every structural measure when possible.
- Similar to Arch Creek, Little River Outside (NS-LRO) and Miami River Outside (NS_MRO) were on the outside of the Little River and Miami River storm surge barrier structural measures.
- MA's for Cutler Bay (NS-CB), North Beach (NS-NB) and South Beach (NS-NB) were the full extent of the refined focus area.
- Floodplains were then created using the water levels from the save point data for each of the nonstructural MAs where HEC-RAS inundation data was not available. The extents of the floodplain within each MA was then used to refine the MA even further.

Dividing the study area into MAs facilitates evaluation of flood damage by breaking the study area down into several areas having some common features, and analyzing them separately also speed up the economic modeling process. It is important to have the best representation of MAs as possible otherwise the model may falsely be producing damage at structures when the water would never reach the site.

2.1.1 Model Area Types

The study area is divided into 12 model areas as mentioned previously. Each MA has two types: Unprotected MA and Upland MA. An unprotected modeled area is a polygon boundary within

G2CRM that contains assets and derives associated stage from the total water level (i.e. storm surge plus wave contribution plus sea level change contribution plus tide contribution) calculated for a given storm, without any mediation by a protective system element (PSE). An upland modeled area is a polygon boundary within G2CRM that contains assets and derives associated stage from the total water level (i.e. storm surge plus wave contribution plus sea level change contribution plus tide contribution) calculated for a given storm, as mediated by a protective system element such as a bulkhead/seawall that must be overtopped before water appears on the modeled area. It can also have an associated volume-stage relationship to account for filling behind the bulkhead/seawall during the initial stages of overtopping.

Each of the 12 MAs were modeled as an Upland MA. Only the MAs with a structural measure require an Upland MA, but the team used Upland MA on the nonstructural side as well. This was done by adding a bulkhead with 0 elevation therefore it mimics an Unprotected MA. Therefore, having each MA be a component of an Upland MA in the existing and future without project condition was a modeling strategy utilized in order to model the future with project condition.

Each MA requires waterside ground elevation data to be put into the database. Typically, this is the ground elevation on the outside of the bulkhead/seawall. This data is used in calculating the depth limited wave height.

2.1.2 Protective System Elements

Flood hazard as manifested at the storm location is mediated by the associated bulkhead/seawall PSE. The PSE prevents transmission of the flood hazard into the MA until the flood hazard exceeds the top elevation of the bulkhead/seawall. The flood hazard is instantaneously transmitted into the MA unmediated by the bulkhead/seawall as soon as the flood hazard exceeds the bulkhead/seawall top elevation. Using a volume-stage relationship allows the model to gradually fill the MA whereas without one it fills it up instantaneously as soon as the bulkhead is overtopped.

PSEs are defined in G2CRM to capture the effect of built flood risk management (FRM) infrastructure (i.e. what in G2CRM is categorized as a bulkhead/seawall). Therefore, for both the existing and future without condition simulation, the top elevation is specified at the approximate existing ground elevation within the MA. In this way, the bulkhead/seawall does not influence the existing condition consequences of the flood hazard. For the future with project condition the bulkhead/seawall top-elevation is raised and its influence on consequences is captured.

2.1.3 Volume-Stage Functions

Volume-stage functions (alternatively called stage-volume functions) are associated with an upland MA. For the study area, the volume-stage functions were derived from the digital terrain model (the same used to determine ground elevation of structures) provided by Engineering and GIS sections and describe the relationship between the volume contained in the model area and the associated stage (water depths) for the each MA. Water level within the MA are computed by first estimating the volume of water passing over the PSE and then using the stage-volume

relationship to determine water level within the MA. Once the storage area in the MA is filled, the flood hazard is transmitted into the MA unmediated by the bulkhead/seawall.

2.2 Assets

Assets are spatially located entities that can be affected by storms. Typically, they start off as building polygons taken from structure inventory. Centroids, usually a point in the center of the building polygon, are created and used for input in G2CRM in the correct format required. For this analysis, assets were taken for all structures in Miami-Dade County and then eventually narrowed to cover the refined focus areas. Miami-Dade County is a highly urbanized, relatively flat community with a mean elevation of 5 feet NAVD88. The low elevations and tidal connections place a significant percentage of the county at risk of flooding from coastal storms. The number of structures will change depending on the design water elevation, which can vary throughout the study due to optimization of using sea level change rates. Table 9 shows the most likely depreciated replacement value for structures and contents for all the structures within the MAs. This includes all possible structures in the refined focus areas and not the Tentatively Selected Plan.

Table 9. Most Likely Structure and Content Values in Modeled Areas

Modeled Areas	Structures	Most Likely Structure Values	Most Likely Content Values
Arch Creek East	3,222	$2.25 Billion	$539 Million
Arch Creek West Outside	4,608	$1.38 Billion	$399 Million
Aventura Center	1,059	$5.97 Billion	$1.11 Billion
Aventura East	1,006	$3.14 Billion	$656 Million
Aventura West	1,746	$546 Million	$203 Million
Biscayne Canal	29,559	$9.03 Billion	$3.12 Billion
Cutler Bay	15,346	$4.49 Billion	$1.64 Billion
Edgewater	860	$1.95 Billion	$401 Million
Little River	57,348	$15.69 Billion	$5.20 Billion
Miami River	76,093	$49.14 Billion	$12.01 Billion
North Beach	3,388	$2.93 Billion	$625 Million
South Beach	2,208	$6.50 Billion	$1.15 Billion
Grand Total	**196,443**	**$103 Billion**	**$27.1 Billion**

2.3 Evacuation Planning Zones

According to the Fourth National Climate Assessment, communities in the Southeast are particularly vulnerable to flooding. Extreme weather and climate-related events can have lasting mental health consequences in affected communities, particularly if they result in degradation of livelihoods or community relocation. Populations including older adults, children, low-income communities, and some communities of color are often disproportionately affected by, and less

resilient to, the health impacts of climate change. Lessons from numerous coastal storm events have made it clear that even if the elderly, functionally impaired persons, and/or low income residents wish to evacuate from areas at risk from a pending coastal storm, they are unable to evacuate due to their physical or socioeconomic condition. Flooding in urban areas can cause serious health and safety problems for the affected population. The most obvious threat to health and safety is the danger of drowning in flood waters. Swiftly flowing waters can easily overcome even good swimmers. When people attempt to drive through flood waters, their vehicles can be swept away in as little as two feet of water.

An evacuation planning zone (EPZ) is a spatial area, defined by a polygon boundary that is used within loss of life calculations in G2CRM to determine the population remaining in structures during a storm (i.e. population that did not evacuate). Since the study area was divided into 12 MAs, the extent of each MA is the same as that of the EPZ. G2CRM then assigns each asset within that MA to the EPZ for potential life loss given a storm event. The remaining population is also needed as a percent minimum, most likely, and maximum.

The 2012 Statewide Regional Evacuation Study Program – Volume 1-11 Technical Data Report South Florida Region Appendix IIIB was used to fill in information needed in the EPZ. The EPZ requires data such as the evacuation rate per storm threat scenario as shown in Table 10.

Table 10. Evacuation Rate for Residents Living in Site-Built Homes in Miami-Dade County

Evacuation Rate (%)	Storm Threat Scenario				
Site-Built Homes	**Cat 1**	**Cat 2**	**Cat 3**	**Cat 4**	**Cat 5**
Cat 1 Surge Evacuation Zone	40	50	65	80	90
Cat 2 Surge Evacuation Zone	30	45	60	80	90
Cat 3 Surge Evacuation Zone	20	25	60	80	85
Cat 4 Surge Evacuation Zone	10	15	30	70	85
Cat 5 Surge Evacuation Zone	8	8	15	55	80
Inland of Surge Evacuation Zones	5	5	5	10	20

The MAs were overlaid on top of the Hurricane Evacuation Zones as shown in Figure 5. The appropriate remaining population data was filled in depending on where the MAs landed on the zones. Cat 5, 3, and 1 data from Table 10 was used to fill in the minimum, most likely, and maximum remaining population data respectively which is required for the EPZ. The percentages used in the EPZ file were subtracted from 100 since the EPZ requires the population estimate to be the population remaining instead of evacuating.

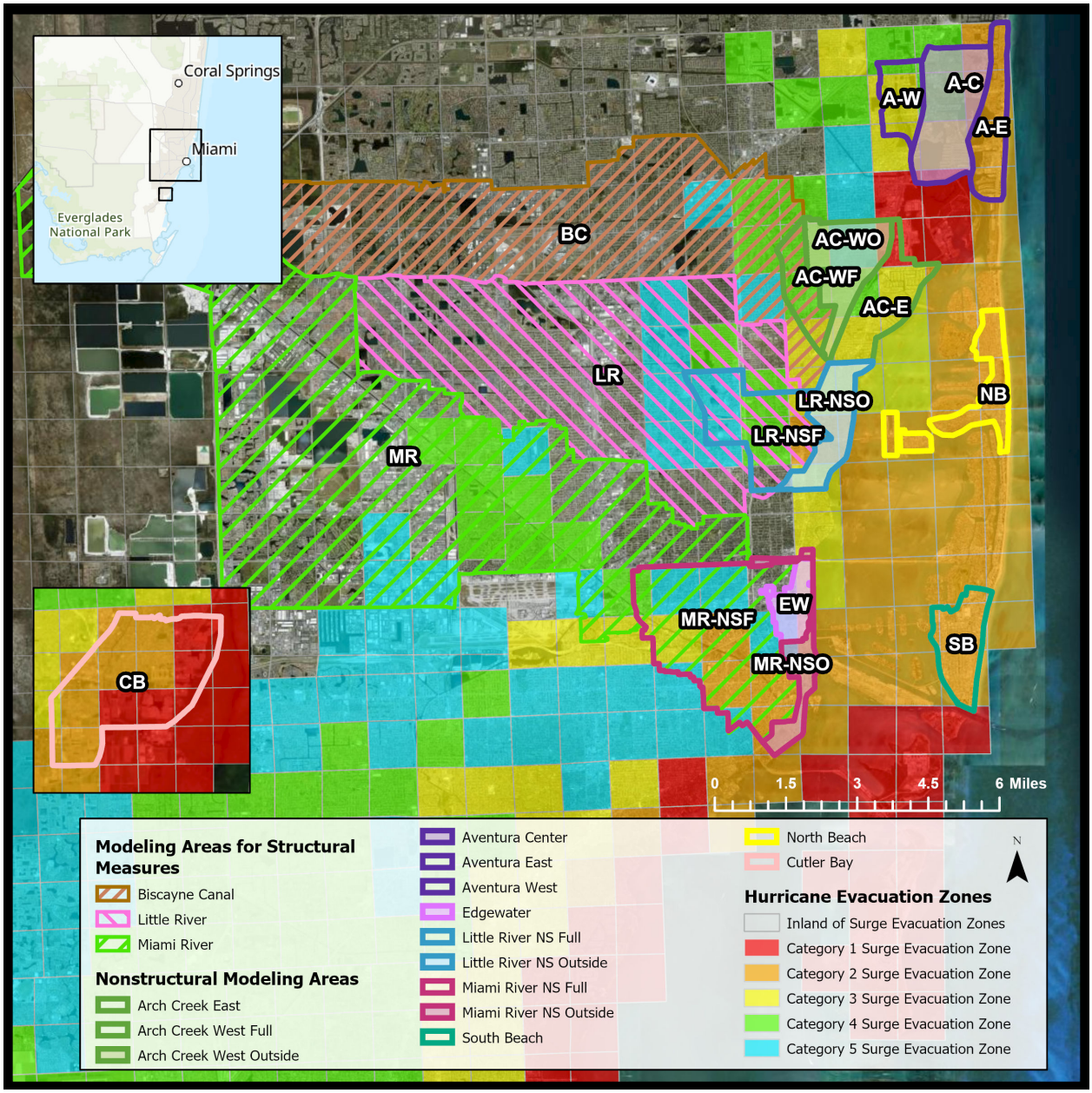

Figure 5. Modeled Areas over Hurricane Evacuation Zones

In G2CRM, life loss calculations are performed on a per-structure per-storm basis. The EPZ does not get activated unless 2 feet of storm surge is present in the storm. Loss of life calculations are separated out by certain parameters. G2CRM requires the asset file to have population separated into four columns: over 65 years of age during the day, over 65 years of age during the night, under 65 years of age during the day, and under 65 years during the night. Data from the US Census 2010 was taken to determine assumptions to fill in these columns such as average number of people per residential home and percent of population over and under 65. There are three possible lethality functions for structure residents: safe, compromised,

and chance. Safe has the lowest expected life loss although safe does not imply that there is no life loss. Chance would have the highest expected life loss.

3 FUTURE WITHOUT PROJECT CONDITION

3.1 Modeling Assumptions

The G2CRM model was utilized to evaluate flood damage using risk-based analysis. Damage was reported at the index location for each of the study areas for which a structure inventory had been conducted. The model also used the number of years that stages were recorded at a given gage to determine the hydrologic uncertainty surrounding the stage-probability relationships.

The possible occurrences of each variable were derived through the use of Monte Carlo simulation, which used randomly selected numbers to simulate the values of the selected variables from within the established ranges and distributions. For each variable, a sampling technique was used to select from within the range of possible values. With each sample, or iteration, a different value was selected. The number of iterations performed affects the simulation execution time and the quality and accuracy of the results. This process was conducted simultaneously for each economic and hydrologic variable. The resulting mean value and probability distributions formed a comprehensive picture of all possible outcomes. A mean and standard deviation was automatically calculated for the damage at each stage. Below are the run conditions used for each MA and description of the condition or further explanation of the run condition value:

Number of Iterations: **100**

Number of iterations that the simulation should perform. 100 iterations was selected for the analysis. More or less iterations may be needed depending on the standard deviation of the results.

Start Year: **2020**

The year that the simulation is to begin in. By starting in the year 2020, the structure inventory can evolve and any residential structures that are substantially damaged will have first floor elevations elevated to a target first elevation set in the model by the user. This is typically the FEMA BFE + 1 foot of freeboard described earlier in section 1.6.

Base Year: **2030**

The year that the simulation is to measure present value from. This assumes all construction is completed by the year 2030 and benefits start accruing.

Sea Level Change Basis Year: **1992**

This is the year of the stillwater levels in the save points.

Interest Rate: **0.0275**

The interest rate used to calculate the net present value factor for the simulation. 0.0275 is the latest interest rate for Fiscal Year 2020.

Sea Level Change Rate: **0.012 ft./yr.**

Sea level change rate in average feet per year over the time period start month/year to simulation end date. NOAA Vaca Key, Florida Bay, FL - Station ID: 8723970 was used as the tide gage of reference for this study. Further information discussing the reasoning is in Appendix B. Figure 6 shows the relative sea level trend for this tide gage which shows the trend at 3.85 millimeters per year based on monthly mean sea level data from 1971 to 2019. 3.85 millimeters per year is equivalent to 0.012 feet per year.

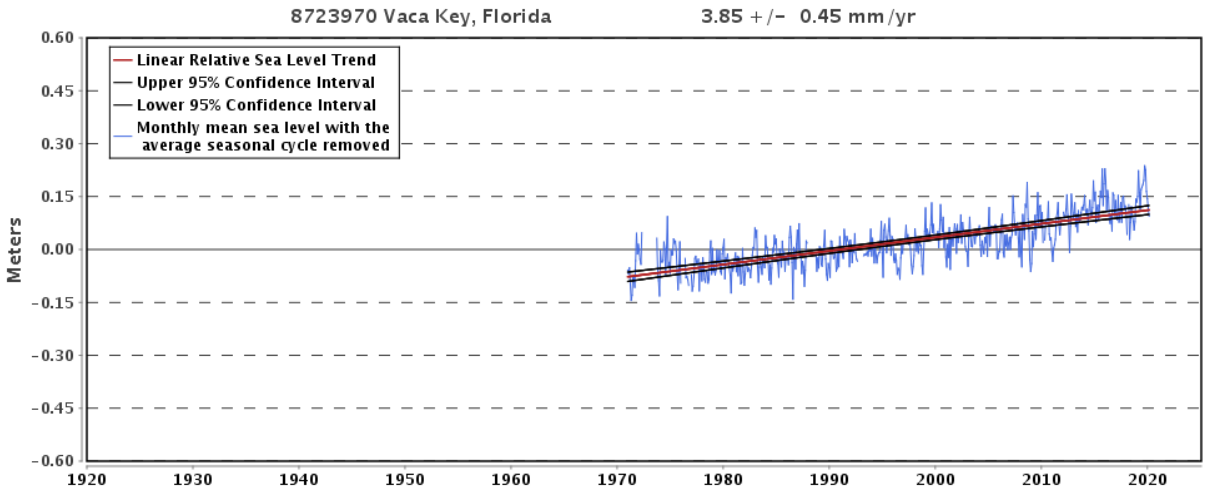

Figure 6. Vaca Key Relative Sea Level Trend

It should be noted that unlike other models, G2CRM gradually adds sea level rise depending on when the storms get activated instead of adding the full amount over the period of analysis from the beginning. For instance, if a storm was stimulated in the year 2040, only the sea level rise until 2040 will be added to the total water level calculations.

USACE Sea Level Change Curve: **High Curve**

For the initial runs of this study, the USACE high curve was used for all analysis. This is the curve that is recognized by the Southeast Florida Regional Climate Change Compact as the most likely scenario for their region.

Calculate Depreciation: **No**

Turning this on will make the simulation depreciate assets linearly over the lifecycle of the simulation. The decision was made not to turn this on since the structures are already valued at the depreciated replacement value. It is also assumed that over time, structures typically

appreciate instead of depreciate. It could also be possible that homeowners or business owners will remodel or upgrade parts of their building throughout its life. Due to these reasons, the team did not want to add additional depreciation to the structures which would lower its valuation.

Raise Structures: **Yes**

By turning this one, it lets the model know that assets should be raised once it is substantially damaged. As mentioned previously in this appendix, this is defined by FEMA as total cost of repairs is 50 percent or more of the structure's market value before the disaster occurred. Once that level is reached, the structure would be raised to the effective FEMA BFE plus one additional foot to account for freeboard.

Calculate Assets: **Yes**

This means the model will use assets (structures) during its simulation.

Use Benefit Base: **No**

This feature indicates whether the statistics for the simulation should recognize the in-benefits base status of the structure ("Yes") or assume all structures are in the benefits base ("No"). This depends on the homeowner or locality's compliance with Section 308 of the Water Resources Development Act (WRDA) 1990 which disallows counting any benefits from a home towards a Federal project's benefit-cost analysis if it was not built to compliance. That is, if a structure was built or substantially improved after July 1 of 1991 (when the Act became effective), it needs to have its first floor elevation above the FEMA BFE as well as any freeboard the locality requires.

Cumulative Damage Removal: **No**

This is an indicator telling the model to remove structures from the inventory once it reaches a certain damage threshold multiplier of the structure's value. There is no policy or evidence from studies that a structure would be acquired after it receives a certain amount of damage; therefore, the team decided not to use this feature. The team did analyze the damage per structure and compared it to its value. Any structures that were receiving more than two times its value in damage were looked into further to ensure there were no errors in any of the attributes.

Calculate Life Loss: **Yes**

This feature allows the model to calculate life loss during the simulation. This is based on the population data that is filled in the asset file. As mentioned previously in Section 2.3, population data is needed for Day Time Under 65 years of age, Night Time Under 65, Day Time Over 65, and Night Time Over 65. Original structure inventory was populated using National Structure Inventory 2.0 which uses census block data to attribute individual structures based on weighted numbers. It also accounts for relative likelihood of who would be over 65. Population data was recalculated using US Census data for Miami-Dade County such as average persons per household of 3 and persons over 65 at 16% of the entire county population. An assumption was

made that 1 of 3 people would be at home during the day, and all 3 would be home at night. Anyone over 65 were assumed to be present the entire time during the day and the night.

Population attributed to condos/high-rise buildings were calculated with the assumption that only the population on the first floor is at risk unless total failure of the building. Vertical evacuation would also be an option to reduce risk. The number of units and number of floors per structure was known from the County Parcel Data which helped determine the number of units per floor. The same assumption for residential buildings was applied as mentioned above – 3 persons per unit.

All nonresidential structures had population data removed since it is assumed these would not be occupied during a storm event. Any critical infrastructure were kept with population data in case of emergencies.

Auto-Generated Waves: **No**

Save points for this study already have a separate wave file associated with it so there was no need to add auto-generated waves.

3.1.1 Sea Level Rise Scenarios

The without-project conditions and benefits for the Tentatively Selected Plan (TSP) were developed employing the USACE high sea level rise scenario. The benefits and costs will be further evaluated during optimization of the TSP which occurs prior to the Agency Decision Milestone – the next major milestone of this study. This will be done by evaluating the USACE low and intermediate sea level rise scenarios.

3.2 Modeling Results

The forecast of the future without project condition reflects the conditions expected during the period of analysis and provides the basis from which alternative plans are evaluated, compared, and selected since a portion of the flood damage would be prevented (i.e. flood damage reduced) with a Federal project in place.

The same structures in the Miami-Dade County Study Area will continue to be affected by the risk of flooding from coastal storms and suffer increasing losses each year. The following tables display the mean expected present value (PV) damage and average annual damage for the study area by modeled areas for the without project condition and are designated as structural or nonstructural.

Table 11. Future Without Project Condition Damage--Structural

Model Area	Present Value Damage	Average Annual Damage
Biscayne Canal	$3,875,010,000	$143,534,000
Little River	$5,489,812,000	$203,348,000
Miami River Opt 1	$38,436,886,000	$1,423,738,000
Total	**$47,801,708,000**	**$1,770,619,000**

Table 12. Future Without Project Condition Damage--Nonstructural

Model Area	Present Value Damage	Average Annual Damage
Arch Creek	$1,459,218,000	$54,051,000
Aventura	$4,509,077,000	$167,020,000
Cutler Bay	$1,372,062,000	$50,822,000
Edgewater	$700,052,000	$25,931,000
Little River	$543,020,000	$20,114,000
Miami River	$703,160,000	$26,046,000
North Beach	$272,484,000	$10,093,000
South Beach	$2,867,495,000	$106,215,000
Critical Infrastructure	$354,010,000	$13,113,000
Total	**$12,780,578,000**	**$473,405,000**

According to Table 11, there are approximately $47.8 billion in expected PV or about $1.77 billion in average annual flood damage due to coastal storm for the period of analysis under the future without project condition in areas where structural measures are proposed. According to Table 12, there are approximately $12.8 billion in expected PV or about $473 million in average annual flood damage in areas where nonstructural measures are proposed. Under the future

without project condition, which represents expected damage in the absence of a flood risk management project, damage are expected to increase. Exacerbating the flooding is the phenomenon of relative sea level rise, which is the combination of water level rise and vertical land movement.

4 FUTURE WITH PROJECT CONDITION

The future with project condition is the most likely condition expected to exist in the future if a specific project is undertaken. There are as many future with project conditions as there are project alternatives. A total of eight alternatives were considered for this study. The analysis did not formulate a project alternative for recreation because it is considered incidental to the project. The analysis includes a discussion of residual flood damage and flood damage reduction for each alternative.

4.1 Formulation of Alternatives

A formulation strategy is a systematic way of combining measures into alternative plans based on the planning objectives. No single formulation strategy will result in a diverse array of alternatives so a variety of strategies is needed. Chapter 6 of the main report describes the process used in formulating the alternatives.

4.2 Initial Array of Alternatives

The initial array of alternatives were formulated in spite of known data gaps, then refined throughout the planning process as information was collected and developed. The initial array of alternatives consist of a variety of measures which include structural, nonstructural, and natural and nature-based features. Structural coastal flood risk management measures are man-made, constructed measures that counteract a flood event in order to reduce the hazard or to influence the course or probability of occurrence of the event. Nonstructural coastal flood risk management measures are permanent or contingent measures applied to a structure and/or its contents that prevent or provide resistance to damage from flooding. Natural and nature-based coastal flood risk management measures work with or restore natural processes with the aim of wave attenuation and storm surge reduction.

The initial array of alternatives consisted of 8 alternatives and the following table provides descriptions for each alternative.

Table 13. Initial Array of Alternatives

Alternative Number	Alternative Name	Description
1	No Action	No Action by Federal Government or local interests
2	Critical Infrastructure Only	Analyzing critical infrastructure throughout all of Miami-Dade County on priority asset categories. This includes wet and dry floodproofing.
3	Miami River Basin + Alternative 2	Surge barrier at Miami River (plus associated pump stations) + Floodwalls (plus associated pump stations and riprap) + Nonstructural outside of surge barrier + Critical Infrastructure
4	Nonstructural + Alternative 2	Acquiring, elevating, and wet and dry floodproofing of structures in Arch Creek, Aventura, Cutler Bay, Little River, Miami River, North Beach, and South Beach areas + Critical Infrastructure
5	Inland Storm Surge Reduction (Structural) + Alternative 2	Surge barriers at Miami River, Little River, and Biscayne Canal (plus associated pump stations) + Floodwalls (plus associated pump stations and riprap) + Critical Infrastructure
6	Alternative 3 + 4	Miami River Basin + Nonstructural** + Critical Infrastructure
7	Alternative 4 + 5	Nonstructural** + Structural + Critical Infrastructure
8	Alternative 2 + 4 + 5 + Nonstructural at Edgewater - floodwall at Edgewater	Nonstructural** + Surge barriers at Miami River, Little River, and Biscayne Canal (plus associated pump stations) + Floodwalls (plus associated pump stations and riprap) +Critical Infrastructure + Nonstructural at Edgewater

4.3 Alternatives Screening

The PDT performed additional planning iterations with a focus on screening measures and alternatives that would not meet the planning objectives in an effective and efficient manner. Without substantial data to base the screening on, professional judgment was used to assess how well measures met a set of criteria.

4.4 Final Array of Alternatives

Based on the screening assessment, none of the alternatives were able to be excluded from further analysis.

4.5 Evaluation of Alternatives

Relevant data for each of the alternatives described above were entered into G2CRM as alternative plans and potential for flood damage reduced were calculated. The modeling results for each alternative are summarized in Tables 14 and 15.

Table 14. Future With Project Conditions – Structural

Model Area	Present Value Damage	Average Annual Damage
Biscayne Canal	$492,865,000	$18,256,000
Little River	$2,048,828,000	$75,890,000
Miami River Opt 1	$3,228,651,000	$119,592,000
Total	**$5,770,344,000**	**$213,738,000**

Table 15. Future With Project Conditions Damage – Nonstructural

Model Area	Present Value Damage	Average Annual Damage
Arch Creek	$531,996,000	$19,706,000
Aventura	$2,150,146,000	$79,643,000
Cutler Bay	$505,832,000	$18,736,000
Edgewater	$4,790,000	$177,000
Little River	$120,274,000	$4,455,000
Miami River	$444,758,000	$16,474,000
North Beach	$116,692,000	$4,322,000
South Beach	$1,190,341,000	$44,091,000
Critical Infrastructure	$195,209,000	$7,231,000
Total	**$5,260,038,000**	**$194,835,000**

A more thorough summary of the damage and benefits was created before reorganizing the model areas by alternative shown in Tables 16, 17, and 18.

Table 16. Net Remaining Benefits – Structural

Cost Item[1]	STRUCTURAL		
	Biscayne Canal	Little River	Miami River Opt 1
Present Value Damages FWOP	$3,875,000,000	$5,489,800,000	$38,436,900,000
Present Value Damages FWP	$492,900,000	$2,048,800,000	$3,228,700,000
Present Value Benefit	$3,382,100,000	$3,441,000,000	$35,208,200,000
Average Annual Damages FWOP	$143,500,000.00	$203,300,000.00	$1,423,700,000.00
Average Annual Damages FWP	$18,300,000.00	$75,900,000.00	$119,600,000.00
Total Average Annual Benefits (Rounded)	$125,300,000	$127,500,000	$1,304,100,000

Table 17. Net Remaining Benefits Nonstructural – Arch Creek, Aventura, Cutler Bay, and Edgewater

	Arch Creek	Aventura	Cutler Bay	Edgewater
Present Value Damages FWOP	$1,459,200,000	$4,509,100,000	$1,372,100,000	$700,100,000
Present Value Damages FWP	$532,000,000	$2,150,100,000	$505,800,000	$4,800,000
Present Value Benefit	$927,200,000	$2,358,900,000	$866,200,000	$695,300,000
Average Annual Damages FWOP	$54,100,000	$167,000,000	$50,800,000	$25,900,000
Average Annual Damages FWP	$19,700,000	$79,600,000	$18,700,000	$200,000
Total Average Annual Benefits	$34,300,000	$87,400,000	$32,100,000	$25,800,000

Table 18. Net Remaining Benefits Nonstructural – Little River, Miami River, North Beach, and South Beach

	Little River	Miami River	North Beach	South Beach
Present Value Damages FWOP	$543,000,000	$703,200,000	$272,500,000	$2,867,500,000
Present Value Damages FWP	$120,300,000	$444,800,000	$116,700,000	$1,190,300,000
Present Value Benefit	$422,700,000	$258,400,000	$155,800,000	$1,677,200,000
Average Annual Damages FWOP	$20,100,000	$26,000,000	$10,100,000	$106,200,000
Average Annual Damages FWP	$4,500,000	$16,500,000	$4,300,000	$44,100,000
Total Average Annual Benefits	$15,700,000	$9,600,000	$5,800,000	$62,100,000

Table 19. Alternative Evaluation

Alt #	Alternative Name	Total Average Annual Benefits	Net Remaining Benefits
1	No Action	$0	$0
2	Critical Infrastructure Only	$9,325,000	$5,615,000
3	Miami River Basin + Alternative 2	$1,345,494,000	$1,254,759,000
4	Nonstructural + Alternative 2	$421,980,000	$298,715,000
5	Inland Storm Surge Reduction (Structural) + Alternative 2	$1,588,658,000	$1,444,215,000
6	Alternative 3 + 4 + 2	$1,614,329,000	$1,427,574,000
7	Alternative 4 + 5 + 2	$1,835,591,000	$1,606,866,000
8	Alternative 2 + 4 + 5 + Nonstructural at Edgewater - Structural at Edgewater	$1,835,782,000	$1,640,071,000

4.6 Alternative Comparison

Comparison of benefits with regards to costs was performed for each alternatives. These comparisons provide the framework for completing the evaluation of alternative plans.

4.6.1 Rough Order of Magnitude Costs

Continuing the comparison process, first cost estimates were developed for each of the alternatives that were evaluated. The Rough Order of Magnitude (ROM) costs were provided by Cost Engineering Section Division in FY20 price levels (reference Engineering Appendix for more details). For comparison to the benefits, which are average annual flood damage reduced, the first costs were stated in average annual equivalent also based on the FY20 discount rate

and period of analysis. Interest during construction (IDC) was added to the ROM first costs assuming 50 years for structural measures. In addition, annual operation and maintenance (O&M) costs were also added to the alternatives where applicable. This included Environmental mitigation O&M related to structural measures. More information regarding O&M is available in the Appendix B - Engineering Cost Subappendix. The following Tables display the results of the costs calculation. All costs are rounded to the nearest hundred thousands, include a capital recovery factor of 0.03704, priced at an interest rate of 2.75%, and include contingency when applicable.

Table 20. Project Costs – Structural

Cost Item	STRUCTURAL		
	Biscayne Canal	**Little River**	**Miami River Opt 1**
Civil Works Breakdown Structure			
Total Levees & Floodwalls	$158,300,000	$517,200,000	$367,900,000
Total Environmental and Cultural Mitigation	$105,800,000	$109,400,000	$234,200,000
Total Lands and Damages	$19,300,000	$43,600,000	$413,300,000
PED[1] Total	$21,400,000	$69,800,000	$49,700,000
CM[2] Total	$22,900,000	$75,000,000	$53,400,000
Subtotal First Cost	$327,800,000	$815,000,000	$1,118,500,000
Interest During Construction (Total Amount)	$22,900,000	$56,900,000	$78,100,000
Annualized Investment Cost	$13,700,000	$34,000,000	$46,700,000
Annualized O&M Cost	$3,300,000	$3,400,000	$5,900,000
Total Average Annualized Cost	$17,000,000	$37,400,000	$52,600,000

[1] Preconstruction Engineering and Design
[2] Construction Management

Table 21. Project Costs – Nonstructural Arch Creek, Aventura, Cutler Bay, and Edgewater

Cost Item	Arch Creek	Aventura	Cutler Bay	Edgewater
Total Floodproofing Cost	$124,700,000	$204,100,000	$155,800,000	$37,200,000
Total Elevation Cost	$177,200,000	$275,900,000	$105,300,000	$2,200,000
Total Acquisition Cost	$0	$0	$0	$0
PED Total	$41,200,000	$65,500,000	$35,900,000	$5,400,000
CM Total	$43,800,000	$70,300,000	$38,500,000	$5,800,000
Subtotal First Cost	$389,800,000	$620,600,000	$340,200,000	$50,900,000
Interest During Construction	$1,300,000	$2,000,000	$1,100,000	$200,000
Total Average Annualized Cost	$15,300,000	$24,400,000	$13,400,000	$2,000,000

Table 22. Project Costs – Nonstructural Little River, Miami River, North Beach, and South Beach

Cost Item	Little River	Miami River	North Beach	South Beach
Total Floodproofing Cost	$24,100,000	$12,100,000	$32,600,000	$311,400,000
Total Elevation Cost	$193,000,000	$0	$1,800,000	$43,000,000
Total Acquisition Cost	$0	$0	$0	$0
PED Total	$29,600,000	$1,600,000	$4,700,000	$48,300,000
CM Total	$31,800,000	$1,800,000	$5,000,000	$51,900,000
Subtotal First Cost	$280,700,000	$15,500,000	$44,300,000	$458,200,000
Interest During Construction	$900,000	$100,000	$100,000	$1,500,000
Total Average Annualized Cost	$11,000,000	$600,000	$1,700,000	$18,000,000

The tables above depict life cycle costs for the final array of alternatives including average annual construction costs, the annual operation and maintenance costs, and the total average annual costs. The interest during construction costs is also included in the calculation of total average annual costs. It should be noted that interest during construction (IDC) was calculated for nonstructural measures. The assumption is that elevation and floodproofing of structures will take three months if the structure has a crawl foundation, four months if the structure has a slab foundation, and one month for acquisition of any structures.

4.6.2 Benefits to Costs

The equivalent annual benefits were then compared to the average annual cost to develop net benefits and a benefit-to-cost ratio (BCR) for each alternative. The net benefits for each alternative were calculated by subtracting the average annual costs from the equivalent average annual benefits, and a BCR was derived by dividing average benefits by average annual costs. Net benefits were used for identification of the NED plan in accordance with the Federal objective. For comparative purposes, the following Table summarizes the equivalent annual damage (benefits), average annual costs, first cost, net benefits, and BCR for each alternative.

4.7 Tentatively Selected Plan

According the USACE Planning and Guidance Notebook (i.e. ER 1105-2-100), Chapter 2-3, (4):

Section 904 of the Water Resources Development Act of 1986 (WRDA of 1986) requires the Corps to address the following matters in the formulation and evaluation of alternative plans:
- *Protecting and restoring the quality of the total environment.*
- *The well-being of the people of the United States*
- *The prevention of loss of life.*
- *The preservation of cultural and historical values*

The ER goes on to state in Chapter 3-3 (11), Flood Damage Reduction:

… An essential element of the analysis of the recommended plan is the identification of residual risk for the sponsor and the flood plain occupants, including residual damage and potential for loss of life, due to exceedance of design capacity. …

Moreover, ER 1105-2-101, Planning, Risk Assessment For Flood Risk Management Studies, 5.Context:

…All flood risk managers must balance the insights of USACE's professional staff with stakeholder concerns for such matters as residual risks, life safety, reliability, resiliency and cost while acknowledging no single solution will meet all objectives, and trade-offs must always be made….

As a result of the comparison of the alternatives, Alternative 8 was identified as the Tentatively Selected Plan (TSP) and the National Economic Development (NED) plan. It has the greatest net national economic benefit consistent with protecting the nation's environment. The expected annual benefits attributable to the project alternative were converted to an equivalent time frame by using the FY20 Federal discount rate of 2.75 percent for the TSP. The base year for this conversion is the year 2030 for the TSP. The equivalent annual benefits were then compared to the average annual costs to develop a benefit-to-cost ratio for the alternative. The net benefits for the alternative were calculated by subtracting the average annual costs from the equivalent annual benefits. The net benefits were used to determine the economic justification of the project alternative.

Even though Alternative 8 does not yield the highest BCR, the benefits were greater than its costs. In other words, Alternative 8 maximizes net benefits, which is the criterion used for identification of the NED plan in accordance with the Federal objective. Therefore, the NED Plan, Alternative 8, was recommended to be the TSP.

4.7.1 Life Loss Analysis

G2CRM is capable of modeling life loss using a simplified life loss methodology. The future without project condition was modeled to serve as a baseline due to the uncertainty in modeling life loss. Therefore, when compared to the future with project condition, any addition or reduction of life loss from the baseline would serve as a proxy in identifying impacts to life safety the alternatives might have. The following Table presents the mean life loss estimates for each measure in the study area over the 50 year period of analysis.

Using the proper lethality function, a random number is generated and interpolated using the Lethality Function Values to get the expected fraction of life loss. The way the default lethality functions are formed is that the smaller the random number, the higher the life loss. This interpolation from the lethality function is multiplied by the nighttime population for the corresponding age range and the remaining population fraction in order to calculate the life loss under 65 and life loss for 65 and older. This is recorded in fractions of lives, so depending on the level of output, there exists small rounding differences.

There exists much uncertainty regarding the modeling of life loss; therefore, the results of the modeling should be viewed as more qualitative as oppose to a quantitative assessment of life loss even though the results are stated in numerical values. Also, the results should be viewed

in terms of order of magnitude compared to the baseline. Viewing the results in this manner is a better use of the model to understand whether or not any recommended alternatives might or could have an impact to life safety as oppose to no action (e.g. introducing more risk of flooding).

4.8 Summary of Alternatives and NED Plan

A description of each alternative and a breakdown of their respective benefits and costs can be seen in Table 23 which shows the full summary of all alternatives. The NED plan is economically justified with a BCR of 9.4 and net-benefits of **$$1,640,071,000**.

Table 23. Summary of Alternative Economics

Alternative Number	Alternative Name	Total Average Annual Benefits ($1000s)	Total Average Annualized Cost ($1000s)	Project First Cost* ($1000s)	BCR	Net Remaining Benefits ($1000s)	Description
1	No Action	$0	$0	$0	**N/A**	**$0**	No action. Continue as-is without any recommendations.
2	Critical Infrastructure Only	$9,325	$3,710	$94,504	**2.5**	**$5,615**	Analyzing critical infrastructure throughout all of Miami-Dade County on priority asset categories. This includes wet and dry floodproofing.
3	Miami River Basin Structural + Alt. 2	$1,345,494	$90,735	$1,944,047	**14.8**	**$1,254,759**	Surge barrier at Miami River (plus associated pump stations) + Floodwalls (plus associated pump stations and riprap) + Nonstructural outside of surge barrier + Critical Infrastructure
4	Nonstructural + Alt. 2	$421,980	$123,265	$3,139,955	**3.4**	**$298,715**	Acquiring, elevating, and wet and dry floodproofing of structures in Arch Creek, Aventura, Cutler Bay, Little River, Miami River, North Beach, and South Beach areas + Critical Infrastructure
5	Inland Storm Surge Reduction (Structural) + Alt. 2	$1,588,658	$144,443	$3,067,164	**11.0**	**$1,444,215**	Surge barriers at Miami River, Little River, and Biscayne Canal (plus associated pump stations) + Floodwalls (plus associated pump stations and riprap) + Critical Infrastructure
6	Alt. 3 + 4 + 2	$1,614,329	$186,755	$4,390,024	**8.6**	**$1,427,574**	Miami River Basin + Nonstructural** + Critical Infrastructure
7	Alt. 4 + 5 + 2	$1,835,591	$228,725	$5,214,162	**8.0**	**$1,606,866**	Nonstructural** + Structural + Critical Infrastructure
8	Alt. 4 + 5 + 2 + EW NS - EW FW	$1,835,782	$195,711	$4,585,650	**9.4**	**$1,640,071**	Nonstructural** + Surge barriers at Miami River, Little River, and Biscayne Canal (plus associated pump stations) + Floodwalls (plus associated pump stations and riprap) +Critical Infrastructure + Nonstructural at Edgewater – Edgewater floodwall

Table 24. Economic Summary of the NED Plan at 2.75%

Economic Summary of NED Plan	Alternative 8
Price Level	FY20
FY20 Water Resources Discount Rate	2.75%
Total Average Annual Benefits	$1,835,782,000
Total Average Annualized Cost	$195,711,000
Net-Benefits	$1,640,071,000
Benefit Cost Ratio	9.4

The average annual damage and benefits, total annual costs, benefit-to-cost ratio, and net remaining benefits for the Recommended Plan are displayed in Table 24 above. The Recommended Plan has the highest net remaining benefits and thus constitutes the National Economic Development (NED) Plan.

4.9 Results at the OMB 7% Discount Rate

Project costs, OMRR&R, equivalent annual project damage, benefits, and net benefits have been similarly calculated using the Office of Management and Budget (OMB) discount rate of 7 percent for each measure in the Recommended Plan. These calculations are available upon request.

5 REGIONAL ECONOMIC DEVELOPMENT

5.1 RECONS Methodology

When the economic activity lost in the study area can be transferred to another area or region in the national economy, these losses cannot be included in the NED account. However, the impacts of the employment, income, and output of the regional economy are considered part of the Regional Economic Development (RED) account. The input-output macroeconomic model, RECONS, was used to address the impacts of the construction spending associated with the Tentatively Selected Plan (TSP).

For this Regional analysis, the regional economic development (RED) effects of implementing the TSP or Alternative 8 will be estimated. The RECONS Standard Geographic Area for the Miami-Dade County was selected using an expenditure year of 2026.

This RED analysis, using RECONS, employs input-output economic analysis, which measures the interdependence among industries and workers in an economy. This analysis uses a matrix representation of a region's economy to predict the effect of changes, the implementation of a project of a specific USACE Business Line, to the various industries that would be impacted. The greater the interdependence among industry sectors, the larger the multiplier effect on the economy. Changes to government spending drive the input-output model to project new levels of sales (output), value added (Gross Regional Product or GRP), employment, and income for each industry.

The specific input-output model used in this analysis is RECONS (Regional Economic System). This model was developed by the Institute for Water Resources (IWR), Michigan State University, and the Louis Burger Group. RECONS uses industry multipliers derived from the commercial input-output model IMPLAN to estimate the effects that spending on USACE projects have on a regional economy. The model is linear and static, showing relationships and impacts at a certain fixed point in time. Spending impacts are composed of three different effects: direct, indirect, and induced.

Direct effects represent the impacts the new federal expenditures have on industries which directly support the new project. Labor and construction materials can be considered direct components to the project. Indirect effects represent changes to secondary industries that support the direct industries. Induced effects are changes in consumer spending patterns caused by the change in employment and income within the industries affected by the direct and induced effects. The additional income workers receive via a project and spent on clothing, groceries, dining out, and other items in the regional area are secondary or induced effects.

The inputs for the RECONS model are expenditures that are entered by work activity or industry sector, each with its own unique production function. The Flood Risk Management production

function of “Flood Risk Management Construction” was selected to gauge the impacts of the construction of Alternative 3. The production function “Flood Risk Management Operations and Maintenance” was selected to gauge the impacts of the operations and maintenance costs associated with the features of the Seawall measure. The baseline data used by RECONS to represent the regional economy of Miami-Dade County are annual averages from the Bureau of the Census, the Bureau of Labor Statistics, and the Bureau of Economic Analysis for the year 2019. The model results are expressed in 2026 dollars.

5.2 RECONS Assumptions

Input-output analysis rests on the following assumptions. The production functions of industries have constant returns to scale, so if inputs are to increase, output will increase in the same proportion. Industries face no supply constraints; they have access to all the materials they can use. Industries have a fixed commodity input structure; they will not substitute any commodities or services used in the production of output in response to price changes. Industries produce their commodities in fixed proportions, so an industry will not increase production of a commodity without increasing production in every other commodity it produces. Furthermore, it is assumed that industries use the same technology to produce all of its commodities. Finally, since the model is static, it is assumed that the economic conditions of 2019, the year of the socio-economic data in the RECONS model database, will prevail during the years of the construction process.

5.3 RECONS Metrics

“Output” is the total sum of transactions that take place as a result of the construction project, including both value added and intermediate goods purchased in the economy. “Labor Income” includes all forms of employment income, including employee compensation (wages and benefits) and proprietor income. “Gross Regional Product (GRP)” is the value-added output of the study region. This metric captures all final goods and services produced in the study areas because of the project’s existence. It is different from output in the sense that one dollar of a final good or service may have multiple transactions associated with it. “Jobs” is the estimated worker-years of labor required in full time equivalent units to build the project.

5.4 RECONS Results

The expenditures associated with All Work Activities, with Ability to Customize Impact Area and Work Activity at Miami-Dade (FL) are estimated to be $2,442,114,000. The remainder of the expenditures will be captured within the state impact area and the nation. These direct expenditures generate additional economic activity, often called secondary or multiplier effects. The direct and secondary impacts are measured in output, jobs, labor income, and gross regional product (value added) as summarized in the following tables. The regional economic effects are shown for the local, state, and national impact areas. In summary, the expenditures $2,442,114,000 support a total of 20,578.0 full-time equivalent jobs, $1,362,545,000 in labor income, $1,916,992,000 in the gross regional product, and $3,384,927,000 in economic output in the local impact area. More broadly, these expenditures support 30,496.9 full-time equivalent

jobs, $2,173,519,000 in labor income, $3,157,740,000 in the gross regional product, and $5,627,467,000 in economic output in the nation.

Table 25. Project Expenditure

Business Line	Flood Risk Management
Work Activity	FRM - CWB - General
Work Activity	2026
Current Expenditure ($)	$2,442,114,000

Table 26. Spending Profile

	Spending Category	Percentage (%)
1	Metals and Steel Materials	4%
2	Aggregate Materials	1%
3	Cement Materials	4%
4	Machinery Materials	1%
5	Electrical Materials	2%
6	Construction or Major Rehabilitation of Buildings and Structures	1%
7	Construction or Major Rehabilitation of Highways, Bridges, and Streets	1%
8	Construction or Major Rehabilitation of Water Resources Infrastructure	17%
9	Construction or Major Rehabilitation of Residential Structures	1%
10	Construction or Major Rehabilitation of Utilities and Power Structures	1%
11	Construction Equipment	3%
12	Architectural, Design, Engineering, and Related Services	14%
13	Environmental Compliance, Planning, and Technical Services	1%
14	Repair and Maintenance of Locks, Dams, and Other Industrial Equipment	6%
15	Insurance and Bond	1%
16	USACE Overhead	10%
17	USACE Wages and Benefits	20%
18	Private Sector Labor or Staff Augmentation	12%

Table 27. Local Purchase Coefficients

IMPLAN Code	Industry	Expenditure ($000)	Local Purchase Coefficients		
			Local	State	US
31	Sand and gravel mining	$13,436,091	4%	39%	99%
54	Construction of new power and communication structures	$24,421,140	100%	100%	100%

56	Construction of new highways and streets	$24,421,140	100%	100%	100%
57	Construction of new commercial structures, including farm structures	$24,421,140	100%	100%	100%
58	Construction of other new nonresidential structures	$415,159,380	100%	100%	100%
59	Construction of new single-family residential structures	$24,421,140	100%	100%	100%
205	Cement manufacturing	$76,639,490	85%	85%	87%
217	Iron and steel mills and ferroalloy manufacturing	$80,594,903	2%	6%	74%
271	All other industrial machinery manufacturing	$22,129,912	1%	4%	69%
334	Switchgear and switchboard apparatus manufacturing	$41,697,755	1%	14%	54%
395	Wholesale trade	$32,477,106	93%	99%	100%
408	Air transportation	$351,179	78%	78%	80%
409	Rail transportation	$5,285,777	26%	70%	99%
410	Water transportation	$164,507	98%	98%	100%
411	Truck transportation	$20,276,961	92%	92%	99%
437	Insurance carriers	$24,421,140	81%	81%	87%
445	Commercial and industrial machinery and equipment rental and leasing	$73,263,420	76%	87%	99%
449	Architectural, engineering, and related services	$341,895,960	89%	90%	96%
455	Environmental and other technical consulting services	$24,421,140	47%	81%	100%
462	Office administrative services	$244,211,400	99%	99%	100%
507	Commercial and industrial machinery and equipment repair and maintenance	$146,526,840	100%	100%	100%
535	Employment and payroll of federal govt, non-military	$488,422,800	75%	100%	100%
5001	Private Labor	$293,053,680	100%	100%	100%
	Total	**$2,442,114,000**			

Table 28. Overall RECON Summary

Area	Local Capture ($000)	Output ($000)	Jobs*	Labor Income ($000)	Value Added ($000)
Local					
Direct Impact		$2,069,933	12,159.2	$905,526	$1,156,102
Secondary Impact		$1,314,994	8,418.8	$457,019	$760,890
Total Impact	$2,069,933	$3,384,927	20,578.0	$1,362,545	$1,916,992
State					
Direct Impact		$2,231,656	13,490.0	$1,031,874	$1,315,342
Secondary Impact		$1,904,831	11,938.5	$625,068	$1,067,281

Total Impact	$2,231,656	$4,136,487	25,428.5	$1,656,943	$2,382,622
US					
Direct Impact		$2,367,403	13,923.2	$1,142,851	$1,411,030
Secondary Impact		$3,260,064	16,573.7	$1,030,668	$1,746,711
Total Impact	$2,367,403	$5,627,467	30,496.9	$2,173,519	$3,157,740

* Jobs are presented in full-time equivalence (FTE)

Table 29. Local Impacts

		Output ($000)	Jobs*	Labor Income ($000)	Value Added ($000)
	Direct Impacts				
31	Sand and gravel mining	$569	2.2	$91	$295
54	Construction of new power and communication structures	$24,421	178.3	$8,765	$13,773
56	Construction of new highways and streets	$24,421	127.2	$6,569	$9,618
57	Construction of new commercial structures, including farm structures	$24,421	167.0	$8,715	$12,536
58	Construction of other new nonresidential structures	$415,159	2669.2	$136,413	$202,615
59	Construction of new single-family residential structures	$24,421	157.1	$7,055	$12,112
205	Cement manufacturing	$65,360	96.0	$8,744	$26,577
217	Iron and steel mills and ferroalloy manufacturing	$1,323	1.2	$41	$102
271	All other industrial machinery manufacturing	$298	1.2	$66	$77
334	Switchgear and switchboard apparatus manufacturing	$495	1.5	$71	$98
395	Wholesale trade	$30,092	103.2	$10,770	$19,811
408	Air transportation	$273	0.6	$62	$119
409	Rail transportation	$1,350	2.7	$622	$756
410	Water transportation	$162	0.2	$20	$61
411	Truck transportation	$18,576	113.7	$5,218	$6,025
437	Insurance carriers	$19,759	39.4	$4,767	$10,168
445	Commercial and industrial machinery and equipment rental and leasing	$56,010	134.4	$25,668	$43,036
449	Architectural, engineering, and related services	$303,795	1738.3	$149,221	$150,808
455	Environmental and other technical consulting services	$11,377	115.6	$8,113	$6,917
462	Office administrative services	$241,764	3719.5	$163,203	$169,830

507	Commercial and industrial machinery and equipment repair and maintenance	$146,516	731.3	$66,285	$104,451
535	Employment and payroll of federal govt, non-military	$366,317	2059.5	$295,047	$366,317
5001	Private Labor	$293,054	0.0	$0	$0
	Direct Impact	**$2,069,933**	**12159.2**	**$905,526**	**$1,156,102**
	Secondary Impact	**$1,314,994**	**8418.8**	**$457,019**	**$760,890**
	Total Impact	**$3,384,927**	**20578.0**	**$1,362,545**	**$1,916,992**

* Jobs are presented in full-time equivalence (FTE)

Table 30. State Impacts

		Output ($000)	Jobs*	Labor Income ($000)	Value Added ($000)
	Direct Impacts				
31	Sand and gravel mining	$5,235	20.1	$934	$2,716
54	Construction of new power and communication structures	$24,421	178.3	$8,765	$14,224
56	Construction of new highways and streets	$24,421	127.2	$6,569	$9,746
57	Construction of new commercial structures, including farm structures	$24,421	167.9	$8,715	$12,536
58	Construction of other new nonresidential structures	$415,159	2669.2	$136,413	$205,285
59	Construction of new single-family residential structures	$24,421	157.1	$7,055	$12,545
205	Cement manufacturing	$65,360	99.3	$8,744	$26,577
217	Iron and steel mills and ferroalloy manufacturing	$4,819	4.5	$346	$702
271	All other industrial machinery manufacturing	$981	3.9	$261	$305
334	Switchgear and switchboard apparatus manufacturing	$5,824	17.1	$1,394	$1,908
395	Wholesale trade	$32,217	118.4	$11,530	$21,210
408	Air transportation	$273	0.6	$62	$119
409	Rail transportation	$3,684	9.5	$1,698	$2,063
410	Water transportation	$162	0.2	$20	$61
411	Truck transportation	$18,576	113.7	$5,355	$6,511
437	Insurance carriers	$19,759	42.2	$4,767	$10,168
445	Commercial and industrial machinery and equipment rental and leasing	$63,845	187.4	$29,258	$49,056

449	Architectural, engineering, and related services	$308,572	1765.6	$152,100	$153,688
455	Environmental and other technical consulting services	$19,749	202.8	$14,271	$12,007
462	Office administrative services	$241,764	3719.5	$173,936	$180,939
507	Commercial and industrial machinery and equipment repair and maintenance	$146,516	731.3	$66,285	$104,555
535	Employment and payroll of federal govt, non-military	$488,423	3154.3	$393,396	$488,423
5001	Private Labor	$293,054	0.0	$0	$0
	Direct Impact	**$2,231,656**	**13490.0**	**$1,031,874**	**$1,315,342**
	Secondary Impact	**$1,904,831**	**11938.5**	**$625,068**	**$1,067,281**
	Total Impact	**$4,136,487**	**25428.5**	**$1,656,943**	**$2,382,622**

* Jobs are presented in full-time equivalence (FTE)

Table 31. U.S. Impacts

		Output ($000)	Jobs*	Labor Income ($000)	Value Added ($000)
	Direct Impacts				
31	Sand and gravel mining	$13,349	51.3	$3,142	$7,740
54	Construction of new power and communication structures	$24,421	178.3	$10,442	$15,003
56	Construction of new highways and streets	$24,421	127.2	$7,971	$10,241
57	Construction of new commercial structures, including farm structures	$24,421	167.9	$10,251	$13,028
58	Construction of other new nonresidential structures	$415,159	2669.2	$164,218	$213,600
59	Construction of new single-family residential structures	$24,421	157.1	$8,558	$13,403
205	Cement manufacturing	$66,320	100.8	$10,188	$26,978
217	Iron and steel mills and ferroalloy manufacturing	$59,687	56.1	$5,358	$11,015
271	All other industrial machinery manufacturing	$15,295	61.2	$4,326	$5,326
334	Switchgear and switchboard apparatus manufacturing	$22,409	65.6	$5,364	$7,869
395	Wholesale trade	$32,477	119.3	$11,623	$21,381
408	Air transportation	$283	0.6	$68	$124
409	Rail transportation	$5,253	13.5	$2,421	$2,941
410	Water transportation	$165	0.2	$22	$62
411	Truck transportation	$19,979	122.3	$6,907	$8,186
437	Insurance carriers	$21,367	45.6	$5,155	$11,654

445	Commercial and industrial machinery and equipment rental and leasing	$72,823	213.8	$33,372	$55,954
449	Architectural, engineering, and related services	$328,518	1879.7	$178,730	$179,916
455	Environmental and other technical consulting services	$24,421	250.8	$20,783	$15,011
462	Office administrative services	$244,211	3757.2	$189,709	$198,530
507	Commercial and industrial machinery and equipment repair and maintenance	$146,527	731.3	$70,845	$104,646
535	Employment and payroll of federal govt, non-military	$488,423	3154.3	$393,396	$488,423
5001	Private Labor	$293,054	0.0	$0	$0
	Direct Impact	**$2,367,403**	**13923.2**	**$1,142,851**	**$1,411,030**
	Secondary Impact	**$3,260,064**	**16573.7**	**$1,030,668**	**$1,746,711**
	Total Impact	**$5,627,467**	**30496.9**	**$2,173,519**	**$3,157,740**

* Jobs are presented in full-time equivalence (FTE)

6 CONCLUSION

Miami-Dade County is highly susceptible to damage from storm surge. When factoring in the potential for sea levels to rise in excess of baseline projections, significant economic damage from coastal forces can be expected to increase dramatically.

In an effort to reduce as much damage as possible, the modeling team considered a multitude of alternatives to most efficiently address the risks from storm surge. Years of technical expertise, best professional judgment and rigorous modeling efforts were all leveraged to determine a plan that maximizes net-benefits and contributes to national economic development. In conclusion, it was determined that the NED plan was alternative 8, which maximized NED benefits and met the objectives of the study. The BCR is 9.4 and the net benefits are $1,640,071,000. The plan is efficient, acceptable, and complete.

7 REFERENCES

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