US Army Corps of Engineers ®
Jacksonville District

SAN JUAN METRO AREA, PUERTO RICO

COASTAL STORM RISK MANAGEMENT STUDY
DRAFT INTEGRATED FEASIBILITY STUDY AND ENVIRONMENTAL ASSESSMENT

JULY 2020

APPENDIX C: ECONOMIC ANALYSIS

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1 Introduction

1.1 Background

1.1.1 Purpose

The U.S. Army Corps of Engineers (USACE) study is an interim response to the study authority to determine Federal interest in a plan to reduce damages to infrastructure as a result of flooding from coastal storms and hurricanes along the back bay areas in the municipality of San Juan and adjacent municipality communities. More specifically, this study will assess back bay flooding risks due to storm surge, which also includes wave contributions and tidal influences, as well as sea level change under the Coastal Storm Risk Management (CSRM) mission. The study develops and evaluates CSRM alternatives for the San Juan Metropolitan Area, which for this study includes the municipalities of San Juan, Cataño, and Guaynabo. The alternatives described in this report are formulated to reduce risk to residents, industries, businesses and infrastructures which are critical to the nation's economy. The long-term strategy for resilience in the San Juan Metropolitan Area is a layered solution that includes elements executed by the non-Federal sponsor, other federal agencies, and/or non-governmental organizations in addition to the recommendations for implementation by the USACE study. The study seeks to not only reduce coastal storm risk from storm surge, but also to build on resilience by implementing strategic approaches that address identified stresses and potential shocks such as nuisance flooding risk, major storms and the impact on residents and economic activity.

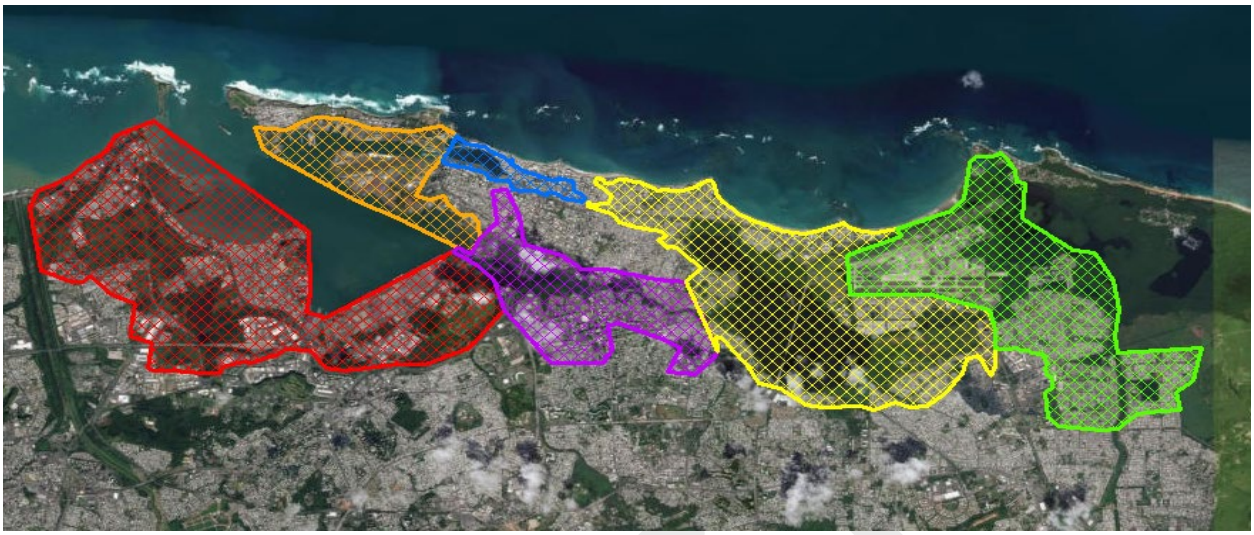
1.1.2 Authority

This report is an interim response to the study authority. Authority for the San Juan Metro coastal storm risk management (CSRM) study is granted under Section 201 of the Flood Control Act of 1970, Public Law 91-611 which authorizes the Secretary of the Army, acting through the Chief of Engineers, to prepare plans for the development, utilization and conservation of water and related land resources of drainage basins and coastal areas in the Commonwealth of Puerto Rico. Study funds for this study were appropriated under Bipartisan Budget Act of 2018 115-123.

1.1.3 Location

Puerto Rico is the smallest of the Greater Antilles and is located in the Northeast of the Caribbean shield made up of the Greater Antilles and Minor Antilles. In addition, it is in the 18.5° N Parallel of the Tropic of Cancer at latitude 65° W. this position makes it extremely vulnerable to hurricanes due to the warmer temperatures of the waters in those zones.

The study focuses on the areas most likely to experience damages from storm surge within the San Juan Metro Area, and which results in West San Juan Bay (WSJB) reach and Condado Lagoon (CL) reach. The combined study area encompasses approximately 9.5 square miles and contains approximately 22 structures identified as critical infrastructure, approximately 14 schools and major hurricane and tsunami evacuation routes.



1.2 Problems and Opportunities

Problems and opportunities have been identified by the Project Delivery Team (PDT) in several ways, including coordination with the sponsor, municipalities, as well as scoping letter comments received from local residents and stakeholders, GIS data, reports from other agencies and USACE reports.

1.2.1 Reach 1 – West San Juan Bay

- Storm surge inundation from hurricanes and storms causes damage to structures, vehicles, and critical infrastructure, including Tsunami and Hurricane evacuation route, PR-165.

- Storm surge inundation from hurricanes and storms results in inaccessibility to critical infrastructure, including evacuation routes before, during and after storm events.
- Storm surge inundation from hurricanes and storms can cause standing water and results in public safety risks, including health risks from waterborne diseases.
- Wave attack during hurricanes and storms causes erosion and damages around waterfront areas in Cataño, in the WSJB-3 planning reach.
- Sea level rise will cause increased risk of storm surge flooding.
- Note that for all problems described above, the source of inundation is from the San Juan Bay.

1.2.2 Reach 3 – Condado Lagoon

- Storm surge inundation from hurricanes and storms causes damage to structures, vehicles, and critical infrastructure, including Tsunami and Hurricane evacuation route, PR-24.
- Storm surge inundation from hurricanes and storms results in inaccessibility to critical infrastructure, including evacuation routes before, during and after storm events.
- Storm surge inundation from hurricanes and storms can cause standing water and results in public safety risks, including health risks from waterborne diseases.
- Sea level rise will cause increased risk of storm surge flooding.
- "Sunny day flooding" (frequent tidal flooding events) results in damages, public safety concerns, health risks, and accessibility concerns as described above.
- Note that for all problems described above, the source of inundation is from the Condado Lagoon.

Opportunities are positive conditions in the study area that may result from implementation of a Federal project.

1.3 Objectives

The Federal objective, as stated in the P&G, is to contribute to national economic development (NED) consistent with protecting the nation's environment, pursuant to national environmental statutes, applicable executive orders, and other Federal planning requirements. Contributions to NED are increases in the net value of the national output of goods and services, expressed in monetary units. Contributions to NED are the direct net economic benefits that accrue in the study area and the rest of the nation.

The Federal objective is to maximize net benefits to the nation, and as such, it does not seek to identify specific targets within objectives. For example, targeting a pre-defined storm frequency (100-year storm) relative to the storm damage reduction objective would be inappropriate. Rather, the planning process includes formulation of alternative plans to maximize benefits relative to costs. The Federal objective to maximize net benefits would supersede any project-specific target output.

The overarching goal of this study is to formulate alternatives for coastal study risk management to determine if Federal participation in reduction of the damage to infrastructure caused by storm surge within the study area is warranted and economically justified.

1.4 Constraints

A constraint is a restriction that limits the extent of the planning process; it is a statement of effects that alternative plans should avoid. Constraints are designed to avoid undesirable changes between without and with-project future conditions. The planning constraint for this study area is to avoid conflict with Federal regulations, as stated in Federal law, USACE regulations, and executive orders.

Local and state laws do not constrain NED formulation. However, they may be considered in the selection of a Locally Preferred Plan (LPP).

1.5 Performance Metrics, Data Sources, & Models

1.5.1 Models

The 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 of different types that may interact hydraulically and may be defended by coastal defense elements that serve to shield the areas and the assets they contain from storm damage. The model is scalable in that different levels of detail can be used for the data that drives the model, with lower levels of detail at early stages of model application (fewer storms, aggregated assets) and more refined representations used as new data become available.

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.

Within each general component category (e.g. PSEs, MAs, Assets), different element types exist with data needs specific to that type. Due to the object-oriented paradigm of the model, it is relatively simple to add new elements and change the characterization and behavior of existing model elements, for example to add a more sophisticated approach to rebuilding for assets.

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 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.

2 Inventory of Existing Conditions

2.1 Structure Inventory

The San Juan Metro structure developed based on geospatial data provided by SAJ GIS personnel. Data sources used to assemble the structure inventory include the following:

- Puerto Rico US Geological Survey (USGS) 2015 1m x 1m LiDAR Digital Elevation Model (DEM) & Digital Surface Model (DSM);
- Humanitarian OpenStreetMap Team (HOTOSM) Puerto Rico Buildings (OpenStreetMap Export)

The building polygons were horizontally projected and aligned base on the DSM and aerial images. Some polygons were manually digitized due to incomplete data. The digital terrain model was subtracted from the digital surface model to estimate building heights. The number of floors per building was obtained using zonal statistics and verified by comparing a sample of 30 polygons per area of interest to Google Maps aerial im ages. Google Maps was also used to assign the occupancy type for each building. Building square footage was determined using the building polygons and a sample of 30 polygons were randomly selected in order to determine the error in the estimate. The DTM was also used along with the building footprints to determine the building grade elevation.

The aforementioned spatial data was compiled into a format suitable for use with G2CRM. Buildings were organized into the occupancy type categories listed in Table 2-1. Asset general occupancy groupings are as follows:

- COM – Commercial structures & non-residential buildings
- COMM – Community centers, churches
- GOV – Publically owned buildings
- HOSP – Hospitals, clinics, & medical offices
- MFR – Multi-family residential structures
- SFR – Single-family residential structures
- ES – Empty Structures (Vacant buildings)
- AUTOS - Vehicles
- SHED, TRAILER, GAZEBO – Indicative of non-engineered assets such as gazebos, and storage buildings.

A suffix was concatenated to the occupancy code to denote the number of floor range and construction profile. The following bulleted list shows the number of stories along with the construction assumptions:

- SS – Single Story masonry, slab on grade buildings
- MS - Multistory (2 to 4 stories) Masonry slab on grade assets
- MR – Midrise (5 to 9 stories) reinforced masonry slab on grade buildings
- HR – High-rise (10 stories or greater) reinforced masonry high rise buildings with basements / subterranean value.

Based on site visits, accounts from SAS real estate personnel, and consultations with locals most asset 1st floor elevations tend to be within 8” of the grade. Structure values were developed by SAS real estate personnel and are based on a sample of the compiled asset data. All structure value is comprised of depreciated replacement cost represented in FY 2020 price levels.

Vehicles were represented as geospatial point shape features superimposed on assets with SFR and MFR occupancy categorizations. Vehicle values were obtained using the National Structure Inventory (NSI) version 1.0 for the San Juan Puerto Rico and are based on the median vehicle value for a single family residence. It is assumed that just around 27% of vehicles receive damages during storm events.

Table 2-1: Damage Element Occupancy Types

Occupancy Type	Occupancy Type Description
COM-HR	Commercial Bldg High Rise
COMM-MR	Community Center Bldg Mid-Rise
COMM-MS	Community Center Bldg Multi-Story
COM-MR	Commercial Bldg Mid-Rise
COM-MS	Commercial Bldg Multi-Story
COMM-SS	Community Center Bldg Single Story
COM-SS	Commercial Bldg Single Story
ES-MS	Vacant Multi-Story
ES-SS	Vacant Single Story
GAZEBO-SS	Gazebo Single Story
GOV-HR	Government Bldg High Rise
GOV-MR	Government Bldg Mid-Rise
GOV-MS	Government Bldg Multi-Story
GOV-SS	Government Bldg Single Story
HOSP-MR	Hospital Medical Bldg Mid-Rise
HOSP-MS	Hospital Medical Bldg Multi-Story
HOSP-SS	Hospital Medical Bldg Single Story
MFR-HR	Multi-Family Residence High Rise
MFR-MR	Multi-Family Residence Mid-Rise
MFR-MS	Multi-Family Residence Multi-Story
MFR-SS	Multi-Family Residence Single Story
SFR-MS	Single Family Residence Multi-Story
SFR-SS	Single Family Residence Single Story
SHED-MS	Sheds Multi-Story
SHED-SS	Sheds Single Story
TRAILERS-MS	Trailers Multi-Story
TRAILERS-SS	Trailers Single Story
GAZEBO-MS	Gazebo Multi-Story
AUTO-MFR-HR	Vehicles for Multi-Family Residence High Rises
AUTO-MFR-MR	Vehicles for Multi-Family Residence Mid-Rises
AUTO-MFR-MS	Vehicles for Multi-Family Residence Multi-Story Assets
AUTO-MFR-SS	Vehicles for Multi-Family Residence Single Story Assets
AUTO-SFR-MS	Vehicles for Single Family Residence Multi-Story Assets
AUTO-SFR-SS	Vehicles for Single Family Residence Single Story Assets

2.2 Depth Damage Functions

Occupancy and number of stories were the chief determinants in assigning structure damage functions while the occupancy of the 1st livable level closest to the grade was the determining factor for content damage function assignments. The reason for this is that a number of assets have mixed use occupancy designations in densely populated urban environments.

NACCS and IWR non-residential depth damage functions were used to describe flood damages to buildings for the San Juan Metro Study. Depth damage function for vehicles was based on the EGM 09-04 Generic Depth Damage Relationships for Vehicles. Table 2-2 and Table 2-3 provides detail on the NACCS and IWR damage functions respectively. Table 4 and Table 5 show the distribution of damages and content to structure value ratios (CSVR) by occupancy type.

Table 2-2:NACCS Damage Functions Considered

Inundation Damage Function	General Occupancy	Description	Structure Damage Function Table #	Content Damage Function Table #
NACCS-Prototype-1A-1	Residential	Apartments : One-Story: No Basement	12	13
NACCS-Prototype-1A-3	Residential	Apartments : Three-Stories: No Basement	22	23
NACCS-Prototype-2	Commercial	Commercial-Engineered	25	26,27
NACCS-Prototype-3	Commercial	Commercial-Non-Engineered	35	36,37
NACCS-Prototype-4A	Residential / Commercial	Urban High Rise	46	47
NACCS-Prototype-4B	Residential / Commercial	Beach High Rise	49	50
NACCS-Prototype-5A	Residential	Single Story Residence: No Basement	56	57
NACCS-Prototype-5B	Residential	Two Story Residence: No Basement	67	68
NACCS-Prototype-6A	Residential	Single Story Residence: Basement	75	76
NACCS-Prototype-6B	Residential	Two Story Residence: Basement	83	84
NACCS-Prototype-7A	Residential	Building on Open Pile Foundation	91	92
NACCS-Prototype-7B	Residential	Building on Enclosed Pile Foundation	99	100

Table 2-3: IWR Nonresidential Flood Depth Damage Functions

Inundation Damage Function	General Occupancy	Description	Structure Damage Function Tables	Content Damage Function Tables	Source
IWR-Prototype-1	Public	Apartment Buildings	D-1	D-43	IWR: Nonresidential Flood Depth Damage Functions Derived from Expert Elicitation
IWR-Prototype-2	Commercial	Large Grocery Store, One-Story	D-2	D-44	
IWR-Prototype-3	Commercial	Convenience Store; One-Story	D-3	D-45	
IWR-Prototype-4	Commercial	Hotel/Motel: One-Story	D-4	D-46	
IWR-Prototype-5	Commercial	Medical Office: One-Story	D-5	D-47	
IWR-Prototype-6	Commercial	Hospital: One-Story	D-6	D-48	
IWR-Prototype-7	Commercial	Office Building: One-Story	D-7	D-49	
IWR-Prototype-8	Commercial	Fast Food Restaurant: One-Story	D-8	D-50	
IWR-Prototype-9	Commercial	Non-Fast Food Restaurant: One-Story	D-9	D-51	
IWR-Prototype-10	Commercial	Electronic Retail Store: One-Story	D-10	D-52	
IWR-Prototype-11	Commercial	Furniture Retail Store: One-Story	D-11	D-53	
IWR-Prototype-12	Commercial	Clothing Retail Store: One-Story	D-12	D-54	
IWR-Prototype-13	Commercial	Service Station: One-Story	D-13	D-55	
IWR-Prototype-14	Industrial	Industrial Light Manufacturing: One-Story	D-14	D-56	
IWR-Prototype-15	Industrial	Warehouse, Non-Refrigerated: One Story	D-15	D-57	
IWR-Prototype-16	Industrial	Warehouse, Refrigerated: One-Story	D-16	D-58	
IWR-Prototype-17	Public	Correctional Facility: One Story	D-17	D-59	
IWR-Prototype-18	Public	Protective Services: One Story	D-18	D-60	
IWR-Prototype-19	Community	Recreational Facility: One-Story	D-19	D-61	
IWR-Prototype-20	Community	Religious Facility: One-Story	D-20	D-62	
IWR-Prototype-21	Educational	School, One Story	D-21	D-63	

Table 4: Damage Functions & CSVRs by Occupancy Type (Part 1)

Occupancy	Damage Category	Description	Structure	Contents	CSVR
COM-HR	COM	Commercial Bldg High Rise	NACCS-Prototype-4A	NACCS-Prototype-4A	0.38
COMM-MR	COMM	Community Center Bldg Mid-Rise	NACCS-Prototype-4A	NACCS-Prototype-4A	0.13
COMM-MS	COMM	Community Center Bldg Multi-Story	NACCS-Prototype-2	IWR COMM Contents Composite DDF	0.13
COM-MR	COM	Commercial Bldg Mid-Rise	NACCS-Prototype-4A	NACCS-Prototype-4A	0.38
COM-MS	COM	Commercial Bldg Multi-Story	NACCS-Prototype-2	IWR COM Contents Composite DDF	0.38
COMM-SS	COMM	Community Center Bldg Single Story	IWR-Prototype-19	IWR COMM Contents Composite DDF	0.13
COM-SS	COM	Commercial Bldg Single Story	NACCS-Prototype-2	IWR COM Contents Composite DDF	0.38
ES-MS	MFR	Vacant Multi-Story	NACCS-Prototype-2	NULL	0.00
ES-SS	MFR	Vacant Single Story	NACCS-Prototype-2	NULL	0.00
GAZEBO-SS	IND	Gazebo Single Story	NACCS-Prototype-3	NULL	0.37
GOV-HR	GOV	Government Bldg High Rise	NACCS-Prototype-4A	NACCS-Prototype-4A	0.47
GOV-MR	GOV	Government Bldg Mid-Rise	NACCS-Prototype-4A	NACCS-Prototype-4A	0.47
GOV-MS	GOV	Government Bldg Multi-Story	NACCS-Prototype-2	IWR GOV Contents Composite DDF	0.47
GOV-SS	GOV	Government Bldg Single Story	NACCS-Prototype-2	IWR GOV Contents Composite DDF	0.47
HOSP-MR	HOSP	Hospital Medical Bldg Mid-Rise	NACCS-Prototype-4A	IWR HOSP Contents Composite DDF	0.21
HOSP-MS	HOSP	Hospital Medical Bldg Multi-Story	NACCS-Prototype-1A-3	IWR HOSP Contents Composite DDF	0.21
HOSP-SS	HOSP	Hospital Medical Bldg Single Story	IWR-Prototype-6	IWR HOSP Contents Composite DDF	0.21

Table 5: Damage Functions & CSVRs by Occupancy Type (Part 2)

Occupancy	Damage Category	Description	Structure	Contents	CSVR
MFR-HR	MFR	Multi-Family Residence High Rise	NACCS-Prototype-4A	NACCS-Prototype-4A	0.10
MFR-MR	MFR	Multi-Family Residence Mid-Rise	NACCS-Prototype-4A	NACCS-Prototype-4A	0.10
MFR-MS	MFR	Multi-Family Residence Multi-Story	NACCS-Prototype-1A-3	NACCS-Prototype-1A-3	0.10
MFR-SS	MFR	Multi-Family Residence Single Story	NACCS-Prototype-1A-1	NACCS-Prototype-1A-1	0.10
SFR-MR	SFR	Single Family Residence Mid-Rise	NACCS-Prototype-5B	NACCS-Prototype-5B	0.50
SFR-MS	SFR	Single Family Residence Multi-Story	NACCS-Prototype-5B	NACCS-Prototype-5B	0.50
SFR-SS	SFR	Single Family Residence Single Story	NACCS-Prototype-5A	NACCS-Prototype-5A	0.50
SHED-MS	IND	Sheds Multi-Story	NACCS-Prototype-3	IWR IND Contents Composite DDF	0.37
SHED-SS	IND	Sheds Single Story	NACCS-Prototype-3	IWR IND Contents Composite DDF	0.37
TRAILERS-MS	IND	Trailers Multi-Story	NACCS-Prototype-3	IWR IND Contents Composite DDF	0.37
TRAILERS-SS	IND	Trailers Single Story	NACCS-Prototype-3	IWR IND Contents Composite DDF	0.37
GAZEBO-MS	IND	Gazebo Multi-Story	NACCS-Prototype-3	NULL	0.00

2.3 Structure Inventory Profile by Planning Reach

The damage element inventory contains 19,675 damageable structures with an estimated value of $3.83B, with structure and content valuations of $2.72B and $1.11B respectively. The following sections break down structure inventory by planning reach.

2.3.1 Reach 1 – West San Juan Bay

West San Juan Bay consists of 17,973 separable damage elements with an overall estimated value of $3.14B, with structure and content valuations of $2.21B and $933M respectively. The structure and content value distribution within West San Juan Bay is broken down by occupancy type in Table 2-5.

Table 2-6: West San Juan Bay future without-project damages by Occupancy Type

Occupancy Type	Count of Occupancy Type	Existing Content Value	Existing Structure Value	Percent of Total in Reach
AUTO-MFR-HR	2	$0.00	$271,454.40	0.01%
AUTO-MFR-MR	4	$0.00	$155,116.80	0.02%
AUTO-MFR-MS	545	$0.00	$66,583,886.40	3.03%
AUTO-MFR-SS	28	$0.00	$361,939.20	0.16%
AUTO-SFR-MS	3366	$0.00	$21,755,131.20	18.73%
AUTO-SFR-SS	4450	$0.00	$28,761,240.00	24.76%
COM-HR	5	$15,354,625.12	$40,836,770.23	0.03%
COMM-MS	80	$1,773,350.00	$14,000,000.00	0.45%
COM-MR	27	$20,826,927.70	$55,390,755.88	0.15%
COM-MS	495	$64,562,288.28	$171,708,075.00	2.75%
COMM-SS	63	$1,396,511.67	$11,025,000.00	0.35%
COM-SS	309	$40,302,516.12	$107,187,465.00	1.72%
ES-SS	1	$0.00	$450,000.00	0.01%
GAZEBO-MS	1	$0.00	$0.00	0.01%
GAZEBO-SS	11	$952,380.00	$2,574,000.00	0.06%
GOV-HR	2	$7,595,640.00	$16,334,708.09	0.01%
GOV-MR	8	$7,631,616.00	$16,412,075.82	0.04%
GOV-MS	111	$51,615,000.00	$111,000,000.00	0.62%
GOV-SS	67	$31,155,000.00	$67,000,000.00	0.37%
HOSP-MS	2	$0.00	$0.00	0.01%
HOSP-SS	1	$82,779.00	$403,800.00	0.01%
MFR-HR	2	$1,633,470.00	$16,334,708.09	0.01%
MFR-MR	4	$3,282,415.95	$8,206,037.91	0.02%
MFR-MS	545	$9,537,500.00	$95,375,000.00	3.03%
MFR-SS	28	$490,000.00	$4,900,000.00	0.16%
SFR-MS	3366	$290,580,541.77	$581,162,959.12	18.73%
SFR-SS	4450	$384,160,290.69	$768,322,985.17	24.76%
Total	**17973**	**$932,932,852.30**	**$2,206,513,108.31**	**100%**

West San Juan Bay (WSJB) is broken up further into eleven (11) sub-reaches. These sub-reaches are described in detail below, and the overall content and structure value distribution within the reach is displayed in Figure 2-2.

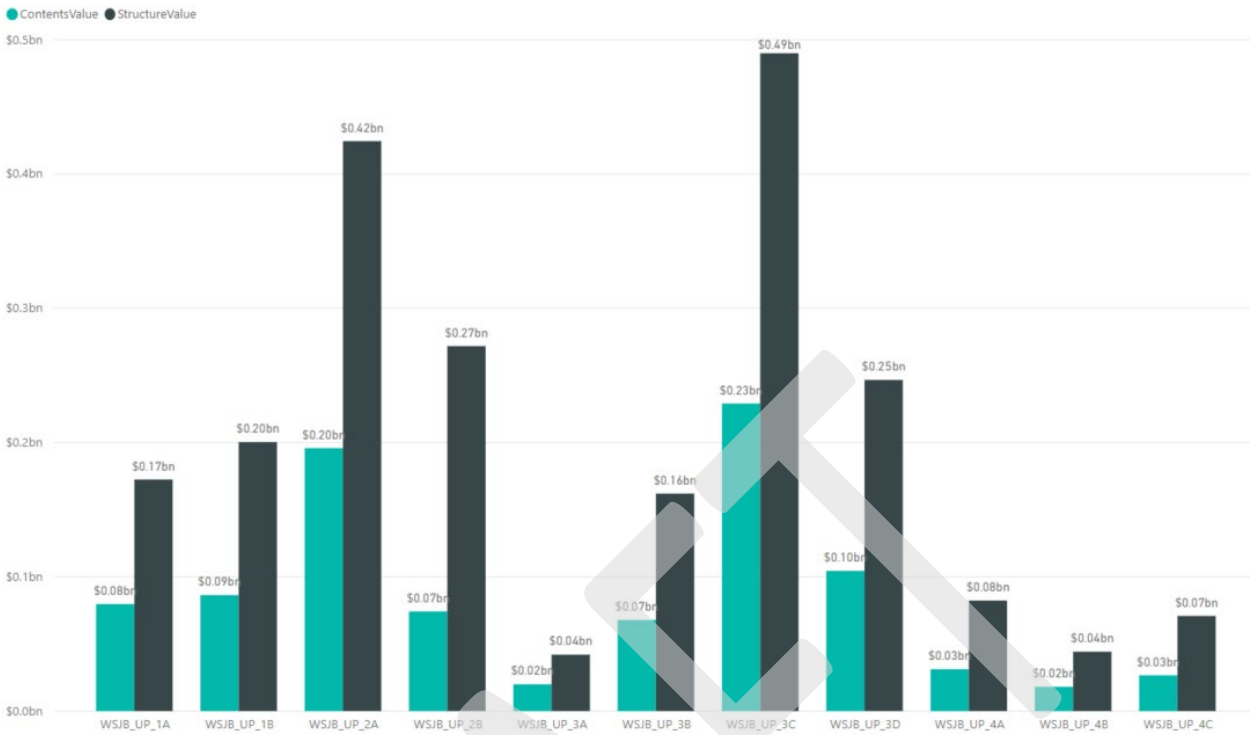


Figure 2-1: Existing content and structure values for West San Juan Bay sub-reaches

2.3.1.1 West San Juan Bay 1

WSJB 1 has two sub areas. 1A contains 420 government, commercial, community and residential damage elements. The overall estimated value totals $252M, with structure and content valuations of $172M and $79M respectively. 1B contains 1,781 government, commercial, community and residential damage elements. The overall estimated value totals $286M, with structure and content valuations of $200M and $86M respectively.

2.3.1.2 West San Juan Bay 2

WSJB2 has two sub areas. 2A contains 4,296 government, commercial, community, hospital and residential damage elements. The overall estimated value totals $620M, with structure and content valuations of $424M and $196M respectively. 2B contains 2,327 government, commercial, community, and residential damage elements. The overall estimated value totals $346M, with structure and content valuations of $272M and $74M respectively.

2.3.1.3 West San Juan Bay 3

WSJB3 has four sub areas. 3A contains 428 government, commercial, community, and residential damage elements. The overall estimated value totals $62M, with structure and content valuations of $42M and $20M respectively. 3B contains 1,287 government, commercial, community, hospital and residential damage elements. The overall estimated value totals $230M, with structure and content valuations of $162M and $68M respectively. 3C contains 5,227 government, commercial, community, and residential damage elements. The overall estimated value totals $719M, with structure and content valuations of $490M and $229M respectively. 3D contains 1,778 government, commercial, community, and residential damage elements. The overall estimated value totals $351M, with structure and content valuations of $247M and $104M respectively.

2.3.1.4 West San Juan Bay 4

WSJB4 has three sub areas. 4A contains 205 government, commercial and residential damage elements. The overall estimated value totals $113M, with structure and content valuations of $82M and $31M respectively. 4B contains 64 government, commercial, and community damage elements. The overall estimated value totals $62M, with structure and content valuations of $44M and $18M respectively. 4C contains 160 commercial damage elements. The overall estimated value totals $97M, with structure and content valuations of $71M and $27M respectively.

2.3.2 Reach 2 – East San Juan Bay

East San Juan Bay consists of 480 separable damage elements with an overall estimated value of $476M, with structure and content valuations of $342M and $134M respectively. The structure and content value distribution within Condado Lagoon is broken down by occupancy type in Table 2-4.

Table 2-7: East San Juan Bay future without-project damages by Occupancy Type

Occupancy Type	Count of Occupancy Type	Existing Content Value	Existing Structure Value	Percent of Total in Reach
AUTO-MFR-HR	4	$0.00	$25,852.80	0.83%
AUTO-MFR-MR	4	$0.00	$25,852.80	0.83%
AUTO-MFR-MS	39	$0.00	$252,064.80	8.13%
AUTO-MFR-SS	1	$0.00	$6,463.20	0.21%
AUTO-SFR-MS	39	$0.00	$252,064.80	8.13%
AUTO-SFR-SS	34	$0.00	$219,748.80	7.08%
COM-HR	5	$8,165,917.73	$21,717,866.31	1.04%
COMM-MS	4	$520,068.02	$4,105,800.12	0.83%
COM-MR	18	$13,479,780.26	$35,850,479.41	3.75%
COM-MS	50	$18,168,418.50	$48,320,261.97	10.42%
COMM-SS	2	$33,205.89	$262,151.75	0.42%
COM-SS	58	$13,003,279.92	$34,583,191.27	12.08%
ES-SS	2	$0.00	$0.00	0.42%
GOV-MR	6	$10,311,933.90	$22,176,201.93	1.25%
GOV-MS	42	$49,245,884.59	$105,905,128.15	8.75%
GOV-SS	50	$15,176,372.93	$32,637,361.14	10.42%
HOSP-MS	1	$942,819.09	$4,599,117.50	0.21%
MFR-HR	4	$1,160,779.26	$11,607,792.62	0.83%
MFR-MR	4	$473,600.04	$4,736,000.36	0.83%
MFR-MS	39	$1,014,758.28	$10,147,582.84	8.13%
MFR-SS	1	$14,398.84	$143,988.38	0.21%
SFR-MS	39	$1,335,560.15	$2,671,120.29	8.13%
SFR-SS	34	$1,157,888.52	$2,315,777.04	7.08%
Total	**480**	**$134,204,665.92**	**$342,561,868.28**	**100%**

This planning reach is broken up further into six sub-reaches, the content and structure value distribution is displayed below in Figure 2-1. East San Juan Bay (ESJB) 1A, 1B and 2A are predominantly

commercial and government structures (18, 28 and 34 damage elements, respectively). ESJB 1C, 2B and 2C additionally have residential, hospital and community structures in addition to commercial and governmental (174, 197 and 29 damage elements, respectively).

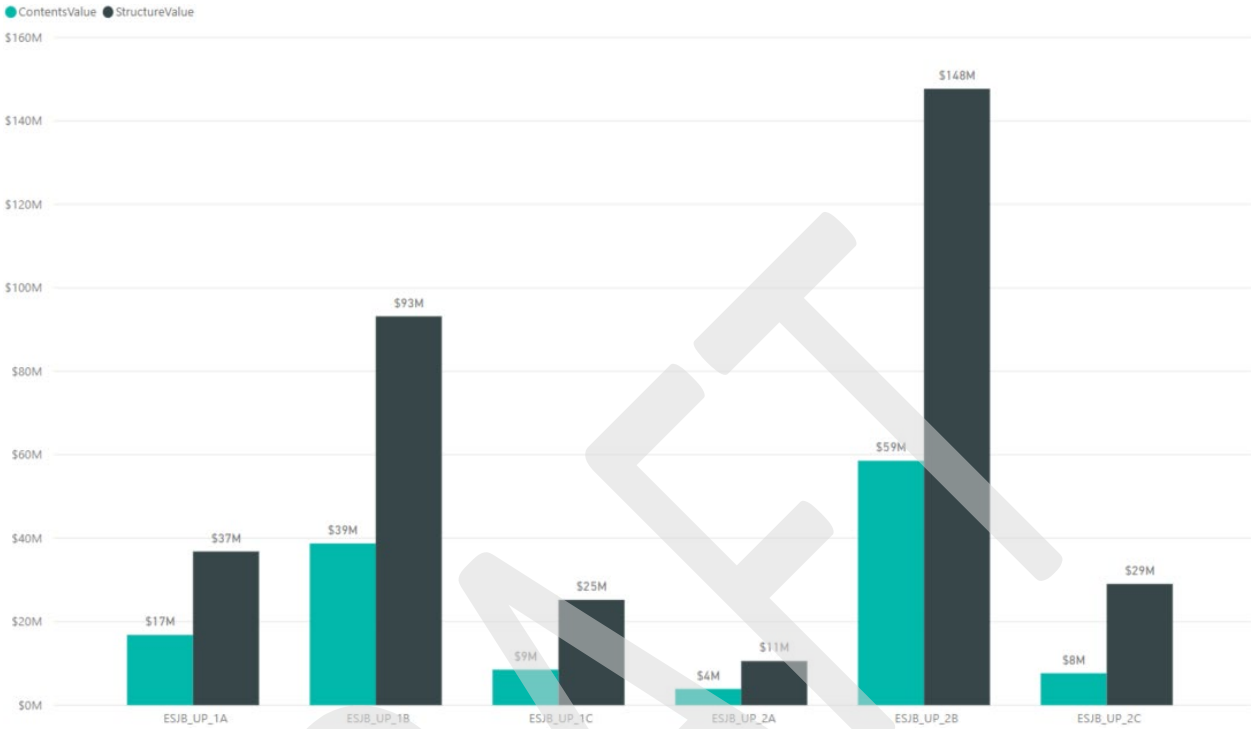


Figure 2-2: Existing content and structure values for East San Juan Bay sub-reaches

2.3.3 Reach 3 – Condado Lagoon

Condado Lagoon consists of 1,222 separable damage elements with an overall estimated value of $208M, with structure and content valuations of $169M and $39M respectively. The structure and content value distribution within Condado Lagoon is broken down by occupancy type in Table 2-3.

Table 2-8: Condado Lagoon future without-project damages by Occupancy Type

Occupancy Type	Count of Occupancy Type	Existing Content Value	Existing Structure Value	Percent of Total in Reach
AUTO-MFR-HR	64	$0.00	$3,729,266.40	5.24%
AUTO-MFR-MR	59	$0.00	$2,478,637.20	4.83%
AUTO-MFR-MS	152	$0.00	$6,385,641.60	12.44%
AUTO-MFR-SS	11	$0.00	$142,190.40	0.90%
AUTO-SFR-MS	161	$0.00	$1,040,575.20	13.18%
AUTO-SFR-SS	101	$0.00	$652,783.20	8.27%
COM-HR	4	$1,977,453.00	$5,259,184.33	0.33%
COMM-MS	14	$1,565,511.00	$12,359,290.01	1.15%
COM-MR	10	$2,083,831.00	$5,542,105.89	0.82%
COM-MS	52	$6,254,331.00	$16,633,863.37	4.26%
COMM-SS	8	$96,270.00	$760,025.55	0.65%
COM-SS	30	$2,123,528.00	$5,647,673.26	2.45%
GAZEBO-SS	2	$41,869.00	$113,161.76	0.16%

GOV-MS	2	$390,396.00	$839,562.05	0.16%
GOV-SS	3	$43,055.00	$92,591.00	0.25%
HOSP-MS	1	$46,763.00	$228,114.21	0.08%
MFR-HR	64	$4,058,047.00	$40,580,476.97	5.24%
MFR-MR	59	$1,054,218.00	$10,542,220.90	4.83%
MFR-MS	152	$1,905,738.00	$19,057,413.92	12.44%
MFR-SS	11	$232,944.00	$2,329,450.48	0.90%
SFR-MS	161	$11,298,335.00	$22,596,660.55	13.18%
SFR-SS	101	$6,133,902.00	$12,267,801.84	8.27%
Total	**1222**	**$ 39,306,191.00**	**$ 169,278,690.09**	**100%**

57.53% of structures in this planning reach are single story, predominantly slab foundation (43.94%)

2.4 Structure Inventory Uncertainties

The structure inventory was compiled using virtual databases and Google Earth. Data used may not be up to date to include new structures, vacant buildings and lots or correct occupancy types.

3 Forecast of Conditions (FWOP)

3.1 FWOP Condition Assumptions

Assumptions made for the future without project condition (FWOP)

- Start Year: 2020
- Base Year: 2029[1]
- Number of Iterations: 5[2]
- Duration: 55 years
- SLC Rate: 0.0066929 / Intermediate

3.1.1 Life Loss Assumptions

Data sources:

1) National Structure Inventory 1.0 for Puerto Rico
2) NOAA National Storm Surge Hazard Map ArcGIS Story Map for Puerto Rico and U.S. Virgin Islands
3) Online Puerto Rico Seismic Network Tsunami Program Flood and Evacuation Maps

National Structure Inventory (NSI) data for Puerto Rico was used to determine population per occupancy type over and under 65 years old, during the day and night. Data was averaged per study reach for each FEMA-occupancy type, and was then converted into the USACE-defined occupancy types used in the structure inventory. These values were then assigned to the assets within the structure inventory. Assets with unique population values (schools, hospitals, etc.) were researched to find the actual population values. This was unsuccessful for some assets.

[1] Base year was originally 2025 and was updated to 2029 based on construction durations

[2] Damages presented for FWOP are from 5-iteration model runs and are a good representation of damages. 50-iteration model runs will be used for refined benefits analysis

There have been mandatory evacuations due to hurricanes in Puerto Rico, recorded for Hurricanes Maria (2017) and Hugo (1989). Both hurricanes were category 4 upon landfall in Puerto Rico. The evacuation for Hugo was determined based on the SLOSH decision-arc methodology, whereas the evacuation for Maria was due to the storm's proximity to Hurricane Irma (2017, category 5 upon landfall) that struck the island only two weeks prior. Other recorded evacuations indicated that 28,000+ people evacuated for Hurricane Georges (1998, category 4) although no evacuation orders were issued. Hurricane Jeanne (2004, category 3) triggered an evacuation near Río Grande De Añasco, but only after rainfall caused damages to roadways and bridges.

Storm surge hazard maps are available for the study area displaying flooding vulnerability during a hurricane for all five category storms. Historically, evacuations have not been issued for storms categorized below a category 3. Using the National Storm Surge Hazard Maps for San Juan, water levels that would trigger evacuation orders can be determined for each study area from category 3 and above storms. For example, Condado Lagoon experiences levels less than 3 ft above ground for a majority of the study area up through a category 3 storm. Once a category 4 storm is mapped, over half of the Evacuation Planning Zone is inundated with levels over 3 ft.

There are no evacuation plans set in Puerto Rico based off of storm surge levels. Current evacuation plans put in place are for a tsunami, with designated evacuation areas, routes, assembly areas and siren locations. The sensors used for the tsunami warning system record and analyze seismic activity, only reporting activity measuring 4.5 or higher on the Richter scale. However, seismic activity does not always correlate to a tsunami or definite change in water level.

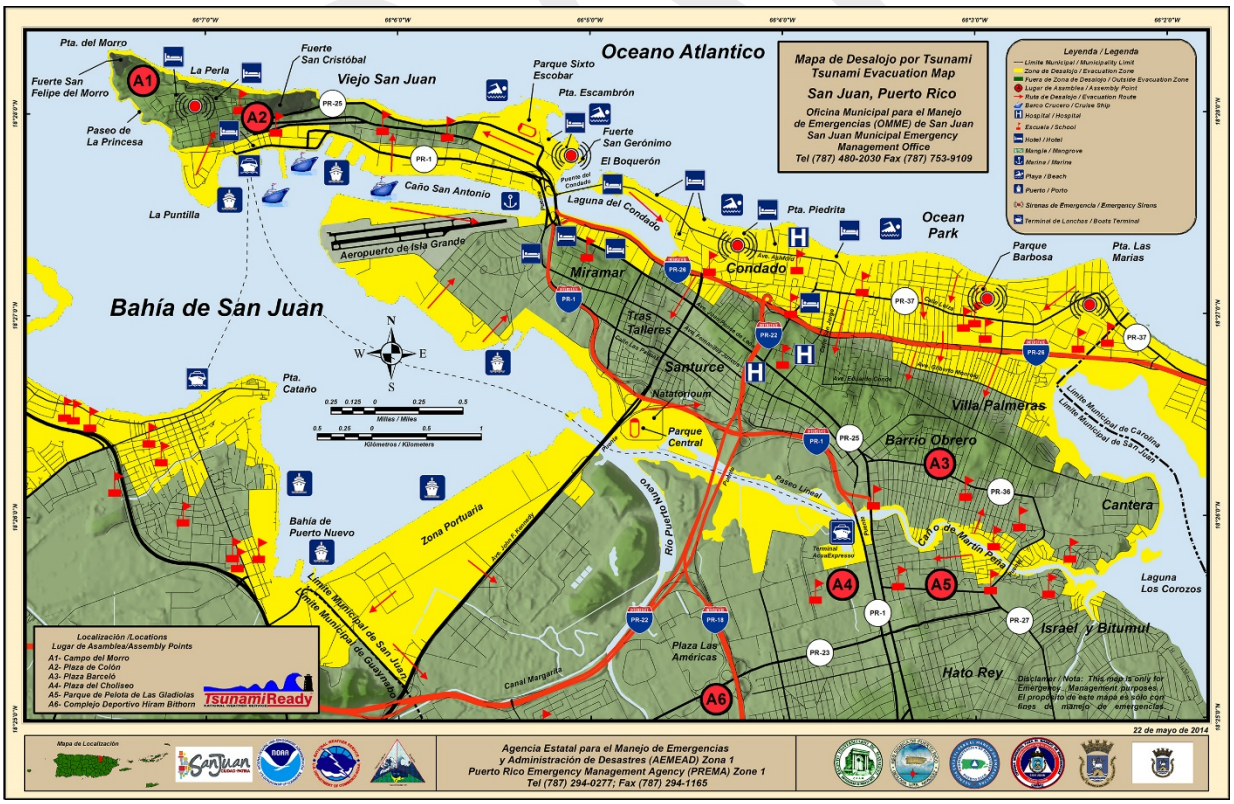


Figure 3-1: Tsunami evacuation map for San Juan, Puerto Rico

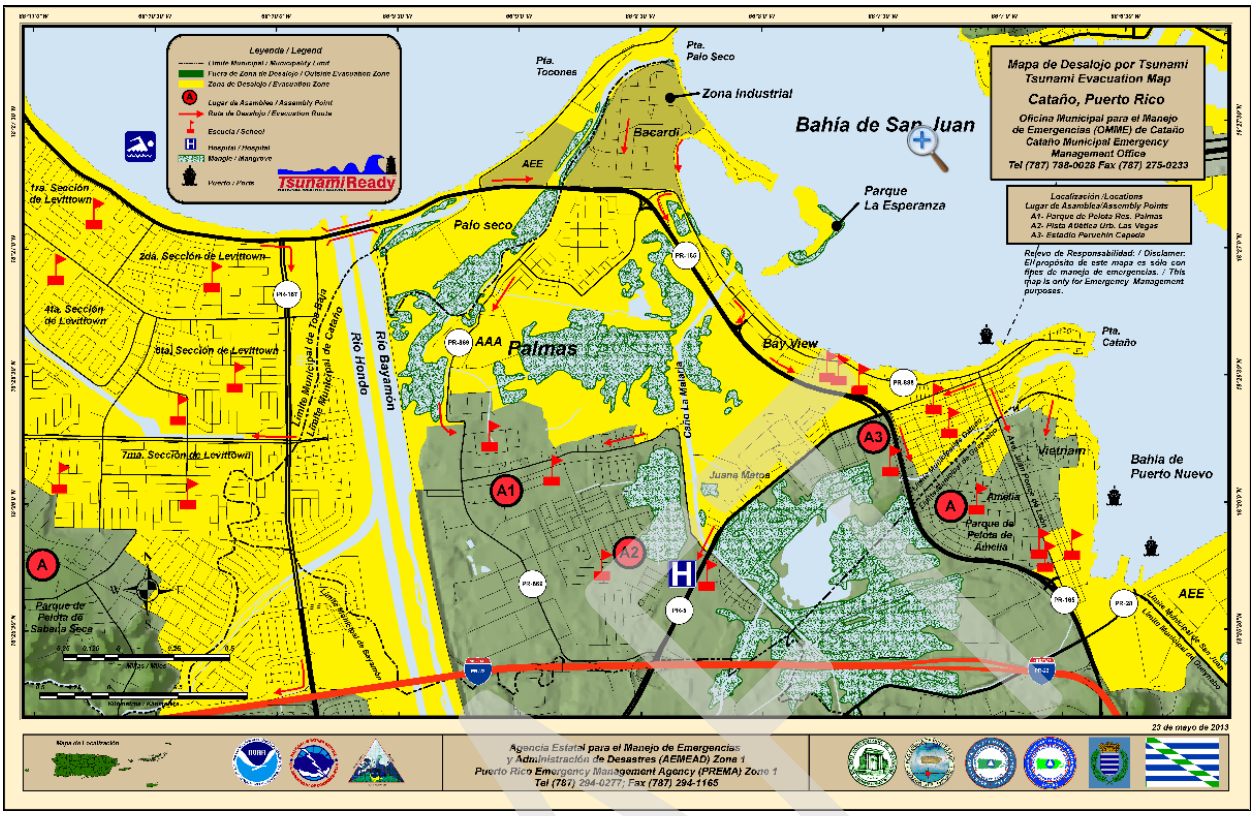


Figure 3-2: Tsunami evacuation map for San Juan, Puerto Rico

3.2 FWOP Condition Damages

3.2.1 FWOP: Overall Damage Statistics

50 iteration model runs for future without-project conditions across the study area modeled a range of damages between $1.6B and $3.6B in present value dollars. Descriptive statistics on the FWOP models are displayed in Table 3-1. Figure 3-2 shows the distribution of PV damages by model area and sub-reach.

Table 3-1: Future without-project condition damages

Model Area	Minimum Value	Lower Quantile	Median Value	Upper Quantile	Maximum Value	Mean PV Damages
Condado Lagoon	$33,638,480.46	$38,709,954.00	$46,652,969.81	$59,183,011.31	$66,362,912.03	$48,698,622.80
East San Juan Bay	$14,344,808.27	$18,166,652.54	$24,189,794.89	$35,491,167.15	$42,063,585.80	$26,576,144.29
West San Juan Bay	$1,621,872,645.55	$1,916,368,643.71	$2,405,674,624.04	$3,060,341,351.94	$3,543,856,322.54	$2,490,720,820.31
Total	**$1,699,855,934.28**	**$1,973,245,250.25**	**$2,476,517,388.74**	**$3,155,015,530.39**	**$3,652,282,820.37**	**$2,565,995,587.41**

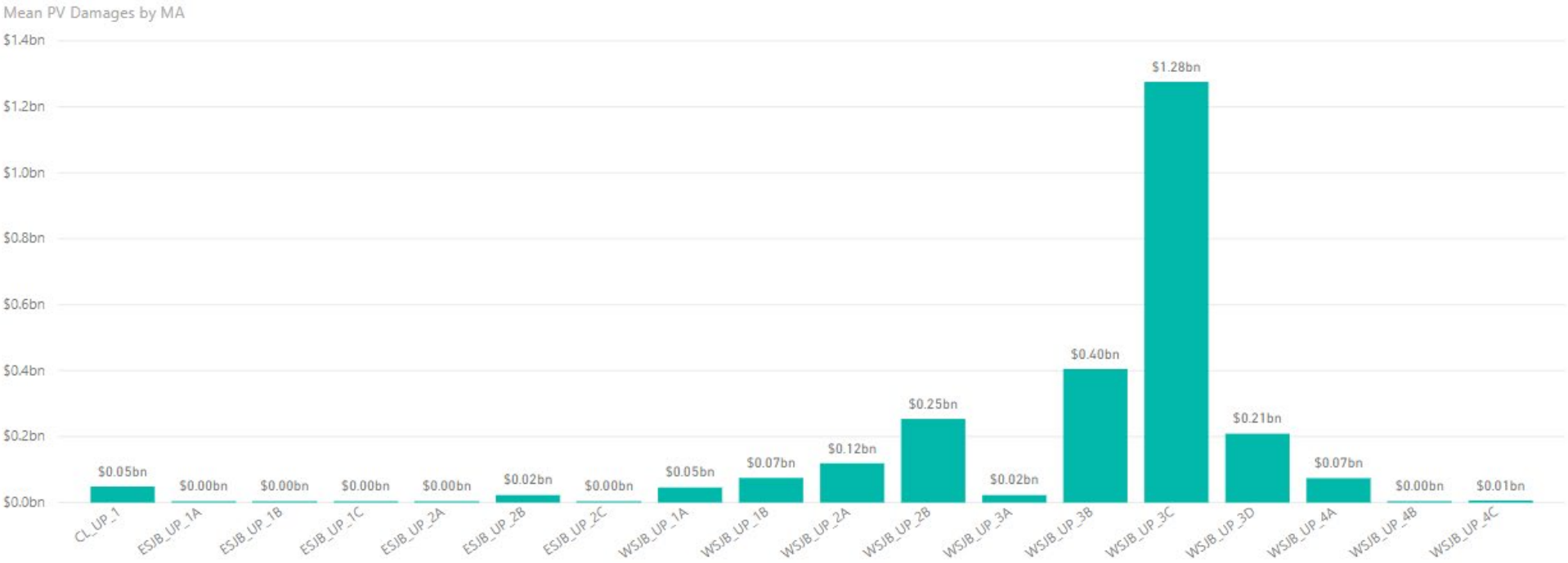


Figure 3-3: Mean PV Damages by Model Area

3.2.1.1 Reach 1 – West San Juan Bay

50 iteration model runs for future without-project conditions across the study area modeled a range of damages between $1.6B and $3.5B in present value dollars. Descriptive statistics on the FWOP models for the WSJB sub-reaches are displayed in Table 3-1.

Table 3-2: West San Juan Bay future without-project condition damages

Model Area	Minimum Value	Lower Quantile	Median Value	Upper Quantile	Maximum Value	Mean PV Damages
WSJB_UP_1A	$22,694,652.00	$29,194,227.98	$40,320,052.67	$62,917,406.80	$79,123,194.49	$45,879,285.62
WSJB_UP_1B	$46,894,065.49	$55,665,945.45	$70,942,425.12	$94,001,889.06	$109,682,629.14	$74,746,504.84
WSJB_UP_2A	$65,917,672.93	$82,967,277.89	$110,116,630.13	$154,162,607.79	$195,156,058.47	$119,269,664.87
WSJB_UP_2B	$154,173,151.62	$180,249,663.88	$229,323,250.48	$323,447,267.44	$413,098,770.97	$253,700,921.75
WSJB_UP_3A	$8,776,015.77	$13,155,210.57	$22,756,910.95	$31,352,307.84	$39,691,537.10	$22,750,393.00
WSJB_UP_3B	$255,862,038.54	$322,292,806.37	$409,060,527.75	$487,522,347.51	$545,257,667.41	$404,868,622.31
WSJB_UP_3C	$898,027,208.63	$1,024,839,423.95	$1,244,970,604.69	$1,526,309,185.40	$1,718,049,146.46	$1,275,946,339.25
WSJB_UP_3D	$134,189,962.01	$156,274,224.84	$201,796,594.44	$261,325,688.47	$298,116,295.21	$208,869,918.60
WSJB_UP_4A	$32,056,442.67	$47,026,857.85	$66,818,632.87	$102,498,479.65	$125,141,354.88	$73,941,107.58
WSJB_UP_4B	$1,720,942.56	$1,972,080.12	$4,293,022.12	$6,276,938.36	$7,168,745.04	$4,222,278.73
WSJB_UP_4C	$1,560,493.32	$2,730,924.80	$5,275,972.82	$10,527,233.64	$13,370,923.37	$6,525,783.76
Total	**$1,621,872,645.54**	**$1,916,368,643.70**	**$2,405,674,624.04**	**$3,060,341,351.96**	**$3,543,856,322.54**	**$2,490,720,820.31**

3.2.1.2 Reach 2 – East San Juan Bay

50 iteration model runs for future without-project conditions across the study area modeled a range of damages between $14.3M and $42.1M in present value dollars. Descriptive statistics on the FWOP models for the ESJB sub-reaches are displayed in Table 3-3.

Table 3-3: East San Juan Bay future without-project condition damages

Model Area	Minimum Value	Lower Quantile	Median Value	Upper Quantile	Maximum Value	Mean PV Damages
ESJB_UP_1A	$53,449.44	$555,878.06	$930,307.50	$2,268,805.58	$3,029,669.40	$1,341,778.48
ESJB_UP_1B	$222,385.65	$294,876.64	$551,632.37	$574,639.87	$589,234.70	$452,343.46
ESJB_UP_1C	$18,914.84	$47,101.35	$99,072.05	$405,073.70	$629,188.54	$220,277.26
ESJB_UP_2A	$173,990.09	$313,835.53	$613,282.89	$1,547,454.69	$2,118,268.46	$910,269.50
ESJB_UP_2B	$13,396,354.57	$16,373,215.91	$21,235,225.12	$29,512,702.37	$34,291,283.44	$22,781,584.31
ESJB_UP_2C	$479,713.68	$581,745.07	$760,274.97	$1,182,490.93	$1,405,941.26	$869,891.29
Total	**$14,344,808.27**	**$18,166,652.56**	**$24,189,794.90**	**$35,491,167.14**	**$42,063,585.80**	**$26,576,144.30**

3.2.1.3 Reach 3 – Condado Lagoon

The future without project damages across the Condado Lagoon study area ranged between $33.6 M and $66.4 M present value dollars. Descriptive statistics on the FWOP model for Condado Lagoon is displayed in

Table 3-4: Condado Lagoon future without-project condition damages

Model Area	Minimum Value	Lower Quantile	Median Value	Upper Quantile	Maximum Value	Mean PV Damages
Condado Lagoon	$33,638,480.46	$38,709,954.00	$46,652,969.81	$59,183,011.31	$66,362,912.03	$48,698,622.80

3.2.2 FWOP: Damages by Occupancy

Pursuant to estimating future without project condition damages and associated costs for the San Juan Metro study area, G2CRM was used to estimate damages and costs for the following categories:

- Structure Damage: Economic losses resulting from the structures situated within a low-lying area prone to flooding from coastal storms and hurricanes. Structure damages account for approximately 61.7% of the total FWOP damages
- Content Damage: The material items housed within the structures that are potentially subject to damage. Content damages make up approximately 38.3% of the total FWOP damages.

Table 3-4 provides greater detail on the composition of the average FWOP damages by category and damage element type based on the *AssetDamageDetail.csv* model output files

Table 3-5: Distribution of FWOP Damages by Category and Type

Damage Element Type	Average PV Structure Loss	Average PV Contents Loss	Total Loss PV	Percent of Total Loss
AUTO	$71,199,545	$0	$71,199,545	0.56%
COM	$798,441,189	$373,655,901	$1,172,097,177	9.14%
COMM	$30,245,163	$3,521,071	$33,766,215	0.26%
GOV	$715,964,605	$305,209,998	$1,021,174,586	7.96%
HOSP	$2,058,973	$246,596	$2,305,570	0.02%
MFR	$66,542,224	$20,937,050	$87,479,261	0.68%
OTHER	$7,157,974	$0	$7,157,974	0.06%
SFR	$6,221,273,566	$4,204,746,869	$10,426,020,514	81.32%
Total	**$7,912,883,239**	**$4,908,317,485**	**$12,821,200,842**	**100.00%**

3.2.2.1 Single Family Residences (SFR)

Single family residences consist of 1-3 story structures of varying construction type and value. This category accounts for the majority of the damage elements in the study area. 81.23% of the total FWOP damages are associated with the direct damages to these structures and their contents. This damage element type is well distributed across the study area, but has a high concentration in West San Juan Bay.

3.2.2.2 Multi-Family Residences (MFR)

Multi-family residences consist of multi-story structures of varying construction type and value. This category accounts for 0.68% of the total FWOP damages. There is a high concentration of this damage element type in Condado Lagoon as well as West San Juan Bay sub-reach 2.

3.2.2.3 Commercial (COM)

Damages associated with commercial structures and their contents make up 9.14% of the overall FWOP damages. Types of structures associated with this damage element include retail, banks, entertainment, parking and recreation. This damage element type is well distributed across the study area.

3.2.2.4 Government (GOV)

Damages associated with Government buildings and their contents make up 7.96% of the overall FWOP damages

3.2.2.5 Hospital (HOSP)

Damages associated with hospitals and their contents make up only 0.02% of the overall FWOP damages. There were only 5 structures within this category for the entire study area.

3.2.2.6 Other Damage Elements

The remaining structures include AUTO, COMM and OTHER damage element types. The damages associated with these structures and their contents make up a combined 0.88% of the overall FWOP damages

3.2.3 FWOP Damages over Space

There are several reaches within the study area modeled where the FWOP damages are the greatest. West San Juan Bay 3 makes up 83.54% of the overall FWOP damages. FWOP present value damages by study area reach is summarized in Table 3-5.

Table 3-6: FWOP present value damages by Category and Model Area

Model Area	Sub Reach	Average PV Structure Loss	Average PV Contents Loss	Total Loss PV	Percent Total Loss
Condado Lagoon	n/a	$178,329,473	$65,163,431	$243,492,983	1.90%
East San Juan Bay	1A	$5,419,295	$1,289,597	$6,708,893	0.05%
East San Juan Bay	1B	$0	$2,261,695	$2,261,695	0.02%
East San Juan Bay	1C	$891,227	$210,168	$1,101,387	0.01%
East San Juan Bay	2A	$3,497,804	$1,053,532	$4,551,343	0.04%
East San Juan Bay	2B	$74,652,565	$39,255,374	$113,907,923	0.89%
East San Juan Bay	2C	$1,639,598	$2,709,843	$4,349,429	0.03%
West San Juan Bay	1A	$147,145,075	$82,251,308	$229,396,274	1.79%
West San Juan Bay	1B	$233,375,604	$140,356,607	$373,732,385	2.91%
West San Juan Bay	2A	$322,579,884	$273,768,352	$596,348,245	4.65%
West San Juan Bay	2B	$692,306,256	$576,198,189	$1,268,504,401	9.89%
West San Juan Bay	3A	$73,096,371	$40,655,558	$113,751,953	0.89%
West San Juan Bay	3B	$1,324,654,146	$699,688,514	$2,024,342,551	15.78%
West San Juan Bay	3C	$3,903,254,901	$2,467,701,273	$6,370,956,222	49.66%
West San Juan Bay	3D	$649,437,971	$394,911,266	$1,044,349,253	8.14%
West San Juan Bay	4A	$268,786,692	$100,918,828	$369,705,582	2.88%
West San Juan Bay	4D	$10,606,855	$10,504,557	$21,111,413	0.16%
West San Juan Bay	4C	$23,209,522	$9,419,393	$32,628,910	0.25%
Total		**$7,912,883,239**	**$4,908,317,485**	**$12,821,200,842**	**100%**

The following maps (Figure 3-3 to Figure 3-8) show the damage elements in each study area. The DE are color coded based on the legend at the top of each figure. The size of the DE bubble correlates to the Total Loss PV: the higher the loss the larger the bubble.

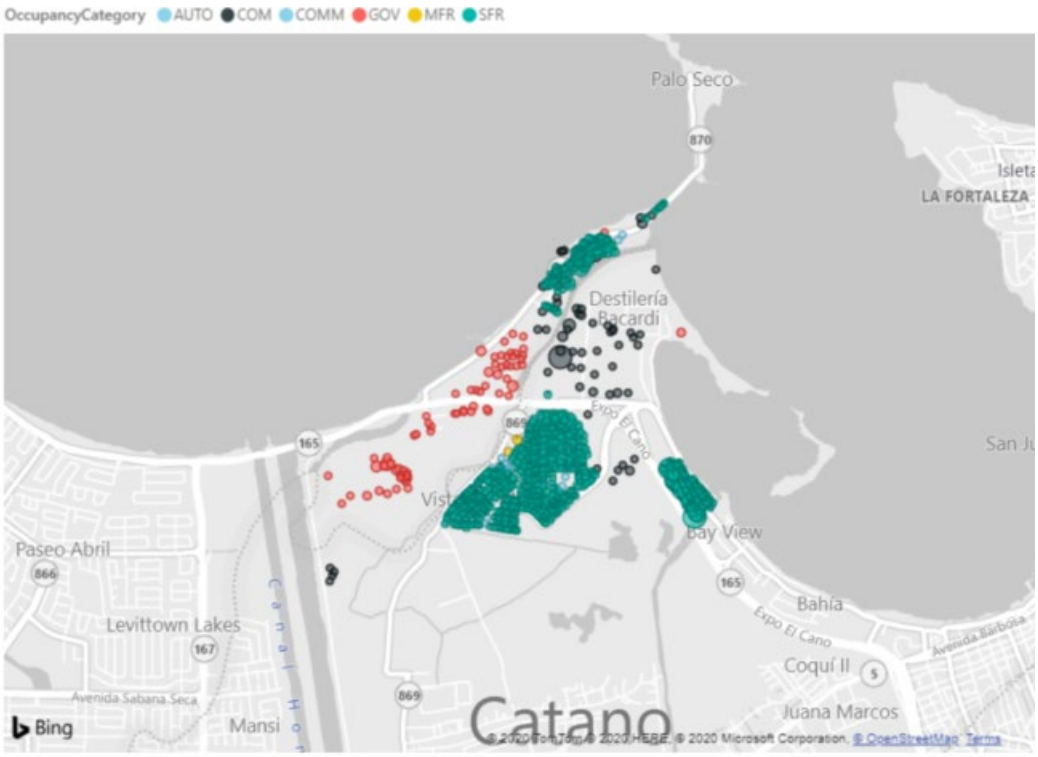


Figure 3-4: West San Juan Bay 1 Damage Elements

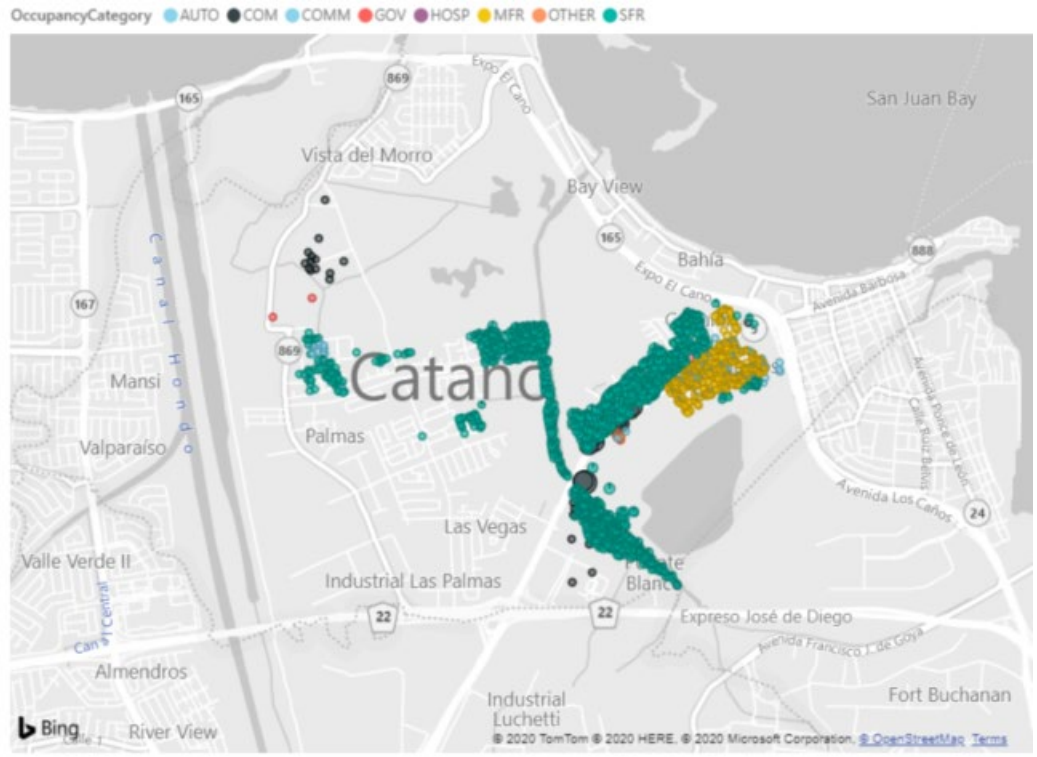


Figure 3-5: West San Juan Bay 2 Damage Elements

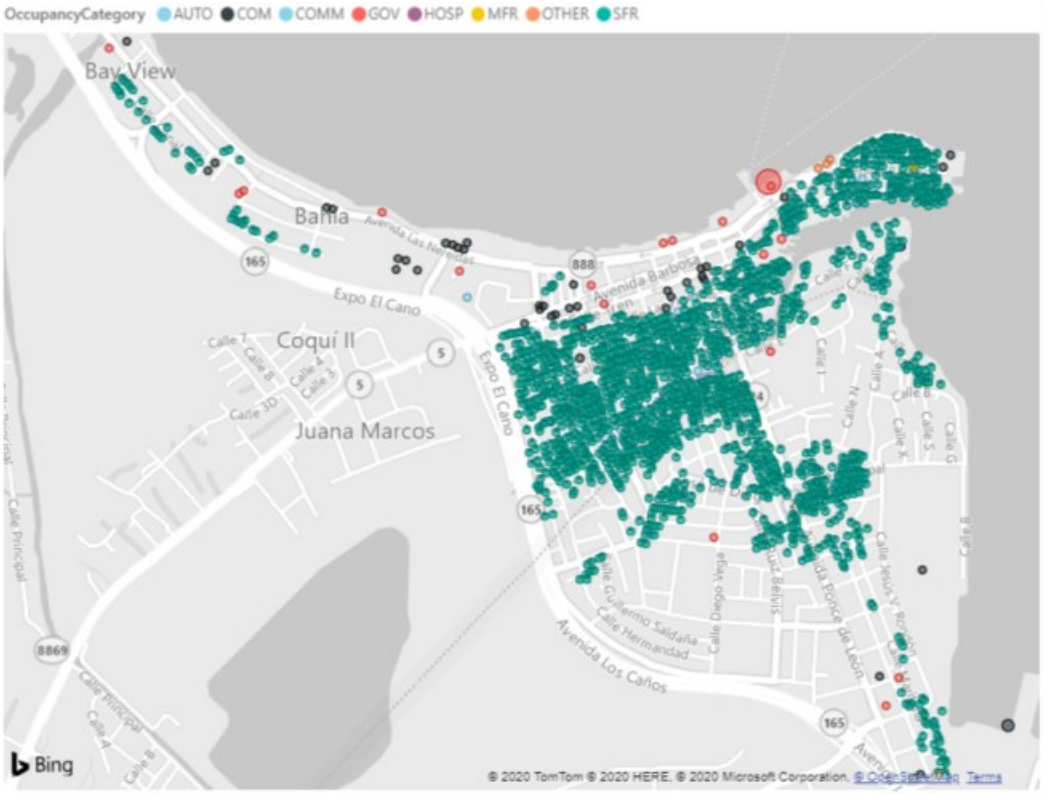


Figure 3-6: West San Juan Bay 3 Damage Elements

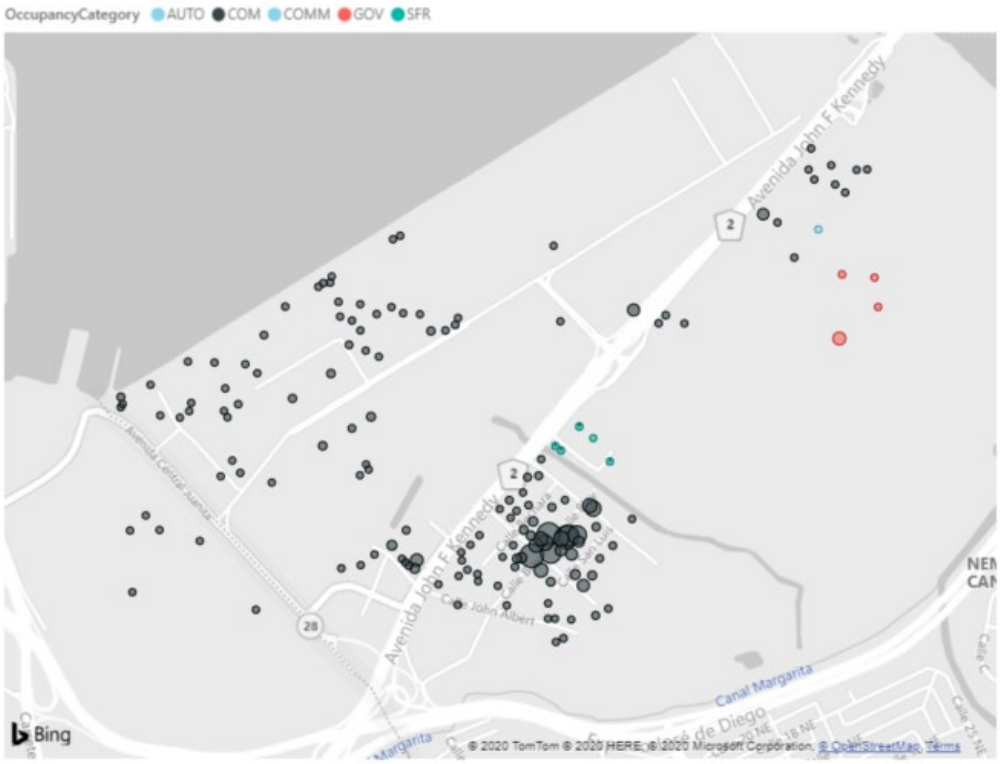


Figure 3-7: West San Juan Bay 4 Damage Elements

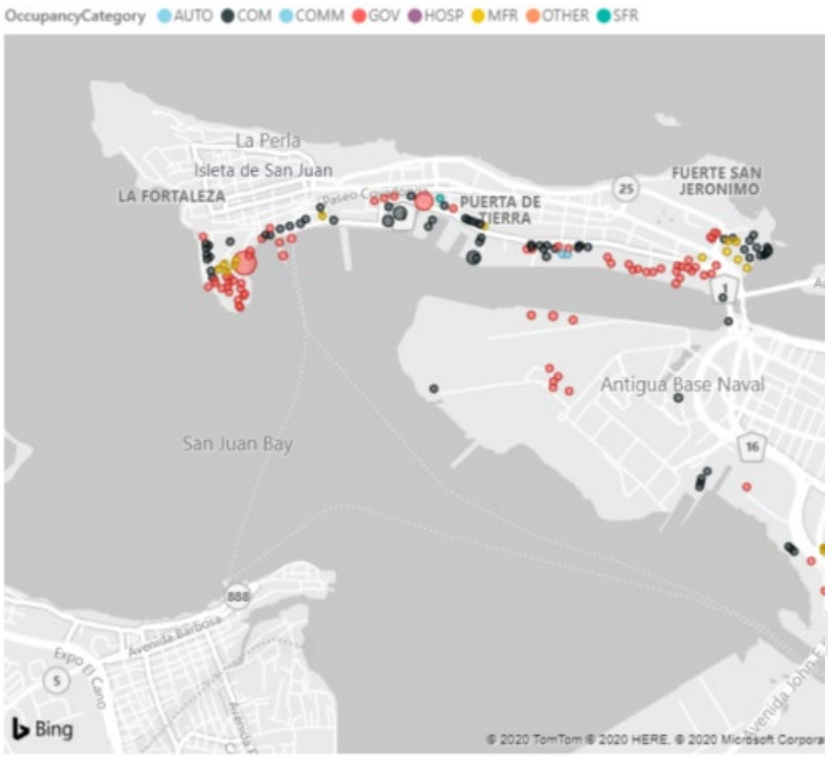


Figure 3-8: East San Juan Bay Damage Elements

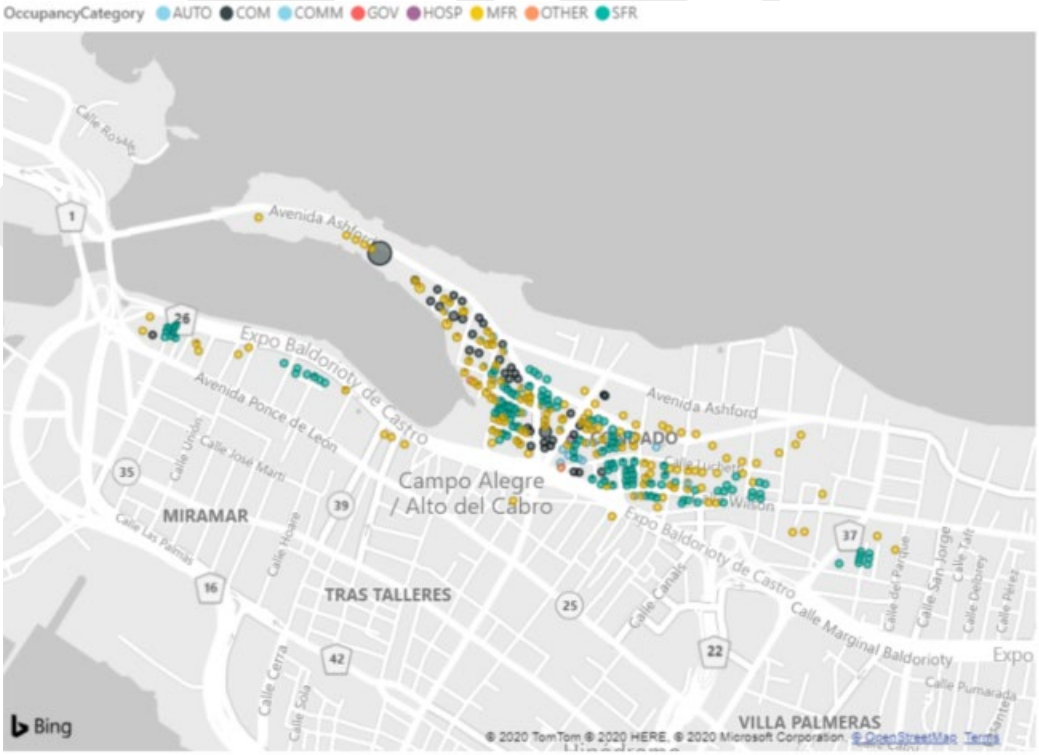


Figure 3-9: Condado Lagoon Damage Elements

3.2.4 FWOP: Damages over Time

Figure 3-7, Figure 3-8 and Figure 3-9 show the distribution of PV damage over time in each study reach.

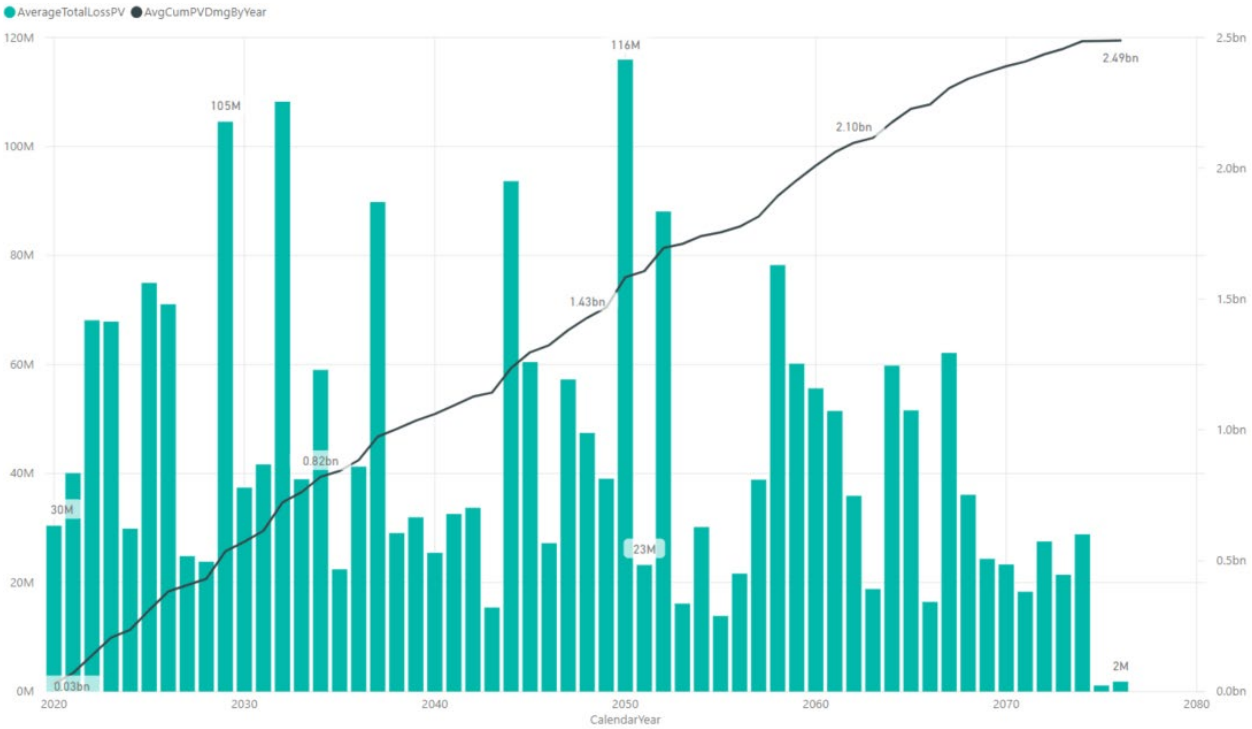


Figure 3-10: West San Juan Bay Damages over Time

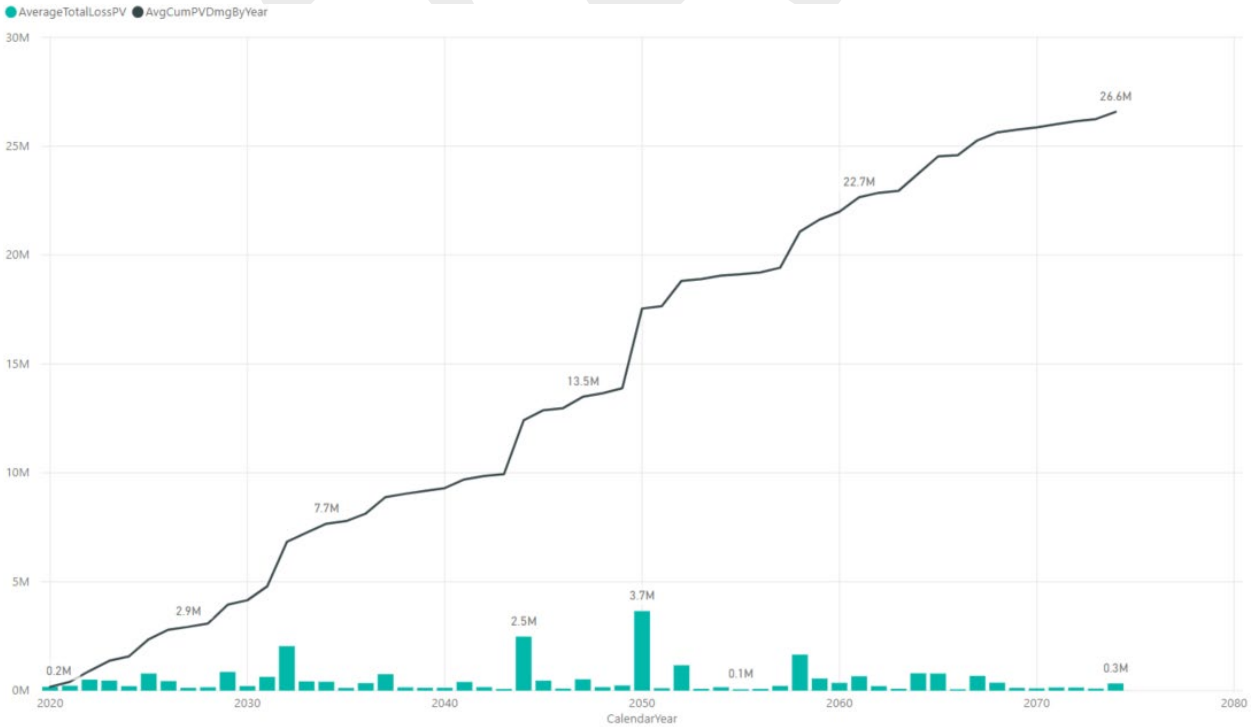


Figure 3-11: East San Juan Bay Damages over Time

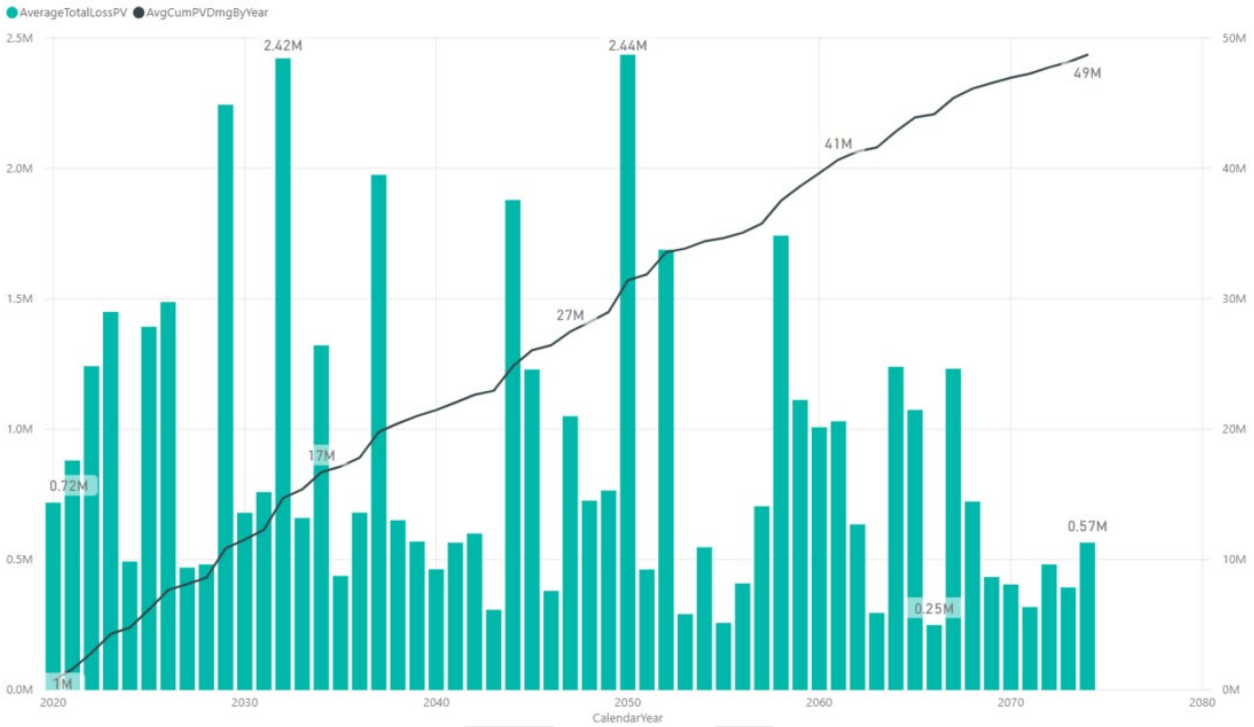


Figure 3-12: Condado Lagoon Damages over Time

3.2.5 FWOP: Damages by Flood Water Level

3.2.5.1 Reach 1 – West San Juan Bay

The figure below shows the flood water levels and cumulative damages caused at different stages. Majority of damages are caused by stages of 2 feet ($820M), with cumulative damages up to $2.49B occurring up to 8 feet.

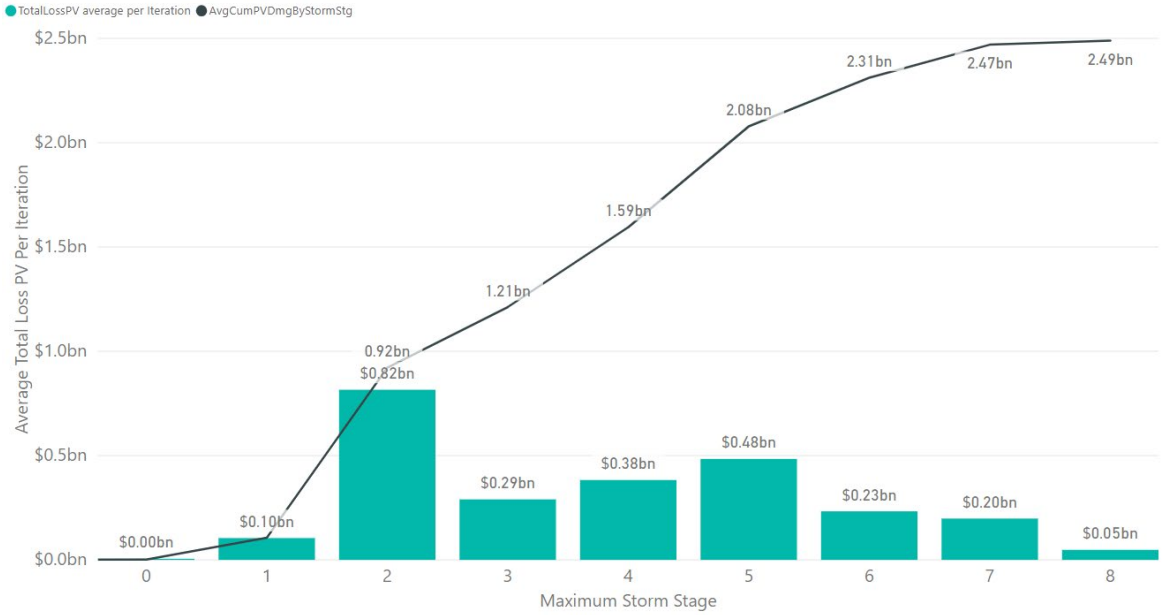


Figure 3-13: West San Juan Bay Damages by Maximum Storm Stage

3.2.5.2 Reach 2 – East San Juan Bay

The figure below shows the flood water levels and cumulative damages caused at different stages. Damages begin to occur at a stage of 1 foot, with cumulative damages up to $26.6M occurring up to 8 feet. Majority of damages in this area are caused by stages of 8 feet ($14.4M).

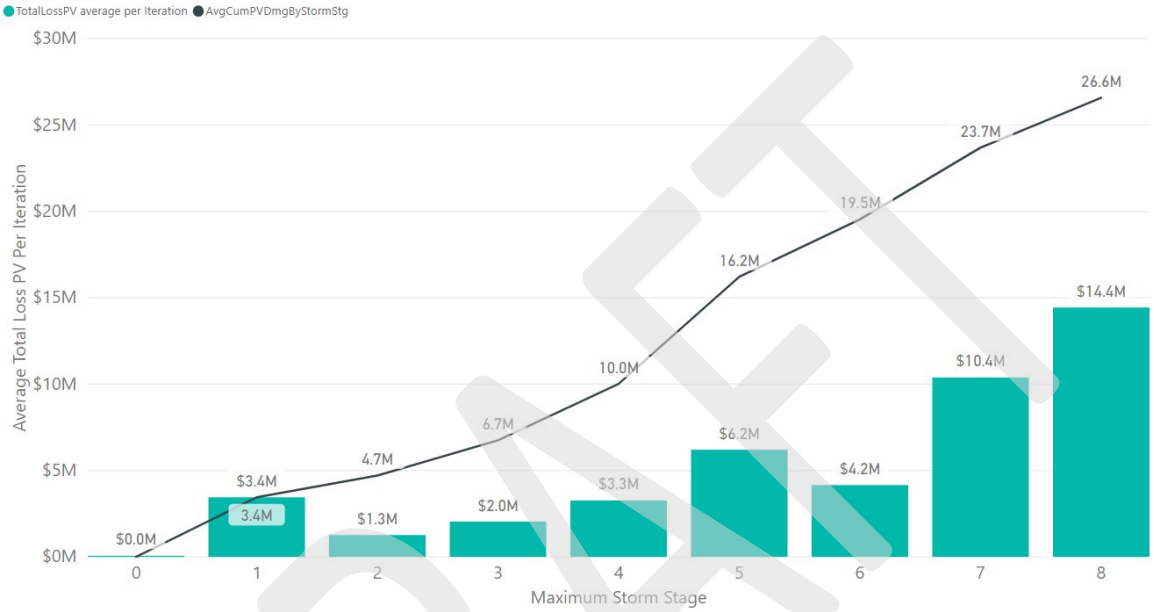


Figure 3-14: East San Juan Bay Damages by Maximum Storm Stage

3.2.5.3 Reach 3 – Condado Lagoon

The figure below shows the flood water levels and cumulative damages caused at different stages. Majority of damages are caused by stages of 2 feet($14.2M), with cumulative damages up to $49M occurring up to 8 feet.

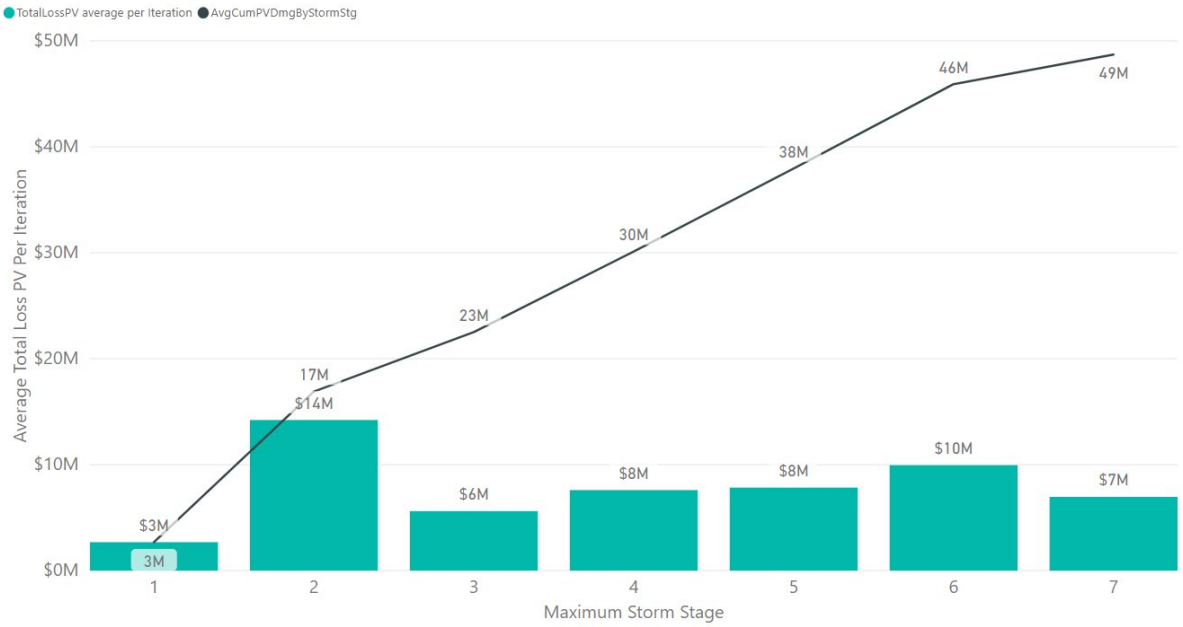


Figure 3-15: Condado Lagoon Damages by Maximum Storm Stage

3.2.6 FWOP: Life Loss

Future without-project life loss analysis compared the populations over 65 and under 65 years old during storm events based on an evacuation and non-evacuation scenario. **Figure 3-16** shows lost lives for the population over 65 for each model area sub-reach, and **Figure 3-17** shows the lost lives for population under 65.

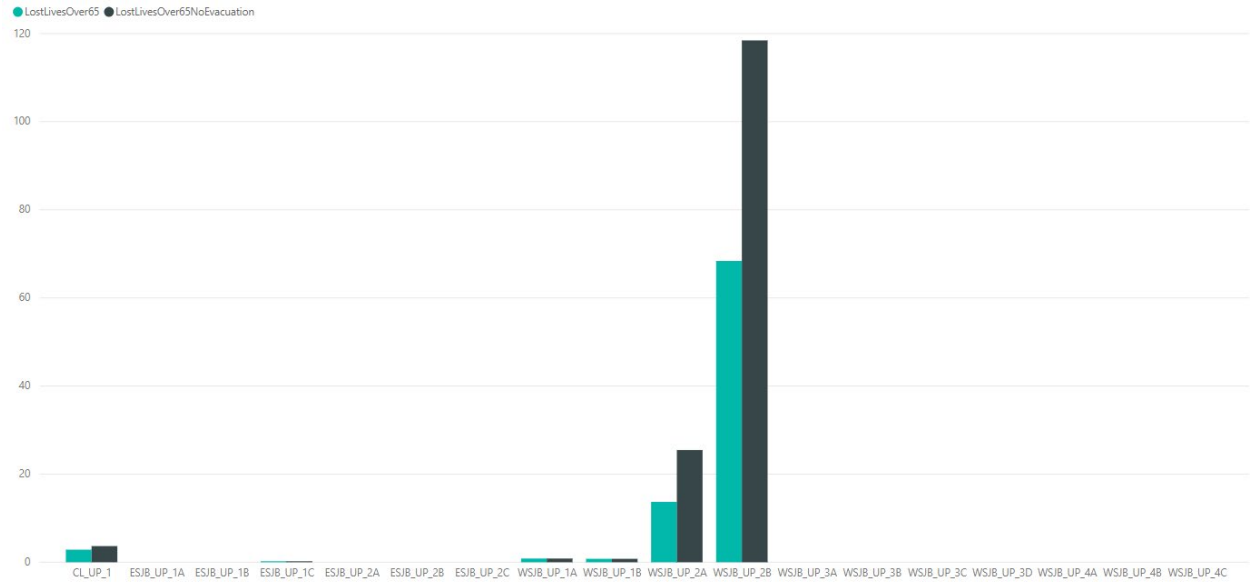


Figure 3-16: Future without-project condition life loss for population Over 65

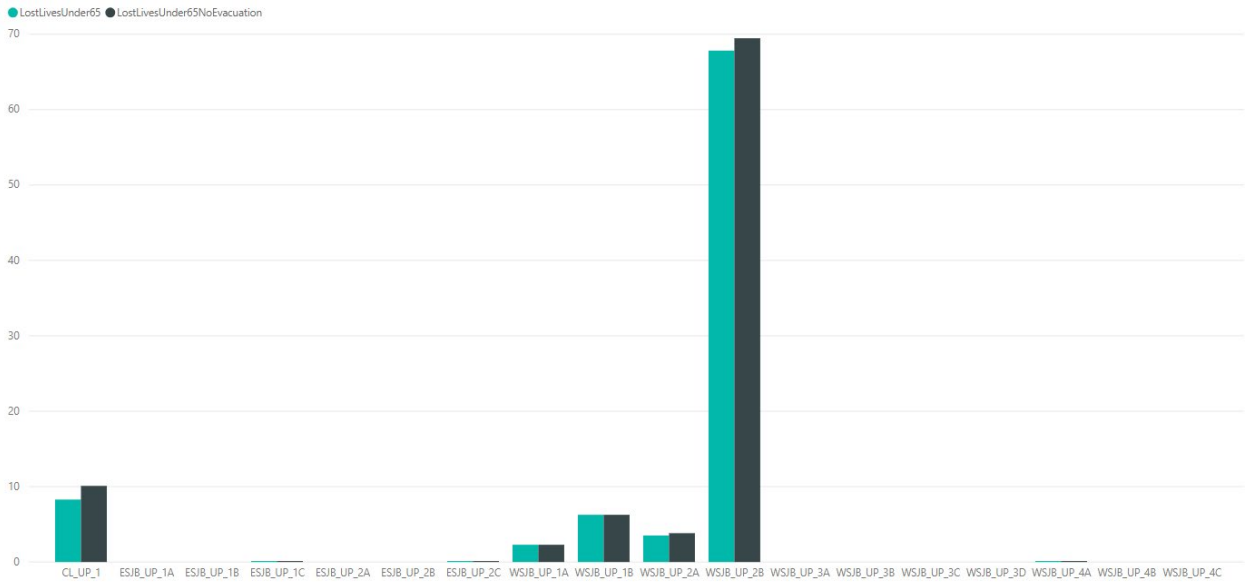


Figure 3-17: Future without-project condition life loss for population Under 65

4 Formulate Evaluate & Compare (FWP)

4.1 Alternatives

A description of each alternative and a breakdown of their respective benefits and costs can be seen in Table 4-1. Five NED alternative plans are identified in this table, one for each model area.

Table 4-1 Economic Summary of Alternatives

Model Area	Alt ID	Alt	Measure	Duration	Total Investment Cost	AAEQ NED Benefits	AAEQ NED Costs	AAEQ Net NED Benefits	BCR	Selection
CL	1	Alt 1	Seawall	33.00	$74,661,828	$1,615,029	$2,765,543	-$1,150,513	0.58	
	2	Alt 2	Recreational Seawall	38.00	$82,099,822	$1,615,029	$3,041,053	-$1,426,024	0.53	
	3	Alt 3	Recreational Seawall + Vegetation	57.00	$85,792,472	$1,615,029	$3,177,832	-$1,562,803	0.51	
	4	Alt 4	Elevated Living Shoreline	31.00	$31,681,267	$1,615,029	$1,173,503	$441,526	1.38	NED Plan
	5	Alt 5	Seawall North + Elevated Living Shoreline South	34.00	$59,763,688	$1,615,029	$2,213,702	-$598,673	0.73	
	6	Alt 6	Recreational Seawall North + Elevated Living Shoreline South	34.00	$64,289,497	$1,615,029	$2,381,342	-$766,313	0.68	
WSJB_1	7	Alt 1a	Seawall + Levee (1A)	14.00	$36,879,554	$845,901	$1,366,053	-$520,152	0.62	
	8	Alt 1b	Seawall + Levee + Elevated Living Shoreline (1B)	26.00	$41,873,923	$2,489,862	$1,551,049	$938,813	1.61	NED Plan
	9	Alt 2b	Seawall + Levee (1B)	27.00	$47,955,498	$2,489,862	$1,776,316	$713,546	1.40	
	10	Alt 1(a+b)	Shoreline	59.00	$106,955,249	$3,520,179	$3,961,721	-$441,542	0.89	
WSJB_2	11	Alt 1	Levee + Seawall	30.00	$38,308,933	$10,560,200	$1,418,998	$9,141,202	7.44	
	12	Alt 2	Horizontal Levee + Seawall	36.00	$40,542,284	$10,560,200	$1,501,723	$9,058,477	7.03	
	13	Alt 3	Small Storm Surge Gate + Partial Levee + Seawall	20.00	$25,097,681	$12,722,287	$929,641	$11,792,646	13.69	NED Plan
	14	Alt 4	Small Storm Surge Gate + Partial Horizontal Levee + Seawall	22.00	$25,639,600	$12,722,287	$949,714	$11,772,572	13.40	
	15	Alt 5	Buyout in low lying elevations	36.00	$244,422,328	$13,532,392	$9,053,628	$4,478,764	1.49	
WSJB_3	16	Alt 1	Seawall + T-Wall	87.00	$187,720,996	$63,239,363	$6,953,358	$56,286,005	9.09	
	17	Alt 2	Seawall + Breakwater	82.00	$162,889,774	$63,826,013	$6,033,587	$57,792,426	10.58	
	18	Alt 3	Seawall + Spoil Island	61.00	$158,333,319	$63,239,363	$5,864,812	$57,374,551	10.78	
	19	Alt 4	Seawall + Recreational Seawall + Breakwater	65.00	$165,193,235	$63,826,013	$6,118,909	$57,707,103	10.43	
	20	Alt 5	Seawall + Living Shoreline + 1.83m Breakwater	83.00	$156,429,143	$63,826,013	$5,794,279	$58,031,734	11.02	NED Plan
WSJB_4	22	Alt 1	Seawall	19.00	$41,729,432	$2,667,710	$1,545,697	$1,122,014	1.73	
	23	Alt 2	Levee + Seawall	17.00	$36,993,886	$2,667,710	$1,370,288	$1,297,423	1.95	NED Plan

A description of costs, benefits, and percent risk reduction for each alternative can be found below in table 4-2.

Table 4-2 Economic Summary of Alternatives

Model Area	Alt ID	Alt	Measure	Total Investment Cost	AAEQ NED Benefits	AAEQ NED Costs	AAEQ Net NED Benefits	BCR	% Risk Reduction
CL	1	Alt 1	Seawall	$74,661,828	$1,615,029	$2,765,543	-$1,150,513	0.58	90%
	2	Alt 2	Recreational Seawall	$82,099,822	$1,615,029	$3,041,053	-$1,426,024	0.53	90%
	3	Alt 3	Recreational Seawall + Vegetation	$85,792,472	$1,615,029	$3,177,832	-$1,562,803	0.51	90%
	4	Alt 4	Elevated Living Shoreline	$31,681,267	$1,615,029	$1,173,503	$441,526	1.38	90%
	5	Alt 5	Seawall North + Elevated Living Shoreline South	$59,763,688	$1,615,029	$2,213,702	-$598,673	0.73	90%
	6	Alt 6	Recreational Seawall North + Elevated Living Shoreline South	$64,289,497	$1,615,029	$2,381,342	-$766,313	0.68	90%
WSJB_1	7	Alt 1a	Seawall + Levee (1A)	$36,879,554	$845,901	$1,366,053	-$520,152	0.62	50%
	8	Alt 1b	Seawall + Levee + Elevated Living Shoreline (1B)	$41,873,923	$2,489,862	$1,551,049	$938,813	1.61	90%
	9	Alt 2b	Seawall + Levee (1B)	$47,955,498	$2,489,862	$1,776,316	$713,546	1.40	90%
	10	Alt 1(a+b)	Storm Gate + Seawall + Levee + Elevated Living Shoreline	$106,955,249	$3,520,179	$3,961,721	-$441,542	0.89	79%
WSJB_2	11	Alt 1	Levee + Seawall	$38,308,933	$10,560,200	$1,418,998	$9,141,202	7.44	76%
	12	Alt 2	Horizontal Levee + Seawall	$40,542,284	$10,560,200	$1,501,723	$9,058,477	7.03	76%
	13	Alt 3	Small Storm Surge Gate + Partial Levee + Seawall	$25,097,681	$12,722,287	$929,641	$11,792,646	13.69	92%
	14	Alt 4	Small Storm Surge Gate + Partial Horizontal Levee + Seawall	$25,639,600	$12,722,287	$949,714	$11,772,572	13.40	92%
	15	Alt 5	Buyout in low lying elevations	$244,422,328	$13,532,392	$9,053,628	$4,478,764	1.49	98%
WSJB_3	16	Alt 1	Seawall + T-Wall	$187,720,996	$63,239,363	$6,953,358	$56,286,005	9.09	89%
	17	Alt 2	Seawall + Breakwater	$162,889,774	$63,826,013	$6,033,587	$57,792,426	10.58	90%
	18	Alt 3	Seawall + Spoil Island	$158,333,319	$63,239,363	$5,864,812	$57,374,551	10.78	89%
	19	Alt 4	Seawall + Recreational Seawall + Breakwater	$165,193,235	$63,826,013	$6,118,909	$57,707,103	10.43	90%
	20	Alt 5	Seawall + Living Shoreline + 1.83m Breakwater	$156,429,143	$63,826,013	$5,794,279	$58,031,734	11.02	90%
WSJB_4	22	Alt 1	Seawall	$41,729,432	$2,667,710	$1,545,697	$1,122,014	1.73	85%
	23	Alt 2	Levee + Seawall	$36,993,886	$2,667,710	$1,370,288	$1,297,423	1.95	85%

4.2 Evaluation and Comparison

Economic descriptions of each NED alternative plan can be found in tables 4-3 through 4-7. The NED plan alternative 4 for the model area Condado Lagoon is economically justified with a BCR of 1.38. See table 4-3 for a complete summary.

Table 4-3 Economic Summary of NED Plan Alternative 4

Economic Summary of NED Plan	Alt ID 4 (Alt 4)
Price Level	FY20
FY20 Water Resources Discount Rate	2.75%
Total Average Annual Benefits	$1,615,029
Total Average Annual Cost	$1,173,503
Net-Benefits	$441,526
Benefit Cost Ratio	1.38

The NED plan alternative 1b for the model area West San Juan Bay 1 is economically justified with a BCR of 1.61. See table 4-4 for a complete summary.

Table 4-4 Economic Summary of NED Plan Alternative 1b

Economic Summary of NED Plan	Alt ID 8 (Alt 1b)
Price Level	FY20
FY20 Water Resources Discount Rate	2.75%
Total Average Annual Benefits	$2,489,862
Total Average Annual Cost	$1,551,049
Net-Benefits	$938,813
Benefit Cost Ratio	1.61

The NED plan alternative 3 for the model area West San Juan Bay 2 is economically justified with a BCR of 13.69. See table 4-5 for a complete summary.

Table 4-5 Economic Summary of NED Plan Alternative 3

Economic Summary of NED Plan	Alt ID 13 (Alt 3)
Price Level	FY20
FY20 Water Resources Discount Rate	2.75%
Total Average Annual Benefits	$12,722,287
Total Average Annual Cost	$929,641
Net-Benefits	$11,792,646
Benefit Cost Ratio	13.69

The NED plan alternative 5 for the model area West San Juan Bay 3 is economically justified with a BCR of 11.02. See table 4-6 for a complete summary.

Table 4-6 Economic Summary of Alternative 5

Economic Summary of NED Plan	Alt ID 20 (Alt 5)
Price Level	FY20
FY20 Water Resources Discount Rate	2.75%
Total Average Annual Benefits	$63,826,013
Total Average Annual Cost	$5,794,279
Net-Benefits	$58,031,734
Benefit Cost Ratio	11.02

The NED plan alternative 5 for the model area West San Juan Bay 4 is economically justified with a BCR of 1.95. See table 4-7 for a complete summary.

Table 4-7 Economic Summary of Alternative 2

Economic Summary of NED Plan	Alt ID 23 (Alt 2)
Price Level	FY20
FY20 Water Resources Discount Rate	2.75%
Total Average Annual Benefits	$2,667,710
Total Average Annual Cost	$1,370,288
Net-Benefits	$1,297,423
Benefit Cost Ratio	1.95

4.2.1 Comparison of Potential Tentatively Selected Plans

Table 4-8 contains economic comparisons of different potential NED plans. The table also presents information on various alternatives that reasonably maximize NED benefits and one that maximizes NED benefits. These potential TSP consist of combined NED plans.

Table 4-8 TSP Comparison

	Model Areas	Alternative	Description	Total Investment Cost	AAEQ NED Benefits	AAEQ NED Costs	AAEQ Net NED Benefits	BCR	% Difference from plan that Generates Highest Benefit	% Difference from plan that Generates Highest net benefit	Change in Cost
TSP	CL	CL-Alt 4	Elevated Living Shoreline	$31,681,267	$1,615,029	$1,173,503	$441,526	1.38	1.94%	0.61%	$260,394,633
	WSJB_1	WSJB1-Alt 1b	Seawall + Levee + Elevated Living Shoreline (1B)	$41,873,923	$2,489,862	$1,551,049	$938,813	1.61	2.99%	1.29%	$250,201,976
	WSJB_2	WSJB2-Alt 3	Small Storm Surge Gate + Partial Levee + Seawall	$25,097,681	$12,722,287	$929,641	$11,792,646	13.69	15.27%	16.27%	$266,978,219
	WSJB_3	WSJB3-Alt-5	Seawall + Living Shoreline + 1.83m Breakwater	$156,429,143	$63,826,013	$5,794,279	$58,031,734	11.02	76.60%	80.04%	$135,646,757
	WSJB_4	WSJB4-Alt-2	Levee + Seawall	$36,993,886	$2,667,710	$1,370,288	$1,297,423	1.95	3.20%	1.79%	$255,082,013
	Maximizes Net NED Benefits	CL+WSJB(1+2+3+4)	NED Plans for CL+WSJB(1+2+3+4)	$292,075,899	$83,320,901	$10,818,760	$72,502,141	7.70	100.00%	100.00%	$0
	Reasonably maximizes net NED benefits	WSJB(1+2+3+4)	NED Plans for WSJB(1+2+3+4)	$260,394,633	$81,705,872	$9,645,257	$72,060,615	8.47	98.06%	99.39%	$31,681,267
		WSJB(2+3+4)	NED Plans for WSJB(2+3+4)	$218,520,709	$79,216,010	$8,094,208	$71,121,802	9.79	95.07%	98.10%	$73,555,190
		WSJB(2+3)	NED Plans for WSJB(2+3)	$181,526,823	$76,548,300	$6,723,920	$69,824,379	11.38	91.87%	96.31%	$110,549,076
		WSJB(1+2+3)	NED Plans for WSJB(1+2+3)	$223,400,747	$79,038,161	$8,274,969	$70,763,192	9.55	94.86%	97.60%	$68,675,153

5 The Selected Plan

The PDT selected CL+ (WSJB1+2+3+4) as the TSP. The future without and future with project conditions were ran with the following parameters:

- Start Year: 2020
- Base Year: 2029
- Number of Iterations: 50
- Duration: 60 years
- SLC Rate: 0.0066929 / Intermediate

In addition to these updated runs, project costs were updated to include PED, OMRR&R as well as revisions to the real estate costs. Table 15 provides detail on the updated cost estimate. Table 16 and Table 17 details the annual O&M cost and the NED cost breakdown. Table 18 displays the economic summary in average annual equivalent terms.

Table 7: Updated TSP Costs ($1,000)

Item	Cost	Contingency	Total
Fish & Wildlife Facilities	$5,565	$2,226	$7,792
Levees & Floodwalls	$9,474	$3,789	$13,263
Pumping Plant	$28,800	$11,520	$40,320
Floodway Control & Diversion Structure	$5,982	$2,393	$8,375
Recreation Facilities	$7,220	$2,888	$10,108
Breakwater & Seawalls	$116,916	$46,766	$163,682
Construction Cost Subtotal	$173,957	$69,583	$243,540
Lands & Damages	$26,302	$7,890	$34,192
PED	$24,677	$9,870	$34,548
RE Admin Costs (Federal)	$150	$45	$195
RE Admin Costs (Non-Federal)	$350	$105	$455
Construction Management	$13,339	$5,336	$18,674
Non-Construction Cost Subtotal	$64,817	$23,247	$88,064
Grand Total	**$238,774**	**$92,830**	**$331,604**

Table 8: Average Annual O&M Cost

Sub-Reach	O&M Cost
CL	$158,419
WSJB1	$130,005
WSJB2	$178,877
WSJB3	$1,752,664
WSJB4	$50,132
Total	**$2,270,097**

Table 9: NED Cost Breakdown

Cost Item	CL	WSJB1	WSJB2	WSJB3	WSJB4	TSP
Construction Cost	$19,711,000	$29,219,000	$25,511,300	$144,872,800	$24,226,000	$243,540,100
Non-Construction Cost	$14,045,550	$18,760,250	$6,051,150	$36,314,750	$12,892,400	$88,064,100
Total 1st Construction Costs	$33,756,550	$47,979,250	$31,562,450	$181,187,550	$37,118,400	$331,604,200
Interest During Construction Costs	$1,404,524	$1,696,996	$909,799	$18,066,525	$896,158	$22,974,003
Total Investment Costs	$35,161,074	$49,676,246	$32,472,249	$199,254,075	$38,014,558	$354,578,203
Annualized Investment Costs	$1,302,398	$1,840,054	$1,202,802	$7,380,554	$1,408,094	$13,133,903
Annual O&M Costs	$158,419	$130,005	$178,877	$1,752,664	$50,132	$2,270,097
AAEQ NED Costs	$1,460,817	$1,970,059	$1,381,679	$9,133,218	$1,458,226	$15,404,000

Table 10: TSP Economic Summary (AEQ)

Sub-Reach	NED Benefits	NED Costs	Net Benefits	BCR
CL	$1,478,799	$1,460,817	$17,982	1.01
WSJB1	$2,532,702	$1,970,059	$562,643	1.29
WSJB2	$10,029,970	$1,381,679	$8,648,291	7.26
WSJB3	$62,965,473	$9,133,218	$53,832,254	6.89
WSJB4	$2,418,761	$1,458,226	$960,535	1.66
TSP Total	**$79,425,705**	**$15,404,000**	**$64,021,704**	**5.2**