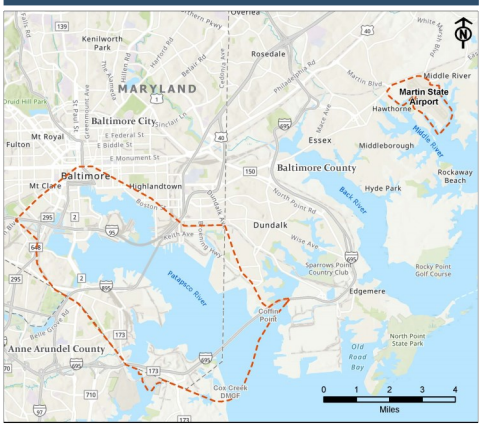
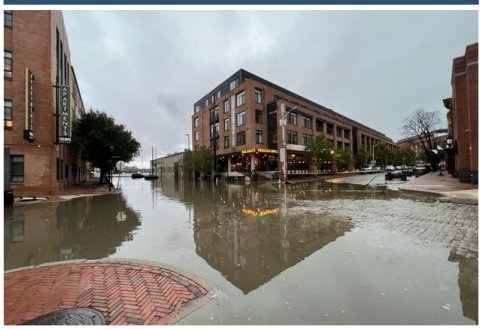
US Army Corps of Engineers®

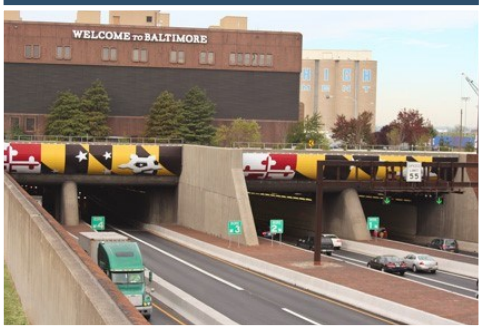
Baltimore Metropolitan Coastal Storm Risk Management Feasibility Study

Draft Integrated Feasibility Report & Environmental Assessment

JULY 2022







Baltimore Coastal Storm Risk Management

Feasibility Study

Draft Integrated Feasibility Report and Environmental Assessment

July 2022

MARYLAND DEPARTMENT OF TRANSPORTATION

US Army Corps of Engineers
Baltimore District
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410-962-3511

Front cover: Study area map and flooding in Baltimore City (credit: USACE). Fort McHenry Tunnel entrance (photo credit: Maryland Transportation Authority).

Back cover: Baltimore Inner Harbor, flooding in Baltimore City (photo credit: USACE).

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EXECUTIVE SUMMARY

This Draft Integrated Feasibility Report and Environmental Assessment (IFR/EA) documents the U.S. Army Corps of Engineers (USACE) feasibility study planning process for the Baltimore Coastal Storm Risk Management Feasibility Study (Baltimore Coastal Study) and compliance with the National Environmental Policy Act (NEPA) and other environmental laws as integrated into the planning process.

Following Hurricane Sandy in 2012, the USACE completed the North Atlantic Coast Comprehensive Study (NACCS), which identified nine high-risk areas on the Atlantic Coast that warranted further investigation of coastal storm risk management (CSRM) solutions. The Baltimore Metropolitan area, which includes the City of Baltimore, Baltimore County, and Anne Arundel County, was identified as one of the nine high-risk areas recommended by NACCS for a follow-on feasibility study to investigate solutions to coastal flooding problems.

The North Atlantic Coast is vulnerable to the impacts of coastal flooding and the potential for future, more devastating events due to rising sea levels. The Metropolitan Baltimore region supports densely populated areas encompassing trillions of dollars of largely fixed public, private, and commercial investment. Coastal communities in this region must begin to consider long-term coastal storm risk.

The Baltimore Coastal Study Feasibility Cost Share Agreement (FCSA) was signed by USACE and the Maryland Department of Transportation (MDOT) on August 5, 2019. MDOT is the non-federal sponsor for the Baltimore Coastal Study.

The study authority is under the Baltimore Metropolitan Water Resources authority, which was adopted by a resolution of the Committee on Public Works and Transportation of the United States House of Representatives on April 30, 1992. This study authority was identified by the Baltimore District Office of Counsel (in a memorandum dated April 22, 2014) 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. Although the study authority also identifies other purposes, this study will focus solely on CSRM. This draft IFR/EA will culminate in a Chief's Report on March 27, 2024, as an interim response to the authority.

The purpose of the study is to evaluate the feasibility of federal participation in implementing solutions to problems and opportunities associated with coastal storm damage to reduce coastal flood risk, risk to vulnerable populations, properties, infrastructure, and environmental and cultural resources along the banks of the Patapsco River in the vicinity of Baltimore City including northern Anne Arundel County and eastern Baltimore County, Maryland and Martin State Airport (MSA) in Baltimore County, Maryland. Coastal storms have produced extensive property damage and loss of life resulting from storm surge and flooding in the recent past, particularly from Hurricane

Isabel in 2003, which resulted in costs of $4.8 million to the City of Baltimore, up to $252 million in total damages in Southern Baltimore County, and one fatality.

The study area encompasses the portion of the City of Baltimore and surrounding metropolitan areas to 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 E-1). The study area was defined to also include assets of importance to MDOT, including MSA in Baltimore County. Within the study area, Baltimore City contains approximately 69 miles of Patapsco River shoreline. The Baltimore County study area contains approximately 4 miles of shoreline along Martin State Airport. The study area is located in a densely populated urban setting with residential/mixed-use neighborhoods in areas further inland along Inner Harbor, and industrial facilities primarily serving the Port of Baltimore and associated facilities in the City of Baltimore. Notable historic resources include the Fells Point, Canton, Federal Hill, and Locust Point Historic Districts, the Baltimore Municipal Airport Harbor Field, the Baltimore Municipal Airport Air Station, the Western Electric Company/Point Breeze Historic District, the Canton Grain Elevator, and the Fort McHenry National Monument and Historic Shrine (Fort McHenry). Important cultural resources include the Star-Spangled Banner National Historic Trail and the Captain John Smith Chesapeake National Historic Trail.

The Baltimore Coastal study area has experienced an increase in the number of days of minor tidal flooding over time, which will be exacerbated with rising sea levels.

The USACE low, intermediate, and high SLC scenarios were evaluated for the without and with-project condition, and with respect to determining tipping points/thresholds for impacts over the 50-year period of analysis and 100-year adaptation timeframe, and at multiple storm frequencies.

The historic relative sea level rise (SLR) trend is 0.01 feet/year based on the record for the National Oceanic and Atmospheric Administration's (NOAA)'s Baltimore, MD NOAA gauge 8574680, which is closest to the study area. The period of analysis for this study is 50-years per Engineer Regulation (ER) 1105-2-100 Planning Guidance Notebook, April 22nd, 2000. The planning horizon starts in baseline year 2031, when the project is anticipated to begin accruing CSRM benefits, and ends in year 2080. Existing conditions reflect the conditions in place during the feasibility study through year 2024. Future without project (FWOP) conditions consider a range of activities from year 2021, the most recent year for which complete data was obtained, and projects that are planned to be implemented or are already underway that would be constructed in the absence of this project. Future with-project (FWP) conditions are the conditions forecasted during the planning horizon, from years 2031 to 2080, with implementation of the tentatively selected plan (TSP). The TSP will also be assessed for engineering and environmental performance out to 100 years from the baseline year, to ensure coastal sustainability of

the TSP and adaptation to SLR. The analysis is conducted using the fiscal year 2022 discount rate of 2.250 percent (October 2021 price level).

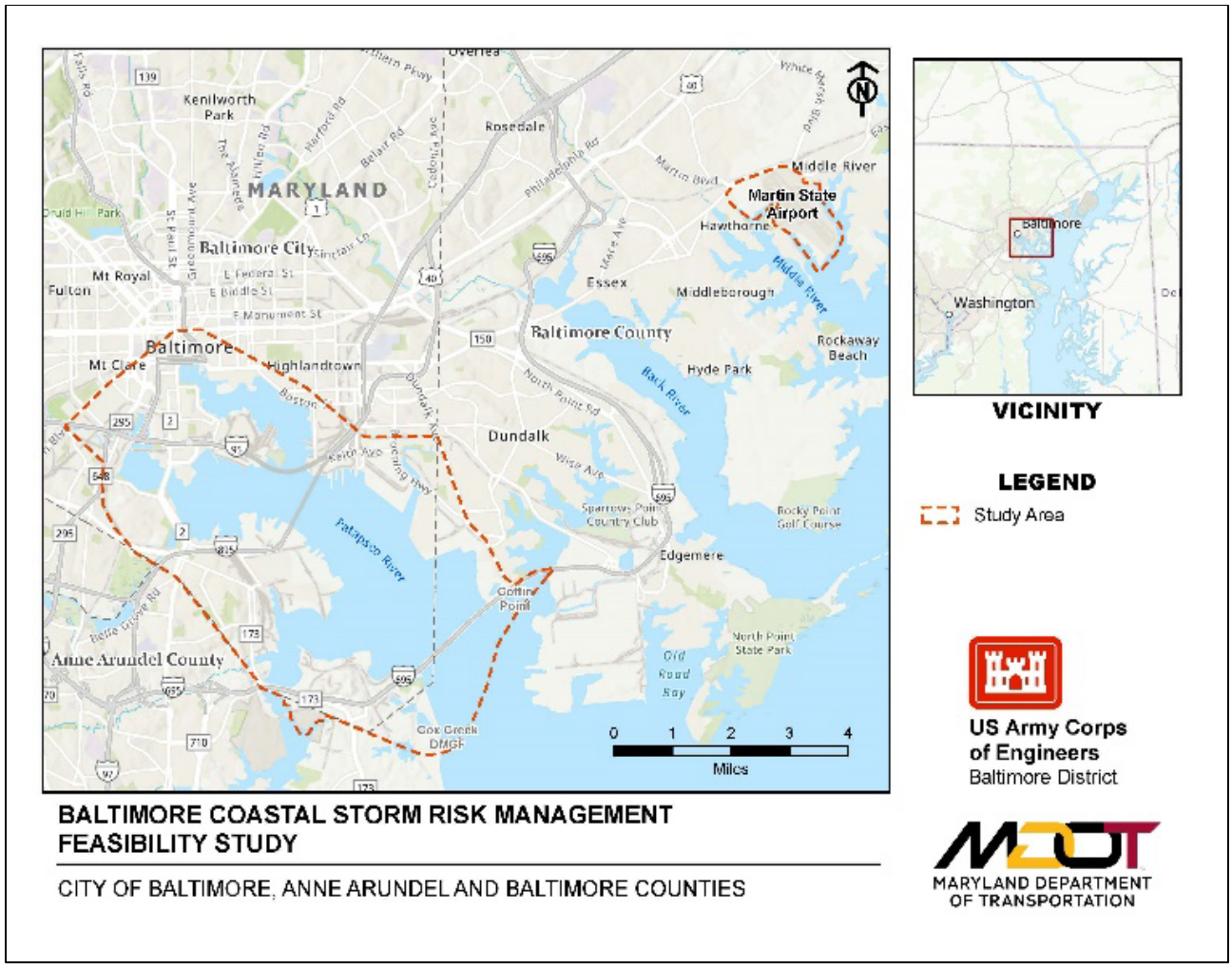

Figure E-1. Study Area

Plan formulation was conducted with a focus on achieving the federal objective of water and related land resources project planning, which is to contribute to National Economic Development (NED) consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable executive orders (EO), and other federal planning requirements. Plan formulation considers the four system of accounts: NED, Regional Economic Development (RED), Environmental Quality (EQ), and Other Social Effects (OSE). The plan formulation process focuses on establishing alternatives considering non-structural and structural measures initially and then adds natural and nature-based features (NNBF) to the final array of alternatives as design considerations that will enhance the performance and effectiveness of structural measures included in those alternatives.

The development and screening of measures and formulation of alternatives went through several iterations starting with an initial array of 10 alternatives in addition to the no action plan. These alternatives were screened to a final array of six alternatives including the no action alternatives and five action alternatives that propose structural and nonstructural measures to address CSRM impacts to critical infrastructure and mixed-use/residential areas within the study area. Of these five action alternatives, three resulted in positive net benefits; Alternative 4: Critical Infrastructure Plan, Alternative 5: Critical Infrastructure and Nonstructural Measures Plan, and Alternative 5A: Critical Infrastructure with Select Nonstructural Measures Plan. Alternative 5A: Critical Infrastructure with Select Nonstructural Measures Plan was identified as the NED Plan because it reasonably maximizes net benefits and is also identified as the plan that maximizes comprehensive benefits. Alternative 5A: Critical Infrastructure with Select Nonstructural Measures Plan is chosen as the TSP in this report. The TSP maintains historic neighborhood character, access to water, and enhances community resilience. The TSP has net annual benefits of $4,429,000 and a benefit-to-cost ratio (BCR) of 2.0. The total project cost for the TSP is approximately $138 million.

The TSP incorporates floodwalls and closure structures at the Interstate (I)-95 and I-895 Tunnels and supporting transportation critical facilities (the Fort McHenry and Harbor Tunnels ventilation buildings) as well as floodproofing (ranging from 1 to 5 percent Annual Exceedance Probability [AEP] design elevations) as nonstructural measures in the Baltimore City neighborhoods of Canton, Fells Point, Inner Harbor, Riverside, and Locust Point. Figure E-2 shows the location of the proposed structural measures and focus areas for nonstructural measures.

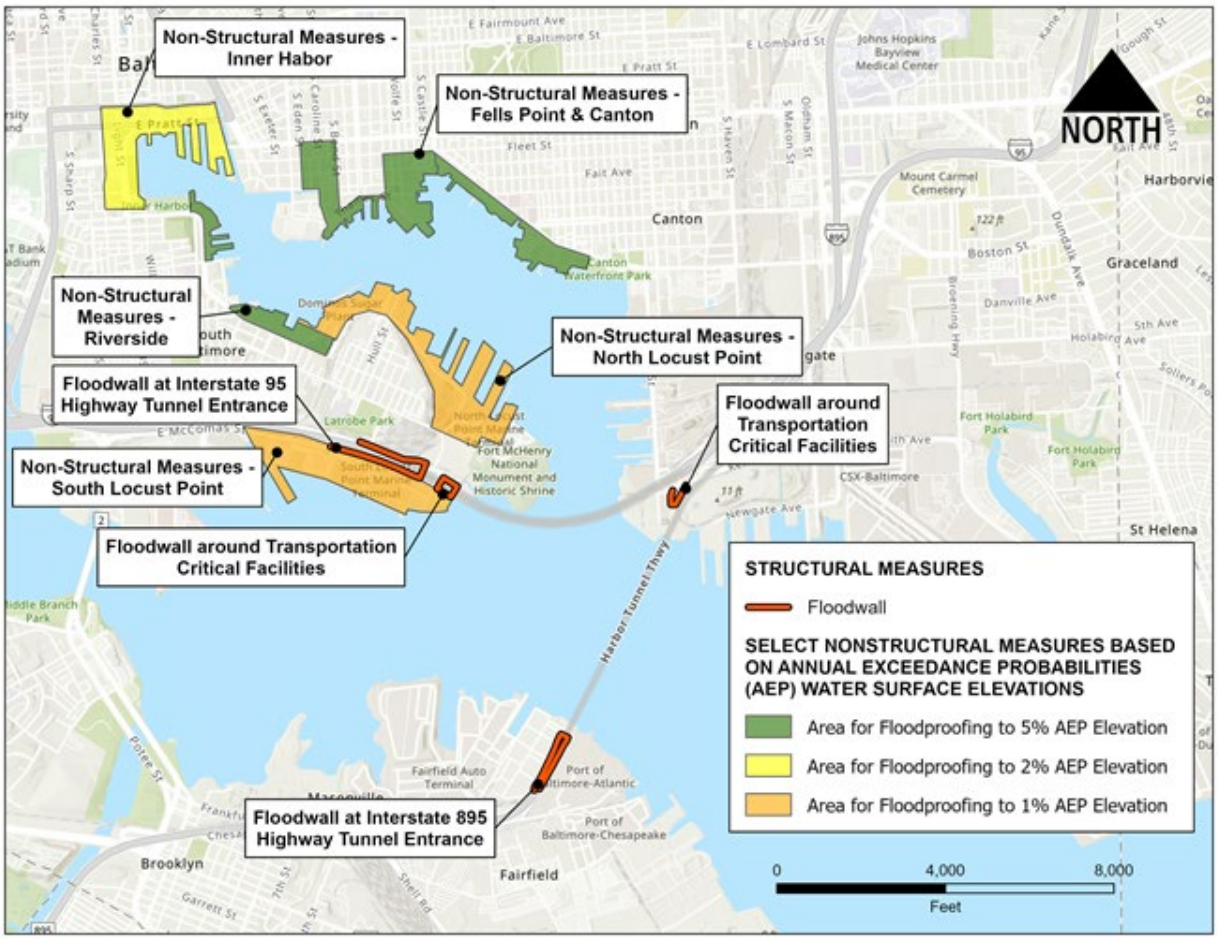

Figure E-2. Tentatively Select Plan – Alternative 5A Critical Infrastructure with Select Nonstructural Measures Plan

During the Pre-Construction Engineering and Design (PED) and construction phases, the project would be cost shared 65 percent federal and 35 percent non-federal. The project may have two separate non-federal sponsors during the PED and construction phases: one for the structural (floodwall) components and one for the nonstructural (floodproofing) components. The non-federal sponsor for the structural components is likely to be the Maryland Transportation Authority (MDTA), which is an authority under MDOT. The non-federal sponsor for the nonstructural components is yet to be determined.

Lands, easements, rights-of-way, and relocations (LERRs) required for project construction must be provided by the non-federal sponsor as part of the non-federal construction cost share amount. At this preliminary stage the lands and damages real estate cost estimate is approximately $15 million. These costs include acquisition administration costs, contingency, and estimated damages for both structural and nonstructural components of the TSP.

The annualized Operations and Maintenance (O&M) for the I-895 tunnel floodwall and associated transportation critical facility is estimated to be $7,000. The annualized O&M for the I-95 tunnel floodwall and the associated transportation critical facility floodwall is estimated to be $10,000. The concrete floodwalls at the tunnel entrances and support facilities would require minimal maintenance over the 50-year period of analysis. The stoplog structures would be deployed during flood events and would be operated and maintained in accordance with the O&M specifications. O&M on the floodwalls at the tunnel entrances and the tunnel support facilities would be managed by the MDTA. The annualized O&M for the nonstructural (floodproofing) components is approximately $27,000. The O&M for the nonstructural components would be managed by the project sponsor. Combining the O&M for the structural and the nonstructural components, the total O&M for Alternative 5A, the TSP, is $44,000 per year based on a 50-year period of analysis.

The structural components of the TSP have three project areas: I-95 Fort McHenry Tunnel in Locust Point, the I-895 Tunnel in Fairfield, and their associated transportation critical facilities. It is estimated that the construction duration at the I-95 Fort McHenry Tunnel in Locust Point would be 14 months. Duration of construction at the I-895 Tunnel in Fairfield would be 12 months. Construction at the associated transportation critical facilities would be approximately 6 months. There are no time-of-day restrictions, and the cost estimate assumes 12-hour days for all three areas. Materials would be brought in by land via by flatbed trucks, trailers, and dump trucks. The design phase for the structural components assumes two years to start in October 2024 and end in September 2026. The construction window for all areas would likely start in 2026 and end in 2027. Construction would occur concurrently.

The non-structural components of the TSP would require multiple steps during the real estate acquisition process. It is anticipated that the process to obtain necessary easements and agreements would be approximately 48 months. Design and construction phase schedules have not been determined for this draft report and would vary with participation rates, types of structure, and non-structural floodproofing measures utilized.

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Table of Contents

Table of Figures

List of Tables

List of Appendices

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Acronyms

ACHP	Advisory Council for Historic Preservation
ADM	Agency Decision Milestone
AEP	Annual Exceedance Probability
AGST	Above Ground Storage Tanks
AMM	Alternatives Milestone Meeting
APE	Area of Potential Effects
ASA(CW)	Assistant Secretary of the Army Civil Works
ASMFC	Atlantic States Marine Fisheries Commission
BCC	Birds of Conservation Concern
BCR	Benefit Cost Ratio
BGE	Baltimore Gas and Electric
BH	Bulkhead
BMP	Best Management Practices
C-STORM	Coastal Storm Modeling System
CAP	Continuing Authorities Program
CBP	Chesapeake Bay Program
CENAB	U.S. Army Corps of Engineers, Baltimore District
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CO_2	Carbon Dioxide
CSRM	Coastal Storm Risk Management
CSX	CSX Corporation
CSVR	Content-to-Structure Value Ratios
CZMA	Coastal Zone Management Act
CZMP	Coastal Zone Management Program
dBA	Decibel
DFE	Design Flood Elevation

DMCF	Dredged Material Containment Facility
DO	Dissolved Oxygen
DP3	Baltimore's Disaster Preparedness and Planning Project
DRV	Depreciated Replacement Value
EA	Environmental Assessment
EAD	Equivalent Annual Damages
ECB	Engineering Construction Bulletin
EDR	Environmental Data Resources
EFH	Essential Fish Habitat
EIP	Environment Integrity Project
EIS	Environmental Impact Statement
EJ	Environmental Justice
EO	Executive Order
EOP	U. S. Army Corps of Engineers Environmental Operating Principles
EPZ	Evacuation Planning Zone
EQ	Environmental Quality
ER	Engineer Regulation
ERDC	Engineering Research and Development Center
ESA	Endangered Species Act
F	Fahrenheit
FAA	Federal Aviation Administration
FCSA	Feasibility Cost Share Agreement
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FONSI	Finding of No Significant Impact
FPRP	Flood Preparedness and Response Plan
FRAM	Flood Risk Adaptive Measures
FRM	Flood Risk Management
FRMP	Flood Risk Management Program
ft	foot/feet

FWCA	Fish and Wildlife Coordination Act
FWOP	Future Without Project
FWP	Future With-Project
G2CRM	Generation II Coastal Risk Model
GCR	General Conformity Rule
GIS	Geographic Information System
GHG	Green House Gases
GWMP	George Washington Memorial Parkway
HTRW	Hazardous, Toxic, and Radioactive Waste
I	Interstate
IDA	Intensively Developed Area
IDC	Interest During Construction
IFR/EA	Integrated Feasibility Report and Environmental Assessment
IPaC	Information for Planning and Consultation
LDA	Limited Development Area
LiDAR	Light Detection and Ranging
LOD	Limits of Disturbance
MA	Model Area
MAA	Maryland Aviation Administration
MARC	Maryland Area Regional Commuter
MBRI	Middle Branch Resiliency Initiative
MDDNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
MDOT	Maryland Department of Transportation
MES	Maryland Environmental Service
MHT	Maryland Historical Trust
MHHW	Mean Higher High Water (MHHW)
MSA	Martin State Airport

MSL	Mean Sea Level
MDTA	Maryland Transportation Authority
N/A	Not Applicable
NAAQS	National Ambient Air Quality Standards
NACCS	North Atlantic Coast Comprehensive Study
NAVD88	North Atlantic Vertical Datum of 1988
NED	National Economic Development
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NLEB	Northern Long-eared Bat
NMFS	National Marine Fisheries Service
NNC	National Nonstructural Committee
NNBF	Natural and Nature-Based Features
NOAA	National Oceanic and Atmospheric Administration
NO_X	Nitrogen oxides
NO_2	Nitrogen dioxide
NPL	National Priorities List
NRHP	National Register of Historic Places
NWI	National Wetland Inventory
NWR	National Wildlife Refuge
O&M	Operation and Maintenance
OMRR&R	Operation, Maintenance, Repair, Rehabilitation, and Replacement
OSE	Other Social Effects
P&G Criteria	Principles & Guidelines for Federal Investments in Water Resources
PA	Programmatic Agreement
PCB	Polychlorinated Biphenyls
PDT	Project Delivery Team
PED	Pre-construction Engineering, and Design

PGN	Planning Guidance Notebook
P.L.	Public Law
PLCA	Probabilistic Life Cycle Analysis
PPA	Project Partnership Agreement
Ppb	Parts Per Billion
PSE	Protective System Element
PV	Present Value
RCA	Resource Conservation Area
RCRA	Resource Conservation and Recovery Act
RED	Regional Economic Development
RECONS	Regional Economic System
ROI	Region of Interest
ROM	Rough Order of Magnitude
SAV	Submerged Aquatic Vegetation
SIP	State Implementation Plan
SHPO	State Historic Preservation Office
SLC	Sea Level Change
SLOSH	Sea, Lake, and Overland Surges from Hurricanes
SLR	Sea Level Rise
SMART	Specific, Measurable, Attainable, Risk Informed, Timely
SPGP	State Programmatic General Permit
sqft	Square Feet
SVOC	Semi volatile Organic Compounds
SWL	Sea Water Level
TMDL	Total Maximum Daily Load
TSDF	Treatment, Storage, and Disposal Facilities
TSP	Tentatively Selected Plan
U.S.	United States
USACE	United States Army Corps of Engineers

USDA	United States Department of Agriculture
U.S.C.	United States Code
USCG	United States Coast Guard
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UST	Underground Storage Tanks
VOCS	Volatile Organic Compounds
WIP	Watershed Implementation Plan
WQC	Water Quality Certification
WRDA	Water Resources Development Act
WSEL	Water Surface Elevation
WWTP	Wastewater Treatment Plant

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1 INTRODUCTION

1.1 Introduction

This Draft Integrated Feasibility Report and Environmental Assessment (IFR/EA) documents the U.S. Army Corps of Engineers (USACE) feasibility study planning process for the Baltimore Coastal Storm Risk Management Feasibility Study (Baltimore Coastal Study) and compliance with the National Environmental Policy Act (NEPA) and other environmental laws as integrated into the planning process. The sections of this report that satisfy the National Environmental Policy Act of 1969 (NEPA) requirements, as outlined in 40 Code of Federal Regulations (CFR) 1501.5(c), are marked with an asterisk (*). Evaluations of the final array of alternatives revealed no significant effects to environmental and cultural resources or the human environment. For this reason, an Environmental Impact Statement (EIS) is not required.

The purpose of the study is to evaluate the feasibility of federal participation in implementing solutions to problems and opportunities associated with coastal storm damage to reduce coastal flood risk, risk to vulnerable populations, properties, infrastructure, and environmental and cultural resources along the banks of the Patapsco River in the vicinity of Baltimore City including northern Anne Arundel County and eastern Baltimore County, Maryland and Martin State Airport (MSA) in Baltimore County, Maryland. Coastal storms have produced extensive property damage and loss of life resulting from storm surge and flooding in the recent past, particularly from Hurricane Isabel in 2003, which resulted in costs of $4.8 million to the City of Baltimore, up to $252 million in total damages in Southern Baltimore County, and one fatality.

Project costs and benefits associated with each alternative solution were compared to identify and recommend the best plan. The models used to forecast the future conditions and changes for the Baltimore Coastal study are consistent with those used on other Coastal Storm Risk Management (CSRM) projects and have been certified by USACE.

The Baltimore Coastal Study Feasibility Cost Share Agreement (FCSA) was signed by USACE and the Maryland Department of Transportation (MDOT) on August 5, 2019. MDOT is the non-federal sponsor for the Baltimore Coastal Study. The study area encompasses the portion of the City of Baltimore and surrounding metropolitan areas 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.

This draft IFR/EA will culminate in a Chief's Report on March 27, 2024 as an interim response to the authority.

1.2 USACE Planning Process

The SMART (Specific, Measurable, Attainable, Risk Informed, Timely) planning process is used for conducting civil works feasibility studies for water resources development

projects. The purpose of this process is to improve and streamline feasibility studies, reduce cost, and expedite completion of the study. The SMART planning process follows a 3x3x3 approach with the goal of completing the study in 3 years, for no more than $3 million (M) dollars and with three levels of review.

Due to study delays and interruption in funding of the Baltimore Coastal study, the project delivery team (PDT) requested a 3x3x3 exemption for time, which is currently under review. The schedule approved under the 3x3x3 exemption established a signed Chief's Report date of March 27, 2024.

The feasibility study is broken into 4 segments: Scoping, Alternatives Evaluation and Analysis, Feasibility Analysis of Selected Plan and Washington Level Review (Figure 1-1). The Alternatives Milestone Meeting (AMM) was achieved on November 18, 2019. The Baltimore Coastal Study has completed segment 2 with the confirmation of the Tentatively Selected Plan (TSP) at the milestone meeting held on May 2, 2022. The PDT is working on Segment 3 and the next milestone is the Agency Decision Milestone (ADM) scheduled for October 20, 2022.

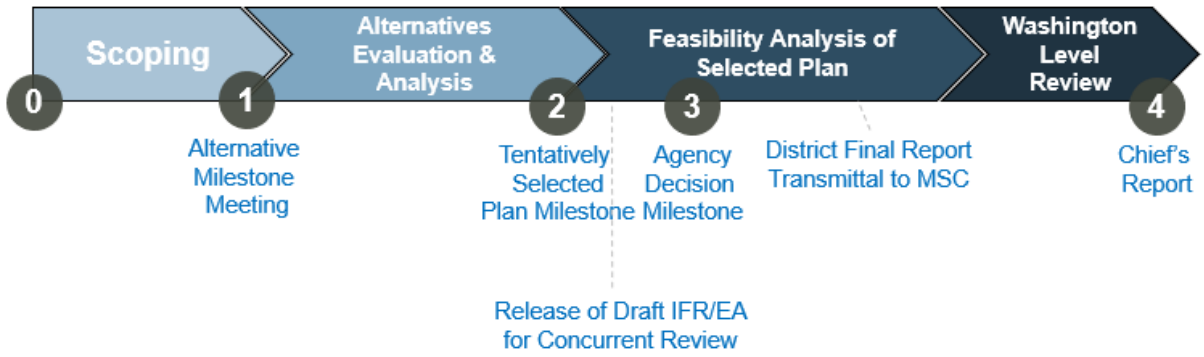

Figure 1-1. Feasibility Study Timeline

This draft IFR/EA was prepared in accordance with the Principles and Guidelines for Water and Land Related Resources Implementation Studies (P&G) and Engineer Regulation (ER) 1105-2-100 Planning Guidance Notebook (PGN) April 22, 2000 and follows the Final Feasibility Report Format and Content Guide October 26, 2021. To ensure sound decisions are made with respect to the development of alternatives, and with respect to plan selection, the plan formulation process requires a systematic and repeatable approach. This draft IFR/EA includes all NEPA sections for an EA. This draft IFR/EA presents the CSRM problem to be addressed by the study, lays out the plan formulation process leading to the final array of alternatives, discusses the existing and future with and without-project conditions, evaluates environmental effects and consequences of the alternatives, and explains the decision leading to the selection of the TSP.

1.3 Study Authority

The study authority is under the Baltimore Metropolitan Water Resources authority. The Committee on Public Works and Transportation of the United States House of Representatives adopted a House resolution on April 30, 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, Eighty 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 protection, navigation, erosion, sedimentation, fish and wildlife, water quality, environmental restoration, recreation, and other related purposes.*

This study authority was identified by the U.S Army Corps of Engineers, Baltimore District (CENAB) Office of Counsel (in a memorandum dated April 22, 2014) 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. Although the study authority also identifies other purposes, this study will focus solely on CSRM. This study is an interim response to the study authority.

1.4 Study Area (Planning Area)

The study encompasses the portion of the City of Baltimore and surrounding metropolitan areas in eastern Baltimore County and northern Anne Arundel County 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 1-2). The study area includes the Baltimore coastline from Coffin Point to the Cox Creek Dredged Material Containment Facility (DMCF). The study area was defined to also include assets of importance to MDOT, including MSA in Baltimore County. Within the study area, Baltimore City contains approximately 69 miles of Patapsco River shoreline. The Baltimore County study area contains approximately 4 miles of shoreline along Martin State Airport.

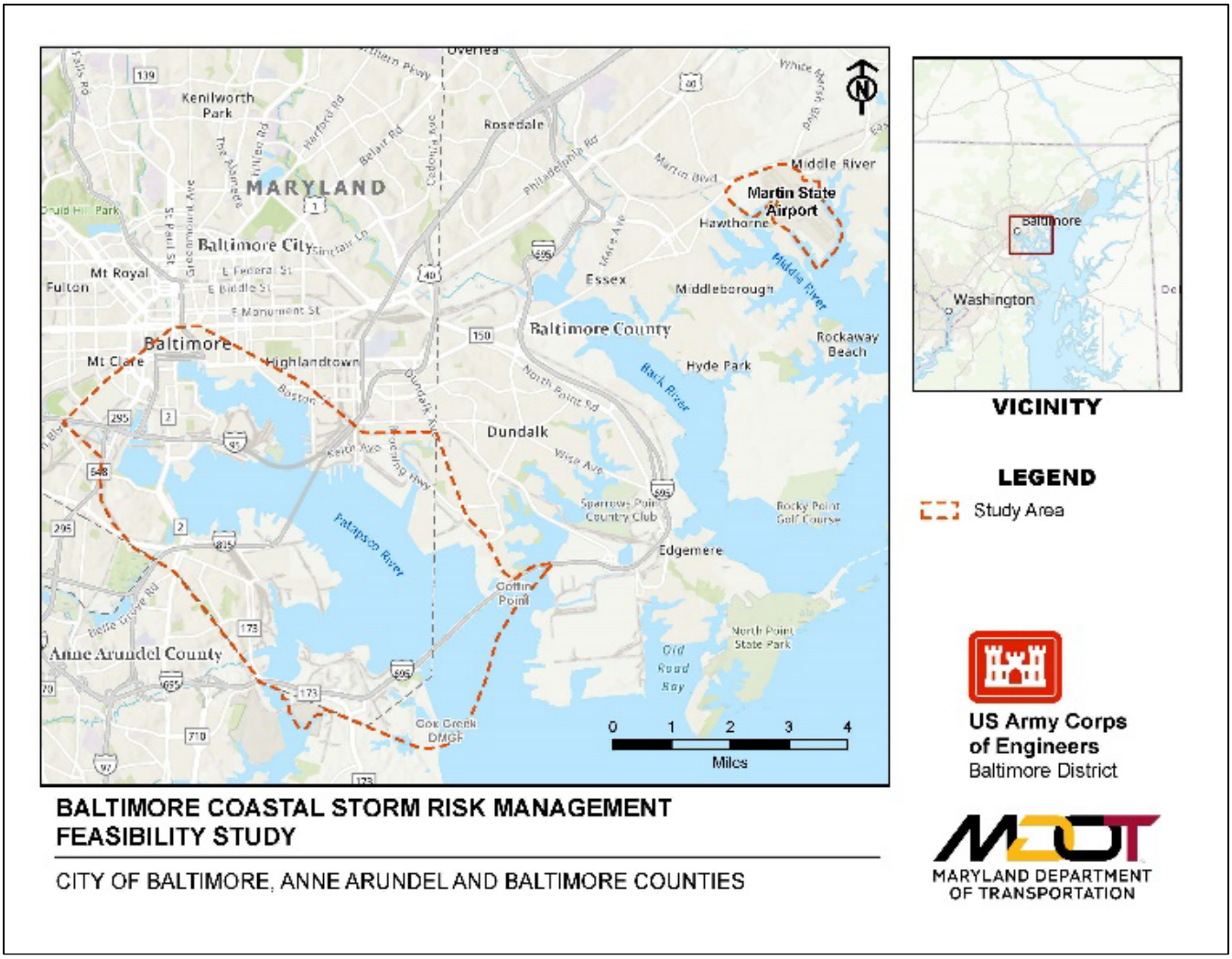

Figure 1-2. Study Area

1.5 Background and History

Following Hurricane Sandy in 2012, USACE completed the North Atlantic Coast Comprehensive Study (NACCS), which identified nine high-risk areas on the Atlantic Coast, including the Baltimore Metropolitan region, that warranted further investigation of coastal flood risk management (FRM) solutions. For a comprehensive overview of NACCS, please refer to the NACCS Main Report, appendices, and associated study products at: https://www.nad.usace.army.mil/CompStudy/ (USACE, 2015).

1.6 Study Purpose and Need for the Action*

The purpose of the study is to evaluate the feasibility of federal participation in implementing solutions to problems associated with coastal storm damage and to support resilient communities in the study area. The study is needed to consider alternatives to reduce coastal flood risk, risk to vulnerable populations, properties, infrastructure, and environmental and cultural resources in the study area, considering future climate and sea level change (SLC) scenarios.

The study area has been impacted by numerous major tropical and extratropical events, most notably by the Hurricane Able (September 1952), Hurricane Hazel (November 1954), Hurricane Connie (August 1955), Tropical Storm Agnes (June 1972), Tropical Storm David (September 1979), Hurricane Isabel (September 2003), Tropical Storm Ernesto (September 2006), Tropical Storm Hanna (September 2008), and Hurricane Irene (August 2011). Hurricane Isabel in 2003 resulted in extreme water levels and caused millions of dollars of damage to residences, businesses, and critical infrastructure. High storm surges occurred along the Chesapeake Bay and its tributaries. Over 570 homes and 15 businesses were declared uninhabitable from flooding. 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.

1.7 Problems and Opportunities

The problem in the study area is economic damage and life loss resulting from inundation caused by coastal storms. The following have been identified as particular problems in the study area:

Life Safety

- Coastal flooding in the densely populated study area endangers lives; socially vulnerable populations may not be able evacuate ahead of storm surge.

Property and Critical Infrastructure

- Shorelines are developed with limited opportunity for storm surge and wave attenuation and storage of floodwaters. There is limited opportunity for application of natural and nature-based features (NNBF) in most of the study area.
- Storm surge inundation results in:
    - Damages to residential, commercial, industrial, government, and port and airport properties.
    - Disruption to critical infrastructure including water, electric and communication services, evacuation and transportation routes, and drainage systems.
    - Hindering the delivery of emergency services and other essential goods and services, disaster response, recovery, and overall resiliency.
    - Damage to important cultural and historic properties.

Opportunities exist to:

- Reduce vulnerability of coastal population and properties.
- Identify critical infrastructure vulnerabilities and improve resiliency.
- Increase public understanding of flood risk.
- Incorporate NNBF to reduce risk from storm surge inundation due to coastal storms and provide improved habitat.

- Identify beneficial reuse opportunities (e.g., wetland restoration within Middle Branch).

1.8 Objectives and Constraints

The goal of the study is to support resilient communities by recommending actions to manage flood risk to vulnerable populations, properties, infrastructure, transportation assets, and environmental and cultural resources. Planning objectives are summarized in statements that describe the desired results from solving or alleviating problems or realizing opportunities. All objectives for this study apply to the 50-year period of analysis, beginning in 2031.

1.8.1 Objectives

Baltimore City:

- Reduce risk to **human health and safety** from coastal storm impacts in the study area.
- Reduce **economic damages** from coastal flooding in the study area to residential, commercial, industrial, and government buildings.
- Reduce disruption of **critical infrastructure** assets, services, and interdependent systems caused by coastal flooding in communities throughout the study area.
- Improve the **resiliency of critical infrastructure** in the study area to impacts from coastal storms.

Martin State Airport:

- Reduce coastal flooding impacts that disrupt or damage **transportation and emergency service infrastructure** and assets at supporting operations at Martin State Airport.

Consideration will be given for incorporation of **NNBF** in solutions.

1.8.2 Planning Constraints

Constraints are restrictions that limit the extent of the planning process. There were no absolute constraints during plan formulation; however, several considerations were identified. The PDT sought to:

- Minimize impacts to operations at Port of Baltimore, specifically Seagirt Terminal
- Minimize impacts to major transportation assets (I-95, I-895)
- Avoid exacerbating contaminated brownfield and Superfund sites
- Minimize adverse effects to historic structures and districts
- Avoid adverse effects to other properties and vulnerable populations within the study area

1.9 Study Scope

ER 1105-2-100, PGN defines the contents of feasibility reports for CSRM. This IFR/EA documents the studies and coordination conducted to determine whether the federal government should participate in CSRM in Baltimore City and surrounding metropolitan areas. Studies of potential CSRM consider a wide range of alternatives and environmental consequences of those alternatives but focus mainly on coastal storm risk and flooding.

The study area encompasses the portion of Baltimore City and the surrounding metropolitan areas along the tidally influenced areas that were subject to flooding, storm surge, and coastal storm damages because of Hurricane Sandy and other recent storms. The study area includes the Baltimore coastline from Coffin Point, the site of Maryland Transportation Authority (MDTA) offices at the Francis Scott Key Bridge (I-695) to the Cox Creek DMCF, just south of the Francis Scott Key Bridge and, at the request of our non-federal sponsor, MSA because it is a critical transportation asset. The study area was defined to include many assets of importance to MDOT.

1.10 Prior Studies and Reports

An extensive set of prior reports for this study area have been completed, including those produced by USACE and other agencies and jurisdictions. The most recent and/or relevant to the evaluation of CSRM within the study area are included below.

USACE

- *Assessment of Flood Risk Adaptive Measures, Baltimore City, Maryland (2019)*: This report, produced by CENAB for the Maryland Silver Jackets Team evaluated and recommended “flood risk adaptive measures” (FRAMs) for use on properties for residential, commercial, and public buildings. FRAMs are physical and nonphysical FRM measures that reduce flood risk by modifying the characteristics of structures or modifying the behavior of people living in or near floodplains. The assessment evaluated and recommended FRAMs for features on nine sample buildings. Baltimore City plans to incorporate the results of the assessment into a design guidance manual for floodproofing historic buildings.
- *North Atlantic Coast Comprehensive Study (NACCS; 2015)*: In 2015, the U.S. Army Corps of Engineers completed a report detailing the results of a two-year study to address coastal storm and flood risk to vulnerable populations, property, ecosystems, and infrastructure affected by Hurricane Sandy in the United States’ North Atlantic region. The NACCS study was designed to help local communities better understand changing flood risks associated with climate change and to provide tools to help those communities better prepare for future flood risks. It builds on lessons learned from Hurricane Sandy and attempts to bring to bear the latest scientific information available for state, local, and tribal planners. The

Baltimore Metropolitan study area was included as part of the NACCS Focus Area analysis.

- *Tidal Middle Branch, Baltimore, MD Section 206 (2009)*: The Middle Branch is one of the major tidal portions of the Patapsco River and is the receiving body of water for the Gwynns Falls and Patapsco River. Middle Branch is located entirely within the City of Baltimore; thus, the watershed consists of a highly urbanized metropolitan setting. The Middle Branch study included the area upstream of Fort McHenry and the Fairfield Auto Terminal and continues north up the Gwynns Falls to Washington Boulevard and the I-395 exchange. Implementation of the project was not recommended due to the high cost of the project, which was shown to have minimal environmental benefits.
- *Warner Street, Middle Branch of the Patapsco River, Section 510 (2006)*: The Warner Street project consists of two phases. Phase I called for the design and construction of a trash interceptor to prevent trash and debris from smothering wetland vegetation along the shoreline of the river. Phase II called for the design and construction of a tidal emergent wetland along the shoreline. Phase I was completed in September 2006. Phase II was not constructed.
- *Hanover Street Wetlands Environmental Restoration Project Baltimore, Maryland Section 206 (2004)*: Under the Continuing Authorities Program Section 206, Aquatic Ecosystem Restoration authority, a three-acre wetland restoration project was proposed to be constructed between Hanover Street and land adjacent to City Garage. The project also proposed the construction of a trash interceptor on a stormwater outfall near Warner Street in Ridgeley's Cove. The trash interceptor was constructed while no wetland restoration was undertaken due to concern over mud-waving impacts to the Hanover Street Bridge. The project was terminated in 2011.
- *Baltimore Metropolitan Water Resources Study, Reconnaissance Report (1994)*: This reconnaissance report examined water resource problems in the Patapsco and Gunpowder River watersheds, including shallow draft navigation, flood damage reduction, and environmental restoration. The report concluded that there was federal interest in preparing water resource plans for various sub-basins. The report also recommended floodproofing for individual structures and updating existing flood warning systems.
- *Gwynns Falls, Baltimore, Maryland Local Flood Protection (1991)*: This feasibility study recommended the construction of a levee, starting at the embankment of Interstate (I)-95 on the left bank of the Gwynns Falls and extending downstream a distance of 400 feet to the CSX Corporation (CSX) Railroad tracks. From that point, the existing levee constructed by the City of Baltimore in 1987 would be raised about 2 feet for a distance of 1000 feet. Two closures structures would be needed

where the line of protection crosses railroad tracks. The project was not constructed due to issues with CSX.

- *Flood Insurance Study, City of Baltimore, MD (1973)*: The study analyzed the flood potential of the City of Baltimore, Maryland at the request of the Federal Insurance Administration of the Department of Housing and Urban Development.
- *Hurricane Survey Baltimore Metropolitan Area (1960)*: Several alternative plans for preventing hurricane tidal damage in the study area were examined but none were found to be economically justified. The alternative plans included several plans of surge barriers and a brief examination of floodwalls. Because the alternatives were not justified economically, and local interests did not desire the protection studied, no improvements were made.
- *Martin State Airport Flood Preparedness and Response Plan (2005)*: This Flood Preparedness and Response Plan (FPRP) provides information and tools for use in preparing for and responding to flooding threats at MSA, Baltimore County, Maryland, especially those due to tropical storms, hurricanes, and Nor'easters. The goals of this plan are to protect life, preserve property and assets, and to limit the impacts to operation before, during, and after a storm event by recognizing the threats of flooding to MTN Airport and mitigating the effects of those threats. This plan was requested by the Maryland Aviation Administration (MAA).

Baltimore City

- *Baltimore City Nuisance Flood Plan (2020)*: Maryland lawmakers, local and state governments, and citizens recognize that tidally-driven flood events are happening with more frequency. While "nuisance flooding" may not pose a serious threat or result in major damage, it interrupts daily routines and can negatively impact businesses. The definition of nuisance flooding, for the purpose of this plan and in accordance with §3-1001 of the Natural Resource Article of the Maryland Annotated Code, is "high tide flooding that causes a public inconvenience." The legislation requires that the Nuisance Flood Plan include three critical components: 1) Inventory of known flood hazard areas where tidal nuisance flooding occurs; 2) Identification of flood thresholds/ water levels/ conditions that lead to tidal nuisance flooding; and 3) A mechanism to document tidal nuisance flood events from 2020 to 2025.
- *Disaster Preparedness and Planning Project (DP3) (2018)*: Baltimore's Disaster Preparedness and Planning Project (DP3) was first produced by the Department of Planning in 2013 to address both existing hazards and the predictions of the impacts of climate change on these natural hazards, including but not limited to heat waves, sea level rise (SLR), increased precipitation, and flooding. Hazard mitigation planning is a continuous process for the City of Baltimore. This 2018

update fulfills Federal requirements to regularly update the formal plans, but the City includes additional elements it plans to develop over the next 2-3 years.

- *City of Baltimore Commission for Historical & Architectural Preservation Fells Point Flood Mitigation Guidelines (2018)*: Many of Baltimore's historic neighborhoods are vulnerable to flooding, particularly those close to waterfronts like Fells Point. Whether on the roads, sidewalks, or directly impacting buildings, flooding is becoming a more common problem across the City of Baltimore. The historic, attached rowhouse buildings of Fells Point are particularly vulnerable and pose a real challenge for owners seeking to minimize flood damage. The information presented in this guide is intended to provide information to property owners and tenants on evaluating options to minimize the impact of flooding to their historic rowhouse properties in Fells Point.

2 EXISTING AND FUTURE WITHOUT PROJECT CONDITIONS

This section describes the Existing Conditions, as well as a forecast of the Future Without Project (FWOP) Conditions, that together provide a basis for plan formulation discussed in Section 3. The Existing Conditions and the FWOP Conditions provide a description of the human environment, which is subdivided into the natural, physical, economic, and built environments. The Existing Conditions represent the Affected Environment for NEPA purposes. The Existing and FWOP Conditions serve as a baseline that are compared to the Future With-Project (FWP) Condition to evaluate and compare the alternative plans. This comparison is integral to the selection of the TSP (Section 6). The final array of alternatives does not include in-water work. Therefore, impacts to in-water resources including submerged aquatic vegetation (SAV), benthic resources, and fish and fishery resources are not anticipated and are not discussed in this report.

2.1 Period of Analysis

The period of analysis for this study is 50-years per ER 1105-2-100 Planning Guidance Notebook. The planning horizon starts in baseline year 2031 (when the project is anticipated to begin accruing FRM benefits) and ends in year 2080. Existing conditions reflect the conditions in place during the feasibility study through year 2024. FWOP conditions consider a range of activities from year 2021, the most recent year for which complete data was obtained, and projects that are planned to be implemented or are already underway that would be constructed in the absence of this project. FWP Conditions are the conditions forecasted during the planning horizon, from years 2031 to 2080, with implementation of the TSP. The TSP will also be assessed for engineering and environmental performance out to 100 years from the baseline year, to ensure coastal sustainability of the TSP and adaptation to SLR.

2.2 General Setting

The study area located in Baltimore City is characterized as a densely populated urban setting, consisting of commercial, industrial, and residential areas. The study area located at MSA includes a runway, multiple hangars, and areas leased by the Maryland Air National Guard.

There are several locations of national significance in the study area, including Fort McHenry (a national park), historic structures and districts, and an important U.S. Coast Guard (USCG) boatyard and drydock facility. Critical infrastructure in the study area includes the Port of Baltimore, I-95 and I-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. The general setting of the study area is not expected to change under the FWOP Condition.

2.3 Natural Environment*

2.3.1 Wetlands

Most wetlands within the Baltimore Metro study area exists along the Patapsco River and Inner Harbor coastlines and consist of estuarine, tidally influenced systems. A tidal wetland is located southwest of Fort McHenry and east of the Fort McHenry Tunnel Ventilation Building (referred to as the Fort McHenry West Ventilation building). The MSA study area contains similar wetland systems surrounding the property, with additional palustrine systems located within the interior.

2.3.1.1 FWOP Condition

Wetlands that exist within the vicinity of the MSA study area may continue to receive brackish water inflow during storm surge, high tides, and heavy rain events, which has the potential of disrupting the current hydrologic regime and hydrophytic vegetation within the wetlands. Conversely, the State of Maryland continues to work with State and local agencies to implement wetland restoration and conservation programs in an effort to protect the state's remaining coastal wetlands from climate change (USEPA, January 2021c). The Port of Baltimore partnered with the Living Classrooms Foundation, the National Aquarium, Maryland Environmental Service (MES), and United States Fish and Wildlife Service (USFWS) to create Masonville Cove, the nation's first Urban Wildlife Refuge Partnership. One of Masonville Cove's objectives is to promote conservation through education and experiences. Masonville Cove contains 251 bird species and is named one of the state's top birding spots (Masonville, 2022). In addition, Reimagine Middle Branch, an initiative led by the City of Baltimore, South Baltimore Gateway Partnership, and the Parks & People Foundation, is expected to restore existing marshes and Chesapeake maritime forests along the Middle Branch area (Lynch, 2022).

2.3.2 Wildlife

CENAB submitted an online request in February 2022 through the USFWS Information for Planning and Consultation (IPaC) online web service to determine the presence of protected resources and species (under jurisdiction of the USFWS) within the Baltimore and MSA study areas. As reported through the USFWS IPaC Resource List, there are no critical habitats, fish hatcheries or National Wildlife Refuge (NWR) lands within the study areas. The IPaC report is in Appendix H: Agency and Public Involvement Coordination.

In accordance with Section 2(b) of the Fish and Wildlife Coordination Act (16 U.S.C. 1513 et seq.) and Section 7 of the Endangered Species Act (16 U.S.C. 1513 et seq.), the USFWS provided a Fish and Wildlife Coordination Act (FWCA) letter to CENAB on April 6, 2022. The FWCA letter is located in Appendix H.

2.3.2.1 Threatened and Endangered Species

The IPaC report identified only one threatened/endangered species as having the potential to occur in the study areas; the threatened northern long-eared bat (NLEB) (*Myotis septentrionalis*). Although the species was identified in the screening, the

developed nature of the study area is not a suitable habitat for this species. There are no hibernacula or maternity roosts located within or nearby the study areas. The FWCA letter identified the monarch butterfly (*Danaus plexippus*) as a candidate species and not yet listed or proposed for listing. There are no requirements under Section 7 of the Endangered Species Act (ESA) for candidate species.

2.3.2.2 At-Risk Species

Several at-risk species, or species whose populations are in decline but are not yet determined to be threatened or endangered, were identified in the IPaC report. Species include the monarch butterfly, American oystercatcher (*Haematopus pilliatus*), cerulean warbler (*Dendrocia cerulea*), eastern whip-poor-will (*Antrostomus vociferus*), ruddy turnstone (*Arenaria interpres morinella*) and wood thrush (*Hylocichla mustilina*). Common tern (*Sterna hirundo*) and royal tern (*Sterna Thalasseus maximus*) may also be present within the study area. Additionally, there is an annual nesting common tern colony on a barge off the coast of Masonville Cove, approximately one mile from the study area.

2.3.2.3 Migratory Birds

The IPaC report generated a list of migratory birds and Birds of Conservation Concern BCC) within the study areas. This list is located in the IPaC report in Appendix H.

The Patapsco River portion of the study area is a maintenance watershed for the American black duck (*Anas rubripes*). Maintenance areas currently contain enough food to support black duck populations.

The bald eagle (*Haliaeetus leucocephalus*) was identified by IPaC due to its protection under the Migratory Bird Treaty Act and Bald and Golden Eagle Protection Act. The nearest bald eagle nest is located approximately one mile from the Baltimore study area at Masonville Cove.

2.3.2.4 FWOP Conditions

The City of Baltimore, along with the Baltimore Waterfront Partnership and other Harbor stakeholders and business communities, have developed the Baltimore Inner Harbor 2.0 Master Plan. The framework of the Master Plan includes connecting the Baltimore Harbor Promenade with open spaces, integrating green infrastructure, and restoring native habitats. The Plan proposes the identification of potential locations for living shorelines, floating wetlands, rain gardens, enhanced tree canopy, and native plant habitat (Baltimore Waterfront, 2013). Over the last decade, the Master Plan has acted as a guideline for the City's future development plans. Although many of the projects within the Plan have yet to be developed, the intention is to create a more suitable, native habitat for at-risk species and migratory birds.

2.4 Physical Environment*

2.4.1 Land Use

Land use within the Baltimore Metro study area consists of commercial, industrial, high and medium-density residential housing, as well as several other developed areas according to the Maryland Department of Planning and Maryland Environmental Resource & Land Information Network (MERLIN, 2010). The Patapsco River creates a peninsula around South Baltimore and is the main tributary to other waterways around the study area including Gwynns Falls, Colgate Creek and Bear Creek. The study area includes numerous shipping and transportation facilities such as the Port of Baltimore-Seagirt Terminal, Port of Baltimore- Chesapeake, Fairfield Auto Terminal, Port Covington, Locust Point Industrial Area, as well as CSX and Norfolk Southern railroad facilities. Notable landmarks within the Baltimore Metro study are include the Inner Harbor, Fort McHenry National Monument and Historic Shrine, the National Aquarium, Horseshoe Casino, and M & T Bank Stadium (Figure 2-1). Baltimore City is also located within the Chesapeake Bay Critical Area – Intensively Developed Area (IDA), Limited Development Area (LDA), and Resource Conservation Area (RCA). Section 2.4.11 includes more details on the Chesapeake Bay Critical area.

MSA encompasses over 740 acres of land in Middle River, MD. The airport is bordered by Eastern Boulevard to the north, Frog Mortar Creek to the east, Stansbury Creek to the south, and Dark Head Creek and Wilson Point Road to the west (Figure 2-2). The three creeks surrounding the airport are all tidally influenced systems. The airport is operated by the MAA and includes one runway, taxiways, a fuel storage facility, multiple hangars, and operations and maintenance buildings. The airport is utilized by private and corporate aircraft and is also used by the Maryland Air National Guard, which leases approximately 20 percent of the property from MAA (MAA, 2017). According to the Baltimore County Department of Zoning, MSA is zoned as Manufacturing, Heavy. Typical uses permitted by right include industrial uses requiring assembly, production, processing, packaging, or treatment of various elements, boat yard, laboratory, office, medical clinic, equipment, and material storage yard (Baltimore County, 2015).

Refer to the Baltimore Metropolitan Council's Land Use/Land Cover Map for land use maps of the Baltimore Metro Study Area and the Martin State Airport study area (Baltimore Metropolitan Council, 2018).

Additionally, the MSA is located within the Chesapeake Bay Critical Area – IDA. IDAs have the least restrictive land-use classifications and are designated for high-intensity development, which is encouraged to minimize forest destruction and impervious surface cover (CBF, 2004). Section 2.4.11 includes more information on the Chesapeake Bay Critical Area. The specific regulations of the Critical Area Act can be found in the Annotated Code of Maryland Regulations (COMAR 27.01.01).

2.4.1.1 FWOP Conditions

Within the Baltimore study area, future development is expected to reshape areas along Baltimore's waterfront. Construction is currently underway in the Warner Street district and is anticipated to transform Baltimore's old and underused industrial zone into a new, mixed-use entertainment center. Further development at Harbor Point, one of Baltimore's newest waterfront neighborhoods located between Harbor East and Fells Point, is continuing to transform the former industrial area into a mixed-use community of businesses, luxury apartments, and restaurants. The project is currently in Phase III of development and will include a 4.5-acre park space, an additional office building, and residential and retail facilities (Baltimore.org, 2022). The MSA and its surrounding areas are identified in Baltimore County's 2020 Master Plan proposed Middle River Redevelopment Area. The Redevelopment Area proposed for MSA will be classified as "T-Institutional", and more specifically, T-4 (General Urban Zone). The T-4 Zone is intended to be characterized by mixed-use but will focus on transit-oriented development (Martin, 2022).

2.4.2 Geology

2.4.2.1 Physiography

The study area lies within the embayed section of the Atlantic Coastal Plain province, which extends along the east coast of the United States (U.S.) from Massachusetts to Florida. The Coastal Plain is underlain by a wedge of unconsolidated sediment that includes silt, gravel, sand, and clay. This area is characterized by nearly level to rolling topography, with elevations ranging from sea level to 330 feet. The lithology or physical characteristics of the rock formations in the area are mainly composed of fine to medium sand, often micaceous and gravel, with some lesser amounts of silt and clay (Maryland Geological Survey, 2020).

2.4.2.2 Soils

The study area consists of numerous types of soils. Soil is a mixture of mineral and organic ingredients, with the composition changing from one location to another. The soil-forming process is affected by a variety of factors including parent material, living organisms, landscape position, time, and climate. Within urban environments, soil composition may form as a result of different types of human-deposited material such as loamy fill over natural sand, dredge spoil, coal ash, or construction debris (USDA, 2020). Urban environments can contain non-soil areas with names such as urban land, dumps, water or rubble land. The designation of 'Urban land' indicates that an area is primarily covered with impervious materials such as pavement, driveways, and buildings.

Soil survey information retrieved from the U.S. Department of Agriculture Natural Resources Conservation Service (USDA-NRCS) Web Soil Survey mapping tool, provides the soil types within the study area. Urban land (Soil Map Unit Symbol 44UC) is the primary soil type listed for the Baltimore study area. Urban land and Mattapex-urban land

complex are the major soil types found within the MSA study area. Soil types found within both study areas are listed in Appendix G: Environmental and Cultural Resources Compliance.

2.4.2.3 Drainage and Watershed

The study area is within a dendritic drainage system, with numerous branching streams, eventually flowing into the Chesapeake Bay. The Chesapeake Bay watershed covers an area of 64,000 square miles (165,760 square kilometers) and includes parts of six states (Virginia, Maryland, Delaware, West Virginia, Pennsylvania, and New York), as well as all of the District of Columbia. The watershed's rivers all drain into one shallow tidal basin, the Chesapeake Bay, and the bay's tidal tributaries. There are more than 100,000 rivers, streams, and creeks within the Chesapeake Bay watershed. Each stream has its own watershed, which are part of larger watersheds that drain into larger streams or rivers. The Chesapeake Bay watershed is located in the middle of the Atlantic Coastal Plain province and was formed when the lower valley of the Susquehanna River was drowned as glaciers melted during the post-Wisconsin rise in sea level.

The study areas are located within the Gunpowder-Patapsco sub-watershed, which encompasses portions of Frederick, Carroll, Howard, Anne Arundel and Harford Counties, most of Baltimore County, and all of Baltimore City. The Baltimore City portion of the study area lies within Baltimore Harbor watershed of the Patapsco River (Maryland 8-digit watershed 02130903). The MSA is located within the Middle River/Browns watershed of the Gunpowder River (Maryland 8-digit watershed 02130807).

2.4.2.4 FWOP Conditions

Under the No Action Alternative/FWOP, conditions would remain the same and there would be no impacts to geology or drainage.

2.4.3 Water Quality

Water draining from the Chesapeake Bay watershed has a significant impact on water quality in the Chesapeake Bay. Within the study area, the urban nature of the Patapsco River watershed has detrimental impacts on the water quality of the Patapsco River and its tributaries, due to urban runoff and contaminants from industrial pollution.

Watershed implementation plans (WIP) are generated by each jurisdiction to outline steps, measures and practices that will be implemented to achieve the goals of the Chesapeake Bay total maximum daily load (TMDL) by the year 2025. The Maryland WIP Phase III, which outlines pollution reduction goals needed from 2018 to 2025, sets nutrient pollution limit goals of 45.8 million pounds of total nitrogen per year, 3.68 million pounds of total phosphorous per year, and sediment discharge limits of 1.3 billion pounds of sediments per year (MDE, 2019). The Patapsco and Middle Rivers are grouped under the western shore state basin, which has a pollution reduction target under the Maryland WIP Phase III of 9.0 million pounds per year for nitrogen and 0.96 million pounds per year for phosphorous.

The Patapsco and Middle Rivers are both designated as “Use Class II.” Use II waters are defined as supporting estuarine and marine aquatic life and shellfish harvesting. Within the study area this includes the following Use II subcategories: support of seasonal migratory fish spawning and nursery, seasonal shallow-water SAV, open-water fish and shellfish use, and shellfish harvesting use. The Patapsco River is also designated as suitable for the support of deep-water fish and shellfish and for deep channel refuge use. Frog Mortar Creek is designated as “Use I,” which is defined as supporting water contact recreation, fishing, growth and propagation of fish (not trout) and other aquatic life and wildlife, as well as agricultural and industrial water supply.

The Patapsco River is currently “listed” or included in the 303(d) list as being impaired and needing TMDLs for a variety of pollutants including polychlorinated biphenyls (PCBs), lead in sediment, zinc in sediment and chlorides. Middle River is listed for PCBs in fish tissue due to contaminated sediments. Table 2-1 presents a list of all impaired waterbodies within the study area that do not currently have a TMDL or do not have a TMDL that has been approved by the U.S. Environmental Protection Agency (EPA).

TMDLs have been developed and approved for nitrogen and phosphorous pollution impacting fish and shellfish ecosystems within the Middle River. The Patapsco River also has approved TMDLs for a variety of pollutants, some of which are part of the “Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorous and Sediment” (Chesapeake Bay TMDL) (USEPA, 2010). Table 2-2 lists impaired waterbodies within the study area for which TMDLs have been approved, as well as their corresponding designated uses, causes of pollution, indicators, and pollution sources (if known).

Table 2-1. Impaired Waterbodies within the Baltimore Metro Study Area Currently in the 303 (d) list

Year First Listed	Basin Name	Designated Use	Cause/ TMDL Impairment	Indicator/Pollution Sources
1998	Patapsco River-Northwest Branch, Middle Harbor	Aquatic life and wildlife	Zinc in sediment	Direct measurement/ source unknown
1998	Patapsco River-Northwest Branch	Aquatic life and wildlife	Lead in sediment	Direct measurement/ source unknown
2004	Patapsco River	Aquatic life and wildlife	Cause unknown	Benthic Index of Biological Integrity (IBI)/source unknown
2006	Middle River-Browns	Fishing	PCBs in fish tissue	Direct measurement/ contaminated sediments
2010	Patapsco River-Middle Branch, Northwest Branch	Water contact sports	Enterococcus	Direct measurement/ source unknown
2014	Baltimore Harbor	Aquatic life and wildlife	Total suspended solids	Fish and benthic IBIs/ urban runoff & storm sewers
2014	Baltimore Harbor	Aquatic life and wildlife	Chloride	Direct Measurement/ urban runoff & storm sewers
2014	Baltimore Harbor	Aquatic life and wildlife	Sulfate	Direct measurement/ urban runoff &storm sewers

Table 2-2. Impaired Waterbodies within the Baltimore Study Area that have Approved TMDLs

Basin Name	Designated Use	Cause/ TMDL Impairment	Indicator/Pollution Sources
Middle River	Open-water fish and shellfish subcategory. Seasonal migratory fish spawning and nursery subcategory	Nitrogen	Dissolved oxygen
Middle River	Open-water fish and shellfish subcategory. Seasonal migratory fish spawning and nursery subcategory	Phosphorous	Dissolved oxygen
Patapsco River	Seasonal shallow-water SAV- SAV grow zone	Total suspended solids	SAV and water clarity/ source unknown
Patapsco River	Open-water fish and shellfish subcategory. Seasonal migratory fish spawning and nursery subcategory	Nitrogen, total	Dissolve oxygen/ municipal point source discharges
Patapsco River	Open-water fish and shellfish subcategory. Seasonal migratory fish spawning and nursery subcategory	Phosphorous, total	Dissolved oxygen/ municipal point source discharges
Patapsco River-Littoral zone of the Middle Branch and the Northwest Branch	Water contact sports	Trash	Direct measurement/ Illegal dumps or other inappropriate waste disposal
Patapsco River	Seasonal deep-water fish and shellfish subcategory	Phosphorous, total	Dissolved oxygen/ municipal point source discharges
Patapsco River	Seasonal deep-water fish and shellfish subcategory	Nitrogen, total	Dissolved oxygen/ municipal point source discharges

Basin Name	Designated Use	Cause/ TMDL Impairment	Indicator/Pollution Sources
Baltimore Harbor Watershed	Fishing	Chlordane	Direct measurement/ contaminated sediments
Baltimore Harbor Watershed	Fishing	PCBs in fish tissue	Direct measurement/ discharges from municipal separate storm sewer systems (MS4)
Patapsco River	Seasonal deep-channel refuse use, navigation channel	Phosphorous, total	Dissolved oxygen/ source unknown
Patapsco River	Seasonal deep-channel refuse use, navigation channel	Nitrogen, total	Dissolved oxygen/ source unknown
Patapsco River- lower North Branch	Aquatic life and wildlife	Total suspended solids	Habitat evaluation/ urban runoff, storm sewers
Patapsco River –North Branch	Water contact sports	*Escherichia coli* (E. Coli)	Sanitary sewer overflows (collection system failures)

2.4.3.1 FWOP Condition

The State of Maryland, as well as federal and local agencies, continue to strive towards improving water quality within the Chesapeake Bay watershed through WIPs as stated above. However, challenges arise when quantifying the effects that continued urbanization, climate change, and associated warming sea temperatures may have on local water quality standards.

Wastewater treatment plants in the region continue to evolve with the most up-to-date technology in an effort to reduce nutrients in wastewater. As part of a 2002 consent decree between the U. S. Environmental Protection Agency (USEPA), the U.S. Department of Justice, and the Maryland Department of the Environment, the Baltimore City Department of Public Works recently completed construction on a headworks project at the Back River Wastewater Treatment Plant. The project is estimated to eliminate more than 80 percent of the sewage volume overflowing from the city's system (ENR, 2021).

2.4.4 Floodplains

Floodplains are typically flat or gently rolling lands adjacent to streams and rivers that receive floodwaters once the waterway has overtopped the bank of the main channel. Overtopping is usually a result of a higher-than-normal influx of precipitation caused by intense meteorological events, tropical storms, and hurricanes. Overtopping can also be a result of excessive water moving from higher elevations to lower elevations, normally seen during flash flood events. Floodplains can often become vulnerable due to development directly adjacent to or within a designated floodplain area and is most seen in densely populated cities. Due to increased development, floodplains lose their proper functions and values of flood storage, nutrient reduction, and wildlife habitat, among others. The Baltimore Metro study area consists of hardened shorelines and there are minimal natural floodplains. There are several areas that are openly exposed to flooding. The study areas fall within the Patapsco River estuary where the main component of flooding is caused by excessive runoff from impervious surfaces. In some instances, tidal storm surges can occur in some locations throughout the study area. Tidal storm surge is a result of constant, sustained winds pushing the water column landward from low elevations to high elevations due to coastal storms and hurricanes.

2.4.4.1 FWOP Condition

The floodplain is expected to move inland as sea level rises. Refer to Appendix B: Hydrology and Hydraulics Analysis, for the Federal Emergency Management Agency's (FEMA) Coastal Modeling.

2.4.5 Hazardous Materials and Wastes

According to the USEPA EJScreen report (USEPA, 2020), there are 34 hazardous waste treatment, storage, and disposal facilities (TSDF) within the 1-mile radius of the Baltimore Metro study area. Six similar facilities exist within the MSA 1-mile radius study area.

A Hazardous, Toxic, Radioactive Waste (HTRW) Investigation Report was completed by CENAB in March 2022 and can be found in Appendix G. CENAB reviewed Federal environmental records, State and Tribal environmental records, Environmental Data Resources, Inc (EDR®) proprietary records, aerial photographs, city directory abstract and historical topographic maps. The EDR® report includes properties within a one-quarter mile radius of the study area as required by American Society for Testing and Materials (ASTM) E1527-13. Several areas are identified in the EDR® report as having a history of contamination events. Numerous waste generators were listed within the MSA study area and range from Large Quantity Waste Generators to Very Small Quantity Waste Generators. The report identified Underground Storage Tanks (USTs) and Above Ground Storage Tanks (AGSTs) as containing heating oil, diesel fuel, gasoline, aviation jet fuel, used oil, and motor oil within the MSA study area. There have been cases of spills resulting in contamination of the soil and groundwater as well. Continued actions have occurred at MSA to investigate the extent of the presence of total petroleum hydrocarbon, volatile organic compounds (VOCs), semi volatile organic compounds, inorganic compounds, and PCBs in the groundwater and the soil. In addition, in 2000, a contractor uncovered pieces of unexploded ordnance at MSA. The Army's Explosive Ordnance Division investigated and found the items to be unfused, unarmed, and contained inert material. Any ground disturbance would need to take into consideration the location of the waste generators and any possible contamination in the path of the construction.

Additionally, there are several marine terminals and industrial complexes surrounding the entrance points of the Baltimore Harbor Tunnel and the Fort McHenry Tunnel. Many of these areas are listed in one or more of the above-mentioned categories. Due to the age of some of the existing properties within Baltimore City, there is a potential for asbestos and lead paint-containing material within some of the properties. The exact locations and properties would not be known until initial inspections take place as the project progresses.

2.4.5.1 FWOP Condition

Under the No Action Alternative/FWOP, the chance for hazardous materials and wastes to infiltrate the Chesapeake Bay or public water supply remains a threat during flooding events. Hazardous materials and wastes, including gases and oils from the motor vehicles, USTs, AGSTs can continue to impact the Bay and other local waterways during flooding events.

2.4.6 Transportation and Navigation

The City of Baltimore uses multi-modal transit systems throughout the study area and includes local and commuter buses, light rail, metro subway, Maryland Area Regional Commuter (MARC) train service, and a paratransit mobility system. Additionally, MDTA is responsible for maintenance of freight rail lines in Maryland and Delaware. Baltimore City currently has 60 bus lines that serve the City's transportation needs and include high

frequency lines such as CityLink, LocalLink, and Express BusLink routes, which connect surrounding suburbs to downtown Baltimore. The Charm City Circulator is a free and widely used bus system that allows visitors and residents to travel throughout the city (Visit Baltimore, 2022). The Baltimore Metro system is comprised of 14 stations over 15.5 miles, from Owings Mills through downtown Baltimore to Johns Hopkins Hospital. The system is used to connect communities to major sports events, universities, and government and private businesses throughout the Baltimore City area. Each station contains at least one street level entrance at each end that leads down to the Mezzanine level via stairs, elevators, or escalators (Jacobs, 2006).

Several major interstates and highways intersect or bypass the Baltimore study area. I-895 and I-95 are vital interstates that connect commuters from southwest of Baltimore City to northeast via the Baltimore Harbor Tunnel and Fort McHenry Tunnels. The tunnels were completed and opened for public use in 1957 and 1985, respectively. The Baltimore Harbor Tunnel receives approximately 27.6 million vehicles per year, while the Fort McHenry Tunnel receives about 45.4 million vehicles per year (commuting both directions) (MDTA, 2021).

The MSA is located on a small peninsula adjacent to the Middle River with the nearest intersecting roadways being Eastern Boulevard (MD-150) and White Marsh Boulevard (MD-43), which ends directly outside of the airport's main gate. Strawberry Point Road and Lynbrook Road are located on either side of the airport and allow access to the airport's business park. During a traffic count study in 2020, MDOT State Highway Administration calculated approximately 5,315 cars traveling on Strawberry Point Road over a 48-hour period (MDOT SHA, 2021). Additionally, the MARC rail line runs perpendicular to MSA and contains a stop for commuters to board and un-board the train directly outside of the airport's main entrance.

The Port of Baltimore is operated by the Maryland Port Administration and is one of the largest port facilities on the eastern seaboard. Some of the leading cargo and transportation businesses in the world use the Port of Baltimore to transport goods and services and include Maersk Edinburgh, General Electric/Haier, Evergreen Line, Volkswagen, and Mercedes-Benz. The Port has five terminals: Dundalk Marine Terminal, Seagirt Marine Terminal, Fairfield Marine Automobile Terminal, North Locust Point, and South Locust Point (MPA, 2021).

2.4.6.1 FWOP Condition

Under the No Action Alternative/FWOP, areas such as the Inner Harbor and MSA would continue to experience localized flooding driven by high tides, coastal storms, and regular meteorological events. Local roadways would continue to be temporarily closed by flooding events, which would affect local businesses, commuter traffic, and tourism. Both the Fort McHenry and Baltimore Tunnels would continue to be susceptible to coastal flooding, particularly the MDTA-owned buildings that house mechanical and electrical

support systems for the tunnels. Secondary and tertiary effects target the Port of Baltimore – Seagirt Terminal, and emergency air operations at the MSA. The former may continue to be vulnerable to coastal flooding in a FWOP condition. A wide array of vehicles, commercial, industrial, and agricultural machines and equipment remain susceptible to potential flood waters. Additionally, emergency air operations at the MSA may be stalled in the event of a coastal flooding event, inhibiting access to the helipad that houses the Maryland State Police 'MEDEVAC' helicopter.

2.4.7 Noise

To ensure a suitable living environment, the Department of Housing and Urban Development has developed a noise abatement and control policy, as seen in 24 CFR Part 51 – Environmental Criteria and Standards. According to this policy, noise not exceeding 65 decibels A (dBA) is considered acceptable. Noise above 65 dBA, but not exceeding 75 dBA is normally acceptable, but noise above 75 dBA is unacceptable. Normal freeway traffic noise levels range from 70 to 90 dBA. The Bureau of Transportation Safety publishes the National Transportation Noise Map, showing approximate noise exposure. In the Baltimore Metropolitan area, the highest noise exposures occur along commuter rail lines, CSX tracks, and Interstates I-95, I-895, and I-83 (Figure 2-3). The MSA is the primary source for the highest noise exposure in its respective study area (Figure 2-4). The airport has developed a Noise Abatement Plan which is established pursuant to the Maryland Environmental Noise Act of 1974 (Transportation Article 5-819, Annotated Code of Maryland). The Plan is formulated to minimize noise disturbance to neighboring communities while maintaining airport operations (Martin, 2004).

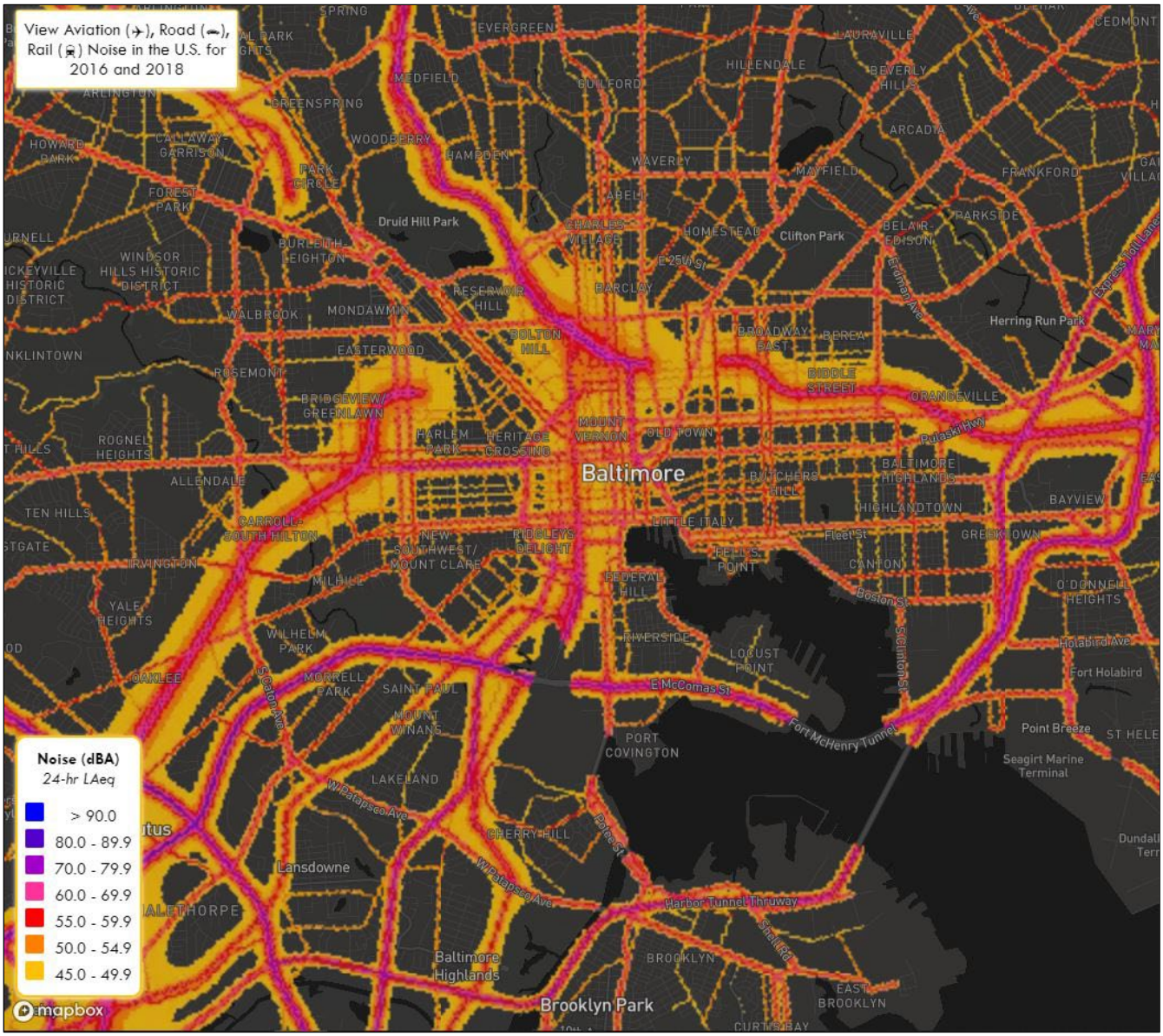

Figure 2-3. Noise Map of Baltimore Metropolitan area

Source: Bureau of Transportation Safety, 2018

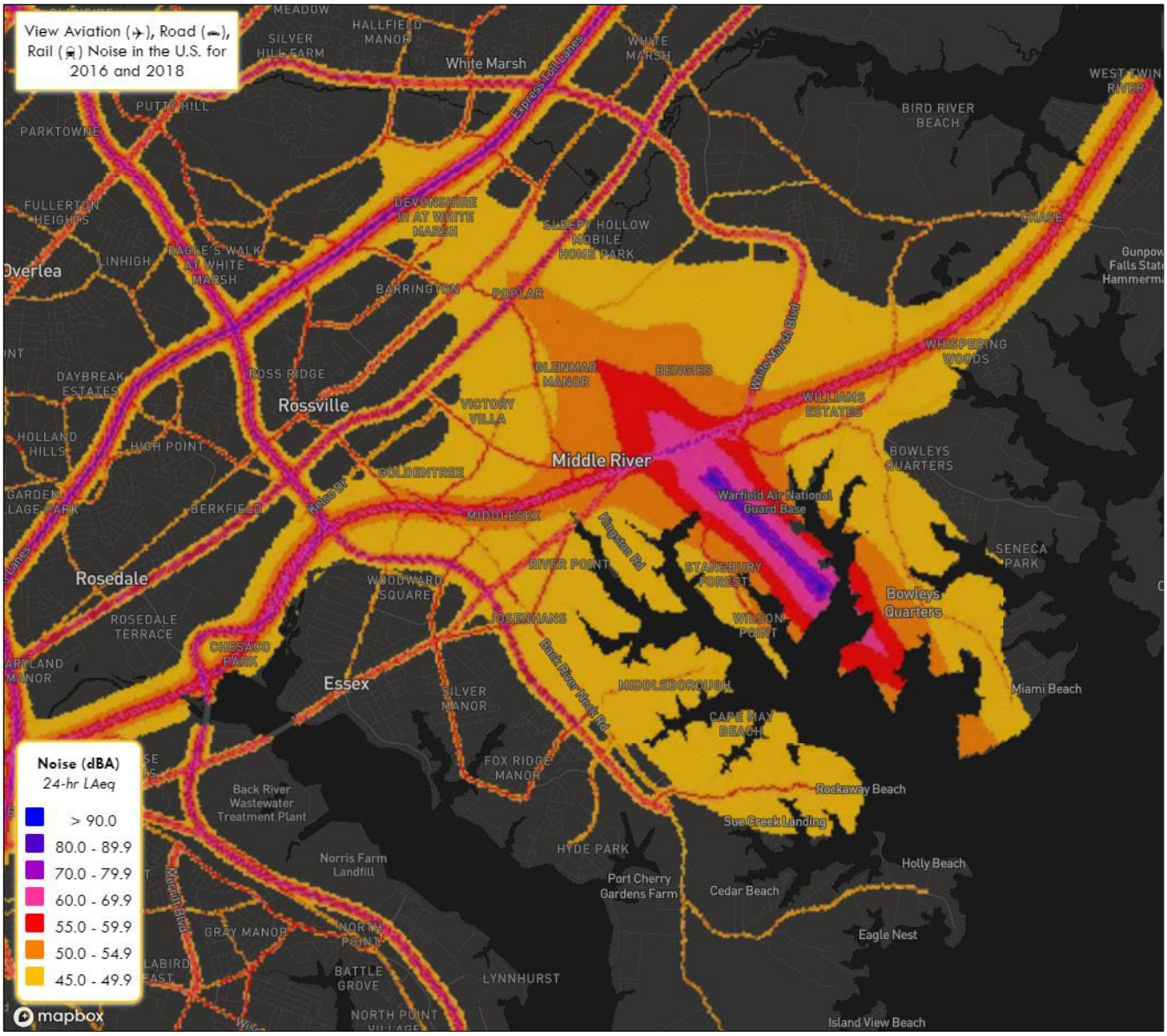

Figure 2-4. Noise Map of Martin State Airport

Source: Bureau of Transportation Safety, 2018

2.4.7.1 FWOP Condition

Under the No Action Alternative/FWOP, noise would remain the same or consistent with the continued urbanization and growth of the study area.

2.4.8 Air Quality

As of December 21, 2021, Baltimore City is in nonattainment for the 8-hour Ozone pollutant, based on the 2015 standard. Nonattainment means that an area is not meeting or is above a given safe standard set by the USEPA for the particular criteria pollutant (USEPA, 2021a). State agencies develop air quality plans, which are also referred to as

State Implementation Plans (SIPs), designed to attain and maintain National Ambient Air Quality Standards (NAAQS) set by the USEPA and to prevent significant deterioration of air quality in areas that demonstrate air that exceeds the NAAQS. Maryland has individual SIPs for various pollutants, including nitrogen dioxide (NO_2), particulate matter ($PM_{2.5}$), 8-hour ozone (O_3), regional haze, lead, etc. Federal agencies must ensure that their actions conform to the SIP in a nonattainment area, and do not contribute to new violations of ambient air quality standards, or an increase in the frequency or severity of existing violations, or a delay in timely state and/or regional attainment standards.

The purpose of the General Conformity Rule (GCR) is to:

- Ensure Federal activities do not interfere with the budgets in the SIPs
- Ensure the attainment and maintenance of NAAQS
- Ensure actions do not cause or contribute to new violations of NAAQS

A general air conformity analysis was completed (Appendix G) with respect to the 8-hour ozone NAAQS. The results of this analysis are summarized in Section 4.2.8.

2.4.8.1 FWOP Condition

The USEPA strengthened the health-based air quality standard for 8-hour ozone in Fall 2021, lowering the standards from 75 parts per billion (ppb) to 70 ppb. The updated standard will improve public health protection, particularly for at-risk groups such as children, older adults, and people with heart or lung diseases. Maryland has continued to enforce strong regulations and monitoring programs that introduce protective regulations and regional collaborations with assistance from the Maryland Department of the Environment (MDE) (MDE, 2022).

2.4.9 Greenhouse Gas Emissions

Human activities account for almost all the increase in greenhouse gas emissions within the atmosphere over the last 150 years. Greenhouse gas emissions continue to increase and build up in the atmosphere causing increased climate warming. Greenhouse gases are produced from five major sources: transportation, electricity production, industry, commercial and residential, and agriculture (USEPA, 2021b). According to a World Resources Institute Report published in 2020, Maryland leads the nation in the number of emissions reductions (38 percent) in a 12-year period (MDE, 2021 & WRI, 2020). Over the past ten years, Maryland has orchestrated an extensive set of plans, action strategies, and legal authorities, as well as worked with other local, state, and federal agencies in an attempt to mitigate and adapt to climate change. Below are some initiatives and plans that the State of Maryland has developed from 2006-2016.

Table 2-3. Maryland Climate Change Plans and Initiatives

Year of Action	Plan/Action/Order/Act	Description
2006	Healthy Air Act – MD joins Regional Greenhouse Gas Initiative (RGGI)	Require regulation of carbon monoxide emissions. RGGI – a cooperative effort among nine northeastern states to reduce carbon dioxide emissions from fossil fuel-fired power plants.
2007	Clean Cars Act Commission on Climate Change Executive Order	Require regulation of carbon monoxide emissions.
2008	Climate Action Plan	Created to develop a Climate Action Plan to limit climate change by reducing greenhouse gas emissions and guide the state's efforts to adapt to the changing climate.
2009	Greenhouse Gas Emissions Reduction Act (GGRA)	Established the commitment to reduce emissions by 25% by 2020
2012	Climate Change and Coast Smart Executive Order	Developed to apply siting and design criteria to avoid or minimize impacts associated with sea-level rise and coastal flooding on state-funded capital projects.
2016	Greenhouse Gas Emissions Reduction Act extended	Extended from the 2009 act to achieve the goal of reducing emissions by 40% by 2030.

2.4.9.1 FWOP Condition

In 2022, Maryland passed a significant environmental bill into law, called the Climate Solutions Now Act. The law calls for a 60 percent reduction in climate-warming carbon emissions by 2031 and net-zero emissions by 2045. This Act is one of the most ambitious greenhouse gas reductions of any state in the nation. Notable requirements within the Act include improving the energy efficiency of large existing builds; thus, reducing carbon emissions. By 2030, all state facilities would be required to get at least 75 percent of their electricity from low-to zero-carbon sources. A five million dollar fund for climate projects was established in the Act and directed 40 percent to be spent in low-to moderate income neighborhoods (Wheeler, 2022).

2.4.10 Coastal Zone Management Program (CZMP)

The Coastal Zone Management Program (CZMP) includes goals to protect coastal land and water habitat. The program is a partnership among local, regional, and State agencies to ensure proposed Federal activities are consistent with Maryland's resource goals and policies. According to the National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management, Section 307 of the "Coastal Zone Management Act of 1972", called the "federal consistency" provision, gives states an opportunity to coordinate with Federal agencies within the decision-making processes for activities that may affect a state's coastal uses or resources. The Federal consistency provision is a major incentive for states to join the National CZMP and is a tool that state programs use to manage coastal activities and resources, as well as facilitate cooperation and coordination with Federal agencies.

The Federal consistency requires that any Federal actions, within and outside the coastal zone, that may have future effects on any coastal use (land or water), or natural resource of the coastal zone be consistent with the enforceable policies of a state's federally approved coastal management program. NOAA states, "Federal actions include federal agency activities, federal license or permit activities, and federal financial assistance activities. Federal agency activities must be consistent to the maximum extent practicable with the enforceable policies of a state coastal management program, and license and permit and financial assistance activities must be fully consistent" (National Oceanic and Atmospheric Administration [NOAA], 2021). Baltimore City and Baltimore County are both listed as Coastal Zone counties and may be subject to some of the Program's enforceable policies to coastal resources and uses, such as the Chesapeake and Atlantic Coastal Bays Critical Area, historical and archeological sites, and transportation. More information on Maryland's Coastal Zone Management Act (CZMA) and policy checklists can be found in Appendix G.

2.4.10.1 FWOP Condition

Under the No Action Alternative/FWOP, Maryland would continue coordination efforts with Federal agencies in an effort to ensure any new activities comply with the CZMA.

2.4.11 Chesapeake Bay Critical Area

In 1984, the Maryland General Assembly enacted the Critical Area Act to address the increasing pressures placed on Chesapeake Bay resources from an expanding population. The Act defines a critical area as "all land within 1,000 feet of the MHW [mean high water] Line of tidal waters or the landward edge of tidal wetlands and all waters of and lands under the Chesapeake Bay and its tributaries".

The Critical Area Law mandates that local governments preserve "Habitat Protection Areas", which include nontidal wetlands and a surrounding 25-foot buffer; a 100-foot vegetated buffer zone on the landward edge of tidal waters, wetlands, or tributary streams; threatened and endangered species and their habitat; significant plant and

wildlife habitat; and anadromous fish spawning areas. Significant plant and wildlife habitat is defined as colonial water bird nesting areas, historic waterfowl concentration areas, riparian forests, undisturbed forest tracts (100 acres or more) containing breeding populations of forest interior-dwelling birds, areas that contain the “best examples” of plant and animal communities, and other areas determined to have local significance. The Critical Area Law also categorizes land as IDAs, LDAs, or RCAs, and regulates development that can occur in each. Baltimore City is located within the IDA and RCA. The MSA study area is located within the LDA and IDA (Figure 2-5). Habitat used by rare, threatened, or endangered species can be protected under critical area regulations (MDDNR, 2004).

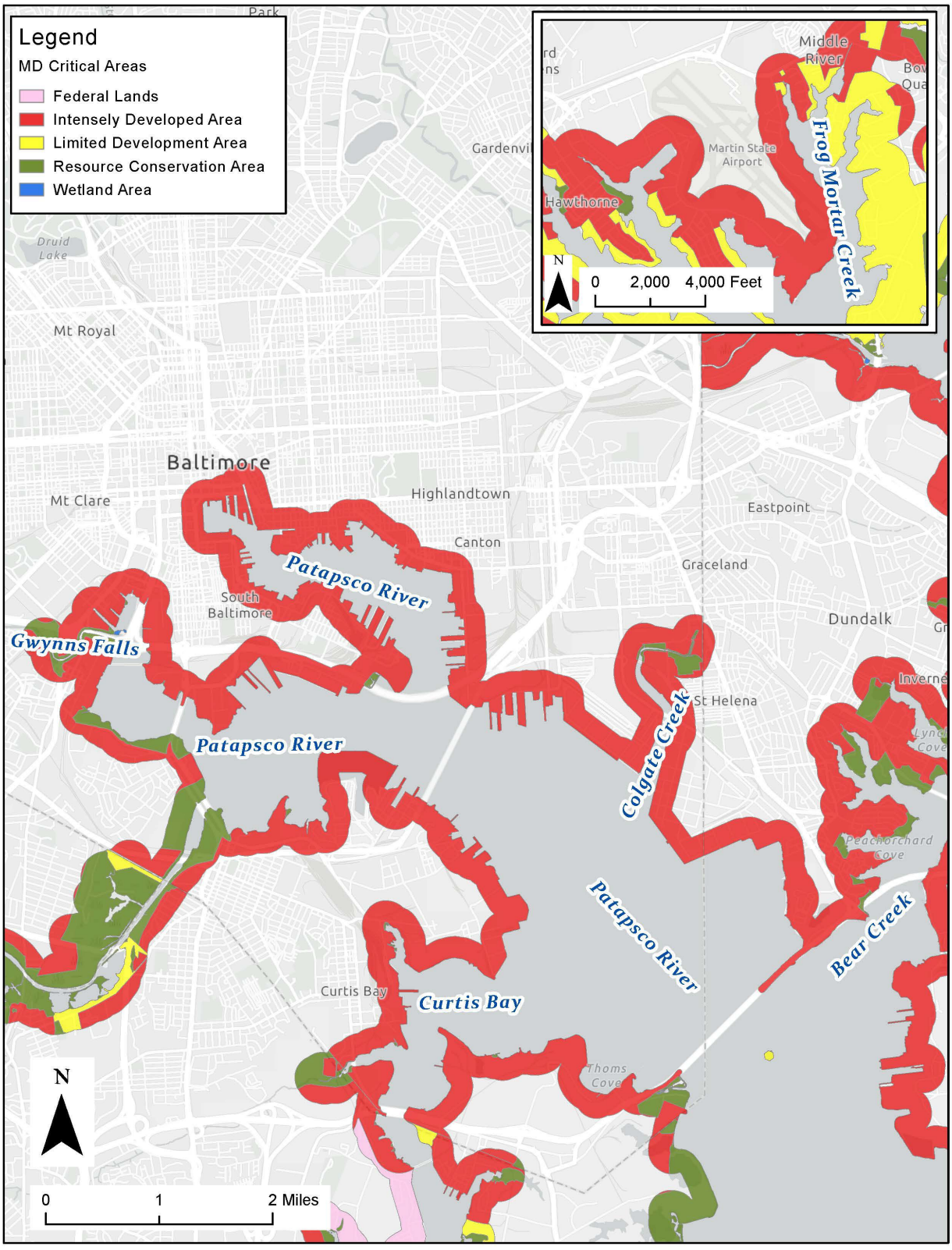

Figure 2-5 Critical Areas of Baltimore City and Martin State Airport

2.4.11.1 FWOP Condition

Future development within both Baltimore and MSA study areas is anticipated within the Chesapeake Bay Critical Area as stated in Section 2.4.1. Any new development or activities taking place in the Critical Area will have to comply with Maryland or Baltimore City Critical Area regulations.

2.4.12 Climate Change and Sea Level Change

Although initiatives have been developed to combat climate change at a regional scale, the City of Baltimore continues to deal with climate-related issues. Nuisance flooding, also known as tidal flooding or high tide flooding, is an issue that portions of Baltimore continue to experience. Nuisance flooding causes public inconveniences, such as road closures, blocks access to homes and businesses, and can lead to significant trash accumulation following its recession. Nuisance floods can be caused by a variety of weather-related events, including astronomically influenced extreme high tide cycles, long-sustained off-shore winds, and coastal storm systems. NOAA predicts that Baltimore could experience as many as 50-160 nuisance flooding events by 2050 (NOAA, 2019). Areas around Baltimore that have been most impacted by nuisance flooding are Lower Fells Point and areas along the Inner Harbor promenade. However, with climate change affecting sea-level rise in the near future, other areas that are expected to be influenced by flooding include, Canton, Locust Point, Middle Branch, Port Covington, Westport, Fairfield and Curtis Bay. All these areas have been identified as vulnerable locations and residential, commercial, industrial, and government properties all exist within these areas and could potentially be affected.

The MSA is also susceptible to climate change and SLR due to its proximity to Middle River, Frog Mortar Creek, and Stansbury Creek. A flood preparedness and response plan was prepared by CENAB in 2005, which identified the airport's susceptibility to coastal and tidal flooding. Several of the airport's hangars, administration buildings, and Marine Police Units were shown to be susceptible to flood damage during a 100-year storm event. An investigation performed by URS Greiner, Inc in 1998, found that the 100-year floodplain elevation at MSA was at 10.0-feet above mean sea level (MSL) and the 500-year floodplain elevation at 12.0 feet above sea level. Most of the buildings or units on the property range from 4-9 feet above MSL (MTN, 2005).

2.4.12.1 FWOP Condition

As part of its water resources management missions and operations, USACE has been working together with other federal agencies, academic experts, nongovernmental organizations, and the private sector to translate climate science into actionable science for decision-making. The USACE Civil Works Program has developed tools to analyze the potential effects and uncertainties associated with climate change and SLC relative to the USACE portfolio.

Engineering Construction Bulletin (ECB) no. 2018-14 provides guidance for incorporating climate change information in hydrological analysis in accordance with the USACE overarching climate change adaptation policy (USACE 2018). It calls for a qualitative analysis. The goal of a qualitative analysis of potential climate threats and impacts to USACE hydrology-related projects and operations is to describe the observed present and possible future climate threats, vulnerabilities, and impacts of climate change specific to the study. This includes consideration of both past (observed) changes as well as potential future (projected) changes to relevant meteorological and hydrologic variables.

Below in Figures 2-6 and 2-7, the NOAA SLR Viewer was used as a tool to evaluate and understand what the effects of SLR would look like in the Baltimore and MSA study areas. Inundated areas are in blue, with deepest areas dark blue and a gradation to shallower areas shown in lighter blues. Areas in green are low-lying. The NOAA SLR viewer is a preliminary analysis and can be used for feasibility studies. The maximum observed water level for Baltimore was at 6.49-feet mean higher high water (MHHW) during Hurricane Isabel on September 19, 2003.

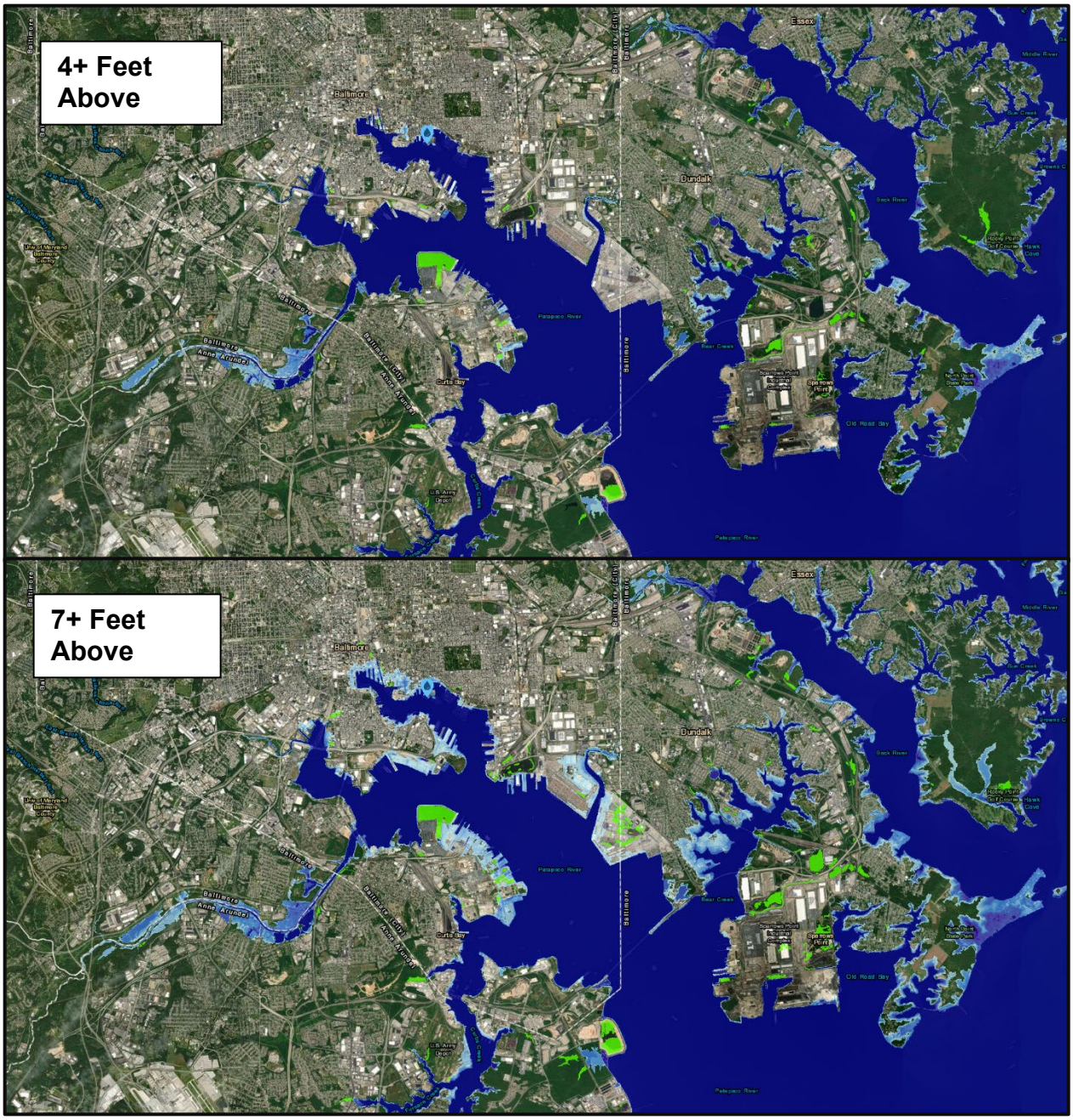

Figure 2-6. Sea Level Rise Viewer of Baltimore Study Area

The top figure shows the Baltimore Study Area at MHHW +4 feet of Sea Level Rise.

The bottom figure shows the existing water level at Mean High Higher Water +7 feet (epoch: 1983-2001) (NOAA 2022).

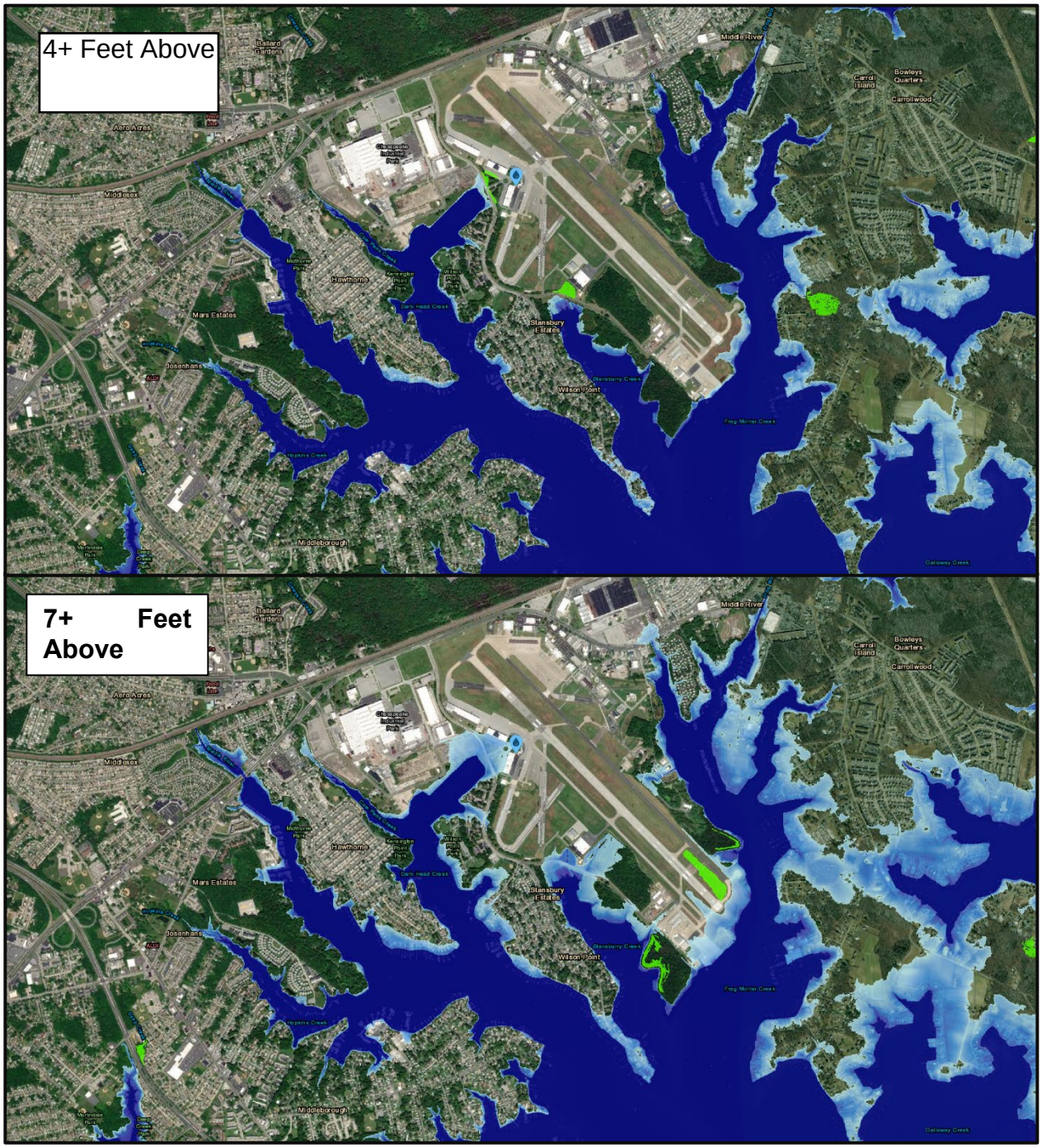

Figure 2-7. Sea Level Rise Viewer of Martin State Airport Area
The top figure shows the Martin State Airport Area at MHHW +4 feet of SLR. The bottom figure shows the existing water level at Mean High Higher Water +7 feet (epoch: 1983-2001) (NOAA 2022).

2.4.13 Cultural Resources

This section identifies and describes the cultural resources within the study's area of potential effects (APE) that are either eligible for or listed in the National Register of Historic Places (NRHP).

Cultural resources are locations of human activity, use, or occupation. They can be defined by expressions of human culture and history in the physical environment such as prehistoric or historic archaeological sites, buildings, structures, objects, districts, sacred sites, among others. Cultural resources may also include natural features, plants, and animals that are deemed important or significant to a group or community. It is important to note that historic properties, as defined by 36 CFR Part 800, the implementing regulations of Section 106 of the National Historic Preservation Act (NHPA) of 1966, as amended, are cultural resources that are eligible for or listed in the NRHP. Additionally, to be considered a historic property, the resource must possess at least one of the following significance criteria:

- Association with events that have made a substantial contribution to the broad patterns of our history; or,
- Association with the lives of persons substantial in our past; or,
- Embodiment of the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic value, or that represent a substantial or distinguishable entity whose components may lack individual distinction; or,
- Have yielded, or may be likely to yield, information important in prehistory or history.

A historic property must also possess enough integrity to portray its significance. A resource that retains integrity will embody several, and usually most, of the seven aspects of integrity:

- *Location* is the place where the historic property was constructed or the place where the historic event occurred.
- *Design* is the combination of elements that create the form, plan, space, structure, and style of a property.
- *Setting* is the physical environment of a historic property.
- *Materials* are the physical elements that were combined or deposited during a particular period of time and in a particular pattern or configuration to form a historic property.
- *Workmanship* is the physical evidence of the crafts of a particular culture or people during a given period in prehistory or history.
- *Feeling* is a property's expression of aesthetic or historic sense of a particular period of time.

- *Association* is the direct link between an important historic event or person and a historic property.

Section 106 of the NHPA requires consultation with the State Historic Preservation Office (SHPO), federally recognized Native American tribes, and other interested consulting parties for proposed federal actions that may affect historic properties. The Maryland Historical Trust (MHT) is designated as the SHPO for Maryland. USACE initiated Section 106 consultation via letter dated February 3, 2022, with MHT, Baltimore City Commission for Historical and Architectural Preservation, Baltimore County Department of Planning, Delaware Nation, Delaware Tribe of Indians, and the Seneca-Cayuga Tribe of Oklahoma.

As part of Section 106 consultation, a preliminary APE was defined to identify any potential historic properties that could be affected by the proposed project alternatives. The preliminary APE includes those areas where direct impacts are proposed and areas within which the undertaking may directly or indirectly cause alterations in the character or use of historic properties, including visual effects. For this project the preliminary direct APE includes construction areas of proposed levee, floodwall, and any associated staging areas. The preliminary indirect APE includes the viewsheds of any nearby historic properties.

The potential for historic properties within the direct and indirect APEs was assessed primarily using MHT's cultural resources information database, Medusa. Information gathered from Medusa included files pertaining to previously mapped archaeological and architectural/above-ground resources within 0.5 miles of the APE. These are listed and discussed in Section 2.4.14.1 below.

2.4.13.1 Archaeological and Architectural/Above-Ground Resources

USACE used Medusa to gather existing information on previously identified archaeological and architectural/above-ground resources within 0.5 miles of the APE associated with structural measures. This information is presented in Table 2-4, and only resources noted as potentially eligible for, eligible for, or listed in the NRHP are featured below.

One hundred and thirty-seven (137) historic properties are located within 0.5 miles of the project alternatives, consisting of individual properties and historic districts; however, many individual resources or resources contributing to historic districts remain unevaluated for the NRHP. Factoring in unevaluated resources, the total number of resources within 0.5 miles expands to 693. Of the 137 historic properties within 0.5 miles, 31 are within, or in the immediate vicinity of, the currently proposed alternative alignments.

Table 2-4. Archaeological and Architectural/Above-ground Resources within 0.5 miles of APE

MIHP/Archaeological Site Number	Resource Name	NRHP Eligibility
B-3685	Coca-Cola Company Baltimore Branch	Listed
B-8	Fort McHenry National Monument & Historic Shrine	Listed
B-1367	Baltimore & Ohio Locust Point Grain Terminal Elevator	Listed
B-5223	Locust Point Historic District	Listed
B-4584	Bridge 8022	Eligible
B-1343	USS SANCTUARY	Eligible
B-5094	Naval Reserve Readiness Center, Building 3, Fort McHenry	Eligible
B-5333	Baltimore Harbor Tunnel	Eligible
B-4611	S.S. John W. Brown	Listed
B-5268	Clinton Street Marine Terminal Pier 1	Eligible
B-985	Canton Grain Elevator	Eligible
B-5298	Western Electric Company, Point Breeze Plant Historic District	Eligible
B-3603	Baltimore Municipal Airport, Harbor Field	Eligible
B-3935	Business and Government Historic District	Listed
B-1400	Little Montgomery Street Historic District	Listed
B-4112	U.S.S. TORSK (submarine)	Listed
B-5139	Riverside Historic District	Listed
B-11	Otterbein Church	Listed
B-29	U.S.S. CONSTELLATION	Listed
B-5313	Union Brothers Furniture Company	Listed
B-3713	Federal Hill Historic District	Listed
B-3718	CHESAPEAKE (lightship)	Listed
B-5092	Federal Hill South Historic District	Listed
B-79	Howard Street Tunnel	Listed
B-4222	Seven-Foot Knoll Lighthouse	Listed
B-1021	Pratt Street Power Plant	Listed
B-4289	Southern District Police Station	Listed

MIHP/Archaeological Site Number	Resource Name	NRHP Eligibility
B-2934	Leadenhall Street Baptist Church	Listed
B-36	United States Custom House	Listed
B-5081	Holy Cross Church Complex	Listed
B-4200	U.S.C.G. TANEY (WHEC-37)	Listed
B-1042	Baltimore Copper Paint Company	Eligible
B-148	Camden Station	Eligible
B-5286	George Hyde (G.H.) Fallon Federal Building	Eligible
B-5319	Sheppard Katzenstein Building/Moses Sheppard House	Eligible
B-5318	U.S. Fidelity and Guaranty (USF&G) Building	Eligible
B-3687	Merchants & Merchants National Bank, site	Eligible
B-15	Flag House	Listed
B-61	St. Vincent de Paul Church	Listed
B-3691	St. Leo's Church	Listed
B-5098	South Central Avenue Historic District	Listed
B-3709	Continental Trust Company Building	Listed
B-3726	United States Post Office and Courthouse	Listed
B-33	Zion Lutheran Church	Listed
B-60	Baltimore City Hall	Listed
B-4293	239 North Gay Street	Listed
B-3706	Chamber of Commerce Building	Listed
B-40	Mercantile Trust and Deposit Company	Listed
B-42	Eastern Female High School	Listed
B-9	Old Town Friends' Meeting House	Listed
B-117	Alex Brown Building	Listed
B-3714	Fells Point Historic District	Listed
B-3705	Canton House	Listed
B-1020	Hendler Creamery	Listed
B-3707	Chizuk Amuno Synagogue	Listed

MIHP/Archaeological Site Number	Resource Name	NRHP Eligibility
B-14	Battle Monument	Listed
B-4294	Old Town Savings Bank	Listed
B-3688	Garrett Building	Listed
B-13	Peale's Baltimore Museum	Listed
B-16	Shot Tower	Listed
B-3741	President Street Station	Listed
B-3699	Baltimore Branch of the Federal Reserve Bank of Richmond	Listed
B-1011	Bagby Furniture Company Building	Listed
B-3994	Gay Street Historic District	Listed
B-19	McKim's School	Listed
B-1002	Candler Building	Eligible
B-5054	Harford Run Headwall & Drain, under Central Avenue	Eligible
B-5283	North Gay Street Survey Area	Eligible
B-2784	Jonestown Historic District	Eligible
B-1047	Eastern Avenue Pumping Station	Eligible
B-1099	William G. Scarlett Seed Company (South Building), site	Eligible
B-5192	Jones Falls Conduit	Eligible
B-5121	Little Italy Historic District	Eligible
B-4285	BALTIMORE (tug)	Listed
B-3694	Douglass Place	Listed
B-3700	BANCROFT (motor vessel)	Listed
B-3928	Public School No. 25	Listed
B-1009	Procter and Gamble Baltimore Plant	Listed
B-5055	Hercules Company Office Building	Eligible
B-3704	Canton Historic District	Listed
B-5123	Upper Fells Point Historic District	Listed
B-3703	Butchers Hill Historic District	Listed
B-5122	Holy Rosary Roman Catholic Church Complex	Eligible

MIHP/Archaeological Site Number	Resource Name	NRHP Eligibility
B-4607	Patterson Park	Eligible
B-3704-1	St. Brigid's School and Covent	Listed
B-996	The National Brewing Company	Listed
B-998	Gunther Brewing Company	Listed
B-5169	Highlandtown-Brewers Hill Historic District	Listed
B-992	Atlantic Southwestern Broom Company	Eligible
B-5161	Kauffman Electric Company	Eligible
B-1013	Maryland White Lead Works	Listed
B-5309	Gould Street Generating Station	Eligible
B-1394	Pigtown Historic District	Listed
NR	Equitable Gas Works	Listed
B-1086	Hanline Paint Company	Eligible
B-1025	United Railway & Electric Carroll Park Shops	Eligible
B-1342	Westport Historic District	Eligible
B-1097	Baltimore Novelty Steam Boiler Works	Eligible
B-1062	Westport Power Station	Eligible
B-3668	Spring Garden Bridge	Eligible
BA-2081	Glenn L. Martin Airport	Eligible
BA-2824	Glenn L. Martin Company Plant No. 2	Eligible
BA-2094	Baltimore Municipal Airport, Air Station	Eligible

2.4.13.2 FWOP Condition

Significant cultural resources would likely be affected by ongoing coastal flooding and SLR under the FWOP condition.

2.4.14 Socioeconomics

Socioeconomics describes a community by examining its social and economic characteristics. Demographic variables such as population size, level of employment, and income range assist in analyzing the fiscal condition of a community and its government, school system, public services, healthcare facilities and other amenities. For this study, a one-mile radius was added to the proposed Region of Interest (ROI) (see figures in section 2.4.15) from the study area boundaries. The total population and population breakdown by ethnicity based on data from the 2019 American Community Survey (ACS) are shown on Table 2-5 for the ROI and compared with Baltimore City, Baltimore County, the State of Maryland, and the United States (USCB, 2019). The population in the ROI is estimated to be 107,380 and is provided from the USEPA EJScreen ACS Summary Report 2014-2018 (USEPA EJScreen, 2022).

Table 2.5. Study Area Demographic Characteristics

Geographic Area	Total Population	Ethnicity						
		White	Black	American Indian	Asian	Pacific Islander	Other	Two or More
Baltimore City ROI	107,380	64,976 (61%)	31,723 (30%)	503 (0%)	4,631 (4%)	66 (0%)	2,082 (2%)	3,399 (3%)
Baltimore City	609,032	185,489 (31%)	379,751 (62%)	1,732 (0%)	15,693 (3%)	229 (0%)	10,972 (2%)	15,166 (2%)
Martin State Airport ROI	12,255	8,891 (73%)	2,597 (21%)	104 (1%)	114 (1%)	30 (0%)	126 (1%)	393 (3%)
Baltimore County	828,018	501,423 (61%)	239,308 (29%)	2,460 (0%)	49,885 (6%)	726 (0%)	11,104 (1%)	23,112 (3%)
Maryland	6,018,848	3,343,003 (56%)	1,799,094 (30%)	16,762 (0%)	378,126 (6%)	3,034 (0%)	1,011 (0%)	206,692 (3%)
United States	324,697,795	235,377,662 (73%)	41,234,642 (13%)	2,750,143 (0%)	17,924,209 (6%)	599,868 (0%)	16,047,369 (5%)	10,763,902 (3%)

Table 2-6 below presents data on educational attainment for the ROI, Baltimore City, the State of Maryland, and the United States based on the 2019 ACS 5-year estimates.

Table 2.6. Education Attainment, 2019 ACS 5-Year Estimates

Level of Education	High School or equivalent, no college	Some college or Associate's Degree	Bachelor's degree or higher
Baltimore City ROI	14,854 (18%)	15,521 (19%)	42,881 (53%)
Baltimore City	15,956 (28.6%)	23,659 (42.0%)	9,619 (17.1%)
Martin State ROI	3,702 (43%)	2,787 (32%)	1,357 (16%)
Baltimore County	24,049 (33.2%)	31,589 (43.6%)	9,313 (12.9%)
Maryland	161,982 (30.6%)	219,949 (41.5%)	84,975 (16.0%)
United States	9,921,331 (32.7%)	13,168,280 (43.4%)	3,621,479 (11.9%)

Source: U.S. Census Data, Educational Attainment 2019 ACS 5-Year Estimates. Educational attainment for individuals aged 18-24 years old. The ROI data based on the USEPA EJScreen does not provide fractions of percentages.

Table 2-7 below shows the labor force, employment and unemployment estimates for ROIs, Baltimore city, Baltimore County, the State of Maryland, and the United States.

Table 2-7. Labor Force, Employment, and Unemployment. 2019 ACS Estimates

Area	Labor Force	Employed (%)	Unemployed (%)
Baltimore City ROI	63,586	69	31
Baltimore City	306,279	61.8	5.1
Martin State ROI	6,422	65	35
Baltimore County	446,676	64	2.8
Maryland	3,269,234	67.7	3.4
United States	164,629,492	63.4	3.4

Source: U.S. Census Data, Comparative Economic Characteristics, 2019 ACS 5-Year Estimates. The ROI data based on the EPA EJScreen does not provide fractions of percentages.

Table 2-8 below presents the percentage of the population under 5 years for age and percentage of the population over 64 years of age for the ROIs, Baltimore City, Baltimore County, the State of Maryland, and the United States.

Table 2-8. Population Breakdown by Age Groups

Area	Under 5 Years of Age (%)	Over 64 Years of Age (%)
Baltimore City ROI	6%	9%
Martin State ROI	6%	9%
Baltimore County	6%	17%
Baltimore City	6%	14%
Maryland	6%	15%
United States	6%	16%

2.4.14.1 FWOP Condition

Under the No Action Alternative/FWOP, socioeconomic trends would remain consistent within each representative area. However, a FWOP condition may lead to displacement of residents and communities based on severity and frequency of coastal flooding events.

2.4.15 Environmental Justice

Executive Order (EO) 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations" was signed in 1994, declaring that each federal agency make environmental justice (EJ) part of its mission. The USEPA defines environmental justice as the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation and enforcement of environmental laws, regulations, and policies. Analysis of EJ is initiated by determining the presence and proximity of "underserved communities", which are communities that have been systematically denied a full opportunity to participate in aspects of economic, social, and civic life. As of July 2021, USACE began implementing the Justice40 Initiative to civil works projects. The goal of the Justice40 Initiative is to deliver at least 40 percent of the overall benefits from Federal investments in climate and critical clean water and waste infrastructure for disadvantaged communities. The Justice40 Initiative prioritizes EJ in civil works areas that include design, construction, and operation phases of projects primarily for FRM, CSRM, and aquatic ecosystem restoration. (USACE, 2021).

In accordance with current EO's and initiatives, the UESPA EJ Screen was used to identify census block groups located within one mile of the Baltimore City and MSA study areas. One-hundred and sixty block groups were identified through this investigation. Of the 160 block groups, 88 census block groups were identified within the Baltimore City and MSA study areas (USEPA, 2022). EJ Screen 2021 data was used to identify block groups in the 80th percentile nationwide for percent low-income, minority, linguistically isolated, over age 64, and/or with less than a high school education. For the purposes of this analysis, the following definitions and descriptions apply:

Underserved Community. The term "underserved communities" refers to communities that have been systematically denied a full opportunity to participate in aspects of economic, social, and civic life. For purpose of this analysis, a community with a disproportionate percentage (80th percentile nationwide or above) of *any* of the following populations may be considered an underserved community:

- People-of-color population
- Low-income population
- Linguistically isolated population
- Population with less than high school education
- Population over age 64

People-of-Color Population. Refers to the proportion of individuals in a geographic area who are not non-Hispanic whites, as defined by the Census Bureau. Forty-three census block groups within the study area and 1-mile buffer are in the 80th percentile or greater nationally for percent people-of-color population (Figure 2-8)

Low-Income Population. Refers to the proportion of individuals in a geographic area whose income is at or below 200 percent of the poverty line, as defined by the Census Bureau. Forty-nine census blocks within the study area and 1-mile buffer are in the 80th percentile or greater nationally for percent of the population that is at or below 200 percent of the federal poverty line (Figure 2-9). For a household of 4 people, the 200 percent of the federal poverty level is equal to $53,000.

Linguistically Isolated Population. Refers to the proportion of households in a geographic area in which no one over the age of 14 speaks English "very well," as defined by the Census Bureau. Seventeen census blocks within the study area and 1-mile buffer are in the 80th percentile or greater nationally for percent of the population that is linguistically isolated (Figure 2-10).

Population with Less than High School Education. Refers to the proportion of individuals in a geographic area who are over age 25 and have not attained a high school diploma. Forty-nine census blocks within the study area and 1-mile buffer are in the 80th percentile or greater nationally for percent of the population over age 25 with less than a high school diploma (Figure 2-11).

Population over Age 64. Refers to the proportion of individuals in a geographic area who are age 64 or older. Twenty census blocks within the study area and 1-mile buffer are in the 80th percentile or greater nationally for percent of the population over age 64 (Figure 2-12).

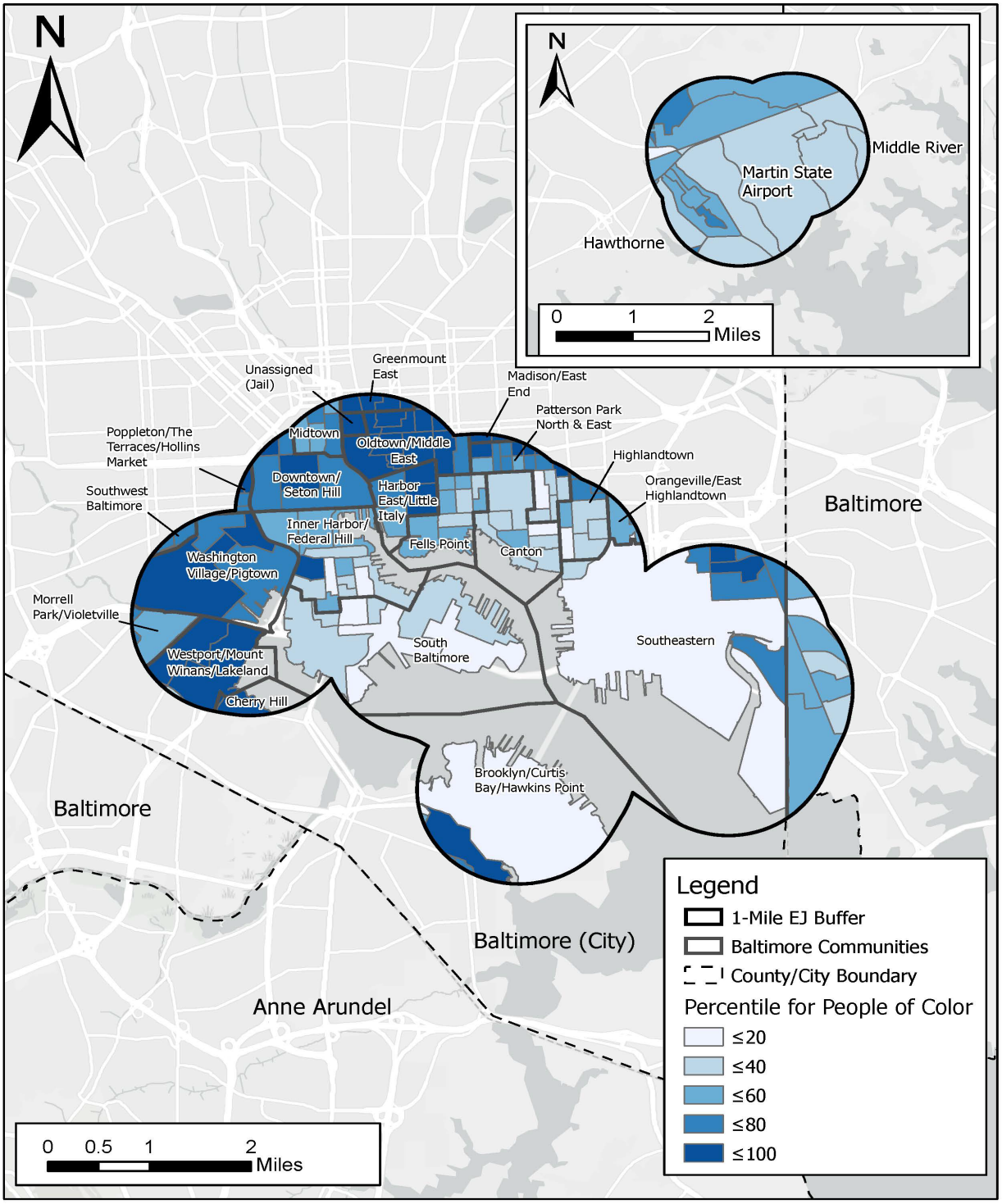

Figure 2-8. Census block groups located within the Baltimore City and MSA study areas with a one-mile buffer of the study areas, which represents the percent people of color population (percentile) in each census tract (USEPA, 2022)

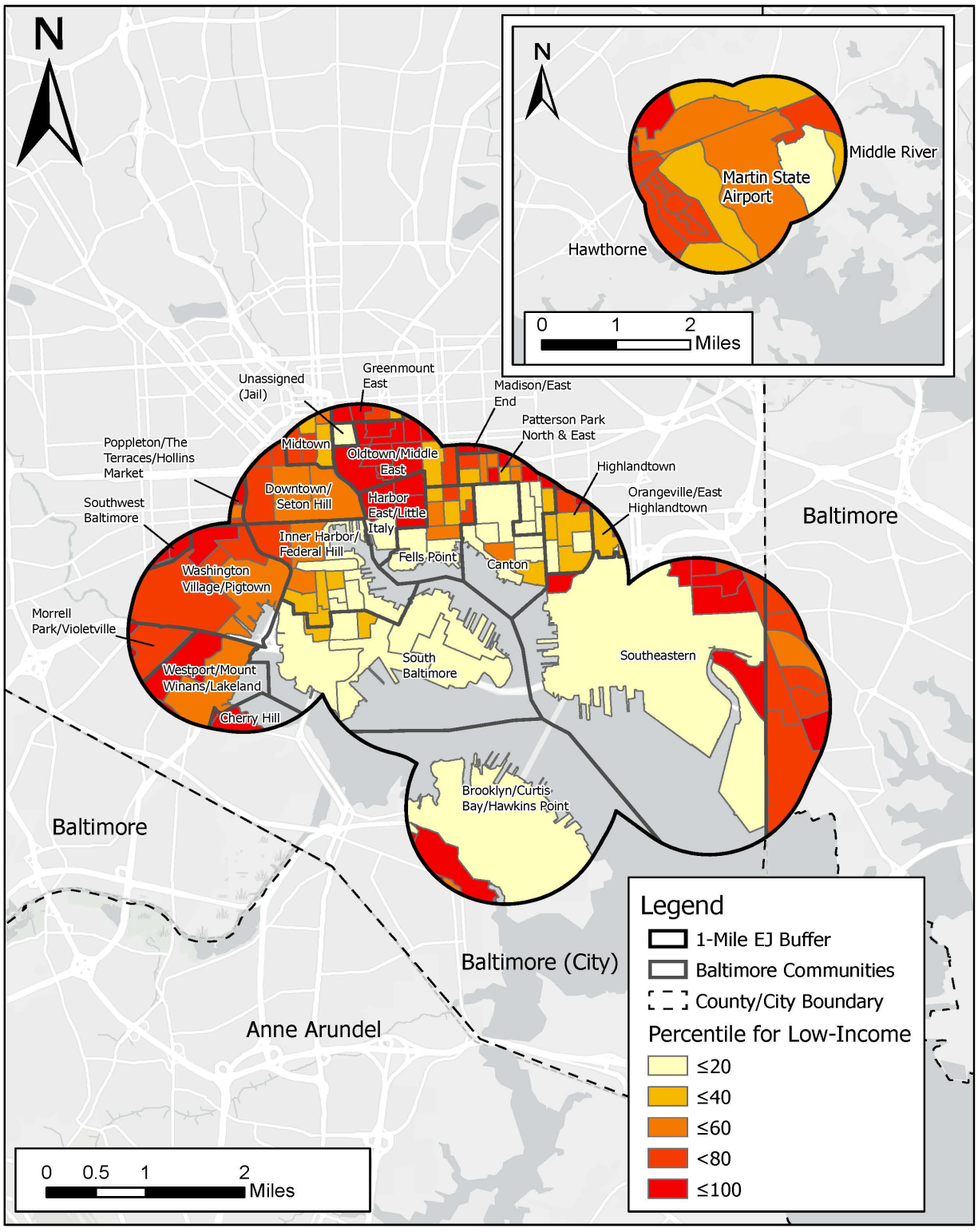

Figure 2-9. Census block groups located within the Baltimore City and MSA study areas with a one-mile buffer of the study areas, which represents the percent low-income population (percentile) in each census tract (USEPA, 2022)

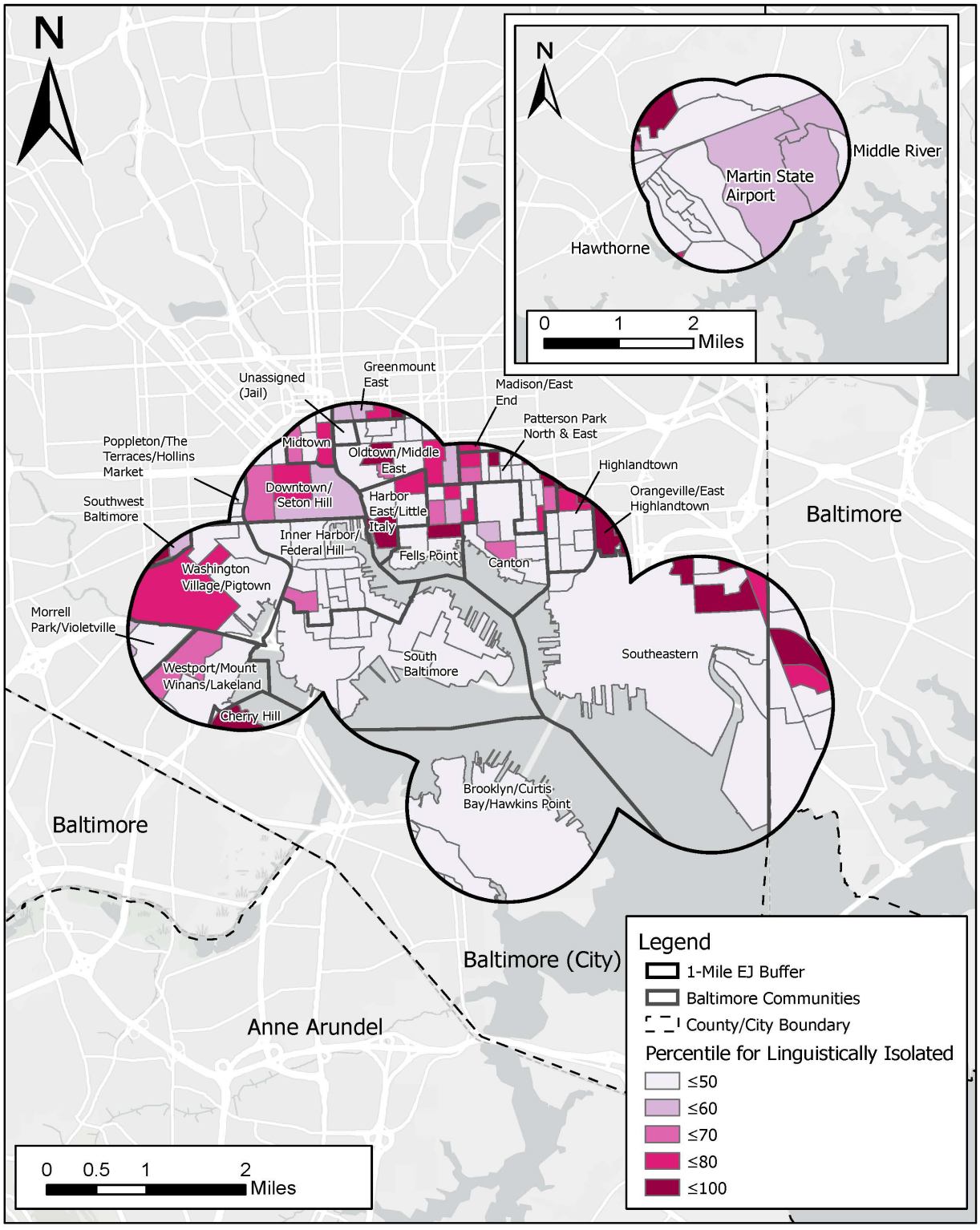

Figure 2-10. Census block groups located within the Baltimore City and MSA study areas with a one-mile buffer of the study areas, which represents the percent linguistically isolated population (percentile) in each census tract (USEPA, 2022)

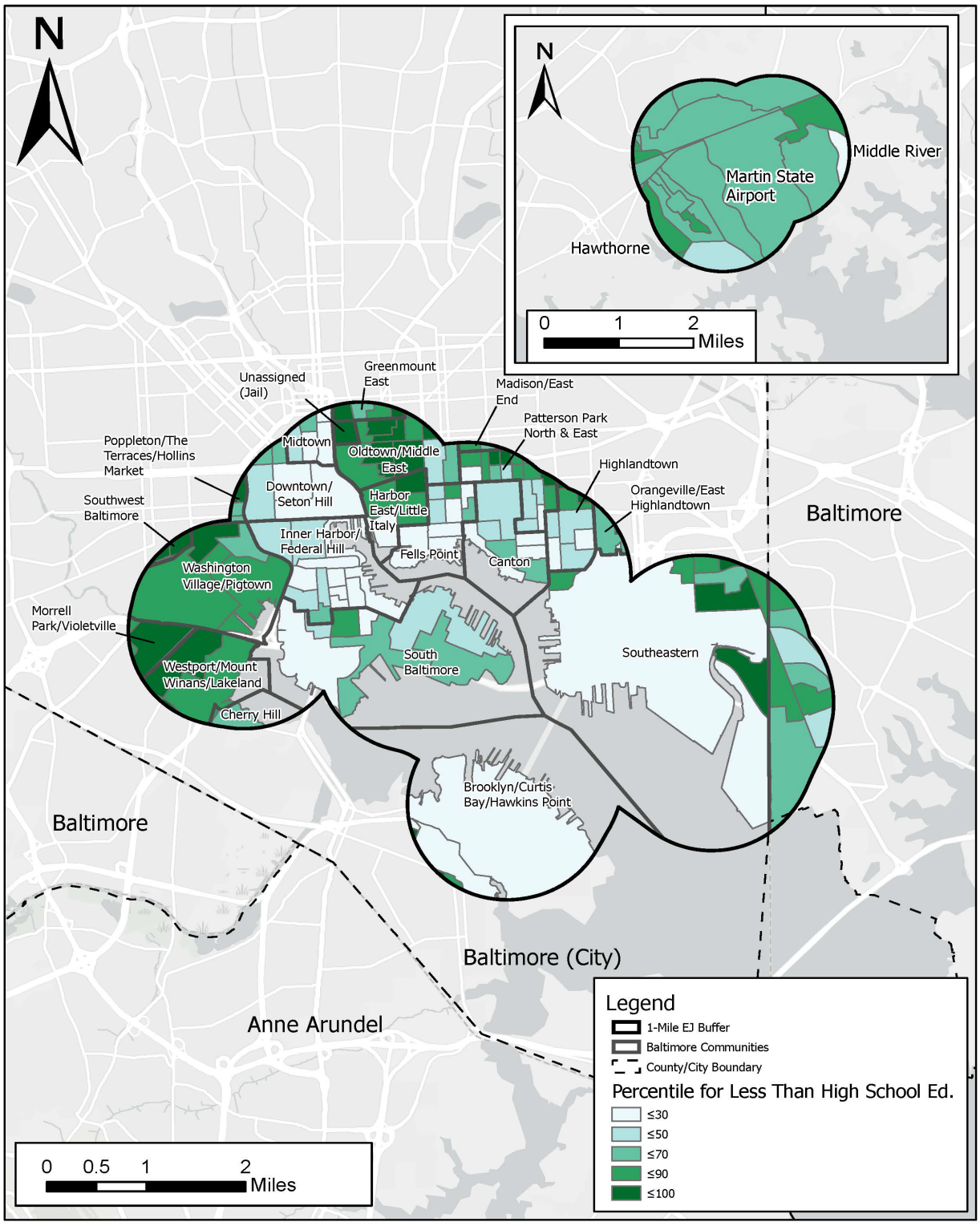

Figure 2-11. Census block groups located within the Baltimore City and MSA study areas with a one-mile buffer of the study areas, which represents the percent population with less than a high school education (percentile) in each census tract (USEPA, 2022)

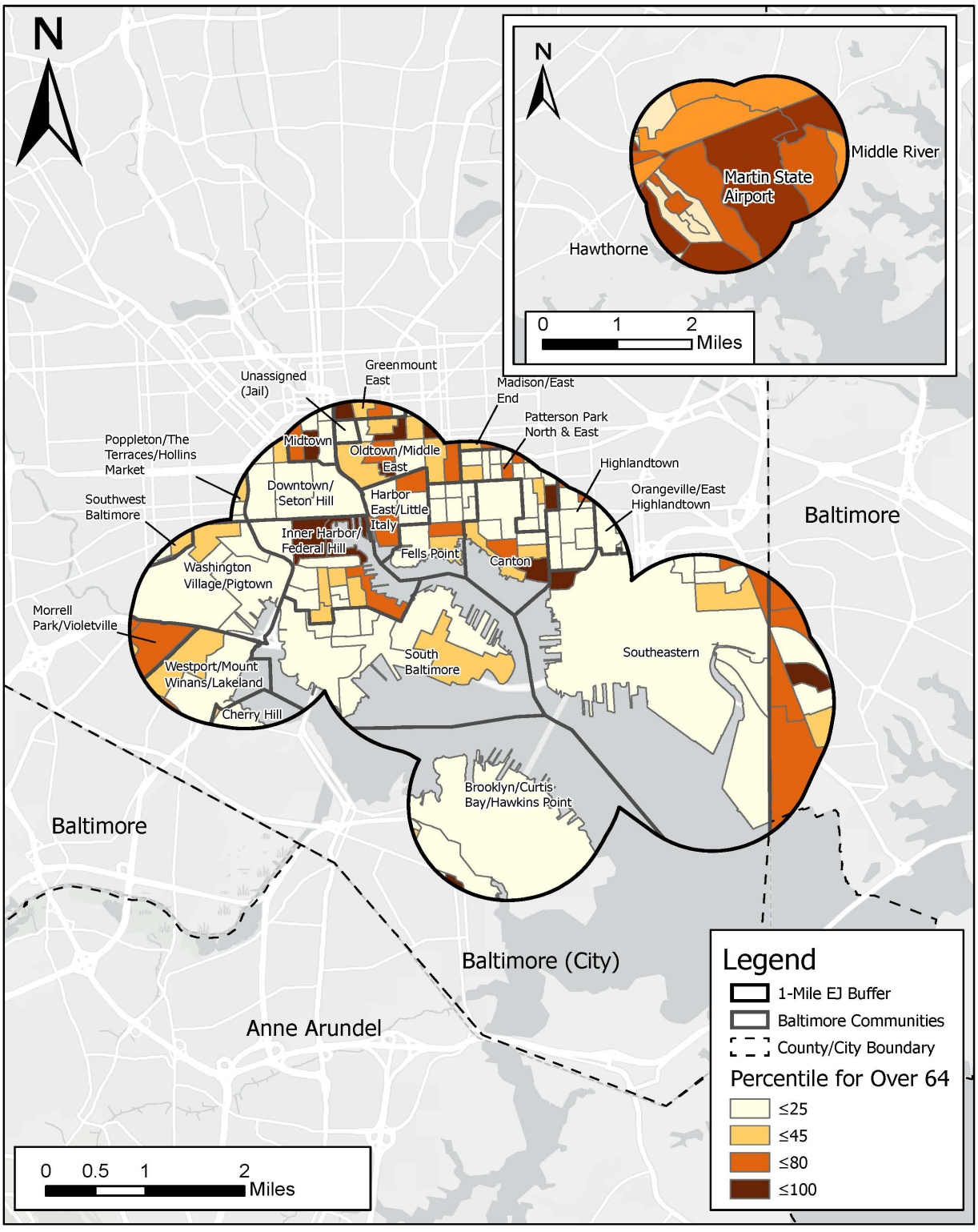

Figure 2-12. Census block groups located within the Baltimore City and MSA study areas with a one-mile buffer of the study areas, which represents the percent population over age 64 (percentile) in each census tract (USEPA, 2022)

Table 2-9 represents Baltimore City communities and how they correlate to individual neighborhoods and their associated census tracts.

Table 2-9. Baltimore City Community Breakdown

Community	Neighborhood	Census Tracts
Brooklyn/Curtis Bay/Hawkins Point	Brooklyn, Curtis Bay, Fairfield Area, Hawkins Point, Curtis Bay Industrial Area	250500, 250600, 250401, 250402
Canton	Canton, Patterson Park	010400, 010300, 010100
Cherry Hill	Cherry Hill, Middle Branch/Reedbird Parks	250207, 250204, 250203
Downtown/Seton Hill	Downtown, Seton Hill, University of Maryland	170100, 040100, 040200
Fells Point	Butcher's Hill, Fells Point, Upper Fells Point	020200, 020300, 020100, 010500
Highlandtown	Brewers Hill, Highlandtown	260900, 261100, 260800
Inner Harbor/Federal Hill	Federal Hill, Inner Harbor, Otterbein, Ridgely's Delight, Riverside, Sharp-Leadenhall, Stadium Area, Downtown West, SBIC (now South Baltimore), South Baltimore	220100, 240200, 240300, 230100, 230200
Madison/East End	Madison-Eastend, McElderry Park, Milton-Montford	070200, 070100, 070300
Morrell Park/Violetville	Morrell Park, Oaklee, Saint Agnes, Saint Paul, Violetville, Wilhelm Park	250303, 250103, 250206
Orangeville/East Highlandtown	Greektown, Orangeville, Eastwood, Joseph Lee (now Bayview), Kresson, Baltimore Highlands, Hopkins Bayview, Bayview, Orangeville Industrial Area, Pulaski Industrial Area	260404, 260501, 260700
Patterson Park North & East	Baltimore-Linwood (now Patterson Park Neighborhood), Patterson Place, Ellwood Park/Monument	261000, 060200, 060100, 010200, 060300
Poppleton/The Terraces/Hollins Market	Hollins Market, Poppleton	180200, 180300, 180100
South Baltimore	Locust Point, Port Covington, Locust Point Industrial Area	240400, 240100, 230300
Southeastern	Spring Garden Industrial Area, Canton Industrial Area, Graceland Park, Holabird Industrial Park,	260605, 260604

Community	Neighborhood	Census Tracts
	Medford, O'Donnell Heights, Saint Helena, Dundalk Marine Terminal	
Southwest Baltimore	Booth-Boyd, Carrollton Ridge, Franklin Square, Millhill, Penrose/Fayette Street Outreach, Shipley Hill, Union Square, New Southwest/Mt. Clare	200400, 200500, 190100, 200200, 190200, 200300, 200100, 190300
Washington Village/Pigtown	Barre Circle, Carroll Park, Caroll-Camden Industrial Area, Washington Village/Pigtown	210100, 210200
Westport/Mount Winans/Lakeland	Lakeland, Mt. Winans, Westport	250301, 250205
Unassigned – Jail		100300
Oldtown/Middle East	Dunbar-Broadway, Gay Street, Middle East, Oldtown, Penn-Fallsway, Pleasant View Gardens, CARE	100200, 060400, 070400, 280500, 080800
Harbor East/Little Italy	Washington Hill, Jonestown, Little Italy, Perkins Homes	030100, 030200
Midtown	Bolton Hill, Charles North, Greenmount West, Mid-Town Belvedere, Mount Vernon	110100, 110200, 140100, 120500
Greenmount East	Greenmount Cemetery, Johnston Square, Oliver	080700, 090900, 100100, 080600

Traffic

The EJ communities experience some of the most notable traffic routes in the Baltimore Metro area due to their proximity to major roadways including I-95, I-895, I-295, and I-83, in addition to Routes 1, 2, and 40. Figure 2-13 shows the census tracts in the Baltimore Metro area, outlined in yellow, and their proximity to traffic noise and volume. These communities are likely affected by higher-than-average noise levels.

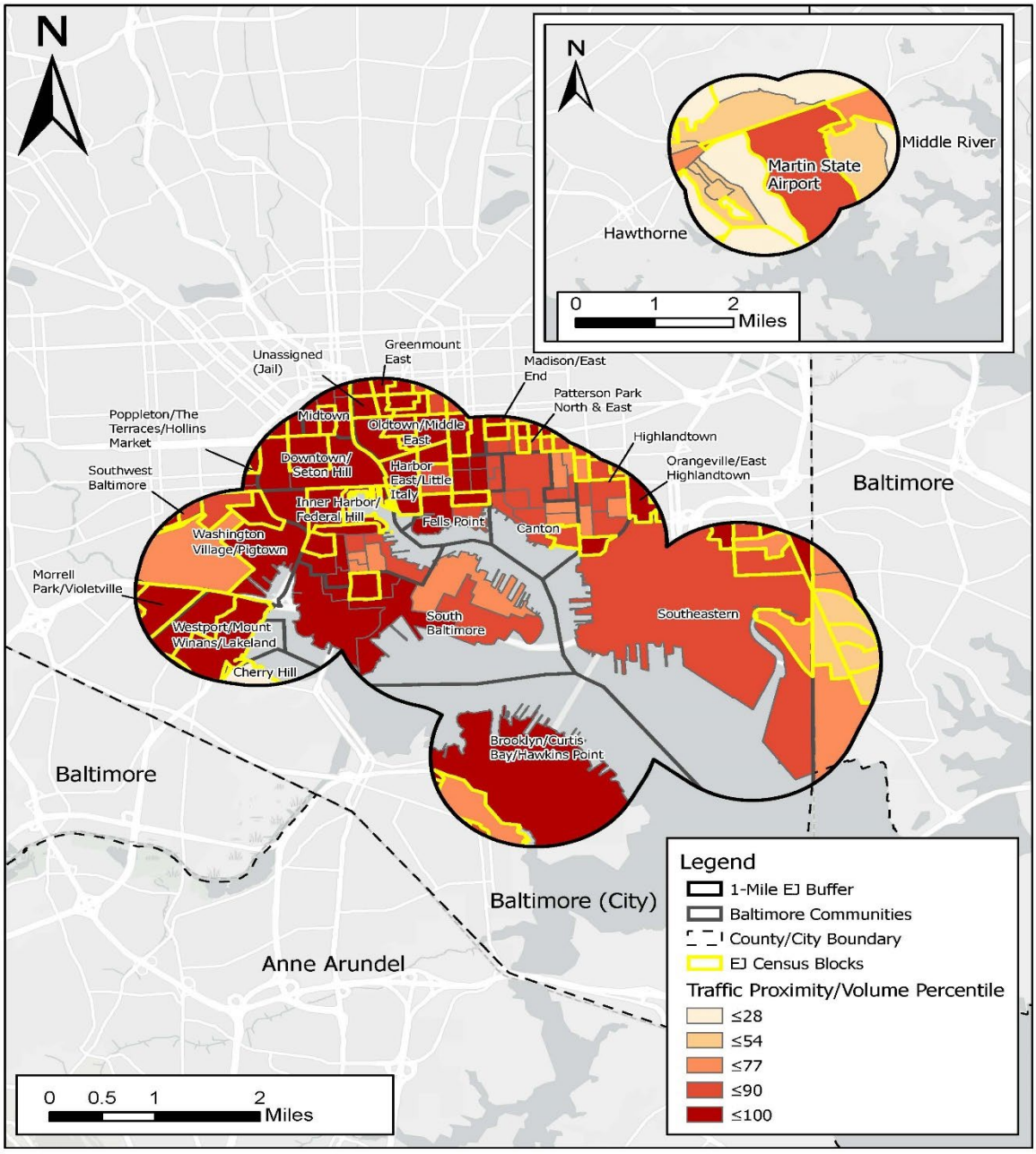

Figure 2-13. Environmental Justice Census Block Groups Proximity to Traffic (USEPA, 2022)

Air Quality

The Baltimore City Planning Unit is in non-attainment for the 8-hour ozone pollutant based on the NAAQS 2015 standard. Figure 2-14 below shows the EJ communities and their exposure to ozone in percentiles. In general, EJ communities located closer to Baltimore City industrial areas have a higher exposure to ozone than EJ communities located farther away from the city center.

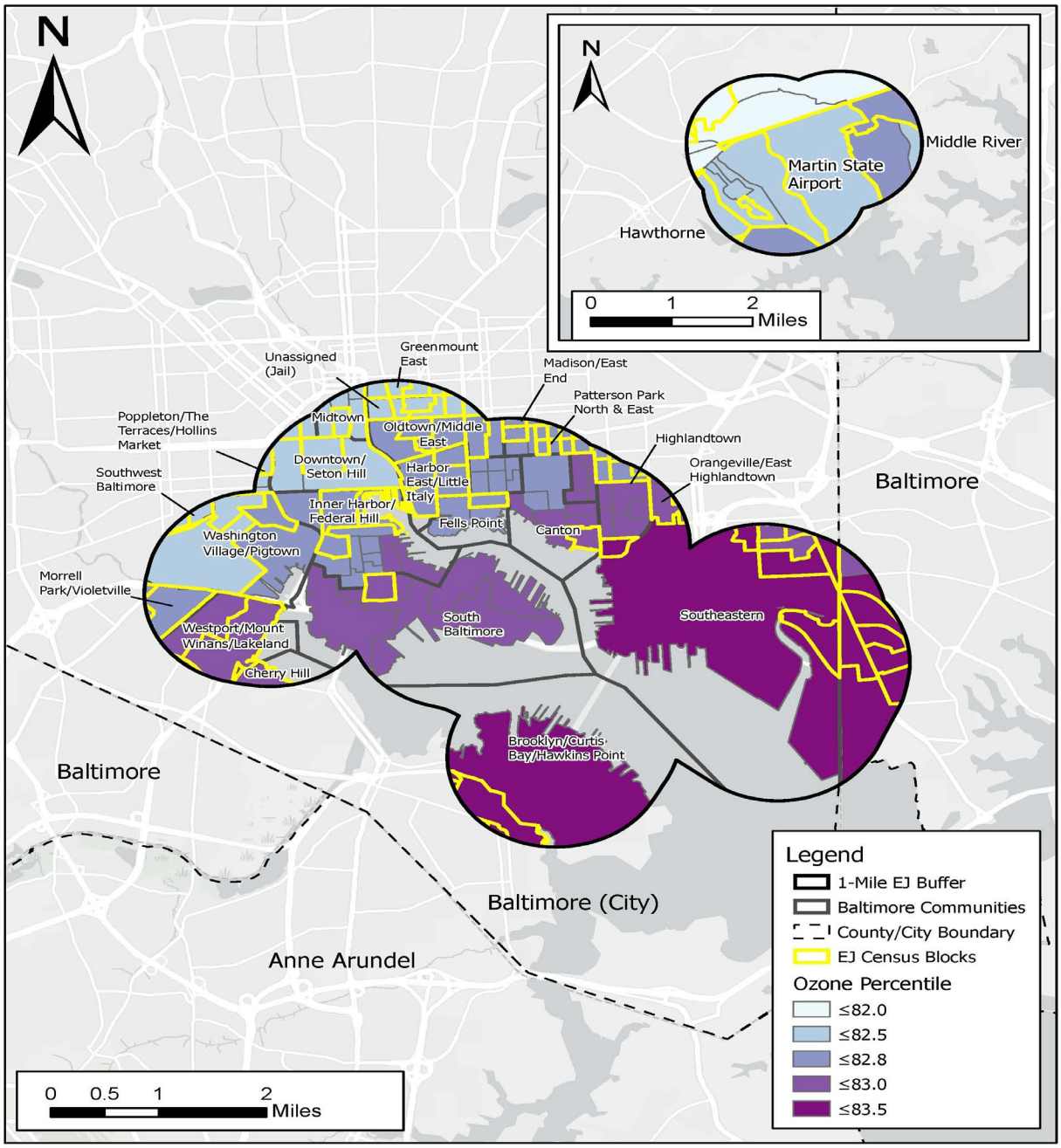

Figure 2-14. Environmental Justice Census Block Groups and their Exposure to Ozone (USEPA, 2022)

Hazardous Waste

There are several TSDF that exist within the Baltimore City and MSA study areas. Nearly all EJ communities identified in the Baltimore Metro area are in close proximity to a TSDF. Figure 2-15 shows these communities and their proximities to the areas.

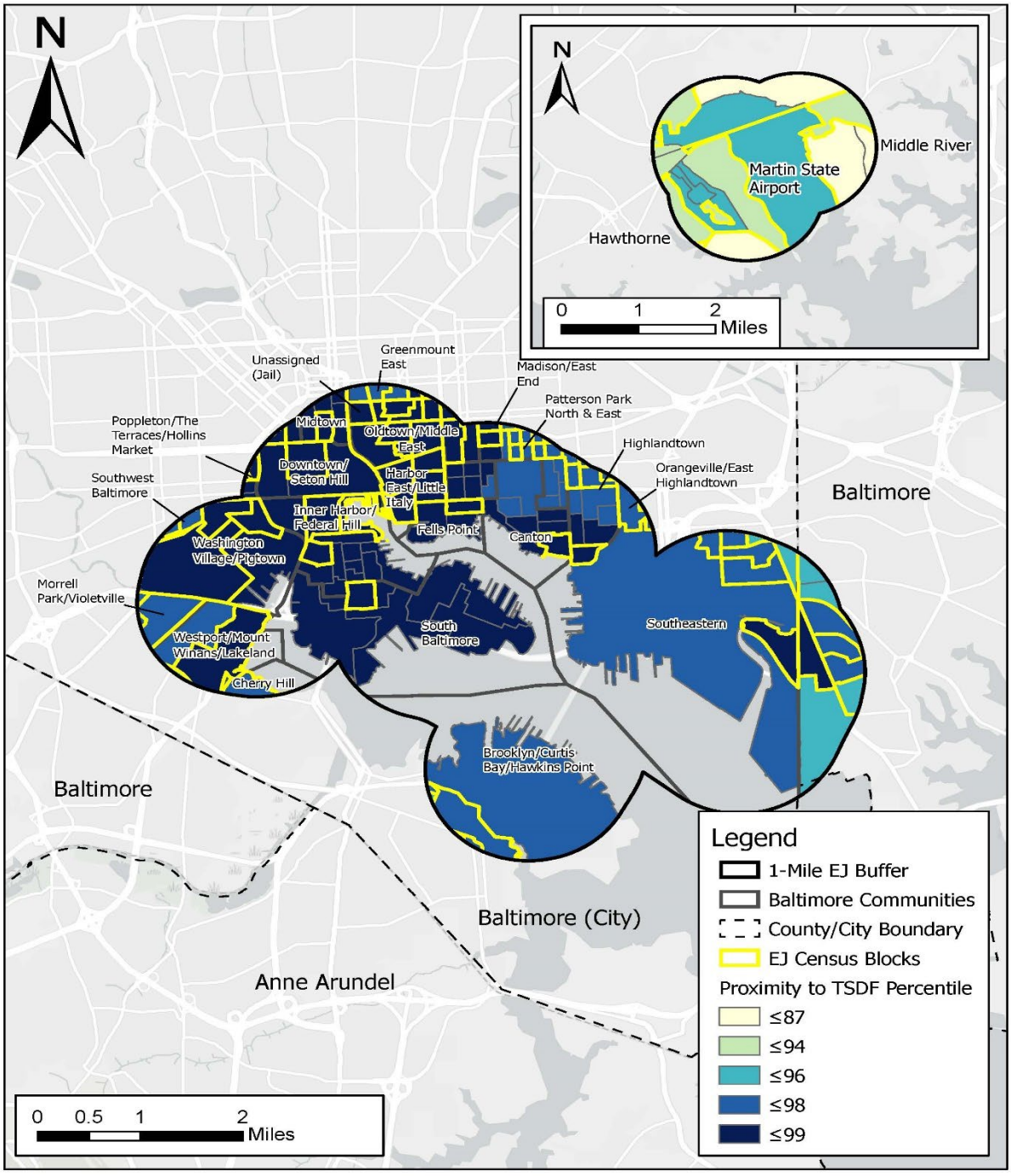

Figure 2-15. Environmental Justice Census Block Groups and their Exposure to Ozone (USEPA, 2022)

2.4.15.1 FWOP Condition

A FWOP condition may disproportionately displace communities that have the potential to fall within an EJ criterion. Potential future flooding events may impact communities who lack appropriate transportation mechanisms if or when evacuation is needed. Flooding events may also isolate communities if transportation corridors are impassable. Flash flood warning systems are used by local media outlets but residents in low-income areas who may not have access to internet or cable may be unable to sufficiently receive warnings in a timely manner. Flooding events also have the potential of causing long-term mold damage to residential properties and local businesses if flood damage is not remediated in a timely and effective manner. Additionally, in areas specific to Baltimore City, residents continually experience overloaded sewer systems that routinely release high volumes of raw human waste into neighborhood streams, Baltimore Harbor, and the Chesapeake Bay. During flooding events, sewage releases may be amplified by surface and groundwater infiltration into exposed sewer lines which can often create back-ups in residential houses. EJ communities are particularly vulnerable as remediation methods may not be attainable in low-income areas. Organizations like the Environmental Integrity Project (EIP), who are a 501(c)(3) nonpartisan, nonprofit watchdog organization would continue to advocate for EJ communities and ensure residents are represented fairly. EIP is comprised of former USEPA enforcement attorneys, public interest lawyers, analysts, and community organizers. The EIP has three main goals:

- Illustrate how the failure to enforce or implement environmental laws increases pollution and harms public health,
- Identify federal, state, and individual corporations and hold them accountable for failing to enforce or comply with environmental laws, and
- To help communities obtain the protections of environmental laws.

The EIP serves the EJ communities by engaging directly with residents, making air and water pollution data more accessible. In addition, the EIP examines permits for current and proposed projects that would impact EJ communities (EIP, 2022).

2.4.16 Recreational Resources

Recreational uses of the study area consist of general tourism, running, walking, hiking, kayaking, fishing, boating, and sightseeing. Baltimore has several historic and cultural districts within the study area that appeal to a range of local audiences as well as national and international interests. Entertainment attractions include two major sport venues in the heart of the city, M & T Bank Stadium and Oriole Park at Camden Yards, Horseshoe Casino, the National Aquarium, Pier Six Pavilion, and Maryland Science Center, among many others. Several recreational fields, parks, and waterfront promenades exist within the study area and include the Canton Waterfront Park, Patterson Park, Federal Hill Park, and the Baltimore Waterfront Promenade. The Promenade is a brick-paved, public

pedestrian walkway/shared use bicycle path that follows the water's edge for approximately eight miles around the Inner Harbor, from Fort McHenry to the Canton Waterfront Park. Areas along the east side of the Promenade contain a boardwalk and are accessible by foot or wheelchair (Baltimore Planning, 2018).

2.4.16.1 FWOP Conditions

Recreational resources may continue to be at risk and incur damages during flooding events. Areas around the Inner Harbor, Canton, Fells Point, Locust Point, and Fort McHenry may continue to be affected during high tide events, coastal storms, and other meteorological events. In early 2022, the State of Maryland assigned a $166 million investment to revitalize Baltimore's downtown area and the Inner Harbor. Funding will be dispersed to several areas and businesses, including the Inner Harbor Promenade, National Aquarium, Port Discovery, the Maryland Science Center, and the Downtown Partnership for Baltimore, among others. Other initiatives like Reimagine Middle Branch are currently being developed as well. The goal of Reimagine Middle Branch is to reconnect South Baltimore to its shoreline, with the study area containing 19 neighborhoods, 30 parks, and more than 11 miles of shoreline. Reimagine Middle Branch includes expanding Middle Branch Park and adding improved boating and fishing piers along with an expanded playground, improving areas around Ridgley's cove to include a "maritime park", and creating a new trail (The Loop Trail), that would connect all of the new parks and open spaces with bike and walking trails (Lynch, 2022). Rash Field is another example of a project that was included in the Master Plan and has been brought to fruition. The field is the first large-scale public space redevelopment at the Inner Harbor in decades. The 8-acre park includes a nature walk trail, bioretention ponds, rain garden, café, two playgrounds and a year-round skatepark (Cassie, 2021).

2.4.17 Visual Aesthetics

Visual resources can be defined as the natural and man-made features that constitute the aesthetic qualities of an area. Natural visual resources occur in the landscape, typically without human assistance, and include native or mostly undisturbed landforms, water bodies, vegetation, and animals, both wild and domesticated. The MSA study area rests on a peninsula in eastern Baltimore County. While the visual aesthetics around the airport are limited to an industrial and residential setting, natural resources and wildlife can be spotted along Frog Mortar Creek, Stansbury Creek, and Middle River. Baltimore City consists of a similar industrial/commercial setting. Viewers can generally see several historic and culturally significant landmarks from the Harbor and its surrounding areas. Elevated roads, highways, and bridges can provide views of the study area. The Francis Scott Key Bridge which connects Hawkins Point and Sollers Point in Baltimore County provides a panoramic view of Baltimore City.

2.4.17.1 FWOP Condition

Local organizations, like The Baltimore Waterfront Partnership, continue efforts to beautify Baltimore through initiatives like 'Healthy Harbor', 'Mr. Trash Wheel', 'Floatilla', and 'Mr. Trash Wheel's Community Beautification Grant'. However, without proper flood control measures, visual aesthetics around locations such as the Baltimore Waterfront Promenade and Inner Harbor, Canton, Fells Point, and Locust Point, as well as historic districts, structures, and piers may be continually impeded by future flood events. As mentioned in Section 2.4.17, Reimagine Middle Branch is expected to increase visual aesthetics around South Baltimore with the implementation of boardwalks, trails, overlooks, and living shorelines.

2.4.18 Utilities

The Baltimore City and MSA study areas contain an abundance of utility lines and services to support its industrialized and urban settings. Utilities range from underground fiber optic cables, storm drains, telecommunications, gas, water, sewer, and electric lines. Some underground utility lines in Baltimore City are still in place dating back from the early 1900s, although they're not in use today.

2.4.18.1 FWOP Condition

Under the No Action Alternative/FWOP, utilities may continue to be exposed to flooding events and would continue to degrade with brackish water intrusion from the bay. Baltimore continues to deal with impaired sewer lines, and the likelihood of untreated sewage leaking from corroded or unrepaired pipes remain high during flood events. This also introduces issues to potable water lines that may have openings within their lines and would continue to be infiltrated by polluted flood waters. Underground fiber optic cables, electrical, and gas lines are also at risk of being damaged if not protected from flood waters.

2.5 Built Environment

The Baltimore Coastal study area is characterized by coastal storm risk as the Patapsco River meets the Chesapeake Bay. FRM infrastructure for coastal flooding is being pursued at the following locations:

Middle Branch: The Middle Branch Resiliency Initiative (MBRI) is a comprehensive approach to mitigating hazards from storm surge, tidal flooding, and SLR around the entire shoreline of the Middle Branch of the Patapsco River. It is the natural outgrowth of 13 years of focused planning work by a range of different agencies and community leaders, including the FEMA-approved Baltimore City Disaster Preparedness and Planning Project (DP3), the Maryland Hazard Mitigation Plan, and Baltimore's 2019 FEMA Advance Assistance award. It is also the logical outgrowth of a wide range of Federal, State, and Local laws, regulations, and policies prioritizing nature-based infrastructure to provide shoreline resiliency. Stage I of the MBRI uses nature-based infrastructure to protect two critical Community Lifelines: Baltimore Gas and Electric

(BGE) Spring Gardens and MedStar Harbor Hospital. Stage I of MBRI has received funding from the FEMA Building Resilient Infrastructure and Communities grant program. Several other projects in the Middle Branch addressing coastal resiliency are also funded through multiple different sources.

Martin State Airport: A Final Environmental Assessment (EA) was signed February 23, 2022 for Phase I Improvements at MSA. Proposed actions in the EA include shifts to Runway 15-33 location, modification to Runway 15-33 grade, and modifications to General Aviation and Landside facilities at the Strawberry Point Complex among many other actions. The purpose of implementing the proposed action of the EA is to meet various Federal Aviation Administration (FAA) standards, enhance airfield safety; improve airfield efficiency; accommodate existing and anticipated demand at MTN; and acquire property for drainage improvements and future mitigation.

Dundalk Marine Terminal: The Dundalk Marine Terminal Resiliency and Flood Mitigation Improvement project will enable MDOT MPA to provide resiliency and flood mitigation improvements at the Dundalk Marine Terminal. The project will install sea curbs to prevent the terminal from flooding during storm surges; install back flow preventers on 15 existing storm drain outfalls to prevent storm surges from flooding low level areas on the terminals; and install a new 10 foot by 5 foot concrete box culvert to increase the capacity of the existing collection system to handle extreme rainfall events. The project is expected to be completed in 2026.

2.6 Economic Environment

2.6.1 Existing Conditions

2.6.1.1 Economic Modeling Description

The Generation II Coastal Risk Management (G2CRM) model is used to estimate economic damages from coastal storm impacts in this study. G2CRM is a desktop computer model that implements an object-oriented probabilistic life cycle analysis (PLCA) model using event-driven Monte Carlo simulation. Monte Carlo simulation 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. 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 (modeled 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.
- *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.
- *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.

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 (PSE) are limited to bulkheads/seawalls.

Damages to structures and contents have been modeled G2CRM software. Hydraulic and Hydrology storm data was input into G2CRM from NACCS C-STORM modeling. The C-STORM modeling combines the Ocean Circulation Model and STWAVE (wave modeling). A discussion of these models may be found in Appendix B: Hydrology and Hydraulics Analysis and their application to economic modeling in Appendix E: Economic Analysis.

The following damage categories were investigated using the economic modeling:

Physical Damages

- Structures and Contents
- Vehicles
- Roads/bridges
- Runways
- Rail
- Airport equipment
- Wastewater treatment facilities and infrastructure

Loss of Functionality or Transportation Delays

- Roads
- Heavy Rail (passenger/freight)

- Airport
- Light Rail

Emergency Costs

- HTRW cleanup (e.g., petroleum/chemicals)
- FEMA Housing Assistance (repair to damaged homes, temporary housing)
- FEMA Other Needs Assistance (cleanup items, personal property, moving and storage, medical expenses)

Life Safety

2.6.1.2 Assets

Parcel and building data were 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 Sea, Lake, and Overland Surges from Hurricanes (SLOSH) Category 4 maximum of maximum inundation extent. The structure inventory identified 8,917 structures and vehicles. The structures are broken down as residential and commercial structures with their structure and content values. The inventory also included assets representing infrastructure and cargo at the Port of Baltimore facilities, the Fort McHenry Tunnel with the depreciated replacement value (DRV) with $4.1 billion on I-95 and Harbor Tunnel with DRV of $2.2 billion on I-895, Baltimore Shot Tower Metro Station with DRV of $60.5 million, and the munition depot with $50 million at MSA. The office of engineers at MSA provided the DRV of the munition depot. The tunnels' replacement values are prepared by the MDTA consultant. The consultant used National Highway Consultation Cost Index (NHCCI) to develop the DRV. Table 2-10 summarizes the asset inventory for the study area.

Table 2-10. 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

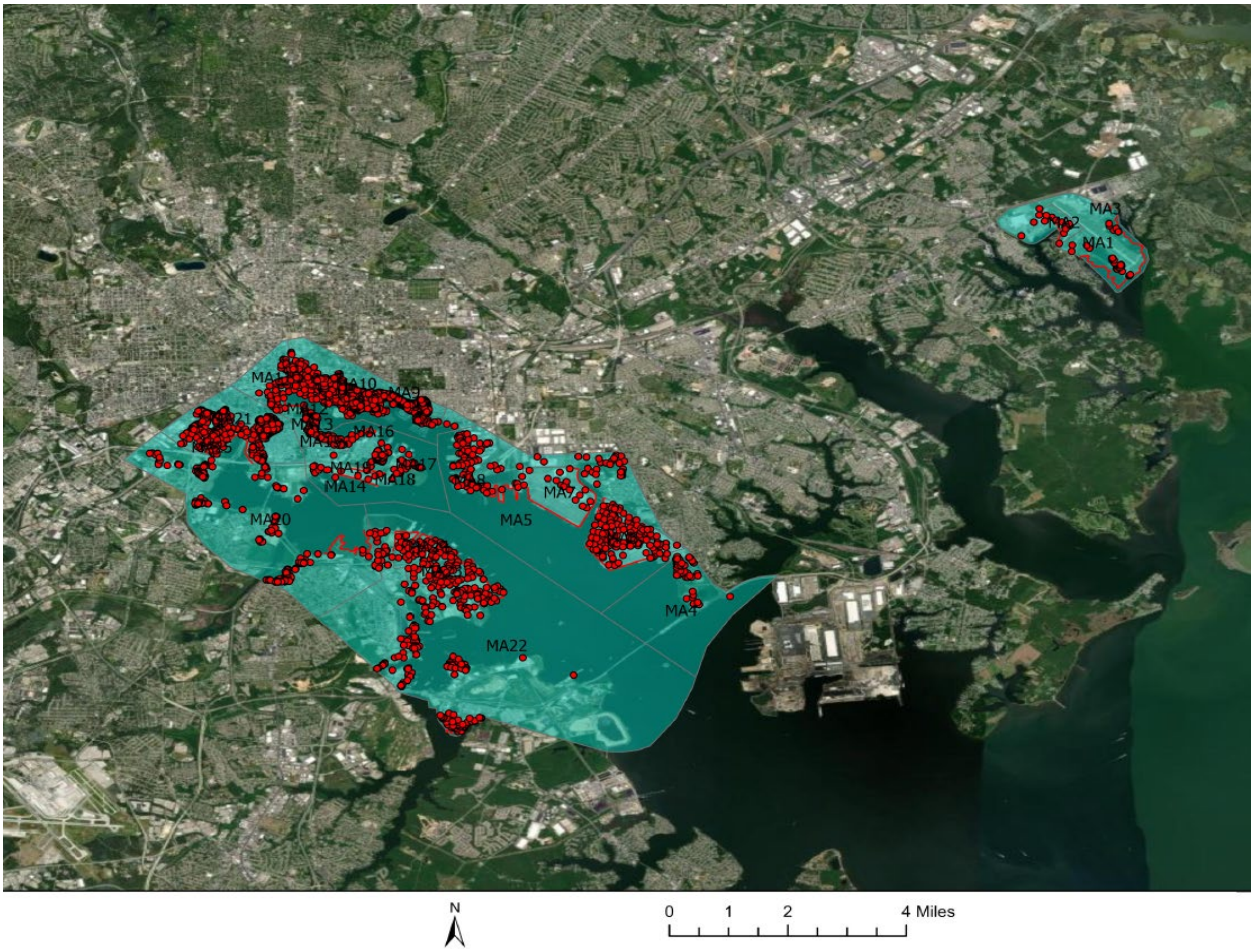

Figure 2-16. Location of Assets within the Study Area

The Baltimore Metropolitan study area structure inventory, as modeled, contains 8,917 structures (Figure 2-16). 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. Figure 2-17 below, shows the proportion of each occupancy type in the Baltimore Metropolitan area. Note that the proportion is rounded to a whole number.

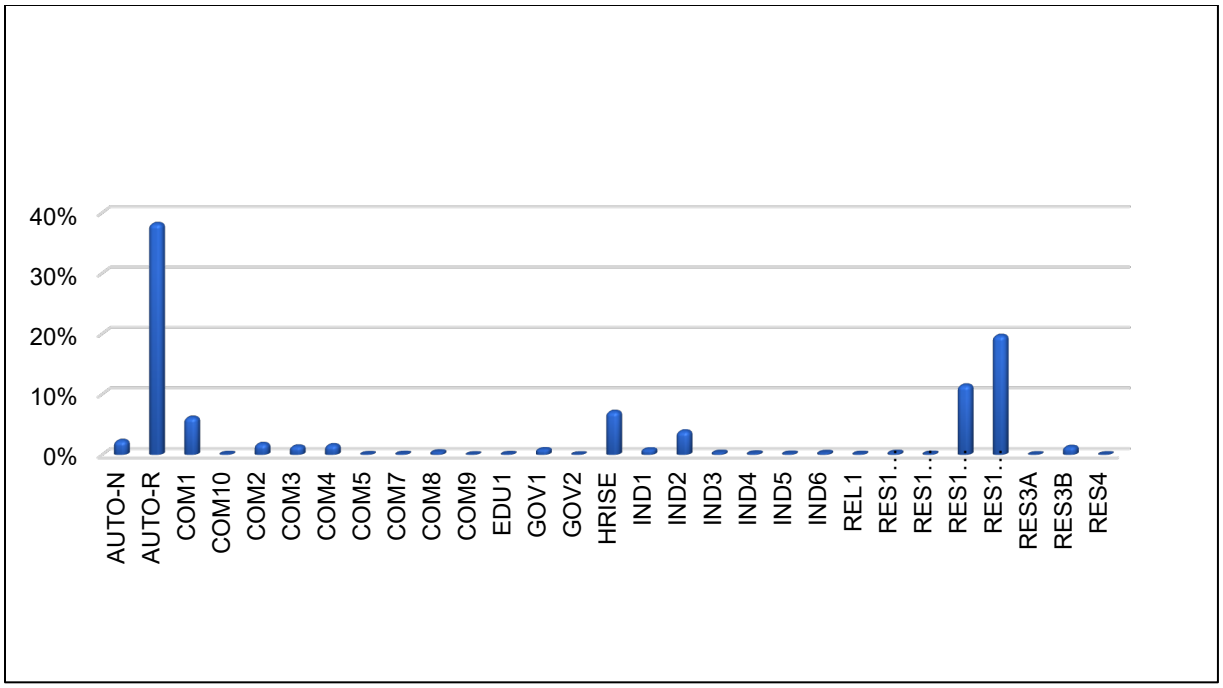

Figure 2-17. Proportion of Occupancy Types in the Baltimore Metropolitan study area

2.6.1.3 Content-to-Structure Value Ratios (CSVR)

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.

Table 2-11. 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
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

2.6.1.4 Summary of the Inventory

The assets were categorized as residential or nonresidential which were then further categorized into occupancy types. Table 2-12 below displays the count and structure value by the occupancy types.

Table 2-12. Structure Inventory by Occupancy Type

Occupancy Type	Description	Count	Structure Value	Content Value
AUTO-N	Auto/Commercial	207	$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
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 percent Annual Exceedance Probability (AEP) areas except Sharp Leadenhall which is in 0.2 percent AEP. Industrial sites 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 MSA in Baltimore County, and the Curtis Bay USCG yard in Anne Arundel County. The historic relative sea level trend is 0.01 feet/year based on NOAA's Baltimore MD tide gauge. Based on FWOP condition hydraulic data, by 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 percent AEP event.

2.6.1.5 Model Areas

Model areas (MA) are established to represent the various geographic parts of the study area that have uniform flood elevations. Boundaries are defined by natural or built topological features (e.g., a ridge, highway, or railway line), therefore, correspond to the drainage divides separating local-scale watersheds. This facilitates analysis by grouping MAs into areas that share common features, as well as accelerates the economic modeling process. 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.

The study area consists of 25 MAs. The 25 MAs 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 MAs are spatial areas defined by geospatial polylines as shown in Figures 2-14.

There are two types of MAs: 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, wave contribution, SLC contribution, plus tide contribution) calculated for a given storm, without any mediation by a PSE. An upland modeled area is a polygonal boundary within G2CRM that contains assets and

derives associated stages from the total water level calculated for a given storm, as mediated by a PSE (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. 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 FWOP condition was a modeling strategy utilized in order to model the FWP condition.

2.6.1.6 Protective System Elements

Flood hazard manifested at the storm location is mediated by the 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 FRM infrastructure (i.e., what in G2CRM is categorized as a bulkhead/seawall or a flood barrier). Figure 2-14 shows the protected MAs with bulkhead for the FWP conditions in the study area.

The top elevation is specified at the approximate existing ground elevation within the MA for both the existing and FWOP 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 FWP condition the bulkhead/seawall or the flood barrier top-elevation is raised in the alternative file and its influence is captured.

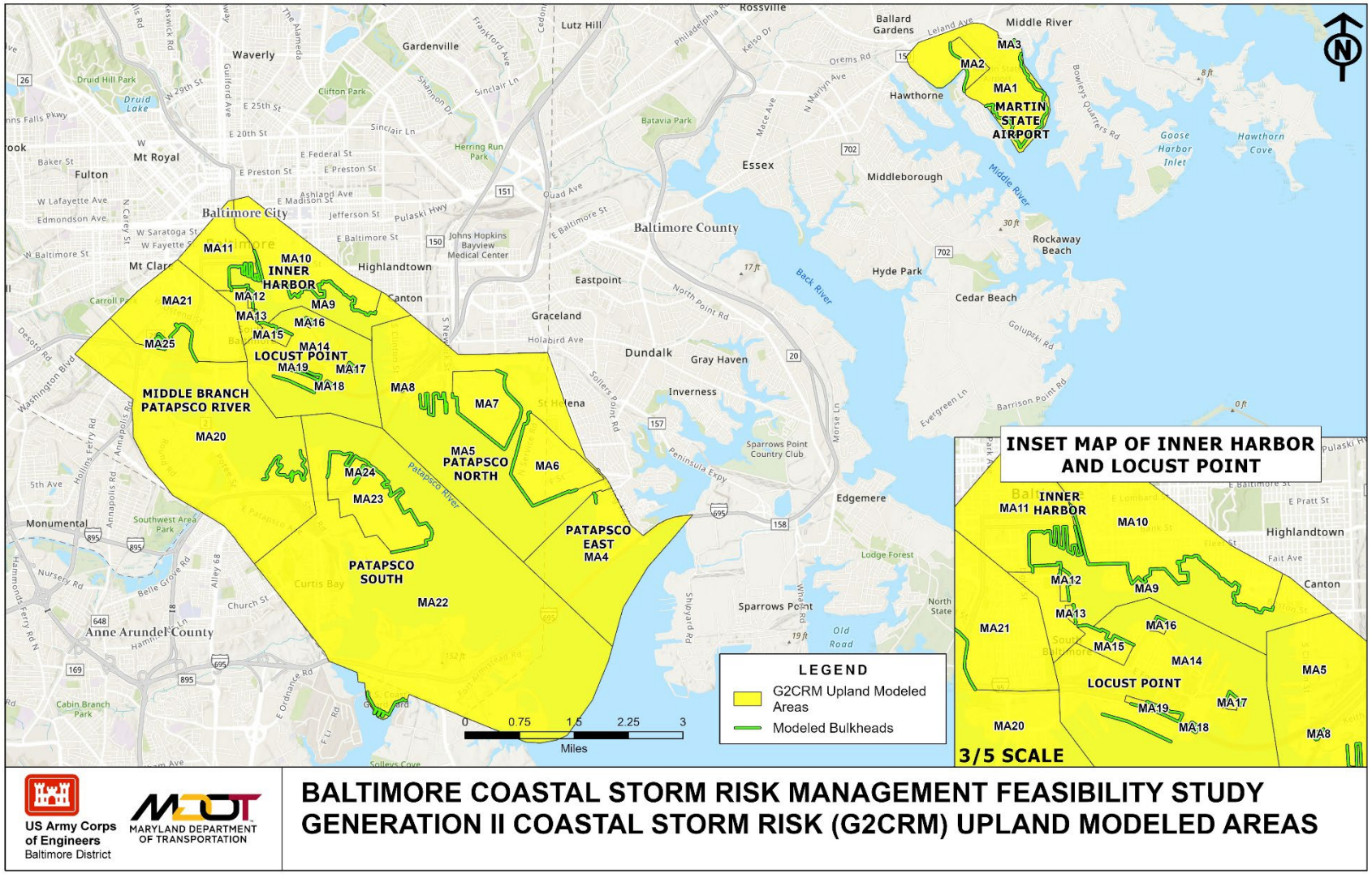

Figure 2-18. Baltimore CSRM Upland Modeled Areas and Modeled Bulkheads

2.6.1.7 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 generated from the Baltimore Metropolitan Area Light Detection and Ranging (LIDAR) (Baltimore City-Baltimore County-Anne Arundel County) collected and published by MDDNR in 2017 and provided by the non-Federal sponsor for this study. Volume-stage functions describe the relationship between the volume contained in the MA 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.

2.6.1.8 Evacuation Planning Zones (EPZ)

Communities in the Baltimore Metropolitan area are vulnerable to flooding. There are approximately 48,000 people in the study area that are within the extent of a Category 4 hurricane, based on NOAA's SLOSH model. In addition, thousands of commuters and tourists are in the Baltimore Metropolitan area daily. 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 who wish to evacuate from areas at risk from a pending coastal storm may sometimes be 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 polygon boundary that is used within loss of life calculations in G2CRM and used 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 then assigned to an EPZ and 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 by age categorization into under 65 and older. They are also categorized as daytime or nighttime. There are three possible lethality functions for structure residents: safe, compromised, and chance. Safe would have the lowest expected life loss, but not implying no life loss, and chance would have the highest expected life loss.

2.6.2 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. Every iteration represents expected PV damages for the period of analysis and cumulative damages of assets converged at approximately 100 iterations.

The sum of all damages for each life cycle was 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 (see Appendix E: Economic Analysis) 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.

2.6.3 Economic FWOP

2.6.3.1 Background

According to the Fourth National Climate Assessment (4th NCA) report on Region 2, the Chesapeake Bay watershed is experiencing stronger and more frequent storms, an increase in heavy precipitation events, increasing bay water temperatures, and a rise in sea level. These trends vary throughout the watershed and over time but are expected to continue over the next century.

The USACE low, intermediate, and high SLC scenarios were evaluated for the FWOP and FWP condition, and with respect to determining tipping points/thresholds for impacts over the 50-year period of analysis and the 100-year adaptation timeframe, and at multiple storm frequencies. The historic relative sea level trend is 0.01 feet/year based on NOAA's Baltimore MD tide gauge. Sea level is projected to rise as shown on Table 2-13

and Figure 2-19, based on the records at the Baltimore, MD NOAA gauge 8574680, which is closest to the study area.

Table 2-13. Sea Level Change Projection for Baltimore Harbor (in feet, NAVD 88)

Year	Low	Intermediate	High
2031	0.36	0.50	0.93
2080	0.86	1.55	3.73
2130	1.36	3.06	8.43

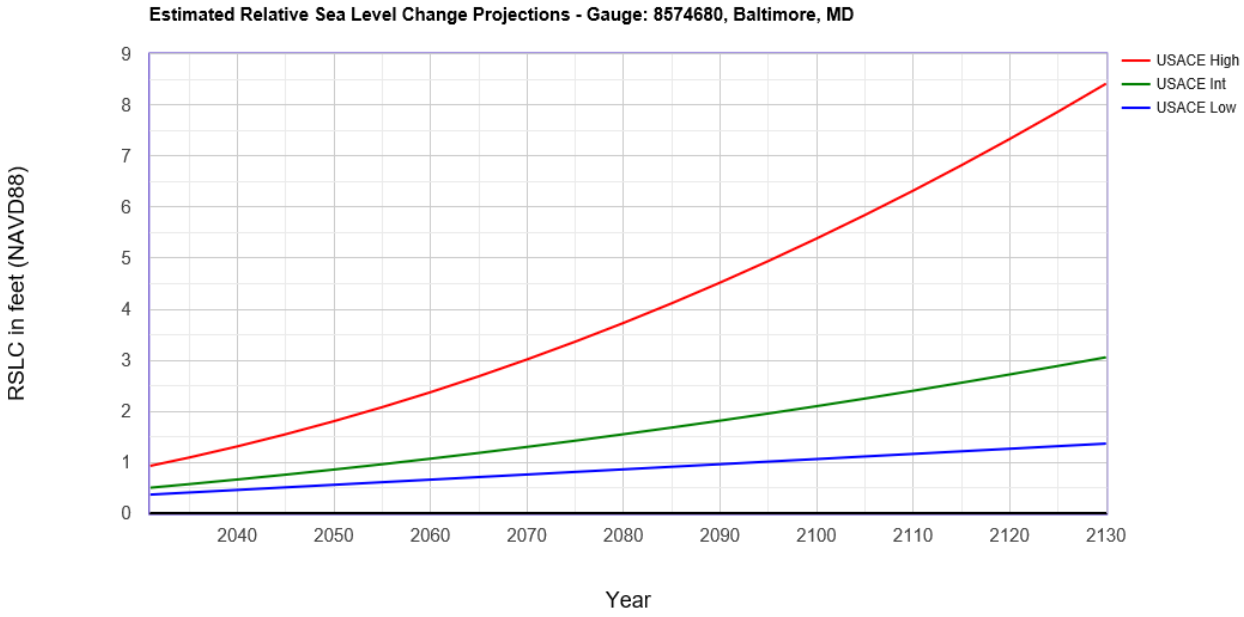

Figure 2-19. Sea Level Change Projections for Baltimore Harbor, 2031 to 2130

2.6.3.2 FWOP Condition Modeling Results

The years 2031-2080 were selected to represent the FWOP 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 would continue to be affected by the flooding from coastal storms and suffer increasing losses each year. Figure 2-20, Figure 2-21, and Table 2-17 below display the expected PV in the FWOP condition. In addition, Table 2-14 shows the equivalent annual damages (EAD) for the study area by MAs for the FWOP by MA. Inner Harbor MAs make up the most damages of structures in the study area followed by the tunnels MAs. The FWOP condition 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.

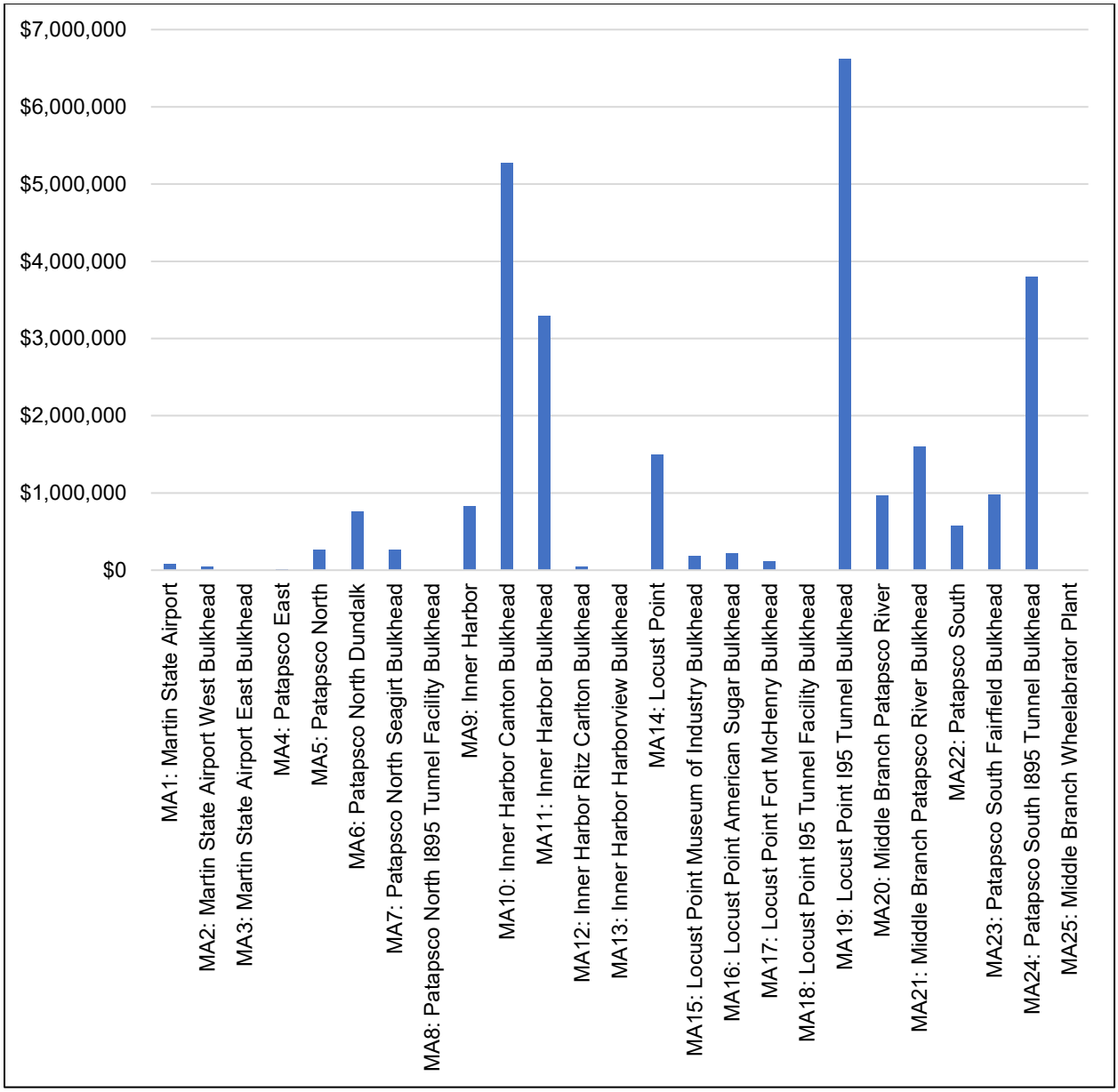

Figure 2-20. FWOP Condition Damages by MA

Table 2-14. FWOP Condition 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
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**

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 SLR 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 FWOP 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.

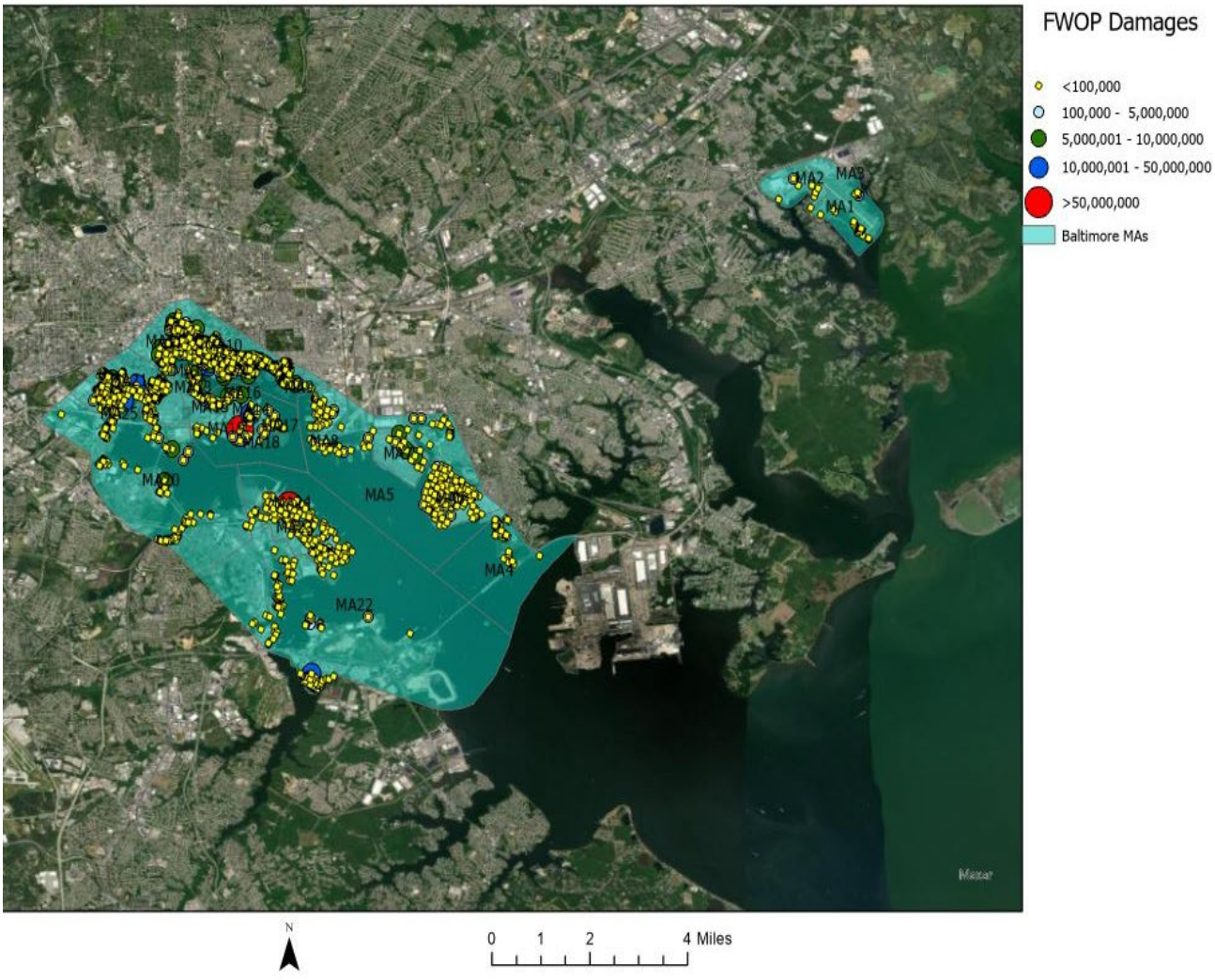

Figure 2-21. Dot Plot of Cumulative PV Damages for the FWOP

3 PLAN FORMULATION AND EVALUATION

3.1 Planning Framework

The guidance for conducting civil works planning studies, ER 1105-2-100, Planning Guidance Notebook, requires the systematic formulation of alternative plans that contribute to the federal objective. To ensure sound decisions are made with respect to the development of alternatives, and with respect to plan selection, the plan formulation process requires a systematic and repeatable approach. This chapter presents the results of the plan formulation process leading to the selection of the TSP.

Plan formulation has been conducted with a focus on achieving the federal objective of water and related land resources project planning, which is to contribute to National Economic Development (NED) consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable EOs, and other federal planning requirements. Plan formulation also considers the four economic accounts: NED, Regional Economic Development (RED), Environmental Quality (EQ), and Other Social Effects (OSE). The plan formulation process focuses on establishing alternatives with structural and nonstructural measures initially and then considers natural and NNBF to the final array of alternatives as design considerations that would enhance the performance and effectiveness of structural measures included in those alternatives.

Structural CSRM measures are man-made, constructed measures that counteract a flood event in order to reduce the hazard or to influence the course or probability of occurrence of the event. This includes gates, levees, and flood walls (permanent and deployable) that are implemented to protect people and property.

Nonstructural CSRM measures are permanent or contingent measures applied to a structure and/or its contents that prevent or provide resistance to damage from flooding. Nonstructural measures differ from structural measures in that they focus on reducing the consequences of flooding instead of focusing on reducing the probability of flooding. Relocation, home elevation and floodproofing are examples of nonstructural measures.

NNBF CSRM measures work with or restore natural processes with the aim of wave attenuation and storm surge inundation.

The planning strategy for formulating alternatives is summarized in Figure 3-1, which is a distillation of the six-step planning process used by USACE. The PDT participated in weekly meetings to discuss and evaluate existing information about the study area and coastal storm risk in the study area. Existing USACE reports including those listed in Section 1.10 of this IFR/EA and reports generated by MDOT, Baltimore City, and stakeholder groups, include important information about existing conditions and proposed future conditions for project alternatives.

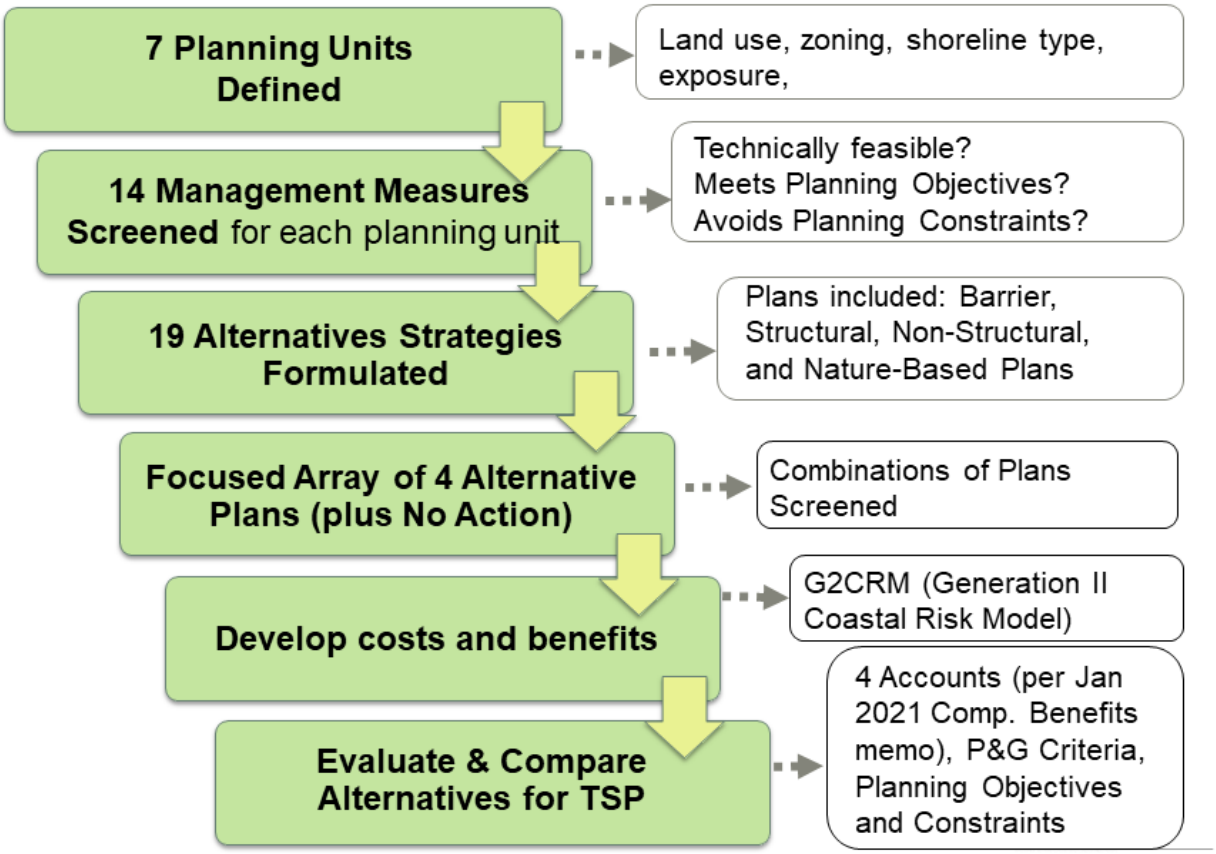

Figure 3-1. Plan formulation strategy for developing alternatives

3.2 Assumptions

Within Baltimore City, it is assumed that all new or substantially improved construction projects for residential and non-residential structures would adhere to Baltimore City floodplain policy (Article 7 Nat. Res, Division 1 Floodplain Management of the Baltimore City Code). As such, it is assumed that new and substantially improved structures are substantially protected to the flood-protection elevation, which is the modeled elevation of the 0.2 percent chance of flood plus 2 feet of freeboard in the tidal floodplain as listed on the Flood Insurance Study. Therefore, several development projects currently underway or recently constructed have been excluded from consideration for FRM through this study.

The eight-mile waterfront promenade in Baltimore City is a public pedestrian walkway/shared use bicycle path and is within this study's planning areas: The promenade represents a mixture of public and privately owned land and development along the promenade must conform to various City policies (Figure 3-2). As such, this study assumes that all public access corridors to the promenade, as outlined in Article 32 Zoning, Division 12 Special Purpose Districts, § 12-906 of the Baltimore City Code, must

be open to the public 24 hours a day, 7 days a week unless agreed to by the Director of Planning and must be free of other impeding obstacles.

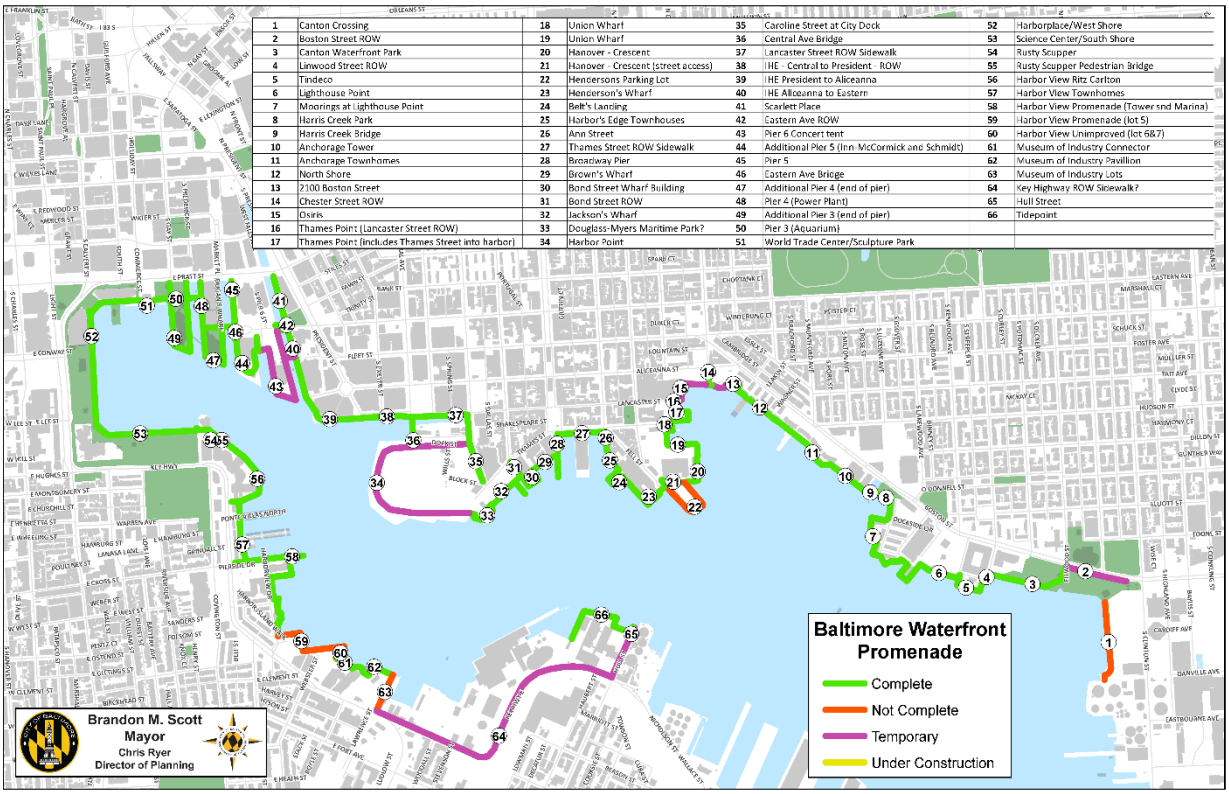

Figure 3-2. Baltimore Waterfront Promenade (Baltimore City Department of Planning)

3.3 Planning Units

The study area was segmented into seven planning units (Figure 3-3). Each planning unit has similar land use, shoreline type, zoning, opportunities, and constraints. The planning units are Patapsco East, Patapsco North, Inner Harbor, Locust Point, Middle Branch, Patapsco South, and Martin State Airport.

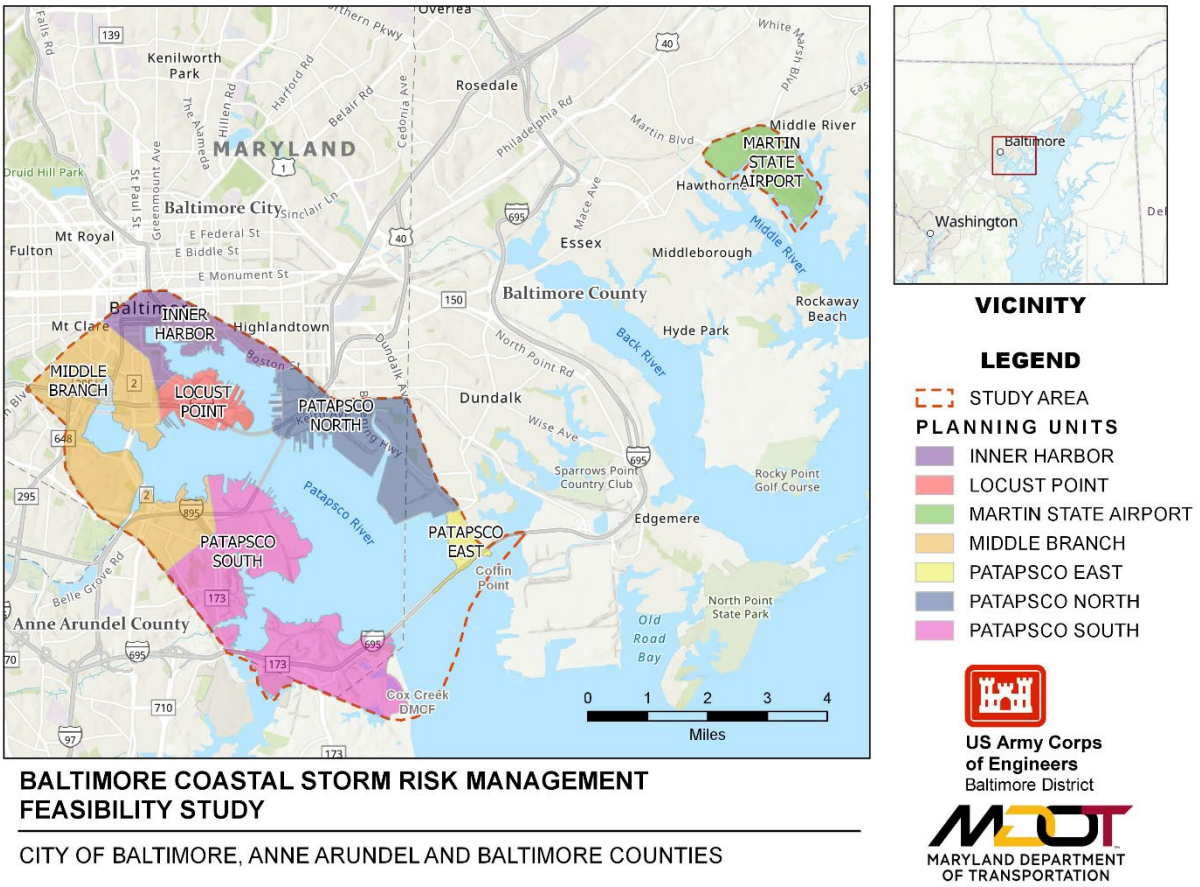

Figure 3-3. Planning Units

The years 2031-2080 were selected to represent the FWOP condition. If no federal action is taken, more than 1,200 structures would be subject to coastal storm inundation with present sea level conditions during a storm with a 1 percent chance of occurrence. Using the intermediate SLR curve, more than 1,400 structures are expected to be subject to coastal storm inundation in 2080, fifty years from the project base year.

A description of the planning units is included below, as well as the modeled inundation extent for each planning unit under the 1 percent AEP for the base year (2031) and for year 2080.

3.3.1 Patapsco East

This planning unit includes the northern shorelines of the Patapsco River, from Coffin Point (including the I-695 bridge to Sparrows Point) to the Dundalk Marine Terminal. This planning unit is in Baltimore County. The shoreline contains the Francis Scott Key Bridge (I-695) toll plaza, MDTA Offices, the Riverside Generating Station (retired) and electrical distribution facility, and a residential neighborhood adjacent to the Dundalk Marine

Terminal. For the existing and FWOP condition, the primary impact would be to the retired Riverside Generating Station and electrical distribution facility. As part of BGE's Key Crossing Reliability Initiative, the electrical distribution facility is currently being upgraded. The residential neighborhood occupies higher ground along the shoreline. Figure 3-4 shows the coastal flood inundation extent in the Patapsco East planning unit.

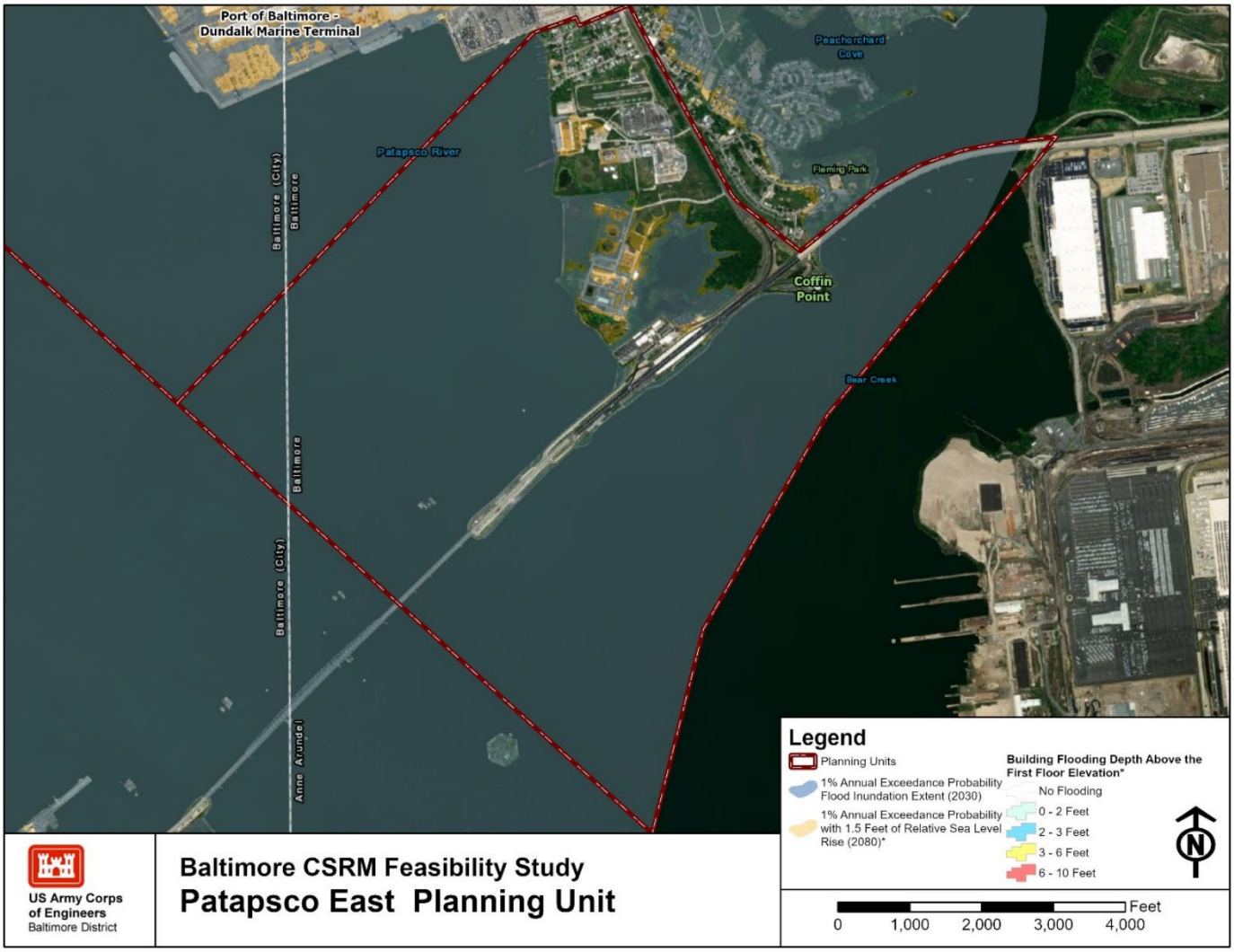

Figure 3-4. Patapsco East Planning Unit Coastal Flood Inundation Extent

3.3.2 Patapsco North

The Patapsco North planning unit includes the Dundalk Marine Terminal on the east and includes a small portion of Baltimore County while the rest of the area is within Baltimore City. The shoreline is characterized by marine terminals and marine activity and also includes the northern entrances and facilities of the I-895 and I-95 (Baltimore Harbor and Fort McHenry) tunnels. Colgate Creek divides the Dundalk and Seagirt Marine Terminals. Much of the Dundalk and Seagirt Marine Terminals may be inundated in the FWOP

conditions under 1 percent and 0.2 percent AEP, as would be piers and associated marine infrastructure. Support facilities for the I-895 Baltimore Harbor Tunnel may also be vulnerable under the FWOP conditions. Figure 3-5 shows the coastal flood inundation extent in the Patapsco North planning unit.

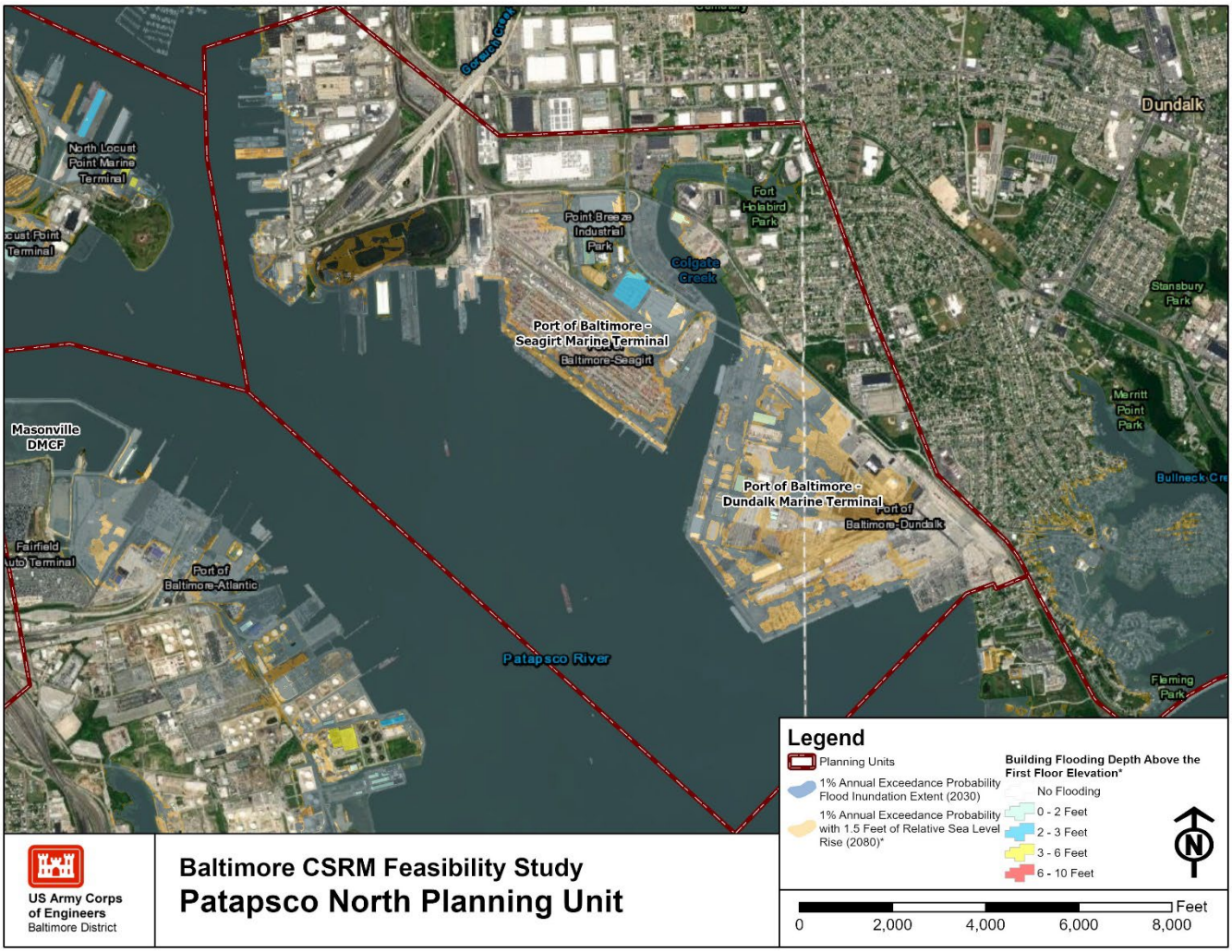

Figure 3-5. Patapsco North Planning Unit Coastal Flood Inundation Extent

3.3.3 Inner Harbor

The Inner Harbor planning unit includes much of what is considered the downtown Baltimore City waterfront. The Inner Harbor planning unit encompasses the majority of Baltimore's Waterfront Promenade (see Figure 3-2). Included within this planning unit are the Baltimore City Police Marine Unit, the neighborhoods of Canton, Fells Point, Harbor Point, Harbor East, and the Inner Harbor. Land use in the area is primarily residential and commercial, with a walkable/bikeable Waterfront Promenade along nearly all of the waterfront.

Inundation for the 1 and 0.2 percent AEP with SLC would result in extensive inundation in Fells Point, Harbor East, and the Inner Harbor. Harbor Point is a redevelopment of former contaminated industrial site and buildings are generally elevated. Figure 3-6 shows the coastal flood inundation extent in the Inner Harbor planning unit.

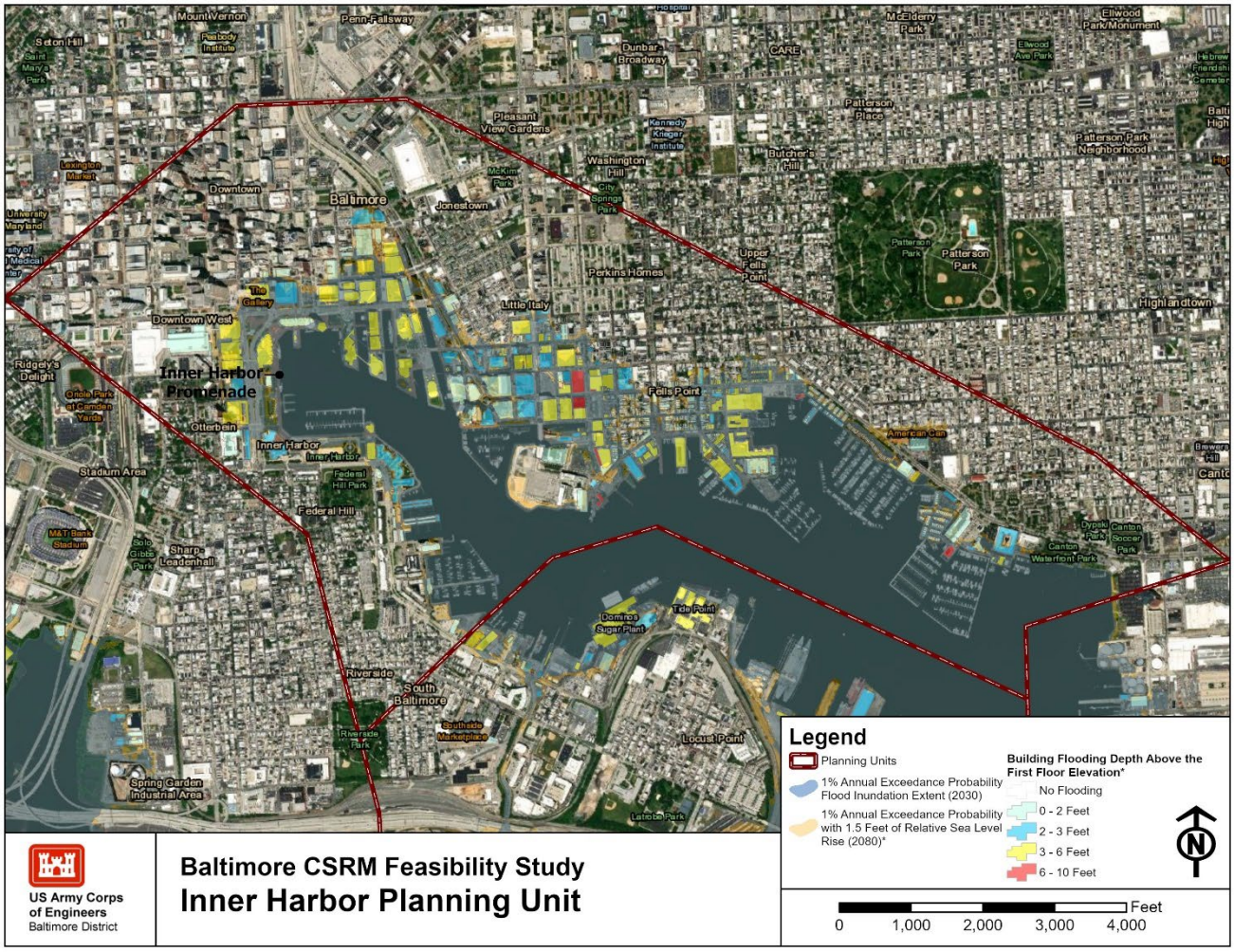

Figure 3-6. Inner Harbor Planning Unit Coastal Flood Inundation Extent

3.3.4 Locust Point

The Locust Point planning unit includes the Locust Point Peninsula, which separates the Inner Harbor from the Middle Branch of the Patapsco River. The planning unit extends around the peninsula to the beginning of the Port Covington development. Areas that would be inundated under FWOP conditions are primarily industrial, commercial, port facilities, and transportation assets. Flooding would affect the Dominos Sugar Plant, the Tide Point office complex, the Baltimore Fire Department Marine Unit, CENAB Fort McHenry facility, and the public marine terminals of North and South Locust Point Marine Terminals. The area also contains the southern entrance to the I-95 Fort McHenry Tunnel and its support facilities.

The Locus Point Peninsula is also home to Fort McHenry, administered by the National Park Service. The I-95 Fort McHenry Tunnel and its support facilities would be vulnerable under the 1 percent AEP with SLC. Figure 3-7 shows the coastal flood inundation extent in the Locust Point planning unit.

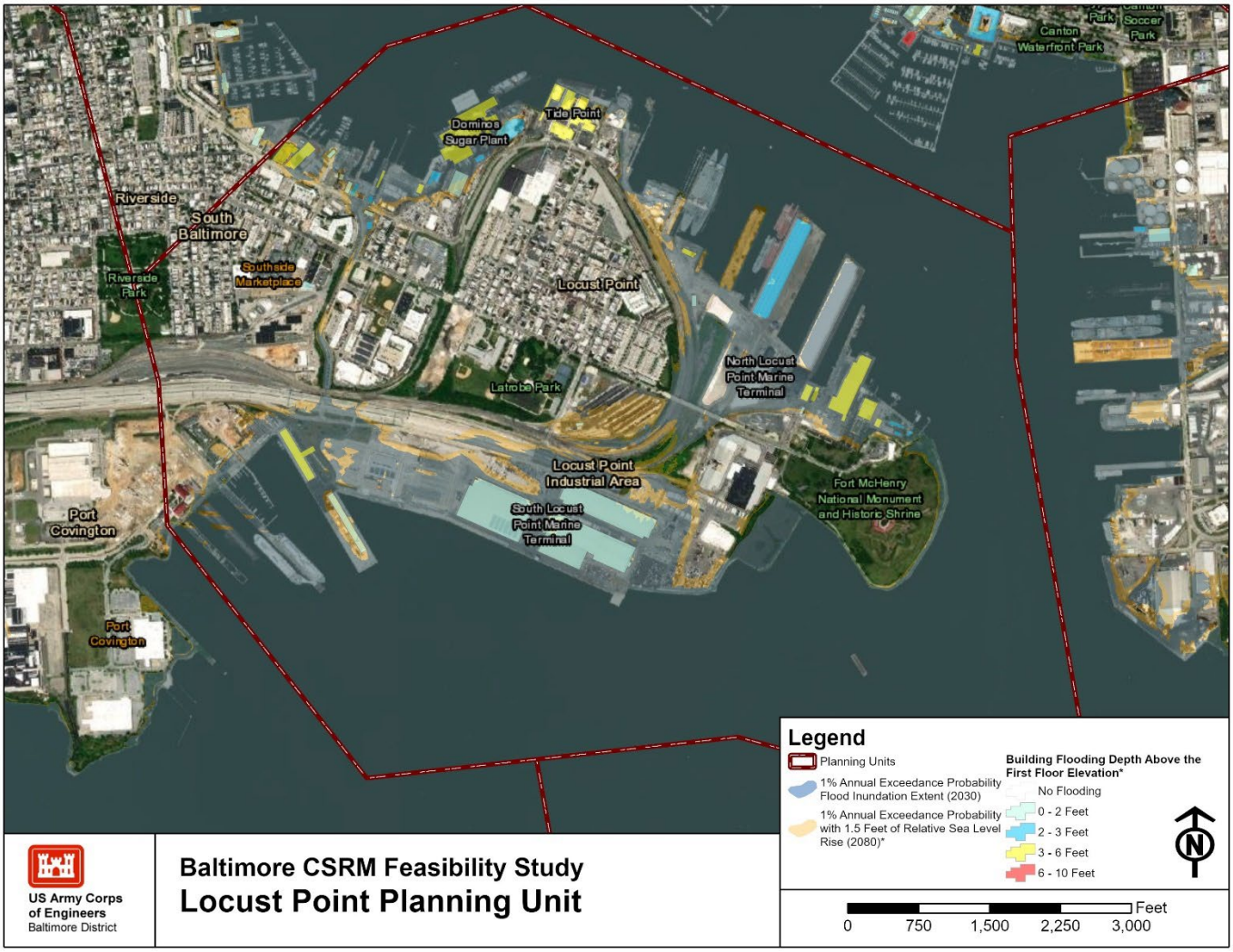

Figure 3-7. Locust Point Planning Unit Coastal Flood Inundation Extent

3.3.5 Middle Branch

The Middle Branch Planning unit encompasses much of the waterfront areas of the Middle Branch of the Patapsco River. The waterfront area extends from Port Covington to the Masonville DMCF. There is an existing effort within much of the area to enhance the shoreline for coastal resiliency, enhancing recreation, reconnecting people to the water, and ecosystem restoration. The Reimagine Middle Branch Project has secured funding to begin development of elements of the master plan, including protection of the vulnerable BGE Spring Garden natural gas facility.

This planning area includes a mix of industrial and commercial uses, previously developed shoreline, and public parks. Multiple large development projects are underway or in the planning phases and new development will incorporate design to protect against flooding and SLC. Projects include Port Covington and the Under Armour Campus, Casino Entertainment District, and Westport waterfront redevelopment. Parts of the Casino Entertainment District would be inundated under the FWOP 1 percent scenario. Under the 0.2 AEP scenario, inundation would extend further into the entertainment district and into a small portion of the Carroll Camden Industrial Area. A portion of the southern parking lot of Harbor Hospital would also be inundated under the 0.2 percent AEP scenario. Figure 3-8 shows the coastal flood inundation extent in the Middle Branch planning unit.

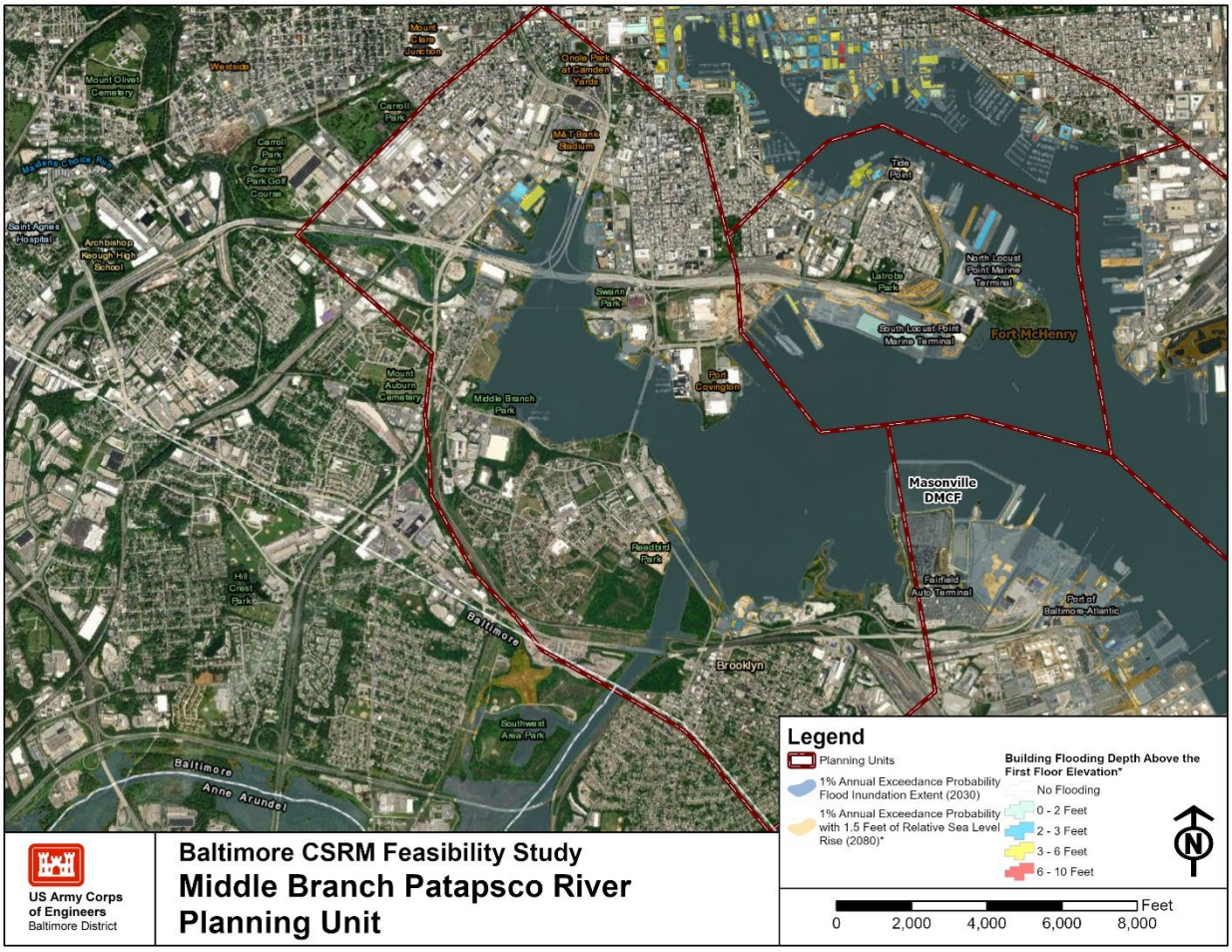

Figure 3-8. Middle Branch Planning Unit Coastal Flood Inundation Extent

3.3.6 Patapsco South

The Patapsco South planning unit includes the shoreline of the Patapsco River from Masonville Dredged Material Contain Facility to the Cox Creek DCMF. Most of the area

is in Baltimore City, though a small portion extends into Anne Arundel County. The shoreline is largely industrial. Areas at risk of inundation under FWOP conditions include Fairfield Marine Terminal, multiple private marine terminals, the Patapsco wastewater treatment plant, and the southern tunnel entrance for the I-895 tunnel (Baltimore Harbor Tunnel). The Curtis Bay Coast Guard Yard also has portions of its facility that are at risk of inundation. Figure 3-9 shows the coastal flood inundation extent in the Patapsco South planning unit.

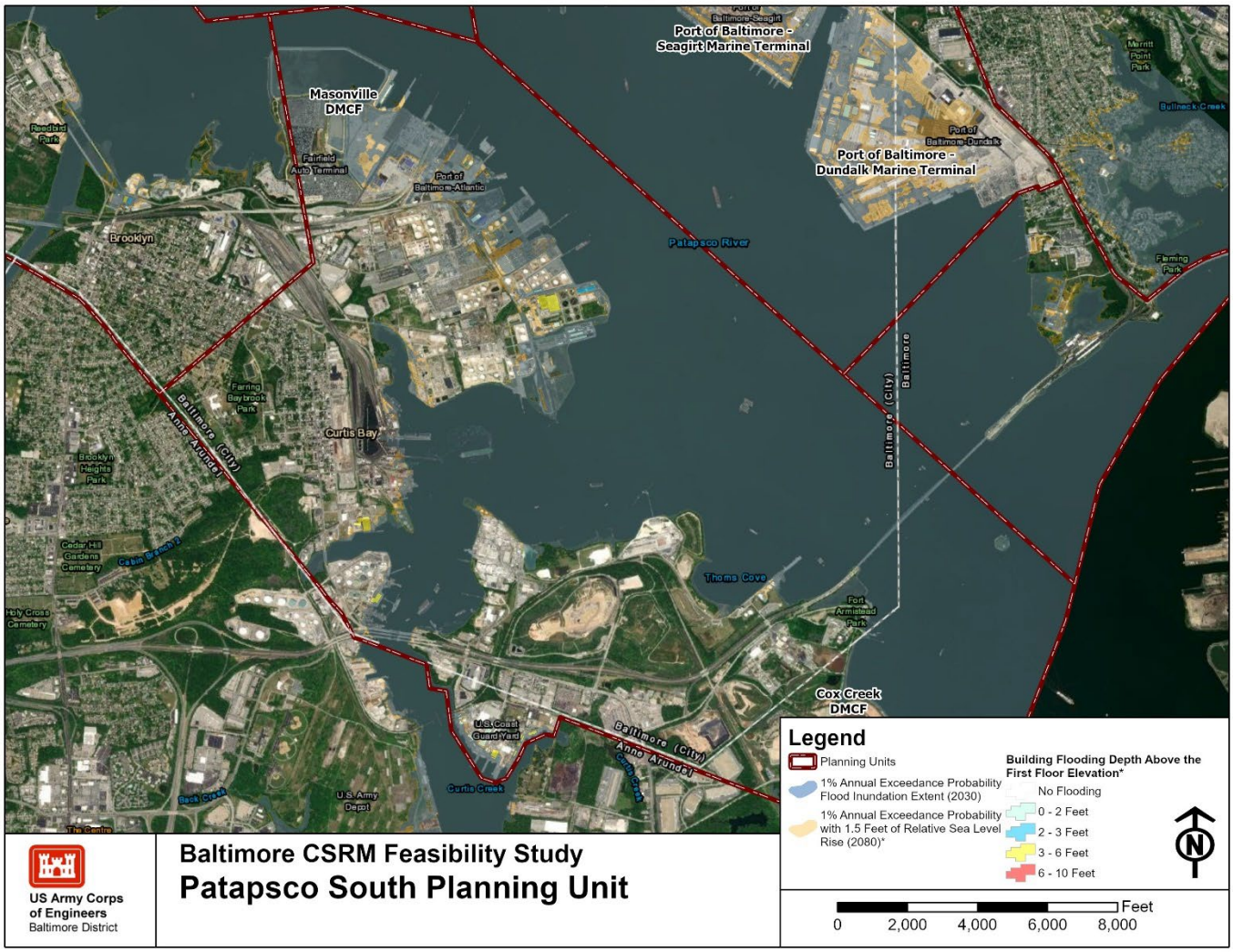

Figure 3-9. Patapsco South Planning Unit Coastal Flood Inundation Extent

3.3.7 Martin State Airport

The MSA planning unit is not contiguous with the other planning units and lies to the northeast of Baltimore City in Baltimore County on Middle River. The planning unit includes the Maryland State-owned MSA, the Warfield Air National Guard Base, and Chesapeake Industrial Park.

For the 1 percent AEP FWOP conditions, supporting infrastructure at the southern portion of the airport would be inundated, including hangers for the Baltimore City Police aviation unit and Baltimore County Police aviation unit, and the airport fuel facility. Several structures at the Air National Guard base would also be inundated. Additionally, Wilson Point Road which is the main access to Wilson Point, would be inundated at the entrance to Martin State Airport. In the 0.2 AEP scenario, the main buildings of MSA would be inundated as would the main entrance road to the Warfield Air National Guard Base. Figure 3-10 shows the coastal flood inundation extent in the MSA planning unit.

Figure 3-10. Martin State Airport Planning Unit Coastal Flood Inundation Extent

3.3.8 Summary of Flooding Impacts

Infrastructure and cargo would be damaged at the Port of Baltimore. Of particular concern are vehicles parked waiting for import/export on exposed parking lots at the Dundalk, South Locust Point, and Fairfield terminals. At any given time, these terminals have thousands of vehicles that are vulnerable to damage from coastal flooding.

Maryland State Highway Administration assets are vulnerable to damage from coastal flooding. Of particular concern are the I-95 and I-895 tunnels (Fort McHenry and Harbor Tunnels respectively) and their supporting transportation critical facilities (the tunnel ventilation buildings). Flood waters may enter the tunnels and the transportation critical

facilities. In addition to severe transportation disruption, flooding could cause damage to the tunnels, systems in the tunnels, and structures on land housing ventilation and other critical equipment.

The southern portion of the MSA runway would be inundated in a coastal storm and is susceptible to damage. Strawberry Point at the southern end of the airport houses the Maryland State Police aviation unit's hangers, which would be damaged and for which operations would need to be relocated in the event of storm damage. The airport's fuel farm would be inundated. Wilson Point Road would be inundated, cutting off access to the residential community of Wilson Point. 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 could damage mitigation systems in place for the remediation of groundwater contamination at MSA.

There are numerous development projects, both proposed and under construction, within the Baltimore City 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) will be replacing underwater high voltage transmission cables at the Key Bridge with an overhead crossing of the Patapsco River in 2022. When the transmission line is replaced, the existing Sollers Point terminal station would be deactivated. This terminal station is at risk of flooding from coastal storms.

As previously mentioned, the Reimagine Middle Branch is being undertaken by the South Baltimore Gateway Partnership using federal funds from FEMA to enhance coastal resilience in the Middle Branch area, including the BGE Spring Gardens natural gas storage and distribution facility.

The Port of Baltimore is expected to continue to attract a diverse array of vessels transporting containers, coal, vehicles, and general cargo. Maryland Port Administration and its partners upgraded Berth 3 at the Seagirt Marine Terminal in 2022, which would allow for two berths to service large container ships of around 14,000 TEU capacity. Maryland Port Administration has partnered with U. S. Maritime Administration to provide upgrades to all berths at the Dundalk Marine Terminal, installing a "sea curb" during the upgrade process which would provide some risk reduction to coastal flooding.

3.4 Management Measures

The PDT identified management measures in accordance with the study-specific planning objectives, existing plans, analyses, and studies. For each planning unit, a list of FRM measures were evaluated and screened. Measures that were evaluated include:

Structural:

- Storm surge barrier (large, e.g., regional)
- Tide gates

- Seawall, bulkheads
- Groins, breakwaters
- Floodwalls & levees
- Deployable floodwalls
- Drainage improvements (e.g., pump house)
- Channel improvements
- Shoal removal/dredging (in-channel)
- Road raising/elevation

Non-Structural:

- Floodproofing
- Building elevation
- Acquisition & relocation
- Enhanced warning systems

NNBF*

- Living shoreline
- Wetland restoration
- Reefs
- SAV
- Beach restoration (dunes)
- *NNBF features were considered for optimization of alternatives

3.4.1 Description of Structural Measures Considered

Structural measures are engineering features that help reduce damage from coastal storms and erosion as well as to manage flood risk from coastal storms.

3.4.1.1 Storm Surge Barrier

Storm surge barriers reduce risk to estuaries against storm surge flooding and waves. In most cases the barrier consists of a series of movable gates that normally stay open under normal conditions to let the flow pass but are closed when storm surges are expected to exceed a certain level. Four alignments of a storm surge barrier were considered in the Baltimore Metropolitan Area Survey Report, 1960. At each location a rock-faced hydraulic fill barrier with a navigation opening was considered. No plan was found to be economically justified in 1960 and none were supported by local interests.

3.4.1.2 Tide Gates

Tide gates are coastal storm flood risk reduction measures that provide a barrier between the ocean and a waterbody at a location that is considered or designed to be non-navigable. Tide gates are designed to stay open under normal conditions to let tidal flow pass but are closed when water levels are expected to exceed a certain level. Tide gates do not allow for navigation or passage of vessels or small boats. A tide gate is typically a reinforced concrete superstructure supported on steel pipe piles, with a steel sheet pile cut-off wall as a seepage control measure. In some instances, tide gates are

accompanied by a pump station that is operated in the event of gate closure to discharge stream flows from the upstream waterbody and maintain safe water levels.

3.4.1.3 Seawall and Bulkheads

These are often large concrete, wood, or metal structures designed to withstand storm waves (Hayes and Michel 2010). Once constructed, seawalls can have three potential impacts: impoundment, passive erosion, and active erosion. Impoundment is the area lost because of the structure itself. Passive erosion results when there is landward shoreline migration after a hard structure is built. The result would be the gradual loss of the beach in front of the seawall as the water deepens and the shoreface migrates landward. Active erosion occurs downcoast of the seawall. Bulkheads are typically made of wood or sheet-piling and are generally much smaller than seawall structures.

3.4.1.4 Groins and Breakwaters

Groins are common shore protection structures built connected to the shore and perpendicular to the shoreline to trap sediment conveyed by littoral transport. They sometimes are made of rubble, but other materials such as wood, rocks, sandbags, or gabions are also used. Multiple groins are usually installed to increase beach sedimentation along a stretch of shoreline with a terminal groin being the most downcoast structure in the groin field. Breakwaters are constructed offshore to dissipate the energy of approaching waves and form a protected shadow zone on their landward sides. Breakwaters attenuate wave energy and can provide additional recreational opportunities, novel aquatic habitat, and carbon or nutrient sequestration with wetlands incorporated into the design.

3.4.1.5 Floodwalls and Levees

Floodwalls are structures used to prevent flooding and to project relatively small areas or areas with limited space for large flood protection measures. Floodwalls are most frequently used in urban and industrial areas. Levees are embankments constructed along a waterfront to prevent flooding in relatively large areas for high levels of flood risk.

3.4.1.6 Deployable Floodwalls

Rapid deployment floodwalls are structures that are temporarily erected along the banks of a river or estuary, or in the path of floodwaters. Rapid deployment floodwalls prevent water from reaching the area behind the structure and are usually used in location where space is limited.

3.4.1.7 Drainage Improvements (e.g. pump station)

A drainage system can carry water away via conveyance systems and, during times of high water, may store water until it can be carried away. Conveyance systems utilize measures such as pump stations, culverts, drains, and inlets to remove water from a site quickly and send it to larger streams. Storage facilities are used to store excess water until the storm or flood event has ended.

3.4.1.8 Channel Improvements

Channel modifications are measures carried out to reduce out-of-bank stage (and hence, damage) by modifying the geometry or by reducing the energy loss. The out-of-bank stage can be reduced for a given discharge rate if the channel is modified to increase the effective cross-sectional area. As water is conveyed in a channel, energy is converted from one form to another or "lost". As this loss of energy results in increased stage, stage may be reduced by reducing the energy loss. This may be accomplished by smoothing the channel boundary, straightening the channel, or minimizing the impact of obstructions in the channel.

3.4.1.9 Shoal Removal/Dredging (in-channel)

Increasing channel volume through the removal of shoals or dredging channels deeper is similar to channel improvements in that the out-of-bank stage can be reduced for a given discharge rate if the effective cross-sectional area is increased.

3.4.2 Description of Nonstructural Measures Considered

Nonstructural CSRM measures are intended to reduce the consequences of flooding to buildings and other assets in areas prone to flood inundation. Nonstructural CSRM measures include floodproofing (wet and dry), acquisition and relocation, elevation of buildings, basement filling, and programmatic considerations including enhanced flood warning systems, land use regulations, and floodplain management and zoning. The PDT considered nonstructural measures identified in NACCS and determined if they meet planning objectives for flood risk reduction for the different planning units in the study area. This section discusses nonstructural measures considered during plan formulation in this study.

3.4.2.1 Floodproofing

Floodproofing involves reducing damage to buildings by waterproofing, shields, or other means that allow floodwaters to pass through or around the building unimpeded. Floodproofing offers the opportunity to reduce flood damages to structures and contents for an individual structure-by-structure basis or for a group of structures. Floodproofing costs can vary substantially depending on the type of floodproofing method being considered and the type, size, age, and location of the structure(s).

3.4.2.2 Dry Floodproofing

Dry floodproofing of existing structures is a common floodproofing technique applicable for flood depths of three (3) feet or less on buildings that are structurally sound. Dry floodproofing involves sealing building walls by waterproofing preventing the entry of floodwaters into a structure. Installation of temporary closures or flood shields is a commonly used floodproofing technique. A flood shield (sometimes termed flood gate) is a watertight barrier designed to prevent the passage of floodwater though doors, windows, ventilating shafts, and other openings of the structure exposed to flooding. Such shields are typically made of steel or aluminum and are installed on structures only prior

to anticipated flooding. However, flood shields can only be used on structures with walls that are strong enough to resist the flood-induced forces and loadings. Exterior walls must be made watertight in addition to the use of flood shields. This technique is not applicable to areas subject to flash flooding (less than one hour) or where flow velocities are greater than three (3) feet per second. It would also not be applicable to mobile homes, due to the type of construction and typical lack of anchoring to a foundation. Aside from the cost, dry floodproofed homes and businesses can still suffer flood damages due to the potentially incomplete nature of the solution. Enclosures for windows and doors require human intervention to fully implement the solution, and this action would have to occur in a relatively short timeframe.

3.4.2.3 Wet Floodproofing

Wet floodproofing is also a common way of reducing flood damages for structures with an uninhabited basement or other subgrade portion of a building. Wet floodproofing involves modifications of structures to allow for flood waters to enter and inundate portions of the building to minimize structural damage. This type of floodproofing can include raising of utilities, raising building contents above the flood elevation, or moving to higher floors, using flood damage-resistant materials in the building interior and exterior, and installing flood opening in the structure foundation walls to reduce water pressure on the structure. This approach can minimize but would not eliminate flood damages to the structure and requires extensive cleanup and maintenance. Wet floodproofing may not be feasible in certain areas based on the velocity and volume of the flood source.

3.4.2.4 Building Elevation

Elevation of structures is a common CSRM measure that requires raising of the structure in place above the design flood elevation (DFE). Elevation is most suitable for single family houses with good structural integrity. Buildings are elevated by raising on temporary framing followed by extending foundation walls or structural fill up to the design elevation. Another option common in coastal areas is to elevate buildings on pilings, which may not be suitable for low flood elevations.

For structures that cannot be elevated, other measures may be feasible to reduce flood risk. These include retrofitting or raising electrical equipment above flood elevation, using flood damage resistant materials in portions of a structure with direct contact with flood waters, and basement infill. Basement infill includes filling a basement located below the flood elevations and retrofitting first floor openings to allow for movement of floodwater (FEMA 2015).

3.4.2.5 Acquisition and Relocation

Acquisition consists of buying out buildings and associated land parcels located within the floodplain. After acquisition, the building is demolished or relocated outside of the floodplain, reducing flood risk to communities. Acquisitions are generally implemented to structures at extreme risk of flooding that have been flooded one or more times. While

acquisition with demolition or relocation reduces flood risk and restore floodplains, it can have a negative impact on neighborhood cohesion and the vitality of coastal communities.

Relocation involves physically moving a building at-risk of flooding to an area of lower risk, typically outside of the floodplain. This measure can eliminate flood risk while restoring the floodplain, but it can be costly and time consuming.

3.4.2.6 Enhanced Warning Systems

Despite improved tracking and forecasting techniques, the uncertainty associated with the size of a storm, the path, or its duration necessitate warnings be issued as early as possible. Evacuation planning is imperative for areas with limited access, such as high density housing areas, elderly population centers, cultural resources, and areas with limited transportation options.

3.4.3 Description of Natural and Nature Based Features Considered

NNBF mimics natural features or processes to prevent erosion and reduce damage to shorelines through restoration of coastal habitats or creation of reefs, wetlands, or living shorelines.

3.4.3.1 Living Shoreline

Living shorelines are essentially tidal wetlands constructed along a shoreline to reduce coastal erosion. Living shorelines maintain dynamic shoreline processes, and provide habitat for organisms such as fish, crabs, and turtles. As essential component of a living shoreline is constructing a rock structure (breakwater/sill) offshore and parallel to the shoreline to serve as protection from wave energy that would impact the wetland area and cause erosion and damage or removal of the tidal plants.

3.4.3.2 Wetland Restoration

The dense vegetation and shallow waters within wetlands can slow the advance of storm surge somewhat and slightly reduce the surge landward of the wetland or slow its arrival time. Wetland can also dissipate wave energy; potentially reducing the amount of destructive wave energy propagating on top of the surge, though evidence suggests that slow-moving storms and those with long periods of high winds that produce marsh flooding can reduce this benefit.

3.4.3.3 Reefs

The development of artificial reefs provides a means to reestablish and enhance reef communities. Artificial reefs provide shoreline erosion protection and may provide wave attenuation.

3.4.3.4 Submerged Aquatic Vegetation

SAV performs many important functions, including: wave attenuation and sediment stabilization; water quality improvement; primary production; food web support for secondary consumers; and, provision of critical nursery and refuge habitat for fisheries species.

3.4.3.5 Beach Restoration (dunes)

Beach and dune restoration is the supply of sand to the beach to increase or restore its width. A wider beach can reduce storm damage to coastal structures by dissipating energy across the surf zone and protecting upland structures and infrastructure from storm surges. The dunes that may back a beach act as a physical barrier that reduces inundation and wave attach to the coast landward of the dune. Although the dune may erode during a storm, it provides a sediment source for recovery after a storm passes.

3.4.4 Measures Screening Criteria

Management measures were evaluated and screened using several criteria. Measures were first screened if the measure is technically feasible. For each planning unit the measure was evaluated on shoreline type and characteristics, engineering feasibility and Tier I & II NACCS information. Those that met the screening criteria are marked with an "X" under the applicable planning units as shown in Table 3-1. Measures were also evaluated and screened using the feasibility study's planning objectives (Table 3-2). Measures were also screened to ensure they avoided planning constraints.

Plan formulation is the process of building alternative plans that meet planning objectives and avoid planning constraints. Alternatives are a set of one or more management measures functioning together to address one or more planning objectives. A management measure is a feature or activity that can be implemented at a specific geographic location to address one or more planning objectives. A feature is a "structural" element that requires construction or assembly on-site whereas an activity is defined as a "nonstructural" action.

These measures were investigated to identify means in which they could be combined to improve resiliency from coastal storm risk in the Baltimore area. The combined measures formed the initial array of alternatives described in the next section.

Table 3-1. Measures Screening Matrix (X-retained)

MEASURES		PLANNING UNITS						
		Patapsco E. (Sollers Pt)	Patapsco N. (Canton/ Dundalk)	Inner Harbor	Locust Point	Middle Branch	Patapsco S. (Fairfield/ Hawkins Pt)	Martin State Airport
Structural	Storm Surge Barrier – Regional	X	X	X	X	X	X	
	Tide Gates – Inlet		X			X		
	Shoreline Stabilization (Seawall, revetment, bulkheads)	X	X	X		X	X	X
	Beach Fill Stabilization – Breakwaters*					X		
	Beach Fill Stabilization – Groins*					X		
	Floodwall (levee, dike, berm)	X	X	X	X	X	X	X
	Deployable Floodwall		X	X	X	X	X	X
	Drainage Improvements (Pumps, Culverts, Storage)	X	X	X	X	X	X	X
	Channel Improvements							
	Shoal Removal/Dredging							
Non-Structural	Structure Elevation	X	X	X	X	X	X	X
	Acquisition/Relocation	X	X	X	X	X	X	X
	Flood Proofing	X	X	X	X	X	X	X
	Enhanced Warning Systems	X	X	X	X	X	X	X
NNBF	Living Shoreline	X			X	X	X	X
	Wetland Restoration	X			X	X	X	X
	Reefs					X	X	
	SAV					X	X	X
	Beach Restoration							
Policy/Programmatic		X	X	X	X	X	X	X

*Provides level of protection only when in combination with beach dune
**NNBF would not provide meet planning objectives on their own but are considered for optimization of other alternatives.

Table 3-2. Management Measures Screened with Study Objectives

	Study Objectives			
	Reduce risk to human health and safety	Reduce economic damages	Reduce disruption of critical infrastructure	Improve resiliency of critical infrastructure
Measure Name	Do the following non structural considerations meet the study objectives? (Yes/No)			
Storm surge barrier	Yes	Yes	Yes	Yes
Tide gates	Yes	Yes	Yes	Yes
Shoreline stabilization	Yes	Yes	Yes	Yes
Groins, breakwaters	No	No	No	No
Floodwalls and levees	Yes	Yes	Yes	Yes
Deployable floodwalls	Yes	Yes	Yes	Yes
Drainage improvements	Yes	Yes	Yes	Yes
Channel improvements	No	No	No	No
Shoal removal/dredging	No	No	No	No
Flood-proofing	Yes	Yes	Yes	Yes
Building elevation	Yes	Yes	Yes	Yes
Acquisition & relocation	Yes	Yes	Yes	Yes
Enhanced warning systems	Yes	No	No	Yes
Living shoreline	Yes	No	No	Yes
Wetland restoration	No	No	No	Yes
Reefs	No	No	No	No
SAV	No	No	No	No
Beach restoration (dunes)	No	No	No	No

The management measures that met the screening criteria are storm surge barriers and tide gates, shoreline stabilization, deployable floodwalls, floodwalls and levees, drainage improvements, floodproofing, building elevation, and relocation/acquisition, living shorelines, and wetland restoration. It was determined that concrete I-walls or T-walls were best suited for most developed areas, as compared to a seawall or bulkhead. Bulkheads may be more suitable for areas with waterborne vessel traffic. Structure elevation is not suitable for many parts of the study area due to the building types (connected rowhouses, large commercial structures, warehouses). Inundation from three flood scenarios: 5 percent (20-year storm), 2 percent (50-year storm), and 1 percent AEP

(100-year storm), did not result in a high enough water level to warrant relocation/acquisition of any structures. Therefore, relocation/acquisition was not further evaluated and instead the non-structural plan focused on floodproofing

3.5 Arrays of Alternatives

From the compiled table of management measures, the team formulated "lines of defense" representing alternative plans, based on logical groupings of measures and planning units. Lines of defense are shown in Table 3-2 and include storm surge barriers, floodwalls along the shoreline, critical infrastructure, and a nonstructural plan. Alternatives were formulated using the 1 percent AEP and the intermediate SLC curve in 2080. Coastal storm risk benefits were developed for the initial alternatives using G2CRM and Class 5 costs were developed based on NACCS costs inflated to year 2019. Class 5 costs are commonly referred to as Rough Order of Magnitude (ROM) costs and include high contingencies due to a higher level of uncertainty. Class 5 or ROM costs use broad-based assumptions, costs from comparable projects and data, and cost engineering judgement. Initial alternative benefits and costs are available in Appendix E: Economic Analysis.

Table 3-2. Lines of Defense

Line of Defense	Strategy	Planning Unit
Storm Surge Barrier	Construction of a coastal **storm surge barrier** at a strategic location near the opening of the Patapsco River, to provide comprehensive protection.	Inner Harbor, Locust Point, Middle Branch, Patapsco North, Patapsco South, Patapsco East
Shoreline line of defense (floodwall)	Reduce risk to property and infrastructure through **structural** features (floodwall)	Inner Harbor, Locust Point, Patapsco North
Critical Infrastructure	Reduce risk to critical infrastructure through structural features (levees, floodwall)	Locust Point, Patapsco North, Patapsco South, Martin State Airport
Nonstructural plan	Application of **nonstructural** measure to reduce damages and increase resilience to coastal communities	Inner Harbor, Locust Point, Patapsco South, Matin State Airport

Natural Areas Plan* **for optimization of above plans, not stand alone*	Restoration of **natural features**, such as living shorelines and wetlands, where possible.	Entire Study Areas

The following sections show the iterative planning process, starting with the initial array of the alternatives developed for the AMM held in November 2019, through the final array of alternatives evaluated and compared for the TSP Milestone held in May 2022. Each section builds upon the former with additional details added to alternative plan descriptions, applied screening criteria, revisions to alternatives alignments, limits of disturbance (LOD) and optimization of alternatives.

3.5.1 Initial Array of Alternatives

The Initial Array of Alternatives are shown in Table 3-3. Figure 3-10 to 3-18 illustrate each alternative. Descriptions of the Initial Array of Alternatives are provided below, and include features originally presented at the AMM.

Table 3-3. Initial Array of Alternatives

Alternative Plan Number	Description
No Action	No Action
1	Surge Barrier 1 (Outer)
2	Surge Barrier 2 (Inner)
3	Nonstructural Only
4	Critical Only
5	Critical & Nonstructural
6	Critical Balanced
7	Mid-tier Balanced
8	Mid-tier w/NNBF
9	Mid-tier, Max NNBF
10	High-tier

3.5.1.1 Alternative Plan 0: No Action or Future Without Project Condition

Under the No Action or FWOP condition, no federal action would be undertaken to address coastal storm risk in the study area. FWOP conditions are presented in Section 2.

3.5.1.2 Alternative Plans 1 and 2: Surge Barrier Plans

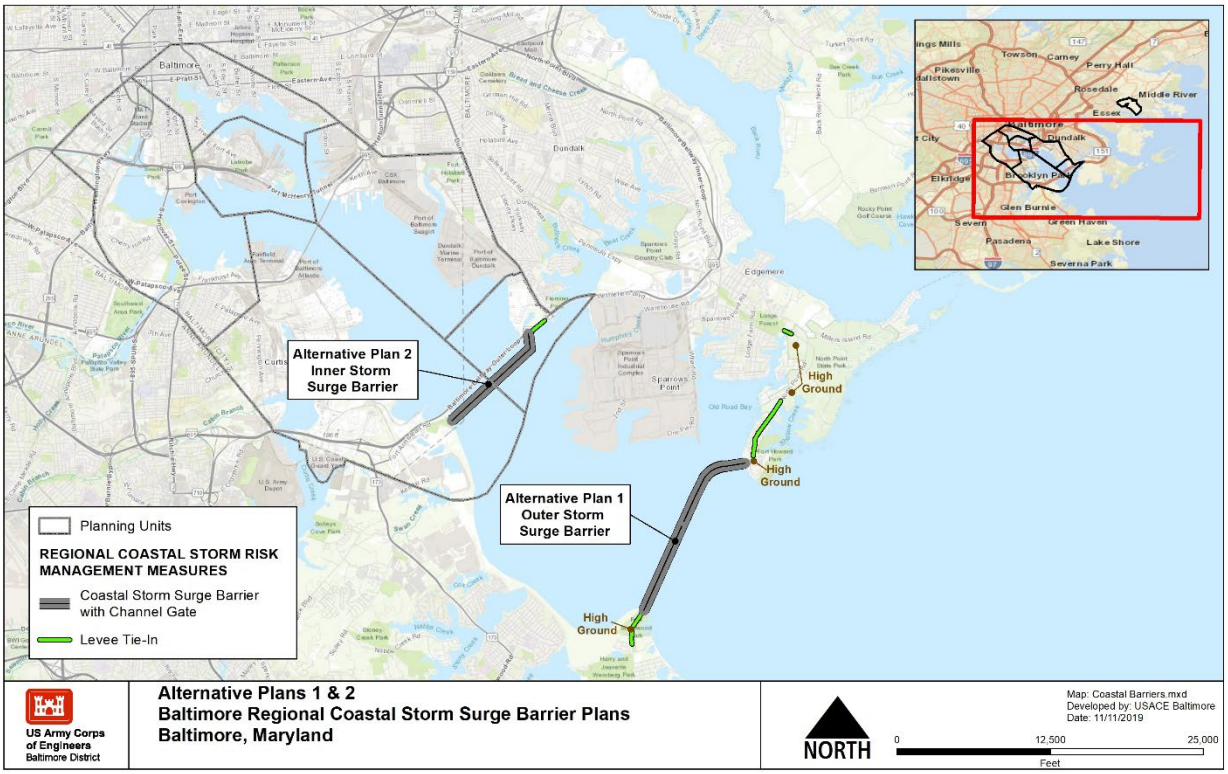

Figure 3-11. Alternative Plans 1 & 2 – Regional Barrier Plans

These alternatives include the storm surge barrier plans (Figure 3-11). Alternative Plan 1 (Outer Coastal Surge Barrier Plan) consists of a proposed storm surge barrier from Fort Smallwood Park to Fort Howard. Alternative Plan 2 (Inner Coastal Surge Barrier Plan) consists of a surge barrier running parallel to and just outside the Francis Scott Key Bridge, from Fort Armistead Park to Coffin Point. Both plans consist of surge barriers with 1,000-foot-long sector gate openings.

Both of these plans would protect 6 of the 7 planning units with a coastal surge barrier and would protect MSA with a flood levee. The ROM costs for the Outer Coastal Barrier (Alternative Plan 1) and Inner Coastal Barrier (Alternative Plan 2) were estimated by escalating costs developed for the same alignments from a prior USACE study (Baltimore Metropolitan Area Hurricane Survey, CENAB 30 NOV 1960), and incorporating a 1,000-foot sector gate closure with costs derived from modern USACE barrier projects in other regions. Base capital costs were estimated at approximately $1.4 billion for the outer barrier (Fort Smallwood Part to Fort Howard) and approximately $1.3 billion for the inner barrier (Fort Armistead Park to Coffin Pt.). The ROM benefits for these alternatives were barely positive (low NED benefits and preliminary Benefit-to-Cost Ratio [BCR] of 1.03 and 1.10, respectively). The assessed risk for both of these plans was unacceptably high.

Environmental impacts are of great concern as a “fishable, swimmable” harbor is a goal of many stakeholders. Due to the all-or-nothing nature of these plans in contrast to other alternative plans, benefits would not begin to accrue until the entire plan is implemented. Given the magnitude of the total cost estimated for this alternative, the uncertainty about whether these ROM costs adequately captured the full costs of construction (e.g., additional gate closures, environmental mitigation costs, etc.), the high risks that these plans would not be found acceptable, and the likelihood that the realized benefits would be significantly below the theoretical maximum damages (particularly with respect to high-frequency, lower-intensity events), these alternative plans were screened from consideration.

3.5.1.3 Alternative Plan 3: Nonstructural Plan

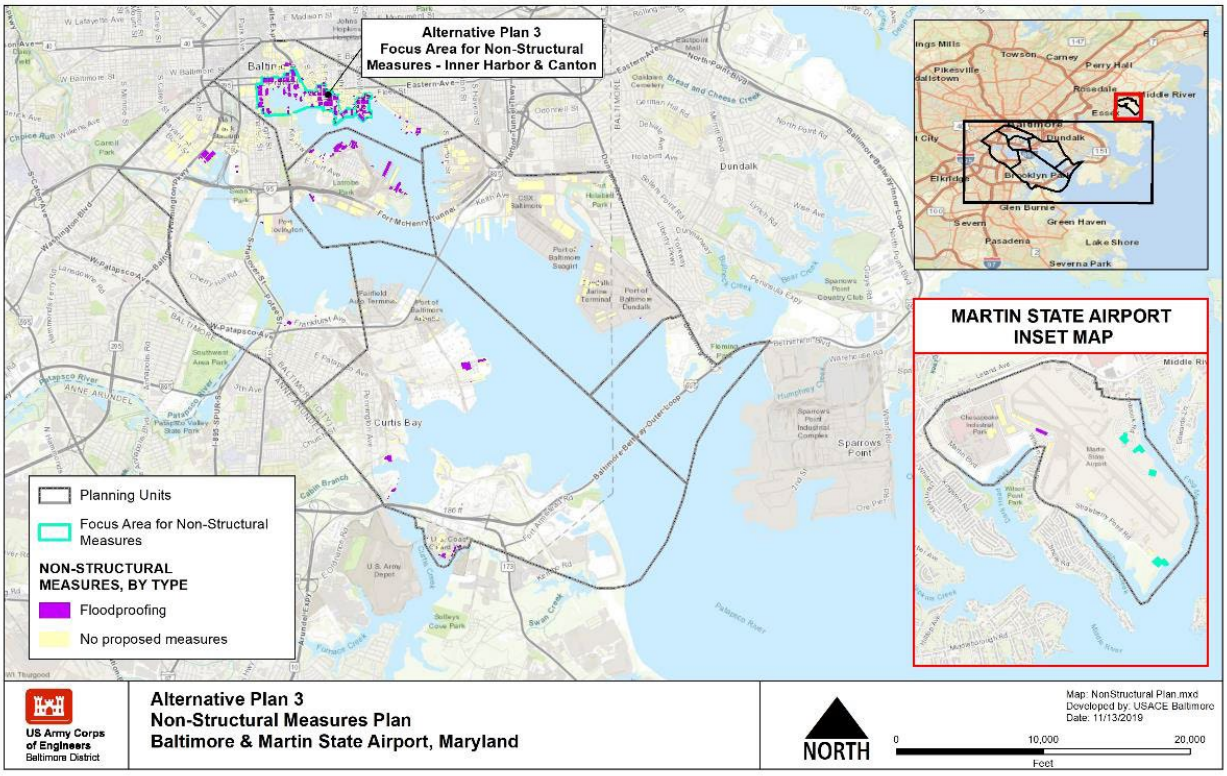

Figure 3-12. Alternative Plan 3 – Nonstructural Plan

Alternative Plan 3 (Figure 3-12) consists solely of the use of nonstructural measures to reduce flood risk to structures. Over 1,400 structures have been identified as being at risk within the study area by 2080, under the one percent AEP with intermediate SLC scenario. These include commercial, residential, industrial, and institutional structures.

This plan consists of the exclusive use of nonstructural measures. Due to the number of structures at risk and uncertainty regarding critical parameters (first floor elevation,

structure construction and condition, etc.), detailed costs were not developed for this plan. ROM costs were estimated for the at-risk structures under the 1 percent AEP. The NACCS nonparametric cost of $100K for floodproofing was used for structures with occupancy type “residential”, “commercial”, or “high-rise”. The NACCS nonparametric value of $3.74M for ring wall-type structures was used for “educational” and “government” structures. Costs were not estimated for “industrial” structures. This plan was determined to be unlikely to adequately protect certain critical infrastructure elements (i.e., the interstate highway tunnel entrances), and therefore could not fully meet the study objectives. This alternative plan was therefore screened from further consideration.

3.5.1.4 Alternative Plan 4: Critical Infrastructure Plan

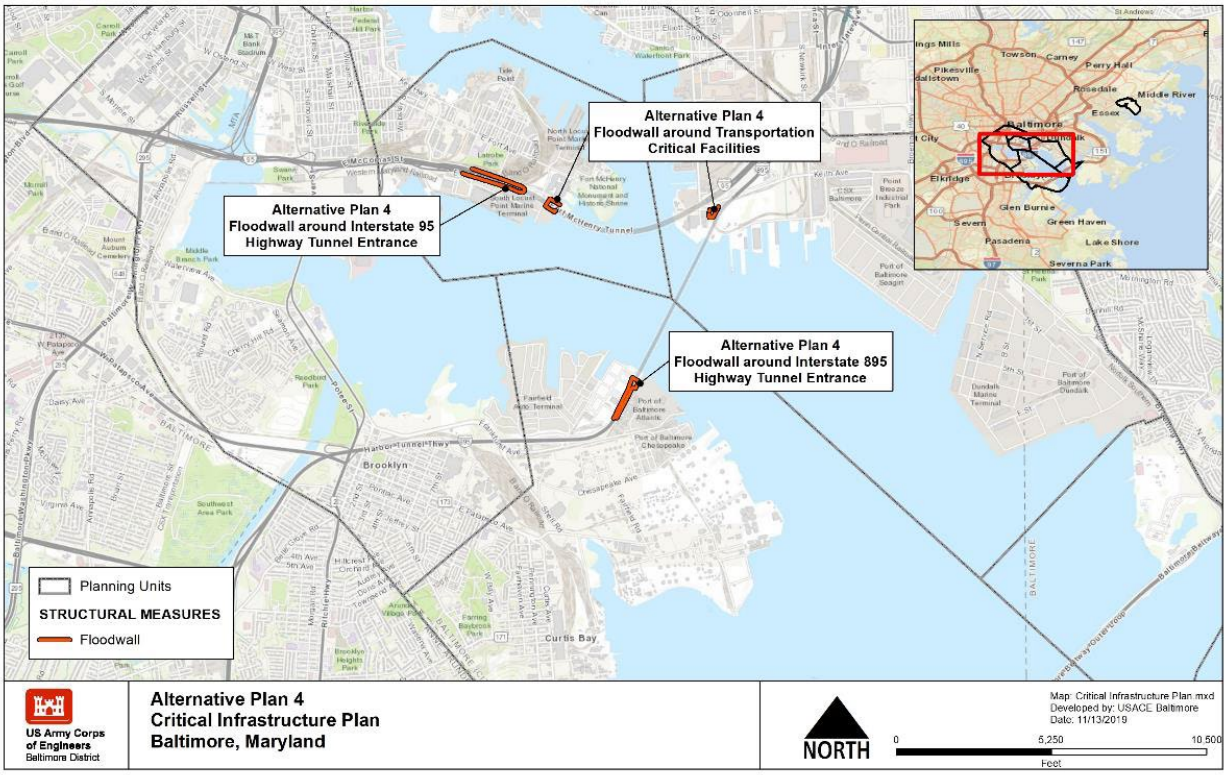

Figure 3-13. Alternative Plan 4 – Critical Infrastructure Plan

Alternative Plan 4 (Figure 3-13) is the Critical Infrastructure Plan. This plan would protect some of the most critical transportation assets in the study area: the Fort McHenry Tunnel that connects I-95 and the Baltimore Harbor Tunnel that connects I-895. The components of this alternative would include floodwalls along the tunnel entrances on the southern approach of I-895 and I-95 and their associated transportation critical facilities.

This plan achieves the planning objectives, avoids constraints, has acceptable levels of risk, appears to provide strong benefits and is likely to have a favorable BCR. This plan was retained for the focused array of alternatives.

3.5.1.5 Alternative Plan 5: Critical Infrastructure and Nonstructural Plan

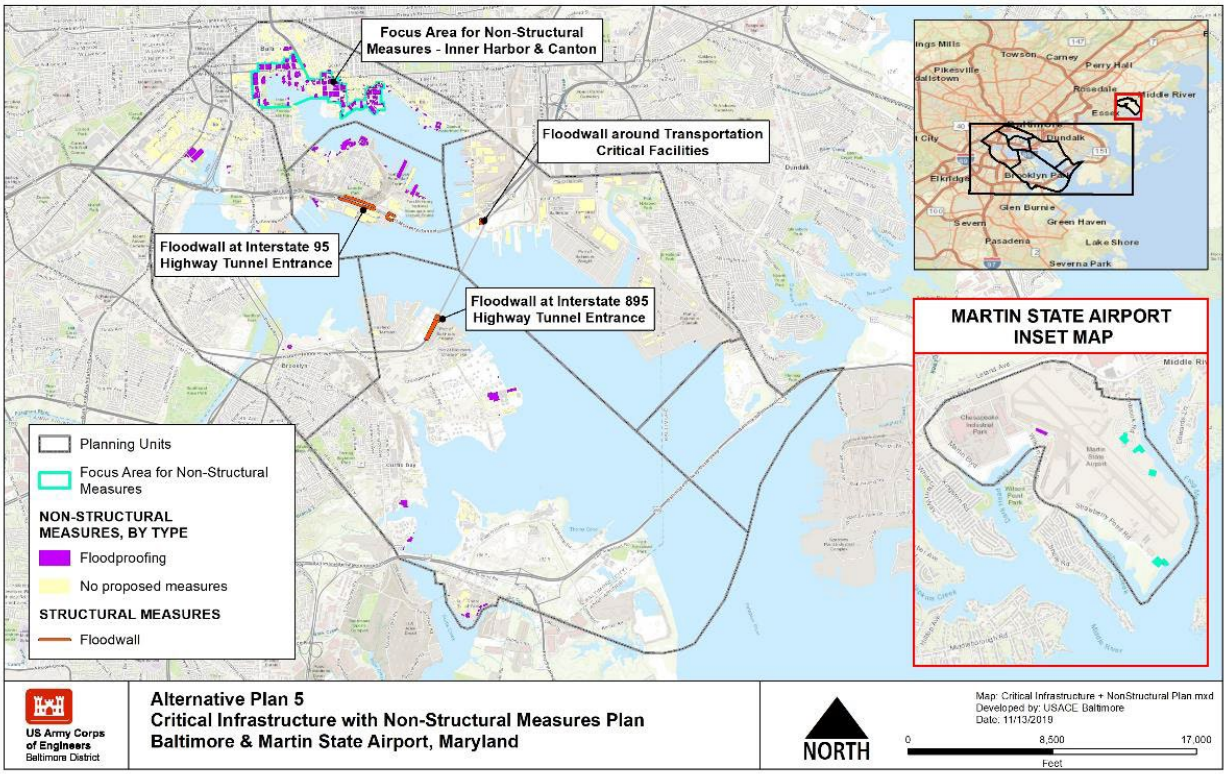

Figure 3-14. Alternative Plan 5 – Critical Infrastructure with Nonstructural Measures Plan

Alternative Plan 5 (Figure 3-14) includes all elements of Alternative Plan 4 as well as nonstructural measures for remaining at-risk structures, as described in Alternative Plan 3.

This plan achieves the planning objectives, avoids constraints, has acceptable levels of risk, appears to provide strong benefits and appears likely to have a favorable BCR. This plan was retained for the focused array of alternatives. Note that this plan still includes extensive use of nonstructural measures for vulnerable properties, and the same limitations described under Alternative Plan 3, above, apply to this plan.

3.5.1.6 Alternative Plan 6: Critical Infrastructure Balanced Plan

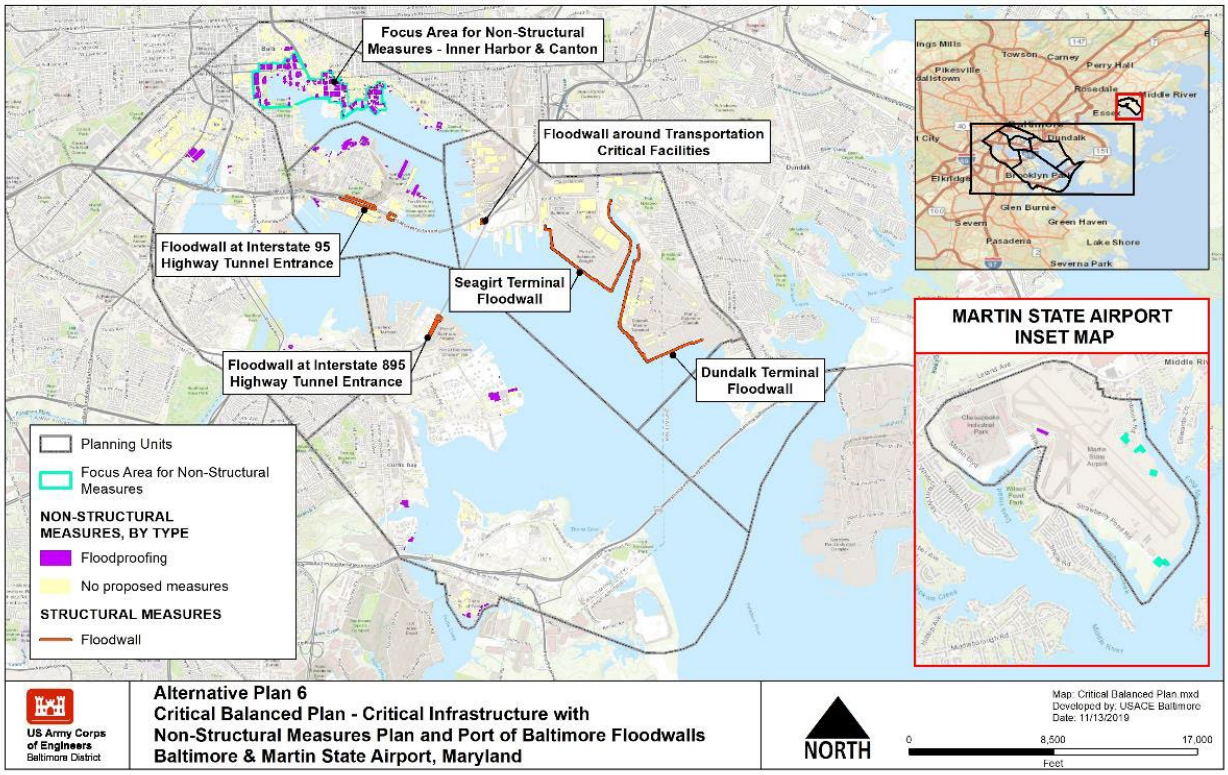

Figure 3-15. Alternative Plan 6 – Critical Infrastructure with Nonstructural Measures Plan and Port of Baltimore Floodwalls

Alternative Plan 6 (Figure 3-15) includes all elements of Alternative Plan 5 and incorporates a coastal floodwall at Seagirt Marine Terminal and an elevated road-on-levee at Martin State Airport. A coastal floodwall at the Dundalk Marine Terminal was also part of this plan during initial formulation but was dropped from consideration because funding was secured by Maryland Port Administration for this project element, initiating design and construction activities.

This plan achieves the planning objectives, avoids constraints, has acceptable levels of risk, appears to provide strong benefits and appears likely to have a favorable BCR. This plan was retained for the focused array of alternatives.

3.5.1.7 Alternative Plan 7: Mid-Tier Plan

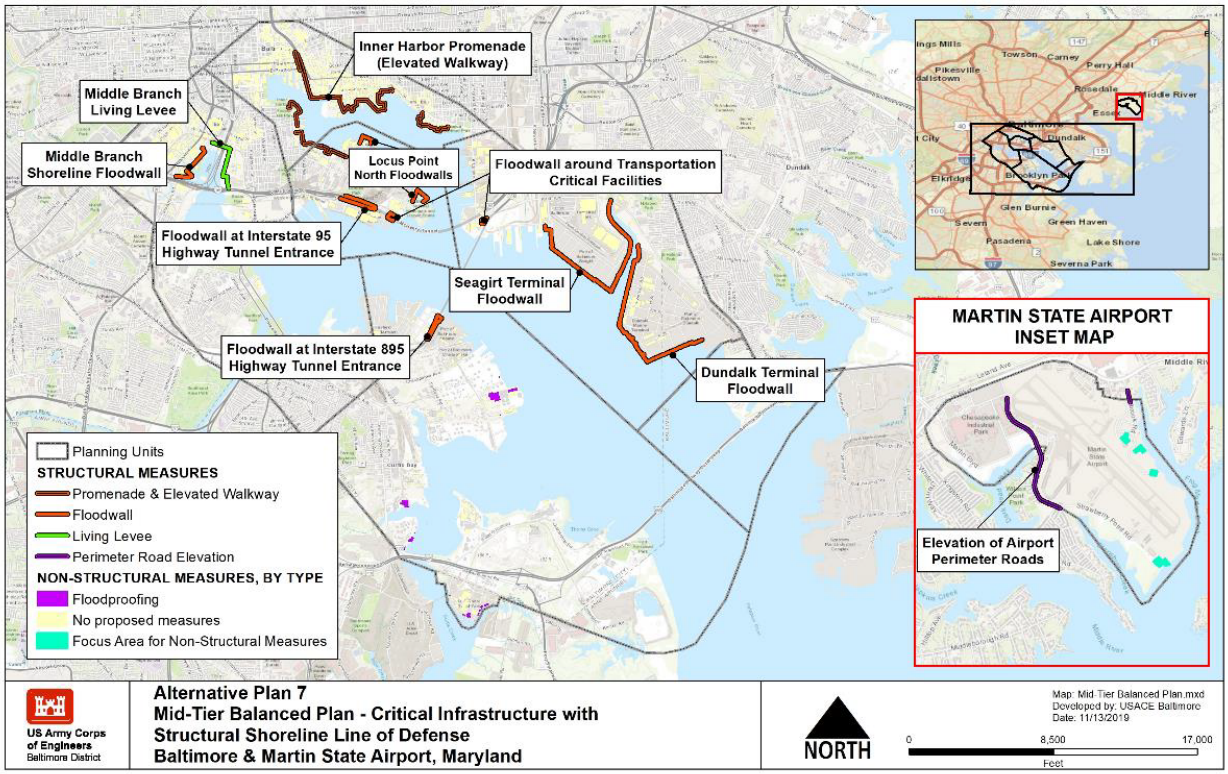

Figure 3-16. Alternative Plan 7 – Mid-Tier Plan

Alternative Plan 7 (Figure 3-16) includes all structural elements of Alternative Plan 6, except that, within the Inner Harbor planning unit (Inner Harbor, Canton, Fells Point), linear floodwalls are proposed instead of nonstructural measures. This plan also proposes the creation of a drive-on levee, through the elevation of the airport perimeter road (Wilson Point Rd) at the Martin State Airport, which provides protection to the airport from flooding from Dark Head Cove and ensures that residents of Wilson Point can safely evacuate or be reached by emergency responders.

This plan previously included a living levee proposed in the Middle Branch planning unit and a floodwall along Dundalk Terminal at the Port of Baltimore. However, these components have been approved under separate initiatives and were not carried forward as part of the final array of alternatives.

This plan achieves the planning objectives, avoids constraints, has acceptable levels of risk, appears to provide strong benefits and appears likely to have a favorable BCR. This plan was retained for the focused array of alternatives.

3.5.1.8 Alternative Plan 8: Mid-Tier with Enhanced NNBF Plan

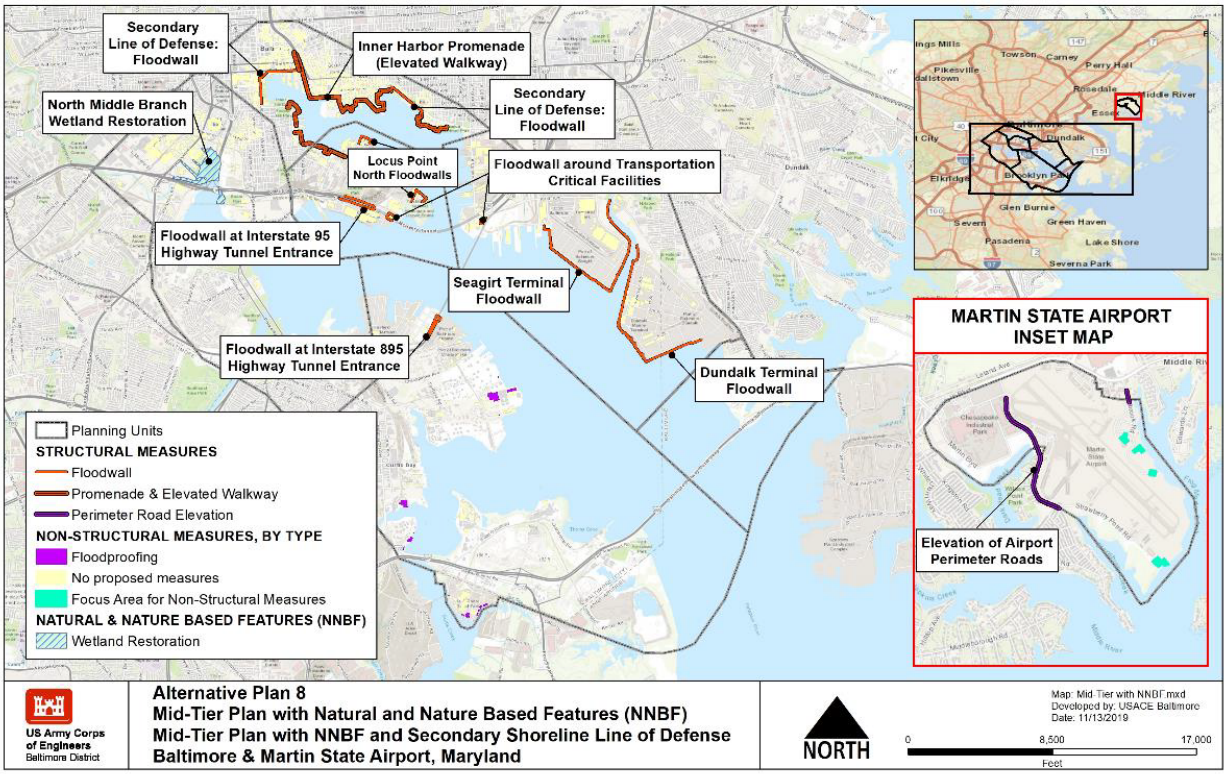

Figure 3-17. Alternative Plan 8 – Mid-Tier with NNBF Measures Plan

Alternative Plan 8 (Figure 3-17) includes all elements of Alternative Plan 7 and incorporates expanded NNBF wetland and coastal upland creation elements within upper Middle Branch.

This plan achieves the planning objectives, avoids constraints, appears to provide benefits and appears likely to have a favorable BCR. However, this plan has higher risk, higher costs, weaker NED benefits and lower BCR than Alternative Plan 7. Additionally, funding for elements of the Reimagine Middle Branch plan has been secured. Funded elements would address coastal flooding in the Middle Branch utilizing NNBF solutions. The This plan was screened from further consideration.

3.5.1.9 Alternative Plan 9: Mid-Tier with Maximum NNBF Plan

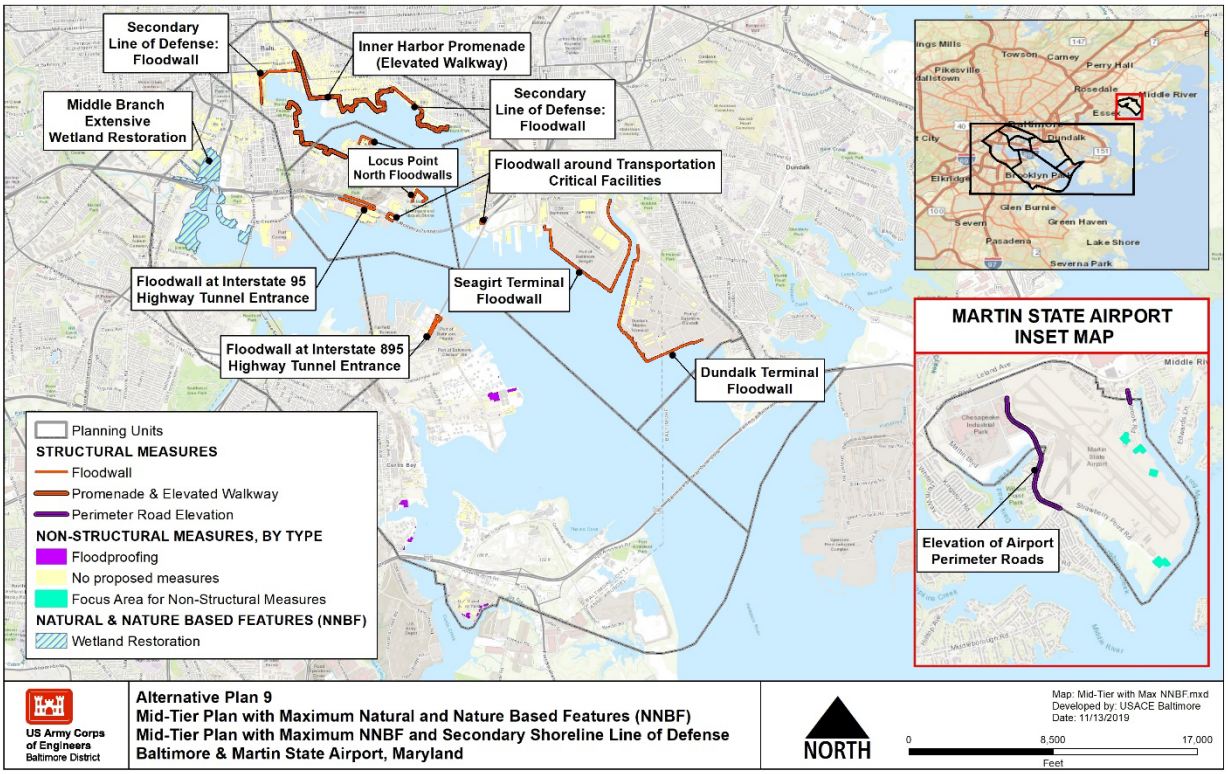

Figure 3-18. Alternative Plan 9 – Mid-Tier with Maximum NNBF Measures Plan

Alternative Plan 9 (Figure 3-18) includes all elements of Alternative Plan 8 but greatly expands the proposed use of NNBF wetland and coastal upland creation elements within Middle Branch.

This plan achieves the planning objectives, avoids constraints, appears to provide strong benefits and appears likely to have a favorable BCR. However, this plan has higher risk, higher costs, weaker NED benefits and lower BCR than Alternative Plan 7. Additionally, funding for elements of the Reimagine Middle Branch plan has been secured. Funded elements would address coastal flooding in the Middle Branch utilizing NNBF solutions. This plan was screened from further consideration.

3.5.1.10 Alternative Plan 10: High-Tier with Maximum NNBF Plan

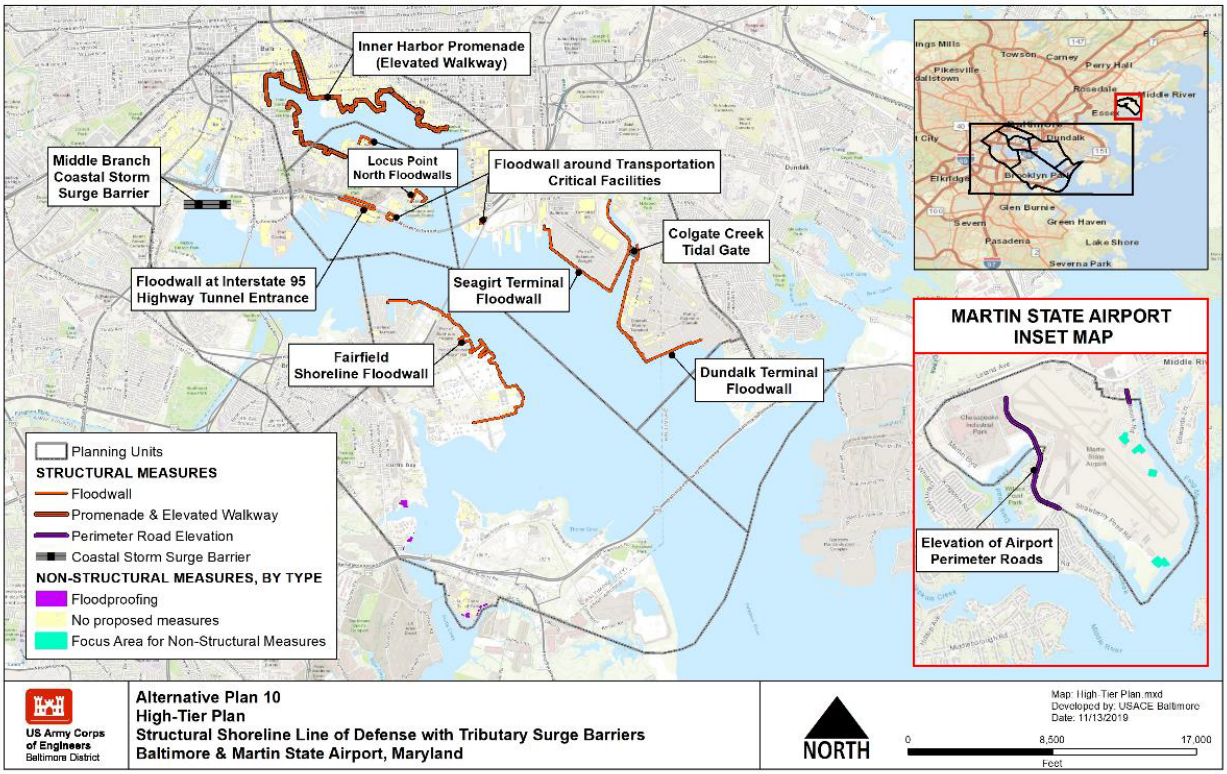

Figure 3-19. Alternative Plan 10 – High-Tier Measures Plan

Alternative Plan 10 (Figure 3-19) includes all elements of Alternative Plan 7 but further adds extensive shoreline floodwall structures around Fairfield Marie Terminal and nearby properties and replaces the proposed levee and floodwall structures in Middle Branch with a local surge barrier structure.

This plan achieves the planning objectives, avoids constraints, has acceptable levels of risk, appears to provide strong benefits and appears likely to have a favorable BCR. However, this plan has higher costs, weaker NED benefits and lower BCR than Alternative Plan 7. Additionally, funding for elements of the Reimagine Middle Branch plan has been secured. Funded elements would address coastal flooding in the Middle Branch utilizing NNBF solutions. This plan was screened from further consideration.

3.5.2 Nonstructural measures refinement

Nonstructural measures can vary based on planning objectives, building characteristics, and flood exposure. The planning objectives were used for initial scoping and screening of measures for planning units. Further breakdown of planning units by neighborhoods was based on information from local jurisdictions and used to cluster buildings that are appropriate for nonstructural measures in the study area. Buildings in these

neighborhoods were clustered for suitability of nonstructural measures using flood inundation mapping from surface water levels (SWLs) in the C-STORM modeling completed for NACCS in 2014. The buildings selected for each cluster were based on flood inundation depth for the 1 percent AEP (100-year storm) with consideration for the 5 percent and 2 percent AEP in base year 2031. See Table 3-4 for the clustering approach.

Table 3-4. Consideration for Selection of Neighborhood Clusters for Formulation of Nonstructural Measures

Planning Units/Neighborhoods	
Nuisance flooding issues	Yes/No
Flood Hazard Exposure for Buildings	
Consider flooding between 5% and 1% AEP in base year 2030, select buildings based on 1% AEP	Flood Depth
Consider impacts of Intermediate/High SLC for flooding scenarios (5%, 2%, and 1% AEP) in 2080	Flood Depth

The nonstructural measures were formulated using flood inundation mapping developed based on SWLS in the NACCS C-STORM modeling for the study area. The PDT examined inundation associated with the 5 percent (20-year storm), 2 percent (50-year storm), and 1 percent AEP (100-year storm) flood inundation scenarios. Flood inundation scenarios were used for the base year condition in 2031 (nominal differences in SLC from current condition of 2020) and 50-years from project implementation accounting for SLC using the USACE intermediate and high curve in 2080.

Nonstructural measures were selected based on the building characteristics and the inundation depth as some measures may not be suitable for specific building types based on the foundation of the building, building use, or the inundation depth experienced by that building.

The PDT identified neighborhoods with known nuisance flooding issues using previous reports, media sources, and flood inundation mapping developed during the feasibility study. The neighborhoods were primarily selected for high frequency of flooding (5 percent to 1 percent AEP), which is likely to benefit from nonstructural measures. Neighborhoods with known nuisance flooding issues including Canton, Inner Harbor, and Locust Point. The PDT also included the Patapsco Wastewater Treatment Plant (WWTP), the USCG Curtis Bay Facility, and MSA for nonstructural measures due to flooding concerns to critical infrastructure.

3.5.3 Final Array of Alternatives

The initial array of alternatives was screened based on overall cost supported by modeled damages. The level of performance that was used when designing structural components in the study area was 12.2 feet North Atlantic Vertical Datum of 1988 (NAVD88). This was based on the NACCS 100-year Water Surface Elevation (WSEL) with approximately 95 percent confidence level and intermediate SLC curve through year 2080.

The alternative plans carried forward as the focused or final array of alternatives were further refined and evaluated to reflect changes in existing conditions and FWOP conditions in the study area. The final array of alternatives is described below.

3.5.3.1 Alternative Plan 4: Critical Infrastructure Plan

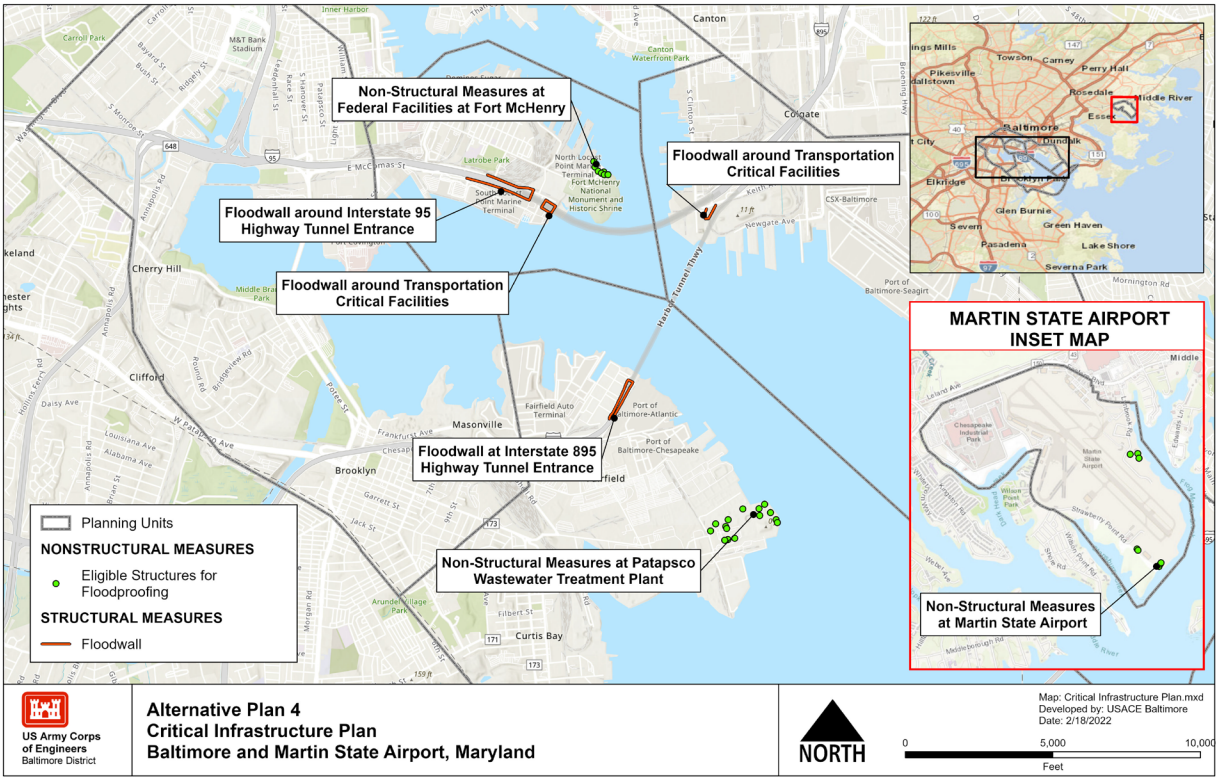

Figure 3-20. Nonstructural Measures in Alternative Plan 4 – Critical Infrastructure Plan

In the final array of alternatives, Alternative Plan 4 was optimized to include nonstructural measures (floodproofing) of critical infrastructure at Fort McHenry, the Patapsco Wastewater Treatment Plant, and at the Martin State Airport, in addition to the structural measures proposed at the I-895 and the I-95 tunnels and associated transportation critical facilities. Figure 3-20 shows the location of the nonstructural and structural measures proposed under Alternative Plan 4.

3.5.3.2 Alternative Plan 5: Critical Infrastructure and Nonstructural Plan

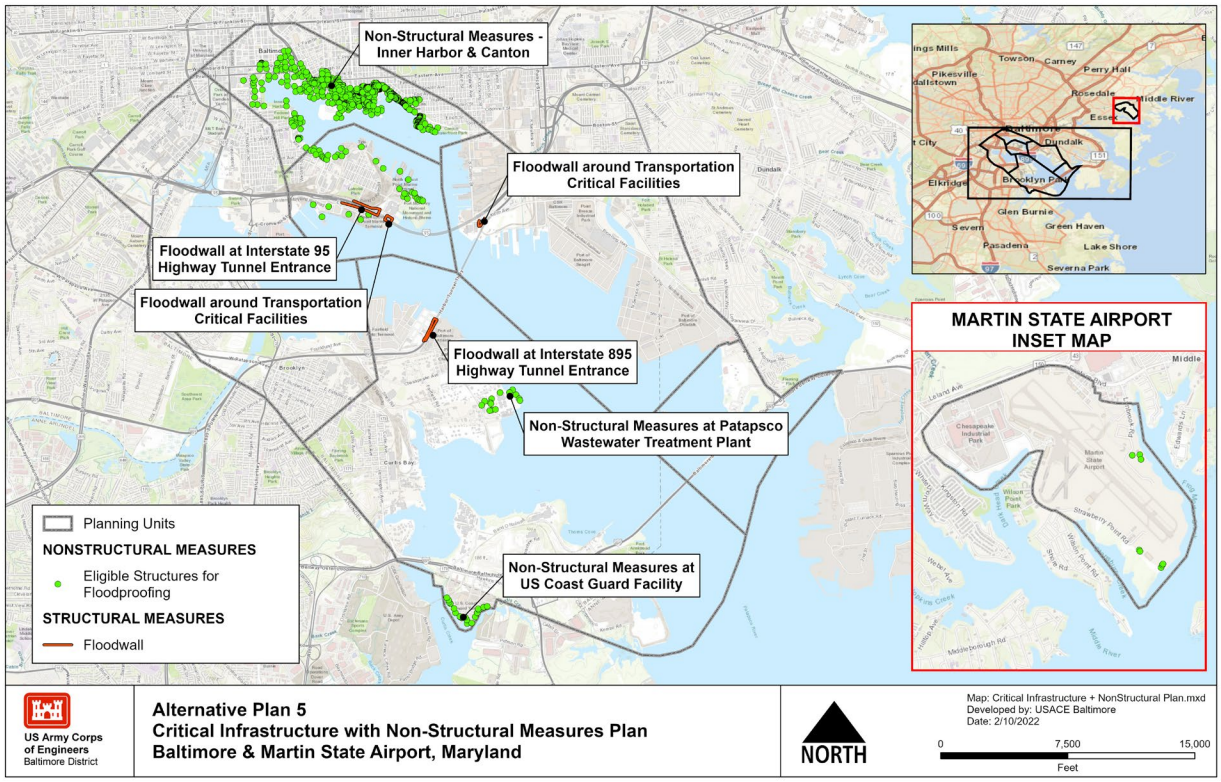

Figure 3-21. Nonstructural Measures in Alternative Plan 5 – Critical Infrastructure with Nonstructural Measures Plan

Alternative Plan 5 includes the elements of Alternative Plan 4, with the addition of the nonstructural plan along the Inner Harbor and Locust Point planning units (Figure 3-21). The nonstructural plan consists solely of the use of nonstructural measures to reduce flood risk to structures. Over 1,400 structures have been identified as being at risk within the study area by 2080, under the 1 percent AEP with intermediate SLC scenario. These include commercial, residential, industrial, and institutional structures. Floodproofing of structures was determined to be the most feasible nonstructural measures in the study area, due to the characteristics of the existing structures and limitations from presence of historic districts in the Inner Harbor planning unit.

3.5.3.3 Alternative Plan 5A: Critical Infrastructure with Select Nonstructural Plan

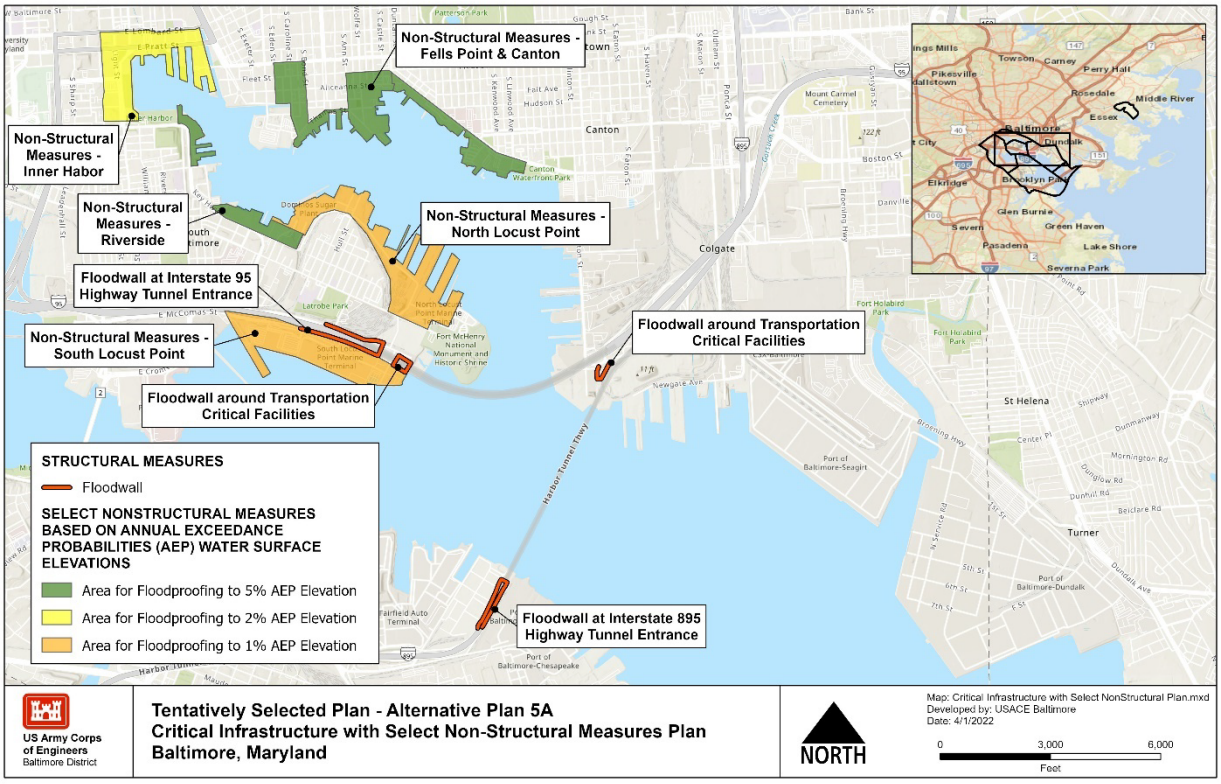

Figure 3-22. Nonstructural Measures in Alternative Plan 5A – Critical Infrastructure Plan with Select Nonstructural Measures Plan

Alternative Plan 5A is an optimization of Alternative Plan 5. It also includes the critical infrastructure components of Alternative Plan 4: the I-895 and I-95 tunnels and their support facilities. Alternative Plan 5A increases overall net benefits of the critical infrastructure and the nonstructural plan by creating focus areas for floodproofing under three AEPs: the 1 percent AEP, 2 percent AEP, and 5 percent AEP (Figure 3-22). Floodproofing of vulnerable structures under the 1 percent AEP is proposed for the North Locust Point and South Locust Point areas. Floodproofing of vulnerable structures under the 2 percent AEP is proposed for the Inner Harbor area. Floodproofing of vulnerable structures under the 5 percent AEP is proposed for the Fells Point, Canton, and Riverside areas. The focus areas under these AEPs yield the highest net benefit, while improving the resiliency of these structures against coastal flood risk.

3.5.3.4 Alternative Plan 6: Critical Infrastructure Balanced Plan

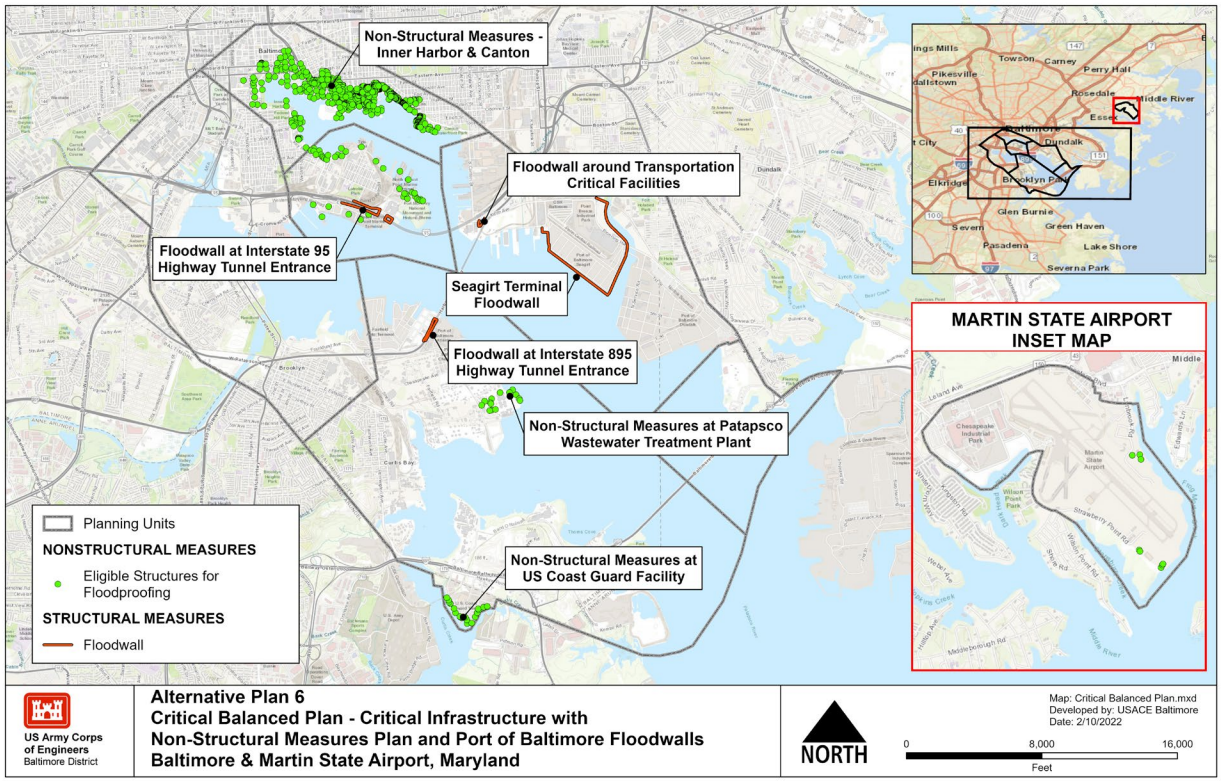

Figure 3-23. Nonstructural Measures in Alternative Plan 6 – Critical Infrastructure Balanced Plan

Alternative Plan 6 expands on Alternative Plan 5, to include the addition of a structural line-of-defense, in the form of an elevated bulkhead (or “sea curb”) along the shoreline of the Port of Baltimore’s Seagirt terminal (Figure 3-23).

3.5.3.5 Alternative Plan 7: Mid-Tier Plan

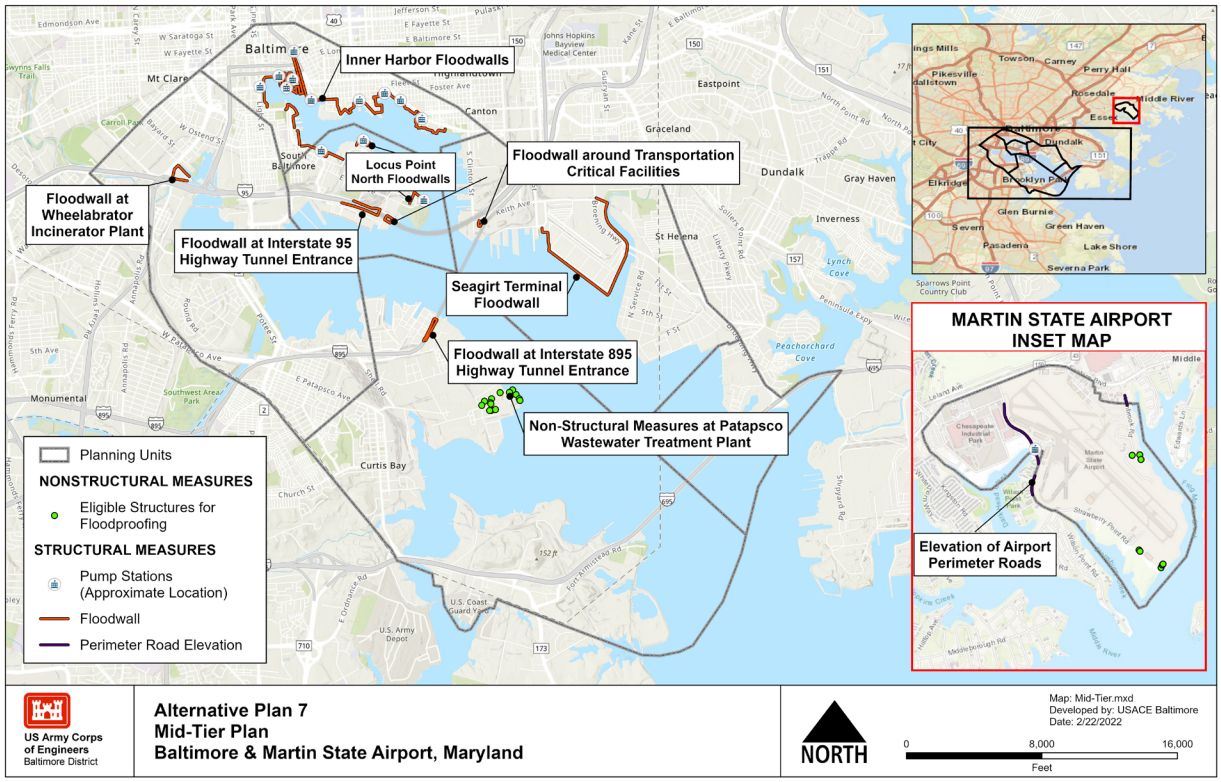

Figure 3-24. Nonstructural Measures in Alternative Plan 7 – Mid-Tier Plan

In Alternative Plan 7, structural lines of defense are proposed along vulnerable portions of the Inner Harbor, Canton, Fells Point and Locust Point areas, instead of nonstructural measures. These structural lines of defense would primarily be permanent floodwalls and could include elevated walkways and deployable floodwalls at certain locations. The floodwalls would generally be located along the shoreline and would include stoplog structures and permanent and temporary pump stations, where needed.

A floodwall around the Wheelabrator Incinerator is also proposed under this alternative. The Wheelabrator Incinerator is a waste-to-energy facility that services Baltimore City and provides steam to the local heating loop and electricity to about 40,000 homes.

In the MSA planning unit, this alternative proposes the creation of a levee via the elevation of Wilson Point Road, which would provide protection to the airport from flooding from Dark Head Cove and would ensure that residents of Wilson Point can safely evacuate or be reached by emergency responders.

Alternative Plan 7 includes some limited floodproofing, specifically at the Patapsco Wastewater Treatment Plant and at the Martin State Airport. Figure 3-24 shows the locations of the nonstructural and structural measures proposed under Alternative Plan

7, as well as approximate locations of the pump stations required for the structural components in the Inner Harbor and Locust Point planning units.

3.6 Alternative Modeling

The final array of alternatives was modeled using G2CRM to determine the life-cycle damage reduction benefits provided. Class 3 cost estimates were developed for alternative features, along with preliminary design and real estate costs. Class 3 costs use a higher level of technical information including preliminary project designs, project planning and scope, construction elements, and quantity development, to generate cost estimates. Floodproofing costs include aggregated estimates of real estate transaction costs, easement costs, and floodproofing measure costs.

3.7 Plan Evaluation

The Economic and Environmental Principles and Guidelines (P&G) for Water and Related Land Resources Implementation Studies dated 10 March 1983, established the P&G criteria used to evaluate water resources projects pursuant to the Water Resources Planning Act of 1965 (Public Law 89-8). The PDT used the P&G Criteria to evaluate the initial array of alternatives while additional engineering information was developed by various disciplines to inform decision-making. The P&G criteria are described below.

3.7.1 P&G Criteria

- **Completeness** - 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. This may require relating the plan to other types of public or private plans if the other plans are crucial to realization of the contributions to the objective.
- **Effectiveness** - Effectiveness is the extent to which an alternative plan alleviates the specified problems and achieves the specified opportunities.
- **Efficiency** - 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** - 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.

The results of this P&G evaluation of the array of alternatives are presented in Table 3-5. The alternatives screened are shown with a strikethrough. The alternatives carried forward in the final array of alternatives are shown in green.

Table 3-5. P&G Criteria Evaluation of Array of Alternatives

Alternative Plan	Completeness	Effectiveness	Efficiency	Acceptability	Overall Risk & Uncertainty	Result
–1 – Surge Barrier 1 (Outer)	High	High	Low	Low	High	Screened Out
–2 – Surge Barrier 2 (Inner)	High	High	Medium	Low	High	Screened Out
–3 – Nonstructural Only	High	Low	Medium	High	Medium	Screened Out
–4 – Critical Only	High	Medium	High	High	Low	Retain
–5 – Critical & Nonstructural	High	High	High	High	Low	Retain
5A – Critical with Select Nonstructural	High	High	High	High	Low	Retain
–6 – Critical Balanced	High	High	High	High	Medium	Retain
–7 – Mid-tier Balanced	High	High	Medium	High	Medium	Retain
–8 – Mid-tier w/NNBF	High	Medium	Medium	Medium	High	Screened Out
–9 – Mid-tier, Max NNBF	High	Medium	Low	Medium	High	Screened Out
–10 – High-tier	High	High	Low	High	Medium	Screened Out

3.7.2 System of Accounts

3.7.2.1 National Economic Development

Contributions to NED are increases in the net value of the national output of goods and services, expressed in monetary units. Contributions to NED are the direct benefits that accrue in the planning area and the rest of the nation. Contributions to NED include increases in the net value of goods and services.

3.7.2.2 Regional Economic Development

The RED account registers changes in the distribution of regional economic activity that result from each alternative plan. Two measures of the effects of the plan on regional economies are used in the account: regional income and regional employment.

3.7.2.3 Environmental Quality

Beneficial effects in the EQ account are favorable changes in the ecological, aesthetic, and cultural attributes of natural and cultural resources. Adverse effects in the EQ account are unfavorable changes in the ecological, aesthetic, and cultural attributes of natural and cultural resources.

3.7.2.4 Other Social Effects

The OSE account is a means of displaying and integrating into water resource planning information on alternative plan effects from perspectives that are not reflected in the other three accounts. The categories of effects in the OSE account include the following: Urban and community impacts; life, health, and safety factors; displacement; long-term productivity; and energy requirements and energy conservation.

The OSE account is expected to focus on the social vulnerability and resilience of the study area community. Social vulnerability is a key dimension for project development in the area and is a focus for many area stakeholders. In particular, alternative plan effects on health and safety, equity, and effects on emergency preparedness are planned to be addressed. Past storm events have resulted in extensive economic damage in the study area, however life lost has been minimal. Life loss estimates have been derived from G2CRM.

3.7.3 Risk and Uncertainty

During the formulation process, there are planning decisions and uncertainties that must be considered and documented. This study uses many sources of existing data for the analysis. For example, the study team determined existing topographic and geotechnical data are sufficient to distinguish between the alternatives considered. Collecting new data was deferred to the Pre-construction Engineering and Design (PED) phase, which is the next phase of the project after the IFR/EA document has been completed and approved. Additional data, such as building specific elevation data, is also needed for the nonstructural plans to further evaluate structures that are eligible for floodproofing.

4 ENVIRONMENTAL EFFECTS AND CONSEQUENCES*

This section describes the environmental consequences or impacts described in Section 2. This section presents the effects analysis of Alternative 4 (Critical Infrastructure Only), Alternative 5 (Critical Infrastructure and Nonstructural), Alternative 5A (Critical Infrastructure with Select Nonstructural Plan), Alternative 6 (Critical Balanced), and Alternative 7 (Mid-Tier Balanced) as required by NEPA (40 CFR 1502.16). The chapter is organized by resource topic as described in Section 2 with the potential effects of each alternative described within the Baltimore City and MSA study areas. Installation of permanent floodwalls around critical infrastructure and facilities, along with nonstructural measures such as deployable floodproofing and elevating existing walkways were considered as part of the alternative analysis.

4.1 Natural Environment

4.1.1 Wetlands

Alternatives 4-7 & Alternative 5A are not expected to impact wetlands or their associated buffers within the Baltimore Metro study area. Alternative 7 has the potential to impact wetland buffers with construction of the elevated roadway along perimeter roads at the MSA. Most of the road work is expected to stay within the road right-of-way. Construction of a proposed floodwall around the Fort McHenry West Ventilation Building would be located adjacent to a tidal wetland but would have no direct or indirect impacts to the wetlands.

4.1.2 Threatened or Endangered Species

Alternatives 4-7 & Alternative 5A

There are several species identified as utilizing the overall project area that are at-risk, or threatened/endangered. However, due to the alternatives being located in highly developed areas with low fish and wildlife species, as reported in the FWCA Coordination Act Letter, the species identified to be within the project area are not likely to be negatively impacted by the alternatives. Coordination with the Maryland Department of Natural Resources (MDDNR) Wildlife and Heritage Service has been initiated but results of state listed species are pending. MDDNR is responsible for the identification and protection of the listed species identified within this report within Maryland. Coordination with NOAA, National Marine Fisheries Service (NMFS) has been completed and concurred that no impacts will occur to Essential Fish Habitat (EFH) or NMFS trust resources (Appendix G). Best management practices (BMPs) will be implemented to avoid potential impacts to aquatic resources, i.e., monitoring any runoff that occurs due to construction. A determination was also reached through the FWCA letter that suitable habitat for the NLEB does not exist within the Baltimore study area and is not likely to affect the mammal. Alternatives 4-7 & Alternative 5A are not anticipated to impact canopy trees within the MSA study area; therefore, any potential hibernacula are not anticipated to be impacted.

USACE will resubmit the information for the NLEB 4(d) Rule for Federal Actions that may affect NLEB into the USFWS IPaC prior to construction.

4.2 Physical Environment

4.2.1 Land Use

Alternatives 4-7 & Alternative 5A

Alternatives 4-7 & Alternative 5A are not expected to impact land use within the study areas.

4.2.2 Soils

Alternatives 4-7 & Alternative 5A

Soils are expected to be temporarily disturbed during construction of the proposed floodwalls in the Baltimore City study area and with the elevation of roadways within the MSA study area. However, soils are expected to be returned to their existing conditions once areas have been back filled around the proposed floodwalls. Soil testing is expected to be performed before construction in an effort to determine and classify potential levels of containments within the soils. More information regarding contaminated soil is described in Section 4.2.5.

4.2.3 Water Quality

Alternatives 4-7 & Alternative 5A

Alternatives 4-7 & Alternative 5A are not expected to impact water quality within the Baltimore City and MSA study areas. No in-water construction or mobilization is anticipated within either study area. All necessary erosion and sediment control practices will be implemented during construction and will follow all state, county, and city BMP guidelines.

4.2.4 Floodplains

Alternatives 4-7 & Alternative 5A

Implementation of floodwalls would reduce the effective volume of available floodplain to coastal floodwaters during a storm event. Areas within the 100-year floodplain include the Inner Harbor, Fells Point, Canton, Locust Point, Seagirt, areas around Middle Branch, and MSA. Accreditation of the new floodwall by FEMA is needed to comply with federal regulation 44 CFR 65.10 – Mapping of areas protected by levee systems. Continued coordination with FEMA is anticipated as the study progresses.

4.2.5 Hazardous Materials and Wastes

Alternatives 4-7 & Alternative 5A

Any alternative that requires tie-down anchoring, which is a method for securing floodwalls, could pose a potential issue depending on the placement. Further investigations in the future will be conducted to determine the extent of contamination

where floodwall placement and anchoring may occur. If contamination is encountered during field sampling, safety precautions and appropriate disposal of contaminated material would be implemented. In an effort to minimize the potential for a release of petroleum-based fluids (i.e., diesel fuel, hydraulic fluid) from construction equipment to the environment, all construction equipment would be maintained in good working order by the contractor daily. If an accidental release of a hazardous material occurs, construction equipment would be equipped with an emergency spill kit and workers would be trained on how to properly deploy the equipment to respond to a release. Any solid waste, including excess vegetation or sediment debris, would be properly composted, reused, or disposed of at a permitted facility. Furthermore, all contractors involved in the project would be responsible for adhering to state and Federal regulations for storage, handling, and disposal of hazardous wastes.

4.2.6 Transportation and Navigation

Alternatives 4-5 & Alternative 5A

The proposed floodwalls around critical infrastructure in places such as the Baltimore and Fort McHenry Tunnels and their associated transportation critical facilities may temporarily cause lane closures or minor traffic delays. Potential smoke and dust may cause temporary visual impairments during construction. Some construction vehicles and potentially large cranes may be seen from the adjacent roadway, causing a temporary distraction to motorists. Coordination with MDOT, State Highway Administration, Maryland Transit Administration, and Federal Highway Administration (FHWA) will continue as the project progresses and as the potential need for signage and digital warnings overhead of roadways may be needed during construction. Access to transportation corridors is expected to remain open during proposed construction. Alternatives 4-7 & Alternative 5A are expected to protect these corridors and their critical infrastructure during flooding events.

Alternatives 6-7

Similar actions are anticipated to occur as mentioned in the section above. Additionally, active construction along the shoreline at Seagirt terminal for the proposed sea curb in Alternatives 6 and 7 may cause temporary disruptions to shipping and cargo that is being imported and exported out of the Port of Baltimore. Active construction and storage of construction equipment may temporarily displace cargo until the sea curb is completed and construction equipment is removed.

4.2.7 Noise

Alternatives 4-7 & Alternative 5A

Minor noise disturbances from construction equipment are expected to occur for all alternatives. All work is expected to be performed during an 8-hour period during daylight hours as to not interfere with lower noise levels around residential communities at night.

Construction equipment is expected to include gas and/or diesel-powered equipment such as dump trucks, excavators, backhoes, and devices used to delivery and lay concrete. Due to the proximity to residential neighborhoods, noise reducing techniques may be used to minimize disturbance. Such techniques include equipping construction equipment with sound-muffling devices available from the equipment manufacturer and limiting engine idling time. To ensure operational maintenance noises do not become a nuisance, equipment would be maintained in good working order and would only be operated during daylight working hours.

4.2.8 Air Quality/Greenhouse Gas Emissions

Alternatives 4-7 & Alternative 5A

An air conformity analysis has been performed in conjunction with USEPA guidelines and standards. See Appendix G for the analysis and results. Alternatives 4-7 as well as Alternative 5A are expected to have short-term, minor adverse impacts to air quality. Potential air quality impacts from construction activities would occur from: 1) combustion emissions due to the use of fossil-fuel-powered equipment and vehicles, and 2) particulate emissions from fugitive dust generated during ground-disturbing activities. Based on the calculations in the air conformity analysis, the total construction emissions for all criteria pollutants would be well below the General Conformity Rule *de minimis* thresholds, and therefore, adverse impacts to air quality would be minor and no mitigation measures are required.

4.2.9 Coastal Zone Management Program

Alternatives 4-7 & Alternative 5A

Baltimore City and Baltimore County are coastal counties and fall within Maryland's CZMP enforceable policies. Appendix G includes findings of the coastal zone and consistency evaluations which are still on-going. Potential effects to the CZMA include areas within the Critical Area. Other policies including historical and archeological sites and transportation were evaluated but are not expected to be negatively impacted.

4.2.10 Chesapeake Bay Critical Area

Alternatives 4-7 & Alternative 5A

The Baltimore City study area and MSA study area fall within the IDA, LDA, and RCA Critical Areas. Minor impacts to the Critical Area 100-foot buffer are expected where structural floodproofing is anticipated – around the Baltimore and Fort McHenry tunnels and associated transportation critical infrastructure. Disturbance or impacts are anticipated to come in the form of maintained lawn disturbance where the new floodwall will tie-in to an existing elevated berm. Coordination with the Baltimore City Critical Area Commission is on-going and will continue as the project progresses. A Critical Area Buffer Management Plan is anticipated to address minor Critical Area 100-foot buffer impacts and would be completed during the PED phase. The Plan would include an existing

conditions site plan, proposed conditions site plan, and any pertinent mitigation or landscape plans or specifications to address any impact.

4.2.11 Climate Change and SLC

Alternatives 4-7 & Alternative 5A

Alternatives 4-7 & Alternative 5A are not anticipated to change the water levels from the existing water level elevation; therefore, SLC will have the same effect on Alternatives 4-7 & Alternative 5A. In accordance with Engineering Regulation ER 1100-2-8162 (incorporating SLCs in Civil Works Program, 31 Dec 2013), USACE performed a sensitivity analysis for SLC. The analysis is used for proposed projects that are subject to coastal storm surges and must be evaluated for a range of possible SLR rates: low, intermediate, and high. Details of this analysis and how Alternatives 4-7 and Alternative 5A correlate with climate change and SLC can be found in Appendices B and E.

4.2.12 Cultural Resources

Alternative 4 Critical Infrastructure Plan

This alternative includes floodwalls around Interstates I-95 and I-895 tunnel entrances and associated transportation critical facilities, and nonstructural floodproofing to federal facilities north of Fort McHenry, at the Patapsco WWTP, and at the MSA.

The majority of the Interstate Highway system is exempt from consideration as a historic property under Section 106 of the NHPA under the Advisory Council for Historic Preservation (ACHP)'s *Section 106 Exemption Regarding Effects to the Interstate Highway System*. Some components of the system are excluded from the ACHP's exemption due to their exceptionalism or national significance and must be considered in the Section 106 process. In Maryland, I-895 and I-95 are excluded from the exemption due to their engineering and national significance. I-895 was determined eligible for the NRHP in 2020 under Criterion A for its significant association with twentieth-century automotive transportation improvements in Maryland and the Baltimore region, and Criterion C for its significant engineering design. I-95 has not reached the 50-year limit stipulated by the NRHP, so it has not been formally evaluated.

The floodwalls proposed in Alternative 4 could have an adverse effect if they significantly alter the aspects of integrity that make a resource significant. For I-895, this includes the roadway approaches on either side of the tunnel, the roadway's ability to convey its original construction and significance as a major transportation and engineering feature, and the associated transportation critical facility. There are no expected archaeological concerns because the proposed floodwalls would be constructed in built-up industrial areas adjacent to roadways and buildings.

Adverse effects to historic properties from implementation of nonstructural measures would be specific to the historic properties treated. Under Alternative 4, nonstructural floodproofing is proposed for federal facilities north of Fort McHenry, the Patapsco

WWTP, and the MSA. If floodproofing occurred to a building eligible for or listed in the NRHP, adverse effects would require avoidance, minimization, or mitigation. Buildings that have not been evaluated for the NRHP would need to be formally evaluated.

Alternative 5 Critical Infrastructure with Non-Structural Measures Plan
This alternative features everything included in Alternative 4; however, there are more properties proposed for nonstructural floodproofing measures. Additional nonstructural measures are proposed throughout the Inner Harbor, Fells Point, Canton, Locust Point, and at Curtis Bay. As mentioned previously, adverse effects to historic properties from implementation of nonstructural measures would be specific to the historic properties treated. If floodproofing occurred to a building eligible for or listed in the NRHP, impacts would require mitigation. Buildings that have not been evaluated for the NRHP would need to be formally evaluated.

Alternative 6 Critical Balanced Plan – Critical Infrastructure with Non-Structural Measures Plan and Port of Baltimore Floodwalls
This alternative features everything included in Alternative 4 and Alternative 5; however, there is an additional proposed floodwall around the Seagirt Marine Terminal. The northern end of the proposed floodwall moves through the Western Electric Company, Point Breeze Plant Historic District, so there could be direct or visual impacts to that resource. Additionally, the proposed floodwall is within the viewshed of the Canton Grain Elevator and the Baltimore Municipal Airport, Harbor Field, so updated designs would need to be evaluated for their effects to these resources.

Alternative 7 Mid-Tier Plan with Secondary Shoreline Line of Defense
This alternative includes floodwalls around Interstates I-895 and I-95 tunnel entrances and associated transportation critical facilities, and elevated walkways and floodwalls within the Inner Harbor, Federal Hill, Locust Point, Fells Point, Canton, around the Wheelabrator Incinerator Plant, and around the Seagirt Marine Terminal. Nonstructural floodproofing measures are proposed at the Patapsco Wastewater Treatment Plant, throughout Curtis Bay. Additionally, road elevation is proposed at the MSA. Proposed walkway elevation and floodwalls could have an adverse impact on the Locust Point Historic District, Federal Hill Historic District, Business and Government Historic District, Fells Point Historic District, and the Canton Historic District, along with at least thirteen known historic properties. Proposed road elevation at MSA may have an effect on the NRHP-eligible Glenn L. Martin Airport and would need to be evaluated as designs progress.

4.2.13 Socioeconomics

Alternatives 4-7 & Alternative 5A

Alternatives 4-6, including Alternative 5A are not expected to impact socioeconomics. The implementation of structural and nonstructural floodproofing may increase the value of properties and businesses adjacent to the proposed structures. Alternative 7 may impact

businesses along the Inner Harbor with the implementation of floodwalls. The structural component along the Harbor would likely cause loss of appeal to the area and potentially cause waterfront businesses to close or relocate.

4.2.14 Environmental Justice

Although air quality and noise may cause temporary disruptions, Alternatives 4-7 & Alternative 5A are not expected to disproportionately impact EJ communities. Further investigations would be needed to determine the presence of underground contaminants prior to construction of any permanent structures to ensure contaminants will not be discharged into local communities. Conversely, Alternatives 4-7 & Alternative 5A would build up coastal resiliency to communities affected by flooding. Major transportation corridors would also be maintained and continue to be uninterrupted as climate change and sea-level rise continue to become a concerning factor for coastal infrastructure.

4.2.15 Recreational Resources

Alternatives 4-7 & Alternative 5A

Visual or access impacts to recreational resources may occur within the Baltimore Metro study area with Alternatives 4-7, including Alternative 5A. Some areas of impacts from nonstructural floodproofing mechanisms may impose access issues to walking trails adjacent to the Baltimore Harbor Promenade, intramural sports fields, and waterfront parks or sitting areas. Alternative 7, and the implementation of structural mechanisms, may cause access issues to some recreational businesses such as the Baltimore Water Taxi, kayak drop-in points, ‘Chessie Dragon Paddle Boats’, sailing tours, sightseeing cruises, and boat rentals.

4.2.16 Visual Aesthetics

Alternatives 4-6 & Alternative 5A

Visual aesthetics are not expected to be impacted under Alternatives 4-6 or Alternative 5A. The proposed structural floodwalls in Alternatives 4-6 and 5A would be installed in urbanized and industrialized areas. Natural landscapes are limited in these areas and with the implementation of the structural components, these landscapes are not expected to be negatively impacted. Nonstructural floodproofing measures, such as deployable flood protections and waterproofing residents and businesses are not expected to negatively impact visual aesthetics.

Alternative 7

Visual aesthetics are expected to be impacted under Alternative 7. Areas that would receive adverse impacts to visual aesthetics are around the Inner Harbor, Canton, Fells Point, and Locust Point. Elevated structural floodwalls with pumping stations are anticipated with this alternative and would cause disruptions to the viewshed. The visual aesthetics around the Inner Harbor are one of many attractions that bring tourists to Baltimore.

4.2.17 Utilities

Alternatives 4-7 & Alternative 5A

Utilities within all alternatives have the potential to be impacted by structural and nonstructural floodproofing. Coordination with utility companies such as Baltimore City Department of Public Works, Baltimore County Department of Public Works, BGE, Miss Utility, and cable and internet providers. Coordination from the contractor will be especially prudent with any implementation of permanent structures or elevation of roadways. For flood control projects, the Sponsor is required to relocate affected facilities and utilities necessary for the construction, operation, and maintenance of a project. A relocation may take the form of an alteration, lowering, raising, or replacement of the affected facility/utility or part thereof.

4.3 Summary of Potential Effects

Table 4-1 summarizes the effects of the final array of alternatives.

Table 4-1. Summary of Potential Effects form the Final Array of Alternatives

Resource	No Action	4- Critical	5- Critical Infrastructure	5A- Critical Infrastructure with Select Nonstructural Plan	6-Critical Balanced	7-Mid-Tier Balanced
Wetlands	No effect.	No effect.	No effect.	No effect.	No effect.	Potential impacts to wetland buffers from construction of elevated roadway (drive-on levee) at Martin State Airport. Impacts to wetlands would be avoided, if possible. If impacts occur, mitigation would be completed.
Threatened and Endangered Species	No effect.	No effect.	No effect.	No effect.	No effect.	No effect.
Land Use	No effect.	No effect.	No effect.	No effect.	No effect.	No effect.
Soils	No effect.	Temporary disturbance of soils during construction.	Temporary disturbance of soils during construction.	Temporary disturbance of soils during construction.	Temporary disturbance of soils during construction.	Temporary disturbance of soils during construction.
Water Quality	Projects to improve water quality within the Chesapeake Bay and its watershed underway.	No in-water construction. Erosion & sediment control measures and BMPs would be implemented during construction.	No in-water construction. Erosion & sediment control measures and BMPs would be implemented during construction.	No in-water construction. Erosion & sediment control measures and BMPs would be implemented during construction.	No in-water construction. Erosion & sediment control measures and BMPs would be implemented during construction.	No in-water construction. Erosion & sediment control measures and BMPs would be implemented during construction.
Floodplains	Floodplains expected to move inland as sea level rises.	Impacts to 100-yr floodplain from floodwalls. Certification, accreditation, and/or letter of map revision for new floodwalls and	Impacts to 100-yr floodplain from floodwalls. Certification, accreditation, and/or letter of map revision for new floodwalls and coordination with FEMA anticipated.	Impacts to 100-yr floodplain from floodwalls. Certification, accreditation, and/or letter of map revision for new floodwalls and coordination with FEMA anticipated.	Impacts to 100-yr floodplain from floodwalls. Certification, accreditation, and/or letter of map revision for new floodwalls and coordination with FEMA anticipated.	Impacts to 100-yr floodplain from floodwalls. Certification, accreditation, and/or letter of map revision for new floodwalls and coordination with FEMA anticipated.

Resource	No Action	4- Critical Infrastructure	5- Critical Infrastructure and Nonstructural Focus Areas	5A- Critical Infrastructure with Select Nonstructural Plan	6-Critical Balanced	7-Mid-Tier Balanced
		coordination with FEMA anticipated.				
Hazardous Materials and Waste	Potential infiltration of hazardous materials and wastes into the Chesapeake Bay or public water supply possible during flooding events.	Contaminated soils could be encountered when anchoring floodwalls. Further investigations to evaluate soils in anchoring areas would be completed prior to construction.	Contaminated soils could be encountered when anchoring floodwalls. Further investigations to evaluate soils in anchoring areas would be completed prior to construction. Potential for asbestos or lead paint-contaminated material.	Contaminated soils could be encountered when anchoring floodwalls. Further investigations to evaluate soils in anchoring areas would be completed prior to construction. Potential for asbestos or lead paint-contaminated material.	Contaminated soils could be encountered when anchoring floodwalls. Further investigations to evaluate soils in anchoring areas would be completed prior to construction.	Contaminants are likely to be encountered where floodwalls are proposed along the Inner Harbor areas, due to historical infilling along shorelines. Further evaluations would be needed prior to construction. Any contaminated soils or hazardous materials would be handled and disposed of in accordance with applicable state and federal regulations.
Transportation and Navigation	Local roadways, I-895 and I-95 tunnels would be vulnerable to disruption from flooding events.	Lane closures, minor, temporary traffic delays possible during construction.	Lane closures, minor, temporary traffic delays possible during construction.	Lane closures, minor, temporary traffic delays possible during construction.	Lane closures, minor, temporary traffic delays possible during construction. Temporary shipping disruptions during construction at Seagirt Terminal.	Lane closures, minor, temporary traffic delays possible during construction. Temporary shipping disruptions during construction at Seagirt Terminal.
Noise	No effect.	Minor, temporary noise disturbances during construction.	Minor, temporary noise disturbances during construction.	Minor, temporary noise disturbances during construction.	Minor, temporary noise disturbances during construction.	Minor, temporary noise disturbances during construction.
Air Quality	No effect.	Short-term, minor, adverse impacts to air quality during construction.	Short-term, minor, adverse impacts to air quality during construction.	Short-term, minor, adverse impacts to air quality during construction.	Short-term, minor, adverse impacts to air quality during construction.	Short-term, minor, adverse impacts to air quality during construction.
Coastal Zone Management Program	No effect.	Coordination on-going.	Coordination on-going.	Coordination on-going.	Coordination on-going.	Coordination on-going.

Resource	No Action	4- Critical Infrastructure	5- Critical Infrastructure and Nonstructural Focus Areas	5A- Critical Infrastructure with Select Nonstructural Plan	6-Critical Balanced	7-Mid-Tier Balanced
Chesapeake Bay Critical Area	No effect.	Minor, permanent impacts to Critical Area 100-foot buffer anticipated from floodwalls around the I-895 and I-95 tunnel entrances and support facilities.	Minor, permanent impacts to Critical Area 100-foot buffer anticipated from floodwalls around the I-895 and I-95 tunnel entrances and support facilities.	Minor, permanent impacts to Critical Area 100-foot buffer anticipated from floodwalls around the I-895 and I-95 tunnel entrances and support facilities.	Minor, permanent impacts to Critical Area 100-foot buffer anticipated from floodwalls around the I-895 and I-95 tunnel entrances and support facilities.	Minor, permanent impacts to Critical Area 100-foot buffer anticipated from floodwalls around the I-895 and I-95 tunnel entrances and support facilities.
Climate Change and SLC	The Baltimore City Metropolitan area is vulnerable to SLC.	No adverse impacts. Beneficial impacts from improved coastal resiliency.	No adverse impacts. Beneficial impacts from improved coastal resiliency.	No adverse impacts. Beneficial impacts from improved coastal resiliency.	No adverse impacts. Beneficial impacts from improved coastal resiliency.	No adverse impacts. Beneficial impacts from improved coastal resiliency.
Cultural Resources	Cultural resources could be vulnerable to SLC and coastal flooding.	Potential impacts to I-895 if aspects of historical significance are impacted. Potential impacts to historical properties from floodproofing measures.	Potential impacts to I-895 if aspects of historical significance are impacted. Potential impacts to historical properties from floodproofing measures.	Potential impacts to I-895 if aspects of historical significance are impacted. Potential impacts to historical properties from floodproofing measures.	Potential impacts to I-895 if aspects of historical significance are impacted. Potential impacts to historical properties from floodproofing measures.	Potential impacts to I-895 if aspects of historical significance are impacted. Potential impacts to historical properties from floodproofing measures. Potential impacts from elevated walkways and floodwalls on historic districts in Inner Harbor areas.
Socioeconomics	Coastal flooding events could lead to displacement of residents and communities.	No effect.	No effect.	No effect.	No effect.	Potential permanent, adverse impacts to waterfront businesses from implementation of floodwalls along the Inner Harbor areas.
Environmental Justice (EJ)	No effect.	No disproportionate impacts to EJ communities. Improved coastal resiliency.	No disproportionate impacts to EJ communities. Improved coastal resiliency. Floodwalls around the tunnel entrances	No disproportionate impacts to EJ communities. Improved coastal resiliency. Floodwalls around the tunnel entrances and	No disproportionate impacts to EJ communities. Improved coastal resiliency. Floodwalls around the tunnel entrances	No disproportionate impacts to EJ communities. Improved coastal resiliency. Floodwalls around the tunnel entrances and support facilities would maintain

Resource	No Action	4- Critical Infrastructure	5- Critical Infrastructure and Nonstructural Focus Areas	5A- Critical Infrastructure with Select Nonstructural Plan	6-Critical Balanced	7-Mid-Tier Balanced
		Floodwalls around the tunnel entrances and support facilities would maintain access to transportation corridors.	and support facilities would maintain access to transportation corridors.	support facilities would maintain access to transportation corridors.	and support facilities would maintain access to transportation corridors.	access to transportation corridors. Improved coastal resiliency from floodwalls around Inner Harbor areas.
Recreational Resources & Visual Aesthetics	Recreational resources may be at risk due to flooding events.	No effect.	No effect.	No effect.	No effect.	Permanent, moderate, adverse effects to recreational and visual access to the water from floodwalls along the Baltimore Promenade.
Utilities	Utilities could be at risk from flooding events.	Potential impacts to utilities from structural and nonstructural components.	Potential impacts to utilities from structural and nonstructural components.	Potential impacts to utilities from structural and nonstructural components.	Potential impacts to utilities from structural and nonstructural components.	Potential impacts to utilities from structural and nonstructural components.

5 PLAN COMPARISON AND SELECTION

The following section outlines the FWP condition and benefits for the final array of alternatives, the four accounts evaluation and the plan comparison leading to the TSP decision. The FWP condition is the most likely condition expected to exist in the future if a specific project is undertaken. A full discussion on the FWP condition and benefits can be found in Appendix E: Economic Analysis.

5.1 Future With-Project Condition

The final array of alternatives includes six alternatives including the no action plan that were compared against each other with an emphasis on outputs and effects that would influence the decision-making process for identifying the TSP. G2CRM was used to estimate PV damages and average annual damages in the FWOP and FWP for each alternative. Table 5-1 through 5-5 summarize the damages expected to occur under the FWOP condition and the damages reduced in the FWP condition.

Table 5-1. Alternative 4 – Critical Infrastructure Plan - FWOP PV Damages , FWP PV Damages, and Damages Reduced Percentage in the FWP condition

Alternative	FWOP Present Value Damages	FWP Present Value Damages	FWP % Damage Reduction
Alternative 4 – Critical Infrastructure Plan with Floodproofing to 1% AEP	$345,611,000	$153,782,000	55.5%
Alternative 4 – Critical Infrastructure Plan with Floodproofing to 2% AEP	$345,611,000	$154,997,000	55.2%
Alternative 4 – Critical Infrastructure Plan with Floodproofing to 5% AEP	$345,611,000	$155,514,000	55.0%

When the FWP conditions were compared to the FWOP conditions, Alternative 4 reduce PV damages by approximately 55 percent from the FWOP condition under all three AEPs evaluated for nonstructural measures.

Table 5-2. Alternative 5 – Critical Infrastructure & Nonstructural Measures Plan FWOP PV Damages , FWP PV Damages, and Damages Reduced Percentage in the FWP Condition

Alternative	FWOP Present Value Damages	FWP Present Value Damages	FWP% Damage Reduction
Alternative 5 – Critical Infrastructure & Nonstructural Measures Plan with Floodproofing to 1% AEP	$700,430,000	$388,145,000	44.6%
Alternative 5 – Critical Infrastructure & Nonstructural Measures Plan with Floodproofing to 2% AEP	$700,430,000	$413,530,000	41.0%
Alternative 5 – Critical Infrastructure & Nonstructural Measures Plan with Floodproofing to 5% AEP	$700,430,000	$443,582,000	36.7%

When comparing the FWP conditions to the FWOP conditions, Alternative 5 reduced the PV damages between 36.7 percent under the 5 percent AEP evaluation and 44.6 percent in the 1 percent AEP evaluation for nonstructural measures.

Table 5-3. Alternative 5A – Critical Infrastructure with Select Nonstructural Measures Plan FWOP PV Damages, FWP PV Damages, and Damages Reduced Percentage in the FWP Condition

Alternative	FWOP Present Value Damages	FWP Present Value Damages	FWP % Damage Reduction
Alternative 5A – Critical Infrastructure & Select Nonstructural Measures Plan	$641,708,000	$371,595,000	43.5%

When comparing the FWP conditions to the FWOP conditions, Alternative 5A reduced the PV damages by 42.1 percent.

Table 5-4. Alternative 6 – Critical Balanced Plan FWOP PV Damages , FWP PV Damages, and Damages Reduced Percentage in the FWP Condition

Alternative	FWOP Present Value Damages	FWP Present Value Damages	FWP % Damage Reduction
Alternative 6 – Critical Balanced Plan with Floodproofing to 1% AEP	$708,155,000	$391,242,000	44.8%
Alternative 6 – Critical Balanced Plan with Floodproofing to 2% AEP	$708,155,000	$416,627,000	41.2%
Alternative 6 – Critical Balanced Plan with Floodproofing to 5% AEP	$708,155,000	$446,679,000	36.9%

When comparing the FWP conditions were compared to the FWOP conditions, Alternative 6 reduced the PV damages between 36.9 percent under the 5 percent AEP evaluation and 44.8 percent in the 1 percent AEP evaluation for nonstructural measures.

Table 5-5. Alternative 7 – Mid-Tier Balanced Plan FWOP PV Damages , FWP PV Damages, and Damages Reduced Percentage in the FWP Condition

Alternative	FWOP Present Value Damages	FWP Present Value Damages	FWP % Damage Reduction
Alternative 7 – Mid-Tier Balanced Plan with Floodproofing to 1% AEP	$623,532,000	$280,250,000	55.1%
Alternative 7 – Mid-Tier Balanced Plan with Floodproofing to 2% AEP	$623,532,000	$281,465,000	54.9%
Alternative 7 – Mid-Tier Balanced Plan with Floodproofing to 5% AEP	$623,532,000	$281,982,000	54.8%

When comparing the FWP conditions to the FWOP conditions, Alternative 7 reduced the PV damages between 54.8 percent under the 5 percent AEP evaluation and 55.1 percent in the 1 percent AEP evaluation for nonstructural measures.

The nonstructural solutions were evaluated for 5 percent, 2 percent, and 1 percent AEP in compliance with the National Nonstructural Committee (NNC) Best Practice Guide 2020-06, dated November 15, 2021, focusing on the structure aggregation methods used in the formulation and evaluation of nonstructural alternatives. A 5 percent AEP event was used instead of a 4 percent AEP (25-year) event because of the availability of hydraulic stage functions. Floodproofing was identified as the most appropriate nonstructural measure for this area based on structure characteristics (building

foundation, construction materials, square footage). Based on G2CRM outputs, Inner Harbor, Locust Point, Patapsco Wastewater Treatment Plant, Martin State Airport, and the federal facilities for the USCG at Curtis Bay and USACE at Fort McHenry were chosen for further evaluation of nonstructural solutions. Table 5-6 shows the number of structures for nonstructural measures (floodproofing) by planning unit for the 1 percent, 2 percent, and 5 percent AEP event.

Table 5-6. Nonstructural Measures Evaluated by Planning Area and AEP

Planning Area (Modeled Areas)	Number of Buildings		
	Nonstructural Measures (1% AEP)	Nonstructural Measures (2% AEP)	Nonstructural Measures (5% AEP)
Inner Harbor (MA9; MA10; MA11; MA12; MA13)	1,011	437	254
Locust Point (MA14; MA15; MA16; MA18; MA19)	35	25	13
Fort McHenry (MA17)	7	7	7
Patapsco WWTP (MA23)	15	4	0
US Coast Guard Curtis Bay (MA22)	20	17	10
Martin State Airport (MA1)	8	3	2

5.2 Future With-Project Benefits

The difference in expected mean PV flood damages in the Baltimore Coastal Study area between the FWOP condition and FWP condition represents the CSRM benefits to the project. Therefore, these benefits represent damages reduced from coastal storm surge inundation with the combination of SLR for each alternative. However, ER 1105-2-100, the PGN, dictates that the calculation of net NED benefits for a plan is calculated in average annual equivalent terms. Therefore, the PV damages were converted to average annual damages and the costs were annualized using the fiscal year 2022 discount rate of 2.25 percent and a 50-year period of analysis for the purpose of the comparison.

5.3 Four Accounts Evaluation

5.3.1 National Economic Development

In accordance with the Federal objective, the NED plan is defined as the cost-effective plan that reasonably maximizes net benefits. The equivalent annual benefits were compared to the average annual cost to develop net benefits and a BCR for each alternative. The net benefits for each alternative were computed by subtracting the

average annual costs from the equivalent average annual benefits. The 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. Table 5-7 summarizes the total costs and annualized costs for the final array of alternative. Table 5-8 summarizes the economic evaluation for the final array of alternatives and are detailed by project component and alternative in Appendix E: Economic Analysis. The NED Plan is Alternative 5A – Critical Infrastructure with Select Nonstructural Measures Plan, which has net annual benefits of $4,429,000 and a BCR of 2.0.

Table 5-7. Total and Annualized Costs by Alternative

Plan Alternatives	First Cost	Interest During Construction (IDC)	Investment Cost	Amortized Cost	Operation and Maintenance (O&M) Costs	Annualized O&M Costs
Alternative 0 – No Action	-	-	-	-	-	-
Alternative 4 – Critical Infrastructure Plan with Floodproofing to 5% AEP	$67,454,000	$900,000	$68,354,000	$2,291,000	$675,000	$22,000
Alternative 4 – Critical Infrastructure Plan with Floodproofing to 2% AEP	$63,002,000	$643,000	$63,645,000	$2,134,000	$630,000	$20,000
Alternative 4 – Critical Infrastructure Plan with Floodproofing to 5% AEP	$61,611,000	$440,000	$62,051,000	$2,080,000	$616,000	$20,000
Alternative 5 – Critical Infrastructure & Nonstructural Measures Plan with Floodproofing to 1% AEP	$395,579,000	$11,784,000	$407,363,000	$13,655,000	$3,957,000	$130,000
Alternative 5 – Critical Infrastructure & Nonstructural Measures Plan with Floodproofing to 2% AEP	$225,894,000	$4,167,000	$230,061,000	$7,712,000	$2,260,000	$75,000
Alternative 5 – Critical Infrastructure & Nonstructural Measures Plan with Floodproofing to 5% AEP	$159,769,000	$1,531,000	$161,300,000	$5,406,000	$1,598,000	$53,000
Alternative 5A – Critical Infrastructure with Select Nonstructural Measures Plan	$135,123,000	$1,503,000	$136,626,000	$4,579,000	$1,352,000	$44,000
Alternative 6 – Critical Balanced Plan with Floodproofing to 1% AEP	$493,492,000	$13,903,000	$507,395,000	$17,008,000	$4,936,000	$163,000
Alternative 6 – Critical Balanced Plan with Floodproofing to 2% AEP	$323,807,000	$6,286,000	$330,093,000	$11,065,000	$3,239,000	$108,000
Alternative 6 – Critical Balanced Plan with Floodproofing to 5% AEP	$257,682,000	$3,650,000	$261,332,000	$8,759,000	$2,577,000	$86,000
Alternative 7 – Mid-Tier Balanced Plan with Floodproofing to 1% AEP	$655,398,000	$11,467,000	$666,865,000	$22,353,000	$6,554,000	$219,000
Alternative 7 – Mid-Tier Balanced Plan with Floodproofing to 2% AEP	$650,946,000	$11,297,000	$662,243,000	$22,198,000	$6,509,000	$217,000
Alternative 7 – Mid-Tier Balanced Plan with Floodproofing to 5% AEP	$649,555,000	$11,261,000	$660,816,000	$22,150,000	$6,496,000	$217,000

Table 5-8. Economic Evaluation by Alternative

Plan Alternatives	Total Cost	Average Annual Cost	Average Annual Benefits	Average Annual Net Benefits	Benefit Cost Ratio (BCR)
Alternative 0 – No Action	-	-	-	-	-
Alternative 4 – Critical Infrastructure Plan with Floodproofing to 5% AEP	$69,029,000	$2,313,000	$6,431,000	$4,118,000	2.8
Alternative 4 – Critical Infrastructure Plan with Floodproofing to 2% AEP	$64,275,000	$2,153,000	$6,390,000	$4,237,000	3.0
Alternative 4 – Critical Infrastructure Plan with Floodproofing to 5% AEP	$62,667,000	$2,099,000	$6,372,000	$4,273,000	3.0
Alternative 5 – Critical Infrastructure & Nonstructural Measures Plan with Floodproofing to 1% AEP	$411,320,000	$13,787,000	$10,469,000	($3,318,000)	0.8
Alternative 5 – Critical Infrastructure & Nonstructural Measures Plan with Floodproofing to 2% AEP	$232,321,000	$7,785,000	$9,617,000	$1,832,000	1.2
Alternative 5 – Critical Infrastructure & Nonstructural Measures Plan with Floodproofing to 5% AEP	$162,898,000	$5,461,000	$8,608,000	$3,147,000	1.6
Alternative 5A – Critical Infrastructure with Select Nonstructural Measures Plan	$137,978,000	$4,625,000	$9,054,000	$4,429,000	2.0
Alternative 6 – Critical Balanced Plan with Floodproofing to 1% AEP	$512,331,000	$17,173,000	$10,624,000	($6,549,000)	0.6
Alternative 6 – Critical Balanced Plan with Floodproofing to 2% AEP	$333,332,000	$11,171,000	$9,772,000	($1,399,000)	0.9
Alternative 6 – Critical Balanced Plan with Floodproofing to 5% AEP	$263,909,000	$8,847,000	$8,763,000	($84,000)	1.0
Alternative 7 – Mid-Tier Balanced Plan with Floodproofing to 1% AEP	$673,419,000	$22,571,000	$11,506,000	($11,065,000)	0.5
Alternative 7 – Mid-Tier Balanced Plan with Floodproofing to 2% AEP	$668,752,000	$22,414,000	$11,465,000	($10,949,000)	0.5
Alternative 7 – Mid-Tier Balanced Plan with Floodproofing to 5% AEP	$667,312,000	$22,366,000	$11,447,000	($10,919,000)	0.5

5.3.2 Regional Economic Development (RED)

The current certified Regional Economic System (RECONS) 2.0 model was used to estimate the RED benefits in the Baltimore Coastal Study. The RED evaluation estimates changes in the distribution of regional economic activity for each alternative plan. The RED evaluation focuses on the creation of jobs and regional contributions to income and economic output associated with investments from the proposed action. The direct and secondary RED impacts are measured in output, jobs, labor income, and gross regional product and are summarized in Table 5-10.

5.3.3 Environmental Quality (EQ)

Wetland information and GIS data were collected from various sources for identification of wetland areas within the study areas. U.S Geological Survey (USGS) topographic quadrangles, U.S. Department of Agriculture (USDA) web soil surveys, FEMA floodplain mapping, and USFWS National Wetland Inventory (NWI) were used to access SAV, soil types, historical resources, archeological sites, EJ 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 and nonstructural measures in the study area.

5.3.4 Other Social Effects (OSE)

5.3.4.1 Life Risk

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 (Appendix E: Economics Analysis). Since there is uncertainty in modeling life loss, the FWOP project condition was modeled to serve as a baseline. Therefore, when compared to the FWP 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 5-9 presents the mean life loss estimates for the final array of alternatives in the study area over a 50-year period of analysis.

Table 5-9. Life Loss Calculations for the Focused Array of Alternatives

Alternative		Life Loss		
		Under 65	Over 65	Total
Alternative 4 – Critical Infrastructure Plan	No Action	0.0	0.0	0.0
	Project	0.0	0.0	0.0
	Incremental Life Loss	0.0	0.0	0.0
Alternative 5 – Critical Infrastructure & Nonstructural Measures Plan	No Action	5.3	82.7	88.0
	Project	5.3	82.7	88.0
	Incremental Life Loss	0.0	0.0	0.0
Alternative 5A – Critical Infrastructure with Select Nonstructural Measures Plan	No Action	5.3	82.5	87.8
	Project	5.3	82.5	87.8
	Incremental Life Loss	0.0	0.0	0.0
Alternative 6 – Critical Balanced Plan	No Action	5.3	82.7	88.0
	Project	5.3	82.7	88.0
	Incremental Life Loss	0.0	0.0	0.0
Alternative 7 – Mid-Tier Balanced Plan	No Action	5.3	78.9	84.2
	Project	4.6	58.3	62.9
	Incremental Life Loss	-0.7	-20.6	-21.3

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 (i.e. ability to reach higher ground via stairs, ladder etc.) 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. As discussed in Section 2.6.2, 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). Surge lethality is also dependent on the population age distribution as described above. Different surge heights are modeled for people over 65 years of age than for those under 65 years of age.

The model cycles through every active structure during each storm. For each structure, the model defaults the lethality function to safe and checks 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 factored 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 between alternatives.

The FWOP condition resulted in annualized life loss of 0.0034 percent while the FWP condition resulted in life loss of 0.0024 percent, a reduction of 0.001 percent life loss when compared to FWOP condition.

In addition to impacts on life, health, and safety factors, the PDT also considered community impacts, displacement, and long-term productivity.

5.3.5 Summary of the Four Accounts Evaluation

Table 5-10 shows the four accounts evaluation. Since the alternative plans add on to each other, some of the benefits and impacts are the same for them. Those highlighted in green have the highest benefit under that account. For EQ, the impacts are similar across all alternatives. The NED Plan is identified as Alternative 5A – Critical Infrastructure Plan with Select Nonstructural Measures, which reasonably maximizes net benefits while maintaining historic neighborhood character, access to water and improving community resiliency. While Alternative 7 – Mid Tier Plan has higher RED benefits resulting from the higher total investment associated with that Plan, it has a BCR below parity and negative net benefits.

There are EJ communities that are in the study area but are not impacted by flooding. These are the Fairfield/Curtis, Brooklyn, Cherry Hill, and Westport neighborhoods. These are elevated or are not directly impacted by coastal flooding. But transportation could be impacted due to coastal flooding. The TSP would maintain access to critical transportation corridors through the tunnels for these EJ communities.

Table 5-10. Four Accounts Evaluation Summary

PLAN SUMMARY		Alternative 4	Alternative 5	Alternative 5A	Alternative 6	Alternative 7
Description		Critical Infrastructure	Critical Infrastructure with NS Plan	Critical Infrastructure with Select NS Plan	Critical Balanced	Mid-Tier
Total Project Costs		$62M-$69M	$163M-$411M	$138M	$263M-$512M	$667M-$673M
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 Alternative 5.	Negative net benefits. Detrimental community and visual impacts.
National Economic Development (NED) Account	**Net Benefits**	$4.1M-$4.2M	$-3.3M-$3.1M	$4.4M	$-6.5M-$-84K	$-11M-$-10M
	BCR	2.8-3.0	0.8-1.6	2.0	0.6-1.0	0.5
Regional Economic Development (RED) Account	**Local-US Jobs**	613-997	1,602-2,353	1,357-1,994	2,596-3,813	6,624-9,729
	Local-US Outputs	$110M-$159M	$304M-$438M	$258M-$371M	$493M-$709M	$1.2B-$1.8B
	Employment Income	$63M-$81M	$176M-$225M	$149M-$191M	$285M-$365M	$728M-$932M
Environmental Quality (EQ) Account		▲Increased community resilience; No significant impacts. Minor critical area buffer impacts (Does not vary across alternatives).				
Other Social Effects (OSE) Account		▲Improve resiliency	▲Maintain historical character and cultural identity. ▲Improve resiliency			▲Improve resiliency ▼Long term negative impacts to aesthetics and water access. Block roads during deployment.
		▲Economic vitality. Ensure connectivity between communities and access to jobs (does not vary across alternatives).				

5.4 Plan Selection

As detailed in Section 3.7.1, the final array of alternatives addresses the study objectives to reduce coastal storm risk, reduce damages, and impacts from coastal inundation to people and critical infrastructure assets and all five action plans meet the P&G screening criteria and are complete, efficient, cost effective, and acceptable.

All six alternatives in the final array of alternatives, including the no action plan, were compared using the four accounts criteria. The no action plan provided a basis for comparing the final array of alternative and represents that no federal CSRM action would be taken as part of this feasibility study effort. As outlined in Table 5-9, the NED Plan is identified as Alternative 5A – Critical Infrastructure Plan with Select Nonstructural Measures, which also has the highest comprehensive benefits across three out of the four accounts (NED, EQ, OSE). It is noted that Alternative 7 has higher RED benefits, but also has a BCR below parity and negative net benefits and therefore is not selected for further evaluation.

Alternative 5A – Critical Infrastructure Plan with Select Nonstructural Measures is selected as the TSP. The TSP – Alternative 5A – Critical Infrastructure Plan with Select Nonstructural Measures reasonably maximizes net benefits while maintaining historic neighborhood character, access to water, and enhancing community resilience. The TSP, Alternative 5A - Critical Infrastructure with Select Nonstructural Measures Plan has net annual benefits of $4,429,000 and a BCR of 2.0.

6 TENTATIVELY SELECTED PLAN

The TSP is Alternative 5A, the Critical Infrastructure with Select Non-Structural Measures Plan, which incorporates floodwalls and closure structures at the I-95 and I-895 Tunnels and supporting infrastructure (Fort McHenry and Harbor Tunnels) as well as floodproofing (at 1-5 percent AEP) as nonstructural measures in Canton, Fells Point, Inner Harbor, Riverside, and Locust Point areas. Figure 6-1 shows the location of the proposed structural measures and focus areas for nonstructural measures.

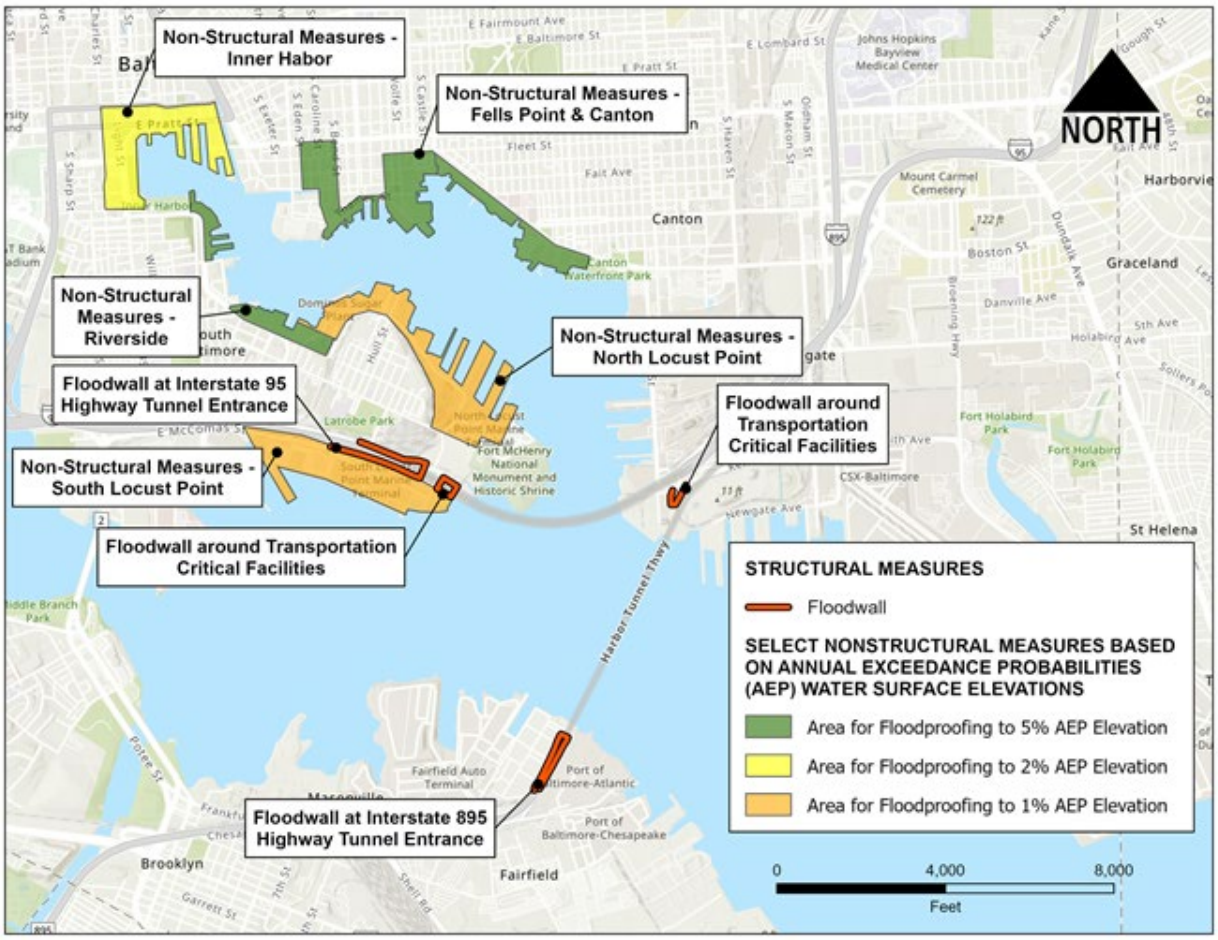

Figure 6-1. Tentatively Select Plan – Alternative 5A Critical Infrastructure with Select Nonstructural Measures Plan

6.1 Plan Accomplishments*

The coastal storm events in the past century that have impacted the Baltimore area left many images and memories of flooded streets, houses, and damage to infrastructure. Baltimore has been resilient, clearing debris and repairing damaged structures. However, the efforts taken to prepare and recover from storms, and the disruption on peoples' lives and livelihoods

have been significant. Those impacts are forecast to continue and may increase in the future with SLC and changing climate conditions.

The TSP has been formulated to reduce economic damages, reduce disruption to critical infrastructure, improve the resiliency of critical infrastructure, and to reduce risk to human health and safety. In turn, these objectives contribute to community resilience and health in the face of changing conditions.

I-95 and I-895 are heavily utilized travel corridors in the Baltimore Metropolitan area and serve a critical role in the efficient transportation of goods, people, and services along the eastern seaboard of the United States. I-95 is a direct link between the communities of South Baltimore and eastern Baltimore City and County, as well as an important route for people to reach job centers further afield. Similarly, I-895 provides a direct link to eastern Baltimore City and County with communities in South Baltimore separated from the rest of the city by the Middle Branch of the Patapsco River, as well as communities in northern Anne Arundel County. It also provides relief for congestion on I-95. If these transportation assets were damaged by a coastal storm, recovery is expected to be costly and time consuming. Loss of these transportation corridors could lead to disruption in emergency services, recovery operations, and nearby community recovery and resilience.

The TSP proposes to protect the assets of the I-95 and I-895 tunnels that are vulnerable to damage from flooding from a coastal storm. Protection of the tunnel's infrastructure through T-walls and closure structures would result in a rapid return to operation if the tunnels were closed during a high water event. Transportation at these critical nodes would resume and resources that would otherwise be directed to recovery at the tunnels could be used in other critical areas. Other transportation corridors, such as I-695, the Baltimore Beltway, would receive less traffic than if the tunnels were forced to close for an extended period of time. People would continue to use the tunnels to access jobs, family, and services.

The nonstructural component of the TSP would also create resilient communities. Past flood events have inundated portions of the downtown core of Baltimore City, as well as historic communities such as Fells Point. There is an opportunity to protect structures in the study area from flood damages and help to build and maintain resilient communities into the future. In the Canton and Fells Point neighborhoods, flood impacts may be experienced by residential rowhouses, businesses occupying rowhouses and older converted waterfront structures, as well as more modern structures. Structures that could be impacted in the Inner Harbor area are typically older high rise structures housing offices or residences. Floodproofing in the Riverside and Locust Point areas would be concentrated on commercial structures that are water dependent. Floodproofing in the TSP would enable a mix of residential and commercial activity to recover quickly and experience lower monetary losses from flood events. Floodproofing would also preserve the historic and cultural characteristics of these areas and maintain visual and physical access to the water.

While the immediate effects would be experienced by people on the waterfront, the Inner Harbor has been described as a "shared public space" (Reimagining the Harbor as a Hub) that can engage "with Baltimore beyond the Harbor". A resilient community, both residential and commercial, enables a thriving waterfront, which itself can enable an invigorated greater Baltimore region. Recent and emerging investment in the Baltimore waterfront is enhanced by a community protected with floodproofing.

Past storm events have led some building owners to install nonstructural solutions to flood risk and enabled these structures to continue to be habitable and productive. Current nonstructural solutions have been shown to enable continuing commerce and community engagement in the face of flood threats. The National Aquarium has installed nonstructural floodproofing, allowing it to continue and expand its mission on the waterfront. The World Trade Center in Baltimore installed floodproofing solutions after devastating flooding following Hurricane Isabel. Flood barriers were deployed during forecast of recent high water, and this allowed normal building activities to continue. Life activities can continue while preparations for storm events are made. With nonstructural floodproofing, community life and the region's connection to the waterfront is maintained.

6.2 Plan Components*

Floodwalls

The floodwalls considered for the protection of the I-95 and I-895 tunnels are cast-in-place concrete T-walls. Two different types of floodwalls were selected and referenced as Type 1 and Type 2. Floodwall Type 1 would be constructed around tunnel entrances while Type 2 would be constructed to protect the tunnel ventilation buildings. The preliminary design results for T-wall types 1 and 2 are provided in Table 6-1 below. A typical cross section of a T-wall is shown in Figure 6-2.

Table 6-1. Floodwall dimensions at Transportation Facilities and Tunnel Entrances

Wall Type	Footing		Stem			Key	
	Width (ft)	Thickness (in)	Height (ft)	Thickness at Crest (in)	Thickness at Base (in)	Depth (ft)	Thickness (in)
1	11.5	18	8.2	12	18	2	12
2	6.67	14	5.2	10	14	1.5	12

*T-wall Preliminary Design Results

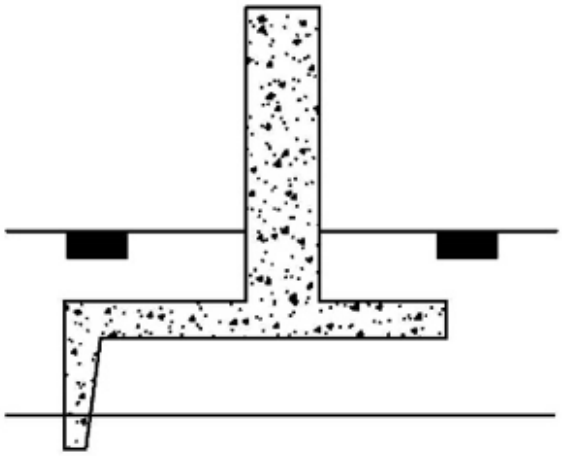

Figure 6-2. Typical Cross Section of a T-wall

The concrete T-walls were analyzed for global stability and structural strength based on the requirements established on EM 1110-2-2100 “Stability Analysis of Concrete Structures”, EM 1110-2-2502 “Retaining and Floodwalls”, ECB No. 2017-2 “Revision and Clarification of EM 2100 and EM 2502”, and EM 1110-2-2104 “Strength Design for Reinforced Concrete Hydraulic Structures”.

Five different loading conditions were used during the analysis in accordance with Table B-5 of EM 1110-2-2100. An additional loading condition, Design Resiliency Check, was also used and includes water at the top of the wall. This case was adapted from the USACE New Orleans District Design Guidelines and applies to structures whose primary function is hurricane flood protection. The case was developed to verify the survivability of a structure during major storm events. Additional information on the analysis can be found in Appendix A: Civil Engineering.

Nonstructural Measures

Either wet or dry floodproofing is proposed as part of the TSP. No building elevation or relocation is proposed as a nonstructural floodproofing measure. Specific application of floodproofing would be determined on a structure-by-structure basis during design phase; however, representative floodproofing applications have been previously explored for Baltimore City (USACE 2019).

Dry floodproofing is an effective option in Baltimore City in certain applications, particularly for masonry buildings, where the final DFE is no greater than 3-4 feet above the finished floor elevation. The challenges for dry floodproofing buildings in Baltimore City include maintaining the historic aesthetics of buildings and the limited warning time that may be available to implement closure barriers, as this aspect of dry floodproofing relies on human response in order to be effective.

Wet floodproofing is an effective option in Baltimore City for a relatively small number of cases where structure type and first floor occupancy allow for it. Implementation would require significant changes to interior building layout and functionality, which may not be desirable in many cases. Allowing flood waters into the structure would require all valuables and utilities to be elevated above the DFE, which may be costly depending on the original building layout. This would also require pumping the water out and cleaning of the sub grade. Typically, these options are also not practical for row homes considering many of these buildings have multiple owners.

Figures 6-3 through 6-5 show pictures of several key features typically found on Baltimore City buildings that routinely result in flooding. A description of how these features can be adapted to reduce flood risk accompanies each figure.

These two paneled historic basement doors can often flood because they are even with or just above the sidewalk. In the interest of preserving the historical appearance of the building exterior, the recommended approach is to provide a certified flood proof basement door, and associated framing behind (or underneath) the existing basement doors, and leave the existing doors in

Figure 6-3. Two Parallel Basement Doors

The low basement window openings can allow flood waters to enter the buildings. To reduce the flood risk, retrofits on the building interior can be implemented that will not impact the exterior integrity and aesthetics of the structure. Structural glass installed in a new steel frame may be anchored to the existing masonry behind the historic windows.

Figure 6-4. Basement Window Retrofit

These low area windows allow flooding of basements. In instances where basements are rarely used, wet floodproofing is the most logical and lowest-cost option. Wet floodproofing the basement area would protect the structure up to the finished first floor elevation. Some of the infilled windows could be fitted with flood louvers to allow the safe passage of water into the building without risk of damage to the structure.

Figure 6-5. Basement Windows and Wet Floodproofing

6.3 Cost Estimate and Cost Sharing Breakdown

During project implementation (PED and construction phases), the project would be cost shared 65 percent Federal and 35 percent non-federal. LERRs required for project construction must be provided by the non-federal sponsor for the non-federal construction cost share amount as described in Section 6.4.

The project may have separate non-federal sponsors during the PED and construction phases: one for the structural (floodwall) components and one for the nonstructural (floodproofing) components. The non-federal sponsor for the structural components is likely to be the MDTA, which is an authority under MDOT. The non-federal sponsor for the nonstructural components is yet to be determined; however, CENAB is coordinating with Baltimore City and other stakeholders to evaluate potential partnership.

The apportionment of the first costs, including associated costs, between the federal government and the non-federal sponsor is shown on Table 6-2.

Table 6-2. Baltimore Coastal Cost Sharing

(October 2021 Price Level)[1]

Item	Federal Share	Non-federal Share	Total Project Cost
Relocations	$2,247,050.00	$1,209,950.00	$3,457,000.00
Levees and Floodwalls	$21,314,800.00	$11,477,200.00	$32,792,000.00
Cultural Resource Preservation	$247,000.00	$133,000.00	$380,000.00
Preconstruction, Engineering & Design (PED)[2]	$6,895,2000	$3,712,800.00	$10,608,000.00
Construction Management (S&I)[2]	$2,483,000.00	$1,337,000.00	$3,820,000.00
Floodproofing	$52,995,800.00	$28,536,200.00	$81,532,000.00
Subtotal Construction	$86,182,850.00	$46,406,150.00	$132,589,000.00
Lands, Easements, Right-of-Ways, Relocations (LERR)	$1,539,200.00	$828,800.00	$2,368,000.00
Total Project First Costs	$87,722,050.00	$47,234,950.00	$134,957,000.00
Credit for Non-Federal LERR			
Total Cost Apportionment			

[1]Cost is based on Project First Cost.
[2]PED and construction cost sharing totals are reflected as 65% federal/35% non-federal.

6.4 Lands, Easements, Rights-of-Way, Relocations, and Disposal

At this current planning stage, the lands and damages real estate cost estimate is $15,164,520. These costs include acquisition administration costs, contingency, and estimated damages for both structural and nonstructural components of the TSP.

The above costs include funds for the LERRs, if applicable. Incidental acquisition costs are also included and include costs for title work, appraisals, appraisal review, coordination

meetings, review of documents, legal support (including but not limited to approval of the nonstandard estate and easement drafting), crediting, project close out, and other costs incidental to the acquisitions and the project.

There are no proposed mandatory buyouts, mandatory relocations or structure elevations included in the TSP. NNC's Best Practice Guide 2020-02 addresses temporary relocation and in paragraph 5.b.iv discusses the ability of an owner to afford to temporarily relocate at their own expense and states that this factor only applies to structures being elevated. Therefore, it implies that no relocation is necessary for wet or dry floodproofing. Nevertheless, as a Federal Project, it must comply with the Uniform Relocation Act.

6.5 Operations, Maintenance, Repair, Replacement and Rehabilitation (OMRR&R)

The annualized O&M for the I-895 tunnel floodwall and associated transportation critical facility is estimated to be $7,000. The annualized O&M for the I-95 tunnel floodwall and the associated transportation critical facility floodwall is estimated to be $10,000. The concrete floodwalls at the tunnel entrances and transportation critical facilities would require minimal maintenance over the 50-year period of analysis. O&M on the floodwalls at the tunnel entrances and the tunnel support facilities would likely be managed by the MDTA.

O&M of the stoplog or closure structures would be as follows:

- Maintenance:

Closure structures for traffic openings shall be Inspected by the superintendent every 90 days to be certain that:

(i) No parts are missing
(ii) Metal parts are adequately covered with paint
(iii) All movable parts are in satisfactory working order
(iv) Proper closure can be made promptly when necessary
(v) Sufficient materials are on hand for the erection of sandbag closures and that the location of such materials will be readily accessible in times of emergency.

Tools and parts shall not be removed for other use. Trial erections of one or more closure structures shall be made once each year, alternating the structures chosen so that each gate will be erected at least once in a 3-year period. Trial erection of all closure structures shall be made whenever a change is made in key operating personnel. Where railroad operation makes trial erection of a closure structure infeasible, rigorous inspection and drill of operating personnel may be substituted therefor. Trial erection of sandbag closures is not required. Closure materials will be carefully checked prior to and following flood periods, and damaged or missing parts shall be repaired or replaced immediately.

- Operation:

Erection of each movable closure shall be started in sufficient time to permit completion before flood waters reach the top of the structure sill. Information regarding the proper method of erecting each individual closure structure, together with an estimate of the time required by an experienced crew to complete its erection, will be given in the O&M Manual which will be furnished to local Interests upon completion of the project. Closure structures will be inspected frequently during flood periods to ascertain that no undue leakage is occurring and that drains provided to care for ordinary leakage are functioning properly. Boats or floating plants shall not be allowed to tie up to closure structures or to discharge passengers or cargo over them.

The annualized O&M for the nonstructural (floodproofing) components is approximately $27,000. The O&M for the nonstructural components would be managed by the project sponsor.

Combining the O&M for the structural and the nonstructural components, the total O&M for Alternative 5A, the TSP, is $44,000 per year based on a 50-year period of analysis.

6.6 Project Risks 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 CSRM 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 USACE 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.”

The PDT identified the environmental and the nonstructural plan risks discussed below.

Environmental

- Contaminated soils may be present in construction areas for the I-95 and I-895 tunnels. Further investigations during PED would be necessary to determine if contaminated soils are present. Risk – Medium

Nonstructural Plan

- Low openings, such as basement windows or doors, are not accounted for in the G2CRM modeling. Therefore, uncertainties exist in the evaluation of structures vulnerable to flooding. There may be structures that were not captured as vulnerable to flooding since low openings were not accounted for. Additional data will be collected during the feasibility phase to refine the nonstructural plan, evaluate, and confirm structures that may be vulnerable to flooding and are eligible to receive floodproofing measures.
- Participation in non-structural floodproofing is voluntary and it is unlikely that all eligible structures would have non-structural measures applied. Structures not floodproofed would be at risk of damage from floods. There is also the probability that not all owners of attached structures (particularly rowhouses) will participate. This may result in nonperformance of floodproofing measures if they were applied to some structures but not others.
- Nonstructural floodproofing may provide a sense of life safety to occupants of houses. There is risk that occupants of floodproofed structures would choose not to evacuate during a high-water event. These people would have elevated life safety and health risk.

Additionally, the PDT is working with USACE higher authority and the District Levee Safety Manager to conduct a risk assessment for this study. The team met with the Levee Safety Center on April 5, 2022 to start scoping the risk effort. G2CRM was used to evaluate life loss and the results can be found in Section 5.2.1 above. The areas being evaluated under this study did not present substantial life threats from flooding and therefore, LifeSim was not used to compute life loss. A potential failure mode analysis would be performed on the current TSP feasibility level design to identify potential failure modes that would need to be addressed as the design matures, to ensure minimal risk to the public and identify cost risks that may affect the total project cost. The risk assessment will be included in the final IFR/EA following the guidance in PB 2019-04 and ER 1105-2-101 for FRM and certain CSRM projects. For more information on Geotechnical and Civil engineering considerations for design, reference (Appendix A: Civil Engineering and Appendix D: Geotechnical Analysis).

6.7 Design and Construction

The structural components of the TSP have three project areas: I-95 Fort McHenry Tunnel in the Locust Point planning unit, the I-895 Tunnel in the Patapsco South planning unit, and the supporting infrastructure for the I-95 Tunnel in the Patapsco North planning unit. It is estimated that the construction duration for the Locust Point planning unit would be 14 months. The Patapsco South planning unit construction duration would be 12 months and the Patapsco North planning unit construction duration would be 3 months. There are no time-of-day restrictions, and the cost estimate assumes 12-hour days for all three areas. Materials would be brought in by land via by flatbed trucks, trailers, and dump trucks.

The design phase for the structural components assumes two years to start in October 2024 and end in September 2026. The construction window for all areas would likely start in 2026 and end in 2027. Construction would occur concurrently.

The non-structural components of the TSP would require multiple steps during the real estate acquisition process. It is anticipated that the process to obtain necessary easements and agreements would be approximately 60 months. Local approvals and permits would also be obtained during this timeframe. Design and construction phase schedules have not been determined for this draft report and will vary with participation rates, types of structure, and non-structural floodproofing measures utilized.

6.8 Environmental Commitments*

- Sediment and erosion controls would be used to minimize impacts to wetlands and waterways.
- Contaminated soils may be present construction areas for the I-95 and I-895 tunnels. Numerous sites were identified for HTRW concern within the search radius used to identify such sites in the study area. Further investigations will be necessary to determine if contaminated soils are present. These investigations would be conducted during PED phase.
- USACE will resubmit the information for the northern long-eared bat required in the USFWS Key to the Northern Long-Eared Bat 4(d) Rule for Federal Actions that May Affect Northern Long-Eared Bats into the USFWS IPaC prior to construction.
- A Critical Area Buffer Management Plan/Landscape plan would be completed during the PED phase and submitted to the Critical Area Commission for potential impacts to the Critical Area 100-foot Buffer.
- A Programmatic Agreement to conduct cultural resource investigations during the PED phase is currently being developed with consulting parties.

6.9 Cumulative Impacts*

Potential cumulative effects of induced flooding from the proposed structural and nonstructural flood protection measures around the Inner Harbor, Locust Point, Riverside, Canton, and Fells Point and other existing flood protection measures in the region will be analyzed. Modeling will be conducted to determine the WSELs under the FWP condition. The modeling will consider other existing flood protection measures in the area. Results of the modeling and the effects of induced flooding will be included in the final IFR/EA.

Construction of the structural and nonstructural floodproofing measures are not expected to result in cumulative effects to wetlands, threatened and endangered species, migratory birds, bald eagles, land use, water quality, natural floodplains, air quality (including greenhouse gases), recreation, aesthetics, noise, or EJ communities.

Cumulative Impacts to cultural resources are not anticipated.

6.10 Project-Specific Considerations

The real estate plan (Appendix F) does not address possible issues related to leasehold/ground rent properties and whether these ground rents will need to be redeemed for a property owner to participate in this project. Leasehold properties are quite common in the Baltimore, MD area.

6.11 Environmental Operating Principles (EOP)*

The USACE Environmental Operating Principles (EOP) were developed to ensure that USACE missions integrate sustainable environmental practices. The EOP relates to the human environment and applies to all aspects of business and operations. The principles were designed to provide direction on how to better achieve stewardship of air, water, and land resources, and to demonstrate a positive relationship between management of these resources and the protection and improvement of a sustainable environment. The EOP informed the plan formulation process and are integrated into the proposed solution for CSRM.

The EOP are:

- Foster sustainability as a way of life throughout the organization
- Proactively consider environmental consequences of all USACE activities and act accordingly
- Create mutually supporting economic and environmentally sustainable solutions
- Continue to meet our corporate responsibility and accountability under the law for activities undertaken by the USACE, which may impact human and natural environments
- Consider the environment in employing a risk management and systems approach throughout the life cycles of projects and programs
- Leverage scientific, economic, and social knowledge to understand the environmental context and effects of USACE's actions in a collaborative manner
- Employ an open, transparent process that respects views of individuals and groups interested in USACE activities

Plan selection considered these principles to ensure the sustainability and resiliency of the NED plan while considering the environmental consequences of implementation. In addition to construction BMPs to maintain water quality standards, other opportunities to implement sustainable measures that are cost effective and comply with USACE construction standards will be further evaluated during the PED phase. The study team considered avoiding and minimizing adverse impacts to existing environmental resources and cultural resources within the project area to the extent practicable during the plan formulation process.

6.12 Views of the Non-Federal Sponsor

The non-federal sponsor for the Baltimore Coastal Study is MDOT. CENAB has been in continuous coordination with MDOT while carrying out the feasibility study and MDOT supports the TSP.

As mentioned in Section 6.3, the project may have two separate non-federal sponsors for the structural and nonstructural components of the TSP, during the PED and construction phases. The non-federal sponsor for the structural components is likely to be the MDTA. The non-federal sponsor for the nonstructural components is yet to be determined; however, CENAB is coordinating with Baltimore City and other stakeholders to evaluate potential partnership.

USACE has initiated and continues consultation in accordance with Section 106 of the NHPA of 1966, as amended, and its implementing federal regulations, 36 CFR 800. Currently, USACE cannot fully determine the TSP's effects on historic properties. When effects on historic properties cannot be fully determined prior to approval of an undertaking, a Programmatic Agreement (PA) may be developed pursuant to 36 CFR 800.14 (b)(ii). To satisfy the requirements under Section 106 of the NHPA, USACE is proposing to develop a PA to allow the draft IFR/EA to move forward, while stipulating cultural resource investigation requirements during PED of the project when more detailed designs are produced. Therefore, USACE defers final identification and evaluation of historic properties until after project approval when additional funding becomes available during the PED phase, and through the execution of an approved PA. The signed PA will be included in Appendix G of the final IFR/EA.

The MDOT supports releasing this report for public and agency input. The MDOT's support for the TSP will be confirmed through a letter of support following public and agency reviews.

6.13 Implementation Schedule

This IFR/EA will culminate in an interim Chief's Report on 27 March 2024. A Chief's Report, the Report of the USACE Chief of Engineers, is developed when a water resources project would require Congressional authorization or a change to existing project authorization. After the final feasibility report is submitted to Headquarters USACE, a Chief's Report is developed.

If Congressional authorization for the project is received, the project would go into the PED phase. The PED phase is anticipated to take two years and is assumed to start in October 2024 and last through September 2026. Construction of the structural components along the I-895 and I-95 tunnel entrances and their support facilities would likely begin October 2026 and end October 2028, assuming a two-year construction window. Construction of the nonstructural components is assumed to take approximately 4 years; however, implementation is dependent upon participation, cooperation of local authorities, and lienholders, and structural characteristics.

7 ENVIRONMENTAL COMPLIANCE*

7.1 Environmental Compliance Table

Compliance with environmental laws and EOs is required for the project alternatives under consideration. Tables 7-1 and 7-2 lists the current compliance status for each environmental and cultural requirement that was identified and considered for the study.

Table 7-1. Status of Compliance with Applicable Environmental and Cultural Resource Laws

LAWS	COMPLIANCE STATUS
Archeological and Historic Preservation Act of 1974	In Progress
Bald and Golden Eagle Protection Act of 1962, as amended	Full
Chesapeake Bay Critical Area Act (1984) and its Criteria (1986)	In Progress
Clean Air Act of 1970, as amended 1977 and 1990	Full
Clean Water Act of 1972, as amended	In Progress
Coastal Barrier Resources Act of 1982	N/A
Coastal Zone Management Act of 1972, as amended	In Progress
Comprehensive Environmental Response, Compensation and Liability Act of 1980	N/A
Endangered Species Act of 1973	In Progress
Fish and Wildlife Coordination Act of 1958, as amended	In Progress
Magnuson-Stevens Fishery Conservation and Management Act	Full
Marine Mammal Protection Act of 1972, as amended	N/A
National Environmental Policy Act of 1969, as amended	In Progress
National Historic Preservation Act of 1966	In Progress
Noise Control Act of 1972, as amended	Full
Resource Conservation and Recovery Act of 1976	In Progress
Rivers and Harbors Act of 1899	N/A
Wild and Scenic Rivers Act of 1968	N/A

Table 7-2. Status of Compliance with Applicable Executive Orders

EXECUTIVE ORDERS	COMPLIANCE STATUS
Protection and Enhancement of Environmental Quality (E.O. 11514/11991)	Full
Protection and Enhancement of Cultural Environment (E.O. 11593)	In Progress
Floodplain Management (E.O. 11988)	In Progress
Protection of Wetlands (E.O. 11990)	Full
Environmental Justice in Minority and Low-Income Populations (E.O. 12898)	In Progress
Protection of Children from Health Risks and Safety Risks (E.O. 13045)	Full
Chesapeake Bay Protection and Restoration (E.O. 13508)	Full
Invasive Species (E.O. 13112)	N/A
Consultation and Coordination with Indian Tribal Governments (E.O. 13175)	In Progress
Responsibilities of Federal Agencies to Protect Migratory Birds (E.O. 13186)	Full

7.2 National Environmental Policy Act

This document follows the "Update to the Regulations Implementing the Procedural Provisions of the National Environmental Policy Act", published by the Council on Environmental Quality (CEQ) in the Federal Register on July 16, 2020. The update affects all NEPA processes that began after September 14, 2020 (85 FR 43304). NEPA requires the preparation of an EIS for any major federal action that could have a significant impact on the quality of the human environment, and the preparation of an EA for those federal actions that do not cause a significant impact but do not qualify for a categorical exclusion.

NEPA regulations provide for a scoping process to identify the scope and significance of environmental issues associated with a project. The process identifies and eliminates from further detailed study issues that are not significant. USACE used this process to comply with NEPA, and it was determined that an EA was the appropriate NEPA document to prepare for this project.

Upon completion of the final IFR/EA and the signing of the Finding of No Significant Impact (FONSI), the project will be in full compliance with NEPA. A draft FONSI is provided in Appendix G.

7.3 Chesapeake Bay Critical Area Act

Construction of a proposed floodwall around the perimeter of the Fort McHenry West Ventilation Building is expected to have minor impacts to the Chesapeake Bay Critical Area 100-foot Buffer. A Critical Area Buffer Management Plan and/or Landscape Plan will be developed to mitigate the impacts.

7.4 Clean Water Act

A Section 401 Water Quality Certification (WQC) is not required from MDE.

7.5 Wetlands

Section 404 of the Clean Water Act and the 404(b)(1) Guidelines at 40 CFR Part 230 require that USACE avoid, minimize, and mitigate impacts to wetlands. The TSP would have no direct effects to wetlands. Construction of a proposed floodwall around the Fort McHenry West Ventilation Building would be located adjacent to a tidal wetland but would have no direct or indirect impacts to the wetland.

7.6 Federal Coastal Zone Management Act

A federal consistency determination in accordance with 15 CFR Part 930 Subpart C has been drafted stating that the TSP is consistent with the enforceable policies of the State of Virginia's federally approved coastal management program (Appendix G).

7.7 Clean Air Act

An Air Conformity Assessment was prepared and can be found in Appendix G. The actions associated with the TSP are exempt from the General Conformity Rules in Section 176c of the Clean Air Act. Ozone precursors, VOCs and oxides of nitrogen (NOx) are below the USEPA threshold of 100 tons per year for all maintenance areas. All other annual emission totals and aggregated study emission totals for criteria pollutants are not anticipated to exceed all other USEPA *de minimis* thresholds; therefore, no mitigation measures are required.

7.8 Magnuson-Stevens Fishery Conservation and Management Act

This Act requires federal action agencies to consult with the NMFS if a proposed action may affect EFH. No in-water work is proposed for the TSP. Therefore, there will be no effect to EFH as a result of the TSP.

7.9 U.S. Fish and Wildlife Coordination Act

The FWCA requires Federal agencies to consult with the USFWS, NMFS, and the state fish and wildlife agencies where the "waters of any stream or other body of water are proposed or authorized, permitted or licensed to be impounded, diverted or otherwise controlled or modified" by any agency under a federal permit or license. Consultation is to be undertaken for the purpose of "preventing loss of and damage to wildlife resources." The intent is to give fish and wildlife conservation equal consideration with other purposes of water resources development projects. A USFWS Coordination Act Letter was completed and submitted to CENAB on April 6, 2022, indicating that species and habitats

identified within the project area are not likely to be impacted by this project. Coordination with USFWS and NMFS for the FWCA will be ongoing through the remainder of the study.

7.10 Endangered Species Act

The TSP is compliant with the Endangered Species Act of 1973 (ESA). USACE determined that the TSP would have no effect on federal and state-listed threatened and endangered species due to the lack of suitable habitat conditions and/or the lack of documented observances where the effects are likely to occur. The TSP would have no effect on threatened and endangered species under the purview of NMFS.

7.11 Marine Mammal Protection Act

The TSP would have no effect on marine mammals.

7.12 Section 106 and 110(f) of the National Historic Preservation Act

The NHPA applies to properties listed in or eligible for listing in the NRHP; these are referred to as “historic properties.” Historic properties eligible for listing in the NRHP include prehistoric and historic sites, structures, buildings, objects, and collections of these in districts. Under Section 106 of the NHPA and its implementing regulations at 36 CFR Part 800, the USACE assessed potential effects on historic properties that are located within the APE. Coordination with the Maryland SHPO and other Section 106 consulting parties will continue through the remainder of the study.

7.13 Resource Conservation and Recovery Act (RCRA)

An HTRW Investigation Report was drafted for this study. Further investigations and field testing are needed to determine the presence of contamination at the proposed construction sites.

7.14 Comprehensive Environmental Response, Compensation and Liability Act (CERCLA or Superfund)

No Superfund sites listed on the National Priorities List (NPL) are located in or nearby the proposed construction sites.

7.15 Executive Order 11988, Floodplain Management

This EO states that federal agencies shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health, and welfare, and to restore and preserve the natural and beneficial values served by floodplains in carrying out agency responsibilities. The TSP would reduce the risk of flood loss, and minimize the impacts of floods on human safety, health, and welfare. USACE continues to conduct modeling to assess the effects of induced flooding.

7.16 Executive Order 11990, Protection of Wetlands

This EO directs all federal agencies to minimize the destruction, loss, or degradation of wetlands and preserve and enhance the natural beneficial values of wetlands in the

conduct of the agency's responsibilities. The TSP would have no direct or indirect effects to wetlands.

7.17 Executive Order 12898, Federal Actions to Address Environmental Justice

No group of people would bear a disproportionately high share of adverse environmental consequences resulting from the TSP.

7.18 Executive Order 13045, Protection of Children from Environmental and Safety Risks

No children would bear a disproportionately high share of adverse environmental consequences resulting from the proposed work and there should be no effect on children.

7.19 Executive Order 13186 Responsibilities of Federal Agencies to Protect Migratory Birds

No migratory birds or their associated habitat will be impacted.

7.20 Rivers and Harbors Act, 33 U.S.C. 401, et seq.

The TSP does not propose construction of any structure in or over navigable waters of the United States.

8 DISTRICT ENGINEER RECOMMENDATIONS

The CENAB recommends that the CSRM measures in Baltimore City, Maryland, be constructed generally in accordance with the selected plan herein, and with such modifications thereof, as per the discretion of the Director of Civil Works, may be advisable at an estimated total project cost of $138 million (October 2021 price level).

Recommendations for provision of Federal participation in the plan described in this report would require the non-federal sponsor to enter into a written Project Partnership Agreement (PPA), as required by Section 221 of Public Law 91-661, as amended, to provide local cooperation satisfactory to the Secretary of the Army. Such local cooperation shall provide, in part, the following draft items of local cooperation:

a. Provide during the periods of design and construction, a minimum of 35 percent of project costs assigned to coastal and storm damage risk reduction as further defined below:

    (1) Provide, during design, 35 percent of design costs allocated to coastal and storm damage reduction in accordance with the terms of a design agreement entered into prior to commencement of design work for the project;

    (2) Provide all lands, easements, rights-of-ways, including suitable borrow areas, and perform or assure performance of all relocations, including utility relocations, as determined by Federal government to be necessary for the initial construction, periodic nourishment or operation and maintenance of the project;

    (3) Provide, during construction, any additional amounts necessary to make its total contribution equal to 35 percent of initial project costs assigned to coastal and storm damage reduction;

b. Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) such as any new developments on project lands, easements, and rights-of-way or the addition of facilities which might reduce the outputs produced by the project, hinder operation and maintenance of the project, or interfere with the project's proper function;

c. Inform affected interests, at least yearly, of the extent of protection afforded by the flood risk management features; participate in and comply with applicable federal floodplain management and flood insurance programs; comply with

Section 402 of the Water Resources Development Act (WRDA) of 1986, as amended (33 U.S.C. 701b-12); and publicize floodplain information in the area concerned and provide this information to zoning and other regulatory agencies for their use in adopting regulations, or taking other actions, to prevent unwise future development and to ensure compatibility with protection levels provided by the flood risk management features;

d. Operate, maintain, repair, replace, and rehabilitate the completed project, or function portion of the project, at no cost to the Federal government, in a manner compatible with the project's authorized purposes and in accordance with applicable Federal and state laws and regulations and any specific directions prescribed by the Federal Government;

e. For so long as the project remains authorized, ensure continued conditions of public ownership and use of the shore upon which the amount of Federal participation is based;

f. Provide and maintain necessary access to roads, parking areas, and other public use facilities, open and available to all on equal terms;

g. At least twice annually and after storm events, perform surveillance of the project to determine losses of material from the project design section and provide the results of such surveillance to the Federal Government;

h. Give the Federal government a right to enter, at reasonable times and in a reasonable manner, upon property that the non-Federal sponsor owns or controls for access to the project for the purpose of completing, inspecting, operating, maintaining, repairing, rehabilitating, or replacing the project;

i. Hold and save the United States free from all damages arising from the initial construction, periodic nourishment, operation, maintenance, repair, replacement, and rehabilitation of the project, except for damages due to the fault or negligence of the United States or its contractors;

j. Keep, and maintain books, records, documents, and other evidence pertaining to costs and expenses incurred pursuant to the project, for a minimum of 3 years after completion of the accounting for which such books, records, documents, and other evidence and required, to the extent and in such detail as will properly reflect total cost of the project, and in accordance with the standards for financial management systems set forth in the Uniform

Administrative Requirements for Grants and Cooperative Agreements to State and local governments at 32 CFR, Section 33.20;

k. Perform, or ensure performance of, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, 42 U.S.C. 9601-9675, that may exist in, on, or under lands, easements, or rights-of-way that the Federal government determines to be necessary for the initial construction, periodic nourishment, operation and maintenance of the project;

l. Assume, as between the Federal government and the non-Federal sponsor, complete financial responsibility for all necessary cleanup and response costs of any hazardous substances regulated under CERCLA that are located in, on, or under lands, easements, or rights-of-way required for the initial construction, periodic nourishment, or operation and maintenance of the project;

m. Agree, as between the Federal government and the non-Federal sponsor, that the non-Federal sponsor shall be considered the operator of the project for the purpose of CERCLA liability, and, to the maximum extent practicable, operate, maintain, repair, replace, and rehabilitate the project in a manner that will not cause liability to arise under CERCLA;

n. Comply with Section 221 of Public Law 91-661, Flood Control Act of 1970, as amended, (42 U.S.C. 1962d-5b) and Section 101(e) of the WRDA 89, Public Law 99-662, as amended, (33 U.S.C. 2211(e)) which provide that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until the non-Federal sponsor has entered into a written agreement to furnish its required cooperation for the project or separable element;

o. Comply with the applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended, (42 U.S.C. 4601-4655) and the Uniform Regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way necessary for construction, operation, and maintenance of the project including those necessary for relocations, the borrowing of material, or the disposal of dredged or excavated material; and inform all affected persons of applicable benefits, policies, and procedures in connection with said act;

p. Comply with all applicable Federal and state laws and regulations, including, but not limited to : Section 601 of the Civil Rights Act of 1964, Public Law 88-352 (42 U.S.C. 2000d), and the Department of Defense Directive 5500.11 issues pursuant thereto; Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army"; and all applicable Federal labor standards requirements including, but not limited to, 40 U.S.C. 3141-3148 and 40 U.S.C. 3701-3708 (revising, codifying and enacting without substantive change the provisions of the Davis-Bacon Act (formerly 40 U.S.C. 276a et seq.), the Contract Work Hours and Safety Standards Act (formerly 40 U.S.C. 327 et seq.), and the Copeland Anti-Kickback Act (formerly 40 U.S.C. 276c)); and

q. Not use funds from other Federal programs, including any non-Federal contribution required as matching share therefore, to meet any of the non-Federal sponsor's obligations for the project unless the Federal agency providing the funds verifies in writing that such funds are authorized to be used to carry out the project;

The recommendations contained herein reflect the information available at this time and current departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national Civil Works construction program nor the perspective of higher review levels within the Executive Branch. Consequently, the recommendations may be modified before they are transmitted to higher authority as proposals for authorization and implementation funding. However, prior to transmittal to higher authority, the sponsor, the states, interested federal agencies, and other parties will be advised of any modifications and will be afforded an opportunity to comment further.

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9 LIST OF PREPARERS

9.1 List of Preparers

The PDT for the study included team members from the USACE (Table 9-1). The team members listed below provided substantial text to the Draft IFR/EA.

Table 9-1. List of Preparers

NAME	AFFILIATION
Joe Bieberich	Project Manager, CENAB-PPMD
Vanessa Campbell	Study Manager, CENAB-PL-P
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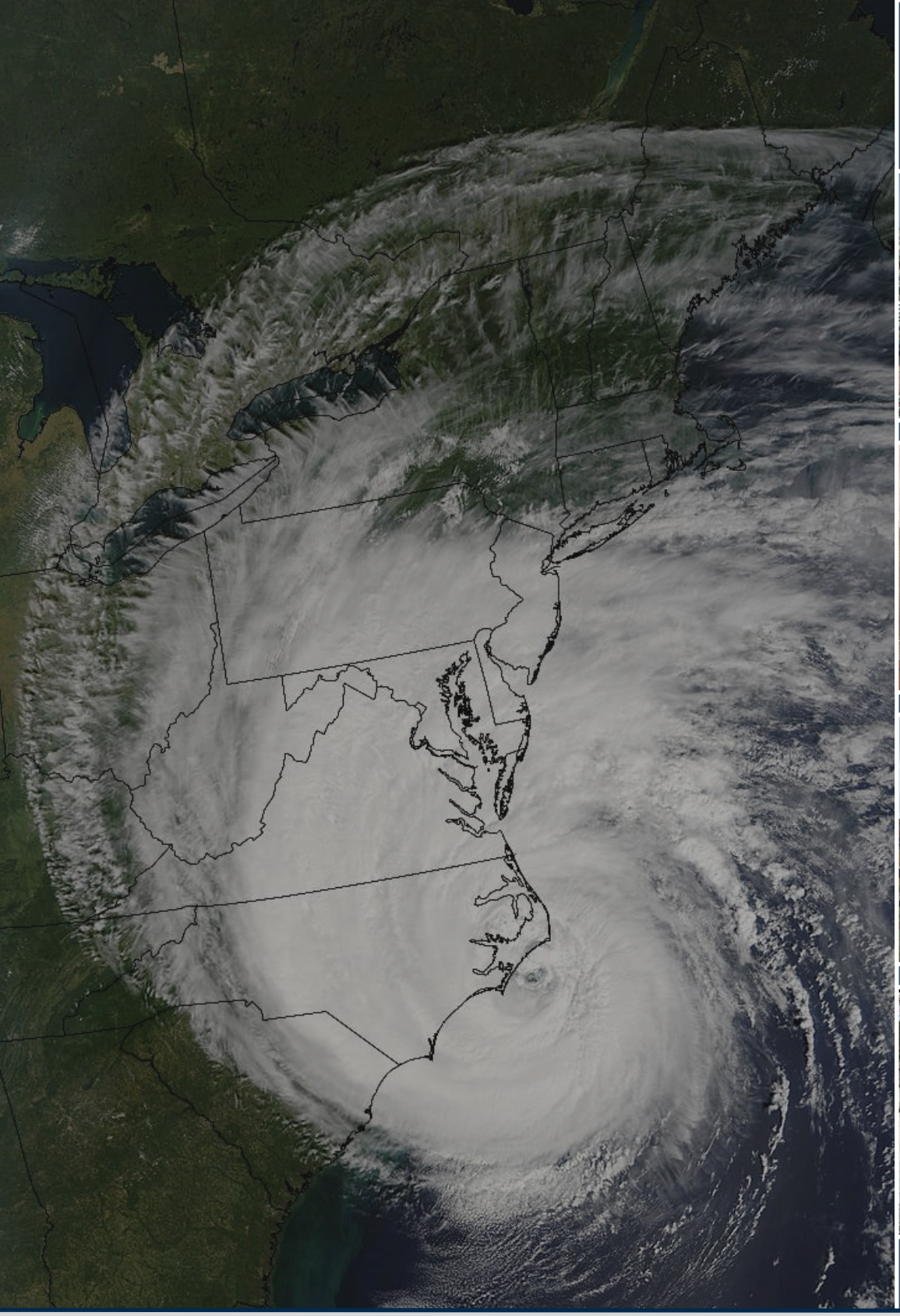

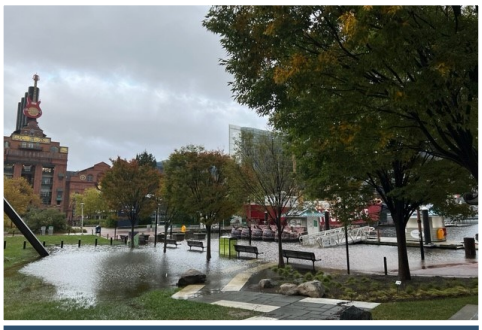

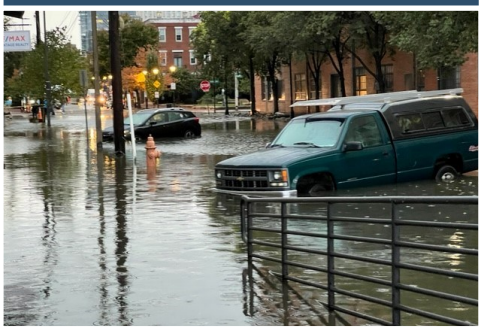

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MARYLAND DEPARTMENT OF TRANSPORTATION

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Baltimore District

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