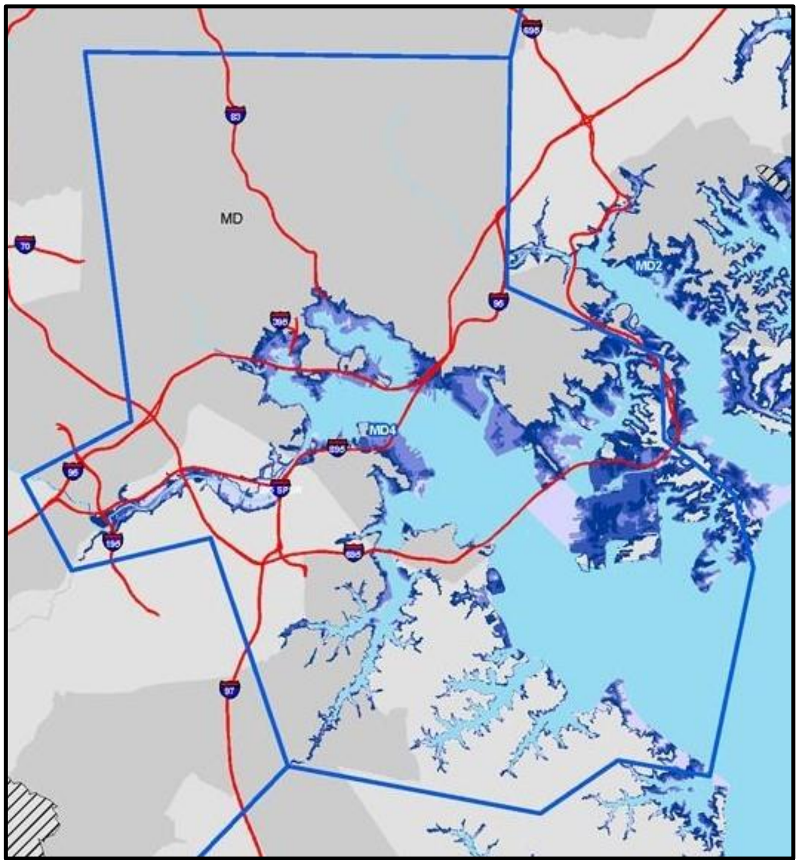
Baltimore Coastal Storm Risk Management Feasibility Study

Appendix E: Economic Analysis



City of Baltimore, Anne Arundel and Baltimore Counties
July 2022

US Army Corps of Engineers
Baltimore District

MDOT
MARYLAND DEPARTMENT OF TRANSPORTATION

US Army Corps of Engineers®

Baltimore Metropolitan, Maryland

Coastal Flood Risk Management Study

Inner Harbor during high tide flooding, October 2019.

Appendix C: Economics

May 2022

Table of Contents

1. INTRODUCTION

This appendix presents an economic evaluation of flood risk reduction for the national economic development (NED), regional economic development (RED), environmental quality, and other social effects accounts undertaken for the Baltimore Metropolitan Coastal Flood Risk Management Study.

2. FLOOD RISK REDUCTION

The Federal objective of water and related land resources project planning is to contribute to NED. Contributions to NED, expressed in monetary units, are the direct net benefits that accrue in the planning area and the rest of the Nation. Benefits from plans for reducing flood hazards accrue primarily through the reduction in actual or potential damages to affected land uses are NED. Inundation reduction benefits are the increases in net income generated by the affected land uses.

2.1 STUDY AUTHORITY

The region has an existing study authorization from Congress: the resolution of the U.S. House of Representatives Committee on Public Works and Transportation dated April 30th, 1992.

> *"Resolved by the Committee on Public Works and Transportation of the United States House of Representatives, That the Board of Engineers for Rivers and Harbors, is requested to review the report of the Chief of Engineers on the Baltimore Metropolitan Area, Maryland, published as House Document 589, Eight-seventh Congress, Second Session, and the reports of the Chief of Engineers on Baltimore Harbor and Channels, Maryland, and Virginia, published as House Document 181, Ninety-fourth Congress, First Session, and House Document 86, Eighty-fifth Congress, First Session, and other pertinent reports, to determine whether modifications of the recommendations contained therein are advisable at the present time, in the interest of flood control, hurricane risk reduction, navigation, erosion, sedimentation, fish and wildlife, water quality, environmental restoration, recreation, and other related purposes."*

The study authority was identified as the most recent authority that includes the study area, with the ability to investigate solutions to coastal flooding problems leading to a USACE recommendation for implementation in the form of a Chief's Report. In April 2014, Baltimore District (NAB) Counsel determined that the Baltimore Metropolitan Area authority may be used to advance feasibility studies identified in the North Atlantic Coast Comprehensive Study (NACCS) appendices identifying focus area assessments warranting further analysis by USACE.

As a result of Hurricane Sandy in October 2012, Congress passed Public Law (P.L.) 113-2, which authorized supplemental appropriations to federal agencies for expenses related to the consequences of Hurricane Sandy. Chapter 4 of P.L. 113-2 identifies those actions directed by Congress specific to the USACE, including preparation of two interim reports to Congress, a project performance evaluation report, and a comprehensive study to address the flood risks of vulnerable coastal populations in areas affected by Hurricane Sandy within the boundaries of the North Atlantic Division (NAD) of the U.S. Army Corps of Engineers.

The impacts from Hurricane Sandy highlighted the national need for a comprehensive and collaborative evaluation to reduce risk to vulnerable populations within the North Atlantic region. The NACCS identified areas warranting additional analysis, one of which was the Baltimore Metropolitan area.

The NACCS was designed to catalyze action in implementing comprehensive CSRM strategies. Study and implementation are performed using a three-tier analysis to better understand and manage coastal risk in a systems context, including: a regional scale analysis (completed as part of the NACCS); a state or study area-scale analysis/plan; and a local or community scale analysis (to incorporate benefit-cost evaluations of CSRM plans).

2.2 PURPOSE

2.2.1 Problem Description

The Baltimore metropolitan area is characterized by low, flat terrain. This is causing the area highly susceptible to flooding from the tidal surges of hurricanes and tropical storms, as well as riverine flooding from excess precipitation. Exacerbating the flooding is the phenomenon of relative sea level rise (RSLR), which is the combination of the water level rising and the land subsiding.

The highest storm surge that has occurred within the Harbor Tunnel's (I-895) or Ft. McHenry Tunnel's (I-95) operating life was Tropical Storm Isabel in September of 2003 which caused tidal surge about 8 feet higher than normal. No damage was suffered at the tunnels from this storm and no other coastal storm has yet reached that water level. However, higher storm water levels are expected within the tunnels' operating life. A storm of similar or greater magnitude has the potential to damage the tunnel infrastructure and support systems.

Some events showed transportation disruptions caused by partial or total shutdown of the tunnels.

a) On 12 August 2014, traffic to the Harbor Tunnel (I-895) was temporarily detoured due to heavy rainfall.

b) On 18 October 2005 both tunnels were closed for over two hours for a "terrorist threat", stranding thousands of motorists. Traffic would have had to reroute to the Key Bridge (I-695) or travel on the western side of I-695."

c) Tunnels and individual bores are periodically closed for maintenance, traffic incidents, and other special events.

2.2.2 Scope of the Study

The purpose of the Baltimore Coastal Flood Risk Management Study is to investigate and recommend potential structural and nonstructural solution sets to reduce damages from coastal storms. Baltimore City and the surrounding metropolitan areas along rivers and coastal shorelines are highly subject to negative environmental impacts such as wastewater treatment facilities, and coastal storms which will be further exacerbated by a combination of sea level rise and climate change over the study period. Without a plan to reduce damages from coastal storm surge inundation, the metropolitan's vulnerability to coastal storms is expected to increase over time.

The primary focus of this study is storm surge inundation. While the Baltimore metropolitan area also experiences flooding from high tides and rainfall, those issues are not within the scope of this study authorization. USACE policy dictates that in urban and urbanizing areas, provision of a basic drainage system to collect and convey local runoff is a non-Federal responsibility [ER 1105-2-100, Section 3-3, b, (6)]. However, mitigation for any adverse impacts to storm water runoff will be included in the recommended plan if necessary.

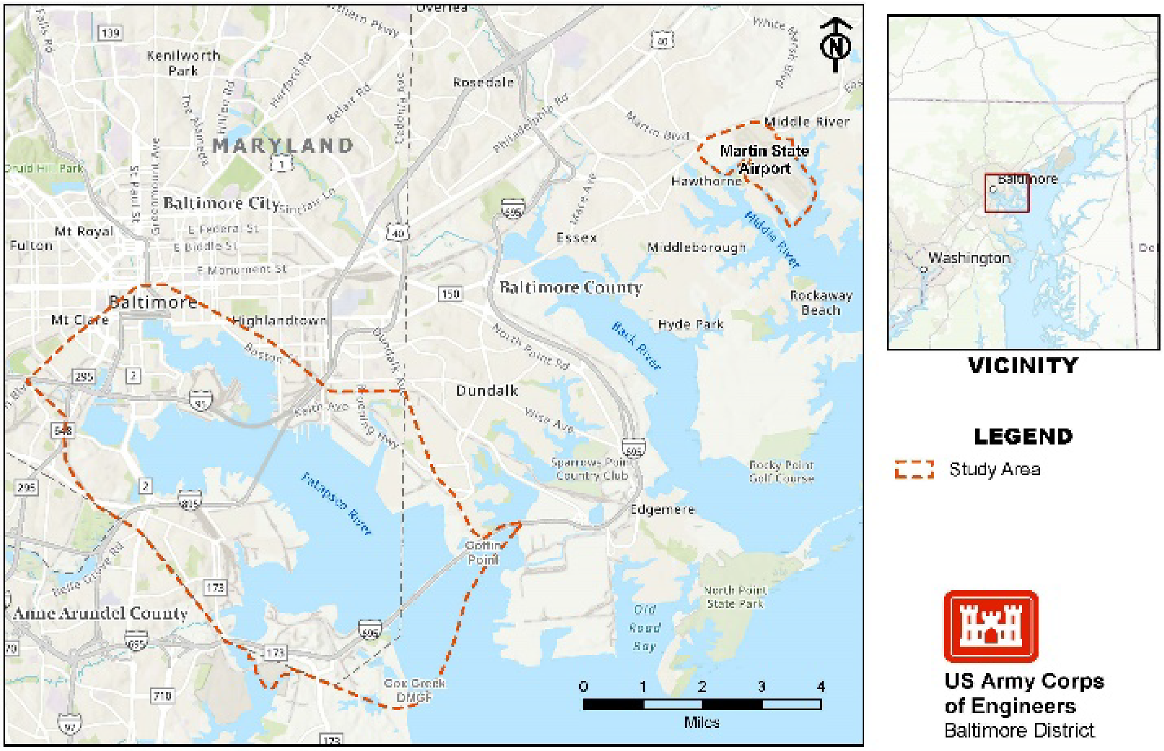
This document explains what is known about the study area, existing condition flood damages, expected future condition flood damages in the absence of flood risk management measures, and development and evaluation of alternative plans to address flooding related to coastal storm events on the Baltimore metropolitan area. It then documents the procedures used to analyze various measures designed to reduce the risk of flood damages, incorporating National Economic Development (NED) guidelines, and culminates in identification of a Tentatively Selected Plan.

2.3 STUDY AREA

The study encompasses the portion of the City of Baltimore and surrounding metropolitan areas bay ward to approximately the Francis Scott Key Bridge (I-695) and along the tidally influenced areas that were subject to flooding, storm surge, and damages because of Hurricane Sandy and other recent storms (Figure 1). The impacts of Hurricane Sandy in the study area were relatively minimal compared to the large-scale damage experienced from Hurricane Isabel in 2003 and other past storm events of record. The problem in the study area is economic damages caused by coastal storms, which produce direct damages through wave action and induce flooding in low lying areas.

The study area was defined to include many assets of importance to the Maryland Department of Transportation including the Martin State Airport.

Figure 1: Baltimore Metropolitan Study Area



BALTIMORE COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

CITY OF BALTIMORE, ANNE ARUNDEL AND BALTIMORE COUNTIES

The Baltimore metropolitan coastline study area is approximately 19.12 square miles. The study authority is much larger, about 1,531.23 square miles.

Coastal storms have produced extensive property damage and loss of life resulting from storm surge and flooding in recent years, particularly from Hurricane Isabel in 2003 which resulted in costs of $4.8 million to the City of Baltimore, up to $252 million in Southern Baltimore County, and one fatality due to flooding. 570 homes and 15 businesses were rendered uninhabitable, and 70,000 people were without power.

The population within the extent of the category 4 inundation zone is approximately 85,000. Within the study area, we have several locations of national significance, including Fort McHenry National Monument and Historic Shrine (a unit of the National Park Service), historic structures and districts, and an important United States Coast Guard (USCG) boatyard and dry-dock facility. Critical infrastructure in the study area includes the Port of Baltimore, Interstate 95 & 895 tunnels and bridges, Fort McHenry Tunnel, Harbor Hospital, Martin State Airport, electrical generation and transmission systems, water and communications utilities, and cargo and commuter rail systems.

There is a need for this study because Baltimore City and the surrounding metropolitan areas along rivers and waterways have been subjected to intense coastal storm events resulting in major damages. Therefore, the Federal Government has an interest in reducing those damages, as doing so not only contributes to National Economic Development (NED) but may also improve the living conditions of the community and preserving historic and cultural resources. For the purposes of the economic appendix, the assets include residential and commercial structures with their content values, residential vehicles, infrastructure and cargo at the Port of Baltimore, Ft. McHenry Tunnel on Interstate 95 and the Harbor Tunnel on Interstate 895, Baltimore Shot Tower Metro Station, and the munition depot at Martin State Airport. In addition to the benefits assessed from these assets, additional benefits are associated with storm surge and the debris clean-up cost reduction.

2.4 SOCIOECONOMIC DATA

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

The Baltimore Metropolitan area is a major tourist destination in the U.S., with the City of Baltimore driving a significant portion of the attraction. In 2018 26.7 million people visited Baltimore, with an estimated $10.7 billion in total business sales connected to tourism. Tourism sustained over 86,000 jobs in the Baltimore region, both directly and indirectly.

The Port of Baltimore constitutes a major platform for the national and international economy not only for the State of Maryland but for the entire United States. The Port was responsible for $2.9 billion in personal income. According to the U.S. Bureau of the Labor Statistics, the Port of Baltimore's average salary for the direct job holder is 16.4 percent higher than the average annual wage for the State of Maryland.

Approximately 33,920 jobs including the cargo and vessel direct activities and the indirect local jobs in the State of Maryland are generated by the port activity. The total of 93,700 other jobs in the State of Maryland are directly related to activities at the Port. Related jobs are those jobs with Maryland companies that chose to import and export their cargo through the Port of Baltimore, but they have the option of shipping their products or supplies through several other ports. These companies benefit from having a healthy port nearby in Baltimore to assist their logistics. If the Port of Baltimore were not available to them, these firms could suffer an economic penalty over the longer term but would likely survive because they are less dependent upon the Port than the direct, induced, and indirect jobs. When combining direct and indirect jobs with related jobs, there are over 127,600 jobs linked to the Port.

Population

Table 1: Historical and Projected Population

	1980		1990		2000		2010		2020		2030	
	Population	Avg. Growth Rate	Population	Avg. Growth Rate	Population	Avg. Growth Rate	Population	Avg. Growth Rate	Population	Avg. Growth Rate	Population	Avg. Growth Rate
Baltimore County	655,615	-	692134	0.5%	754,292	0.9%	805,029	0.7%	854,535	0.6%	849,000	-0.1%
Anne Arundel County	370,775	-	427,239	1.4%	489,656	1.4%	537,656	0.9%	588,261	0.9%	572,800	0.3%

Sources:

U.S. Census Bureau
https://worldpopulationreview.com/us-counties/md/

The study team was unable to locate valid population projections for Baltimore City from 1980 through 2030. Within the study area, the City of Baltimore is the most affected by flooding among the three Baltimore Metropolitan jurisdictions. Baltimore City population declined from 620,770 in 2010 to 585,708 in 2020 according to Census Bureau data.

The population and housing statistics in the planning units from American Community Survey 2017 is presented in Table 2.

Table 2: Population and Housing Statistics in Planning Units

Planning Unit Name	American Community Survey 2017, 5-Year Population Estimate	American Community Survey 2017, 5-Year Housing Unit Estimate
Martin State Airport	0	0
Inner Harbor	24,001	11,483
Patapsco North	3,273	1,522
Patapsco South	0	0
Middle Branch	16,168	6,969
Patapsco East	1,106	412
Locust Point	3,539	1,659
TOTALS	48,087	22,045

Income and Poverty Status

The current median household income in the City of Baltimore, Baltimore County, and Anne Arundel County are respectively $50,379, $76,866, and $100,798 with the poverty rate at 21.2%, 8.9%, and 5.8% in 2019 according to Census Bureau data.

3. METHODOLOGY

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. The future without project condition is the condition that would likely exist in the future without the implementation of a federal project and incorporates projected sea level change. This condition is evaluated for a 50-year period of analysis for coastal storm management projects, and the results are expressed in terms of average annual damages. For this study, the future without project condition is for the years 2035-2084. 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 a 50-year period of analysis for the future project conditions.

The difference in expected annual flood damages to the Baltimore Metropolitan area assets between the future without condition and with project condition 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 present economic analysis attempts to recognize and, where possible, quantify the reduction of damages from coastal storm surge inundation due to the Federal project in the study area.

3.1 ASSUMPTION

This section of the analysis presents the assumptions used in computing average annual equivalent flood damages 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 significant damages within the period of analysis.
- The residential depth-percent damage relationships for structure and content contained in Economic Guidance Memorandum (EGM) 01-03 and 04-01 are assumed to be representative of residential structures in the floodplain.
- Non-residential depth-percent damage relationships for structures and content are from expert elicitation found in the revised 2013 draft report (IWR Report 2013-R-05) 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 damages, first costs, and benefits will be annualized using the FY 2022 Federal discount rate of 2.250% assuming a period of analysis of 50 years.
- All values are equivalent to 2021 dollars.
- All project alternatives are evaluated for a 50-year period of analysis.
- Model simulation begins in 2022. This year determines the start year for the model
- The base year when the benefits of the constructed federal project would be expected to begin is 2035.
- Elevations are in feet (ft) North American Vertical Datum of 1988 (NAVD88).
- Sea level change follows the USACE Intermediate Curve and used a sea level change rate of 0.00994 feet per year.
- Depreciation is calculated for structures (i.e., replacement values) during the life cycle analysis.

3.2 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 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 damages 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).

3.2.1 Modeling Description

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 damages. 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 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. 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.
- *Modeled areas* - 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* - 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 seawalls.
- *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.

3.2.2 Modeling Variables

According to 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.

3.1.1.1 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 study area.

3.1.1.2 Structure Inventory

The parcel data and building data used to develop a structure inventory of residential and nonresidential structures were obtained from Baltimore City, Baltimore County, and Anne Arundel County. Cargo including vehicles at the Port of Baltimore, wastewater treatment facilities, and tunnels data were received from the Maryland Department of Transportation (MDOT; in particular Maryland Port Authority) which is the project sponsor. Privately owned vehicles in the study area were estimated and added to the inventory. Debris clean-up cost that the community occurs during a flood event was evaluated and added to each residential and nonresidential structures. The assets will be further discussed in the Assets section and the emergency costs of this Appendix. This inventory was integrated with data from the National Structure Inventory (NSI 2) and modified by Corps personnel to produce the Spatial Asset Data input for G2CRM. The number of Assets (i.e., structure inventory) were based on city and county tax assessor databases reflecting development up to the year 2018. A total of 14,223 structures including residential structures, nonresidential structures, and synthetic assets (private vehicles and debris clean-up) were in the inventory. Newly permitted construction assets for 2019 through 2021 were not provided by the sponsor. Moreover, to derive the structure values, the 2020 RS Means Square Foot Costs Data catalog was used to assign a depreciated replacement cost to the residential and nonresidential structures assets in the study area. A total of 8,917 assets represents residential, nonresidential structures and auto assets among the 14,223 structures in the inventory. These residential and nonresidential structures and other assets were further categorized in 29 occupancy types for analysis purpose. The following Table 3 displays these occupancy types and descriptions.

Table 3: Occupancy Types for Residential, Nonresidential and Auto assets

Occupancy Type	Description	Count
AUTO-N	Auto/Commercial	64,339
AUTO-R	Auto/Residential	3,404
COM1	Average Retail	548
COM2	Average Wholesale	161
COM3	Average Personal & Repair Services	123
COM4	Average Professional/Technical Services	143
COM5	Bank	10
COM7	Average Medical Office	15
COM8	Average Entertainment/Recreation	44
COM9	Average Theatre	3
COM10	Garage	13
EDU1	Average School	12
GOV1	Average Government Services	81
GOV2	Average Emergency Response	2
HRISE	Average Urban High-Rise, More Than 4 Floors	635
IND1	Average Heavy Industrial	79
IND2	Average Light Industrial	347
IND3	Average Food/Drugs/Chemicals	37
IND4	Average Metals/Minerals Processing	25
IND5	Average High Technology	20
IND6	Average Construction	34
REL1	Church	16
RES1-1SNB	Single Family Residential, 1 Story, No Basement	36
RES1-1SWB	Single Family Residential, 1 Story, With Basement	18
RES1-2SNB	Single Family Residential, 2 Story, No Basement	1,024
RES1-2SWB	Single Family Residential, 2 Story, With Basement	1,755
RES3A	Condominium, Living Area, 1-2 Floors	4
RES3B	Condominium, Living Area, 3-4 Floors	117
RES4	Average Hotel, & Motel	4
Total		8,917

Nonresidential replacement costs per square foot were provided in the RS Means catalog for six exterior wall types with respect to each RS Means building/asset category (2-4 Story Office, Bank, Convenience Store, etc.). An average replacement cost per square foot was calculated using the six exterior wall types specific to the corresponding RS Means building/asset category with respect to the mean square footage calculated for all assets within its category. The RS Means depreciation schedule for non-residential structures provides depreciation percentages for three structure frames: wood frame exterior, masonry on wood frame, and masonry on steel frame.

Most of the non-residential structures in the area reflected the masonry on wood exterior wall construction with an approximate effective age of 30 years. The masonry on wood depreciation percentage of 35% was applied as the most likely condition to all non-residential structures. Furthermore, to account for uncertainty, a triangular distribution was used for deriving the maximum and minimum depreciated replacement costs using a depreciation percentage of 20% and 50%, respectively, reflecting effective ages of 20 and 40 years for masonry on steel frame and wood frame exteriors, respectively. Additionally, a commercial location cost factor of 94% of the national square foot costs for the City of Baltimore was then applied to the depreciated cost per square foot to derive the average depreciated replacement cost per square foot with respect to each building/asset category. Finally, the square footage for each individual structure, obtained from the tax assessor when available, or from the NSI 2 data, was multiplied by the average depreciated replacement cost per square foot for each structure's building/asset category.

Residential replacement costs per square foot were provided for four exterior wall types (wood frame, brick veneer, stucco, or masonry) with respect to each building/asset category (RES1-1SNB, RES1-2SNB, RES1-1SWB, RES1-2SWB, etc.) and its construction class (economy, average, or luxury). An average replacement cost per square foot was calculated using the four exterior wall types specific to the corresponding RS Means building/asset category with respect to the mean square footage calculated for all assets with its category. That is, the mean square footage was calculated for each residential asset category regardless of construction class. Then, an average replacement cost per square foot was calculated using the four exterior wall types with respect to each asset category and construction class.

The RS Means depreciation schedule for residential structures provides depreciation percentages for structures in good, average, or poor condition and with respect to the structures' effective age. Most residential structures in the area had an approximate effective age of 30 years. The average condition depreciation percentage of 30% was applied as the most likely condition to all residential structures regardless of construction class. Furthermore, to account for uncertainty, a triangular distribution was used for deriving the maximum and minimum depreciated replacement costs using a depreciation percentage of 15% and 55%, respectively, reflecting effective ages of 20 and 40 years for structures in good and poor condition, respectively. Additionally, a residential location cost factor of 92% of the national square foot costs for the City of Baltimore was then applied to the depreciated cost per square foot to derive the average depreciated replacement cost per square foot with respect to each building/asset category and its construction class. Finally, the square footage for each individual structure, obtained from the tax assessor when available, and when not available, from the NSI 2, was multiplied by the average depreciated replacement cost per square foot for each structure's building/asset category and construction class.

For a small number of structures, when square footage values were not available from either the tax assessor or NSI 2 data, to determine a square footage per building 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, extension of the ceiling from the living space, etc. The area was multiplied by the number of floors calculate the square footage. The structure's depreciated replacement cost was derived by multiplying the structure category's mean square footage by the category's calculated depreciated replacement cost per square foot. This method was applied to both residential and nonresidential structures.

3.1.1.3 Content-to-Structure Value Ratios

Site-specific Content-to-Structure Value Ratios (CSVR) information was not available for the study area. The nonresidential CSVR were taken from Appendix E Table E-1 of the Nonresidential Flood Depth-Damage Functions Derived from Expert Elicitation Draft Report, revised 2013. Moreover, these functions contained a triangular distribution (i.e., minimum, maximum, most likely) to account for the uncertainty surrounding the ratio for each nonresidential occupancy type. The residential CSVR used a combination of both the aforementioned Expert Elicitation Draft Report and EGM 01-03 and 04-01. Moreover, both EGMs contained guidance to account for uncertainty associated with content/structure value ratio, which implies that the uncertainty in the content-to-structure value ratio should be inherent in the content depth-damage relationship as contained in both respective EGMs.

3.1.1.4 Emergency Costs - Debris Clean-Up Cost

In addition to the costs from the physical impacts on the structures in a study area, the following emergency costs occur in a flooded community.

- Actions taken by police, fire, and the other organizations to warn and evacuate floodplain occupants, direct traffic, and maintain law and order just before and during an event,
- Flood fighting efforts, such as sandbagging and building closures, taken to reduce damage,
- Costs of efforts, such as debris removal, establishing emergency shelters, and the provision of money, food, and clothing, to relieve the financial situation experienced by flood victims during and after an event,
- Evacuation costs for floodplain residents, and
- The administrative costs for public agencies and private relief agencies in delivering emergency services.

Debris clean-up costs are evaluated and included in the Baltimore Metropolitan coastal storm study. The cost of 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. To account for the cost/damage surrounding debris cleanup, values for debris removal were incorporated into the structure inventory for each record according to its occupancy type. These values were then assigned a corresponding depth-damage function with uncertainty in the economic models. All values and depth-damage functions were 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." The debris clean-up values provided in the report were expressed in 2010 price levels for the New Orleans area. These values were converted to FY 2022 price levels to Baltimore Metropolitan area, using the indexes provided by Gordian's 40th edition of "Square Foot Costs with RSMeans Data." The debris removal costs were included in the structure records for the individual residential and nonresidential structures and used to calculate the expected annual without-project and with-project debris removal and cleanup costs.

The following maximum clean-up costs are assumed in G2CRM for each occupancy type.

Table 4 *Debris Clean-Up Maximum Cost for Each Structure*

Occupancy Type	New Orleans Study Prototype	Maximum Debris Clean-Up Cost ($FY2022)
D-COM1	Average Retail	43,145
D-COM2	Average wholesale	44,147
D-COM3	Average Personal & Repair Services	42,452
D-COM4	Average Prof/Tech Services	42,452
D-COM5	Bank	42,452
D-COM7	Average Medical Office	42,452
D-COM8	Average Entertainment/Recreation	42,452
D-COM9	Average Theatre	43,417
D-COM10	Garage	42,452
D-EDU1	Average school	43,417
D-GOV1	Average government services	43,417
D-GOV2	Average Emergency Response	43,417
D-HRISE	High-rise structure, 4 stories and above	43,417
D-IND1	Average heavy industrial	43,417
D-IND2	Average light industrial	53,139
D-IND3	Average Food/Drug/Chem	53,139
D-IND5	Average High Technology	53,139
D-IND6	Average Construction	53,139

Occupancy Type	New Orleans Study Prototype	Maximum Debris Clean-Up Cost ($FY2022)
D-REL1	Church	43,417
D-RES1-1SNB	Res 1, 1 Story no Basement	7,241
D-RES1-1SWB	Res 1, 1 Story w/ Basement	7,241
D-RES1-2SNB	Res 1, 2 Story no Basement	7,241
D-RES1-2SWB	Res 1, 2 Story w/ Basement	7,241
D-RES3A	Multi-Family housing 2 units	10,777
D-RES3B	Multi-Family housing 3-4 units	10,777
D-RES4	Average Hotel, & Motel	42,560

3.1.1.5 Depth-Damage Relationship

Site-specific depth-damage functions (DDF) were not available for the study area for both nonresidential and residential structures. A triangular probability distribution was used to represent the uncertainty surrounding the DDF. 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. These values can be found in NACCS report, Tables 12 through 104 for structures and content. The residential DDFs used a combination of both the aforementioned Expert Elicitation Draft Report and EGM 01-03 and 04-01. Moreover, both EGM 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.

3.1.1.6 First Floor Elevation

The 2017 Light Detection and Ranging (LiDAR) raster (1 meter resolution) in feet NAVD 88 was used to determine ground elevations at the centroid of each parcel where the structure is most likely located using ArcGIS. From Foundation Height Certificates, the foundation height of each structure was added to the ground elevation to come out with probable first floor elevations. The error of plus and minus 0.5 from Lidar data and Foundation Height Certificates were used as uncertainties to develop a triangular distribution for the first floor elevation.

A first-floor standard error of 0.6 feet with a deviation of 0.3 feet assuming normal distribution was used to quantify uncertainty based on guidance found in Engineering Manual (EM) 1110-2-1619, Table 6-5, aerial survey, 2-ft contour interval. The datum used to determine first floor elevations is the same datum used to determine water level elevations for the simulated coastal storms. There are two sources of uncertainty surrounding the first floor elevations: the use of the LiDAR data for the ground elevations, and the methodology used to determine the structure foundation heights above ground elevations.

3.1.1.7 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 may 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 damage. 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 engineering inputs into G2CRM.

3.1.1.8 Storms

The number of storms 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 data applied for the Baltimore study were developed from the NACCS. NACCS produced storm tracks that cover the probability space of potential storms. These tracks allow for selection of relevant storms for study sites. The study applied any storm with a track within a 200 km radius circle of the project site. 291 tropical storms and 100 extra tropical storms were selected. 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 291 tropical storms and 100 extra tropical storms. 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.

For the Baltimore Metropolitan study G2CRM, the bootstrap method was used to determine storm events for the period of analysis. Each G2CRM simulation run starts using the abovementioned reduced storm set which determines the storms that are drawn randomly by bootstrapping. The bootstrap approach is based on choosing the random storms as a Poisson distribution based on average number of storms in the season (as an input) for the study area. The bootstrapping approach also takes into account the relative probability of each storm (i.e., higher probability storms are chosen more often), which is technically bootstrap sampling with replacement. A rate of 0.015 storms per month was applied from June to November for the Tropical season and 0.1689 storms per month was applied for the extratropical season. The Datum conversions for the tide and surge were calculated based on the NACCS CHS conversion data available for Save Points and applied within the metadata files to transform water levels to the NAVD88 datum used for the asset inventory. Each of the 291 tropical storms and 100 extra tropical storms for the study area has an associated storm probability and storm surge information (e.g., water levels) at each save points. However, seven storms, storms identifiers NACCS_96, NACCS_97, NACCS_98, NACCS_99, NACCS_997, NACCS_998, and NACCS_999, have zero water level.

3.1.1.9 Tide gauge

Baltimore Harbor tides are evaluated using NOAA tide gauge 8574680 at Fort McHenry installed in September of 1989. The mean tide range in the Harbor is 1.14 feet and the diurnal range is 1.66 feet. Occasionally, abnormally high, or low water levels occur as a result of changes in atmospheric pressure, storm surge, the magnitude and direction of wind and/or waves, and other meteorological anomalies. The highest water level observed was 8.15 feet MLLW (7.31 feet NAVD88) during Hurricane Isabel on September 19, 2003.

3.1.1.10 Save Points

The numerical modeling aspect of the study area is to provide estimates of waves and water levels for existing conditions, future without project conditions, and future with project conditions. The Advanced Circulation Model (ADCIRC) is a high-fidelity model that predicts water levels and currents based on input parameters including subsurface bathymetry, wind velocity, atmospheric pressure, and storm tracks. The results of ADCIRC are in the form of water level hydrographs and are reported in save points. From many points, three comprehensive save points 5944, 10930, and 13228 were selected in the study area. Save point 5944 is in Fort McHenry, save point 10930 is in Martin State Airport, and save point 13228 is near to Port of Baltimore. These save points contained the water elevations and wave heights for each of the storm to be used in the model and eventually used to represent 25 model areas. Save point 5944 does not have waves actions. The combination of the flood barrier and the bulkheads model areas will be discussed later. These water elevations will be applied to the model areas along with economic inputs to derive flood damages in the existing conditions, future without project conditions, and future with project conditions for the Baltimore Metropolitan study area.

4. EXISTING CONDITION

4.1 ASSETS

Parcel data was obtained from the Baltimore City, Baltimore County, and Anne Arundel County tax assessor's office and used to build a Geographic Information System (GIS) database identifying which parcels and structures fell within the FEMA 0.2% annual chance exceedance event floodplain. The structure inventory identified 8,917 structures and vehicles. The structures are broken down as residential and commercial structures with their content values, infrastructure and cargo at the Port of Baltimore, Ft. McHenry Tunnel with the depreciated replacement value (DRV) with $4.1 billion on Interstate 95 and Harbor Tunnel with DRV of $2.2 billion on Interstate 895, Baltimore Shot Tower Metro Station with DRV of $60.5 million, and the munition depot with $50 million at Martin State Airport. The office of engineers at Martin State airport provided the DRV of the munition depot. The tunnels' replacement values are prepared by the Maryland Transportation Authority consultant. The consultant used National Highway Consultation Cost Index (NHCCI) to develop the DRV. Table 5 shows the repartition of the assets by jurisdictions.

Table 5: Asset Count by Jurisdiction

Jurisdiction	Number of Structures	Number of Vehicles	Total Number of Assets
Baltimore City	5,115	3,515	8,630
Baltimore County	150	96	246
Anne Arundel County	41	0	41
Total	5,304	3,611	8,917

4.1.1 Vehicle Inventory and Valuation

Vehicle valuation is based on data from the 2021 Edmunds Used Vehicle Outlook. Five years used vehicle values are evaluated. The vehicle types selected are sedan, coupe, SUV, truck, and large vehicle. These classes are assumed to be distributed as shown in Table 6 to arrive at a weighted-average vehicle value of $27,977.

Table 6: Average Vehicle Value in the Baltimore Metropolitan study area

Vehicle Type	Percentage in Study Area	Average Cost	Weighted Cost
Sedan	40%	$23,998	$9,599
Coupe	10%	$19,988	$1,999
SUV	20%	$29,399	$5,880
Truck	20%	$32,497	$6,499
Large Vehicle	10%	$40,000	$4,000
		Weighted Average Cost:	$27,977

Note: Average vehicle cost calculated from data in the 2021 Edmunds Used Vehicle Outlook.

Household vehicles included in the structure inventory are private vehicles. Using data from Table 5, "*Percentage of Respondents Moving at Least One Vehicle to Higher Ground*" from the Corps' EGM-09-04 report published in 2009, it is assumed approximately 49.5, 19.4, and 11.9 percent of privately owned vehicles are not evacuated to higher grounds during storm events given warning time of less than 6 hours, 6 to 12 hours, and greater than 12 hours respectively. The triangular vehicle values used in the inventory are presented in Table 7.

Table 7: Private Vehicles Valuation

	Residential Vehicle Valuation		
	Minimum	**Most Likely**	**Maximum**
Weighted Average Cost	$27,977	$27,977	$27,977
Vehicle per Household	1	1	1
Respondents who did not move Vehicles	11.90%	19.40%	49.50%
Vehicle Value per Household	$3,329	$5,428	$13,849

The three evacuation remaining rates resulted in the values of $3,329, $5,428, and $13,849 which were used as the triangular distribution parameters of the structure value.

In additional to the residential vehicles, there are a significant number of cargo vehicles and heavy equipment at the Port of Baltimore. They were counted using aerial imagery. A total of 207 vehicle lots were counted. A conservative assumption was made that 50% of the vehicles would be removed if a flood hazard were anticipated. Hence, a 50-percent is applied to the values of the cargos. Table 8 shows the triangular distribution values of cargo vehicles and heavy equipment at the Port of Baltimore. Vehicles parked at Maryland Port Administration facilities are not assumed to be moved to higher ground during a flood event. Hence their triangular distribution values are shown in the Table 8 below.

Table 8: Maryland Port Administration Vehicle Inventory

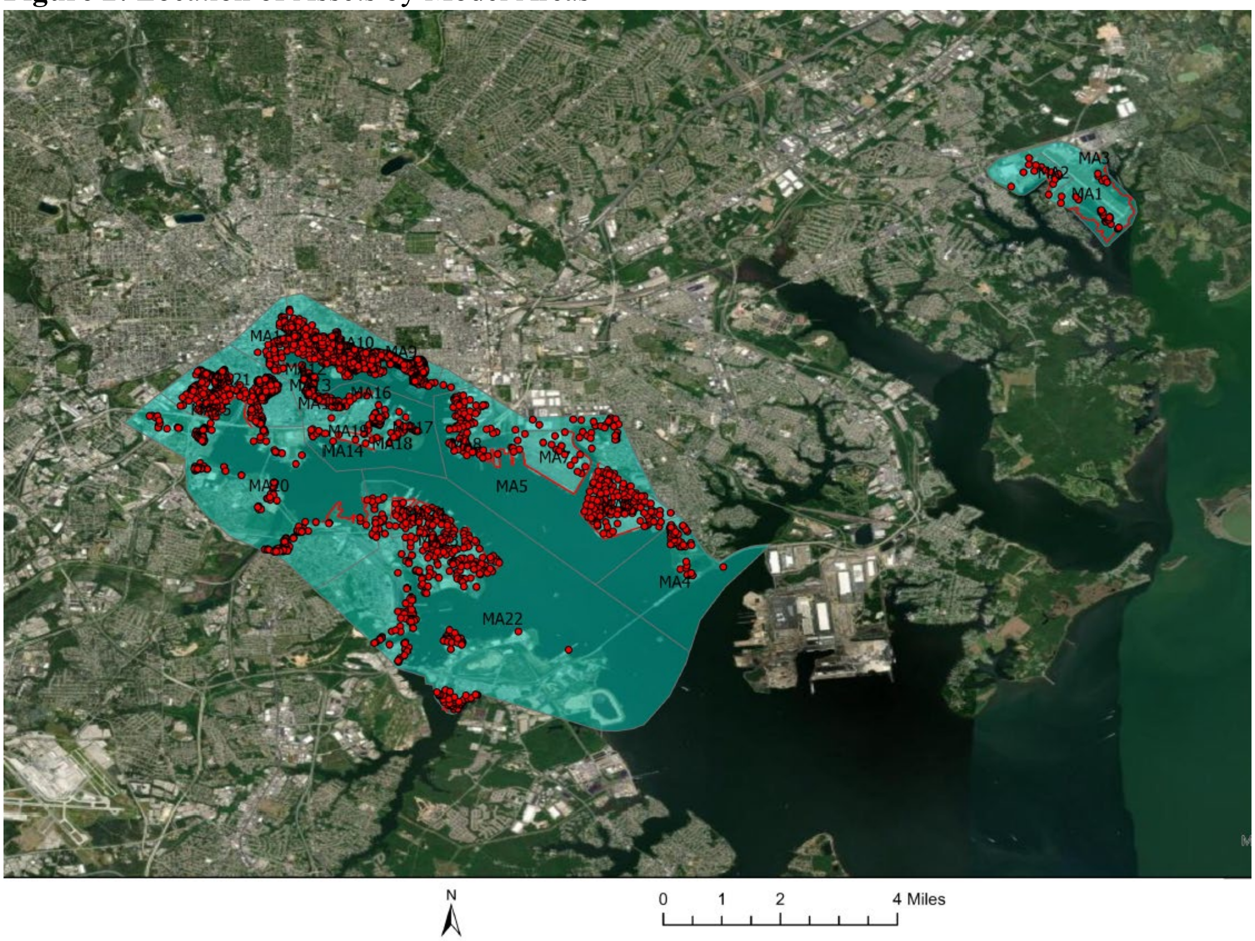
	Port Cargos (Vehicles) Values			
	Count	Minimum	Most Likely	Maximum
Cars	44,664	$7,500	$12,500	$17,500
Heavy Equipment	15,435	$1,150	$12,500	$13,500
Luxury Cars	615	$20,000	$25,000	$30,000
Tractors	804	$10,834	$12,500	$14,167
Trucks	2,821	$12,500	$17,500	$22,500

Residential and commercial vehicle depth-damage relationships were taken from Economic Guidance Memorandum (EGM), 09-04., Generic Depth-Damage Relationships for Vehicles.

Vehicles are entered into the G2CRM model inventory in the same manner as structures. This means they are given a dollar value as discussed previously in this section and utilize vehicle depth-damage functions from data compiled by the USACE New Orleans District (USACE 2006). Vehicle ground elevations are the same as the ground elevation of the structure to which they belong. An arbitrary slab foundation type is assigned to the vehicle to determine the beginning damage elevations.

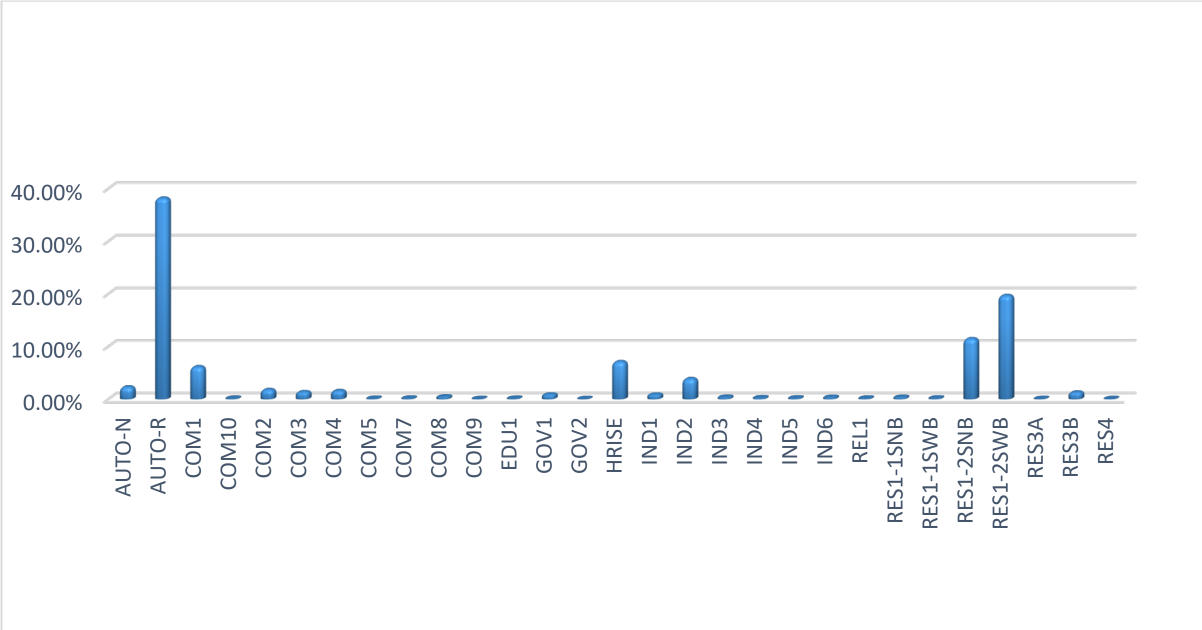
Assets are spatially located entities that can be affected by storms, waves, sea level rise and tides. For this analysis, assets consist of the residential and commercial structures with their content values, residential vehicles, infrastructure and cargo at the Port of Baltimore, Ft. McHenry Tunnel on Interstate 95 and Harbor Tunnel on Interstate 895, Baltimore Shot Tower Metro Station, and the munition depot at Martin State Airport as shown in the Figure 2 below. The study area is a highly urbanized, relatively flat community with nearly all areas below elevation 20 feet. The low elevations and tidal connections to the Baltimore Harbor place a significant percentage of the city at risk of flooding from, tropical storms, extra tropical storms, hurricanes, and other storms.

Figure 2: Location of Assets by Model Areas



The Baltimore Metropolitan study area structure inventory, as modeled, contains 8,917 structures. Out of those residential and nonresidential structures, the occupancy types most found were single Family Residential, Residential Vehicles, Condominium Living Area and Retail Stores, Wholesale, Professional and Technical Services. Below Figure 3 shows the proportion of each occupancy type in the Baltimore Metropolitan area. Note that the proportion is rounded to a whole number.

Figure 3: Proportion of each Occupancy Types in the Baltimore Metropolitan study area



4.1.2 Residential and Non-residential Content-to-Structure Value Ratios

Content to structure value ratios (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 (NACCS 2015) and the Non-residential Flood Depth-Damage Functions Derived from Expert Elicitation Draft Report, revised 2013 (IWR 2013). As shown in Table 9, 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 9: Content-to-Structure Value Ratios (CSVRs)

Category	Occupancy Type	Occupancy Description	Min	Most Likely CSVR %	Max	Source
Commercial	COM1	Retail	37%	45%	53%	2013 Prototype 12
	COM2	Wholesale	31%	37%	43%	NACCS, Prototype 2
	COM3	Personal & Repair Services	56%	66%	74%	2013 Prototype 13
	COM4	Prof/Tech Services	14%	18%	24%	NACCS, Prototype 2
	COM5	Bank	14%	18%	24%	2013 Prototype 7
	COM6	Hospital	35%	44%	50%	2013 Prototype 6
	COM7	Medical Office	53%	60%	66%	2013 Prototype 5
	COM8	Entertainment/Recreation	20%	25%	31%	2013 Prototype 19
	COM9	Theatre	14%	18%	24%	NACCS, Prototype 2
	COM10	Garage	31%	37%	44%	NACCS, Prototype 3
	HRISE	Urban High-Rise	14%	18%	24%	NACCS, Prototype 4A

Category	Occupancy Type	Occupancy Description	Min	Most Likely CSVR %	Max	Source
Public	EDU1	school	5%	7%	9%	2013 Prototype 21
	GOV1	Government Services	14%	18%	24%	NACCS, Prototype 2
	REL1	Church	5%	7%	11%	2013 Prototype 20
Industrial	IND1	Heavy industrial	32%	38%	44%	2013 Prototype 14
	IND2	Light industrial	32%	38%	44%	2013 Prototype 14
	IND3	Food/Drug/Chem	14%	18%	24%	NACCS, Prototype 2
	IND4	Metals/Minerals processing	14%	18%	24%	NACCS, Prototype 2
	IND5	High Technology	14%	18%	24%	NACCS, Prototype 2
	IND6	Construction	32%	38%	44%	2013 Prototype 14
Residential	RES1-1SNB	Res 1, 1 Story no Basement	25%	50%	75%	NACCS, Prototype 5A
	RES1-1SWB	Res 1, 1 Story w/ Basement	25%	50%	75%	NACCS, Prototype 5A
	RES1-2SNB	Res 1, 2 Story no Basement	25%	50%	75%	NACCS, Prototype 5B
	RES1-2SWB	Res 1, 2 Story w/ Basement	25%	50%	75%	NACCS, Prototype 5B
	RES3A	Condominium, 1 Story	8%	10%	14%	NACCS, Prototype 1A-1
	RES3B	Condominium, 2-3 Stories	8%	10%	14%	NACCS, Prototype 1A-3
	RES4	Average Hotel, & Motel	20%	26%	33%	2013 Prototype 4

(1) 2013 – Nonresidential Flood Depth-Damage Functions Derived from Expert Elicitation, Revised 2013
(2) NACCS – NACCS Physical Depth Damage Functions Summary Report

4.1.3 Summary of the inventory

The assets were categorized as residential or nonresidential which were further categorized into occupancy types (reference Table 3 in Structure Inventory section). Table 10 below displays the count and structure value by the occupancy types.

Table 10: Structure Inventory by Occupancy Types

Occupancy Type	Description	Count	Structure Value	Content Value
AUTO-N	Auto/Commercial	64,339	$825,080,000	$0
AUTO-R	Auto/Residential	3,404	$17,947,000	$0
COM1	Average Retail	548	$404,075,000	$181,834,000
COM10	Garage	13	$41,761,000	$15,452,000
COM2	Average Wholesale	161	$499,216,000	$184,710,000
COM3	Average Personal & Repair Services	123	$131,887,000	$87,046,000
COM4	Average Professional/Technical Services	143	$447,510,000	$80,552,000
COM5	Bank	10	$7,119,000	$1,281,000
COM7	Average Medical Office	15	$36,205,000	$21,723,000
COM8	Average Entertainment/Recreation	44	$225,359,000	$56,340,000
COM9	Average Theatre	3	$51,487,000	$9,268,000
EDU1	Average School	12	$61,738,000	$4,322,000

Occupancy Type	Description	Count	Structure Value	Content Value
GOV1	Average Government Services	81	$295,814,000	$53,246,000
GOV2	Average Emergency Response	2	$1,104,000	$773,000
HRISE	Average Urban High-Rise, More Than 4 Floors	635	$7,480,368,000	$1,241,765,000
IND1	Average Heave Industrial	79	$263,301,000	$100,054,000
IND2	Average Light Industrial	347	$1,003,586,000	$441,840,000
IND3	Average Food/Drugs/Chemicals	37	$28,570,000	$55,195,000
IND4	Average Metals/Minerals Processing	25	$21,479,000	$3,866,000
IND5	Average High Technology	20	$175,917,000	$31,665,000
IND6	Average Construction	34	$73,199,000	$6,363,723,000
REL1	Church	16	$27,404,000	$1,918,000
RES1-1SNB	Single Family Residential, 1 Story, No Basement	36	$11,783,000	$5,892,000
RES1-1SWB	Single Family Residential, 1 Story, With Basement	18	$3,432,000	$1,716,000
RES1-2SNB	Single Family Residential, 2 Story, No Basement	1,024	$239,046,000	$119,523,000
RES1-2SWB	Single Family Residential, 2 Story, With Basement	1,755	$353,197,000	$176,599,000
RES3A	Condominium, Living Area, 1-2 Floors	4	$1,361,000	$136,000
RES3B	Condominium, Living Area, 3-4 Floors	117	$64,897,000	$5,768,000
RES4	Average Hotel, & Motel	4	$31,330,000	$8,146,000
Total		**8,917**	**$12,825,175,000**	**$9,254,351,000**

Critical infrastructure in the Baltimore Metropolitan area includes Baltimore City fire stations, Baltimore City Police Department Headquarters, Maryland Transportation Authority Police - Dundalk Marine Terminal, U.S Customs and Border Protection Field Office, Maryland Port Administration World Trade Center Building. Baltimore City is also home to medical facilities in the study area which include MedStar Harbor Hospital, and Mercy Medical Center. Schools such as The Crossroads School, Sharp Leadenhall Elementary School, Mother Seton Academy, and New Century School are in 1% Annual Exceedance Probability (AEP) areas except Sharp Leadenhall which is in 0.2% AEP. Power plants such as Domino Sugar Baltimore, Inner Harbor East Heating Plant, Wheelabrator Baltimore Refuse incineration plant and the Patapsco Wastewater Treatment Plant are subject to flooding. The other critical infrastructure in the Baltimore Metropolitan area includes Martin State Airport in Baltimore County, and the Curtis Bay U.S. Coast Guard yard in Anne Arundel County. Intermediate sea level change rate of 0.00994 feet per year affects the Baltimore Metropolitan area. Based on future without project condition hydraulic data, in the year 2075, police stations, health care facilities, fire stations, and most schools in the Baltimore Metropolitan study area would be flooded during a 4% AEP event.

4.2 MODEL AREAS

Model areas are established to represent the various geographic parts of the study area that have uniform flood elevations. 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. Considerable professional judgment was used in defining MA boundaries including taking into account natural or built topological features (e.g., a ridge, highway, or railway line) to define MA boundaries. Dividing the study area into model areas facilitates evaluation of flood damages by breaking the study area down into several areas having some common features. Analyzing them separately also speed up the economic modeling process. The study area consists of 25 model areas. The 25 model areas are MA1: Martin State Airport unprotected, MA2: Martin State Airport West, MA3: Martin State Airport East, MA4: Patapsco East, MA5: Patapsco North, MA6: Patapsco North Dundalk, MA7: Patapsco North Seagirt, MA8: Patapsco North I895 Tunnel, MA9: Inner Harbor, MA10: Inner Harbor Canton, MA11: Inner Harbor Harborplace, MA12: Inner Harbor Ritz Carlton, MA13: Inner Harbor Harborview, MA14: Locust Point, MA15: Locust Point Museum of Industry, MA16: Locust Point American Sugar, MA17: Locust Point Fort McHenry, MA18: Locust Point I95 Tunnel Facility, MA19: Locust Point I95 Tunnel, MA20: Middle Branch Patapsco, MA21: Middle Branch Patapsco River, MA22: Patapsco South, MA23: Patapsco South Fairfield, MA24: Patapsco South I895 Tunnel, MA25: Middle Branch Wheelabrator Plant. These model areas are spatial areas defined by geospatial polylines as shown in Figures 4, 5 and 6

Figure 4: Model Area Boundaries and their Description

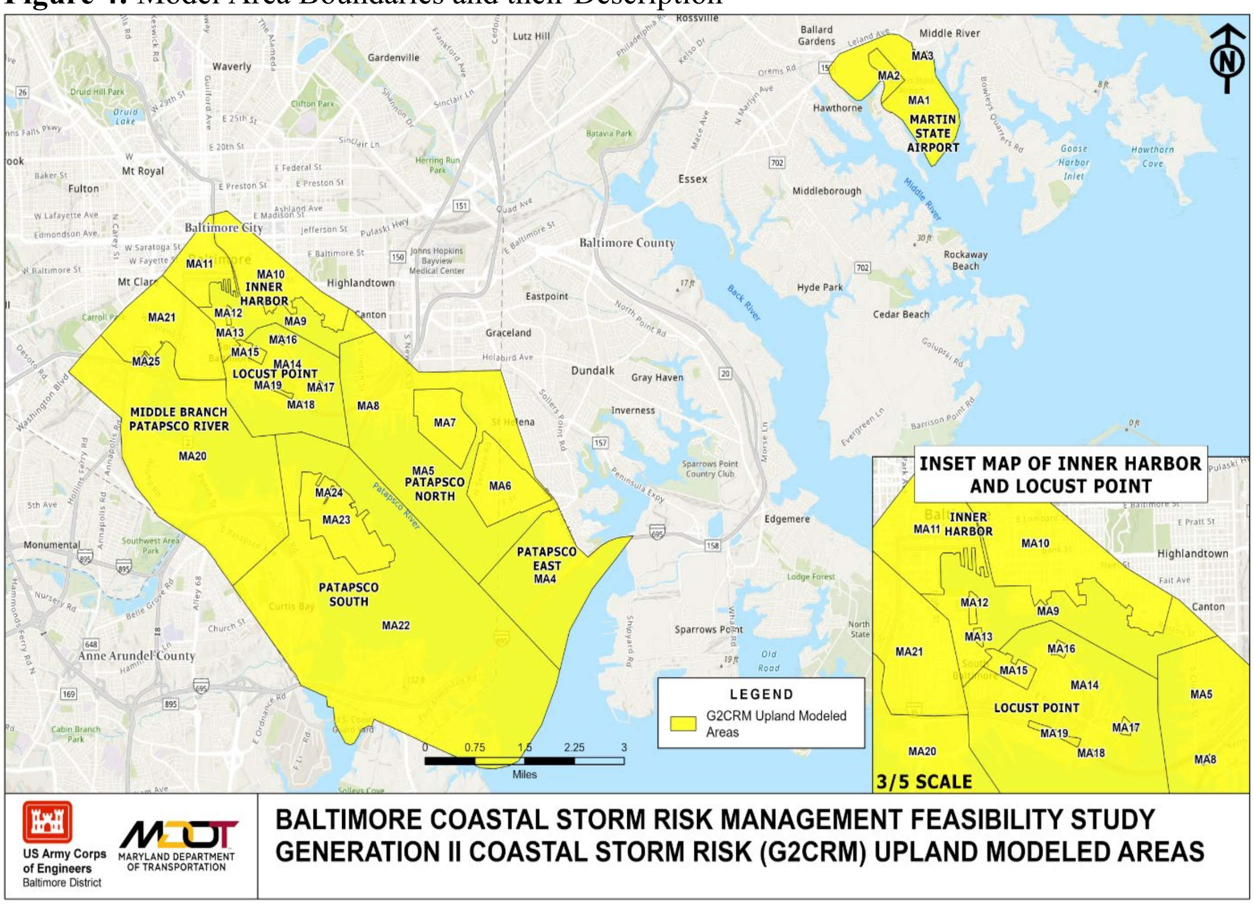


Figure 5: Model Area Boundaries in Harbor Area

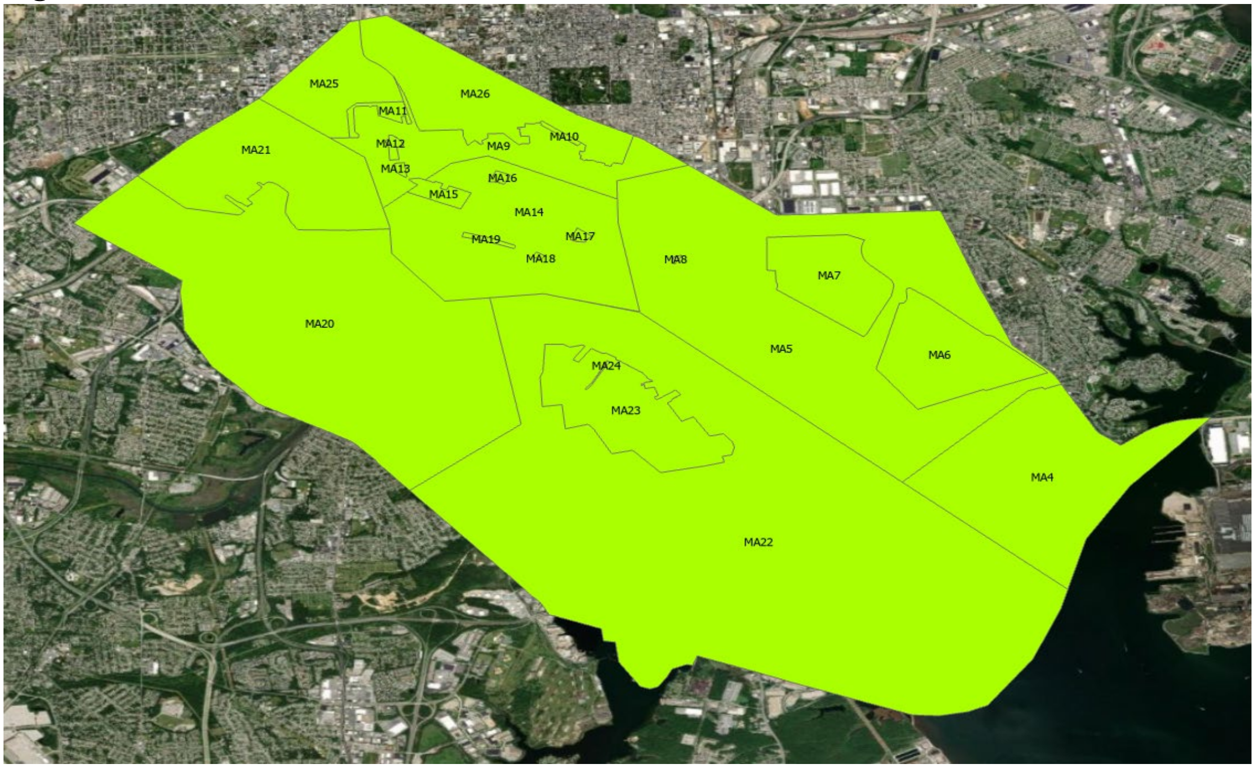


Figure 6: Model Area Boundaries in Martin State Airport

There are two types of model areas: unprotected MAs and upland MAs. An unprotected modeled area is a polygonal 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 polygonal boundary within G2CRM that contains assets and derives associated stage from the total water level calculated for a given storm, as mediated by a protective system element such as a bulkhead/seawall or flood barrier that must be overtopped before water appears on the modeled area. It also has an associated volume-stage relationship to account for filling behind the bulkhead/seawall or flood barrier during the initial stages of overtopping.

Moreover, it is important to note that there is no PSE that exists in the Baltimore Metropolitan area. 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. Table 11 shows the model area with protected or unprotected by bulkheads in the future with project conditions.

Table 11: Model Area Types

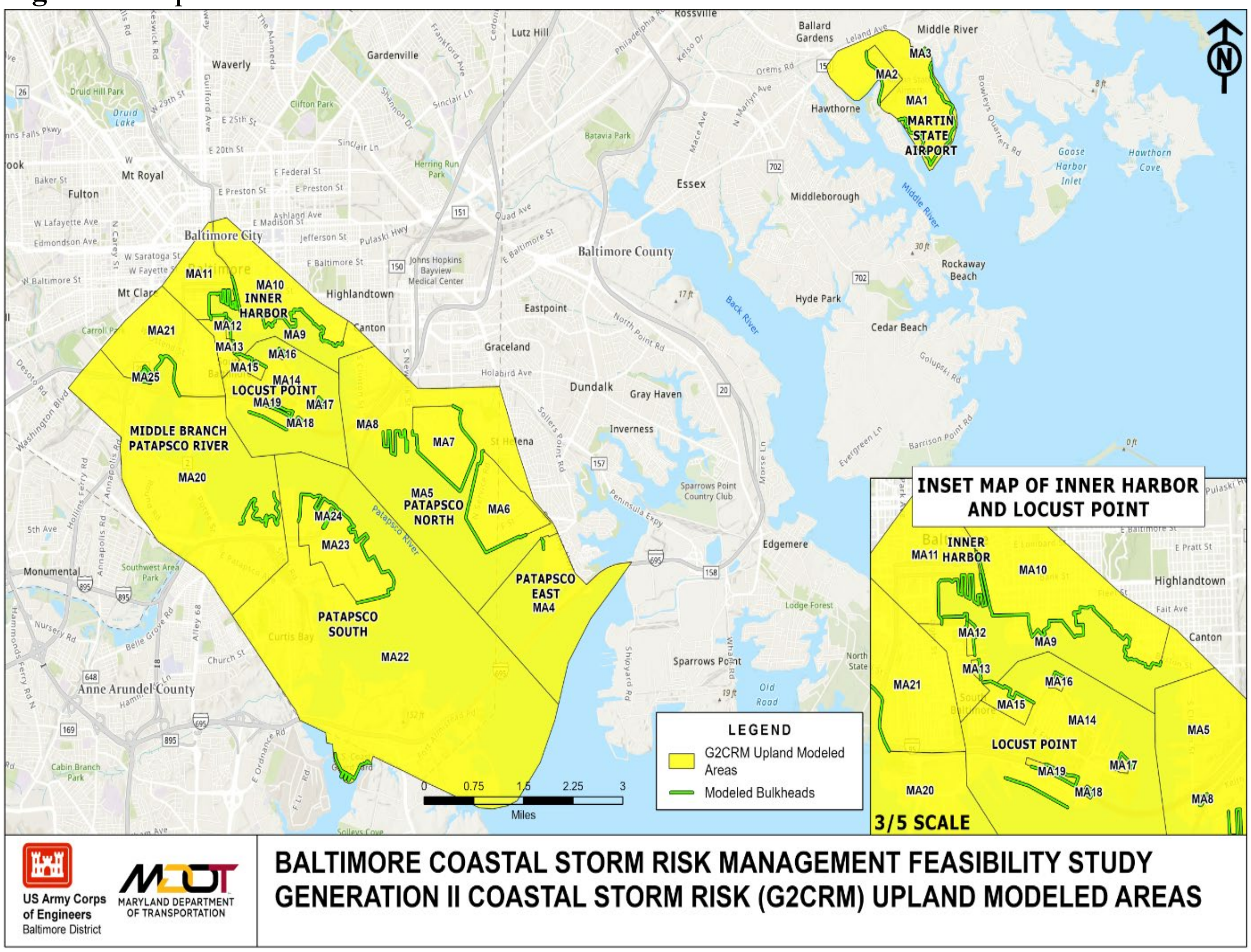
MA	MA Descript	MA Type
MA1	Martin State Airport Unprotected	Upland
MA2	Martin State Airport West Bulkhead	Upland
MA3	Martin State Airport East Bulkhead	Upland
MA4	Patapsco East Unprotected	Upland
MA5	Patapsco North Unprotected	Upland
MA6	Patapsco North Dundalk with existing Bulkhead	Upland
MA7	Patapsco North Seagirt Bulkhead	Upland
MA8	Patapsco North I-895 Bulkhead	Upland
MA9	Inner Harbor Unprotected	Upland
MA10	Inner Harbor Canton Bulkhead	Upland
MA11	Inner Harbor Harborplace Bulkhead	Upland
MA12	Inner Harbor Ritz Carlton Bulkhead	Upland
MA13	Inner Harbor Harborview Bulkhead	Upland
MA14	Locust Point Unprotected	Upland
MA15	Locust Point Museum of Industry Bulkhead	Upland
MA16	Locust Point American Sugar Bulkhead	Upland
MA17	Locust Point Fort McHenry Bulkhead	Upland
MA18	Locust Point I-95 Tunnel Facility Bulkhead	Upland
MA19	Locust Point I-95 Tunnel Bulkhead	Upland
MA20	Middle Branch Patapsco River	Upland
MA21	Middle Branch Patapsco River Bulkhead	Upland
MA22	Patapsco South Unprotected	Upland
MA23	Patapsco South Fairfield Bulkhead	Upland
MA24	Patapsco South I-895 Tunnel Bulkhead	Upland
MA25	Middle Branch Wheelabrator Plant	Upland

4.3 PROTECTIVE SYSTEM ELEMENTS

Flood hazard manifested at the storm location is mediated by the Protective System Element (PSE) such as bulkhead/seawall or flood barrier. The PSE prevents transmission of the flood hazard into the MA until the flood hazard exceeds the top elevation of the bulkhead/seawall or flood barrier. When the flood hazard exceeds the bulkhead/seawall or flood barrier top elevation the flood hazard is instantaneously transmitted into the MA unmediated by the bulkhead/seawall or flood barrier.

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 or a flood barrier). Figure 7 shows the protected MAs with bulkhead for the future with project conditions in the study area.

Figure 7: Unprotected and Protected MAs with Bulkheads



The top elevation is specified at the approximate existing ground elevation within the MA for both the existing and future without condition simulation, in G2CRM. In this way, the bulkhead/seawall or the flood barrier does not influence the existing condition consequences of the flood hazard. For the future with project condition the bulkhead/seawall or the flood barrier top-elevation is raised in the alternative file and its influence is captured.

4.4 VOLUME-STAGE FUNCTIONS

Volume-stage functions also 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 team members and GIS sections and describe the relationship between the volume contained in the model area and the associated stage (water depths) for each MA. Water level within the MAs is computed by first estimating the volume of water passing over the PSEs and then using the stage-volume relationship to determine water level within the MAs. Once the storage area in the MAs is filled, the flood hazard is transmitted into the MAs unmediated by the bulkhead/seawall or the flood barrier.

4.5 EVACUATION PLANNING ZONES

Communities in the Baltimore Metropolitan area are vulnerable to flooding. In addition to more than 48,087 people on the study area, thousands of commuters and tourists are in the Baltimore Metropolitan study area on a daily basis. During storm surge events, the ability of first responders to reach the location of need and the ability of individuals to reach medical facilities can be limited or cut off entirely.

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, many low-income communities, and 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 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. 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 polygonal 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). Therefore, in G2CRM, each Asset is assigned to an MA which is assigned to an EPZ and then modeled in G2RM for potential life loss given a storm event.

In G2CRM, life loss calculations are performed on a per-structure per-storm basis. In order for life loss calculations to be made, the maximum stage in the modeled area has to be greater than the foundation height plus the ground height.

Loss of life calculations are separated out by age categorization with under 65 being one category and 65 and older being the second category. They are also categorized during daytime and nighttime. There are three possible lethality functions for structure residents: safe, compromised, and chance. Safe would have the lowest expected life loss, although safe does not imply that there is no life loss, and chance would have the highest expected life loss.

4.6 EXISTING CONDITION MODELING RESULTS

The assets assigned to each MA and EPZ were modeled in G2CRM using the 291 tropical storms and 100 extra tropical storms with its relative probability-water level relationship. G2CRM used the economic (e.g., Assets) and engineering inputs (e.g., Storms) to generate expected present value (PV) damages for each structure throughout the life cycle (i.e., the period of analysis). The possible occurrences of each economic (i.e., triangular distribution) and engineering (i.e., relative probabilities) variables were derived through the use of Monte Carlo simulation and a total of 100 iterations were executed by the model for this analysis. That is every iteration represents expected PV damages for the period of analysis and cumulative damages of assets converged at about 100 iterations.

The sum of all damages for each life cycle were divided by the number of iterations to yield the expected PV damages for that modeled simulation. A mean and standard deviation were automatically calculated for the PV damages for each MA. For this analysis, G2CRM used 291 tropical storms and 100 extra tropical storms produced by high fidelity coastal modeling (reference Engineer Appendix) for each MA. Seven of 291 tropical storms have zero water level. Each storm had a relative probability associated with it. Any chance of that storm happening in the model simulation was based on that relative probability. Moreover, each storm given its relative probability had an equivalent specific peak water level. These water levels were applied to each structure in each MA and EPZ to determine damages and consequences.

5. FUTURE WITHOUT PROJECT CONDITION

The future without project condition and forecast assumptions based on the existing condition were critical to the planning process since they provide the baseline for the subsequent evaluation and comparison phases. The following discussion includes projections about the future of the Baltimore Metropolitan study area if the federal government or local interests do not address the problems identified in this study.

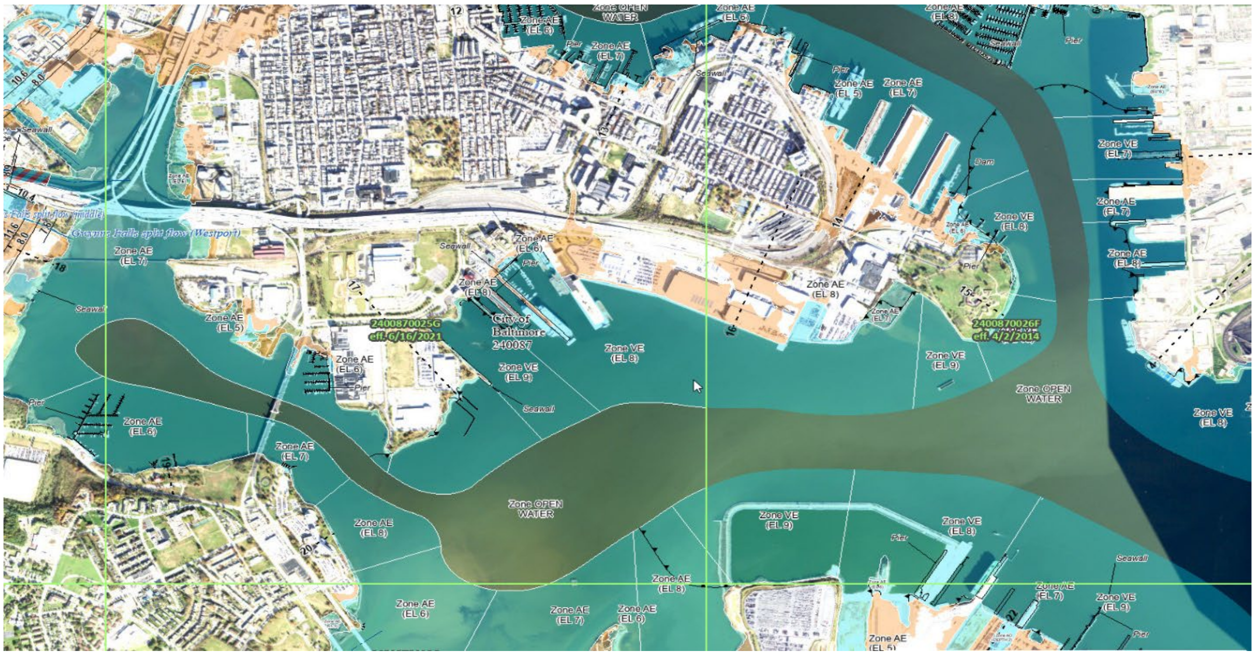
5.1 BACKGROUND

The Baltimore Metropolitan study area has experienced a marked increase in the number of days of “minor coastal flooding” over time, which will increase along with rising sea levels. Similarly, the water table below Baltimore will continue to rise, limiting the effectiveness of gravity drain potential post-storm. Subsidence will increase as soil deposited naturally, or by humans, compacts over time.

The Baltimore Metropolitan study area without-project future conditions will be worsened by tidal influence in the inner harbor in conjunction with development in low lying areas and an overtaxed stormwater. Flooding and wave actions as continued sea level rise also contribute to future storm damages. The reconstruction of substantially damaged buildings to levels above the regulated Base

Flood Elevation (BFE) in accordance with floodplain management regulations will provide them resiliencies against future storms.

Figure 8: BEFs Snapshot in the Inner Harbor



According to the FEMA Flood Insurance Rate Map (FIRM), virtually (Attached figure) the Baltimore Metropolitan study area has been classified as Special Flood Hazard Area (SFHA) Zones AE which are areas of inundation by the 1-percent annual-chance flood, including areas with the 2-percent wave runup, elevation less than 3.0 feet above the ground, and areas with wave heights less than 3.0 feet. These areas are subdivided into elevation zones with BFEs assigned.
To regulate land development in the floodplain, various ordinances and regulations have been enforced to ensure public safety and reduce property damages. The ordinances and regulations call for elevating buildings above the adopted BFE for both new construction projects and substantial improvements to existing structures. The overall future condition of the study area is uncertain.
The NFIP requires that if the costs of reconstruction, rehabilitation, additions, or other improvements to a building equal or exceed 50% of the building's market value, then the building must meet the same construction requirements as a new building. Substantially damaged buildings must be brought up to the same standards. This means that a residence damaged where the cost of repairs equals or exceeds 50% of the building's value before it was damaged must be elevated above the BFE. G2CRM has the capacity to elevate structures once a given level of damage is accrued. Hence, 50% raising damage threshold assumption will be applied to structures that are not currently elevated to the BFE in the FEMA flood zones.

Infrastructure and cargo would be damaged at Maryland Port Administration facilities. Vehicles that are waiting for import/export in the parking lots at the Dundalk, South Locust Point, and Fairfield terminals are subject to flooding. At any given time, these terminals have thousands of vehicles which are vulnerable to damage from coastal flooding. Maryland Port is the economy backbone of the region.

Maryland State Highway Administration assets are vulnerable to damage from coastal flooding. Ones of the most vulnerable areas to flooding are the Interstate 95 Fort McHenry Tunnel, the Interstate 895 Baltimore Harbor Tunnel, and their supporting infrastructure. Floodwaters may enter the tunnels and cause damage to systems in the tunnels, and structures on land housing ventilation and other equipment would be damaged during a coastal flood event. The I-95 Fort McHenry Tunnel is also exposed to waves coming from the south side of the tunnel along McComas Street while the ground elevation of the I-895 Baltimore Harbor Tunnel is at the edge of the water. Floodwaters usually get into these tunnels and impair the circulation of vehicles and the economy of the region.

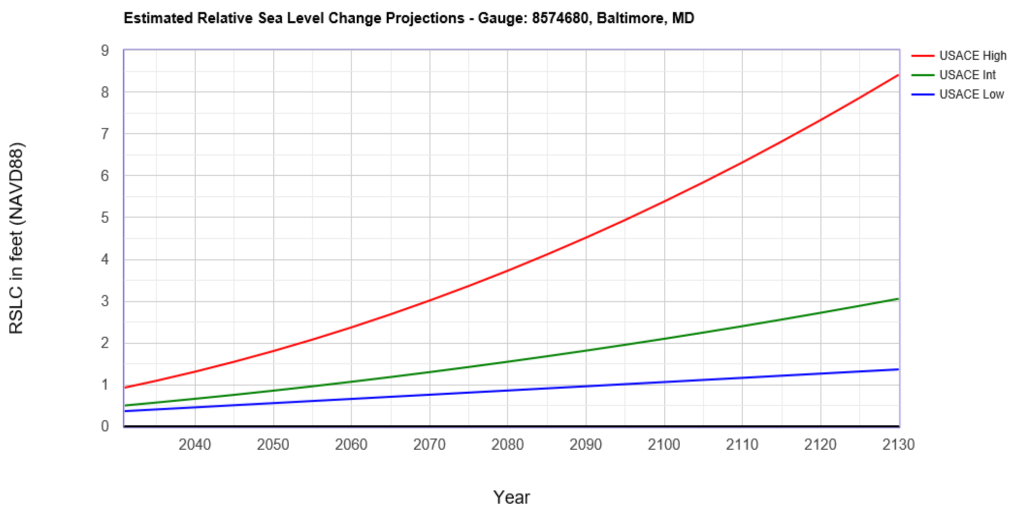
The southern portion of the Martin State Airport runway will be inundated in a coastal storm and is susceptible to damage. Also, on Strawberry Point at the southern end of the airport, hangers housing the Maryland State Police aviation unit would be damaged and operations would need to be relocated. The airport fuel tank farm would be inundated. Wilson Point Road would be inundated. As a result, the access to the residential community of Wilson Point will be cut off. Facilities of the Maryland Air National Guard, a tenant of the airport, would be damaged, including munitions storage, and the primary access road to the base would be inundated. Finally, coastal flooding would damage mitigation systems in place for the remediation of groundwater contamination at Martin State Airport.

The project base year is identified as 2031. Using the intermediate sea level rise curve, many structures in the Baltimore Metropolitan study area will be subject to coastal storm inundation during a storm of 1% annual exceedance probability if no federal action is taken. According to EC 1165-2-211 distinction should be made between global mean see level (GMSL) and local (or “relative”) mean sea level (MSL). NOAA’s GMSL is 0.00997 while MSL at Ft. McHenry tide gauge 8574680 is 0.01010. GMSL was used in G2CRM model to develop the economics.

Sea level is projected to rise as shown in Table 12, based on the sea level gauge at Fort McHenry.

Table 12: Seal Level Change Projection at Ft. McHenry Gauge

Year	Low	Intermediate	High
2031	0.36	0.50	0.93
2080	0.86	1.55	3.73
2130	1.36	3.09	8.43



Source: https://cwbi-app.sec.usace.army.mil/rccslc/slcc_calc.html

There are numerous development projects, both proposed and under construction, within the study area. They are all expected to be built to Baltimore City code with a first floor elevation 2 feet above base flood elevation. No damages are forecast from these developments.

Baltimore Gas and Electric (BGE) is replacing underwater high voltage transmission cables at the Key Bridge with an overhead crossing of the Patapsco River which will be operational in 2022. When the transmission line is replaced, the existing Sollers Point terminal station will be deactivated. This terminal station is at risk of flooding from coastal storms.

The Port of Baltimore is expected to continue to attract a diverse array of vessels transporting containers, coal, vehicles, and general cargo. The Maryland Port Administration and its partners are pursuing upgrades of Berth 3 at the Seagirt Marine Terminal which would allow for two berths to service large container ships of around 14,000 TEU capacity. MPA is also pursuing upgrades to all berths at the Dundalk Marine Terminal, installing a sea coastal curb during the upgrade process which will provide some risk reduction to coastal flooding. Therefore, any damage reduction derived from the Dundalk Marine Terminal will not be considered in the analysis.

5.2 FUTURE WITHOUT PROJECT CONDITION MODELING RESULTS

The years 2035-2084 were selected to represent the future without project condition. No additional development within the study area is anticipated to be at risk since it was assumed that no new development would be subject to future flood risk during the period of analysis. However, a combination of both wealth and complementary effects are likely to contribute to growth in the value of the assets at risk in the study area. The same structures in the Baltimore Metropolitan area will continue to be affected by the flooding from coastal storms and suffer increasing losses each year. The following Table 13 and figures 9 and 10 display the expected present value (PV). In addition, Table 13 shows the equivalent annual damages (EAD) for the study area by model areas for the without project conditions by MA. Inner Harbor MAs make up the most damages of structures in the study area followed by the tunnels MAs.

Table 13: FWOP Condition Expected Annual Damages by MA

Model Area	Present Value Damages	Equivalent Annual Damages
MA1: Martin State Airport	$2,424,000	$81,000
MA2: Martin State Airport West Bulkhead	$1,190,000	$40,000
MA3: Martin State Airport East Bulkhead	$0	$0
MA4: Patapsco East	$456,000	$15,000
MA5: Patapsco North	$7,719,000	$259,000
MA6: Patapsco North Dundalk	$22,649,000	$759,000
MA7: Patapsco North Seagirt Bulkhead	$7,725,000	$259,000
MA8: Patapsco North I895 Tunnel Facility Bulkhead	$20,000	$1,000
MA9: Inner Harbor	$24,529,000	$822,000
MA10: Inner Harbor Canton Bulkhead	$157,240,000	$5,270,000
MA11: Inner Harbor Bulkhead	$98,064,000	$3,287,000
MA12: Inner Harbor Ritz Carlton Bulkhead	$1,307,000	$44,000
MA13: Inner Harbor Harborview Bulkhead	$264,000	$9,000
MA14: Locust Point	$44,591,000	$1,495,000
MA15: Locust Point Museum of Industry Bulkhead	$5,290,000	$177,000
MA16: Locust Point American Sugar Bulkhead	$6,539,000	$219,000
MA17: Locust Point Fort McHenry Bulkhead	$3,515,000	$118,000
MA18: Locust Point I95 Tunnel Facility Bulkhead	$2,000	$0
MA19: Locust Point I95 Tunnel Bulkhead	$197,413,000	$6,617,000
MA20: Middle Branch Patapsco River	$28,831,000	$966,000
MA21: Middle Branch Patapsco River Bulkhead	$47,852,000	$1,604,000
MA22: Patapsco South	$16,995,000	$570,000
MA23: Patapsco South Fairfield Bulkhead	$28,985,000	$972,000

Model Area	Present Value Damages	Equivalent Annual Damages
MA24: Patapsco South I895 Tunnel Bulkhead	$113,252,000	$3,796,000
MA25: Middle Branch Wheelabrator Plant	$302,000	$10,000
Total	**$817,154,000**	**$27,390,000**

Figure 9 shows a dot plot of cumulative PV damages for the FWOP

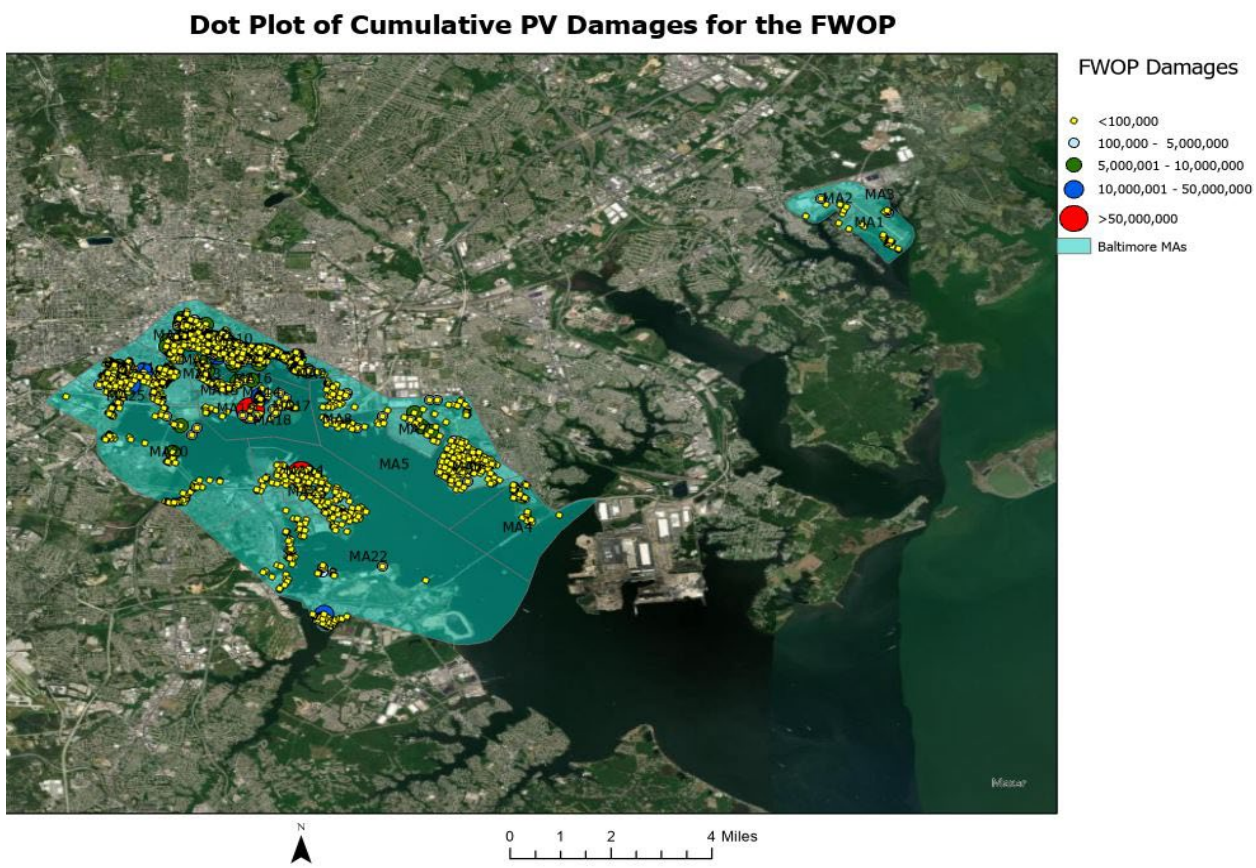
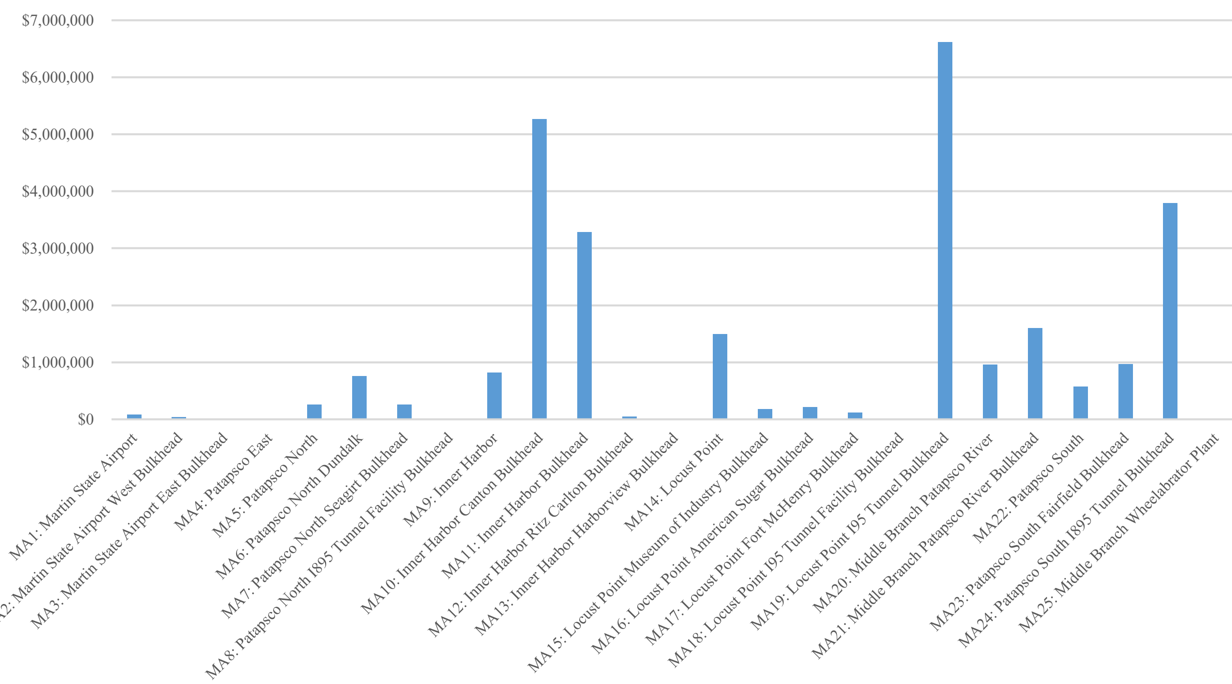


Figure 9: Dot Plot of FWOP PV Cumulative Damages

Figure 10: FWOP EAD by MA



G2CRM used Monte Carlo simulation to derive the expected PV damages with 100 iterations completed. The sum of all damages for each life cycle were divided by the number of iterations to yield the expected PV damages for that modeled simulation. A mean and standard deviation were automatically calculated for the PV damages for each MA to account for uncertainty. These PV damages for each MA were summed to derive the study area expected PV damages.

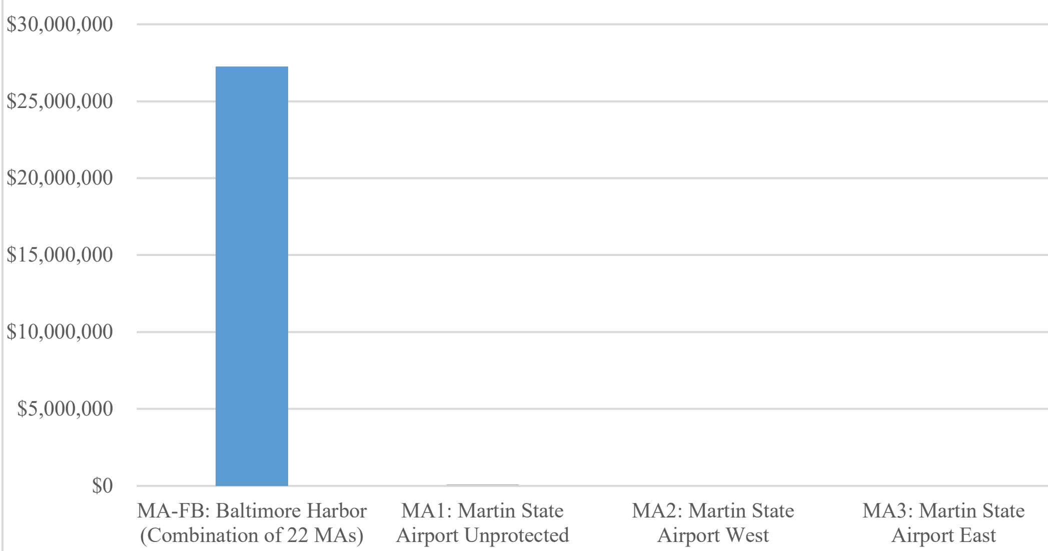
The forecasted sea level rise in the future, without a project in place, resulted in higher expected average PV damages. The total future “without project” PV damages are approximately $817.2 million or about $27.4 million EAD. The forecast of the future without project condition reflects the conditions expected during the period of analysis (2031-2080) and provides the basis from which alternative plans are evaluated, compared, and selected since a portion of the flood damages would be prevented (i.e., flood damages reduced) with a federal project in place.

Note in this section that for one of the project alternatives, surge barrier and bulkheads were combined. The surge barrier would be in the Baltimore Harbor and will protect 25 MAs. The remaining three MAs are in the Martin airport. The following Table 14 and figure 11 show the damages combination for the surge barrier MA and the Martin State Airport MAs.

Table 14: FWOP Damages for the combined Flood Barrier and Bulkheads

Model Area	Present Value Damages	Equivalent Annual Damages
MA-FB: Baltimore Harbor (Combination of 22 MAs)	$813,540,000	$27,269,000
MA1: Martin State Airport Unprotected	$2,424,000	$81,000
MA2: Martin State Airport West	$1,190,000	$40,000
MA3: Martin State Airport East	$0	$0
Total	$817,154,000	$27,390,000

Figure 11: FWOP EAD - Flood Barrier Protection



5.3 SENSITIVITY ANALYSIS – SEA LEVEL RISE

Baltimore Metropolitan study area is subject to an intermediate sea level rise. USACE Guidance document ER 1100-2-8162 require evaluating alternative plans based on future local mean SLC. HNH has evaluated WSL over 100 years while factorizing climate change using risk-inform decision.

Table 15 shows HNH analysis used to formulate the top of PSEs.

Table 15: SLC Scenarios

Year		1992	2031	2031	2031	2080	2080	2080	2130	2130	2130
USACE Sea Level Rise Scenarios		None	Low	Medium	High	Low	Medium	High	Low	Medium	High
Sea Level Rise, ft		0	0.36	0.5	0.93	0.86	1.55	3.73	1.36	3.06	8.43
Recurrence Interval	Percent Chance Exceedance	Water Surface Elevations plus Sea Level Rise, ft (Level of Performance 12.2 ft)									
5000	0.02	17.5	17.9	18.0	18.5	18.4	19.1	21.3	18.9	20.6	26.0
2000	0.05	16.5	16.9	17.0	17.5	17.4	18.1	20.3	17.9	19.6	25.0
1000	0.1	15.6	15.9	16.1	16.5	16.4	17.1	19.3	16.9	18.6	24.0
500	0.2	14.4	14.7	14.9	15.3	15.2	15.9	18.1	15.7	17.4	22.8
200	0.5	12.4	12.8	12.9	13.3	13.3	14.0	16.1	13.8	15.5	20.8
100	1	11.0	11.4	11.5	11.9	11.9	12.5	14.7	12.4	14.1	19.4
50	2	9.6	10.0	10.1	10.6	10.5	11.2	13.4	11.0	12.7	18.1
20	5	8.1	8.5	8.6	9.1	9.0	9.7	11.9	9.5	11.2	16.6
10	10	7.4	7.7	7.9	8.3	8.2	8.9	11.1	8.7	10.4	15.8
5	20	6.9	7.2	7.4	7.8	7.7	8.4	10.6	8.2	9.9	15.3
2	50	6.3	6.7	6.8	7.3	7.2	7.9	10.1	7.7	9.4	14.8
1	100	5.2	5.5	5.7	6.1	6.0	6.7	8.9	6.5	8.2	13.6
(pink)	Flooding will occur during these conditions (WSEL greater than or equal to 12.2 feet NAVD88)										
(green)	No flooding will occur during these conditions (WSEL less than 12.2 feet NAVD88)										

Accordance with Engineering Regulation ER 1100-28162, proposed projects that are subject to coastal storm surges must be also evaluated for a range of possible sea level rise rates: low, intermediate, and high. SLC sensitivity has been developed in Table 16 using triangular distribution in G2CRM modeling in this section by running G2CRM with USACE intermediate sea level rate curve.

Current USACE guidance requires that potential relative sea level change must be considered in every USACE coastal flooding study. The base level of potential relative sea level change is considered the historically recorded changes for the study site, which is estimated to be an increase of 0.00994 feet/year. All economic analyses for which results are tabulated in previous sections of this report were based on this historic intermediate rate of sea level change. However, in accordance with Engineering Regulation ER 1100-28162 (incorporating Sea Level changes in Civil Works Program, 31 Dec 2013), proposed projects that are subject to coastal storm surges must be also evaluated for a range of possible sea level rise rates: low, intermediate, and high. Based on NOAA projection at the gate 8574680 Ft. McHenry, in the base year 2031 low, intermediate, and high sea level rates are respectively 0.36, 0.50, and 0.93 in 2031 while these values will be 0.86, 1.55, 3.73 in a 50-year of period analysis. They will be increased respectively by 0.5, 1.05, and 2.8 over the period of analysis. The results of the FWOP under all three sea level rise conditions for each bulkhead are presented in Table 16.

Table 16: Impact on Sea Level rise on FWOP Damages

FWOP Present Value Damages by Sea Level Change Curve				% Change from Intermediate SLC Curve	
Model Area	**Low**	**Intermediate**	**High**	**Low**	**High**
MA1: Martin State Airport	2,017,000	2,424,000	4,415,000	-16.79%	82%
MA2: Martin State Airport West Bulkhead	1,011,000	1,190,000	2,147,000	-15.04%	80%
MA3: Martin State Airport East Bulkhead	-	-	-	-	-
MA4: Patapsco East	357,000	456,000	959,000	-21.71%	110%
MA5: Patapsco North	6,400,000	7,719,000	15,219,000	-17.09%	97%
MA6: Patapsco North Dundalk	18,740,000	22,649,000	42,044,000	-17.26%	86%
MA7: Patapsco North Seagirt Bulkhead	6,419,000	7,725,000	14,105,000	-16.91%	83%
MA8: Patapsco North I895 Tunnel Facility Bulkhead	14,000	20,000	51,000	-30.00%	155%
MA9: Inner Harbor	20,750,000	24,529,000	42,520,000	-15.41%	73%
MA10: Inner Harbor Canton Bulkhead	133,151,000	157,240,000	271,791,000	-15.32%	73%
MA11: Inner Harbor Bulkhead	83,342,000	98,064,000	182,510,000	-15.01%	86%
MA12: Inner Harbor Ritz Carlton Bulkhead	1,136,000	1,307,000	2,209,000	-13.08%	69%
MA13: Inner Harbor Harborview Bulkhead	221,000	264,000	464,000	-16.29%	76%
MA14: Locust Point	36,829,000	44,591,000	87,495,000	-17.41%	96%
MA15: Locust Point Museum of Industry Bulkhead	4,400,000	5,290,000	10,354,000	-16.82%	96%
MA16: Locust Point American Sugar Bulkhead	5,578,000	6,539,000	12,542,000	-14.70%	92%
MA17: Locust Point Fort McHenry Bulkhead	2,833,000	3,515,000	6,779,000	-19.40%	93%
MA18: Locust Point I95 Tunnel Facility Bulkhead	-	2,000	28,000	-100.00%	1300%
MA19: Locust Point I95 Tunnel Bulkhead	162,900,000	197,413,000	358,914,000	-17.48%	82%
MA20: Middle Branch Patapsco River	23,873,000	28,831,000	59,423,000	-17.20%	106%
MA21: Middle Branch Patapsco River Bulkhead	40,353,000	47,852,000	85,686,000	-15.67%	79%
MA22: Patapsco South	14,188,000	16,995,000	34,113,000	-16.52%	101%
MA23: Patapsco South Fairfield Bulkhead	24,435,000	28,985,000	55,651,000	-15.70%	92%
MA24: Patapsco South I895 Tunnel Bulkhead	94,149,000	113,252,000	192,987,000	-16.87%	70%
MA25 Middle Branch Wheelabrator Incinerator Plant	265,000	302,000	526,000	-12.25%	74%
Summary	**683,361,000**	**817,154,000**	**1,482,932,000**	**-20.41%**	**139.63%**

Evaluating sea level change (SLC) is a vital component in the planning process to ensure alternatives are selected based on risk-informed analysis. To incorporate risk into the analysis the FWOP and FWP conditions must be run assuming three distinct future rates of SLC. EC 1165-2-211 provides both a methodology and a procedure for determining a range of SLC estimates based on the local historic rate, the construction year of the project, and the design life of the project. While the Baltimore Metropolitan project is formulated to the USACE intermediate curve, the high and low curves will be evaluated in the FWOP and FWP conditions and Table 16 will be replaced in the economic appendix prior to the ADM. The TSP will be revaluated to see if it is economically justified for all see level rise scenarios.

6. 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 futures with project conditions as there are project alternatives. Structural and nonstructural alternatives were considered for the 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 damages and flood damage reduction for each alternative.

6.1 FORMULATION OF ALTERNATIVES

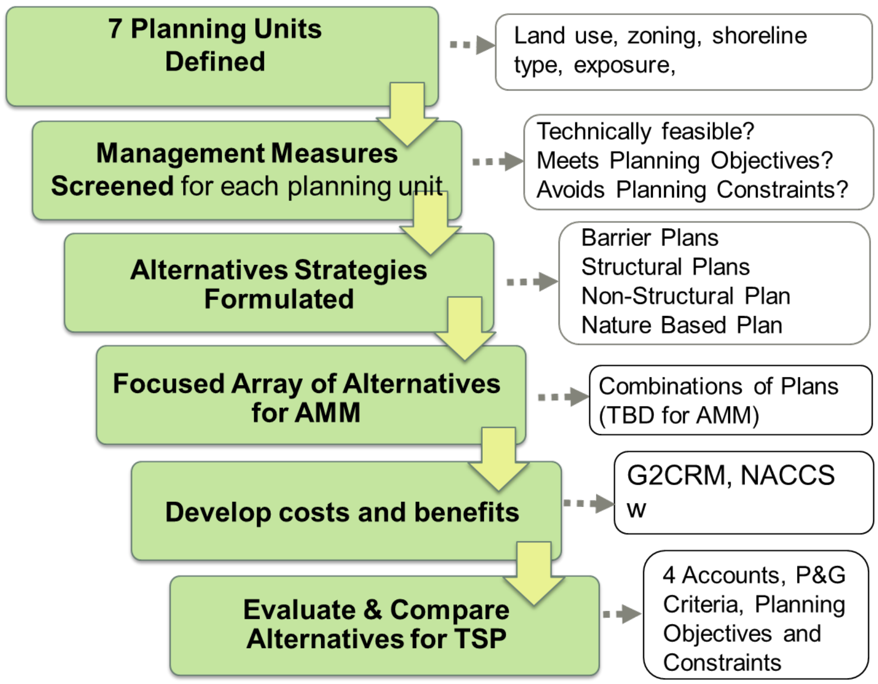
A formulation strategy is a systematic way of combining measures into alternative plans based on the planning objectives. No single formulation strategy will result in a diverse array of alternatives, so a variety of strategies is needed. Measures were combined into logical groupings based on a line of defense strategy. Structural measures were grouped logically landward, beginning with a surge barrier defense which would provide risk reduction for the greatest portion of the study area. The initial array of alternatives was screened based on the overall cost supported by modeled damages. Figure 12 below illustrates the plan formulation strategy.

At this stage of plan formulation, there are large uncertainties about the technical or social feasibility of implementing several measures in the areas in which they are proposed. For example, floodwalls along the Inner Harbor planning unit may have limited land area for implementation. They may require many closure structures which would be costly and difficult to operate in the event of a coastal storm. Floodwalls in this area may also be unacceptable to residents and stakeholders.

Natural and Nature-Based Features (NNBF) solutions in the Middle Branch that rely on placement of dredged material on existing substrate may not be technically feasible. The Tidal Middle Branch Continuing Authorities Program, Section 206 project, undertaken in the mid-2000s found that geotechnical stability in the Middle Branch is problematic and the cost to restore wetlands was found to be very high.

Issues raised during the 1960 investigation of coastal storm barriers remain today. These include concerns about water circulation and impact to navigation. Environmental impacts are of great concern as a “fishable, swimmable” harbor is a goal of many stakeholders. These issues will be explored in depth in selecting the TSP.

Figure 12: Plan Formulation Strategy



6.2 INITIAL ARRAY OF ALTERNATIVES

The initial array of alternatives was formulated despite known data gaps, then refined throughout the planning process as information was collected and developed. The initial array of alternatives consists of a variety of structural, nonstructural, and NNBF measures. Structural coastal flood risk management measures are man-made, constructed measures that counteract a flood event 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 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 eleven alternatives and the following are the descriptions for each alternative.

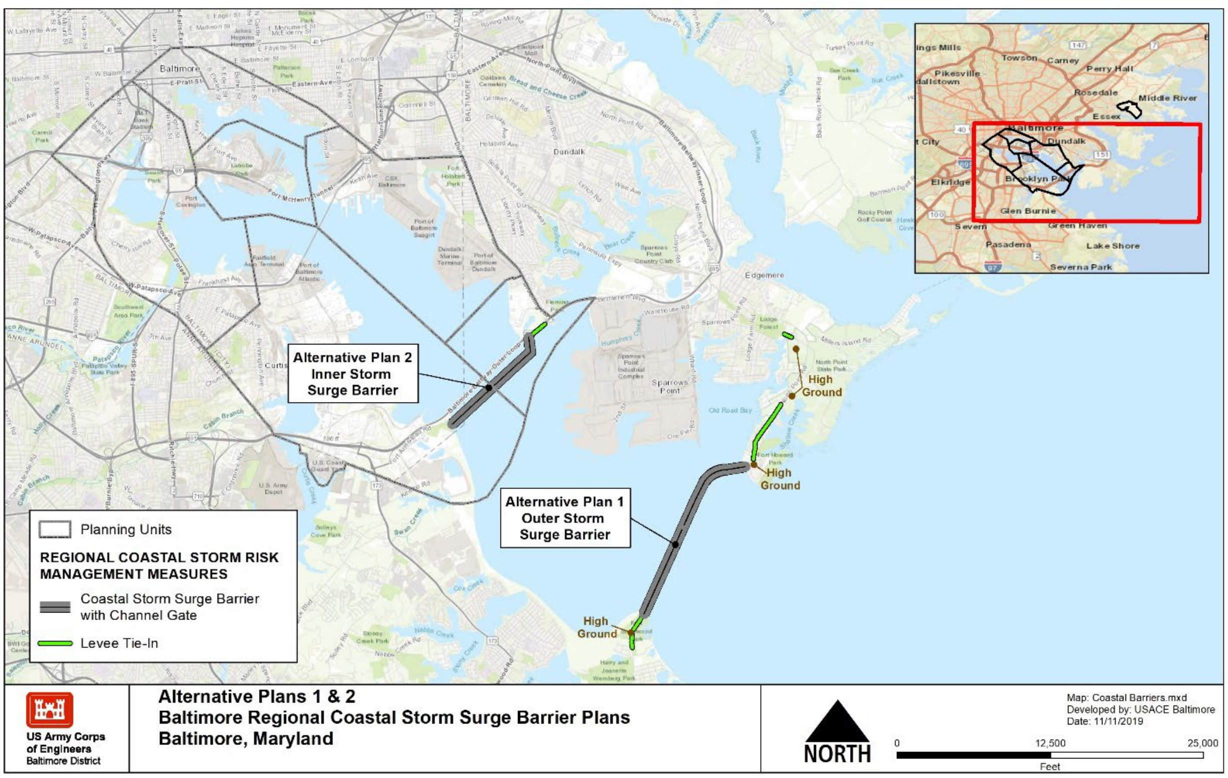
No Action Alternative:

The No Action Alternative assumes that no actions would be taken by the Federal Government or local interests to address the problems identified by the study. Consequently, the No Action Alternative would not reduce damages from coastal storm surge inundation. Although this alternative would not accomplish the purpose of this study, it will be used as a benchmark, enabling decision makers to compare the magnitude of economic, environmental, and social effects of the actionable alternatives. Additionally, the No Action Alternative and future without project condition are assumed to be the same for this study.

Alternative 1 – Outer Surge Barrier and Alternative 2 – Inner Surge Barrier

Two varieties of surge barriers were examined. The Baltimore Outer Harbor 10,000 feet barrier length with 1,000 feet of sector gate, and the Baltimore Inner Harbor 16,000 feet barrier length with 1,000 feet of sector gate were considered during the early formulation process and each protects approximately the same assets. Further analysis determined that the most effective and most efficient type of barrier is the Baltimore Harbor 10,000 feet barrier length with 1,000 feet of sector gate. Therefore, the inner surge barrier was retained for consideration at the initial array of alternatives. Figure 13 shows the location of both surge barriers.

Figure 13: Inner and Outer Surge Barriers



The Baltimore Inner Harbor Storm Surge and Bulkheads management measures are developed in the follow areas:

- 10,000 feet inner surge barrier with 1,000 feet sector gate in Patapsco River that connects at east Hawkins Point Shoal and at west Sollers Point
- Bulkhead protecting the west side of Martin State Airport

- Bulkhead protecting the east side of Martin State Airport

The inner flood barrier provides protection to all infrastructures located in Baltimore City. Harbor Tunnel on Interstate Route I-895, Ft. McHenry Tunnel on Interstate Route I-95 the Patapsco North, Baltimore Fire Department Marine unit, U.S. Army Corps of Engineers Baltimore District facility at Ft. McHenry, Ft. McHenry National Monument, BGE Spring Garden natural gas facility, a casino, a portion of the Carroll Camden industrial neighborhood, Middle Branch Waterfront Park, Cherry Hill Park, Westport, Harbor Hospital, are among the structures protected by this alternative.

The two bulkheads in east and west Martin State Airport provide protection to Maryland State Police Aviation Unit headquarters, Baltimore City Police aviation unit, Baltimore County Police aviation unit, Maryland Air National Guard.

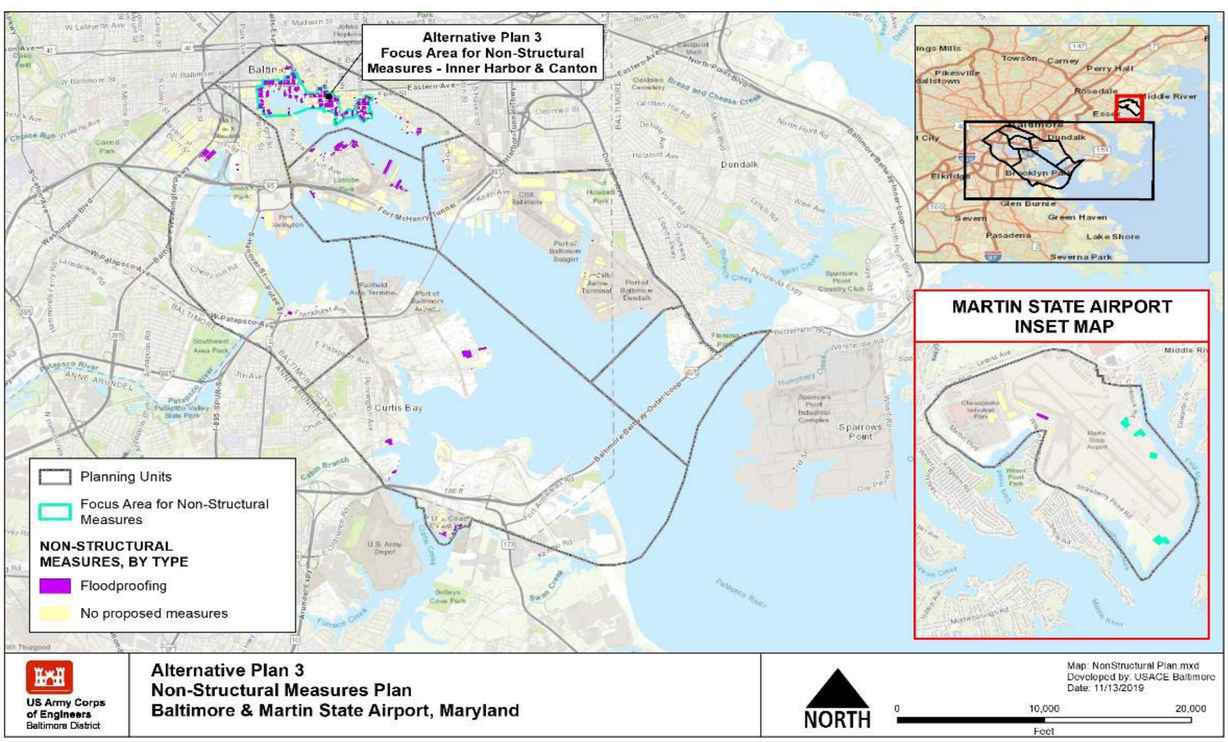
Alternative 3 - Nonstructural Only

The alternative was formulated to include the following actions that can be implemented by USACE:

- Relocation or buyout of structures
- Floodproof structures

Nonstructural treatments have been applied on 1096 structures in 1% AEP, 493 structures in 2% AEP and 286 structures in 5% AEP. Since these structures were in the Baltimore Metropolitan historical district, elevation measures cannot be proposed. Figure 14 show the proposed plan.

Figure 14: Nonstructural Solutions



The second category of measures should be implemented by the non-Federal sponsor:

- Flood warning system
- Revise emergency response plan
- Low-impact development / green infrastructure measures

The structures proposed for relocation, buyout, elevation, or flood proofing located in the Inner Harbor and Canton planning units are shown in Figure 14 Per Corps policy, in urban and urbanizing areas, low-impact development / green infrastructure measures are a non-federal responsibility. Flood warning systems and emergency response plans are also non-federal responsibilities.

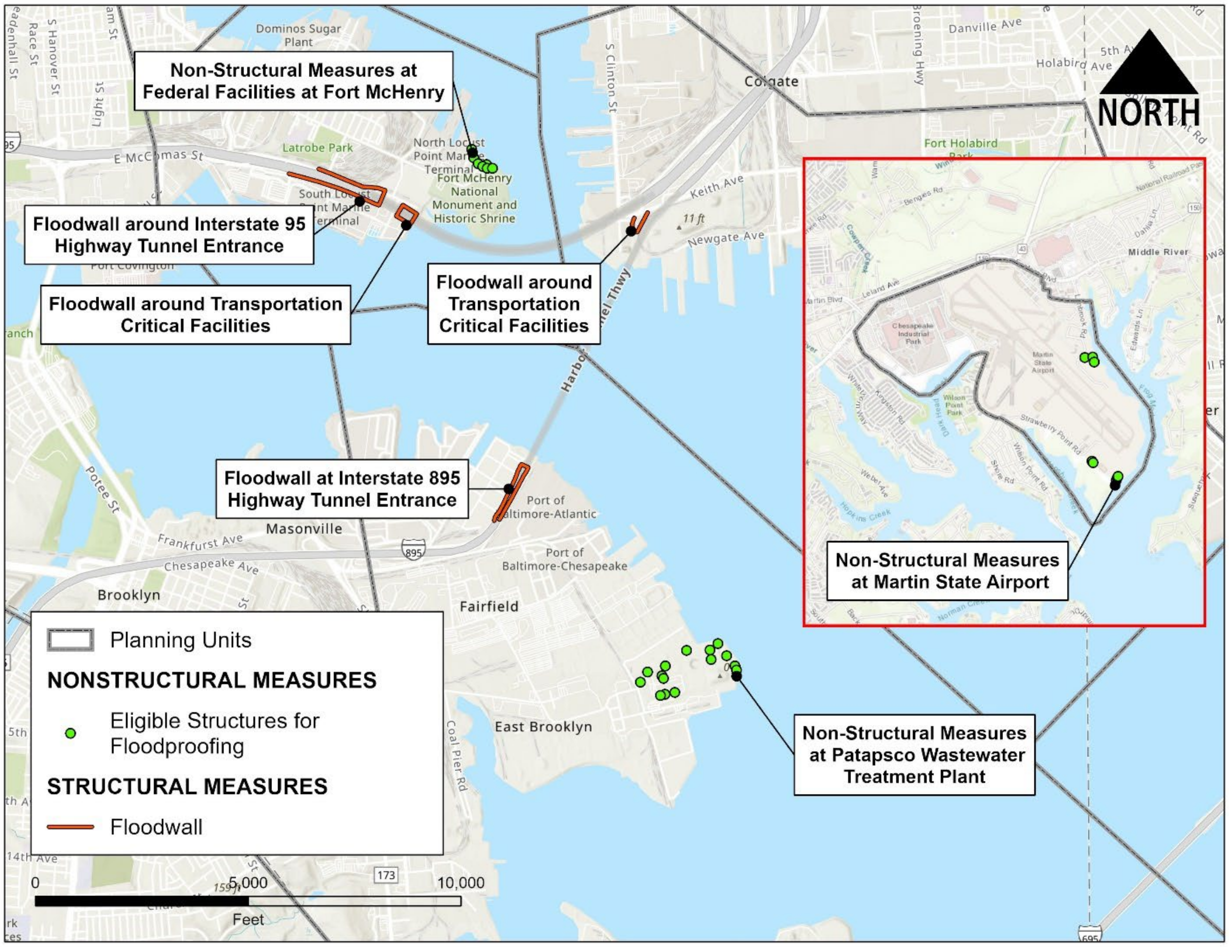
Alternative 4 - Critical Infrastructure Only: Locust Point and Patapsco (BHs 8, 18, 19, 24)

This management measure is developed in the follow areas:

- Masonville dredged material containment facility to Cox creek dredged in Patapsco south.
- Dundalk Marine Terminal to Danville Avenue and Clinton Street in Patapsco north.
- Baltimore Waterfront Promenade at the Baltimore Fire Department maintenance facility on Key Highway to former BGE Gould Street Powerplant at Gould Street in Locus Point.

Bulkhead with a top elevation of 12.2 feet is proposed to protect water for getting into Harbor Tunnel on Interstate Route I-895 and Ft in MA 24. Another bulkhead with the same height is proposed in MA 8 to protect Tunnel I-895 ventilation building. McHenry Tunnel on Interstate Route I-95 in MA 19 and its ventilation building in MA 18 are protecting by two different bulkheads with 12.2 top of protection. Nonstructural measures have been developed in federal facilities within this plan. This measure will avoid transportation disruptions in the region and will protect the most vulnerable infrastructure in the Baltimore Metropolitan area. Figure 15 shows the proposed areas of the plan.

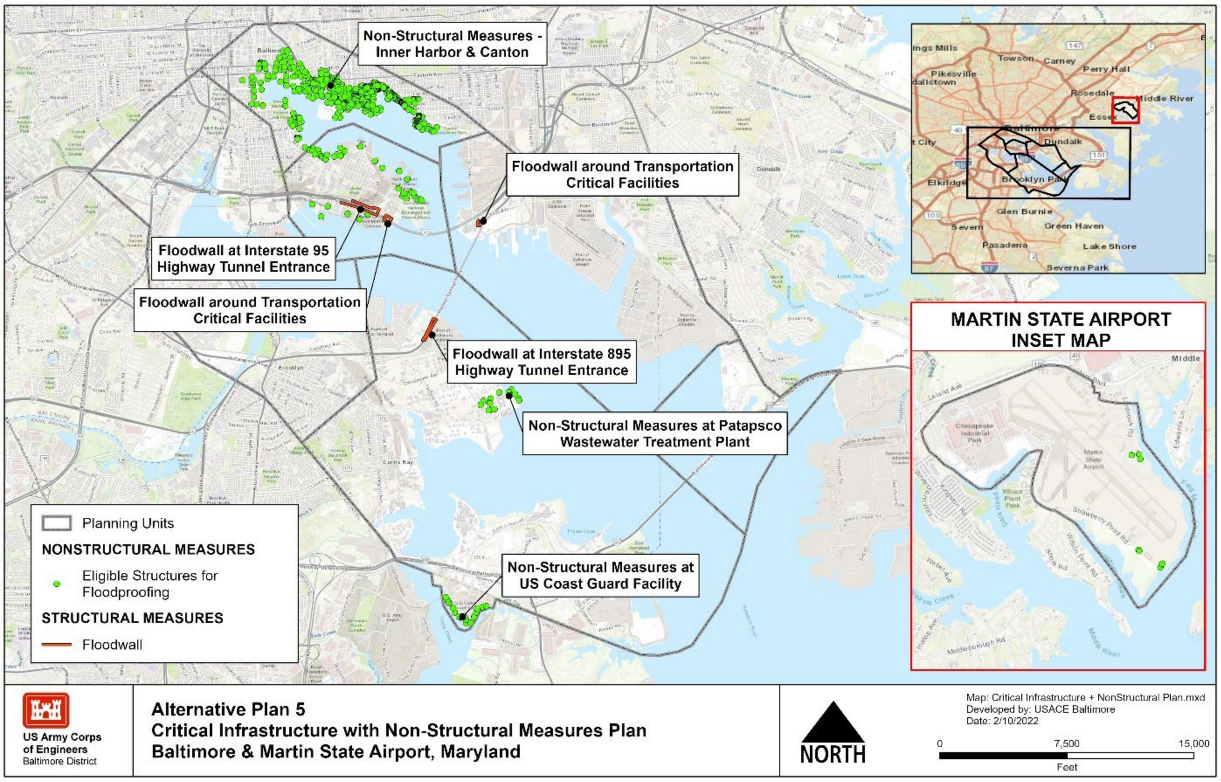
Figure 15: Critical Infrastructure in Locus Point and Patapsco



Alternative 5 - Critical Infrastructure with Nonstructural Measures

This management measure includes critical infrastructure bulkheads described in Alternative 4 in additional of nonstructural treatments on 1096 structures in 1% AEP, 493 structures in 2% AEP and 286 structures in 5% AEP. These categories of structures are residential or nonresidential entities in Martin State Airport, Inner Harbor, Locus Point and Patapsco South neighborhoods. Figure 16 shows the proposed plan.

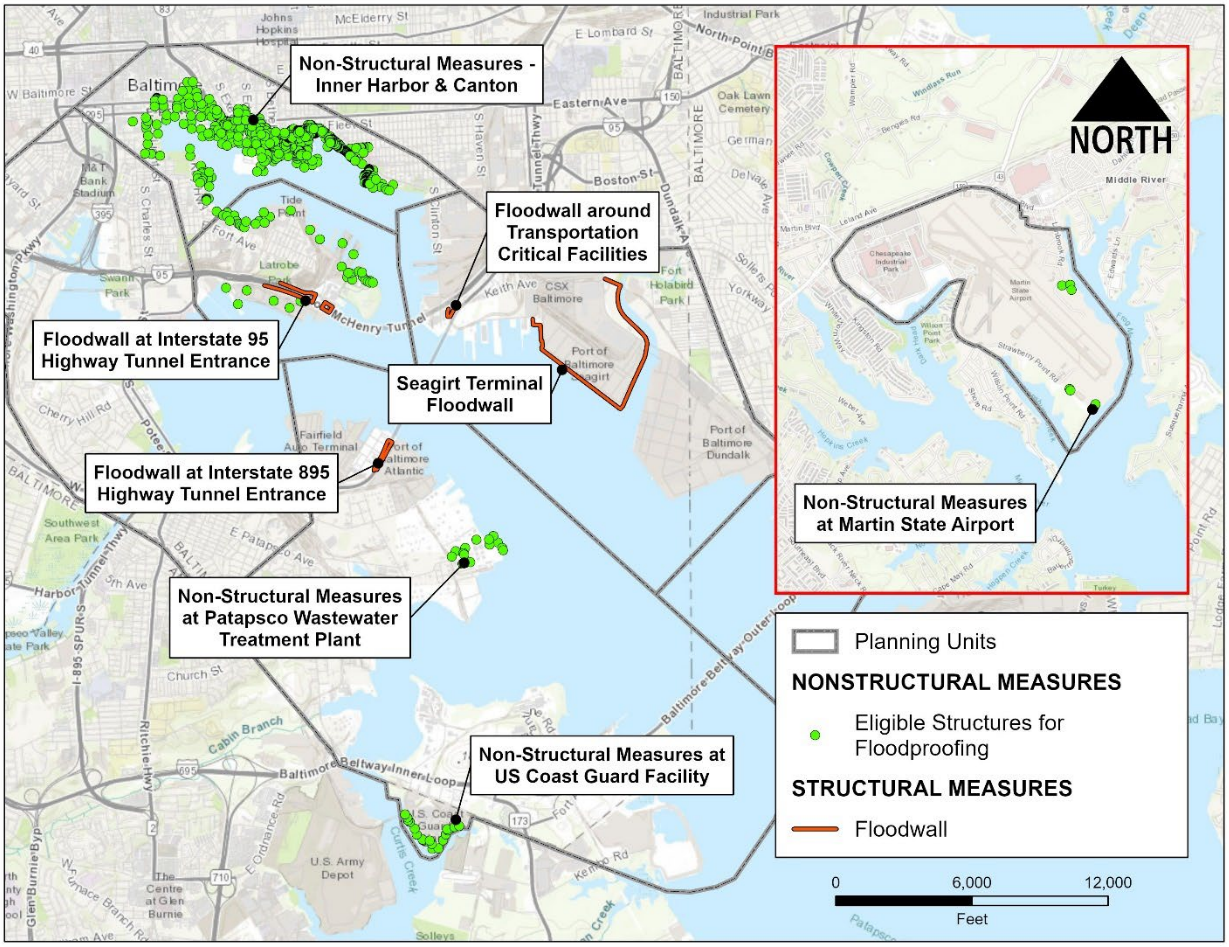
Figure 16: Critical Infrastructure with Nonstructural Measures



Alternative 6 – Critical Infrastructure Balanced (BHs 7, 8, 18, 19, 24)

This management measure includes elements of alternative 5 in additional to the coastal floodwall at Seagirt Marine Terminal in Patapsco North, and at Dundalk Marine Terminal. The latest was dropped since Maryland Port Administration has initiated design and construction of the floodwall. Figure 17 shows the proposed plan area.

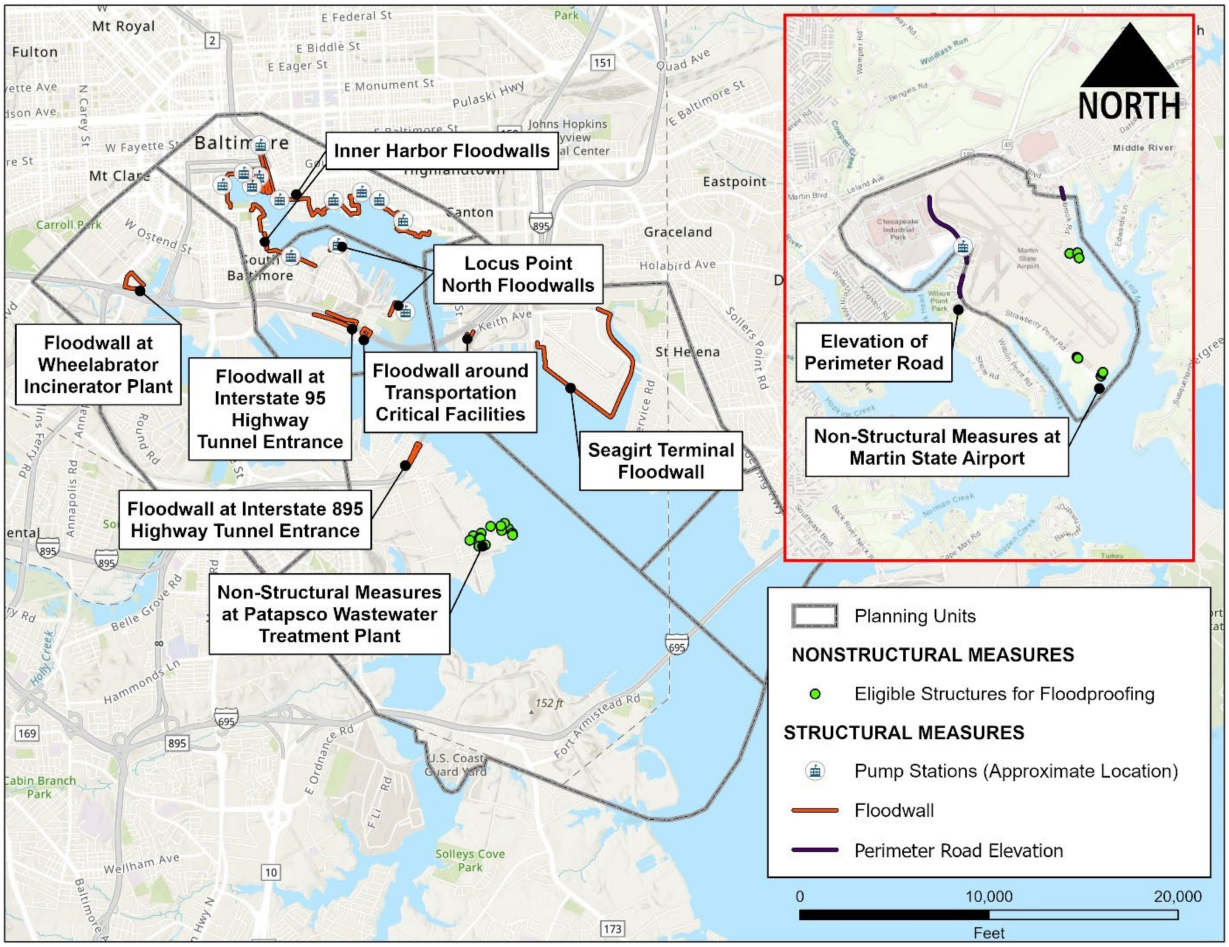
Figure 17: Critical Infrastructure Balanced



Alternative 7 – Mid-tier Balanced (BHs 2, 3, 7, 8, 10, 11, 12, 13, 15, 16, 17, 18, 19, 24, 25)

This management measure proposed 13 floodwalls/levees that seem to be linear coastal barrier in Inner Harbor and Locust Point. Additional 2 floodwalls have been proposed in East and West Martin State Airport. The top of protection of all protective system elements is 12.2 ft. Nonstructural measures have been developed in federal facilities within this plan as shown in Figure 18.

Figure 18: Mid-tier Balanced



The following neighborhoods and infrastructure will be protected:

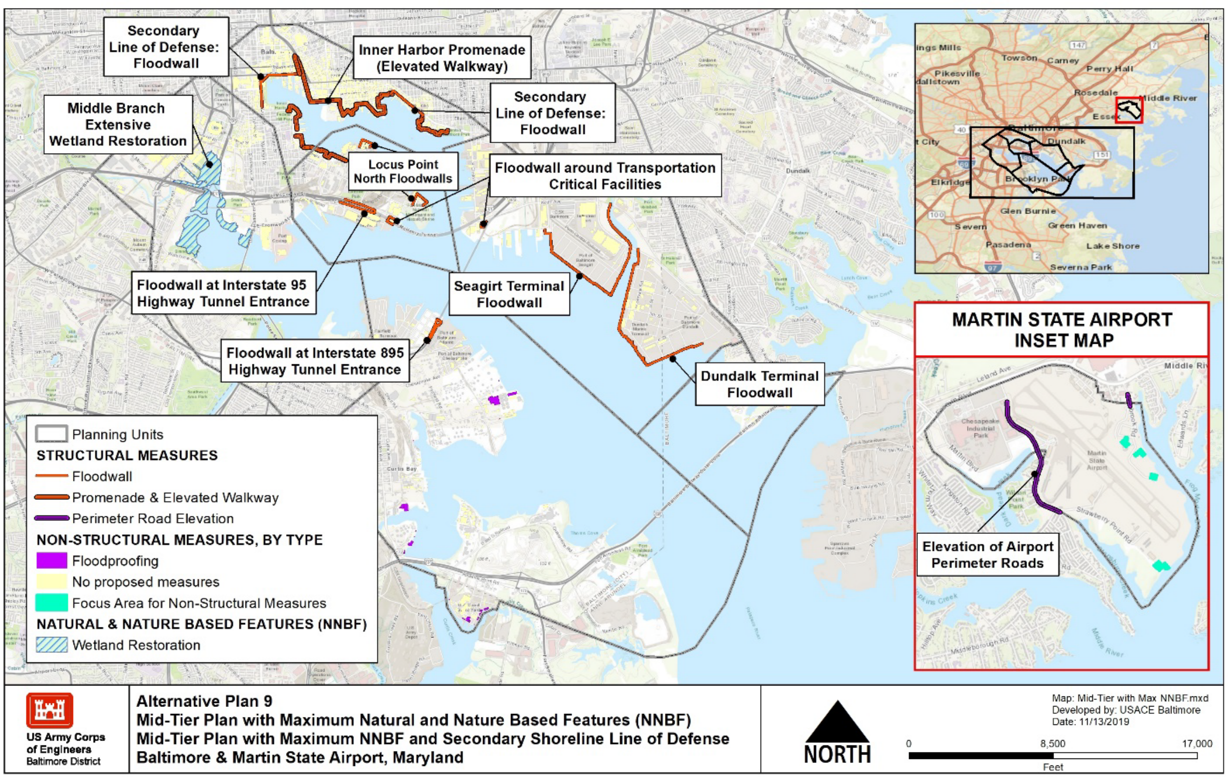
- Masonville dredged material containment facility to Cox creek dredged in Patapsco south.
- Dundalk Marine Terminal to Danville Avenue and Clinton Street in Patapsco north.
- Baltimore Waterfront Promenade at the Baltimore Fire Department maintenance facility on Key Highway to former BGE Gould Street Powerplant at Gould Street in Locus Point.
- Danville Avenue and Clinton Street to the end of the Baltimore Waterfront Promenade at the Baltimore Fire Department maintenance facility on Key Highway.
- Gould Street Powerplant (currently closed) at Gould Street to the Masonville Dredged Material Containment Facility.
- Middle River, Baltimore County, encompassing Martin State Airport and Warfield Air National Guard Base.

Structures included BGE Spring Garden natural gas facility, a casino, a portion of the Carroll Camden industrial neighborhood, Middle Branch Waterfront Park, Cherry Hill Park, Westport, Harbor Hospital, Martin State Airport, Maryland State Police Aviation Unit headquarters, Baltimore City Police aviation unit, Baltimore County Police aviation unit, Maryland Air National Guard.

Alternative 8 - Mid-tier with Enhanced NNBF

This management measure includes elements of alternative 7 in additional to Natural and nature-based features (NNBF). NNBF were initially considered across the different planning units within the study area. However, the urban character and shoreline type along a large portion of the study area limited the use of NNBF within the South Baltimore-East Channel, Port of Baltimore, Masonville to Wagners Point, and Hawkins Point planning units. Federal Aviation Administration guidelines restrict land-use practices such as the construction of wetlands that could attract wildlife in the areas surrounding public airports, due to the hazard wildlife poses to aviation. These restrictions limited the use of NNBF within the Martin State Airport planning unit. Figure 19 show the proposed plan.

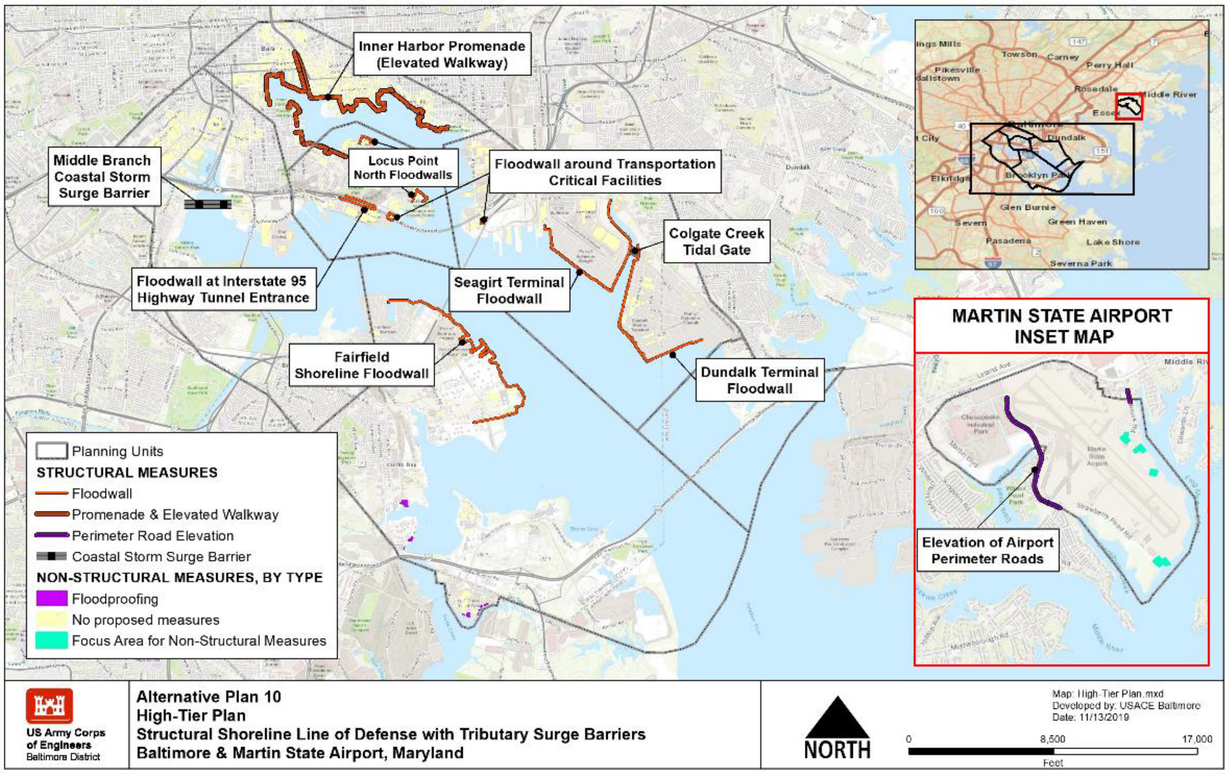
Figure 19: Mid-tier with NNBF



Alternative 9 - Mid-tier with Maximum NNBF

This management measure includes elements of alternative 8 and expanded NNBF to upper Middle Branch planning unit. This planning unit was identified as a suitable area for the use of NNBF to reduce flood risk. The Middle Branch has soft, green shorelines along the water's edge as well as existing parklands and open spaces. There are existing wetlands within the Middle Branch located primarily along the northern portion and near Smith Cove on the southwestern edge. Historically, existing tidal wetlands and natural beaches in the Middle Branch have been impacted and steadily lost as a result of shoreline hardening, development and re-development. The City of Baltimore's Middle Branch Master Plan outlines opportunities to maintain the existing green shoreline and expand environmental restoration through redevelopment initiatives. Area characteristics and ongoing initiatives make the Middle Branch a potentially suitable location for wetland restoration and the implementation of other NNBF.

Figure 20: Mid-tier with Maximum NNBF



Alternative 10 - High-tier

This management measure includes elements of alternative 7 and proposed the replacement of floodwall/levee structures in Middle Branch with a local surge barrier structure.

Alternative 11 - High-tier with Maximum NNBF (shoreline Limit Site Disturbance)

This management measure includes elements of alternative 9 extended shoreline floodwall structures around Fairfield Marie Terminal and nearby properties.

6.3 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 support the screening process, professional judgment was used to assess how well measures met a set of criteria. Engineers, scientists, and stakeholders at the planning charrette screened the measures.

The screening criteria used in this study include effectiveness, efficiency, and acceptability. Effectiveness is the ability of the measure to meet or partially meet a study objective. Efficiency is the extent to which an alternative plan is the most cost effective means of alleviating the specified problems and realizing the specified opportunities, consistent with protecting the Nation's environment. Acceptability is the workability and viability of the alternative plan with respect to acceptance by State and local entities and the public and compatibility with existing laws, regulations, and public policies.

Completeness, constructability, and study constraints were also used as screening criteria, but did not result in elimination of any measures. Completeness is the extent to which a given alternative plan provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects. Constructability at this stage of planning is the subjective assessment of whether a feature could be constructed or implemented using standard industry techniques and is compliant with Corps policy for implementation. Study Constraints is the likelihood that the measure does not violate a constraint. Each conceptual alternative was found to be complete, constructible, and compliant with study constraints.

The following tables 17 and 18 contain an assessment of how well key measures in each alternative met the study objectives and how well each alternative met the four evaluation criteria as prescribed in the Economic and Environmental Principles and Guidelines for Water and Land Related Resources Implementation Studies. More information regarding alternatives screening will be found in the Main Report and Plan Formulation Appendix.

Table 17: Screening Assessment

Alternative	Assessment	Meets Study Objectives?
1. Bulkheads in Locust Point and Patapsco	This strategy prevents waves and water from overtopping floodwalls during coastal events.	Yes
2. Bulkheads in Locust Point and additional in Patapsco North	This strategy prevents waves and water from overtopping floodwalls during coastal events.	Yes
3. Bulkheads in Locust Point, Patapsco, Inner Harbor, Middle Branch, Martin State Airport	This strategy prevents waves and water from overtopping floodwalls during coastal events.	Yes

Alternative	Assessment	Meets Study Objectives?
4. Bulkheads in Locust Point, Patapsco, Inner Harbor, Martin Airport	This strategy prevents waves and water from overtopping floodwalls during coastal events.	Yes
5. Bulkheads in Locus Point, Patapsco South Fairfield, Inner Harbor, Martin State Airport	This strategy prevents waves and water from overtopping floodwalls during coastal events.	Yes
6. Inner Harbor Storm Surge Barrier Only	The strategically placed wall would reduce damages from storm surge inundation, reduce risk to human life and safety, and maintain access to critical facilities, emergency services, and evacuation routes by diverting storm surge water from the metropolitan. Structures in Martin State Airport will not be protected.	No
7. Inner Harbor Storm Surge and Bulkheads	In addition to storm surge wall in Inner Harbor, bulkheads prevent waves and water from overtopping floodwalls at Martin State Airport.	Yes
8. Nonstructural Only	This alternative only includes nonstructural measures and would not address storm surge inundation that limits access to critical facilities, emergency services, and evacuation routes.	No
9. Bulkheads in Locust Point, Patapsco, Inner Harbor, Middle Branch, Martin State Airport + Nonstructural	In addition to the bulkheads, nonstructural measures would be applied to residential structures that may incur damages from storm surge after the bulkheads are constructed.	Yes
10. NNBF/Shoreline Limit Site Disturbance	Urban character and shoreline limited the implementation of NNBF.	No

Table 18: Screening of Alts Based on Evaluation Criteria from the Principles and Guidelines

Alternative	Completeness	Effectiveness	Efficiency	Acceptability	Result
1. Bulkheads in Locust Point and Patapsco	High	High	High	Medium	Retain
2. Bulkheads in Locust Point and additional in Patapsco North	High	High	High	Medium	Retain
3. Bulkheads in Locust Point, Patapsco, Inner Harbor, Middle Branch, Martin State Airport	High	High	High	Medium	Retain
4. Bulkheads in Locust Point, Patapsco, Inner Harbor, Martin Airport	High	High	High	Medium	Retain
5. Bulkheads in Locus Point, Patapsco South Fairfield, Inner Harbor, Martin State Airport	High	High	High	Medium	Retain

Alternative	Completeness	Effectiveness	Efficiency	Acceptability	Result
6. Inner Harbor Storm Surge Barrier Only	High	Medium	Medium	Medium	Screen
7. Inner Harbor Storm Surge and Bulkheads	High	High	High	Medium	Retain
8. Nonstructural Only	High	Low	Low	Medium	Screen
9. Bulkheads in Locust Point, Patapsco, Inner Harbor, Middle Branch, Martin State Airport + Nonstructural	High	High	High	Medium	Retain
10. NNBF/Shoreline Limit Site Disturbance	High	Low	Low	Medium	Screen

6.4 FINAL ARRAY OF ALTERNATIVES

Based on the screening assessment, the flood barrier alternatives, the nonstructural measures Only, and Tier alternatives were screened out for future considerations.

The flood barriers will increase the project scope significantly. The following preliminary considerations indicate that the flood barriers would not be acceptable to resource agencies or local jurisdictions:

- Hydraulic constraints - riverine discharge, induced flooding impacts on either side of the barriers
- Cultural resource constraints - impact on historical communities and other cultural resources
- Environmental - water quality impacts, impacts to endangered species (e.g., Atlantic Sturgeon) and other anadromous fish.
- Initial evaluation shows negative net benefits.

Nonstructural Only alternative was screen out since it cannot address by itself coastal flooding problems in Baltimore Metropolitan area.

Tier alternatives were screened out because of their high costs.

More information on alternatives that have been screened out can be found in Sec. 3 of the main report.

The alternatives carried forward for evaluation included the No Action Alternative, Alternatives 4, 5, 6, 7. These alternatives were considered the final array of alternatives. Since these were the final array of alternatives, additional information has been developed and incorporated into the description of each alternative in the main report. These alternatives were regrouped under 12 new alternatives plus No Action Alternative.

Alt 1: No Action Alternative

There are no changes (reference Initial Array section).

Alt 4 – NS_100YR

- Protecting I-95 and I-895 tunnels from coastal flooding in MAs 8, 18, 19, and 24.
- Developing nonstructural treatments on 30 federal facilities in MAs 1, 17, and 23 with 1% risk reduction.

Alt 4 – NS_50YR

- Protecting I-95 and I-895 tunnels from coastal flooding in MAs 8, 18, 19, and 24
- Developing nonstructural treatments on 14 federal facilities in MAs 1, 17, and 23 with 2% risk reduction.

Alt 4 – NS_20YR

- Protecting I-95 and I-895 tunnels from coastal flooding in MAs 8, 18, 19, and 24.
- Developing nonstructural treatments on 9 federal facilities in MAs 1, 17, and 23 with 5% risk reduction.

Alt 5 – NS_100YR

- Protecting I-95 and I-895 tunnels from coastal flooding in MAs 8, 18, 19, and 24.
- Developing nonstructural treatments on 1096 structures in MAs 1, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23 with 1% risk reduction.

Alt 5 – NS_50YR

- Protecting I-95 and I-895 tunnels from coastal flooding in MAs 8, 18, 19, and 24.
- Developing nonstructural treatments on 493 structures in MAs 1, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23 with 2% risk reduction.

Alt 5 – NS_20YR

- Protecting I-95 and I-895 tunnels from coastal flooding in MAs 8, 18, 19, and 24.
- Developing nonstructural treatments on 286 structures in MAs 1, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23 with 5% risk reduction.

Alt 6 – NS_100YR

- Protecting I-95 and I-895 tunnels from coastal flooding in MAs 8, 18, 19, and 24.
- Protecting Seagirt Marine Terminal from coastal flooding in MA 7.
- Developing nonstructural treatments on 1096 structures in MAs 1, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23 with 1% risk reduction.

Alt 6 – NS_50YR

- Protecting I-95 and I-895 tunnels from coastal flooding in MAs 8, 18, 19, and 24.
- Protecting Seagirt Marine Terminal from coastal flooding in MA 7.
- Developing nonstructural treatments on 1096 structures in MAs 1, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23 with 2% risk reduction

Alt 6 – NS_20YR

- Protecting I-95 and I-895 tunnels from coastal flooding in MAs 8, 18, 19, and 24.
- Protecting Seagirt Marine Terminal from coastal flooding in MA 7.
- Developing nonstructural treatments on 1096 structures in MAs 1, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23 with 5% risk reduction

Alt 7 – NS_100YR

- Protecting Inner Harbor with linear floodwalls/levees in MAs 7, 8, 10, 11, 12, 13, 15, 16, 17, 18, 19, 24, and 25, and Martin State Airport with floodwalls in MAs 2 and 3.
- Developing nonstructural treatments on 23 federal facilities in MAs 1 and 23 with 1% risk reduction.

Alt 7 – NS_50YR

- Protecting Inner Harbor with linear floodwalls/levees in MAs 7, 8, 10, 11, 12, 13, 15, 16, 17, 18, 19, 24, and 25, and Martin State Airport with floodwalls in MAs 2 and 3.
- Developing nonstructural treatments on 7 federal facilities in MAs 1 and 23 with 2% risk reduction.

Alt 7 – NS_20YR

- Protecting Inner Harbor with linear floodwalls/levees in MAs 7, 8, 10, 11, 12, 13, 15, 16, 17, 18, 19, 24, and 25, and Martin State Airport with floodwalls in MAs 2 and 3.
- Developing nonstructural treatments on 2 federal facilities in MAs 1 and 23 with 5% risk reduction.

7. EVALUATION OF ALTERNATIVES

Relevant data for each of the alternatives described above were entered into G2CRM as alternative plans and the potential for flood damage reduction was calculated. The modeling results for each alternative are summarized in the following sections.

7.1 ALT 4-NS_100YR

Harbor Tunnel's I-895 in Patapsco South MA 24 has its support facilities in Patapsco North MA 8. Ft. McHenry Tunnel's I-95 in Locus Point MA 19 has its support facilities in Locus Point MA 18. Tunnels and their facilities are one entity. Each MA has been protected by coastal floodwall. The top of protection for each protective system elements (PSE) is specified at 12.2 feet NAVD88. The PSE prevent transmission of the flood hazard into the model areas until the flood hazard exceeds the top elevation of the bulkheads. When the flood hazard exceeds the PSE top elevation the flood hazard is instantaneously transmitted into the model areas unmediated by the PSE. Both the existing and future without conditions simulate the top elevation for the bulkheads and that top elevation was specified at the approximate existing ground elevation within the MAs. In short, the PSE reduces flood risk (e.g., damages) in the study area up to 12.2 feet NAVD88.

A total of 30 federal facilities in MAs 1, 17, and 23 are receiving 1% risk reduction with floodproofing measures within this plan.

The following table displays the future without project expected damages, the project conditions expected damages, and the damages reduced in Alt 4-NS_100YR.

Table 19: Alt 4 – NS_100YR FWOP Damages, FWP Damages, and Damages Reduced

Model Area	FWOP Present Value Damages	FWP Present Value Damages	Present Value Damages Reduce	% Damages Reduced
BH8: Patapsco North I-895 Tunnel Bulkhead	$20,000	$10,000	$10,000	50.0%
BH18: Locust Point I-95 Tunnel Facility Bulkhead	$2,000	$0	$2,000	100.0%
BH19: Locust Point I-95 Tunnel Bulkhead	$197,413,000	$84,799,000	$112,614,000	57.0%
BH24: Patapsco South I-895 Tunnel Bulkhead	$113,252,000	$37,434,000	$75,818,000	66.9%
MAs 1, 17, 23 NS_100YR	$34,924,000	$31,539,000	$3,385,000	9.7%
Total	$345,611,000	$153,782,000	$191,829,000	55.5%

Note that damage figures have been rounded to the nearest thousand. Hence, a 100-percent damages reduced is less than a 100-percent since there are residual damages and a zero-percent damage reduced is more than a zero-percent.

When compared the project alternative to the future without project conditions, Alt 4 – NS_100YR reduced the mean PV damages by 55.5%. This plan is consistent with Flood Hazards & Community Resilience Policy 2h – Preference of Multi-Purpose Use Projects, Project Accountability, & 50% Reduction in Damages.

7.2 ALT 4-NS_50YR

Alt 4-NS_50YR contains the same structural PSEs as Alt 4-NS_100YR. The only difference resides in nonstructural measures since a total of 14 federal facilities in MAs 1, 17, and 23 are receiving 2% risk reduction with floodproofing measures.

The following table displays the future without project expected damages, the project conditions expected damages, and the damages reduced in Alt 4-NS_50YR.

Table 20: Alt 4 – NS_50YR FWOP Damages, FWP Damages, and Damages Reduced

Model Area	FWOP Present Value Damages	FWP Present Value Damages	Present Value Damages Reduce	% Damages Reduced
BH8: Patapsco North I-895 Tunnel Bulkhead	$20,000	$10,000	$10,000	50.0%
BH18: Locust Point I-95 Tunnel Facility Bulkhead	$2,000	$0	$2,000	100.0%
BH19: Locust Point I-95 Tunnel Bulkhead	$197,413,000	$84,799,000	$112,614,000	57.0%
BH24: Patapsco South I-895 Tunnel Bulkhead	$113,252,000	$37,434,000	$75,818,000	66.9%
MAs 1, 17, 23 NS_50YR	$34,924,000	$32,754,000	$2,170,000	6.2%
Total	$345,611,000	$154,997,000	$190,614,000	55.2%

When compared the project alternative to the future without project conditions, Alt 4 – NS_50YR reduced the mean PV damages by 55.2%. This plan is consistent with Flood Hazards & Community Resilience Policy 2h – Preference of Multi-Purpose Use Projects, Project Accountability, & 50% Reduction in Damages.

7.3 ALT 4-NS_20YR

Alt 4-NS_20YR contains the same structural PSEs as Alt 4-NS_100YR and Alt 4-NS_50YR. The only difference resides in nonstructural measures since a total of 9 federal facilities in MAs 1, 17, and 23 are receiving 5% risk reduction with floodproofing measures.

The following table displays the future without project expected damages, the project conditions expected damages, and the damages reduced in Alt 4-NS_20YR.

Table 21: Alt 4 – NS_20YR FWOP Damages, FWP Damages, and Damages Reduced

Model Area	FWOP Present Value Damages	FWP Present Value Damages	Present Value Damages Reduce	% Damages Reduced
BH8: Patapsco North I-895 Tunnel Bulkhead	$20,000	$10,000	$10,000	50.0%
BH18: Locust Point I-95 Tunnel Facility Bulkhead	$2,000	$0	$2,000	100.0%
BH19: Locust Point I-95 Tunnel Bulkhead	$197,413,000	$84,799,000	$112,614,000	57.0%
BH24: Patapsco South I-895 Tunnel Bulkhead	$113,252,000	$37,434,000	$75,818,000	66.9%
MAs 1, 17, 23 NS_20YR	$34,924,000	$33,271,000	$1,653,000	4.7%
Total	$345,611,000	$155,514,000	$190,097,000	55.0%

When compared the project alternative to the future without project conditions, Alt 4 – NS_20YR reduced the mean PV damages by 55.0%. This plan is consistent with Flood Hazards &

Community Resilience Policy 2h – Preference of Multi-Purpose Use Projects, Project Accountability, & 50% Reduction in Damages.

7.4 ALT 5-NS_100YR

This alternative contains the same structural components as Alt 4-NS_100. The nonstructural measures were expanded in Martin State Airport, Inner Harbor, Locus Point and Patapsco South neighborhoods. A total of 1096 structures in 1% AEP are receiving floodproofing treatments.

The following table displays the future without project expected damages, the project conditions expected damages, and the damages reduced in Alt 5-NS_100YR.

Table 22: Alt 5 – NS_100YR FWOP Damages, FWP Damages, and Damages Reduced

Model Area	FWOP Present Value Damages	FWP Present Value Damages	Present Value Damages Reduce	% Damages Reduced
BH8: Patapsco North I-895 Tunnel Bulkhead	$20,000	$10,000	$10,000	50.0%
BH18: Locust Point I-95 Tunnel Facility Bulkhead	$2,000	$0	$2,000	100.0%
BH19: Locust Point I-95 Tunnel Bulkhead	$197,413,000	$84,799,000	$112,614,000	57.0%
BH24: Patapsco South I-895 Tunnel Bulkhead	$113,252,000	$37,434,000	$75,818,000	66.9%
MAs 1, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23 NS_100YR	$389,743,000	$265,902,000	$123,841,000	31.8%
Total	$700,430,000	$388,145,000	$312,285,000	44.6%

When compared the project alternative to the future without project conditions, Alt 5 – NS_100YR reduced the mean PV damages by 44.6%. This plan is not consistent with Flood Hazards & Community Resilience Policy 2h – Preference of Multi-Purpose Use Projects, Project Accountability, & 50% Reduction in Damages.

7.5 ALT 4-NS_50YR

Alt 5-NS_50YR contains the same structural PSEs as Alt 5-NS_50YR. The only difference resides in nonstructural measures since a total of 493 structures in 2% AEP are receiving 2% risk reduction with floodproofing measures.

The following table displays the future without project expected damages, the project conditions expected damages, and the damages reduced in Alt 5-NS_50YR.

Table 23: Alt 5 – NS_50YR FWOP Damages, FWP Damages, and Damages Reduced

Model Area	FWOP Present Value Damages	FWP Present Value Damages	Present Value Damages Reduce	% Damages Reduced
BH8: Patapsco North I-895 Tunnel Bulkhead	$20,000	$10,000	$10,000	50.0%
BH18: Locust Point I-95 Tunnel Facility Bulkhead	$2,000	$0	$2,000	100.0%
BH19: Locust Point I-95 Tunnel Bulkhead	$197,413,000	$84,799,000	$112,614,000	57.0%
BH24: Patapsco South I-895 Tunnel Bulkhead	$113,252,000	$37,434,000	$75,818,000	66.9%
MAs 1, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23 NS_100YR	$389,743,000	$291,287,000	$98,456,000	25.3%
Total	$700,430,000	$413,530,000	$286,900,000	41.0%

When compared the project alternative to the future without project conditions, Alt 5 – NS_50YR reduced the mean PV damages by 41.0%. This plan is not consistent with Flood Hazards & Community Resilience Policy 2h – Preference of Multi-Purpose Use Projects, Project Accountability, & 50% Reduction in Damages.

7.6 ALT 4-NS_20YR

Alt 5-NS_20YR contains the same structural PSEs as Alt 4-NS_20YR. The only difference resides in nonstructural measures since a total of 286 structures in 5% AEP are receiving 5% risk reduction with floodproofing measures.

The following table displays the future without project expected damages, the project conditions expected damages, and the damages reduced in Alt 5-NS_20YR.

Table 24: Alt 5 – NS_20YR FWOP Damages, FWP Damages, and Damages Reduced

Model Area	FWOP Present Value Damages	FWP Present Value Damages	Present Value Damages Reduce	% Damages Reduced
BH8: Patapsco North I-895 Tunnel Bulkhead	$20,000	$10,000	$10,000	50.0%
BH18: Locust Point I-95 Tunnel Facility Bulkhead	$2,000	$0	$2,000	100.0%
BH19: Locust Point I-95 Tunnel Bulkhead	$197,413,000	$84,799,000	$112,614,000	57.0%
BH24: Patapsco South I-895 Tunnel Bulkhead	$113,252,000	$37,434,000	$75,818,000	66.9%
MAs 1, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23 NS_100YR	$389,743,000	$321,339,000	$68,404,000	17.6%
Total	$700,430,000	$443,582,000	$256,848,000	36.7%

When compared the project alternative to the future without project conditions, Alt 5 – NS_20YR reduced the mean PV damages by 36.7%. This plan is not consistent with Flood Hazards & Community Resilience Policy 2h – Preference of Multi-Purpose Use Projects, Project Accountability, & 50% Reduction in Damages.

7.7 ALT 6-NS_100YR

In additional to structural and nonstructural components in Alt 5-NS_100, Alt 6-NS_100YR has a coastal PSE at Seagirt Marine Terminal. The following table displays the future without project expected damages, the project conditions expected damages, and the damages reduced in Alt 6-NS_100YR.

Table 25: Alt 6 – NS_100YR FWOP Damages, FWP Damages, and Damages Reduced

Model Area	FWOP Present Value Damages	FWP Present Value Damages	Present Value Damages Reduce	% Damages Reduced
BH7: Patapsco North Seagirt Bulkhead	$7,725,000	$3,097,000	$4,628,000	59.9%
BH8: Patapsco North I-895 Tunnel Bulkhead	$20,000	$10,000	$10,000	50.0%
BH18: Locust Point I-95 Tunnel Facility Bulkhead	$2,000	$0	$2,000	100.0%
BH19: Locust Point I-95 Tunnel Bulkhead	$197,413,000	$84,799,000	$112,614,000	57.0%
BH24: Patapsco South I-895 Tunnel Bulkhead	$113,252,000	$37,434,000	$75,818,000	66.9%
MAs 1, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23 NS_100YR	$389,743,000	$265,902,000	$123,841,000	31.8%
Total	$708,155,000	$391,242,000	$316,913,000	44.8%

When compared the project alternative to the future without project conditions, Alt 6 – NS_100YR reduced the mean PV damages by 44.8%. This plan is not consistent with Flood Hazards & Community Resilience Policy 2h – Preference of Multi-Purpose Use Projects, Project Accountability, & 50% Reduction in Damages.

7.8 ALT 6-NS_50YR

Alt 6-NS_50YR contains the same structural PSEs as Alt 5-NS_50YR. The only difference resides in nonstructural measures since a total of 493 structures in 2% AEP are receiving 2% risk reduction with floodproofing measures.

The following table displays the future without project expected damages, the project conditions expected damages, and the damages reduced in Alt 6-NS_50YR.

Table 26: Alt 6 – NS_50YR FWOP Damages, FWP Damages, and Damages Reduced

Model Area	FWOP Present Value Damages	FWP Present Value Damages	Present Value Damages Reduce	% Damages Reduced
BH7: Patapsco North Seagirt Bulkhead	$7,725,000	$3,097,000	$4,628,000	59.9%
BH8: Patapsco North I-895 Tunnel Bulkhead	$20,000	$10,000	$10,000	50.0%
BH18: Locust Point I-95 Tunnel Facility Bulkhead	$2,000	$0	$2,000	100.0%
BH19: Locust Point I-95 Tunnel Bulkhead	$197,413,000	$84,799,000	$112,614,000	57.0%
BH24: Patapsco South I-895 Tunnel Bulkhead	$113,252,000	$37,434,000	$75,818,000	66.9%
MAs 1, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23 NS_100YR	$389,743,000	$291,287,000	$98,456,000	25.3%
Total	$708,155,000	$416,627,000	$291,528,000	41.2%

When compared the project alternative to the future without project conditions, Alt 6 – NS_50YR reduced the mean PV damages by 41.2%. This plan is not consistent with Flood Hazards & Community Resilience Policy 2h – Preference of Multi-Purpose Use Projects, Project Accountability, & 50% Reduction in Damages.

7.9 ALT 6-NS_20YR

Alt 6-NS_20YR contains the same structural PSEs as Alt -NS_20YR. The only difference resides in nonstructural measures since a total of 286 structures in 5% AEP are receiving 5% risk reduction with floodproofing measures.

The following table displays the future without project expected damages, the project conditions expected damages, and the damages reduced in Alt 6-NS_20YR.

Table 27: Alt 6 – NS_20YR FWOP Damages, FWP Damages, and Damages Reduced

Model Area	FWOP Present Value Damages	FWP Present Value Damages	Present Value Damages Reduce	% Damages Reduced
BH7: Patapsco North Seagirt Bulkhead	$7,725,000	$3,097,000	$4,628,000	59.9%
BH8: Patapsco North I-895 Tunnel Bulkhead	$20,000	$10,000	$10,000	50.0%
BH18: Locust Point I-95 Tunnel Facility Bulkhead	$2,000	$0	$2,000	100.0%
BH19: Locust Point I-95 Tunnel Bulkhead	$197,413,000	$84,799,000	$112,614,000	57.0%
BH24: Patapsco South I-895 Tunnel Bulkhead	$113,252,000	$37,434,000	$75,818,000	66.9%
MAs 1, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23 NS_100YR	$389,743,000	$321,339,000	$68,404,000	17.6%
Total	$708,155,000	$446,679,000	$261,476,000	36.9%

When compared the project alternative to the future without project conditions, Alt 6 – NS_20YR reduced the mean PV damages by 36.9%. This plan is not consistent with Flood Hazards & Community Resilience Policy 2h – Preference of Multi-Purpose Use Projects, Project Accountability, & 50% Reduction in Damages.

7.10 ALT 7-NS_100YR

Alt 7-NS_100YR proposed 13 floodwalls/levees that seem to be linear coastal barrier in Inner Harbor and Locust Point. Two additional floodwalls will protect East and West Martin State Airport from flooding.

Fourteen federal facilities in MAs 1 and 23 are receiving 1% risk reduction with floodproofing measures.

The following table displays the future without project expected damages, the project conditions expected damages, and the damages reduced in Alt 7-NS_100YR.

Table 28: Alt 7 – NS_100YR FWOP Damages, FWP Damages, and Damages Reduced

Model Area	FWOP Present Value Damages	FWP Present Value Damages	Present Value Damages Reduce	% Damages Reduced
BH2: Martin State Airport West Bulkhead	$1,190,000	$646,000	$544,000	15.8%
BH3: Martin State Airport East Bulkhead	$0	$0	$0	-
BH7: Patapsco North Seagirt Bulkhead	$7,725,000	$3,097,000	$4,628,000	59.9%
BH8: Patapsco North I-895 Tunnel Bulkhead	$20,000	$10,000	$10,000	50.0%
BH10: Inner Harbor Anchorage Marina Bulkhead	$157,240,000	$71,722,000	$85,518,000	54.4%
BH11: Inner Harbor Harborplace Bulkhead	$98,064,000	$45,738,000	$52,326,000	53.4%
BH12: Inner Harbor Ritz Carlton Bulkhead	$1,307,000	$643,000	$664,000	50.8%
BH13: Inner Harbor Harborview Bulkhead	$264,000	$196,000	$68,000	25.8%
BH15: Locust Point Museum of Industry Bulkhead	$5,290,000	$2,573,000	$2,717,000	51.4%
BH16: Locust Point American Sugar Bulkhead	$6,539,000	$2,329,000	$4,210,000	64.4%
BH17: Locust Point Fort McHenry Bulkhead	$3,515,000	$1,110,000	$2,405,000	68.4%
BH18: Locust Point I-95 Tunnel Facility Bulkhead	$2,000	$0	$2,000	100.0%
BH19: Locust Point I-95 Tunnel Bulkhead	$197,413,000	$84,799,000	$112,614,000	57.0%
BH24: Patapsco South I-895 Tunnel Bulkhead	$113,252,000	$37,434,000	$75,818,000	66.9%
BH25: Middle Branch Wheelabrator Incinerator Plant	$302,000	$289,000	$13,000	4.3%
MAs 1, 23 NS_100YR	$31,409,000	$29,664,000	$1,745,000	5.6%
Total	$623,532,000	$280,250,000	$343,282,000	55.1%

When compared the project alternative to the future without project conditions, Alt 7 – NS_100YR reduced the mean PV damages by 55.1%. This plan is consistent with Flood Hazards & Community Resilience Policy 2h – Preference of Multi-Purpose Use Projects, Project Accountability, & 50% Reduction in Damages.

7.11 ALT 7-NS_50YR

Alt 7-NS_50YR contains the same structural PSEs as Alt 7-NS_100YR. The only difference resides in nonstructural measures since a total of 7 federal facilities in MAs 1 and 23 are receiving 2% risk reduction with floodproofing measures.

The following table displays the future without project expected damages, the project conditions expected damages, and the damages reduced in Alt 7-NS_50YR.

Table 29: Alt 7 – NS_50YR FWOP Damages, FWP Damages, and Damages Reduced

Model Area	FWOP Present Value Damages	FWP Present Value Damages	Present Value Damages Reduce	% Damages Reduced
BH2: Martin State Airport West Bulkhead	$1,190,000	$646,000	$544,000	15.8%
BH3: Martin State Airport East Bulkhead	$0	$0	$0	-
BH7: Patapsco North Seagirt Bulkhead	$7,725,000	$3,097,000	$4,628,000	59.9%
BH8: Patapsco North I-895 Tunnel Bulkhead	$20,000	$10,000	$10,000	50.0%
BH10: Inner Harbor Anchorage Marina Bulkhead	$157,240,000	$71,722,000	$85,518,000	54.4%
BH11: Inner Harbor Harborplace Bulkhead	$98,064,000	$45,738,000	$52,326,000	53.4%
BH12: Inner Harbor Ritz Carlton Bulkhead	$1,307,000	$643,000	$664,000	50.8%
BH13: Inner Harbor Harborview Bulkhead	$264,000	$196,000	$68,000	25.8%
BH15: Locust Point Museum of Industry Bulkhead	$5,290,000	$2,573,000	$2,717,000	51.4%
BH16: Locust Point American Sugar Bulkhead	$6,539,000	$2,329,000	$4,210,000	64.4%
BH17: Locust Point Fort McHenry Bulkhead	$3,515,000	$1,110,000	$2,405,000	68.4%
BH18: Locust Point I-95 Tunnel Facility Bulkhead	$2,000	$0	$2,000	100.0%
BH19: Locust Point I-95 Tunnel Bulkhead	$197,413,000	$84,799,000	$112,614,000	57.0%
BH24: Patapsco South I-895 Tunnel Bulkhead	$113,252,000	$37,434,000	$75,818,000	66.9%
BH25: Middle Branch Wheelabrator Incinerator Plant	$302,000	$289,000	$13,000	4.3%
MAs 1, 23 NS_50YR	$31,409,000	$30,879,000	$530,000	1.7%
Total	$623,532,000	$281,465,000	$342,067,000	54.9%

When compared the project alternative to the future without project conditions, Alt 7 – NS_50YR reduced the mean PV damages by 54.9%. This plan is consistent with Flood Hazards & Community Resilience Policy 2h – Preference of Multi-Purpose Use Projects, Project Accountability, & 50% Reduction in Damages.

7.12 ALT 7-NS_20YR

Alt 7-NS_20YR contains the same structural PSEs as Alt 7-NS_100YR and Alt 7-NS_50YR. The only difference resides in nonstructural measures since a total of 2 federal facilities in MAs 1 and 23 are receiving 5% risk reduction with floodproofing measures.

The following table displays the future without project expected damages, the project conditions expected damages, and the damages reduced in Alt 7-NS_20YR.

Table 30: Alt 7 – NS_20YR FWOP Damages, FWP Damages, and Damages Reduced

Model Area	FWOP Present Value Damages	FWP Present Value Damages	Present Value Damages Reduce	% Damages Reduced
BH2: Martin State Airport West Bulkhead	$1,190,000	$646,000	$544,000	15.8%
BH3: Martin State Airport East Bulkhead	$0	$0	$0	-
BH7: Patapsco North Seagirt Bulkhead	$7,725,000	$3,097,000	$4,628,000	59.9%
BH8: Patapsco North I-895 Tunnel Bulkhead	$20,000	$10,000	$10,000	50.0%
BH10: Inner Harbor Anchorage Marina Bulkhead	$157,240,000	$71,722,000	$85,518,000	54.4%
BH11: Inner Harbor Harborplace Bulkhead	$98,064,000	$45,738,000	$52,326,000	53.4%
BH12: Inner Harbor Ritz Carlton Bulkhead	$1,307,000	$643,000	$664,000	50.8%
BH13: Inner Harbor Harborview Bulkhead	$264,000	$196,000	$68,000	25.8%
BH15: Locust Point Museum of Industry Bulkhead	$5,290,000	$2,573,000	$2,717,000	51.4%
BH16: Locust Point American Sugar Bulkhead	$6,539,000	$2,329,000	$4,210,000	64.4%
BH17: Locust Point Fort McHenry Bulkhead	$3,515,000	$1,110,000	$2,405,000	68.4%
BH18: Locust Point I-95 Tunnel Facility Bulkhead	$2,000	$0	$2,000	100.0%
BH19: Locust Point I-95 Tunnel Bulkhead	$197,413,000	$84,799,000	$112,614,000	57.0%
BH24: Patapsco South I-895 Tunnel Bulkhead	$113,252,000	$37,434,000	$75,818,000	66.9%
BH25: Middle Branch Wheelabrator Incinerator Plant	$302,000	$289,000	$13,000	4.3%
MAs 1, 23 NS_20YR	$31,409,000	$31,396,000	$13,000	0.0%
Total	$623,532,000	$281,982,000	$341,550,000	54.8%

When compared the project alternative to the future without project conditions, Alt 7 – NS_20YR reduced the mean PV damages by 54.8%. This plan is consistent with Flood Hazards & Community Resilience Policy 2h – Preference of Multi-Purpose Use Projects, Project Accountability, & 50% Reduction in Damages.

8. ALTERNATIVE COMPARISON

The benefits were compared to the costs for each alternative. These comparisons provide the framework for completing the evaluation of alternative plans.

8.1 BENEFITS

The difference in expected mean Present Value (PV) flood damages in the Baltimore Metropolitan study area between the future without condition and future with project condition represents the flood risk management benefits to the project. Therefore, these benefits represent damages reduced (National Economic Development - NED) from coastal storm surge inundation with the combination of sea level rise for each alternative. However, Planning Guidance (reference ER 1105-2-100) dictates that the calculation of net NED benefits of a plan is calculated in average annual equivalent terms. Therefore, the PV damages were converted to average annual damages based and the costs were annualized using the FY22 discount rate of 2.25% and a 50-year period of analysis for the purpose of the comparison.

8.2 COSTS

Structural and nonstructural measure cost estimates were provided by the Baltimore District Cost Engineering Section Division in FY2022 (October 2021) price levels (reference Engineering Appendix for more details). To Continue the comparison process, First Cost estimates were used for each of the alternatives that were evaluated. The Interest During Construction (IDC) was computed using the First Cost and the duration of construction. For comparison to the benefits, which are average annual flood damages reduced, the first costs were stated in average annual equivalent also based on the FY2022 discount rate of 2.25% and 50 years period of analysis. The IDC was added to the First Cost to derive the investment cost. In addition, annual operation and maintenance (O&M) costs were also added to the structural alternatives. Table 31 shows the results of the costs computation

Table 31: Cost for Alternatives

Plan Alternatives	Alternative Description	First Cost	IDC	Investment Cost	O&M	Total Cost	Average Annual Cost
FWOP	**No Action**			**-**	**-**	**-**	**-**
	BH8: Patapsco North I-895 Tunnel Bulkhead	3,860,000	7,000	3,867,000	39,000	3,906,000	131,000
	BH18: Locust Point I-95 Tunnel Facility Bulkhead	3,788,000	4,000	3,792,000	38,000	3,830,000	128,000
	BH19: Locust Point I-95 Tunnel Bulkhead	27,502,000	282,000	27,784,000	275,000	28,059,000	940,000
	BH24: Patapsco South I-895 Tunnel Bulkhead	18,441,000	147,000	18,588,000	184,000	18,772,000	629,000
	MAs 1, 17, 23 NS_100YR	13,863,000	460,000	14,323,000	139,000	14,462,000	485,000
Alt 4 - NS_100YR		**67,454,000**	**900,000**	**68,354,000**	**675,000**	**69,029,000**	**2,313,000**
Alt 4 - NS_50YR	BH8: Patapsco North I-895 Tunnel Bulkhead	3,860,000	7,000	3,867,000	39,000	3,906,000	131,000
	BH18: Locust Point I-95 Tunnel Facility Bulkhead	3,788,000	4,000	3,792,000	38,000	3,830,000	128,000
	BH19: Locust Point I-95 Tunnel Bulkhead	27,502,000	282,000	27,784,000	275,000	28,059,000	940,000
	BH24: Patapsco South I-895 Tunnel Bulkhead	18,441,000	147,000	18,588,000	184,000	18,772,000	629,000
	MAs 1, 17, 23 NS_50YR	9,411,000	203,000	9,614,000	94,000	9,708,000	325,000
Alt 4 - NS_50YR		**63,002,000**	**643,000**	**63,645,000**	**630,000**	**64,275,000**	**2,153,000**
Alt 4 - NS_20YR	BH8: Patapsco North I-895 Tunnel Bulkhead	3,860,000	7,000	3,867,000	39,000	3,906,000	131,000
	BH18: Locust Point I-95 Tunnel Facility Bulkhead	3,788,000	4,000	3,792,000	38,000	3,830,000	128,000
	BH19: Locust Point I-95 Tunnel Bulkhead	27,502,000	282,000	27,784,000	275,000	28,059,000	940,000
	BH24: Patapsco South I-895 Tunnel Bulkhead	18,441,000	147,000	18,588,000	184,000	18,772,000	629,000
	MAs 1, 17, 23 NS_20YR	8,020,000		8,020,000	80,000	8,100,000	271,000
Alt 4 - NS_20YR		**61,611,000**	**440,000**	**62,051,000**	**616,000**	**62,667,000**	**2,099,000**
Alt 5 - NS_100YR	BH8: Patapsco North I-895 Tunnel Bulkhead	3,860,000	7,000	3,867,000	39,000	3,906,000	131,000
	BH18: Locust Point I-95 Tunnel Facility Bulkhead	3,788,000	4,000	3,792,000	38,000	3,830,000	128,000
	BH19: Locust Point I-95 Tunnel Bulkhead	27,502,000	282,000	27,784,000	275,000	28,059,000	940,000
	BH24: Patapsco South I-895 Tunnel Bulkhead	18,441,000	147,000	18,588,000	184,000	18,772,000	629,000
	MAs 1, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23 NS_100YR	341,988,000	11,344,000	353,332,000	3,421,000	356,753,000	11,959,000

Plan Alternatives	Alternative Description	First Cost	IDC	Investment Cost	O&M	Total Cost	Average Annual Cost
Alt 5 - NS_100YR		**395,579,000**	**11,784,000**	**407,363,000**	**3,957,000**	**411,320,000**	**13,787,000**
Alt 5 - NS_50YR	BH8: Patapsco North I-895 Tunnel Bulkhead	3,860,000	7,000	3,867,000	39,000	3,906,000	131,000
	BH18: Locust Point I-95 Tunnel Facility Bulkhead	3,788,000	4,000	3,792,000	38,000	3,830,000	128,000
	BH19: Locust Point I-95 Tunnel Bulkhead	27,502,000	282,000	27,784,000	275,000	28,059,000	940,000
	BH24: Patapsco South I-895 Tunnel Bulkhead	18,441,000	147,000	18,588,000	184,000	18,772,000	629,000
	MAs 1, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23 NS_50YR	172,303,000	3,727,000	176,030,000	1,724,000	177,754,000	5,957,000
Alt 5 - NS_50YR		**225,894,000**	**4,167,000**	**230,061,000**	**2,260,000**	**232,321,000**	**7,785,000**
Alt 5 - NS_20YR	BH8: Patapsco North I-895 Tunnel Bulkhead	3,860,000	7,000	3,867,000	39,000	3,906,000	131,000
	BH18: Locust Point I-95 Tunnel Facility Bulkhead	3,788,000	4,000	3,792,000	38,000	3,830,000	128,000
	BH19: Locust Point I-95 Tunnel Bulkhead	27,502,000	282,000	27,784,000	275,000	28,059,000	940,000
	BH24: Patapsco South I-895 Tunnel Bulkhead	18,441,000	147,000	18,588,000	184,000	18,772,000	629,000
	MAs 1, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23 NS_20YR	106,178,000	1,091,000	107,269,000	1,062,000	108,331,000	3,633,000
Alt 5 - NS_20YR		**159,769,000**	**1,531,000**	**161,300,000**	**1,598,000**	**162,898,000**	**5,461,000**
Alt 6 - NS_100YR	BH7: Patapsco North Seagirt Bulkhead	97,913,000	2,119,000	100,032,000	979,000	101,011,000	3,386,000
	BH8: Patapsco North I-895 Tunnel Bulkhead	3,860,000	7,000	3,867,000	39,000	3,906,000	131,000
	BH18: Locust Point I-95 Tunnel Facility Bulkhead	3,788,000	4,000	3,792,000	38,000	3,830,000	128,000
	BH19: Locust Point I-95 Tunnel Bulkhead	27,502,000	282,000	27,784,000	275,000	28,059,000	940,000
	BH24: Patapsco South I-895 Tunnel Bulkhead	18,441,000	147,000	18,588,000	184,000	18,772,000	629,000
	MAs 1, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23 NS_100YR	341,988,000	11,344,000	353,332,000	3,421,000	356,753,000	11,959,000
Alt 6 - NS_100YR		**493,492,000**	**13,903,000**	**507,395,000**	**4,936,000**	**512,331,000**	**17,173,000**
Alt 6 - NS_50YR	BH7: Patapsco North Seagirt Bulkhead	97,913,000	2,119,000	100,032,000	979,000	101,011,000	3,386,000
	BH8: Patapsco North I-895 Tunnel Bulkhead	3,860,000	7,000	3,867,000	39,000	3,906,000	131,000
	BH18: Locust Point I-95 Tunnel Facility Bulkhead	3,788,000	4,000	3,792,000	38,000	3,830,000	128,000
	BH19: Locust Point I-95 Tunnel Bulkhead	27,502,000	282,000	27,784,000	275,000	28,059,000	940,000

Plan Alternatives	Alternative Description	First Cost	IDC	Investment Cost	O&M	Total Cost	Average Annual Cost
	BH24: Patapsco South I-895 Tunnel Bulkhead	18,441,000	147,000	18,588,000	184,000	18,772,000	629,000
	MAs 1, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23 NS_50YR	172,303,000	3,727,000	176,030,000	1,724,000	177,754,000	5,957,000
Alt 6 - NS_50YR		**323,807,000**	**6,286,000**	**330,093,000**	**3,239,000**	**333,332,000**	**11,171,000**
Alt 6 - NS_20YR	BH7: Patapsco North Seagirt Bulkhead	97,913,000	2,119,000	100,032,000	979,000	101,011,000	3,386,000
	BH8: Patapsco North I-895 Tunnel Bulkhead	3,860,000	7,000	3,867,000	39,000	3,906,000	131,000
	BH18: Locust Point I-95 Tunnel Facility Bulkhead	3,788,000	4,000	3,792,000	38,000	3,830,000	128,000
	BH19: Locust Point I-95 Tunnel Bulkhead	27,502,000	282,000	27,784,000	275,000	28,059,000	940,000
	BH24: Patapsco South I-895 Tunnel Bulkhead	18,441,000	147,000	18,588,000	184,000	18,772,000	629,000
	MAs 1, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23 NS_20YR	106,178,000	1,091,000	107,269,000	1,062,000	108,331,000	3,633,000
Alt 6 - NS_20YR		**257,682,000**	**3,650,000**	**261,332,000**	**2,577,000**	**263,909,000**	**8,847,000**
Alt 7 - NS_100YR	BH2: Martin State Airport West Bulkhead	34,900,000	260,000	35,160,000	349,000	35,509,000	1,190,000
	BH3: Martin State Airport East Bulkhead	619,000	1,000	620,000	6,000	626,000	21,000
	BH7: Patapsco North Seagirt Bulkhead	97,913,000	2,119,000	100,032,000	979,000	101,011,000	3,386,000
	BH8: Patapsco North I-895 Tunnel Bulkhead	3,860,000	7,000	3,867,000	39,000	3,906,000	131,000
	BH10: Inner Harbor Anchorage Marina Bulkhead	238,186,000	5,154,000	243,340,000	2,382,000	245,722,000	8,236,000
	BH11: Inner Harbor Harborplace Bulkhead	117,675,000	2,546,000	120,221,000	1,177,000	121,398,000	4,069,000
	BH12: Inner Harbor Ritz Carlton Bulkhead	24,704,000	184,000	24,888,000	247,000	25,135,000	842,000
	BH13: Inner Harbor Harborview Bulkhead	4,930,000	9,000	4,939,000	49,000	4,988,000	167,000
	BH15: Locust Point Museum of Industry Bulkhead	33,108,000	340,000	33,448,000	331,000	33,779,000	1,132,000
	BH16: Locust Point American Sugar Bulkhead	10,698,000	50,000	10,748,000	107,000	10,855,000	364,000
	BH17: Locust Point Fort McHenry Bulkhead	18,658,000	87,000	18,745,000	187,000	18,932,000	635,000
	BH18: Locust Point I-95 Tunnel Facility Bulkhead	3,788,000	4,000	3,792,000	38,000	3,830,000	128,000
	BH19: Locust Point I-95 Tunnel Bulkhead	27,502,000	282,000	27,784,000	275,000	28,059,000	940,000
	BH24: Patapsco South I-895 Tunnel Bulkhead	18,441,000	147,000	18,588,000	184,000	18,772,000	629,000

Plan Alternatives	Alternative Description	First Cost	IDC	Investment Cost	O&M	Total Cost	Average Annual Cost
	BH25: Middle Branch Wheelabrator Incinerator Plant	14,016,000	65,000	14,081,000	140,000	14,221,000	477,000
	MAs 1, 23 NS_100YR	6,400,000	212,000	6,612,000	64,000	6,676,000	224,000
Alt 7 - NS_100YR		**655,398,000**	**11,467,000**	**666,865,000**	**6,554,000**	**673,419,000**	**22,571,000**
Alt 7 - NS_50YR	BH2: Martin State Airport West Bulkhead	34,900,000	260,000	35,160,000	349,000	35,509,000	1,190,000
	BH3: Martin State Airport East Bulkhead	619,000	1,000	620,000	6,000	626,000	21,000
	BH7: Patapsco North Seagirt Bulkhead	97,913,000	2,119,000	100,032,000	979,000	101,011,000	3,386,000
	BH8: Patapsco North I-895 Tunnel Bulkhead	3,860,000	7,000	3,867,000	39,000	3,906,000	131,000
	BH10: Inner Harbor Anchorage Marina Bulkhead	238,186,000	5,154,000	243,340,000	2,382,000	245,722,000	8,236,000
	BH11: Inner Harbor Harborplace Bulkhead	117,675,000	2,546,000	120,221,000	1,177,000	121,398,000	4,069,000
	BH12: Inner Harbor Ritz Carlton Bulkhead	24,704,000	184,000	24,888,000	247,000	25,135,000	842,000
	BH13: Inner Harbor Harborview Bulkhead	4,930,000	9,000	4,939,000	49,000	4,988,000	167,000
	BH15: Locust Point Museum of Industry Bulkhead	33,108,000	340,000	33,448,000	331,000	33,779,000	1,132,000
	BH16: Locust Point American Sugar Bulkhead	10,698,000	50,000	10,748,000	107,000	10,855,000	364,000
	BH17: Locust Point Fort McHenry Bulkhead	18,658,000	87,000	18,745,000	187,000	18,932,000	635,000
	BH18: Locust Point I-95 Tunnel Facility Bulkhead	3,788,000	4,000	3,792,000	38,000	3,830,000	128,000
	BH19: Locust Point I-95 Tunnel Bulkhead	27,502,000	282,000	27,784,000	275,000	28,059,000	940,000
	BH24: Patapsco South I-895 Tunnel Bulkhead	18,441,000	147,000	18,588,000	184,000	18,772,000	629,000
	BH25: Middle Branch Wheelabrator Incinerator Plant	14,016,000	65,000	14,081,000	140,000	14,221,000	477,000
	MAs 1, 23 NS_50YR	1,948,000	42,000	1,990,000	19,000	2,009,000	67,000
Alt 7 - NS_50YR		**650,946,000**	**11,297,000**	**662,243,000**	**6,509,000**	**668,752,000**	**22,414,000**
Alt 7 - NS_20YR	BH2: Martin State Airport West Bulkhead	34,900,000	260,000	35,160,000	349,000	35,509,000	1,190,000
	BH3: Martin State Airport East Bulkhead	619,000	1,000	620,000	6,000	626,000	21,000
	BH7: Patapsco North Seagirt Bulkhead	97,913,000	2,119,000	100,032,000	979,000	101,011,000	3,386,000
	BH8: Patapsco North I-895 Tunnel Bulkhead	3,860,000	7,000	3,867,000	39,000	3,906,000	131,000

Plan Alternatives	Alternative Description	First Cost	IDC	Investment Cost	O&M	Total Cost	Average Annual Cost
	BH10: Inner Harbor Anchorage Marina Bulkhead	238,186,000	5,154,000	243,340,000	2,382,000	245,722,000	8,236,000
	BH11: Inner Harbor Harborplace Bulkhead	117,675,000	2,546,000	120,221,000	1,177,000	121,398,000	4,069,000
	BH12: Inner Harbor Ritz Carlton Bulkhead	24,704,000	184,000	24,888,000	247,000	25,135,000	842,000
	BH13: Inner Harbor Harborview Bulkhead	4,930,000	9,000	4,939,000	49,000	4,988,000	167,000
	BH15: Locust Point Museum of Industry Bulkhead	33,108,000	340,000	33,448,000	331,000	33,779,000	1,132,000
	BH16: Locust Point American Sugar Bulkhead	10,698,000	50,000	10,748,000	107,000	10,855,000	364,000
	BH17: Locust Point Fort McHenry Bulkhead	18,658,000	87,000	18,745,000	187,000	18,932,000	635,000
	BH18: Locust Point I-95 Tunnel Facility Bulkhead	3,788,000	4,000	3,792,000	38,000	3,830,000	128,000
	BH19: Locust Point I-95 Tunnel Bulkhead	27,502,000	282,000	27,784,000	275,000	28,059,000	940,000
	BH24: Patapsco South I-895 Tunnel Bulkhead	18,441,000	147,000	18,588,000	184,000	18,772,000	629,000
	BH25: Middle Branch Wheelabrator Incinerator Plant	14,016,000	65,000	14,081,000	140,000	14,221,000	477,000
	MAs 1, 23 NS_20YR	557,000	6,000	563,000	6,000	569,000	19,000
Alt 7 - NS_20YR		**649,555,000**	**11,261,000**	**660,816,000**	**6,496,000**	**667,312,000**	**22,366,000**

8.3 BENEFITS-COSTS RATIO

The equivalent annual benefits were 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 computed by subtracting the average annual costs from the equivalent average annual benefits. BCR was calculated by dividing average benefits by average annual costs. Net benefits were used for identification of the NED plan in accordance with the Federal objective. The following Table 32 summarizes the equivalent annual benefits, average annual costs, first cost, net benefits, and BCR for each alternative.

Table 32: Costs and Benefits Comparison of Alternatives

Plan Alternatives	First Cost	IDC	Investment Cost	O&M	Total Cost	Average Annualized Cost	Average Annualized Benefits	Average Annualized Net Benefits	BCR
No Action			-	-	-	-	-	-	-
BH8: Patapsco North I-895 Tunnel Bulkhead	3,860,000	7,000	3,867,000	39,000	3,906,000	131,000	1,000	(130,000)	0.0

Plan Alternatives	First Cost	IDC	Investment Cost	O&M	Total Cost	Average Annualized Cost	Average Annualized Benefits	Average Annualized Net Benefits	BCR
BH18: Locust Point I-95 Tunnel Facility Bulkhead	3,788,000	4,000	3,792,000	38,000	3,830,000	128,000	-	(128,000)	0.0
BH19: Locust Point I-95 Tunnel Bulkhead	27,502,000	282,000	27,784,000	275,000	28,059,000	940,000	3,775,000	2,835,000	4.0
BH24: Patapsco South I-895 Tunnel Bulkhead	18,441,000	147,000	18,588,000	184,000	18,772,000	629,000	2,541,000	1,912,000	4.0
MAs 1, 17, 23 NS_100YR	13,863,000	460,000	14,323,000	139,000	14,462,000	485,000	114,000	(371,000)	0.2
Alt 4 - NS_100YR	**67,454,000**	**900,000**	**68,354,000**	**675,000**	**69,029,000**	**2,313,000**	**6,431,000**	**4,118,000**	**2.8**
BH8: Patapsco North I-895 Tunnel Bulkhead	3,860,000	7,000	3,867,000	39,000	3,906,000	131,000	1,000	(130,000)	0.0
BH18: Locust Point I-95 Tunnel Facility Bulkhead	3,788,000	4,000	3,792,000	38,000	3,830,000	128,000	-	(128,000)	0.0
BH19: Locust Point I-95 Tunnel Bulkhead	27,502,000	282,000	27,784,000	275,000	28,059,000	940,000	3,775,000	2,835,000	4.0
BH24: Patapsco South I-895 Tunnel Bulkhead	18,441,000	147,000	18,588,000	184,000	18,772,000	629,000	2,541,000	1,912,000	4.0
MAs 1, 17, 23 NS_50YR	9,411,000	203,000	9,614,000	94,000	9,708,000	325,000	73,000	(252,000)	0.2
Alt 4 - NS_50YR	**63,002,000**	**643,000**	**63,645,000**	**630,000**	**64,275,000**	**2,153,000**	**6,390,000**	**4,237,000**	**3.0**
BH8: Patapsco North I-895 Tunnel Bulkhead	3,860,000	7,000	3,867,000	39,000	3,906,000	131,000	1,000	(130,000)	0.0
BH18: Locust Point I-95 Tunnel Facility Bulkhead	3,788,000	4,000	3,792,000	38,000	3,830,000	128,000	-	(128,000)	0.0
BH19: Locust Point I-95 Tunnel Bulkhead	27,502,000	282,000	27,784,000	275,000	28,059,000	940,000	3,775,000	2,835,000	4.0
BH24: Patapsco South I-895 Tunnel Bulkhead	18,441,000	147,000	18,588,000	184,000	18,772,000	629,000	2,541,000	1,912,000	4.0
MAs 1, 17, 23 NS_20YR	8,020,000		8,020,000	80,000	8,100,000	271,000	55,000	(216,000)	0.2
Alt 4 - NS_20YR	**61,611,000**	**440,000**	**62,051,000**	**616,000**	**62,667,000**	**2,099,000**	**6,372,000**	**4,273,000**	**3.0**
BH8: Patapsco North I-895 Tunnel Bulkhead	3,860,000	7,000	3,867,000	39,000	3,906,000	131,000	1,000	(130,000)	0.0
BH18: Locust Point I-95 Tunnel Facility Bulkhead	3,788,000	4,000	3,792,000	38,000	3,830,000	128,000	-	(128,000)	0.0
BH19: Locust Point I-95 Tunnel Bulkhead	27,502,000	282,000	27,784,000	275,000	28,059,000	940,000	3,775,000	2,835,000	4.0
BH24: Patapsco South I-895 Tunnel Bulkhead	18,441,000	147,000	18,588,000	184,000	18,772,000	629,000	2,541,000	1,912,000	4.0
MAs 1, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23 NS_100YR	341,988,000	11,344,000	353,332,000	3,421,000	356,753,000	11,959,000	4,152,000	(7,807,000)	0.3
Alt 5 - NS_100YR	**395,579,000**	**11,784,000**	**407,363,000**	**3,957,000**	**411,320,000**	**13,787,000**	**10,469,000**	**(3,318,000)**	**0.8**

Plan Alternatives	First Cost	IDC	Investment Cost	O&M	Total Cost	Average Annualized Cost	Average Annualized Benefits	Average Annualized Net Benefits	BCR
BH8: Patapsco North I-895 Tunnel Bulkhead	3,860,000	7,000	3,867,000	39,000	3,906,000	131,000	1,000	(130,000)	0.0
BH18: Locust Point I-95 Tunnel Facility Bulkhead	3,788,000	4,000	3,792,000	38,000	3,830,000	128,000	-	(128,000)	0.0
BH19: Locust Point I-95 Tunnel Bulkhead	27,502,000	282,000	27,784,000	275,000	28,059,000	940,000	3,775,000	2,835,000	4.0
BH24: Patapsco South I-895 Tunnel Bulkhead	18,441,000	147,000	18,588,000	184,000	18,772,000	629,000	2,541,000	1,912,000	4.0
MAs 1, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23 NS_50YR	172,303,000	3,727,000	176,030,000	1,724,000	177,754,000	5,957,000	3,300,000	(2,657,000)	0.6
Alt 5 - NS_50YR	**225,894,000**	**4,167,000**	**230,061,000**	**2,260,000**	**232,321,000**	**7,785,000**	**9,617,000**	**1,832,000**	**1.2**
BH8: Patapsco North I-895 Tunnel Bulkhead	3,860,000	7,000	3,867,000	39,000	3,906,000	131,000	1,000	(130,000)	0.0
BH18: Locust Point I-95 Tunnel Facility Bulkhead	3,788,000	4,000	3,792,000	38,000	3,830,000	128,000	-	(128,000)	0.0
BH19: Locust Point I-95 Tunnel Bulkhead	27,502,000	282,000	27,784,000	275,000	28,059,000	940,000	3,775,000	2,835,000	4.0
BH24: Patapsco South I-895 Tunnel Bulkhead	18,441,000	147,000	18,588,000	184,000	18,772,000	629,000	2,541,000	1,912,000	4.0
MAs 1, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23 NS_20YR	106,178,000	1,091,000	107,269,000	1,062,000	108,331,000	3,633,000	2,291,000	(1,342,000)	0.6
Alt 5 - NS_20YR	**159,769,000**	**1,531,000**	**161,300,000**	**1,598,000**	**162,898,000**	**5,461,000**	**8,608,000**	**3,147,000**	**1.6**
BH7: Patapsco North Seagirt Bulkhead	97,913,000	2,119,000	100,032,000	979,000	101,011,000	3,386,000	155,000	(3,231,000)	0.0
BH8: Patapsco North I-895 Tunnel Bulkhead	3,860,000	7,000	3,867,000	39,000	3,906,000	131,000	1,000	(130,000)	0.0
BH18: Locust Point I-95 Tunnel Facility Bulkhead	3,788,000	4,000	3,792,000	38,000	3,830,000	128,000	-	(128,000)	0.0
BH19: Locust Point I-95 Tunnel Bulkhead	27,502,000	282,000	27,784,000	275,000	28,059,000	940,000	3,775,000	2,835,000	4.0
BH24: Patapsco South I-895 Tunnel Bulkhead	18,441,000	147,000	18,588,000	184,000	18,772,000	629,000	2,541,000	1,912,000	4.0
MAs 1, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23 NS_100YR	341,988,000	11,344,000	353,332,000	3,421,000	356,753,000	11,959,000	4,152,000	(7,807,000)	0.3
Alt 6 - NS_100YR	**493,492,000**	**13,903,000**	**507,395,000**	**4,936,000**	**512,331,000**	**17,173,000**	**10,624,000**	**(6,549,000)**	**0.6**
BH7: Patapsco North Seagirt Bulkhead	97,913,000	2,119,000	100,032,000	979,000	101,011,000	3,386,000	155,000	(3,231,000)	0.0
BH8: Patapsco North I-895 Tunnel Bulkhead	3,860,000	7,000	3,867,000	39,000	3,906,000	131,000	1,000	(130,000)	0.0
BH18: Locust Point I-95 Tunnel Facility Bulkhead	3,788,000	4,000	3,792,000	38,000	3,830,000	128,000	-	(128,000)	0.0
BH19: Locust Point I-95 Tunnel Bulkhead	27,502,000	282,000	27,784,000	275,000	28,059,000	940,000	3,775,000	2,835,000	4.0

Plan Alternatives	First Cost	IDC	Investment Cost	O&M	Total Cost	Average Annualized Cost	Average Annualized Benefits	Average Annualized Net Benefits	BCR
BH24: Patapsco South I-895 Tunnel Bulkhead	18,441,000	147,000	18,588,000	184,000	18,772,000	629,000	2,541,000	1,912,000	4.0
MAs 1, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23 NS_50YR	172,303,000	3,727,000	176,030,000	1,724,000	177,754,000	5,957,000	3,300,000	(2,657,000)	0.6
Alt 6 - NS_50YR	**323,807,000**	**6,286,000**	**330,093,000**	**3,239,000**	**333,332,000**	**11,171,000**	**9,772,000**	**(1,399,000)**	**0.9**
BH7: Patapsco North Seagirt Bulkhead	97,913,000	2,119,000	100,032,000	979,000	101,011,000	3,386,000	155,000	(3,231,000)	0.0
BH8: Patapsco North I-895 Tunnel Bulkhead	3,860,000	7,000	3,867,000	39,000	3,906,000	131,000	1,000	(130,000)	0.0
BH18: Locust Point I-95 Tunnel Facility Bulkhead	3,788,000	4,000	3,792,000	38,000	3,830,000	128,000	-	(128,000)	0.0
BH19: Locust Point I-95 Tunnel Bulkhead	27,502,000	282,000	27,784,000	275,000	28,059,000	940,000	3,775,000	2,835,000	4.0
BH24: Patapsco South I-895 Tunnel Bulkhead	18,441,000	147,000	18,588,000	184,000	18,772,000	629,000	2,541,000	1,912,000	4.0
MAs 1, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23 NS_20YR	106,178,000	1,091,000	107,269,000	1,062,000	108,331,000	3,633,000	2,291,000	(1,342,000)	0.6
Alt 6 - NS_20YR	**257,682,000**	**3,650,000**	**261,332,000**	**2,577,000**	**263,909,000**	**8,847,000**	**8,763,000**	**(84,000)**	**1.0**
BH2: Martin State Airport West Bulkhead	34,900,000	260,000	35,160,000	349,000	35,509,000	1,190,000	18,000	(1,172,000)	0.0
BH3: Martin State Airport East Bulkhead	619,000	1,000	620,000	6,000	626,000	21,000	-	(21,000)	0.0
BH7: Patapsco North Seagirt Bulkhead	97,913,000	2,119,000	100,032,000	979,000	101,011,000	3,386,000	155,000	(3,231,000)	0.0
BH8: Patapsco North I-895 Tunnel Bulkhead	3,860,000	7,000	3,867,000	39,000	3,906,000	131,000	1,000	(130,000)	0.0
BH10: Inner Harbor Anchorage Marina Bulkhead	238,186,000	5,154,000	243,340,000	2,382,000	245,722,000	8,236,000	2,866,000	(5,370,000)	0.3
BH11: Inner Harbor Harborplace Bulkhead	117,675,000	2,546,000	120,221,000	1,177,000	121,398,000	4,069,000	1,754,000	(2,315,000)	0.4
BH12: Inner Harbor Ritz Carlton Bulkhead	24,704,000	184,000	24,888,000	247,000	25,135,000	842,000	22,000	(820,000)	0.0
BH13: Inner Harbor Harborview Bulkhead	4,930,000	9,000	4,939,000	49,000	4,988,000	167,000	2,000	(165,000)	0.0
BH15: Locust Point Museum of Industry Bulkhead	33,108,000	340,000	33,448,000	331,000	33,779,000	1,132,000	91,000	(1,041,000)	0.1
BH16: Locust Point American Sugar Bulkhead	10,698,000	50,000	10,748,000	107,000	10,855,000	364,000	141,000	(223,000)	0.4
BH17: Locust Point Fort McHenry Bulkhead	18,658,000	87,000	18,745,000	187,000	18,932,000	635,000	81,000	(554,000)	0.1
BH18: Locust Point I-95 Tunnel Facility Bulkhead	3,788,000	4,000	3,792,000	38,000	3,830,000	128,000	-	(128,000)	0.0
BH19: Locust Point I-95 Tunnel Bulkhead	27,502,000	282,000	27,784,000	275,000	28,059,000	940,000	3,775,000	2,835,000	4.0

Plan Alternatives	First Cost	IDC	Investment Cost	O&M	Total Cost	Average Annualized Cost	Average Annualized Benefits	Average Annualized Net Benefits	BCR
BH24: Patapsco South I-895 Tunnel Bulkhead	18,441,000	147,000	18,588,000	184,000	18,772,000	629,000	2,541,000	1,912,000	4.0
BH25: Middle Branch Wheelabrator Incinerator Plant	14,016,000	65,000	14,081,000	140,000	14,221,000	477,000	-	(477,000)	0.0
MAs 1, 23 NS_100YR	6,400,000	212,000	6,612,000	64,000	6,676,000	224,000	59,000	(165,000)	0.3
Alt 7 - NS_100YR	**655,398,000**	**11,467,000**	**666,865,000**	**6,554,000**	**673,419,000**	**22,571,000**	**11,506,000**	**(11,065,000)**	**0.5**
BH2: Martin State Airport West Bulkhead	34,900,000	260,000	35,160,000	349,000	35,509,000	1,190,000	18,000	(1,172,000)	0.0
BH3: Martin State Airport East Bulkhead	619,000	1,000	620,000	6,000	626,000	21,000	-	(21,000)	0.0
BH7: Patapsco North Seagirt Bulkhead	97,913,000	2,119,000	100,032,000	979,000	101,011,000	3,386,000	155,000	(3,231,000)	0.0
BH8: Patapsco North I-895 Tunnel Bulkhead	3,860,000	7,000	3,867,000	39,000	3,906,000	131,000	1,000	(130,000)	0.0
BH10: Inner Harbor Anchorage Marina Bulkhead	238,186,000	5,154,000	243,340,000	2,382,000	245,722,000	8,236,000	2,866,000	(5,370,000)	0.3
BH11: Inner Harbor Harborplace Bulkhead	117,675,000	2,546,000	120,221,000	1,177,000	121,398,000	4,069,000	1,754,000	(2,315,000)	0.4
BH12: Inner Harbor Ritz Carlton Bulkhead	24,704,000	184,000	24,888,000	247,000	25,135,000	842,000	22,000	(820,000)	0.0
BH13: Inner Harbor Harborview Bulkhead	4,930,000	9,000	4,939,000	49,000	4,988,000	167,000	2,000	(165,000)	0.0
BH15: Locust Point Museum of Industry Bulkhead	33,108,000	340,000	33,448,000	331,000	33,779,000	1,132,000	91,000	(1,041,000)	0.1
BH16: Locust Point American Sugar Bulkhead	10,698,000	50,000	10,748,000	107,000	10,855,000	364,000	141,000	(223,000)	0.4
BH17: Locust Point Fort McHenry Bulkhead	18,658,000	87,000	18,745,000	187,000	18,932,000	635,000	81,000	(554,000)	0.1
BH18: Locust Point I-95 Tunnel Facility Bulkhead	3,788,000	4,000	3,792,000	38,000	3,830,000	128,000	-	(128,000)	0.0
BH19: Locust Point I-95 Tunnel Bulkhead	27,502,000	282,000	27,784,000	275,000	28,059,000	940,000	3,775,000	2,835,000	4.0
BH24: Patapsco South I-895 Tunnel Bulkhead	18,441,000	147,000	18,588,000	184,000	18,772,000	629,000	2,541,000	1,912,000	4.0
BH25: Middle Branch Wheelabrator Incinerator Plant	14,016,000	65,000	14,081,000	140,000	14,221,000	477,000	-	(477,000)	0.0
MAs 1, 23 NS_50YR	1,948,000	42,000	1,990,000	19,000	2,009,000	67,000	18,000	(49,000)	0.3
Alt 7 - NS_50YR	**650,946,000**	**11,297,000**	**662,243,000**	**6,509,000**	**668,752,000**	**22,414,000**	**11,465,000**	**(10,949,000)**	**0.5**
BH2: Martin State Airport West Bulkhead	34,900,000	260,000	35,160,000	349,000	35,509,000	1,190,000	18,000	(1,172,000)	0.0
BH3: Martin State Airport East Bulkhead	619,000	1,000	620,000	6,000	626,000	21,000	-	(21,000)	0.0

Plan Alternatives	First Cost	IDC	Investment Cost	O&M	Total Cost	Average Annualized Cost	Average Annualized Benefits	Average Annualized Net Benefits	BCR
BH7: Patapsco North Seagirt Bulkhead	97,913,000	2,119,000	100,032,000	979,000	101,011,000	3,386,000	155,000	(3,231,000)	0.0
BH8: Patapsco North I-895 Tunnel Bulkhead	3,860,000	7,000	3,867,000	39,000	3,906,000	131,000	1,000	(130,000)	0.0
BH10: Inner Harbor Anchorage Marina Bulkhead	238,186,000	5,154,000	243,340,000	2,382,000	245,722,000	8,236,000	2,866,000	(5,370,000)	0.3
BH11: Inner Harbor Harborplace Bulkhead	117,675,000	2,546,000	120,221,000	1,177,000	121,398,000	4,069,000	1,754,000	(2,315,000)	0.4
BH12: Inner Harbor Ritz Carlton Bulkhead	24,704,000	184,000	24,888,000	247,000	25,135,000	842,000	22,000	(820,000)	0.0
BH13: Inner Harbor Harborview Bulkhead	4,930,000	9,000	4,939,000	49,000	4,988,000	167,000	2,000	(165,000)	0.0
BH15: Locust Point Museum of Industry Bulkhead	33,108,000	340,000	33,448,000	331,000	33,779,000	1,132,000	91,000	(1,041,000)	0.1
BH16: Locust Point American Sugar Bulkhead	10,698,000	50,000	10,748,000	107,000	10,855,000	364,000	141,000	(223,000)	0.4
BH17: Locust Point Fort McHenry Bulkhead	18,658,000	87,000	18,745,000	187,000	18,932,000	635,000	81,000	(554,000)	0.1
BH18: Locust Point I-95 Tunnel Facility Bulkhead	3,788,000	4,000	3,792,000	38,000	3,830,000	128,000	-	(128,000)	0.0
BH19: Locust Point I-95 Tunnel Bulkhead	27,502,000	282,000	27,784,000	275,000	28,059,000	940,000	3,775,000	2,835,000	4.0
BH24: Patapsco South I-895 Tunnel Bulkhead	18,441,000	147,000	18,588,000	184,000	18,772,000	629,000	2,541,000	1,912,000	4.0
BH25: Middle Branch Wheelabrator Incinerator Plant	14,016,000	65,000	14,081,000	140,000	14,221,000	477,000	-	(477,000)	0.0
MAs 1, 23 NS_20YR	557,000	6,000	563,000	6,000	569,000	19,000	-	(19,000)	0.0
Alt 7 - NS_20YR	**649,555,000**	**11,261,000**	**660,816,000**	**6,496,000**	**667,312,000**	**22,366,000**	**11,447,000**	**(10,919,000)**	**0.5**

8.4 RECOMMENDED NATIONAL ECONOMIC DEVELOPMENT PLAN

In this section, the tentatively selected plan is based on NED benefits. Since NED Plan only should not be the only factor in selection of the TSP further, the four accounts will be compared in the selection of the final 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 damages 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….*

The project delivery team evaluated the optimization of plans and came out with the combination of the plans based on the net benefits. Net benefits are positive in MAs 19, and 24 where Harbor Tunnel's I-895 in Patapsco South MA 24 and Ft. McHenry Tunnel's I-95 in Locus Point MA 19 are located. These two tunnels have their support facilities respectively in Patapsco North MA 8 and in Locus Point MA 18. Tunnels and their facilities are one entity. In additional, nonstructural alternatives MA 9 NS_20YR, MA 10 NS_20YR, MA 11 _NS50YR, MA 12 NS_50YR, MA 14 NS_100YR and MA 15 NS20YR were included in the selected plan because either their net benefits are positive or are near positive. Nonstructural measure will be further reevaluated based on geographical neighborhood with refined costs. The structural plans MA 8, MA 18, MA 19, MA 24, and the nonstructural plans MA 9 NS_20YR, MA 10 NS_20YR, MA 11 _NS50YR, MA 12 NS_50YR, MA 14 NS_100YR, MA 15 NS20YR are not separable elements and constitute Alt 5a, which was identified as the NED Plan. Table 33 is the summary of NED Plan

Table 33: Alt-5a NED Plan

NED Plan	First Cost	IDC	Investment Cost	O&M	Total Cost	Average Annual Cost	Average Annual Benefits	Average Annual Net Benefits	BCR
BH8: Patapsco North I-895 Tunnel Bulkhead	3860000	7000	3867000	39000	3906000	131000	1000	(130000)	0.0
BH18: Locust Point I-95 Tunnel Facility Bulkhead	3788000	4000	3792000	38000	3830000	128000	0	(128000)	0.0
BH19: Locust Point I-95 Tunnel Bulkhead	27502000	282000	27784000	275000	28059000	940000	3775000	2835000	4.0
BH24: Patapsco South I-895 Tunnel Bulkhead	18441000	147000	18588000	184000	18772000	629000	2541000	1912000	4.0
MA9: Inner Harbor_NS20YR	11131000	114000	11245000	111000	11356000	381000	241000	(140000)	0.6
MA10: Inner Harbor Anchorage Marina_NS20YR	54818000	563000	55381000	548000	55929000	1875000	1025000	(850000)	0.5
MA11: Inner Harbor Harborplace_NS50YR	8070000	175000	8245000	81000	8326000	279000	845000	566000	3.0
MA12: Inner Harbor Ritz Carlton_NS50YR	557000	12000	569000	6000	575000	19000	11000	(8000)	0.6
MA14: Locust Point_NS100YR	5565000	185000	5750000	56000	5806000	195000	575000	380000	2.9
MA15: Locust Point Museum of Industry_NS20YR	1391000	14000	1405000	14000	1419000	48000	40000	(8000)	0.8
Alt 5a	135,123,000	1,503,000	136,626,000	1,352,000	137,978,000	4,625,000	9,054,000	4,429,000	2.0

8.5 ECONOMIC RISK ANALYSIS

The values of benefits displayed in tables above, have uncertainties associated with them. There are uncertainties in G2CRM inputs used and in the model by itself. Risk-informed planning should incorporate transparency in the estimation of benefits according to ER 1105-2-101, Planning, Risk Assessment For Flood Risk Management Studies dated on 15 July 2019. ER stated in section 8 Policy and Required Procedures (d.):

> *The estimate of net NED benefits and benefit/cost ratio will be reported both as an expected (mean) value and on a probabilistic basis for each alternative. The probability that net benefits are positive and that the benefit/cost ratio is at or above one (1.0) will be presented for each alternative.*

The probability distributions for the expected mean annual damage for the without project condition and the future with project condition for each alternative will be provided to aid decision makers such as local sponsor, stakeholders, and federal officials to increase their understanding of the uncertainty inherent in each alternative and to determine ways to address residual risks and increase specific and overall resilience.

9. OTHER SOCIAL EFFECTS

The other social effects (OSE) account lays out economics and cultural aspects of different groups when evaluating the dynamics of social interaction in the Baltimore Metropolitan study area. Studies revealed that vulnerable groups and families living in poverty were less resilient when a natural disaster occurs. In order to formulate and mitigate for these issues urban and community life loss, health and safety were examinate in the Baltimore Metropolitan urban and community.

9.1 LIFE LOSS

To identify risk to life safety, each alterative was evaluated for potential life loss calculations. G2CRM is capable of modeling life loss using a simplified life loss methodology (reference to EVACUATION PLANNING ZONES section 4.5 of the Appendix). Since there is uncertainty in modeling life loss, the future without project condition was modeled to serve as a baseline. 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. Table 34 presents the mean life loss estimates for each alternative in the study area over a 50-year period of analysis.

As part of the OSE analysis, it was important to learn the risk to the individuals impacted during a flood event. In addition, vulnerable populations such as the elderly were considered. Therefore, during the G2CRM modeling the vertical evacuation of vulnerable groups was considered. Life loss calculations are separated out by two ages. One category is people under 65 years and the second category is people over 65. There are three possible lethality functions for structure residents: safe, compromised, and chance. Safe would have the lowest expected life loss, although safe does not imply that there is no life loss. Chance would have the highest expected life loss.

Each type of structure has an associated storm surge lethality. The surge over the foundation height is the minimum for a lethality zone (safe, compromised, chance). These surges over foundation heights are age-specific. There is one surge height for under 65 years and another surge height for people aged 65 years and older.

The model cycles through every active structure during each storm. For each structure, the model defaults the lethality function to safe and check for the maximum lethality function such that the modeled area stage is greater than the sum of the first flood elevation of the structure and the lethality function's surge above the foundation. This will be checked separately for under and over 65, as these two age groups can have different lethality functions depending on the age-specific surge above foundation for that occupancy type.

Uncertainty is factorized in the life loss modeling. The results of the modeling should be viewed as more qualitative as opposed to a quantitative assessment of life loss even though the results are stated in numerical values. This result should be used in terms of order of magnitude compared to the baseline, No Action or the FWOP and when comparing the alternatives between each other.

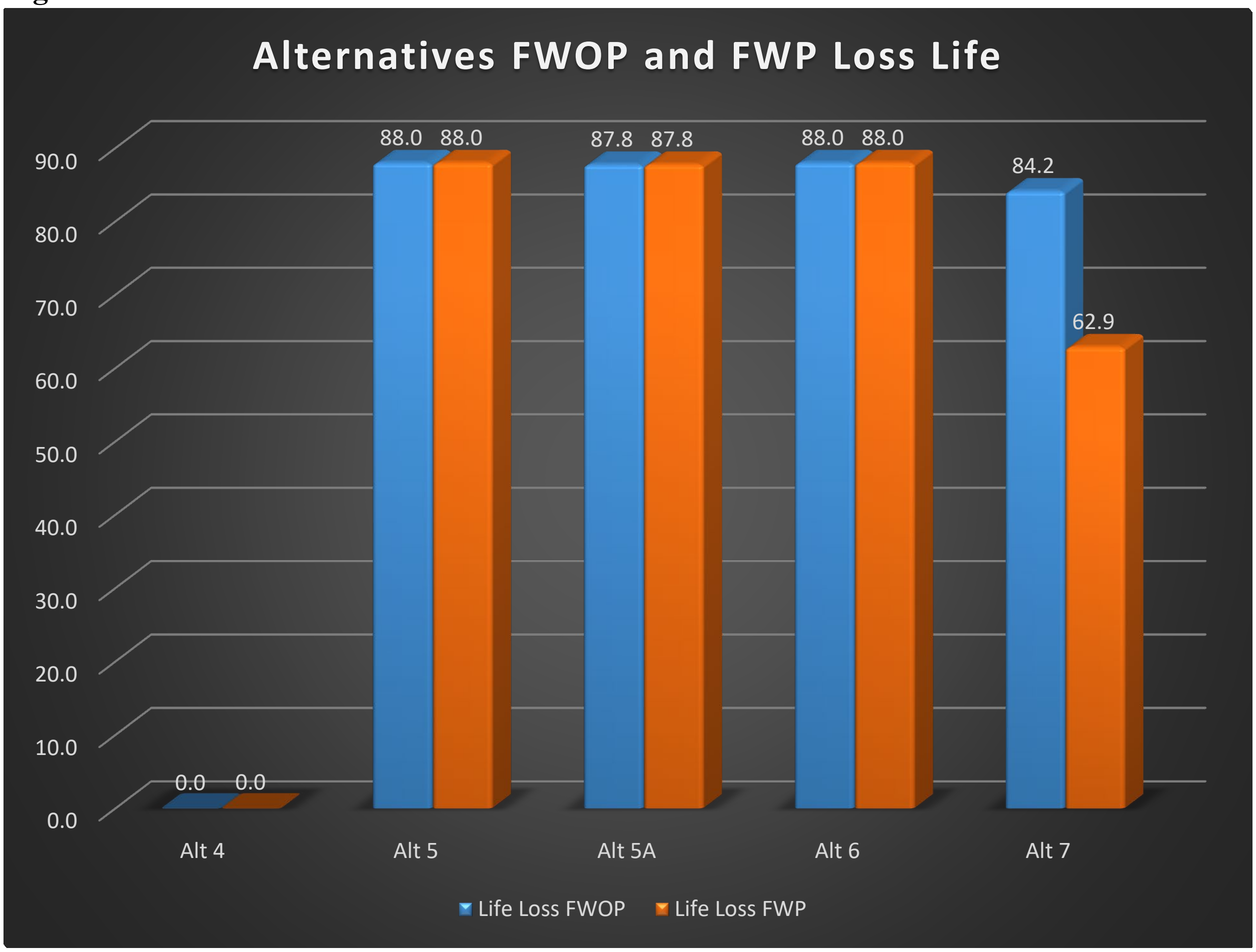
As shown in Table 34, the implementation of project in each alternative would lower or show no increase in the overall life safety risk in the Baltimore Metropolitan study area when compared to the future without project condition.

Table 34: Alternatives Life Loss

Alternative		**Life Loss**		
		Under 65	**Over 65**	**Total**
Alt 4	No Action	0.0	0.0	0.0
	Project	0.0	0.0	0.0
	Incremental Life Loss	0.0	0.0	0.0
Alt 5	No Action	5.3	82.7	88.0
	Project	5.3	82.7	88.0
	Incremental Life Loss	0.0	0.0	0.0
Alt 5a	No Action	5.3	82.5	87.8
	Project	5.3	82.5	87.8
	Incremental Life Loss	0.0	0.0	0.0
Alt 6	No Action	5.3	82.7	88.0
	Project	5.3	82.7	88.0
	Incremental Life Loss	0.0	0.0	0.0
Alt 7	No Action	5.3	78.9	84.2
	Project	4.6	58.3	62.9
	Incremental Life Loss	-0.7	-20.6	-21.3

A population of 89,066 was modeled in the structure inventory. It has been evaluated an annualized percent life loss of 0.0034% will occur without project conditions. Comparative analysis of the FWP group resulted in a reduction of 0.001% loss of life when compared to the FWOP. Loss of life is found in Inner Harbor (MA 9, 10, 11, 12, and 13). Below graph shows a summary of life loss statistics in Baltimore Metropolitan study area.

Figure 21: FWOP and FWP Life Loss Statistics



9.2 HEALTH AND SAFETY

The health and safety of people living in the community within the project area were considered with the project condition in each alternative. Structural and nonstructural measures would protect the health and safety of residents from the direct impact of coastal storms by keeping flood waters away from property and eliminating future damages. Preliminary costs and benefits for providing flood risk management measures for critical infrastructure and other structures were developed for each alternative as part of this study. According to the Census Bureau data the Baltimore Metropolitan area has a high disability population under 65 years, higher African-American population. The per capita income is low in average, but the project will be implemented in areas where the major of the population are not considered as low income.

EJ Screen tool shows high population over 64 years in inner harbor and a concern of environmental justice in Westport neighborhoods in MA 20 where no plans have been proposed. But most of the structures are on high ground. Inundated unoccupied lands are slated for redevelopment and should be constructed with FEMA flood protection requirements. Similarly, the Cherry Hill neighborhood also in MA 20 may show up as an impacted EJ community, but areas impacted are a public park that is separated from the community by a road and a steep hill. The proposed NED Plan will enhance job opportunities in Brooklyn MA 20 and Curtis Bay MA 22 communities since it will maintain close transportation across Harbor to marine terminals, warehouses, and heavy industries.

The PDT will continue to investigate the inclusion of critical infrastructure protection and the nonstructural measures in the communities that would most likely need additional support before, during, and after coastal flooding events. These vulnerable areas will be proposed in the recommended plan.

10. *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 associated with the project alternatives

10.1 RECONS METHODOLOGY

The current certified RECONS 2.0 model was used to develop Northern Virginia Regional Economic Development (RED). The RED effects of each alternative will be examinate. The total cost for each alternative was used to input into the RECONS model.

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 spend on clothing, groceries, dining out, and other items in the regional area are secondary or induced effects.

10.2 RECONS RESULTS

Of the total expenditures, 99 percent will be captured within the local study area. The remainder of the expenditures will be captured within the state or national level. 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 below tables for each alternative. Nonstructural alternatives with 1%, 2% and 5% risk reductions were combined with structural alternatives. Hence, for Alt 4 three sub-alternatives Alt 4 NS_100, Alt 4 NS50YR, and Alt 4 NS_20YR were developed. Among these three sub-alternatives, Alt 4 NS_100 has the highest costs and Alt 4 NS_20 has the lowest costs. The Regional Economic Development summary have been presented using the minimum and the maximum costs for each alternative for simplicity.

Table 35: RECONS - Alt 4 -Min Cost $62,667,000

Area	Local Capture	Output	Jobs*	Labor Income	Value Added
Local					
Direct Impact		$58,522,000	341	$45,472,000	$49,685,000
Secondary Impact		$52,203,000	273	$18,488,000	$32,276,000
Total Impact	$58,522,000	$110,725,000	613	$63,960,000	$81,961,000
State					
Direct Impact		$58,522,000	354	$45,472,000	$49,685,000
Secondary Impact		$52,397,000	273	$18,588,000	$32,392,000
Total Impact	$58,522,000	$110,919,000	628	$64,060,000	$82,077,000
US					
Direct Impact		$59,068,000	419	$49,090,000	$49,976,000
Secondary Impact		$100,038,000	481	$32,850,000	$56,239,000
Total Impact	$59,068,000	$159,106,000	900	$81,940,000	$106,215,000

Table 36: RECONS - Alt 4 -Max Cost $69,029,000

Area	Local Capture	Output	Jobs*	Labor Income	Value Added
Local					
Direct Impact		$68,287,000	377	$53,059,000	$57,976,000

Secondary Impact		$60,914,000	302	$21,573,000	$37,661,000
Total Impact	$68,287,000	$129,201,000	679	$74,632,000	$95,637,000
State					
Direct Impact		$68,287,000	392	$53,059,000	$57,976,000
Secondary Impact		$61,140,000	303	$21,689,000	$37,797,000
Total Impact	$68,287,000	$129,427,000	695	$74,748,000	$95,773,000
US					
Direct Impact		$68,924,000	465	$57,281,000	$58,315,000
Secondary Impact		$116,730,000	533	$38,331,000	$65,623,000
Total Impact	$68,924,000	$185,654,000	997	$95,612,000	$123,938,000

Table 37: RECONS - Alt 5 -Min Cost $162,898,000

Area	Local Capture	Output	Jobs*	Labor Income	Value Added
Local					
Direct Impact		$161,147,000	890	$125,212,000	$136,814,000
Secondary Impact		$143,747,000	712	$50,908,000	$88,875,000
Total Impact	$161,147,000	$304,894,000	1,602.2	$176,120,000	$225,689,000
State					
Direct Impact		$161,147,000	926	$125,212,000	$136,814,000
Secondary Impact		$144,280,000	714	$51,184,000	$89,196,000
Total Impact	$161,147,000	$305,427,000	1,639.9	$176,396,000	$226,010,000
US					
Direct Impact		$162,651,000	1,096.2	$135,175,000	$137,615,000
Secondary Impact		$275,466,000	1,257.4	$90,455,000	$154,860,000
Total Impact	$162,651,000	$438,117,000	2,353.5	$225,630,000	$292,475,000

Table 38: RECONS - Alt 5 -Max Cost $411,320,000

Area	Local Capture	Output	Jobs*	Labor Income	Value Added
Local					
Direct Impact		$406,897,000	2,247.2	$316,162,000	$345,458,000
Secondary Impact		$362,964,000	1,798.4	$128,544,000	$224,410,000
Total Impact	$406,897,000	$769,861,000	4,045.6	$444,706,000	$569,868,000
State					
Direct Impact		$406,897,000	2,337.6	$316,162,000	$345,458,000
Secondary Impact		$364,309,000	1,803.1	$129,240,000	$225,221,000
Total Impact	$406,897,000	$771,206,000	4,140.7	$445,402,000	$570,679,000
US					
Direct Impact		$410,697,000	2,767.8	$341,319,000	$347,480,000
Secondary Impact		$695,556,000	3,174.9	$228,401,000	$391,023,000

Total Impact	$410,697,000	$1,106,253,000	5,942.7	$569,720,000	$738,503,000

Table 39: RECONS - Alt 5A - Cost $137,978,000					
Area	**Local Capture**	**Output**	**Jobs***	**Labor Income**	**Value Added**
Local					
Direct Impact		$136,504,000	754	$106,065,000	$115,893,000
Secondary Impact		$121,766,000	603	$43,123,000	$75,284,000
Total Impact	$136,504,000	$258,270,000	1357	$149,188,000	$191,177,000
State					
Direct Impact		$136,504,000	784	$106,065,000	$115,893,000
Secondary Impact		$122,217,000	605	$43,357,000	$75,556,000
Total Impact	$136,504,000	$258,721,000	1389	$149,422,000	$191,449,000
US					
Direct Impact		$137,779,000	929	$114,504,000	$116,571,000
Secondary Impact		$233,342,000	1065	$76,623,000	$131,179,000
Total Impact	$137,779,000	$371,121,000	1994	$191,127,000	$247,750,000

Table 40: RECONS - Alt 6 -Min Cost $263,909,000					
Area	**Local Capture**	**Output**	**Jobs***	**Labor Income**	**Value Added**
Local					
Direct Impact		$261,071,000	1442	$202,854,000	$221,651,000
Secondary Impact		$232,883,000	1154	$82,476,000	$143,985,000
Total Impact	$261,071,000	$493,954,000	2596	$285,330,000	$365,636,000
State					
Direct Impact		$261,071,000	1500	$202,854,000	$221,651,000
Secondary Impact		$233,746,000	1157	$82,922,000	$144,505,000
Total Impact	$261,071,000	$494,817,000	2657	$285,776,000	$366,156,000
US					
Direct Impact		$263,509,000	1776	$218,995,000	$222,948,000
Secondary Impact		$446,279,000	2037	$146,546,000	$250,886,000
Total Impact	$263,509,000	$709,788,000	3813	$365,541,000	$473,834,000

Table 41: RECONS - Alt 6 -Max Cost $512,331,000					
Area	**Local Capture**	**Output**	**Jobs***	**Labor Income**	**Value Added**
Local					
Direct Impact		$506,822,000	2799	$393,804,000	$430,295,000
Secondary Impact		$452,100,000	2240	$160,112,000	$279,520,000

Total Impact	$506,822,000	$958,922,000	5039	$553,916,000	$709,815,000
State					
Direct Impact		$506,822,000	2912	$393,804,000	$430,295,000
Secondary Impact		$453,775,000	2246	$160,979,000	$280,530,000
Total Impact	$506,822,000	$960,597,000	5158	$554,783,000	$710,825,000
US					
Direct Impact		$511,555,000	3448	$425,140,000	$432,814,000
Secondary Impact		$866,369,000	3955	$284,492,000	$487,050,000
Total Impact	$511,555,000	$1,377,924,000	7402	$709,632,000	$919,864,000

Table 42: RECONS - Alt 7 -Min Cost $673,419,000

Area	Local Capture	Output	Jobs*	Labor Income	Value Added
Local					
Direct Impact		$666,178,000	3679	$517,625,000	$565,590,000
Secondary Impact		$594,250,000	2944	$210,454,000	$367,407,000
Total Impact	$666,178,000	$1,260,428,000	6624	$728,079,000	$932,997,000
State					
Direct Impact		$666,178,000	3827	$517,625,000	$565,590,000
Secondary Impact		$596,452,000	2952	$211,594,000	$368,735,000
Total Impact	$666,178,000	$1,262,630,000	6779	$729,219,000	$934,325,000
US					
Direct Impact		$672,399,000	4532	$558,813,000	$568,900,000
Secondary Impact		$1,138,775,000	5198	$373,942,000	$640,189,000
Total Impact	$672,399,000	$1,811,174,000	9729	$932,755,000	$1,209,089,000

Table 43: RECONS - Alt 7 -Max Cost $667,312,000

Area	Local Capture	Output	Jobs*	Labor Income	Value Added
Local					
Direct Impact		$660,137,000	3646	$512,931,000	$560,460,000
Secondary Impact		$588,861,000	2918	$208,546,000	$364,075,000
Total Impact	$660,137,000	$1,248,998,000	6563	$721,477,000	$924,535,000
State					
Direct Impact		$660,137,000	3792	$512,931,000	$560,460,000
Secondary Impact		$591,043,000	2925	$209,675,000	$365,391,000
Total Impact	$660,137,000	$1,251,180,000	6718	$722,606,000	$925,851,000
US					
Direct Impact		$666,301,000	4490	$553,745,000	$563,741,000
Secondary Impact		$1,128,448,000	5151	$370,551,000	$634,383,000
Total Impact	$666,301,000	$1,794,749,000	9641	$924,296,000	$1,198,124,000

In summary, the construction stimulus in the Baltimore Metropolitan area would generate for each alternative full-time equivalent jobs, labor income, and output in the local, State and the whole Country as shown in above tables.

11. ENVIRONMENTAL QUALITY

Wetland information and Geographic Information System Mapping (GIS) data were collected from various sources for identification of wetland areas within the study areas. USGS topographic quadrangles, U.S. Department of Agriculture (USDA) web soil surveys, Federal Emergency Management Agency floodplain mapping, and U.S. Fish and Wildlife Service's (USFWS) National Wetland Inventory (NWI) were used to access submerged aquatic vegetation, soil types, historical resources, archeological sites, environmental justice community, and aesthetics were examined in the classification of alternatives. The environmental quality (EQ) account used qualitative assessment consistent with ecosystem environmental compliance guidance to assesses the impact of floodwall, levee, and nonstructural measures in the Baltimore Metropolitan study area. The analysis does not include any quantitative EQ benefits. More information can be found in the EA and the Main Reports.

12. COMPARISON OF FOUR ACCOUNTS

In Section 6 of this economic analysis, the NED was developed using G2CRM. Alt 5a has positive net benefits. Detailed costs and benefits were presented but for the simplicity of the comparison the average annual net benefits will be used in this section.

The OSE was estimated in Section 9 using G2CRM model. Each structure has an associated storm surge lethality. The vulnerable group, the elderly over 65 years old was considered separately from the population under 65 years old to assess life loss risk to the individuals impacted during a flood event.

The RED was analyzed in Section 10 of the economic appendix using RECONS model. The expenditures in each alternative were used to capture the direct and indirect impacts within the local, the state or national level. Since RECONS uses the expenditures in the study area to forecast future jobs and value added to the economy, the higher the cost of the project the higher are jobs and value added to the economy. The 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 for each alternative.

The (EQ) account assessed the impact of project on species, historical resources, proximity of project to wildlife, and air quality in the study area. In accordance with ecosystem and environmental compliance guidance the alternatives were compared using qualitative ranking scale.

Table 44 presents the comparative summary of the four accounts as required by the 5 January 2021 Policy Directive (Policy Directive) from the Assistant Secretary of the Army for Civil Works (ASA(CW)) in Comprehensive Documentation of Benefits in Decision Document.

Table 44: Summary of the four P&G Accounts

PLAN SUMMARY			Alt 4			Alt 5			Alt 5A			Alt 6			Alt 7		
Description			Critical Infrastructure			Critical Infrastructure with NS Plan			Critical Infrastructure with Select NS Plan			Critical Balanced			Mid-Tier		
Total Project Costs			$62.7M-$69.0M			$1162.9M-$411.3M			$138.0M			$263.9M-$512.3M			$667.3M-$673.4M		
Comprehensive Benefits			High net benefits, low community resilience.			High net benefits at 5% AEP while maintaining historic neighborhood character, access to water, and community resilience.			Maximizes net benefits while maintaining historic neighborhood character, access to water, and community resilience.			Lower net benefits with negative benefits at Seagirt Marine Terminal. Similar EQ and OSE benefits to Alt 5.			Negative net benefits. Detrimental community and visual impacts.		
National Economic Development (NED)	Net Benefits		$122.9M-$127.5M			$-99.0M-$93.9M			$132.1M			$-2.5M-$195.4M			$-325.8M-$-330.1M		
Regional Economic Development (RED)	Local-US Jobs		900-997			2,354-5,943			1,994			3,813-7,402			9729-9,641		
	Local-US Outputs		$159.1M-$185.7M			$438.1M-$1,106.2M			$371.1M			$709.8M-$1,377.9M			$1,811.2M-$1,794.7M		
	Employment Income		$81.9M-$95.6M			$292.5M-$738.5M			$192.1M			$365.5M-$709.6M			$932.8-$924.3M		
Environmental Quality (EQ)			▲Increased community resilience; No significant impacts. Minor wetland buffer impacts.														
Other Social Effects (OSE)	Life Loss		**Under 65**	**Over 65**	**Total**	**Under 65**	**Over 65**	**Total**	**Under 65**	**Over 65**	**Total**	**Under 65**	**Over 65**	**Total**	**Under 65**	**Over 65**	**Total**
		No Action	**0.0**	**0.0**	**0.0**	**5.3**	**82.7**	**88.0**	**5.3**	**82.5**	**87.8**	**5.3**	**82.7**	**88.0**	**5.3**	**78.9**	**84.2**
		Project	**0.0**	**0.0**	**0.0**	**5.3**	**82.7**	**88.0**	**5.3**	**82.5**	**87.8**	**5.3**	**82.7**	**88.0**	**4.6**	**58.3**	**62.9**
		Incremental	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**-0.7**	**-20.6**	**-21.3**
	Social Vulnerability and Resilience					▲Maintain historical character and cultural identity.											**▼Long term negative impacts to aesthetics and water access. Block roads during deployment.**
	Economic Vitality		▲ Ensure connectivity between communities and access to jobs.														

13. TENTATIVELY SELECTED PLAN

The project delivery team evaluated the optimization of plans. As a result of the comparison of the alternatives in the four accounts, the effects of OSE, and EQ accounts were insignificant. Since RECONS uses expenditures to forecast future jobs and value added to the economy, the higher the cost the higher are jobs and value added to the economy. Hence, RED should not be a driving factor in selection of the TSP. Alt 5a, which is the combination Proposed Floodwalls around Harbor Tunnel's I-895 and Ft. McHenry Tunnel's I-95, and nonstructural solutions in inner harbor and Locus Point has positive net benefits. Alt 5a benefits were greater than the cost. It is identified as the NED Plan and has been recommended to be the TSP. These two tunnels have their support facilities respectively in Patapsco North MA 8 and in Locus Point MA 18. Tunnels and their facilities are one entity. In additional, nonstructural alternatives MA 9 NS_20YR, MA 10 NS_20YR, MA 11 NS_50YR, MA 12 NS_50YR, MA 14 NS_100YR and MA 15 NS_20YR were included in the selected plan because either their net benefits are positive or are near positive. Nonstructural measure will be further reevaluated based on geographical neighborhood with refined costs.