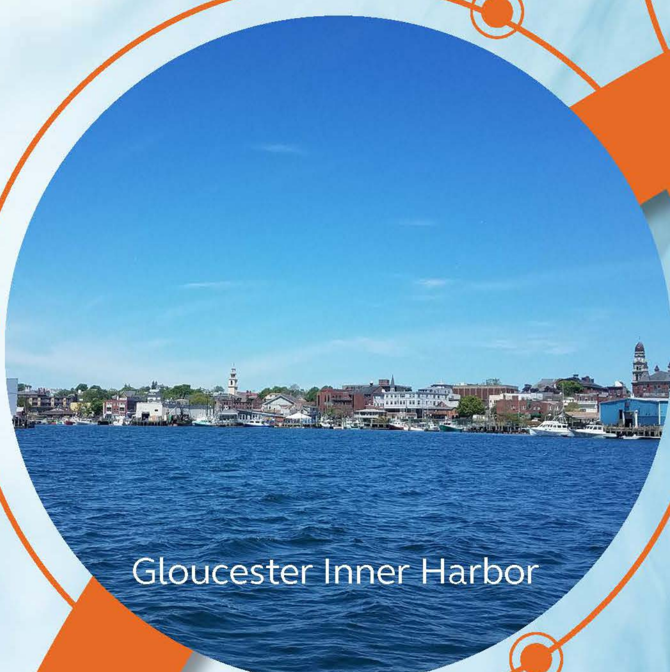
Building Resilience in Massachusetts Designated Port Areas

Resilience for Water Dependent Industrial Users in the Chelsea Creek and Gloucester Inner Harbor Designated Port Areas

June 2021



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June 30, 2021

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Acronyms and Abbreviations

BMP – Best Management Practice

CMR – Code of Massachusetts Regulations

CZM – Coastal Zone Management

DEM – Digital Elevation Model

DEP – Massachusetts Department of Environmental Protection

DFE – Design Flood Elevation

DPA – Designated Port Area

GIS – Geographic Information Systems

LiDAR - Light Detection and Ranging, a remote sensing method

MCC – Motor Control Center

MC-FRM – Massachusetts Coast Flood Risk Model

MEP – Massachusetts Environmental Police

MMHW – Mean Monthly High Water

NOAA – National Oceanic and Atmospheric Administration

RCP – Representative Concentration Pathway

RMAT – Resilient MA Action Team

SHMCAP - State Hazard Mitigation and Climate Adaptation Plan

SLR – Sea Level Rise

WDIU – Water-dependent Industrial Use

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Gloucester Harbormaster

1. Introduction and Executive Summary

Overview

Maritime port areas serve a critical function in the Massachusetts economy, supporting industries such as fishing, tourism, energy, and transportation. The growth and prosperity of many of the Commonwealth's waterfront communities is tied to waterways and the maritime industries they support. The function of a maritime port is largely dependent on locational factors, including proximity to the waterfront, access to navigable waterways and roadways, availability of appropriate waterfront infrastructure, and the presence of maritime support functions and suppliers. The unique combination of physical characteristics, land uses, systems, services, consumers, and suppliers that comprise a thriving port are not easily replicated or created and thus are worthy of protection where they exist.

The Commonwealth has established 10 Designated Port Areas (DPAs) along the Massachusetts' coast including: Gloucester Inner Harbor, Salem Harbor, Lynn, Mystic River, Chelsea Creek, East Boston, South Boston, Weymouth Fore River, New Bedford-Fairhaven, and Mount Hope Bay. DPAs support a variety of uses from commercial fishing and shipping to manufacturing and marine transportation.

The uses protected and promoted under the DPA program are integral to the vibrancy of local, state, regional, and national economies and help support the vitality and character of working waterfront communities in the Commonwealth. However, because these uses must be located on the waterfront in order to operate, they are subject to a range of coastal flood hazards. With projected sea level rise and other climate change related factors, these hazards are expected to increase in severity over the coming century, posing significant risk to working waterfronts. Further, the distinct infrastructure and functionality of water-dependent industrial uses (WDIUs) present unique resilience challenges and opportunities that require specialized technical assessment and innovative solutions.

Massachusetts Designated Port Areas (DPAs) are locations in the Commonwealth with the unique combination of features and conditions necessary to support active water dependent industrial uses (WDIUs). DPAs may be periodically reviewed by the Commonwealth s Office of Coastal Zone Management (CZM) under 301 CMR 25.00. They are regulated under the Waterways Regulation (310 CMR 9.00) by the Massachusetts Department of Environmental Protection (DEP). Massachusetts state policy aims to preserve and enhance the capacity of the DPAs to accommodate WDIUs and prevent significant impairment by non industrial or non water dependent types of development, which have a far greater range of siting options.

The goal of this study is to better enable WDIU stakeholders to understand and address coastal risks. Through stakeholder engagement and a desktop analysis, this study provides a detailed understanding of current and future flood risks facing two of Massachusetts' DPAs over the coming decades. Building on this understanding, the study provides tailored flood resilience strategies to help address flood risks while continuing to support the operational needs of WDIUs in these DPAs.

The Project Mission Statement

In coordination with other ongoing coastal resilience and sustainability initiatives in Chelsea and Gloucester, this study seeks to generate a detailed understanding of the current and future flood risks facing properties and infrastructure in Designated Port Areas. Based on this assessment, the project will examine and communicate how flood impacts can be mitigated through investment in flood resilience measures that reduce risk during flood events but provide for continued operation of facilities during dry conditions. Driven by the inclusive engagement of key stakeholders, the study aims to provide solutions that are reliable, adaptable, implementable, and cost effective, and deliver information that supports stakeholder understanding and action.

How This Report is Organized

This report documents the data, methods, and results of a vulnerability and risk assessment of two DPAs, Chelsea Creek and Gloucester Inner Harbor, and recommends coastal resilience approaches for a range of WDIU typologies found within these DPAs. This information is organized within the following sections, which are summarized below to aid readers in navigating to the content most relevant to them.

Section 1. Introduction and Executive Summary – This section provides an overview of the project's objectives, scope, process, and timeline as well as a summary of the key findings and recommendations.

Section 2. Coastal Hazards Overview – This section introduces key concepts and terms and provides a brief overview of the coastal flood hazards affecting Chelsea Creek and Gloucester Inner Harbor today and in the future.

Section 3. Water Dependent Industrial Use Types, Assets, and Vulnerabilities – This section introduces Chelsea Creek and Gloucester Inner Harbor, defines different types of WDIUs based on their site operations and functionality, and provides an overview of the asset inventory development process.

Section 4. Vulnerability and Risk Assessment – This section details the methodology and results of the vulnerability and risk assessment.

Section 5. Resilience Strategies – This section summarizes how resilience approaches were evaluated, details easy win resilience approaches for all WDIUs, and recommends resilience strategies for representative sites within Chelsea Creek and Gloucester Inner Harbor.

Project Scope and Objectives

This report provides an overview of coastal hazards impacting the Chelsea Creek and Gloucester Inner Harbor DPAs today and in the future; an assessment of existing conditions, including operational and infrastructural needs; the findings of the stakeholder engagement process; results of the coastal flood risk and vulnerability assessment; and near- and long-term resilience strategies to help inform preliminary discussions about flood risk mitigation for marine industrial uses and infrastructure.

Though many of the findings and recommendations in this report are relevant to all of Massachusetts' DPAs, this initial study focuses on Chelsea Creek and Gloucester Inner Harbor and makes resilience strategy recommendations tailored to the unique operational needs and risks of WDIUs in these areas. These two DPAs were selected for initial study because the WDIUs located within them are generally representative of the range of WDIUs found across the Commonwealth and thus offer the opportunity to develop recommendations that are most applicable to WDIUs outside of these areas. It is anticipated that subsequent studies led by CZM will build on this project to examine coastal resilience issues for the other eight DPAs in Massachusetts.

Process and Timeline

The Building Resilience in Massachusetts' Designated Port Areas planning process began in November 2020 and included five key steps as shown in Figure 1. The process included identifying important DPA assets and functions, assessing vulnerability to current and future flooding, identifying actions to reduce flood risk, and evaluating these options. As a result of this process, resilience strategy recommendations for eight key WDIU sites in the Chelsea Creek and Gloucester Inner Harbor DPA were developed.

Engagement with municipal officials in host communities, WDIU property owners, and property users or tenants was integral to the process, from data gathering to the ultimate development of resilience strategies. In addition to the qualitative information collected from stakeholders, this study leveraged a desktop analysis of coastal flood vulnerability and risk based on best available flood hazard data. Using stakeholder feedback and the results of the vulnerability and risk assessment, feasible resilience strategies and best practices were developed, as detailed in **Section 5. Resilience Strategies**.

Figure 1 – Summary of the project process and timeline

Resilient MA Action Team (RMAT) Climate Resilience Design Standards and Guidelines (Draft)

RMAT is a State inter-agency team comprised of representatives from each Secretariat, or State Executive Office. The RMAT is tasked with monitoring and tracking the State Hazard Mitigation and Climate Adaptation Plan (SHMCAP) implementation process, making recommendations to and supporting agencies on plan updates, and facilitating coordination across State government and with stakeholders, including cities, towns, and businesses. *To the extent feasible, the methods and data used in this study are consistent with the draft RMAT process and recommended climate parameters.*

One of the key RMAT initiatives is the creation of Climate Resilience Design Standards and Guidelines.[1] The draft Climate Resilience Design Standards outline a process for establishing a consistent basis-of-design across various projects in the Commonwealth for climate parameters: SLR and storm surge, extreme precipitation, and extreme heat. The process uses an assessment of asset type, useful life, and criticality to provide recommended planning horizon, return period or confidence interval, design criteria, and tiered methodology for calculating design criteria values, including design flood elevations. For coastal flooding and SLR, the standards reference the Massachusetts Coast Flood Risk Model (MC-FRM) that is currently being developed by MassDOT. The MC-FRM is a probabilistic hydrodynamic model that uses the values for SLR adopted by the Commonwealth of Massachusetts (Representative Concentration Pathway (RCP) 8.5 scenario). MC-FRM is used in this study and discussed in greater detail in **Section 2. Coastal Hazards Overview**.

Figure 2 – View of the Chelsea Creek DPA facing northeast

[1] The Commonwealth of Massachusetts released draft Climate Resilience Design Standards and Guidelines developed by the Resilient MA Action Team in Summer 2021. These draft Guidelines are referenced in this this study but should be superseded by final RMAT guidance when available.

Key Findings and Recommendations of this Study

Increasing risks from climate change, especially flooding, pose a significant threat to the long-term health and viability of DPAs. This study finds that nearly all infrastructure within the Chelsea Creek and Gloucester Inner Harbor DPAs is exposed to flooding today and the risks associated with flooding will only increase with projected sea level rise. WDIU stakeholders should take action today to reduce their flood risk by implementing a series of easy win approaches recommended on the following pages and begin developing a comprehensive longer-term resilience strategy for their facilities.

The key findings of this report are summarized below.

1. **DPAs are currently exposed to coastal hazards including storm surge and tidal flooding**
The two primary long-term flood risks facing Chelsea Creek and Gloucester Inner Harbor DPAs are coastal flooding due to storm surge and high tides. Though many WDIUs within these DPAs may not have recently experienced flooding, the best available flood models indicate that they are at risk. Today, 91% percent of WDIU buildings within the Gloucester Inner Harbor DPA are exposed to storm surge due to the 1% annual chance flood.[2] In Chelsea Creek, all (100%) WDIU buildings within the DPA are currently exposed to the 1% annual chance flood. Current exposure to high tide flooding is more limited, with 52% of WDIU buildings in Gloucester and no WDIU buildings in Chelsea currently exposed. High tide flooding is likely to be a widespread issue for buildings in Gloucester Inner Harbor in the near-term.

2. **DPAs will be increasingly exposed to coastal hazards in the coming decades with sea level rise.**
With projected sea level rise and other climate change related factors, coastal flood hazards are expected to increase in severity over the coming century, posing significant risk to working waterfronts like those within DPAs (Figure 3). By 2050, 100% of WDIU buildings within both Chelsea Creek and Gloucester Inner Harbor will be exposed to storm surge during a 1% annual chance flood. Exposure to high tide flooding is also expected to increase, with 88% of WDIU buildings in Gloucester and 90% in Chelsea likely to be exposed. Though the 1% annual chance flood is more severe, high tide flooding is expected to become more frequent over time. While this flooding may at first only present nuisance-level issues for WDIUs, over time the flooding will become more frequent and more disruptive to WDIU operations and the services that support continuity of operations.

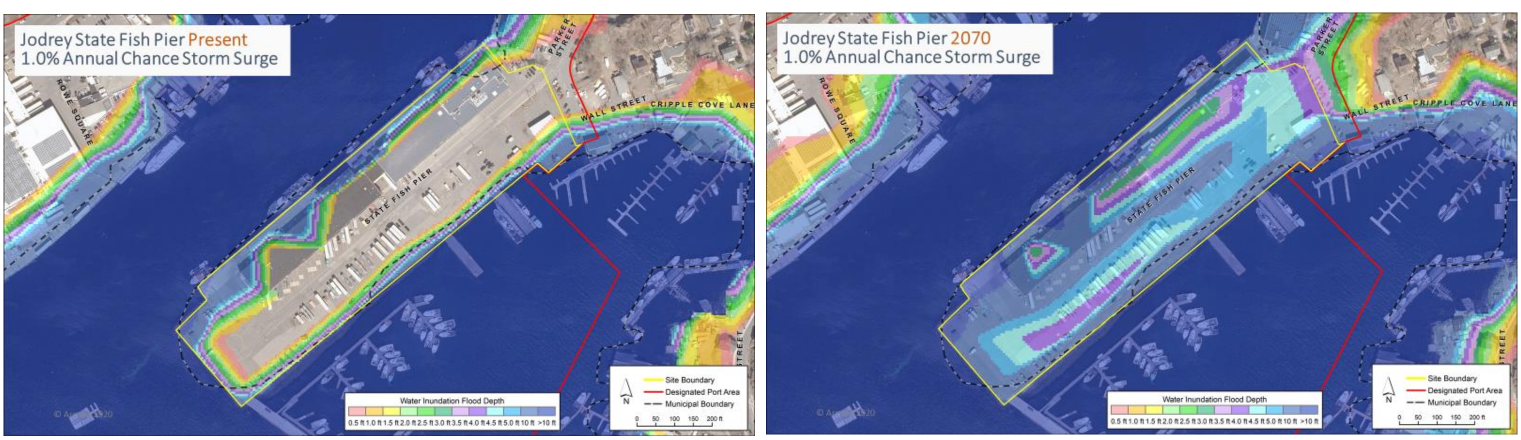

Figure 3 – Present day storm surge flooding at Jodrey State Fish Pier (left) and projected 2070 storm surge flooding (right)

[2] The 1% annual chance storm is representative of a flood that has a 1% chance of occurring in any given year. The 1% annual chance storm is often used as an event of reference when determining the extent of storm surge flooding.

3. **WDIUs can take low-cost, easy-to-implement actions today to reduce their flood risk.**
   Critical infrastructure that supports WDIUs in DPAs is exposed to flooding today. As sea levels rise over time, coastal flooding will pose an increasing risk to the infrastructure and operations of WDIUs. Given the imminent threat of coastal flooding, WDIU property owners, users, and tenants should act now to build their resilience.

   Resilience refers to the ability of communities and systems to withstand, recover from, and adapt to shocks and stresses. Creating a climate resilient DPA requires intentional, proactive action on the part of relevant stakeholders to put in place systems, capacities, and redundancies that reduce risk and transform with evolving conditions over time. The resilience building process helps industrial waterfronts turn climate challenges into opportunities for growth and change that can benefit WDIUs in multiple ways.

   This study recommends a series of easy win resilience approaches that can be implemented by WDIUs to start building resilience to coastal flooding today. These strategies can be implemented within a year, are relatively low cost, and require minimal expert guidance. In many cases, these easy win approaches serve as a necessary foundation for more time- and capital-intensive resilience measures such as elevation and floodproofing of assets. Easy win resilience approaches are explained in greater detail in **Section 5. Resilience Strategies**. These approaches include:
   - Increasing Risk Awareness
   - Developing a Flood Preparedness Plan for Your Business
   - Relocating or Elevating Moveable Assets
   - Purchasing and Maintaining Flood Insurance

4. **WDIUs can continue building resilience over the long-term through comprehensive resilience strategies tailored to the specific performance criteria of the business.**
   A resilience strategy is a logical combination of resilience approaches that can help WDIUs adapt to increasing risk and build the resilience of the business over time. After implementing easy win approaches, WDIUs should prioritize reducing risk for high criticality assets, or those that are necessary to maintain core mission services or life safety. This can be accomplished in a variety of ways, depending on the infrastructural and operational needs of the site. **Section 5. Resilience Strategies** explains recommended resilience strategies for representative sites in each DPA, including key considerations such as:
   - The appropriate timeline for implementation
   - The appropriate scale of implementation
   - Whether the approaches within the strategy complement or build on each other
   - Limitations on the useful life of proposed approaches
   - Potential for integrating the approaches into planned capital improvements

In addition to reading this report, WDIUs interested in learning more about building resilience can:

- Stay up to date on Massachusetts resilience news and resources! Learn more about the Resilient MA Action Team (RMAT) and explore their resources here.
- Get in touch with your Massachusetts CZM Regional Coordinator to take the next steps to build resilience at your site.
- Speak with a licensed professional about implementing resilience strategies like those included in this report
- Work with your municipal officials and coordinate efforts with other stakeholders where feasible.

2. Coastal Hazards Overview

By virtue of their necessary location on the waterfront, DPAs and the variety of uses they support – from commercial fishing and shipping to manufacturing and marine transportation are exposed to coastal flood hazards. Though DPAs may also be exposed to other hazards and climate-related risks, this study exclusively considers coastal flood hazards. Specifically, the extent of coastal flooding due to storm surge and high tides. Both Chelsea Creek and Gloucester Inner Harbor DPAs are exposed to these hazards today. Projected sea level rise will increase the risk that these hazards pose to WDIUs over the next 50 years.

Though many WDIUs within the Chelsea Creek and Gloucester Inner Harbor DPAs may not have experienced flooding in recent years, that does not mean they will not flood in the future. With coastal flood risks increasing, it is important that WDIUs take steps today to proactively mitigate, or reduce, these threats to their critical infrastructure and operations.

This section provides a brief overview of the coastal flood hazards affecting Chelsea Creek and Gloucester Inner Harbor today and in the future. A brief overview of expected changes in precipitation is also presented as it relates to coastal flooding and the need for stormwater management. A full description of the risk and vulnerability assessment methodology and detailed results for the Chelsea Creek and Gloucester Inner Harbor DPAs can be found in **Section 4. Vulnerability and Risk Assessment**.

Understanding Exposure, Vulnerability, Risk, and Criticality

In order to make informed decisions to mitigate risk and build resilience in DPAs, it is important to understand the effects of coastal flooding in these areas. The concepts introduced here are used throughout this report to help define coastal risks for Chelsea Creek and Gloucester Inner Harbor, as discussed in **Section 4. Vulnerability and Risk Assessment**. The definitions provided are consistent with those used by RMAT and within the Massachusetts State Hazard Mitigation & Climate Adaptation Plan.

Natural Hazard – Natural hazards are natural events that threaten lives, property, and other assets. Often, natural hazards can be predicted. They tend to occur repeatedly in the same geographical locations because they are related to weather patterns or physical characteristics of an area. Coastal flooding is a natural hazard.

Exposure – The extent to which something is in direct contact with natural hazards or their related climate change impacts. Exposure is often determined by examining the number of people or assets that lie within a geographic area affected by a natural hazard, or by determining the magnitude of the climate change impact. For example, the number of times a particular intersection has flooded, or the number of heat waves experienced by a county are measurements of exposure.

Vulnerability – The propensity or predisposition to be adversely affected; for example, as applied to building performance (functionality), damage, or the number of people injured. Vulnerability is a function of exposure, sensitivity, and adaptive capacity.

Risk – The potential for an unwanted outcome resulting from a hazard event, as determined by its likelihood and associated consequences; and expressed, when possible, in dollar losses. Risk represents potential future losses, based on assessments of probability, severity, and vulnerability. For example, if a state highway is flooded that also serves as an evacuation route, it will have a high probability of flooding and its consequence of flooding (as measured by its severity, with respect to geographic area and people affected, economic impacts and cascading impacts to other infrastructure) will also be high, which would lead to a high risk rating.

Criticality – the importance of an asset to public safety and infrastructure systems is its criticality. Assets are considered more critical if their functioning is necessary to maintain core mission services or life safety, such as police, fire, emergency medical, or systems such as power, communication, transportation, water, and waste. Criticality can be helpful in prioritizing assets for flood mitigation.

Resilience – Resilience refers to the ability of communities and systems to withstand, recover from, and adapt to shocks and stresses. Creating a climate resilient DPA requires intentional, proactive action on the part of relevant stakeholders to put in place systems, capacities, and redundancies that reduce risk and are able to transform with evolving conditions over time. The resilience building process can help industrial waterfronts turn climate challenges into opportunities for growth and change that benefit WDIUs in multiple ways.

Figure 4 – View of existing revetment along Chelsea Creek at 229 Marginal Street in Chelsea

Coastal Flooding

Coastal flooding is defined as the submergence of low-lying land by seawater – often as a result of storm surge or high tides. Coastal flooding can occur via multiple pathways, including direct flooding and/or overtopping or breaching of an existing barrier, such as a bulkhead. Climate change, with its associated rise in sea levels, as well as the possibility for an increase in the frequency and/or the intensity of storms and changes in wave climate, can be expected to increase the risks of coastal flooding in most coastal locations, including Chelsea Creek and Gloucester Inner Harbor.[3] This study will consider the risk to DPAs posed by three coastal hazards: storm surge, high tide flooding, and heavy precipitation, as summarized in Figure 5.

[3] Robert J Nicholls and Richard S.J Tol, 2006. Impacts and responses to sea-level rise: a global analysis of the SRES scenarios over the twenty-first century. Accessed February 1, 2021. https://royalsocietypublishing.org/doi/full/10.1098/rsta.2006.1754

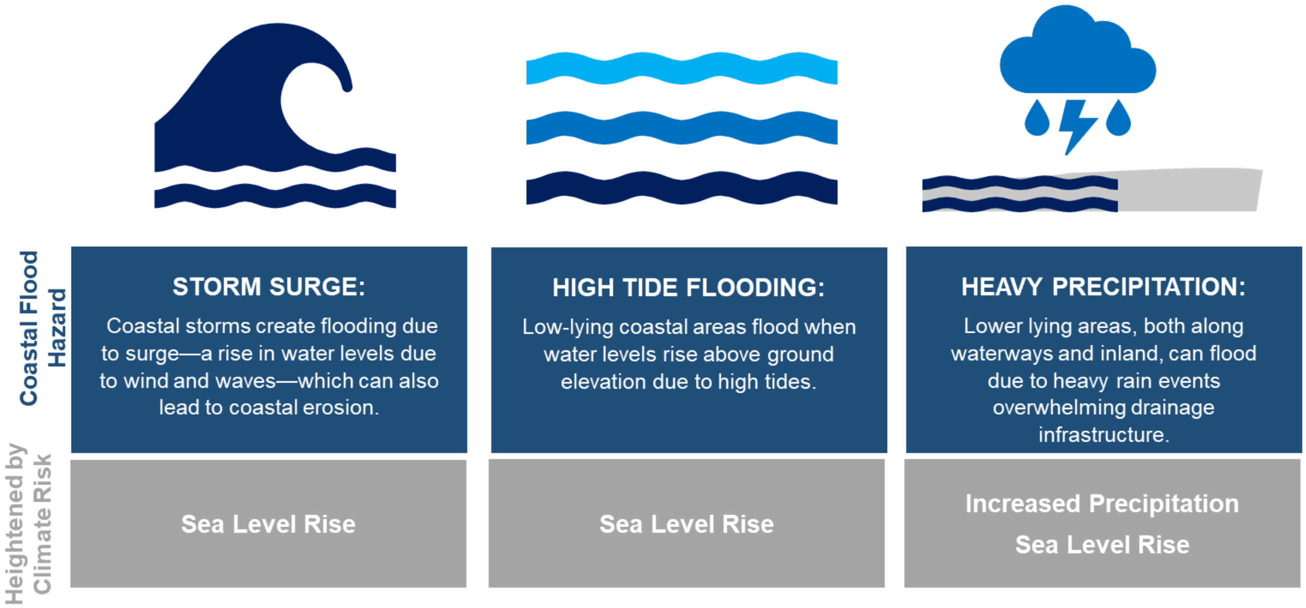

Figure 5 – Summary of the three primary coastal hazards affecting Chelsea Creek and Gloucester Inner Harbor DPAs

Storm Surge

When a storm approaches the coast, strong winds and low-pressure push water towards land and cause a rise in the water level. This is called storm surge. Storm surge can cause major coastal flooding. While coastal flooding resulting from storm surge occurs less frequently than high tide flooding, it can result in far more significant damage and disruption to homes, businesses, infrastructure, and ecosystems. Waves associated with storms can severely damage buildings and infrastructure located along the coast, including the mission critical assets of DPAs. Waves and the associated currents also erode shorelines, which can undermine building foundations and destroy roads and other forms of infrastructure. Storm surge creates deeper water, and when water is deeper, waves can be larger and travel further inland. Together, storm surge and SLR lead to deeper water and more favorable conditions for larger, more damaging waves.

The Commonwealth of Massachusetts is in the process of producing a statewide coastal flood risk model drawing on robust numerical modeling across a range of storm and future climate conditions. These data will be recommended as best available for coastal areas of Massachusetts and are used in this study to evaluate exposure to coastal flooding as described in **Section 4. Vulnerability and Risk Assessment**.

High Tide Flooding

High tide flooding, often referred to as “nuisance” flooding or tidal flooding, is defined by the National Oceanic and Atmospheric Administration (NOAA) as flooding that leads to public inconveniences, such as road closures, overwhelmed storm drains, and deterioration of public infrastructure (e.g., roads).[4] This type of flooding is

[4] National Oceanic and Atmospheric Administration (NOAA) Website. Accessed February 1, 2021. https://oceanservice.noaa.gov/facts/high-tide-flooding.html

becoming increasingly common as sea levels rise and land subsides[5] in coastal communities, resulting in a greater likelihood that high tide will overtop existing bulkheads and coastal protection measures and flood inland areas. According to NOAA, high tide flooding has increased across the U.S. by approximately 50 percent over the last 20 years and 100 percent when compared to 30 years ago. As sea levels continue to rise, high tide flooding will become an increasingly common occurrence.

Unlike flooding from storms, tidal flooding occurs regularly due to predictable fluctuations in the tide on a daily, monthly, and annual basis. For WDIUs, tidal flooding poses a number of critical challenges because the frequency of expected flooding is far greater than flooding associated with coastal storm events. While the risk of structural damage from tidal flooding is generally low, frequent tidal flooding on even a monthly basis can be highly disruptive to normal operations, leading to business interruption, loss of service for critical infrastructure, and increased wear and tear on systems that support business continuity.

Precipitation

Precipitation is an important consideration when assessing impacts from coastal flooding and SLR. Climate change projections for the Commonwealth of Massachusetts indicate that precipitation (including both rainfall and snowfall) patterns are changing, and more significant changes in the amount, frequency, and timing of precipitation are anticipated in future years. The northeastern United States has experienced the most dramatic increases in precipitation intensity.[6] Increases in total rainfall can impact the frequency of flooding events, especially in areas where stormwater and drainage infrastructure has not been adequately designed to manage the increased flows. In addition to chronic flooding in low lying areas due to high tides, SLR will also impact the ability of the stormwater system to provide adequate drainage as outfall pipes will be submerged more frequently, causing drains to surcharge during heavy rainfall events. This is problematic when stormwater flows onto streets, impacting vehicular traffic and emergency vehicles, as well as onto properties, resulting in property damage.

In developing flood resilience strategies for DPAs, change in precipitation is a key consideration. However, a detailed vulnerability and risk assessment of precipitation hazards is beyond the scope of this study. Where appropriate precipitation related considerations, such as stormwater management best management practices, are incorporated into the resilience strategies recommended in **Section 5. Resilience Strategies**.

[5] Subsidence refers to the gradual settling or sinking of the ground due to underground material movement (NOAA)

[6] Massachusetts Climate Change Projections, Northeast Climate Science Center at University of Massachusetts Amherst. Accessed February 1, 2021. https://nescaum-dataservices-assets.s3.amazonaws.com/resources/production/MA%20Statewide%20and%20MajorBasins%20Climate%20Projections_Guidebook%20Supplement_March2018.pdf

3. Water Dependent Industrial Use Types, Assets, and Vulnerabilities

Overview of Maritime Ports

Maritime port areas serve a critical function in the Massachusetts economy, supporting industries such as fishing, tourism, energy, and transportation. The growth and prosperity of many of the Commonwealth's waterfront communities is tied to waterways and the maritime industries they support. While the prominence of these industries has evolved over time as the economy diversified, port areas remain vital to the health and wellbeing of communities across Massachusetts and the region.

The function of a maritime port is largely dependent on locational factors, including proximity to the waterfront, access to navigable waterways and roadways, availability of appropriate waterfront infrastructure, and the presence of maritime support functions and suppliers. The unique combination of physical characteristics, land uses, systems, services, consumers, and suppliers that comprise a thriving port are not easily replicated or created and are worthy of protection where they exist. The challenge is that port areas face numerous threats to their long-term health and viability, including economic shifts, development pressure, and, as explored in this study, increasing risks from climate change, especially flooding.

Reducing the risk of flooding in port areas presents a number of challenges related to the specific needs and functions of water dependent industries. In many cases, the suite of flood risk mitigation and resilience tools that may be effective for other types of uses will not meet the physical and operational needs of water dependent industrial uses. Additionally, operators of these uses are often focused on the near-term needs of their business with little spare time and limited resources to fully evaluate and explore flood risks and the ways these risks might be addressed.

The goal of this study is to better enable WDIUs to understand and address risk by developing a set of actionable steps toward being resilient. To do this, it is necessary to understand the specific performance criteria that must be met for each type of water dependent industry and define flood risk mitigation and resilience approaches that reduce risk to tolerable levels while still enabling critical site functions. It also necessitates understanding port areas as systems that rely on a combination of function, support services, and infrastructure located in close proximity to one another. Loss of service due to flooding for one component of this system can have cascading impacts on other parts of the system. The resilience of the system is highly dependent on the resilience of individual sites and vice versa.

This study examines the question of flood resilience for port areas at both the site and system scale in order to both highlight vulnerabilities at these scales and to develop actionable approaches that water dependent industrial users, owned by both private and public entities, can take to reduce risks from flooding. The flood resilience approaches recommended by this study are tailored to the specific challenges that climate change and sea level rise pose to WDIUs along Chelsea Creek and in Gloucester Inner Harbor and are intended to help property users and operators take immediate action to protect their businesses and begin the process of adapting to these challenges.

DPAs in Massachusetts

Although Massachusetts has ten DPAs, shown in Figure 7, this initial study focuses solely on the current and future coastal flood risk of the Chelsea Creek and Gloucester Inner Harbor DPAs. In order to evaluate flood risk, a comprehensive understanding of the range of WDIU types located in each DPA is necessary, along with an evaluation of the mission critical assets, facilities, and functions exposed to flooding on each site. This section provides an overview of each DPA, including potentially vulnerable WDIUs and their assets, facilities, and functions. This background information is then used to categorize WDIUs into typologies based on their site operations and functionality. Note that not every water dependent user type is considered by this study. WDIU typologies representative of sites found at DPAs throughout the state were considered in this analysis subject to stakeholder participation. An asset inventory was then conducted for eight representative WDIU sites. In **Section 4. Vulnerability and Risk Assessment**, the vulnerability and risk of assets at each representative site are evaluated, and in **Section 5. Resilience Strategies**, strategies are provided for the representative sites**.**

Figure 6 – View of Gloucester Inner Harbor looking south from Gordon Thomas Park

Figure 7 – Designated Port Areas in Massachusetts

Chelsea Creek Designated Port Area

The Chelsea Creek DPA acts as an essential economic provider for the Greater Boston Metro Area and greater New England as it maintains a space for a high concentration of WDIUs to operate. The DPA, shown in Figure 9, is located along Chelsea Creek and is comprised of approximately 297 acres of land in the Cities of Boston, Chelsea, and Revere.[7] The DPA is adjacent to two other DPAs: the East Boston DPA and the Mystic River DPA. The waters' edge consists of coastal banks or beaches, riprap slopes, and bulkheads.

The water-dependent uses on the Creek play a significant regional role in the transportation and storage of petroleum, home heating oil, gasoline, and jet fuel used at Logan Airport. Chelsea Creek DPA is a suitable location for these energy resources due to its close proximity to populated areas and well-established waterfront delivery and distribution systems. In addition to liquid bulk petroleum product imports and distribution, the DPA also provides road salt to approximately 350 public safety organizations in Massachusetts. Eastern Minerals is responsible for salt importing and distribution at the dry bulk terminal it operates and maintains in the DPA. Impacts to the distribution of energy and salt resources within the Chelsea Creek DPA could severely impact the livelihood of the community and the New England economy.

Figure 8 – View of oil terminal in Chelsea Creek DPA

There are portions of the DPA that are currently underutilized and DPA boundary reviews have been conducted as recently as 2015. Two large parcels on the Chelsea side of the DPA provide for parking related uses which is

[7] Boston's Working Port: A Foundation for Innovation. Accessed April 7, 2021. https://www.bostonharbornow.org/wp-content/uploads/2017/12/FOR-RELEASE-Bostons-Working-Port-A-Foundation-for-Innovation-v1-24.pdf

allowed on a temporary basis within DPAs. The non-water dependent uses are intended to be compatible with the overall functionality of the Chelsea Creek DPA.

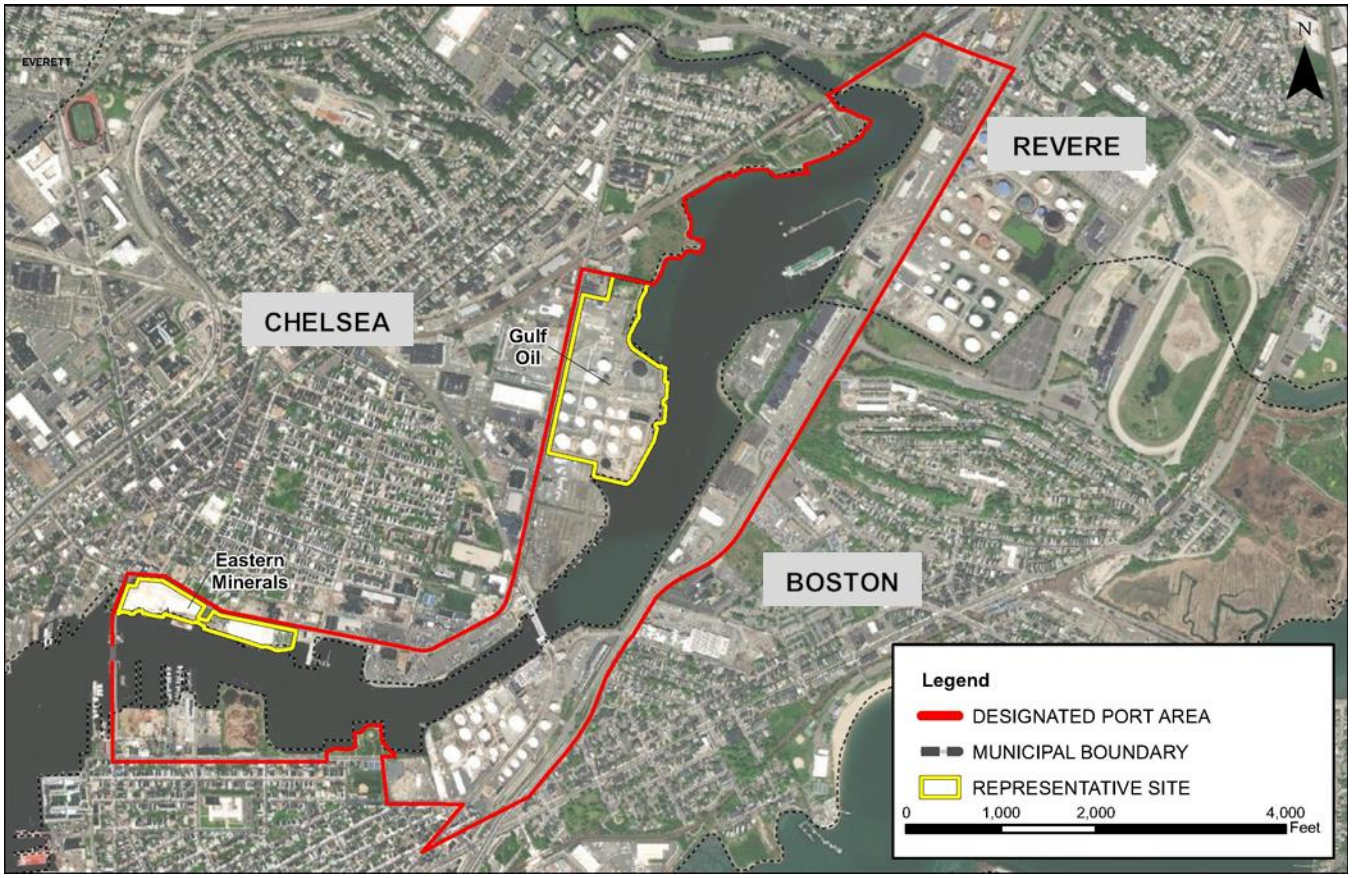

Figure 9 – Chelsea Creek DPA and Representative Sites

Gloucester Inner Harbor Designated Port Area

The Gloucester Inner Harbor DPA, shown in Figure 10, is comprised of water dependent industries of varying sizes. During the 2014 boundary review for the DPA, the following geographic areas were determined to remain in the DPA: Harbor Cove, North Channel, State Fish Pier, Cold Storage East Gloucester, and Rocky Neck. Harbor Cove consists of the land area from Cape Pond Ice on Commercial Street to the U.S. Coast Guard station on Harbor Loop. This area is the oldest portion of the harbor and contains relatively small businesses that primarily support the commercial fishing fleet and utilize the few remaining historic piers.

The majority of the waterfront is used to provide berthing and essential services to vessels, primarily the city’s fishing fleet. Operating on these piers helps retain some of the traditional and historic character of Gloucester Inner Harbor. The North Channel area within the DPA runs from the Harbormaster building on Harbor Loop to Gordon Thomas Park at the head of the North Channel. North Channel includes properties of Americold’s two key

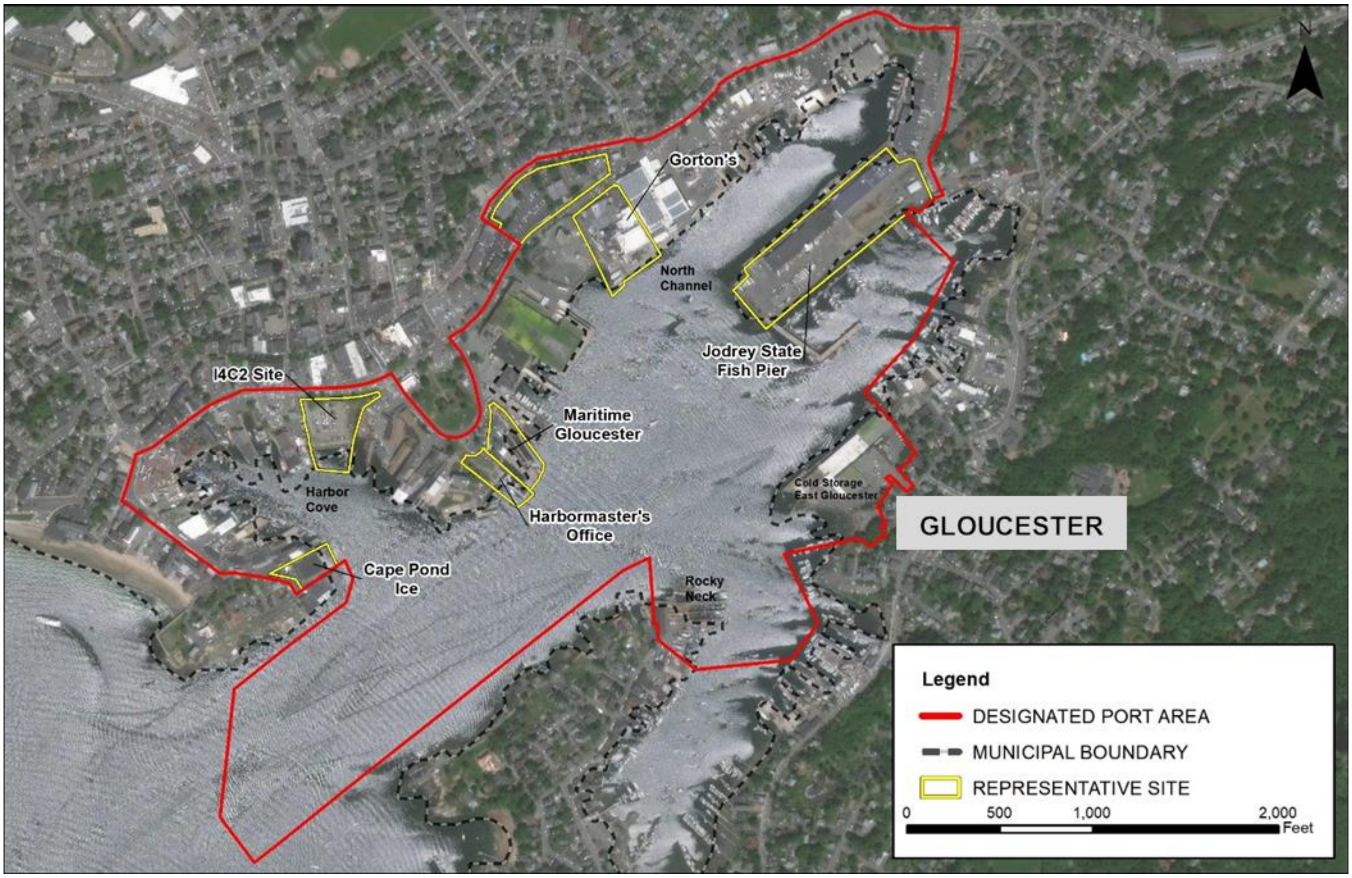

Figure 10 – Gloucester Inner Harbor DPA and Representative Sites

cold storage facilities, several fish and seafood processing facilities including Gorton's, and the Cape Ann Seafood Exchange, the Harbormaster offices, and Maritime Gloucester's marine railway.

Adjacent to the North Channel is the State Fish Pier area, which is located at the head of the harbor and operates as a multi-use pier. The Jodrey State Fish Pier, maintained by MassDevelopment, supports the commercial fishing industry, houses the CZM regional office, and provides berthing for Coast Guard and Massachusetts Environmental Police. This geographic area also includes the land area along Parker Street which until recently housed processing facilities for National Fish and Seafood, as well as office space and parking for the facilities. Cold Storage East Gloucester is comprised of the four-and-a-half-acre peninsula that includes the cold storage facility property of Americold. The property is currently used by multiple fish processing companies in the Gloucester DPA for both storage and processing of fish. Finally, the Rocky Neck area is within the DPA and includes the Gloucester Marine Railways and berthing for commercial vessels. This area is primarily responsible for the repair and maintenance of larger vessels.[8]

[8] Boundary Review of the Gloucester Inner Harbor Designated Port Area, Gloucester MA. Accessed April 7, 2021. http://gloucester-ma.gov/DocumentCenter/View/2724/Gloucester-Inner-Harbor-DPA-Boundary-Designation-Report_2_3_14?bidId=

Overview of WDIU Types

Chelsea Creek and Gloucester Inner Harbor both support a variety of water-dependent industrial users and uses. To better understand how flooding may impact different use types with different infrastructural and operational requirements, this study categorizes WDIUs into typologies based on their site operations and functionality within the Chelsea Creek and Gloucester Inner Harbor DPAs. This study does not consider every water dependent user type. The project team engaged key property owners of sites representative of those found within DPAs throughout the state. The representative sites considered in this study are shown in Figure 9 and Figure 10 above. Tables 1 and 2 define the WDIU typologies determined for each representative site.

Table 1 – Overview of typologies for representative sites in Chelsea Creek DPA

Chelsea Creek WDIU Typologies	Defining Features and Functions	Representative Site
Dry bulk terminal	• Operates as handling and/or storage location for non-containerized dry bulk cargo • Dry bulk cargo includes materials such as salt, cement, metal, fly ash, alumina, and dry food products • Operations at the terminal require access to waterfront for loading, unloading, and handling of cargo from ships or barges • Equipment including cranes and conveyor belts is needed to unload cargo to storage areas	Eastern Minerals
Liquid bulk terminal	• Operates as a storage depot for oil, gasoline, and other bulk liquid products • Berthing systems and a series of pipelines allow for the distribution of products from the oil tank or ship to storage tanks • Access via roadway, railway, or waterway to the site for distribution services is crucial in order for products to be delivered to surrounding agencies and municipalities	Gulf Oil

Table 2 – Overview of typologies for representative sites in Gloucester Inner Harbor DPA

Gloucester Inner Harbor WDIU Typologies	Defining Features and Functions	Representative Site
Fish/seafood processing facility and cold storage	• Fish and seafood, primarily from local sources, are delivered to the facility via boat or trucks for processing before being delivered to customers • Waterfront access may be required for fish and marine product supply to facility • Electrical supply and mechanical equipment operations are needed for essential refrigeration and production processes	Gorton's
Marine railway and boat repair	• Operates to haul ships out of the water for repair • Waterfront access required for vessel access from the water via the railway	Maritime Gloucester
Multi-use pier	• Warehouses for fish and lobster processing and distribution • Electrical supply and mechanical equipment operations are needed for essential refrigeration and production processes • Waterfront access required for material supply and product handling and distribution • Access via roadway to the site for distribution services is crucial in order for product to be delivered to customers • Dockage for commercial and maritime safety vessels	Jodrey State Fish Pier
Ice supply facility/Marine supply	• Electrical supply and mechanical equipment operations are needed for essential refrigeration and ice production processes • Waterfront access required for ice distribution to boats	Cape Pond Ice
Marine support and safety	• Access to safety vessels along the waterfront is essential for maintaining safety within the harbor and correct operations of port facilities • Electrical supply and protection of communication equipment is critical for maintaining operations	Harbormaster's Office
Vacant site	• This site may be developed in the future for additional WDIU. Currently there is commercial dockage storage, parking, commercial dockage access, and a shoreline protective structure on the site. Resilience strategies have been recommended to guide any future development on the property.	I4C2 Site

Asset Inventory and Property Card Development

For each of the eight WDIU site types identified, the project team worked with stakeholders, including municipal officials in host communities, WDIU property owners, and property users or tenants, to identify critical assets and functions at each site. Property cards were developed for the eight representative sites as shown in Table 2 above. The property cards for each representative site can be found in Appendix A. Each property card includes a site map and details the assets on each site, critical elevations, asset criticality, loss of service consequences, flood type and flood exposure for each asset, and resilience strategy recommendations. Resilience strategies were recommended for each identified asset, regardless of the criticality ranking or decade of likely flood exposure. With all assets being located along the waterfront, it is important to understand that all of the assets are vulnerable to flooding to varying extents. The property cards also include information required for project inputs within the RMAT beta Climate Resilience Design Standards tool. The following section describes key elements of the property cards in greater detail.

Asset or System Type – Asset or system type was assigned based on the asset's primary category of use. Asset or system categories included: equipment, shoreline, utility, shipping/receiving, vehicular site access, and finished first floor.

Critical Elevation – Asset's existing elevation, in feet, was calculated using a Digital Elevation Model (DEM) based on the minimum, or lowest, elevation within the asset's footprint.[9]

Ranking Criticality – Assets were included in this analysis if they were considered integral to the continuity of operations on the site. Assets were further ranked in terms of high, medium, or low criticality. Assets were considered highly critical if their functioning is necessary to maintain core mission services or life safety, such as police, fire, emergency medical, or systems such as power, communication, transportation, water, and waste. An asset received a medium criticality ranking if it can be inaccessible and/or inoperable during a flooding event but must be restored immediately following a storm event for full capacity site operations to be maintained. An asset received a low criticality ranking if it does not contribute to essential operations on site, the impact of flooding is limited solely to its location, and/or flooding results in no impacts to human life or the environment. Ranking criticality for assets were refined with input from property and business owners based on operations and priorities on the site. This approach is consistent with the assessment of criticality detailed in the RMAT Climate Resilience Design Standards & Guidelines.

Loss of Service Consequences – If an asset were flooded, the loss of service consequences detail the potential impacts to the individual site and its functionality within the larger port system. Different WDIU site typologies have different loss of service consequences. At the scale of a specific site, loss of service to a specific utility system, like power, could have the consequence of reduced functionality for the facility if backup power is not available. This can then have cascading impacts for the consumers and end users. For instance, loss of service at a dry bulk terminal providing salt supply for winter road treatment could result in a public safety hazard with salt not being distributed prior to or during a winter storm, while loss of service at a fish processing facility may result in fish product shortages at a local or regional level.

[9] Elevation data used for this study is based on Light Detection and Ranging (LiDAR) terrain data derived from the project named "2013-2014 Sandy" conducted in the Fall of 2013 to Spring 2014. This project uses the horizontal datum North American Datum of 1983 (NAD83) and the vertical datum North American Vertical Datum of 1988 (NAVD88).

Flood Exposure– The following section details the vulnerability and risk assessment and describes how the project team determined flood exposure for each site and asset. This assessment considers whether or not an asset is exposed to flooding during different time periods. More detailed analyses are required to assess the depth of flooding that may be expected at each site.

Flood Type – Flood type was classified as either fringe, flood pathway, or no exposure. Fringe flooding indicates that waterfront properties and assets are exposed. Pathway flooding indicates that the waterfront property and asset is exposed and is located in a pathway for flooding to inland properties.

Recommended Resilience Strategies – In the property cards, resilience strategies are recommended for each asset at every representative site based on the assets' flood exposure and infrastructural and operational vulnerabilities. **Section 5. Resilience Strategies** and Appendix D provide additional information about each of the strategies with a focus on high criticality assets.

4. Vulnerability and Risk Assessment

For each of the DPAs and the eight representative sites, a desktop vulnerability and risk assessment was performed. The overarching goal of this assessment was to understand the current and future coastal flood risk to assets and functions described in the previous section, assuming no action is taken to mitigate these risks. This evaluation will help WDIU stakeholders, including municipal officials in host communities, WDIU property owners, and property users or tenants, understand how coastal flood hazards will change over time due to sea level rise. The results of the assessment show how coastal flooding will impact each representative site, help prioritize areas for mitigation, and inform development of appropriate resilience strategies for each site.

As discussed in **Section 2. Coastal Hazards Overview**, the two primary flood risks facing Chelsea Creek and Gloucester Inner Harbor DPAs are coastal flooding due to storm surge and high tides. This study uses the best available, locally applicable data to evaluate present and future vulnerability of the DPAs to coastal flooding due to these hazards. To remain consistent with RMAT and other state initiatives, the outputs of the Massachusetts Coastal Flood Risk Model (MC-FRM) and Massachusetts-specific SLR projections are used.

Though the data and projections used in this assessment are based on some of the most recently available climate change data, they are not guaranteed predictions of future flooding. As climate science, data and modeling continue to advance, it is recommended that these results be updated periodically.

Planning Horizon

Though flood risk was evaluated for several different time frames, 2050 was determined to be the most appropriate planning horizon for this study. This planning horizon is in line with the anticipated design life of many WDIU assets. Additionally, there is relatively more certainty around flood risk projections for 2050 than for longer time horizons (2070, 2100, and beyond). This means that there is higher confidence that flooding observed in 2050 will be similar to the flooding predicted by the models used. By taking action today to mitigate 2050 flood conditions, DPAs can help ensure assets are protected for flooding throughout their design life. Note that for larger, longer term projects, it may be appropriate to consider flood risk over longer time periods.

Storm Surge Assessment

Rising sea levels will exacerbate both coastal flooding due to storm surge and high tide flooding. Although a significant degree of uncertainty exists around the amount of future SLR that can be expected over what time horizon, for planning and design purposes it is often necessary to select specific SLR projections and scenarios based on an evaluation of available data, long-term needs, and risk tolerance. Due to the evolving nature of the science around SLR, the selected projections must be frequently reevaluated in light of new information.

The Massachusetts Coastal Flood Risk Model (MC-FRM) is used in this study to analyze the impacts of current and future coastal flooding due to storm surge. Among available datasets it is the most recent, has the highest spatial resolution, and considers the widest range of present and future storms. This dataset was developed for the Massachusetts Department of Transportation to assess coastal flood risk to transportation systems at risk to future sea levels and coastal storms. The dataset provides state-wide high resolution annual flood exceedance probability and inundation depth maps based on stillwater flooding for the present, 2030, 2050 and 2070. The SLR projections used for MC-FRM are based on the high projections being used by the Commonwealth of Massachusetts.

To determine the vulnerability of DPAs to storm surge, this study considers the MC-FRM 1% annual exceedance storm results for the present, 2030-, 2050-, and 2070-time frames. The 1% annual exceedance storm, also called the 1% annual chance storm or 100-year storm, is representative of a flood that has a 1% chance of occurring in any given year. Properties within the area affected by the 1% annual chance storm are at a high risk of flooding, with at least a 26% chance of flooding over the course of a 30-year period. The 1% annual exceedance storm is often used as a storm of reference as it is shown on the Federal Emergency Management Agency's Flood Insurance Rate Maps and is referenced by state and local codes and standards.

Using geographic information systems (GIS), a basic overlay analysis was performed to analyze which of the assets identified in the previous section are currently exposed to storm surge or will be exposed in 2030, 2050, and 2070. Given the anticipated design life of WDIU assets and uncertainty in climate science and impacts beyond 2050, the project team developed resilience strategies and best practices based on the projected extent of the 2050 1% annual chance storm. The resilience strategies for each representative site can be found in **Section 5. Resilience Strategies.**

Flood depth is another important consideration when evaluating coastal flood risk and developing appropriate resilience strategies. For example, an asset that is flooded by six inches of water will likely have less damage than an asset that is flooded by several feet of water. Deployable flood protection may be an appropriate resilience approach to mitigate risk at the asset projected to experience six inches of flooding. However, more permanent, and robust protection would likely be appropriate for the asset projected to experience several feet of flooding. When evaluating depth of flooding, it is also important to account for sub grade infrastructure that may be vulnerable. Any critical systems or spaces located below grade can fill with water during a flood event unless they are properly floodproofed. Additional analysis of flood depth at each site should be conducted before design and implementation of any resilience approach.

High Tide Assessment

Rising sea levels will exacerbate both coastal flooding due to storm surge and high tide flooding. Although a significant degree of uncertainty exists around the amount of future SLR that can be expected over a given time horizon, for planning and design purposes it is often necessary to select specific SLR projections and scenarios based on an evaluation of available data, long-term needs, and risk tolerance. Due to the evolving nature of the science around SLR, the selected projections must be frequently reevaluated in light of new information.

For analyzing the effects of SLR on future high tide flooding in the Chelsea Creek and Gloucester Inner Harbor DPAs, this study uses the Massachusetts-specific SLR projections adopted by the Commonwealth in 2018 (shown in Figure 11).[10] These data provide the most up to date relative SLR projections for the state and are downscaled from regional and international projections using approaches consistent with the International Panel on Climate Change, the 2017 National Climate Assessment, and the Global and Regional Sea Level Rise Scenarios for The United States (NOAA). The methodology includes a probabilistic assessment of future sea levels using medium (RCP 4.5) and high (RCP 8.5) greenhouse gas concentration scenarios with considerations for two methods of estimating ice sheet loss based on expert elicitation and process-based numerical models.

[10] Massachusetts Climate Change Projections, Northeast Climate Science Center at University of Massachusetts Amherst. Accessed February 1, 2021. https://nescaum-dataservices-assets.s3.amazonaws.com/resources/production/MA%20Statewide%20and%20MajorBasins%20Climate%20Projections_Guidebook%20Supplement_March2018.pdf

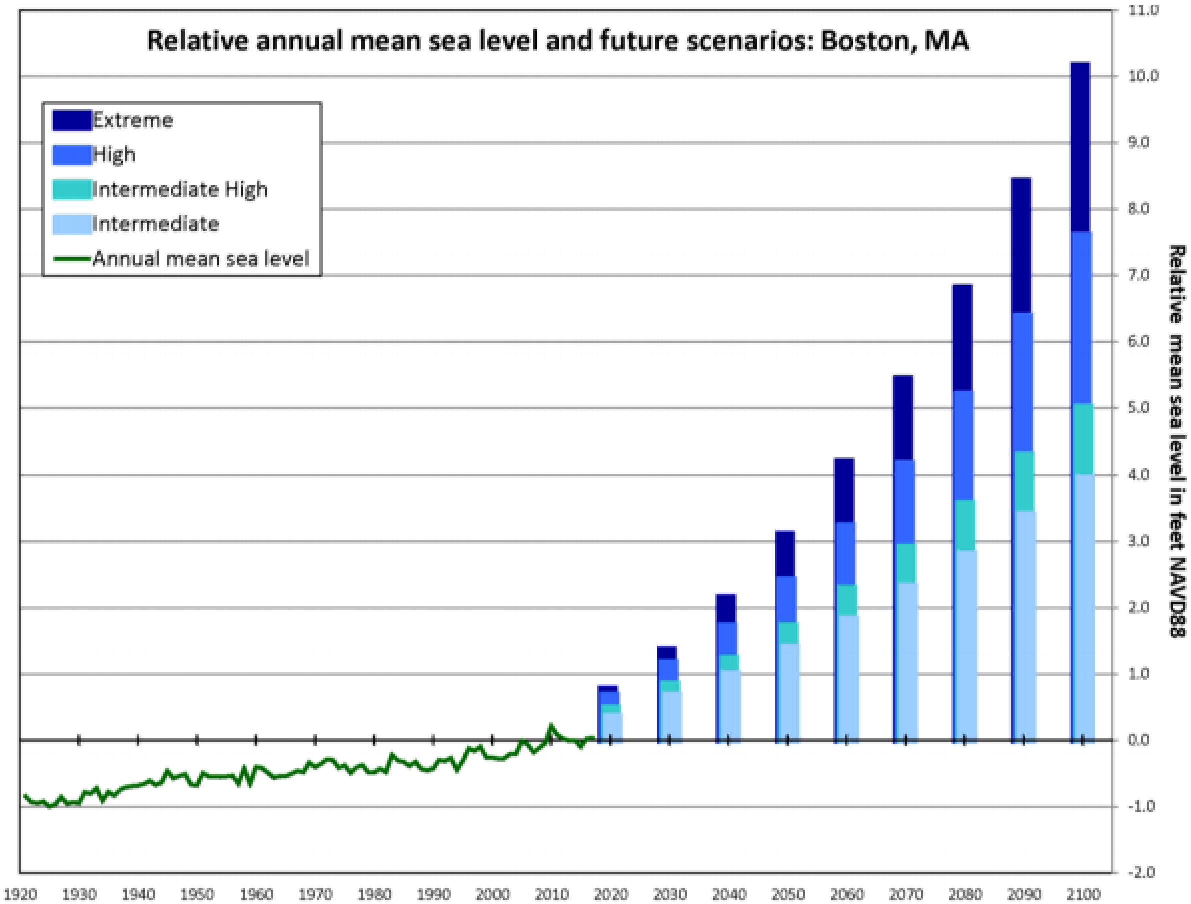

Figure 11 – Relative annual mean sea level and future scenarios for Boston, MA

Mean Monthly High Water (MMHW) is typically exceeded 25 35 times a year and is meant to approximate an identified tipping point of 30 floods per year. MMHW is the tidal level representative of nuisance flooding since the frequency of traditional daily tidal datums (e.g., mean higher high water or mean high water) would be too frequent to be considered "nuisance."

The "High Scenario" is used in this study to evaluate future high tide flooding. A full overview of the methodology can be reviewed is the Massachusetts Statewide and Major Basins Climate Projections report (March 2018). Based on the "High Scenario" for future SLR, the Project Team developed GIS layers representing the extent of mean monthly high water (MMHW) to indicate high tide flooding. For more information on the development of the MMHW layers, see Appendix E. By examining mean monthly high water, decision makers, property and business owners, and operators can better understand potential future nuisance flooding issues and address them through mitigation or adaptation actions before the flooding increases in frequency and becomes disruptive.[11]

Using GIS, a basic overlay analysis was performed to analyze which of the assets identified in the previous section are currently exposed to high tide flooding or will be exposed in 2030, 2050, 2070 and 2100. Given the anticipated design life of WDIU assets and uncertainty in climate science and impacts beyond 2050, the project

[11] New York City Panel on Climate Change 2019 Report Chapter 5: Mapping Climate Risk. Accessed February 16, 2021. https://nyaspubs.onlinelibrary.wiley.com/doi/epdf/10.1111/nyas.14015

team developed resilience strategies and best practices based on the projected extent of the 2050 MMHW. The resilience strategies for each representative site can be found in **Section 5. Resilience Strategies**.

Vulnerability and Risk Assessment Results

Anywhere it can rain, it can flood. WDIUs should keep in mind that coastal flooding is not the only type of flooding they may be vulnerable to. According to the 2018 National Climate Assessment, rainfall intensity and volume are both expected to increase in the Northeast due to climate change.

Industrial waterfronts like those within the Chelsea Creek and Gloucester Inner Harbor DPAs require easy access to the water's edge to maintain their operations. As the results of the vulnerability and risk assessment show, this proximity results in WDIU infrastructure and operations being exposed to coastal flooding today and in the future. As sea levels rise and coastal storms become more frequent and/or more severe, the exposure and vulnerability of WDIU assets at Chelsea Creek and Gloucester Inner Harbor will increase. To determine how much of the infrastructure at Chelsea Creek and Gloucester Inner Harbor is exposed, the study team performed a basic overlay analysis to identify how many buildings, excluding salt piles and oil tanks, were exposed to storm surge and high tide in the present (2020), 2030, 2050, and 2070 time periods. This level of assessment only considers whether or not an asset is exposed to flooding, it does not consider the depth of flooding an asset may experience. In addition, due to limits on available information, sub-grade infrastructure is not included in this assessment. Buildings were selected as a convenient proxy for evaluating coastal flooding impacts to the DPAs.

A limited number of buildings within both DPAs were not exposed to 2070 high tide or storm surge flooding. For these assets, we assume that they will be exposed to flooding at some point beyond 2070. This does not mean that these buildings are safe from flooding until 2070. It means that they are less likely to be flooded in the near term. Additionally, because these buildings are located so close to the coast, a severe storm event, with an extent greater than the 2070 flood conditions, is possible at any time.

Today, 87% percent of all buildings within the Gloucester Inner Harbor DPA are exposed to storm surge due to the 1% annual chance flood. This increases to 91% for WDIU buildings. Figure 12 shows exposure of WDIU buildings in the Gloucester Inner Harbor DPA to the 1% annual chance storm and MMHW event by decade. Present day flooding was confirmed through conversations with DPA stakeholders, and though many stakeholders have been experiencing the impacts of coastal flooding, many expressed uncertainty regarding the appropriate steps for addressing these impacts.

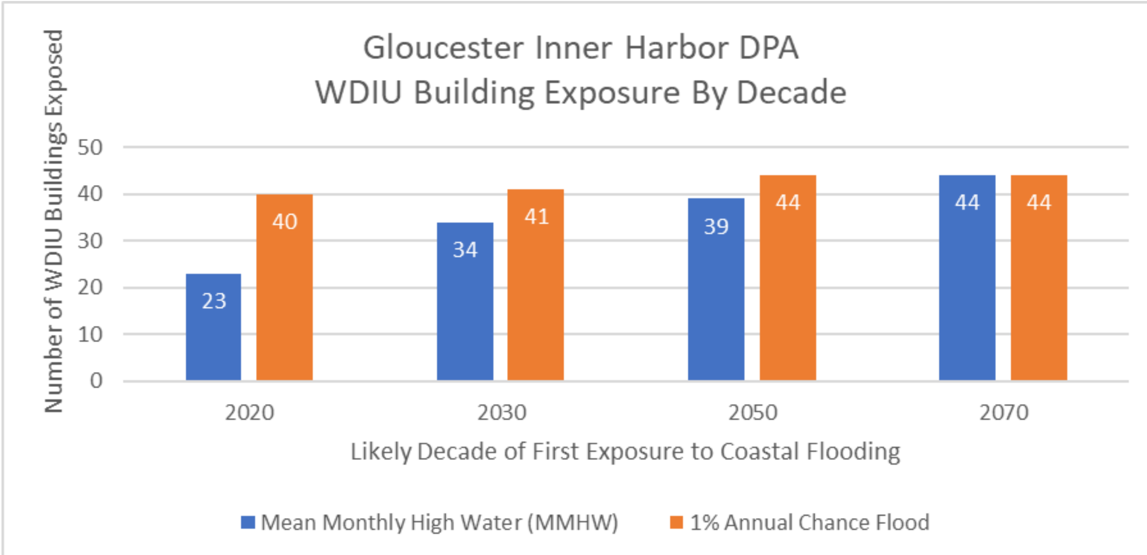

Figure 12 – WDIU building flood exposure summary for 1% annual chance storm event in Gloucester Inner Harbor DPA

In Chelsea Creek, 31% of all buildings are currently exposed to the 1% annual chance flood. This increases to 100% for WDIU buildings. Figure 13 shows exposure of WDIU buildings at Chelsea Creek to the 1% annual chance storm and MMHW event by decade. Present day flooding at Chelsea Creek was also confirmed through conversations with stakeholders. However, in Chelsea Creek, the stakeholders interviewed were aware of the coastal flood hazards and had started taking steps to address it.

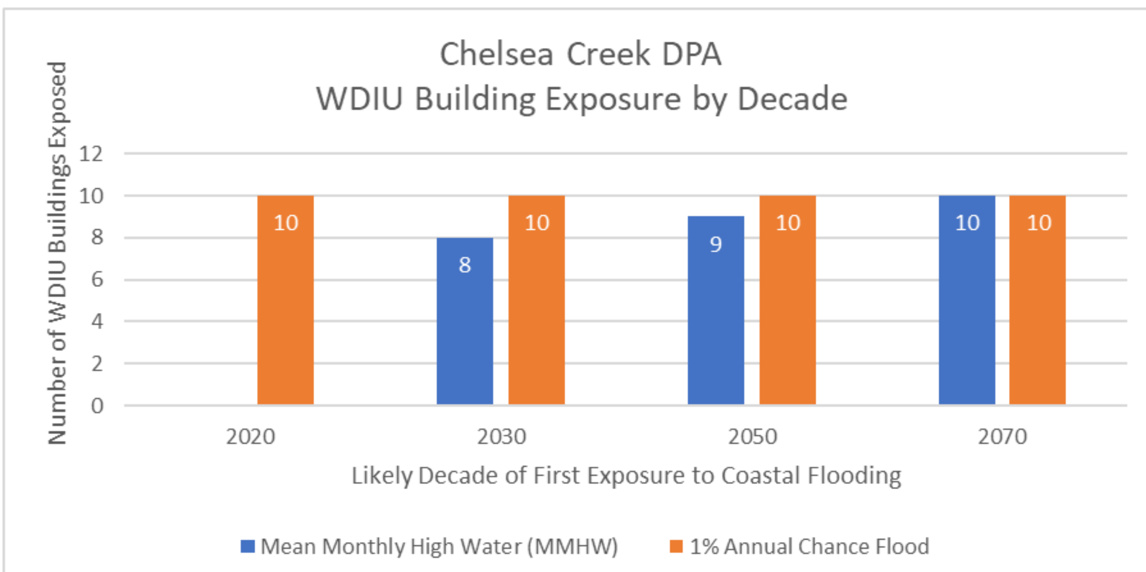

Figure 13 – WDIU building flood exposure summary for 1% annual chance storm event in Chelsea Creek DPA

By 2050, 95% of all buildings in Gloucester Inner Harbor and 62% of buildings in Chelsea Creek are exposed to the 1% annual chance flood. 100% of WDIU buildings at both sites are exposed to the 2050 1% annual chance flood. Figure 14 shows the percentage of buildings at each DPA exposed to the 1% annual chance flood today (2020) and in the future. Note that the buildings in Chelsea Creek are gradually exposed to the 1% annual chance flood over time while nearly all of the buildings in Gloucester Inner Harbor are exposed to storm surge flooding today. This is likely because Gloucester is relatively more exposed to storm surge due to its location and topography. Tucked behind Boston Harbor and the Boston Main Channel, Chelsea Creek is somewhat protected from these hazards. However, by 2070 75% of buildings in Chelsea Creek will be exposed to the 1% annual chance flood.

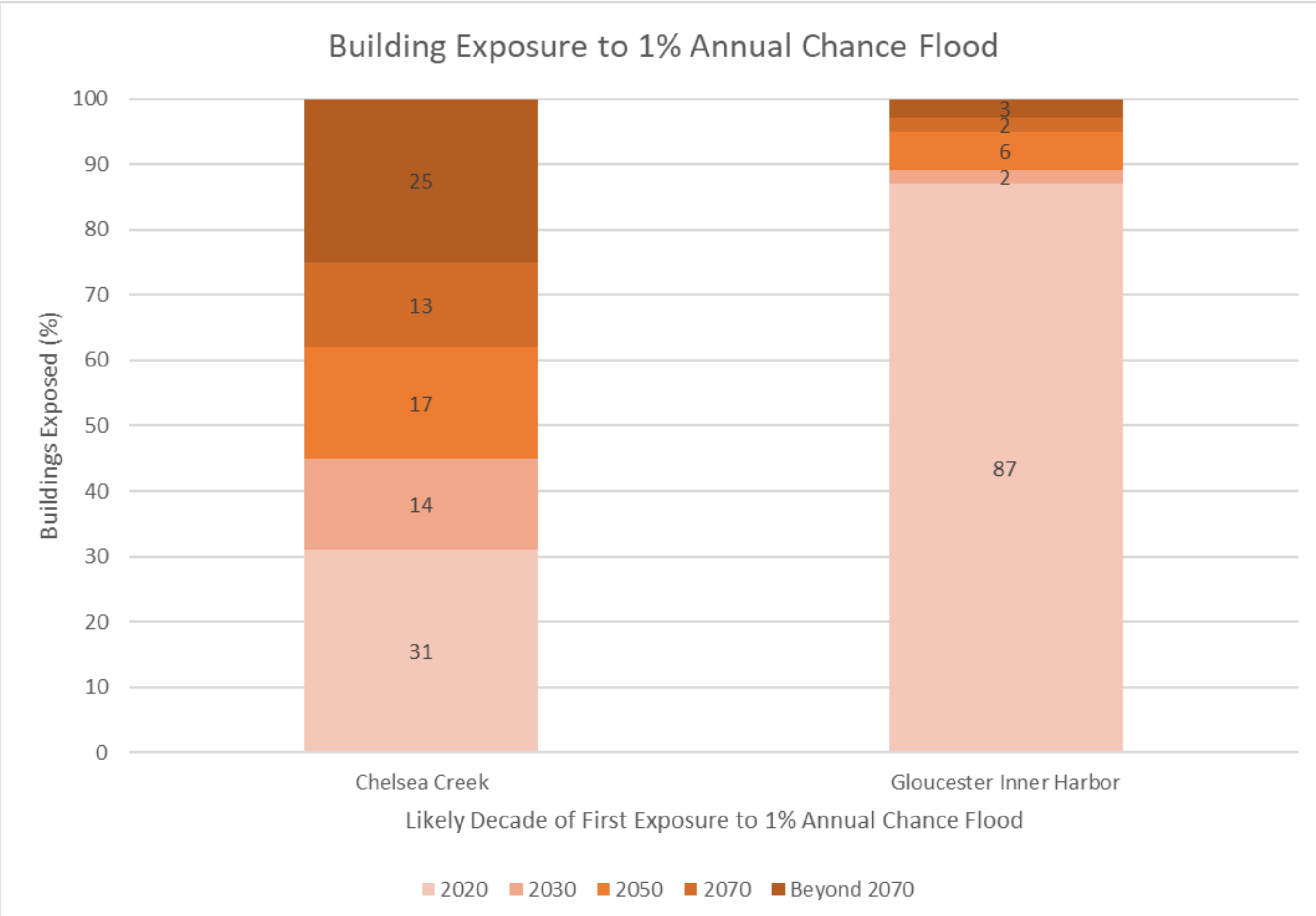

Figure 14 – Percentage of total buildings at each DPA exposed to the 1% annual chance flood today (2020) and in the future

Nearly half (49%) of buildings at Gloucester Inner Harbor are exposed to high tide flooding associated with the mean monthly high water (MMHW) today. This increases slightly to 52% of WDIU buildings within Gloucester Inner Harbor exposed to high tide flooding today. Figure 15 shows exposure of buildings at Gloucester Inner Harbor and Chelsea Creek to high tide flooding by decade.

By 2050, 84% of building in Gloucester Inner Harbor and only 23% of buildings in Chelsea Creek are exposed to high tide flooding. This increases to 88% for WDIU buildings in Gloucester Inner Harbor and 90% for WDIU buildings in Chelsea Creek. As with the 1% annual chance flood, this stark difference in present day vulnerability to high tide flooding is likely due to the locations of each DPA relative to the open coast. Buildings located further inland along Chelsea Creek are likely less vulnerable to high tide flooding due to the decreased tidal influence farther downstream. By 2070, 94% of buildings in Gloucester Inner Harbor and 46% of buildings in Chelsea Creek will be exposed to the high tide flooding. All WDIU buildings at both DPAs will be exposed. Figure 15 shows the percentage of buildings at each DPA exposed to high tide flooding today (2020) and in the future. It is clear from this figure that high tide flooding is more likely to be a widespread issue for buildings in Gloucester Inner Harbor in the near term.

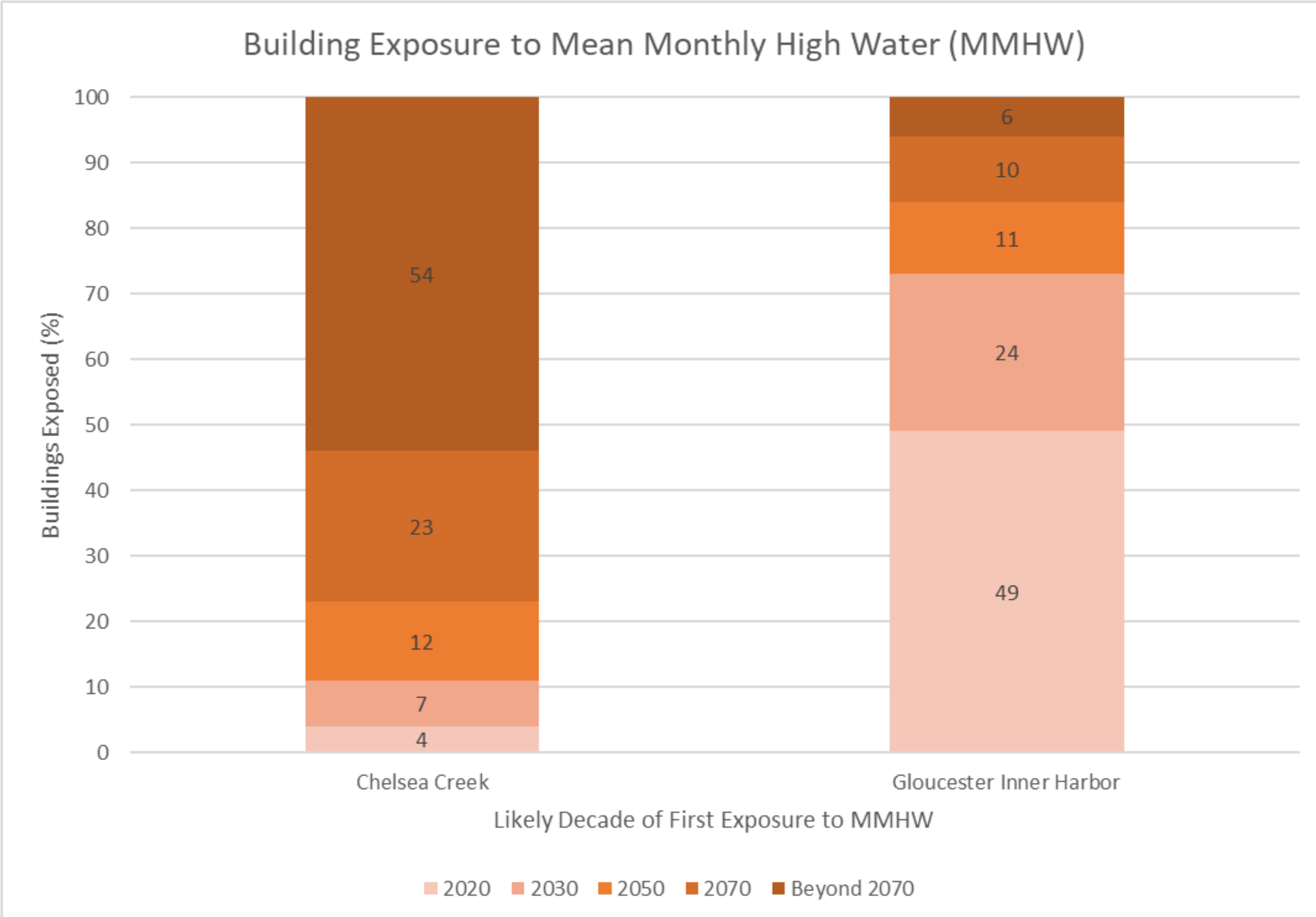

Figure 15 – Percentage of total buildings at each DPA exposed to high tide flooding today (2020) and in the future

Based on this assessment it is clear that even though all DPAs are vulnerable to coastal flooding due to their proximity to the water, they may be exposed to different types of hazards at different time frames. By working proactively to mitigate the risk of coastal flooding, WDIUs at both Chelsea Creek and Gloucester Inner Harbor have the opportunity to reduce their vulnerability in the future.

To determine the most appropriate resilience strategies for each WDIU typology, vulnerability at each of the representative sites was assessed in greater detail. For every asset included in the asset inventory, the study team determined when it would likely be exposed to storm surge and high tide flooding. Loss of service consequences were then determined assuming the site was flooded. This information is available for each representative site in the Property Cards found in Appendix A.

Apart from Gorton's, every DPA site considered in this study is at a high risk of flooding today and in the future. Though DPAs face a number of threats to their long-term health and viability, including economic shifts and development pressure, immediate action is necessary to reduce flood risk and related loss of service consequences.

Table 3 below summarizes the results of the vulnerability assessment for high criticality assets, also referred to as critical assets, at the representative sites. Assets are high criticality if their functioning is necessary to maintain core mission services or life safety, such as police, fire, emergency medical, or systems such as power, communication, transportation, water, and waste. These critical assets should be prioritized for flood risk mitigation and are the focus of the site-based vulnerability assessment and the resilience strategies recommended in **Section 5. Resilience Strategies**.

For example, Jodrey State Fish Pier has 11 total assets and 8 critical assets. Critical assets on the site include the main transformer, warehouse, wharfs, Massachusetts Environmental Police (MEP) building and various docks. Based on the flood risk modeling and desktop analysis, six of these critical assets are exposed to coastal flooding today and all of them are exposed to storm surge by 2030. Reducing the vulnerability of these critical assets, which are essential for the site to function, is the priority of the resilience strategies. Vulnerability of non-critical assets at the site, such as the marine transportation docks and electrical enclosure which supplies electricity to the docks, should be addressed after risk to critical assets has been reduced.

Across all representative sites, the majority of critical assets are exposed to either high tide flooding and/or storm surge flooding today. At five of the eight sites studied within Chelsea Creek and Gloucester Inner Harbor DPAs, over 80% of critical assets are exposed to coastal flooding today. By 2050, over 90% of assets at seven of the sites will likely be exposed to these hazards.

Gorton's was the notable exception with only 33% of their critical assets exposed to coastal flooding today and 58% exposed by 2050. Though several of Gorton's critical assets lie just beyond the extent of coastal flooding, Gorton's has already implemented several flood mitigation strategies including elevation of electrical utilities, installation of pumps, and waterproofing of their main office.

Table 3 – Flooding exposure at representative sites in both DPAs

DPA	Representative Site	Critical Assets Exposed to Coastal Flooding Today	Critical Assets Exposed to Coastal Flooding by 2050	Dominant Flood Type for Critical Assets
Chelsea Creek	Eastern Minerals	83%	94%	Fringe
Chelsea Creek	Gulf Oil	93%	100%	Fringe (50%) and Pathway (50%)
Gloucester Inner Harbor	Cape Pond Ice	100%	100%	Fringe
Gloucester Inner Harbor	Harbormaster's Office	100%	100%	Fringe
Gloucester Inner Harbor	Maritime Gloucester	100%	100%	Fringe
Gloucester Inner Harbor	Gorton's	33%	58%	Fringe
Gloucester Inner Harbor	Jodrey State Fish Pier	75%	100%	Fringe
Gloucester Inner Harbor	I4C2	100%	100%	Fringe

The functions, primary vulnerabilities, and loss of service consequences for each representative site are summarized in the Coastal Flood Exposure Profiles in Appendix C.

Representative Site Coastal Flood Exposure Profiles

For each of the eight representative sites, a profile detailing the site’s functions, critical assets, primary vulnerabilities, and loss of service consequences was developed. The coastal flood exposure profile for Jodrey State Fish Pier is provided as an example on the following page (Figure 16). The profiles summarize key information about the site’s infrastructural and operational flood vulnerability and are a valuable reference for the representative site’s stakeholders and WDIU owners and users at different sites of the same type. The resilience approaches and strategies identified in the following section address the key flood vulnerabilities for high criticality assets noted within these site profiles. Profiles for the remaining sites are available in Appendix C.

Jodrey State Fish Pier

The Pier, owned and operated by MassDevelopment, supports the local fishing and lobster fleets with warehouses on site for processing, storage, and distribution of seafood products. Numerous docking berths are also located at the pier for commercial fishing vessels. In additional to supporting the fishing industry, the site also hosts Coast Guard vessels and a Massachusetts Environmental Police operations building.

PRIMARY LOSS OF SERVICE CONSEQUENCES

- Decrease in fish and lobster supply to local customers and community
- Loss of maritime safety operations

- Due to existing grade and consistent site elevation, once floodwaters overtop shoreline protection majority of site will become inundated
- No flooding experience on site during major storm surge events

Jodrey State Fish Pier Exposure Summary	
Total Number of Assets	11
Number of Critical Assets	8
Critical Assets Exposed to Coastal Flooding Today	75%
Critical Assets Exposed to Coastal Flooding by 2050	100%
Dominant Flood Type for Critical Assets	Fringe

Figure 16 – Potential consequences of flooding exposure at the Jodrey State Fish Pier today (2020) and in 2050

5. Resilience Strategies

To help WDIUs address the vulnerabilities identified in the previous section, the study team has evaluated flood resilience approaches for WDIUs, identified easy win resilience approaches that are applicable for all WDIUs, and developed comprehensive resilience strategies for each representative site. This section consists of three primary topics:

- **Flood Resilience Approaches for Water Dependent Industrial Users –** this section details how best practices scores for potential flood resilience approaches were developed based on evaluation criteria and identifies at which representative site(s) each approach may be appropriate.
- **Easy Win Resilience Approaches for Water Dependent Industrial Users** – in evaluating potential resilience approaches for WDIUs, it became clear that there are a number of relatively low cost and easy to implement resilience approaches that apply to most, if not all, WDIU site types. These easy wins are highlighted in the narrative below.
- **Comprehensive Resilience Strategies for Representative Sites** – for each of the representative sites, resilience strategies are recommended to mitigate the 2050 flood risk at high criticality assets. Each resilient strategy includes several resilient approaches that prioritize protection of high criticality assets, complement one another, and can typically be implemented over time. At least two resilient strategies are recommended for each site: one considers resilience approaches at the asset and structure level and the other considers resilience approaches at the site or district scale. WDIU stakeholders can use the suggested resilient strategies as a guide to inform discussions with implementation professionals and develop a comprehensive plan for resilience. More detailed analyses will be required to determine the most cost-effective strategy for each site.

Note that before taking any actions, it is important that WDIUs consult with a qualified professional to determine the appropriateness and permissibility of a given strategy for the site or facility and obtain all applicable permits and licenses.

Flood Resilience Approaches for Water Dependent Industrial Users

Based on the vulnerability of the representative sites to coastal flooding today and in the future, the project team developed 31 conceptual resilience approaches that are appropriate to address flooding in DPAs due to the 2050 MMHW and 2050 1% annual chance storm. The approaches identified align with the current and future needs and priorities of DPA operators and users, as identified through WDIU interviews conducted for this study. Before implementation, the approaches discussed here will be subject to the requirements of the relevant permitting authorities. Recommended approaches may need to be modified to comply with federal, state, and local regulations and requirements.

Consistency with RMAT Climate Resilience Design Guidelines

The resilience approaches developed are, to the extent feasible, consistent with the Climate Resilience Design Guidelines. The Climate Resilience Design Guidelines are overarching climate resilience principles developed by RMAT that are not specific to specific projects, assets, or hazards. The guidelines fall into three categories: site suitability, regional coordination, and flexible adaptation pathways and are detailed in Table 4. Given the scope of this study, it is not feasible to consider each of the guidelines in detail. However, the recommended strategies are consistent with the spirit of the resilience principles defined by RMAT.

Table 4 Overview of RMAT Climate Resilience Design Guidelines

Guideline Category	Guidelines
Site Suitability	• Reduce exposure to climate hazards • Mitigate adverse climate impacts and provide benefits • Protect, conserve, and restore critical natural resources on site and off site
Regional Coordination	• Assess regional context of vulnerability • Evaluate impacts beyond site specific design • Optimize capital investment opportunities • Prioritize services and assets that serve vulnerable populations
Flexible Adaptation Pathways	• Embed future capacity and design for uncertainty • Design for incremental change • Encourage climate mitigation and other co benefits • Prioritize nature based solutions • Prepare for current and future operational and maintenance needs

Each approach was evaluated using a range of performance-based criteria. The evaluation criteria included applicability to DPAs, cost and cost effectiveness, regulatory considerations, ease of implementation, and operations and maintenance requirements. Each of these evaluation criteria is described in Table 5.

Table 5 - Evaluation Criteria for Flood Resilience Approaches

Evaluation Criteria	Description
Applicability to DPAs	Evaluates the approach’s applicability for water dependent industrial users in terms of preserving critical site functions including access to navigable water and land-based transportation and preserving or enhancing critical waterfront infrastructure. All approaches considered for this study are potentially applicable to DPAs.
Cost	Evaluates the approach’s high-level cost of implementation relative to other approaches. This criterion does not consider scale of implementation or final design components that would be necessary to fully estimate costs. The evaluation should be used for general planning purposes only.
Cost Effectiveness	Evaluates the approach’s potential for cost effectiveness in terms of providing maximum benefit for dollars spent.
Regulatory Considerations	Evaluates constraints that may be placed upon an approach under current state and local regulations. All resilience approaches and strategies are subject to requirements of relevant permitting authorities and may require modifications to comply with applicable regulations.
Ease of Implementation	Evaluates the ease with which an approach may be implemented from a generalized technical perspective, considering the potential need for site assessments, data collection, and design effort that may be necessary to construct the approach.
Operations and Maintenance	Evaluates the estimated annual effort necessary to operate and maintain the approach.

Table 6 summarizes the flood resilience approaches based on their best practice score. The best practice score considers the applicability of the strategy to DPAs broadly and the approach’s complexity score. The complexity score was developed based on the approach’s relative cost, cost effectiveness, regulatory considerations, ease of implementation and maintenance. A higher best practice score indicates the approach is highly applicable to DPAs, relatively low cost, cost effective, is more likely to be permittable, and has low operation and maintenance requirements. Note that because of the scoring system applied, and the fact that resilience approaches inappropriate for DPAs were screened out of the analysis, the lowest possible (worst) score is 5 and the highest possible (best) score is 18. The lowest score awarded to a resilience approach included in our assessment was 9.

Table 6 – Flood resilience approaches based on their best practice score

Best Practice Score	Resilience Approaches
15-18 applicable to most DPAs and relatively low complexity	• Flood preparedness/ business continuity planning • Increase risk awareness • Purchase and maintain flood insurance • Relocation of moveable assets (vehicles, boats, etc.) • Elevate mechanical systems/utilities • Raised interior floor • Relocate critical assets/systems
12-14 applicable to many DPAs and moderately complex	• Backup critical systems (e.g., emergency generator) • Elevate piers/wharfs to DFE • Elevate structures/assets to DFE • Pumps • Sand bags • Outfall tide gates (e.g., flap gates or elastomeric check valves) • Elevate grade to DFE • Deployable flood barriers (e.g., stop logs, tiger dams, etc.) • Improve site drainage/ runoff management • Raise road/ site access to DFE • Wet floodproof structures below DFE • Increase permeable surfaces • Relocate operations/use • Dry floodproof structures below DFE • Elevate/adapt mooring and berthing systems to DFE • Fill structure basements • Vertical enlargement of buildings
5-11 less applicable to most DPAs and relatively high complexity	• Elevate flood and shoreline protection to DFE • Structural Stormwater Best Management Practices (BMPs) • Flood wall/ levee • Raised road (as levee) • Wave attenuation

Design Flood Elevation (DFE)

DFE is defined by RMAT as the anticipated flood elevation to which an asset should be designed to protect the asset. DFE is typically the base flood elevation (BFE), or expected elevation of a 1% annual chance storm, plus freeboard as required by building codes. Freeboard is a factor of safety, accounting for the uncertainty of flooding, and is usually expressed as feet above BFE. Critical assets typically have higher freeboard requirements. The MC FRM DFE incorporates both freeboard and wave heights. DFE determinations should consider criticality and be made on an asset by asset basis in consultation with a qualified professional.

After evaluating the resilience approaches, the project team considered which approaches would be most appropriate for each representative site/ WDIU typology.

Table 7 on the following page summarizes the approaches that may be applicable to each representative site based on its assets, operations, and vulnerability to coastal flooding. Note that resilience approaches may not be recommended for a representative site for variety of reasons, including that the approach has already been implemented at the site. Recommended approaches may require additional analyses prior to implementation. All approaches are subject to the requirements and regulations of the relevant permitting authorities.

Table 7 – Relevant Resilience Approaches for Each Site

Ease of Implementation and Timeframe	Resilience Approach	Eastern Minerals	Gulf Oil	Cape Pond Ice	Gorton's	Harbormaster's Office	I4C2	Maritime Gloucester	Jodrey State Fish Pier
Maintenance, Ongoing	Site maintenance / safe storage of hazardous materials	X	X	X	X	X		X	X
Easy Win, 0-1 year	Flood preparedness / business continuity planning	X		X	X	X	X	X	X
Easy Win, 0-1 year	Increase risk awareness	X	X	X	X	X	X	X	X
Easy Win, 0-1 year	Purchase and maintain flood insurance	X	X	X	X	X	X	X	
Easy Win, 0-1 year	Relocation of moveable assets (vehicles, boats, etc.)	X	X	X	X	X	X	X	X
Larger Investment, 1 – 3 years	Backup critical systems (e.g., emergency generator)		X	X	X				X
Larger Investment, 1 – 3 years	Deployable flood barriers (e.g., stop logs, tiger dams, etc.)	X	X	X	X			X	X
Larger Investment, 1 – 3 years	Dry floodproof structures below DFE	X	X		X			X	X
Larger Investment, 1 – 3 years	Elevate / adapt mooring and berthing systems to DFE	X	X						
Larger Investment, 1 – 3 years	Elevate mechanical systems / utilities	X	X	X	X			X	X
Larger Investment, 1 – 3 years	Elevate piers / wharfs to DFE	X		X			X	X	X
Larger Investment, 1 – 3 years	Elevate structures / assets to DFE	X	X	X	X			X	X
Larger Investment, 1 – 3 years	Fill structure basements								
Larger Investment, 1 – 3 years	Improve site drainage / runoff management		X		X				
Larger Investment, 1 – 3 years	Pumps	X	X	X	X			X	X
Larger Investment, 1 – 3 years	Raised interior floor	X	X	X	X			X	X
Larger Investment, 1 – 3 years	Raised road / site access to DFE	X	X	X	X	X			X
Larger Investment, 1 – 3 years	Relocate critical assets / systems	X	X		X	X		X	X
Larger Investment, 1 – 3 years	Sand bagging	X	X	X	X	X		X	X
Larger Investment, 1 – 3 years	Tidal gate		X		X			X	
Larger Investment, 1 – 3 years	Vertical enlargement of buildings	X	X	X	X			X	X
Larger Investment, 1 – 3 years	Wet floodproof structures below DFE			X	X			X	X
Capital Intensive and Site-Wide, 3+ years	Elevate flood and shoreline protection to DFE	X	X		X		X	X	
Capital Intensive and Site-Wide, 3+ years	Elevate grade to DFE	X	X	X	X	X	X	X	X
Capital Intensive and Site-Wide, 3+ years	Flood wall / levee	X	X		X			X	
Capital Intensive and Site-Wide, 3+ years	Increase permeable surfaces	X		X	X				X
Capital Intensive and Site-Wide, 3+ years	Raised road (as levee)	X			X				
Capital Intensive and Site-Wide, 3+ years	Relocate operations / use				X	X		X	
Capital Intensive and Site-Wide, 3+ years	Structural Stormwater Best Management Practices (BMPs)	X	X		X	X	X		X
Capital Intensive and Site-Wide, 3+ years	Wave attenuation								

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To assist in the development of multi-approach resilience strategies for each site, approaches were further classified based on their relative ease of implementation and the likely timeframe for implementation. There are three classifications in addition to routine maintenance which serves as a prerequisite for successful resilience building.

- **Routine Maintenance -** Routine maintenance is essential to achieving resilience. Sites and their critical assets and infrastructure should be kept in a good state of repair. By practicing good routine maintenance, sites will be more prepared for day-to-day challenges and have more capacity to build resilience through the approaches recommended here.
- **Easy Win** – These approaches are applicable to most WDIU site typologies and can be easily and quickly implemented. They can be implemented within a year without further design or expert consultation and represent easy ways that WDIUs can start building their resilience to coastal flood hazards today. Descriptions of the easy win approaches are provided in the following section.
- **Larger Investment** – These projects may take 1-3 years to implement, require a moderate capital investment and will likely need additional expert consultation or assessment to implement.
- **Capital Intensive and Site-Wide** – Approaches classified as capital intensive and site-wide will require a longer project timeline, higher level of investment, and strategic thinking to achieve site-wide resilience.

Understanding flood risk is the first step stakeholders can take to reduce the flood risk at their WDIU sites.

A temporary water-filled tube in place under a bridge during Tropical Storm Isaias. Angus Mordant/Bloomberg

Constructed floodwall, Nassau County, NY. Perimeter Protection at Bay Park Sewage Treatment Plant

Figure 17 – Overview of implementation time frame by approach type

This classification can help WDIU stakeholders across all DPAs to identify immediate opportunities for risk reduction and encourage them to start thinking about longer term, capital intensive and site-wide resilience building opportunities. Note that these classifications are not directly tied to the best practice score. Because all of the resilience approaches scored relatively well and could be implemented to reduce flood risk at DPAs, this classification allows WDIU stakeholders to more easily prioritize opportunities for risk reduction without additional analyses.

It is important to note that resilience is not something that can be achieved overnight, it is a continually evolving process. By implementing easy-win approaches first, DPAs can take action to reduce their risk today and start building support for more resource intensive resilience activities.

Easy Win Resilience Approaches for all WDIUs

Based on the study team's evaluation of resilience approaches most suitable for each representative site (

Table 7), there are a number of approaches that are applicable to most representative sites and can be easily and quickly implemented. The project team recommends that these approaches, detailed in Table 8, be implemented at WDIUs DPA-wide. These approaches can be implemented without further design or expert consultation and represent easy ways that WDIUs can start building their resilience to coastal flood hazards today.

Given the imminent flood threat to critical assets across the representative sites, these approaches should be implemented as soon as feasible. Easy win approaches like these can be implemented within a year, help get additional stakeholders involved in the conversation, bring attention to the urgency of these issues, and start building consensus around resilience strategies that are more costly or difficult to implement. In many cases, these approaches serve as a necessary foundation for more time and capital-intensive resilience measures, which are recommended in the Resilient Strategy Profiles for each representative site in Appendix D.

Routine maintenance is also vital to achieving resilience. Sites and their critical assets and infrastructure should be kept in a good state of repair. Stormwater drainage structures should be cleaned on a regular basis. Deployable flood barriers should be deployed and tested regularly. Spill prevention control and clean up best practices should be implemented, and mechanical equipment should be regularly serviced. By practicing good routine maintenance, sites will be more prepared for day-to-day challenges and have more capacity to build resilience during emergency situations like severe flood events.

Table 8 – Easy Win Resilience Approaches

Recommended Resilience Approach	Description	Approach Benefits
Purchase and maintain flood insurance	Flood insurance, a type of catastrophe insurance, covers a site for losses sustained by water damage specifically due to flooding. Commercial property insurance DOES NOT usually cover flood damage. Flood insurance policies are available through the National Flood Insurance Program (NFIP) and private insurers. Insurance premiums are generally based on flood zones, property age, elevation, and number of floors. Note that gas and liquid storage tanks, wharves and piers, and machinery or equipment in the open are not insurable under the NFIP. Check with your local insurance professionals for details about available coverage.	Having flood insurance helps businesses recover faster after a flood. Even if a federal disaster is not declared, your property will still be covered by flood insurance. This means that if assets are damaged by flooding, and appropriate proof of loss is provided to the NFIP, businesses will receive a payout to repair or replace the damaged asset(s).
Increase risk awareness	Understanding flood risk is the first step stakeholders, including owners, tenants, staff, etc., can take to reduce the flood risk at their WDIU sites. Risk	Increased risk awareness for all site personnel can contribute to an increase in preparedness and preventative action for a flooding event. This awareness can aid in

Recommended Resilience Approach	Description	Approach Benefits
	awareness can be increased through a variety of stakeholder engagement strategies including participatory mapping, review of flood exposure maps including those in Appendix B, and flood preparedness training exercises.	protecting not only site personnel, but also the site's infrastructure and systems. It can also help build consensus and political will around the importance of taking flood mitigation action.
Flood preparedness and business continuity planning	Flood preparedness and business continuity planning includes, but is not limited to, making an evacuation plan, emergency supply kits, and key operational actions that can be taken to reduce flood risk in the lead up to a storm.	Flood preparedness and business continuity planning can help ensure that all site personnel are ready to evacuate in an orderly manner before rising waters impact the site, business operations, or evacuation routes. This approach can also aid in operations for recovery after a storm event. Flood preparedness plans typically incorporate details about other mitigation efforts. For instance, the plan may identify moveable assets and where they should be relocated to in the event of a flood.
Relocate moveable assets	Moveable assets like vehicles and boats can be moved to less vulnerable areas if a flood is imminent.	Relocating moveable assets to higher elevation and less flood prone areas can reduce the likelihood of flood exposure and damage during flood events. Assets can be moved immediately before a likely flood event and moved back after the flood to minimize disruption of site functions. Additionally, moveable assets that can withstand flooding can be secured to prevent them from floating or being washed away during a flood event. This may prevent them from becoming destructive debris.

Resilience Strategies for Representative Sites

For each representative site, resilience strategies were developed to address the vulnerability of the site's highest criticality assets to 2050 MMHW and 2050 1% annual chance storm flooding. More than one strategy may be recommended for each site. These strategies are a logical combination of resilience approaches to help the WDIU build resilience over time. The strategies fall into three primary categories:

1. **Approaches Applicable to All Strategies.** Some approaches are recommended for all strategies, while other approaches are only recommended for certain strategies based on scale of protection. Approaches applicable to all strategies include relevant Easy Win approaches described in the previous section.
2. **Resilient Strategy 1.** For all sites, Resilient Strategy 1 combines approaches to provide protection to critical assets on an asset-by-asset basis. No passive flood protection measures or site scale approaches are recommended with this strategy. Approaches included in Resilient Strategy 1 include Larger Investment approaches that can build on Easy Wins.
3. **Resilient Strategy 2, 3, 4 (as applicable).** Subsequent strategies integrate the asset scale approaches with site-wide flood resilience approaches, as appropriate. Subsequent strategies are composed of Capital Intensive and Site-Wide approaches. Depending on the site, Resilient Strategy 1 and subsequent strategies may complement one another or the implementation of subsequent strategies may make Resilient Strategy 1 unnecessary.

Once easy win approaches have been implemented at each site, the project team recommends prioritizing the larger investment and capital intensive and site-wide strategies for the site's critical assets, vulnerable to the 2050 flood conditions, as detailed in the Resilient Strategy Profiles in Appendix D. Larger investment projects may take 1-3 years to implement, require a moderate capital investment and will likely need additional expert consultation or assessment to implement. Some resilience strategies that are classified as larger investments include: dry/wet floodproofing, elevating structures, mechanical systems, and utilities to a DFE, installing deployable flood barriers.

Strategies classified as capital intensive and site-wide will require a longer project timeline, higher level of investment and strategic thinking to achieve site-wide resilience. Examples of capital intensive and site-wide projects include elevating site grade, installing perimeter flood walls or relocating operations and uses. Note that though the capital intensive and site-wide strategies will have higher upfront costs and longer project implementation timelines, a detailed benefit cost analysis may be appropriate to determine whether these more aggressive approaches could save money over the lifetime of the site and be preferrable to the larger investment strategies. WDIU should take advantage of any planned capital improvements on their site to integrate large investment and site scale strategies, as appropriate.

Cost benefit analyses and additional technical assessments will likely be necessary to determine the most appropriate resilience strategy for each site. Before making major decisions or designing solutions, WDIUs should consult a licensed architecture and engineering professional. All DFE determinations should consider criticality and be made on an asset by asset basis in consultation with a qualified professional. Further, all strategies are subject to the requirements and regulations of relevant permitting authorities.

Resilient Strategies for Eastern Minerals – Dry Bulk Terminal

Eastern Minerals has a number of high criticality assets including a variety of shoreline protection structures, floating barges and marine loading platforms, salt storage areas, crane pads and subterranean water supply lines. A number of flood protection approaches have already been implemented at the site. These include elevating the office, generator, and truck scales. Stakeholders at the site have also considered using concrete blocks to divert floodwaters in flood-prone areas.

Eastern Minerals can build on these efforts by implementing a number of easy win resilience approaches that are applicable to all of the resilience strategies detailed below. This includes developing a flood preparedness plan which identifies key operational actions that can be taken to reduce flood risk before a storm. These include other easy win approaches like relocating moveable assets to lower flood risk areas prior to a storm and implementing deployable flood protection. Deployable flood protection can be implemented at a number of locations on site including for the salt storage areas.

Additionally, Massachusetts Water Resource Authority (MWRA) subterranean water supply lines are also located on this site. An assessment of the impact of sea level rise on the water table in this area may be warranted with increasingly frequent high tides.

The site also has large areas of flexible open space. Open space can integrate structural stormwater best management practices (BMPs) through rain gardens or bioswales to help build the resilience to stormwater flooding. These BMPs can be considered for implementation at the same time as easy win approaches.

The Eastern Minerals site has several existing flood and shoreline protection structures such as z-pile bulkheads and riprap. These structures were not built to protect against future flooding from storms and high tides and **Resilient Strategy 1** recommends that this infrastructure be elevated to protect against 2070 MMHW. Strategy 1 also includes elevating the dock and unloading area above the future monthly high tide. The mooring and berthing systems at the marine loading platform would also need to be elevated or adapted to future MMHW. Elevating to the future MMHW is likely more feasible for this site because it will offer adequate protection against frequent flooding without incurring the high costs or potential operation disruptions associated with elevating higher to the 1% annual chance flood level.

Resilient Strategy 2, which would need to be undertaken with the City of Chelsea and other stakeholders, recommends raising Marginal Street and site access via the three entrances along Marginal St. Raising the road and site access to the desired flood elevation would maintain access to the site. Note that Marginal St. Entrance 1 is not exposed to 2050 flood conditions so the other entrances should be prioritized for elevation if there are funding or other constraints. Resilient Strategy 2 would be most effective when paired with the asset-by-asset approaches of Strategy 1.

Resilient Strategy 3 includes installing a floodwall or levee along the perimeter of the site. With the installation of a flood wall, the bulk product delivered to the site would need to be lifted over the line of defense, potentially requiring additional infrastructure. Based on WDIU input, a perimeter flood wall would not impact operation of the cranes as the crane pads could either be protected by the wall and operate behind the structure or the crane pads could be left out of the alignment and gates could be installed to allow cranes to access the crane pads. One consideration in installing a flood wall is that pedestrian access and the equipment loading and unloading mechanism will be required to go over the wall or through a gate. Pumps should be installed behind the flood wall to reduce flood impacts during the most severe flood events and manage stormwater. Depending on the level of protection offered by the floodwall, implementation of Resilient Strategies 1 and 2 in full or in part may be necessary to offer comprehensive protection.

Resilient Strategy 4 recommends elevating the grade of the site above the elevation of future MMHW. Since there are few buildings on the Eastern Minerals site and the salt piles are only present part of the year, the grade of the site could be partially or fully elevated with minimal disruption to operation

Resilient Strategies – Eastern Minerals

Resilient Strategy	Resilience Approaches	Strategy Description
Applicable to All Strategies	Easy-Win strategies including develop flood preparedness plan, purchase and maintain flood insurance, increase risk awareness, and relocate moveable assets.	It is recommended that all Easy-Win resilience approaches be implemented on site as it provides a foundation for longer-term and larger investment approaches. For this site, two larger investment approaches are also included. These are specific to this site and can be readily implemented.
	Implement structural stormwater best management practices (BMPs) and assess impacts of sea level rise on water table at MWRA parcel	
	Elevate crane pads above future monthly high tide	
Resilient Strategy 1	Elevate dock and unloading area above future monthly high tide	Strategy 1 provides flood protection to the site through elevation of all existing shoreline protection measures. In addition to shoreline protection, crane pads and all berthing systems and marine loading platforms will need to be elevated above the future monthly high tide.
	Elevate shoreline protection above future monthly high tide	
Resilient Strategy 2	Raise Marginal Street, site access points, and elevate grade at location of salt storage areas	Strategy 2 provides protection to critical assets through approaches that establish protection of an asset on an individual basis. No passive flood protection measures or site-wide approaches are recommended with this strategy.
Resilient Strategy 3	Install perimeter flood wall	Strategy 3 delivers flood protection through the construction of a flood wall along the perimeter of the site.
Resilient Strategy 4	Elevate site grade and all buildings/structures to future monthly high tide	Strategy 4 incorporates the asset scale elevation approaches in Strategy 1 and 2 with a site-wide grade elevation to the future monthly high tide.

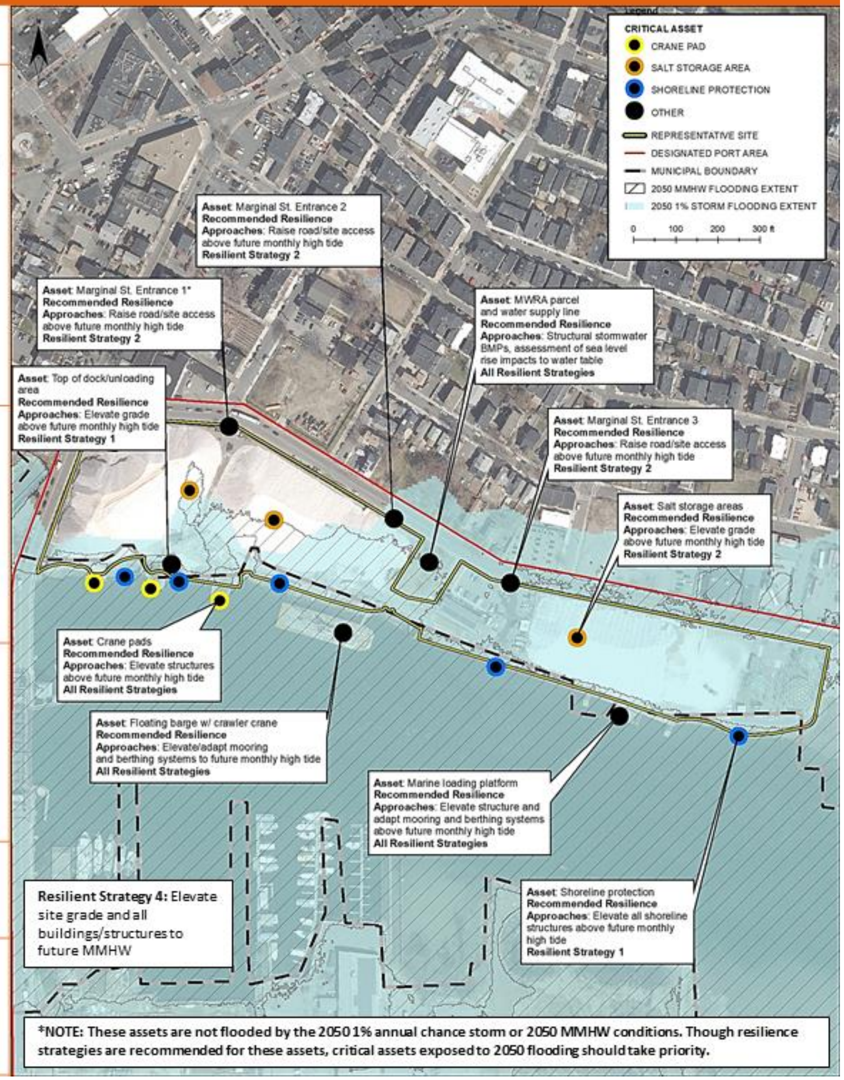


Figure 18 – Summary of Resilient Strategies for Eastern Minerals

Resilient Strategies for Gulf Oil – Liquid Bulk Terminal

Critical assets at Gulf Oil include 18 oil storage tanks, containment berms, shoreline protection structures, marine loading platform and loading rack, and foam house. Environmental contamination is a primary consideration at the site. The site has already implemented some flood and shoreline protection including installing riprap and recently rebuilding the bulkhead. The office foundation has been elevated 20 inches from grade and there are plans in place to protect the motor control center (MCC) building. During precipitation events, sandbags are deployed on the site at the office building to help prevent floodwaters from entering and damaging the building and its contents.

The site can build on these efforts by implementing a number of easy win resilience approaches that are applicable to all of the resilience strategies detailed below. These include developing a flood preparedness plan, purchasing and maintaining flood insurance, increasing risk awareness, and relocating moveable assets. Deployable flood barriers are an appropriate resilience strategy to protect the oil storage tanks and the loading rack. The marine loading platform should be elevated to the DFE regardless of resilient strategy implemented. Mooring and berthing systems associated with the marine loading platform will also need to be adapted or elevated to the DFE.

Resilient Strategy 1 recommends elevating existing flood and shoreline protection structures including the bulkhead and riprap to DFE, where feasible, if they are not already. All DFE determinations should consider criticality and be made on an asset by asset basis in consultation with a qualified professional. Accessibility to the waterfront and maintaining the waterside functionality are important considerations if implementing this strategy.

To complement Resilient Strategy 1, critical assets should be elevated to the DFE. **Resilient Strategy 2** recommends elevating the foam house, containment berms, and marine loading rack and systems. Mechanical systems and utilities within the foam house should also be elevated. If elevation is not feasible for the foam house, it can be dry floodproofed below the DFE. Backflow prevention devices can also be installed in flood drains to prevent the intrusion of floodwaters. As an alternative to elevating the containment berms, deployable flood barriers can be employed as suggested in **Resilient Strategy 3**.

Resilient Strategy 4 recommends a district-scale perimeter flood wall surrounding the entire site. During future flood events, it is expected that floodwaters would enter from offsite and inundate the paved area and loading rack on the north side of the site. If floodwaters enter from the north end of the site, existing shoreline protection will be ineffective, essentially preventing floodwaters from exiting the site. Site scale perimeter flood protection is also ineffective on this site because there are no suitable higher elevation areas within the site to “tie-in” a flood wall or similar structure. For this reason a district-scale perimeter flood wall, implemented in coordination with the municipality, private property owners, and regulatory authorities, is recommended. Resilient Strategy 4 should be considered a necessary complement to the other strategies.

Pumps should be installed behind the flood wall to reduce flood impacts during the most severe flood events and manage stormwater. Pedestrian access and equipment unloading and loading mechanisms would need to be considered in the design of the flood wall. Access could go over the wall or through gates. As an alternative to a flood wall, elevating grade on the northern portion of the site, including the office building and loading rack, may reduce flood risk in this area.

Resilient Strategies – Gulf Oil

Resilient Strategy	Resilience Approaches	Strategy Description
Applicable to All Strategies	Easy-Win strategies including develop flood preparedness plan, purchase and maintain flood insurance, increase risk awareness, and relocate moveable assets.	It is recommended that all Easy-Win resilience approaches be implemented on site as it provides a foundation for longer-term and larger investment approaches. The marine loading platform will need to be elevated regardless of Resilient Strategy implemented.
	Elevate marine loading platform and adapt mooring and berthing systems to DFE	
Resilient Strategy 1	Elevate shoreline protection to DFE	Strategy 1 provides flood protection to the site through elevation of all existing shoreline protection measures. In addition to shoreline protection the marine loading platform and the berthing system needs to be elevate to the DFE.
Resilient Strategy 2	Elevate chemical spill containment berms to DFE	Strategy 2 provides protection to critical assets through approaches that establish protection of an asset on an individual basis. Elevation of the containment berms will provide flood protection for all storage tanks. No passive flood protection measures or site-wide approaches are recommended with this strategy.
	Elevate foam house to DFE or dry floodproof below DFE, and elevate mechanical systems and utilities	
	Raise site entrances at Eastern Avenue street to DFE	
	Elevate loading rack and systems to DFE or install deployable flood barriers	
Resilient Strategy 3	Install deployable flood barriers for oil storage tanks	Strategy 3 incorporates the asset scale protection approaches in Strategy 2 but removes elevation of chemical spill berms. Oil storage tanks will instead be protected with the use of deployable flood barriers.
Resilient Strategy 4	District-scale perimeter flood wall	Strategy 4 delivers flood protection through the construction of a flood wall along the perimeter of the site and adjacent sites.

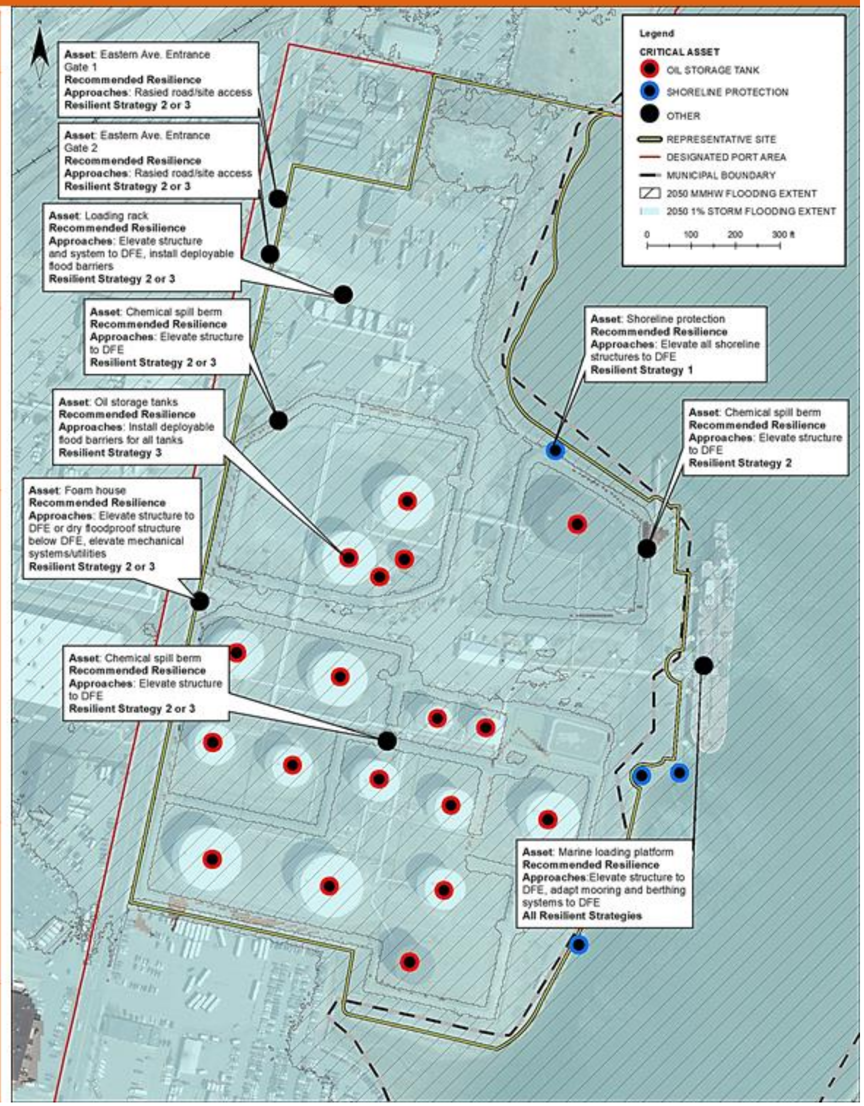


Figure 19 – Summary of Resilient Strategies for Gulf Oil

Resilient Strategies for Gorton’s – Fish/Seafood Processing Facility and Cold Storage

At Gorton’s, highly critical assets include the manufacturing plant, Americold engine room and warehouse, loading dock, transformers and high voltage electrical enclosures, wastewater management system & holding tank, main office, maintenance office, and vehicular access via Rogers Street. Note that some of the assets on the Gorton site are not exposed to 2050 flood conditions. Resilience approaches are recommended for all assets, but priority should be given to the manufacturing plant, Americold engine room and warehouse, and loading dock which are all expected to be exposed to flooding by 2050.

Gorton’s has implemented flood protection approaches including installing pumps and waterproofing the main office and elevating electrical. The site can build on these efforts by implementing a number of easy win resilience approaches that are applicable to all of the resilience strategies detailed below. These include developing a flood preparedness plan, purchasing and maintaining flood insurance, increasing risk awareness and relocating moveable assets. Deploying sandbags at key locations is also an emergency flood protection approach that may be effective at the site, especially as a stopgap measure while Gorton’s works to implement a comprehensive resilience strategy.

During precipitation events, flooding has been observed near the laboratory and main office. To mitigate stormwater flooding, a site scale and upstream stormwater system capacity assessment is recommended in addition to routine drainage structure maintenance such as sediment removal from catch basins. With the stormwater flooding issues the site currently faces installation of structural stormwater BMPs, such as installing permeable pavers and bioswales, could aid in reducing overland flow and precipitation-related flood impacts. Many structural stormwater BMPs are relatively easy and low cost to implement and can be considered for implementation at the same time as easy win approaches.

During coastal storm surge flood events, floodwaters likely enter the site near the Americold engine room and the neighboring site and are diverted east to Rogers Street. After crossing Rogers Street, flooding can reach the laboratory and main office. To address these issues, **Resilient Strategy 1** recommends elevating critical assets to the DFE to mitigate flood damage. Elevation may not be a feasible option for all sites, so dry and wet floodproofing options should also be evaluated. Backflow prevention devices can also be installed in flood drains to prevent the intrusion of floodwaters. Deployable flood barriers are another alternative asset-level resilience approach for the electrical transformers/enclosures and wastewater management system on site.

Resilient Strategy 2 includes elevating site grade and all buildings/structures to DFE. This strategy would require more substantial funding and a longer-term plan to allow for continued operations during construction. If this is not feasible, grade can be elevated in some areas and individual assets can be elevated in others as recommended in Resilient Strategy 1. Alternatively, if the site is ever redeveloped with another water dependent or other use, the opportunity could be used to elevate grade site-wide. Additionally, elevation of Rogers St. would benefit Gorton’s as well as the neighborhood inland. Currently, floodwaters can cross Rogers St. and inundate Gorton’s assets and residential areas. Elevating Rogers St would preserve access to the Gorton’s site during a flood event and prevent floodwaters from reaching the laboratory, main office and inland neighborhood. Once the grade of the site and all assets are above DFE, stormwater management best practices should be implemented to prevent the site from flooding due to precipitation.

Resilient Strategy 3 recommends installation of a perimeter flood wall to keep most floodwaters from entering the site. A flood wall could be installed at either the site or district scale. A multi-parcel perimeter flood wall would be most effective for this site if developed in coordination with Americold and the City of Gloucester. If a flood wall is installed, pumps should be installed behind the flood wall to reduce flood impacts during the most severe flood events and to manage stormwater. Any perimeter structure at this location would need to be designed in a way that maintains access to the waterfront to ensure the long-term potential for dockage and waterside operations.

Dry and wet floodproofing and structural stormwater BMPs as detailed in Resilient Strategy 1 may still be prudent depending on the level of protection provided by the flood wall.

Resilient Strategy 4 proposes relocation of critical assets at this site to areas with lower flood risk. It may be feasible relocate some critical assets including the engine room, electrical transformers and enclosures and wastewater management system to higher elevation areas currently being used for parking across Rogers St. Relocation of the engine room would require coordination and a cooperative approach with Americold as this asset is owned by the company. Relocated assets may not require further flood mitigation, depending on the level of flood risk at the new site and useful life of the assets. Vulnerability of critical assets that cannot be relocated should be addressed through the asset-level approaches recommended in Resilient Strategy 1.

Resilient Strategies – Gorton's

Resilient Strategy	Resilience Approaches	Strategy Description
Applicable to All Strategies	Easy-Win strategies including develop flood preparedness plan, purchase and maintain flood insurance, increase risk awareness, and relocate moveable assets.	It is recommended that all Easy-Win resilience approaches be implemented on site as it provides a foundation for longer-term and larger investment approaches.
Resilient Strategy 1	Elevate Americold engine room to design flood elevation (DFE) or dry floodproof below DFE, elevate mechanical systems/utilities	Strategy 1 provides protection to critical assets through approaches that establish protection of an asset on an individual basis. No passive flood protection measures or site scale approaches are recommended with this strategy.
	Elevate electrical transformers/enclosures and wastewater management system to DFE or install deployable flood barriers	
	Dry floodproof main office below DFE, elevate mechanical systems/utilities	
	Dry/wet floodproof manufacturing plant and Americold warehouse, elevate mechanical systems/utilities	
	Raise site entrance at Roger's Street to DFE	
Resilient Strategy 2	Elevate site grade and buildings/structures to DFE and raise Rogers Street to protect Gorton's property to the north and the interior neighborhood.	Strategy 2 integrates the asset scale elevation approach in Strategy 1 with a site-wide grade elevation to the DFE.
Resilient Strategy 3	Install perimeter flood wall	Strategy 3 delivers flood protection through the construction of a flood wall along the perimeter of the site, with recommended coordination with Americold
Resilient Strategy 4	Relocate engine room, electrical transformers/enclosures, wastewater management system, and additional critical assets and uses to lower flood risk location.	Strategy 4 requires relocation of uses on site, in addition to buildings if feasible, to a lower flood risk area (higher ground across Rogers St.)

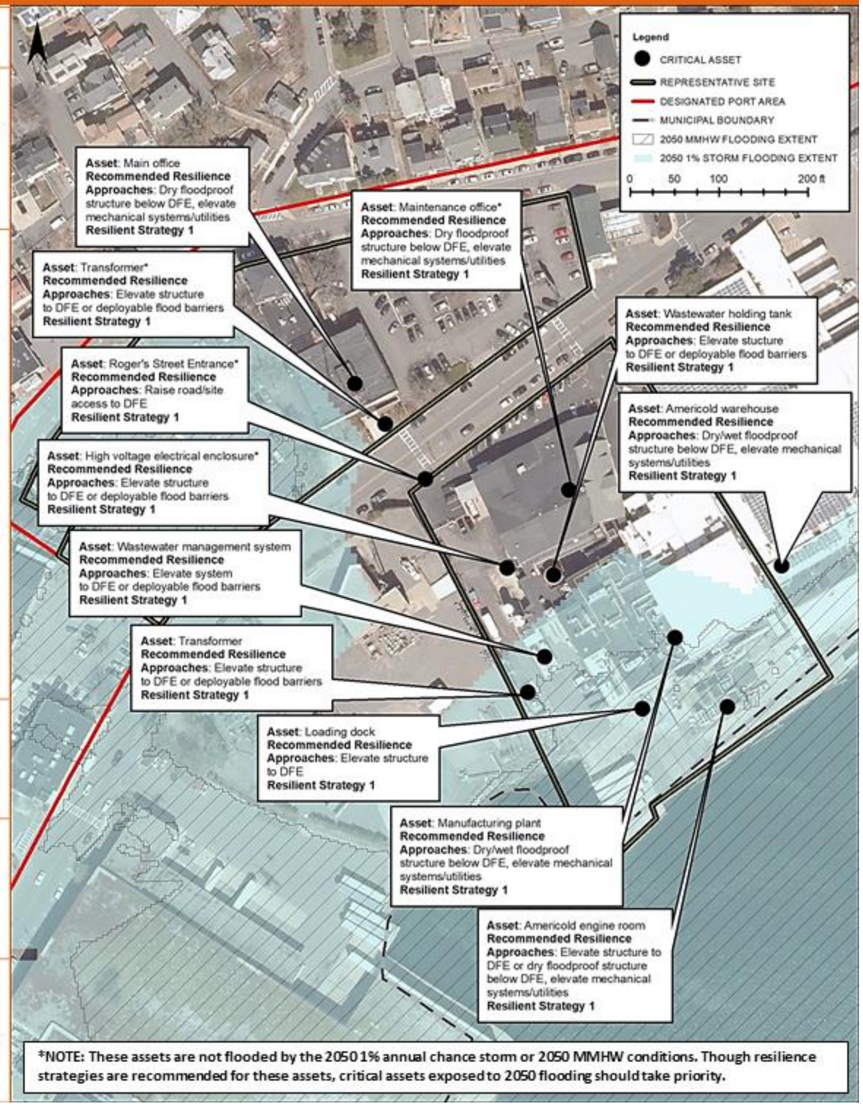


Figure 20 – Summary of Resilient Strategies for Gorton's

Resilient Strategies for Maritime Gloucester – Marine Railway and Boat Repair

High criticality assets at Maritime Gloucester include the marine railway, museum, aquarium, and motor control center (MCC). Protecting the MCC has been identified as a short-term priority for stakeholders at the site. A number of flood protection approaches have already been implemented at Maritime Gloucester, including elevation of interior utilities and assets. The site can build on these efforts by implementing a number of easy win resilience approaches that are applicable to all of the resilience strategies detailed below. These include developing a flood preparedness plan, purchasing and maintaining flood insurance, increasing risk awareness and relocating moveable assets. Deploying sandbags is also an emergency flood protection approach that may be effective at the site, especially as a stopgap measure while Maritime Gloucester works to implement a comprehensive resilience strategy. Given the flooding and inundation issues currently faced by the site, specifically in the low-lying area near the pier, installation of structural stormwater BMPs could aid in reducing overland flow and precipitation-related flooding impacts. Many structural stormwater BMPs are relatively easy to implement and can be considered for implementation at the same time as easy win approaches.

Due to the topography and infrastructure of the site, once floodwater is on the site it is directed towards the buildings with minimal opportunities for diversion. Currently, stakeholders report flooding on site 3-4 times a year. Through **Resilient Strategy 1** the site could address these issues by elevating critical assets including the MCC, aquarium, and museum to the DFE to avoid future flood damage. Elevation may not be a feasible option for assets such as the marine railway system so wet floodproofing options should also be evaluated. Note that since some of the assets on this site are historic, special consideration should be given to regulations and permitting when implementing flood protection measures on this site. Flood risk to the operations to the marine railway can be reduced by identifying opportunities to incorporate water resistant materials on the railway and related mechanical equipment. Dry floodproofing below DFE may also be an option for the MCC, aquarium, and museum. Backflow prevention devices can also be installed in flood drains to prevent the intrusion of floodwaters. Additional analyses will be required to determine the best option for each asset. Whether the assets are elevated or floodproofed, mechanical systems and utilities within the buildings should be elevated above DFE.

Resilient Strategy 2 includes elevating site grade and all buildings/structures to DFE. This strategy would require more substantial funding and a longer-term plan to allow for continued operations during construction. If this is not feasible, grade can be elevated in some areas and individual assets can be elevated in others as recommended in Resilient Strategy 1. Alternatively, if the site is ever redeveloped or if substantial building renovations are planned, the opportunity could be used to elevate grade site-wide.

Resilient Strategy 3 recommends installation of a perimeter flood wall to keep most floodwaters from entering the site. A flood wall could be installed at either the site or district scale. A site scale flood wall could include the neighboring Harbormaster’s Office and would require the use of deployables across the right-of-way. A district scale flood wall would not require deployables but would require coordination with neighboring sites. In either case, pumps should be installed behind the flood wall to reduce flood impacts during the most severe flood events. Gates would also be required to maintain dock and marine railway access to the waterfront. Asset-level approaches recommended in Resilient Strategy 1 may still be prudent depending on the level of protection provided by the flood wall.

Resilient Strategy 4 proposes relocation of critical assets at this site to areas with lower flood risk, potentially to higher ground across Harbor Loop Road near Captain Solomon Jacobs Park. This approach would require coordination with neighboring property owners and may be best considered at a point when critical assets need to be replaced or upgraded. Relocated assets would not likely require further flood mitigation, depending on the level of flood risk at the new site. Vulnerability of critical assets that cannot be relocated should be addressed through the asset-level approaches recommended in Resilient Strategy 1.

Resilient Strategies - Maritime Gloucester

Resilient Strategy	Resilience Approaches	Strategy Description
Applicable to All Strategies	Develop Flood Preparedness Plan	It is recommended that all Easy-Win resilience approaches be implemented on site as it provides a foundation for longer-term and larger investment approaches.
	Purchase and maintain flood insurance	
	Increase risk awareness	
	Relocate moveable assets	
Resilient Strategy 1	Elevate MCC to design flood elevation (DFE), dry floodproof structure below DFE, or relocate system to low flood risk location	Strategy 1 provides protection to critical assets through approaches that establish protection of an asset on an individual basis. No passive flood protection measures or site scale approaches are recommended with this strategy.
	Elevate aquarium to DFE or dry/wet floodproof building below DFE, elevate mechanical systems/ utilities	
	Elevate museum to DFE or dry floodproof building below DFE, elevate mechanical systems/utilities	
	Wet floodproof marine railway system	
Resilient Strategy 2	Elevate site grade and all buildings/structures to DFE	Strategy 2 integrates the asset scale elevation approach in Strategy 1 with a site-wide grade elevation to the DFE.
Resilient Strategy 3	Install perimeter flood wall	Strategy 3 delivers flood protection through the construction of a flood wall along the perimeter of the site.
Resilient Strategy 4	Relocate uses and buildings to lower flood risk location, potentially to higher ground across Harbor Loop	Strategy 4 requires relocation of uses on site, in addition to buildings if feasible, to a lower flood risk area.

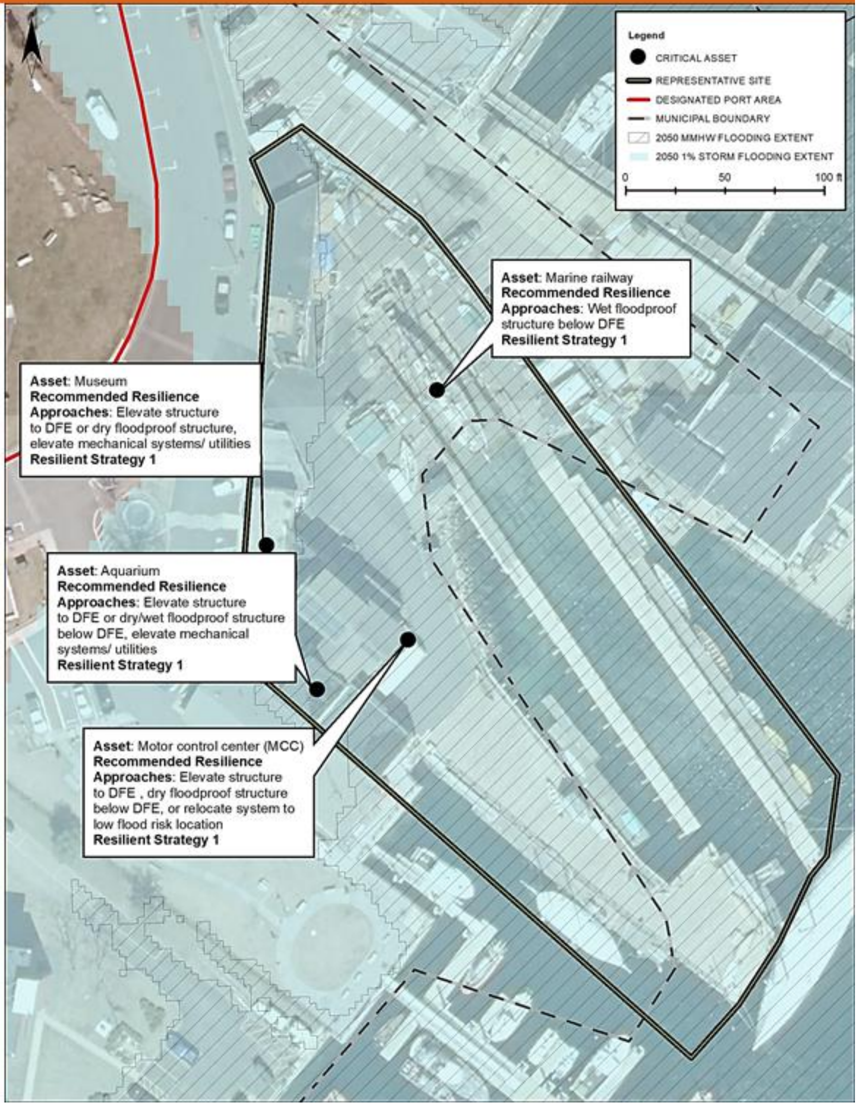


Figure 21 – Summary of Resilient Strategies for Maritime Gloucester

Resilient Strategies for Jodrey State Fish Pier – Multi-use Pier

Jodrey State Fish Pier has a variety of critical assets including warehouses for the fishing/lobster industry, Coast Guard dock, loading docks and wharfs, a building for the Massachusetts Environmental Police (MEP), and a transformer.

Flood protection has not yet been implemented at the pier but there has been discussion about elevating the site in its entirety at the end of the service life of the building currently on site. In the nearer term, there are opportunities for the site to reduce flood risk to its critical assets. An easy win for the site would be developing a flood preparedness plan. The plan can help site owners and users understand the impacts of flooding on the site and how they can be prevented through other easily implemented resilience approaches such as purchasing and maintaining flood insurance, increasing risk awareness, and relocating moveable assets to low flood risk locations prior to a flood event. Deploying sandbags is also an emergency flood protection approach that may be effective at the site, especially as a stopgap measure while the Pier works to implement a comprehensive resilience strategy.

Though the site has not yet experienced flooding, it is relatively flat and once floodwaters overtop the existing edge, they are expected to inundate the majority of the site. **Resilient Strategy 1** can mitigate the effects of this flooding by protecting critical assets at the building or structure level. This includes elevating structures such as the electrical transformer, MEP building, and fixed docks like the Coast Guard Dock to the DFE. Dry floodproofing may also be an option for the MEP building while wet floodproofing should be considered for the warehouses due to the wet seafood processing operations. Within these buildings, mechanical systems and utilities should also be elevated. Backflow prevention devices can be installed in flood drains to prevent the intrusion of floodwaters. This strategy should also include elevation of the site’s entrance at Parker St which is threatened by coastal flooding. To maintain access during more severe flood events, the pier entrance and roadway to the loading docks should be elevated to DFE.

Resilient Strategy 2 proposes elevating the site grade and all buildings and structures on site to DFE. This strategy would require more substantial funding and a longer-term plan to allow for continued operations during construction. If this is not feasible, grade can be elevated in some areas and individual assets can be elevated in others as recommended in Resilient Strategy 1. Alternatively, if the site is ever redeveloped or major capital improvements are planned, the opportunity could be used to elevate grade site-wide. Once the grade of the site and all assets are above DFE, stormwater management best practices should be implemented to prevent the site from flooding due to precipitation.

Resilient Strategies – Jodrey State Fish Pier

Resilient Strategy	Resilience Approaches	Strategy Description
Applicable to All Strategies	Develop Flood Preparedness Plan	It is recommended that all Easy-Win resilience approaches be implemented on site as it provides a foundation for longer-term and larger investment approaches.
	Increase risk awareness	
	Relocate moveable assets including vehicles	
	Deployable flood barriers (main transformer)	
Resilient Strategy 1	Wet floodproof warehouses below DFE, elevate mechanical systems/utilities	Strategy 1 provides protection to critical assets through approaches that establish protection of an asset on an individual basis. No passive flood protection measures or site-wide approaches are recommended with this strategy.
	Elevate North Wharf and other fixed docks to DFE, elevate / adapt mooring and berthing systems to DFE	
	Elevate Massachusetts Environmental Police building to DFE or dry floodproof below DFE, elevate mechanical systems/utilities	
	Raise site entrance at Parker Street to DFE	
	Elevate main transformer to DFE	
Resilient Strategy 2	Elevate site grade and all buildings/structures to DFE	Strategy 2 incorporates the asset scale elevation approach in Strategy 1 with a site-wide grade elevation to the DFE.

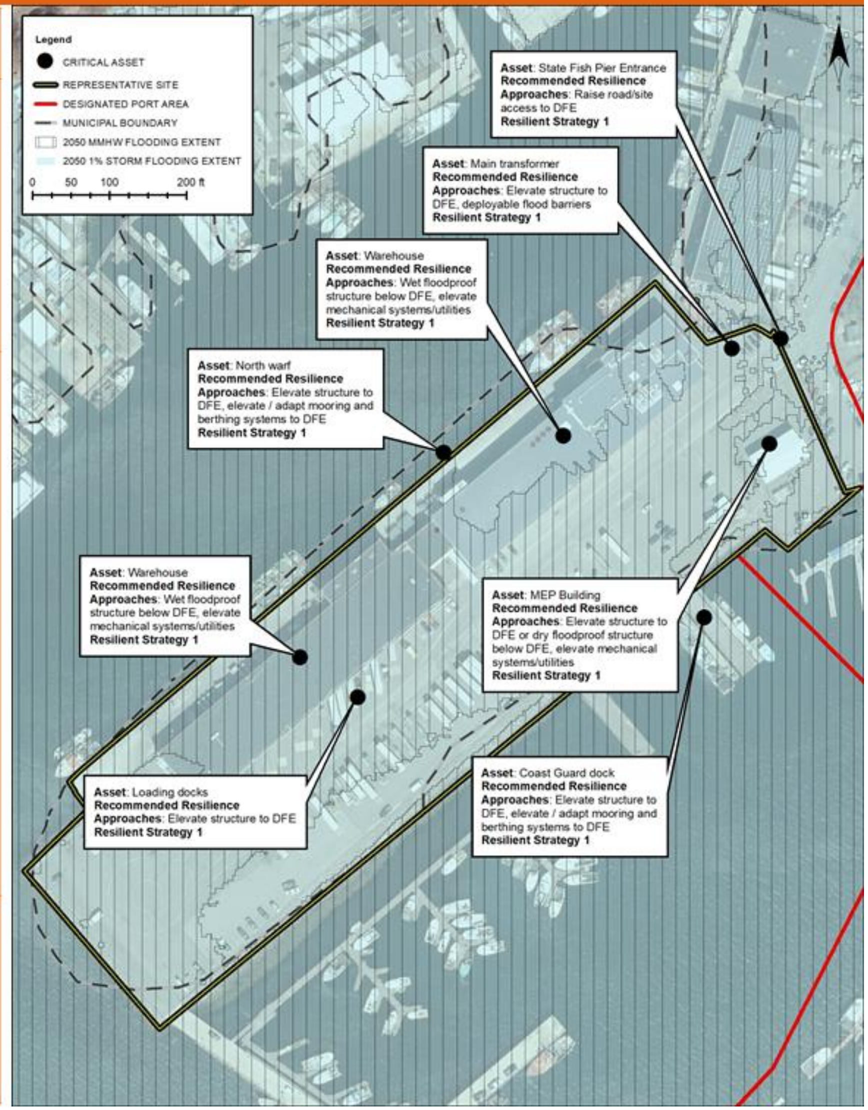


Figure 22 – Summary of Resilient Strategies for Jodrey State Fish Pier

Resilient Strategies for Cape Pond Ice – Ice Supply Facility/Marine Supply

There are two high criticality assets at Cape Pond Ice – the warehouse/ice storage facility and the marine loading platform. Both of these assets are located at the water’s edge. The site does not currently experience any high tide flooding but has experienced flooding during storm events. During storms, floodwaters tend to run along the southern driveway and then recede.

The site has not yet implemented any flood protection approaches. However, given the proximity of its critical assets to the water and the importance of these assets to fishing vessels reliant on ice, Cape Pond Ice should develop a flood preparedness plan. The plan can help site owners and users understand the impacts of flooding on the site and how they can be prevented through other easily implemented resilience approaches like purchasing and maintaining flood insurance, increasing risk awareness, and relocating moveable assets to low flood risk locations prior to a flood event. Deploying sandbags is also an emergency flood protection approach that may be effective at the site, especially as a stopgap measure while the Pier works to implement a comprehensive resilience strategy. Though current flooding on the site is limited, installation of structural stormwater BMPs could aid in reducing overland flow and precipitation-related flooding impacts. Many structural stormwater BMPs are relatively easy to implement and can be considered for implementation at the same time as easy win approaches.

Resilient Strategy 1 recommends that Cape Pond Ice consider elevating the marine loading platform to the DFE to avoid future flood damage. This would require elevation or adaptation of the related mooring and berthing systems. The warehouse and ice storage facility can be wet floodproofed below DFE and mechanical systems and utilities within these buildings can be elevated to DFE. Backflow prevention devices can be installed in flood drains to prevent the intrusion of floodwaters.

Resilient Strategy 2 includes elevating site grade and all buildings/structures to DFE. This strategy would require more substantial funding and a longer-term plan to allow for continued operations during construction. If this is not feasible, grade can be elevated in some areas and individual assets can be elevated in others as recommended in Resilient Strategy 1. Alternatively, if the site is ever redeveloped, the opportunity could be used to elevate grade site-wide. Stormwater management best practices should be implemented to prevent the site from flooding due to precipitation, which coincide with any planned site scale upgrades or as feasible within existing site conditions.

Resilient Strategies – Cape Pond Ice

Resilient Strategy	Resilience Approaches	Strategy Description
Applicable to All Strategies	Develop Flood Preparedness Plan	It is recommended that all Easy-Win resilience approaches be implemented on site as it provides a foundation for longer-term and larger investment approaches.
	Purchase and maintain flood insurance	
	Increase risk awareness	
	Relocate moveable assets including vehicles	
Resilient Strategy 1	Wet floodproof warehouse and ice storage facility below DFE, elevate mechanical systems/utilities	Strategy 1 provides protection to critical assets through approaches that establish protection of an asset on an individual basis. No passive flood protection measures or site-wide approaches are recommended with this strategy.
	Elevate marine loading platform to DFE, elevate / adapt mooring and berthing systems	
Resilient Strategy 2	Elevate site grade and all buildings/structures to DFE	Strategy 2 incorporates the asset scale elevation approach in Strategy 1 with a site-wide grade elevation to the DFE.

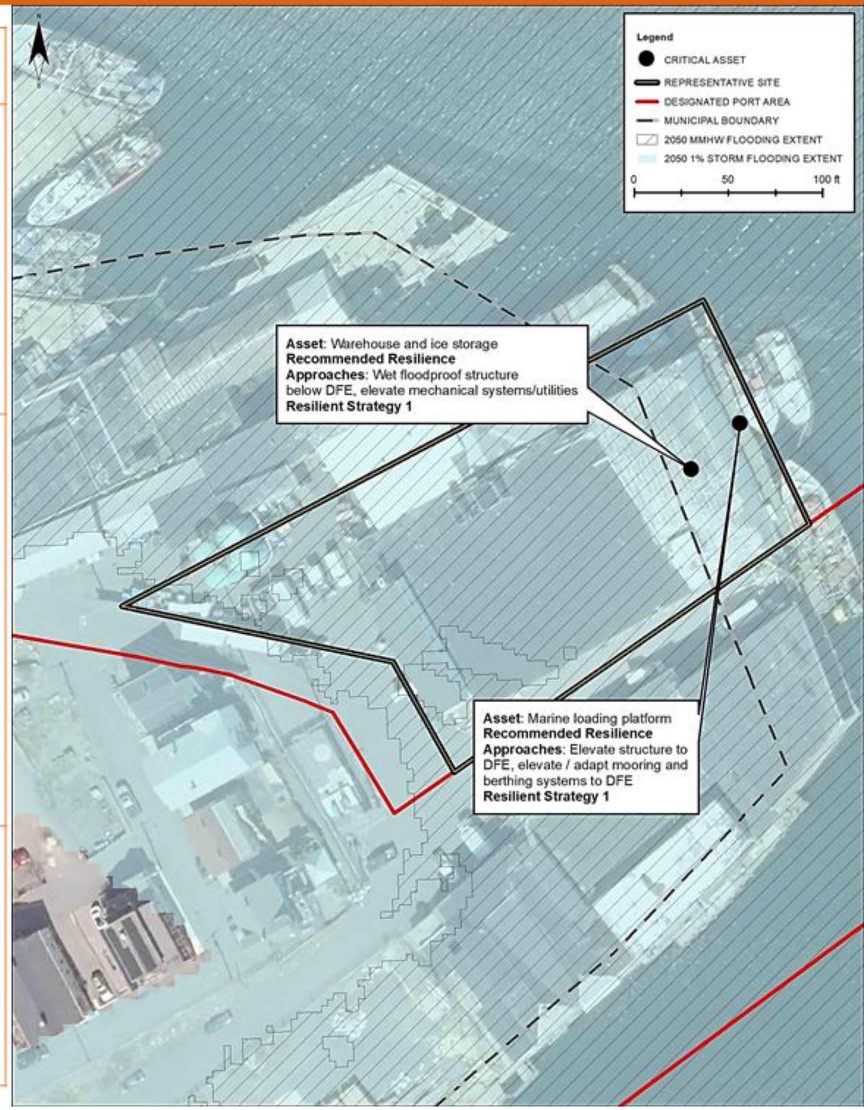


Figure 23 – Summary of Resilient Strategies for Cape Pond Ice

Resilient Strategies for Harbormaster's Office – Marine Support and Safety

The Harbormaster's office and the pier are the two critical assets on this site. The site has been designed for flood protection against the current 1% annual chance storm so building-level approaches typically recommended in Resilient Strategy 1 are not immediately necessary. However, as sea levels rise and storms become more frequent and/or more intense, both assets may be affected by flooding. The Harbormaster's office can continue to be resilient to flooding by developing a flood preparedness plan. The plan can help site owners and users understand the impacts of flooding on the site and how they can be prevented through other easily implemented resilience approaches like purchasing and maintaining flood insurance, increasing risk awareness, and relocating moveable assets to low flood risk locations prior to a flood event.

At the conclusion of the useful life of the existing structures on the site, **Resilient Strategy 2** recommends elevation of grade at the site or relocation of assets to lower flood risk locations, such as higher ground across Harbor Loop Road. Maintaining site access during more severe flood events is also something that should be considered in developing a longer-term plan.

Resilient Strategies – Harbormaster's Office

Resilient Strategy	Resilience Approaches	Strategy Description
Applicable to All Strategies	Develop Flood Preparedness Plan	Although this site is designed for flood protection against the present day 1% annual chance storm, it is recommended that all Easy-Win resilience approaches be implemented on site as they aid in building consensus around existing and future resilience approaches.
	Purchase and maintain flood insurance	
	Increase risk awareness	
	Relocate moveable assets including vehicles	
Resilient Strategy 2	Elevation of site and/or relocate of uses and buildings to lower flood risk location, potentially to higher ground across Harbor Loop	Strategy 2 recommends elevation of the site or relocation to lower flood risk locations such as higher ground across Harbor Loop road after the useful life of the existing structures is exceeded.

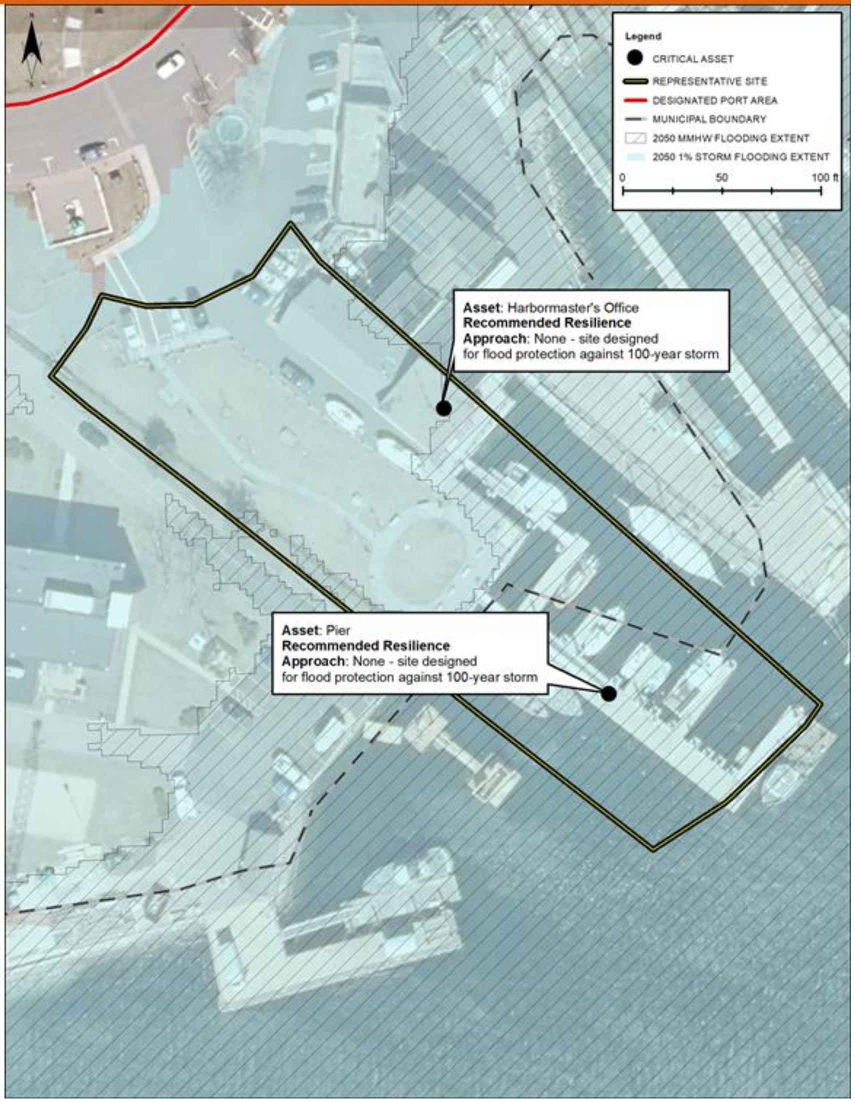


Figure 24 – Summary of Resilient Strategies for the Harbormaster's Office

Resilient Strategies for I4C2 – Vacant Site

I4C2 is a vacant lot with two critical assets – a sheet pile wall and commercial dockage. As the site has not yet been developed, the recommended approaches should be considered with any future WDIU development of the site. Because the site has not yet been developed, there is an opportunity to develop the site in ways that consider future flood risk.

As with the other sites, a developed I4C2 site would also benefit from implementing easy win resilience approaches. Developing a flood preparedness plan in coordination with construction on the site can help site owners and users understand the impacts of flooding on the site and how they can be prevented through other easily implemented resilience approaches like purchasing and maintaining flood insurance, increasing risk awareness, and relocating moveable assets to low flood risk locations prior to a flood event.

Because I4C2 has not been developed, **Resilient Strategy 1** presents a unique opportunity to elevate site grade before development. Whether the site is elevated to current or future DFE would depend on the operational needs of the site and relative vulnerability of its assets over the intended deign life. If elevating the site to DFE is not feasible given the intended use, **Resilient Strategy 2** recommends all utilities and critical assets should be sited in lower risk areas or elevated to the DFE. The study team recommends any infrastructure on site be built to withstand at least the 2070 flood conditions given an assumed 50 year useful life of the infrastructure.

Resilient Strategies – I4C2 – *Future Development*

Resilient Strategy	Resilience Approaches	Strategy Description
Applicable to All Future Strategies	Develop Flood Preparedness Plan	Although this site is vacant, it is recommended that all Easy-Win resilience approaches be implemented on site in its existing condition and with future development as they aid in building consensus around future resilience approaches.
	Purchase and maintain flood insurance	
	Increase risk awareness	
	Relocate moveable assets including vehicles	
Resilient Strategy 1	Elevate site grade and all future buildings/structures to DFE	Strategy 1 is preferred for this undeveloped site. Before development, elevating the site grade to DFE or future DFE is recommended.
Resilient Strategy 1	Design location of utilities and critical assets at or above 2070 DFE	If Strategy 1 is not feasible, Strategy 2 can be implemented to build resilience of the site to future flood risk.
	Floodproof buildings and assets if 2070 flood exposure is expected	

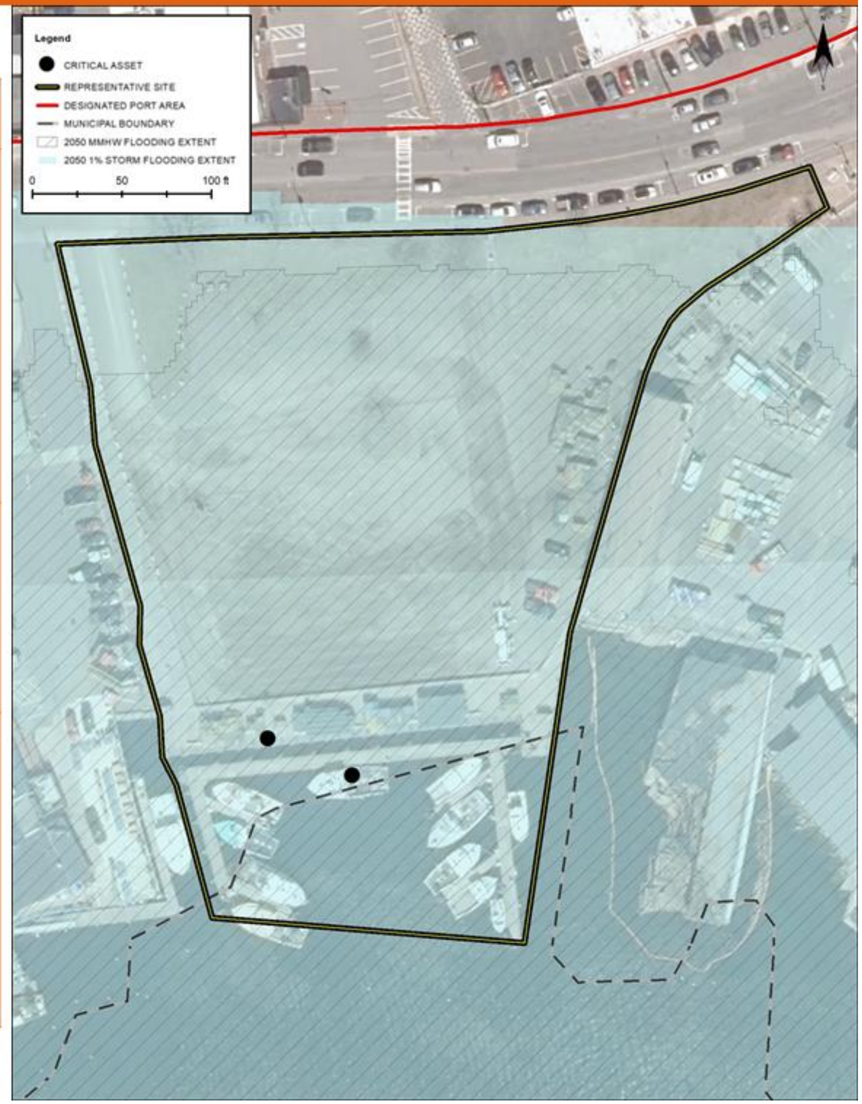


Figure 25 – Summary of Resilient Strategies for I4C2

6. Conclusion

Increasing risks from climate change, especially flooding, pose a significant threat to the long-term health and viability of DPAs across the Commonwealth of Massachusetts. Nearly all infrastructure within the Chelsea Creek and Gloucester Inner Harbor DPAs is exposed to flooding today and the risks associated with flooding will only increase with projected sea level rise over the coming decades.

WDIUs can take action today to reduce their flood risk through easy win resilience approaches identified in this study. Easy win approaches like these can be implemented within a year, help get additional stakeholders involved in the conversation, bring attention to the urgency of these issues, and start building consensus around resilience strategies that are more costly or difficult to implement. In many cases, these easy win approaches serve as a necessary foundation for more time and capital-intensive resilience measures such as elevation and floodproofing of assets.

What WDIUs can do next to build resilience

- Stay up to date on Massachusetts resilience news and resources! Learn more about the Resilient MA Action Team (RMAT) and explore their resources here.
- Get in touch with your Massachusetts CZM Regional Coordinator to take the next steps to build resilience at your site.
- Speak with a licensed professional about implementing resilience strategies like those included in this report
- Work with your municipal officials and coordinate efforts with other stakeholders where feasible.

Appendix A – Representative Site Property Cards

Included as attachment.

Massachusetts Office of Coastal Zone Management

ARCADIS

Building Climate Resilience in Massachusetts' Designated Port Areas

Chelsea Creek DPA Property Card

This form is intended to summarize our understanding of the uses, assets, and critical site features of water dependent industrial uses in the Chelsea Creek Designated Port Area. The purpose of this existing conditions data is to inform a flood risk and vulnerability analysis for each site as part of the Building Resilience in Massachusetts Designated Port Areas project led by the Massachusetts Office of Coastal Zone Management. Questions or comments may be directed to Erikk Hokenson at erikk.hokenson@state.ma.us or by calling 617-626-1234

Primary Contact Information

Name: **Shelagh Mahoney**

Phone Number: **978-251-8553; 617-884-5201**

Email: **smahoney@easternsalt.com**

Site Information

Site Name/Business: **Eastern Minerals**

Address: **99 MARGINAL ST, CHELSEA, MA,02150**

USE (Industrial, Commercial, Mixed Use, etc.): **Commercial**

Site Description: **Dry bulk terminal**

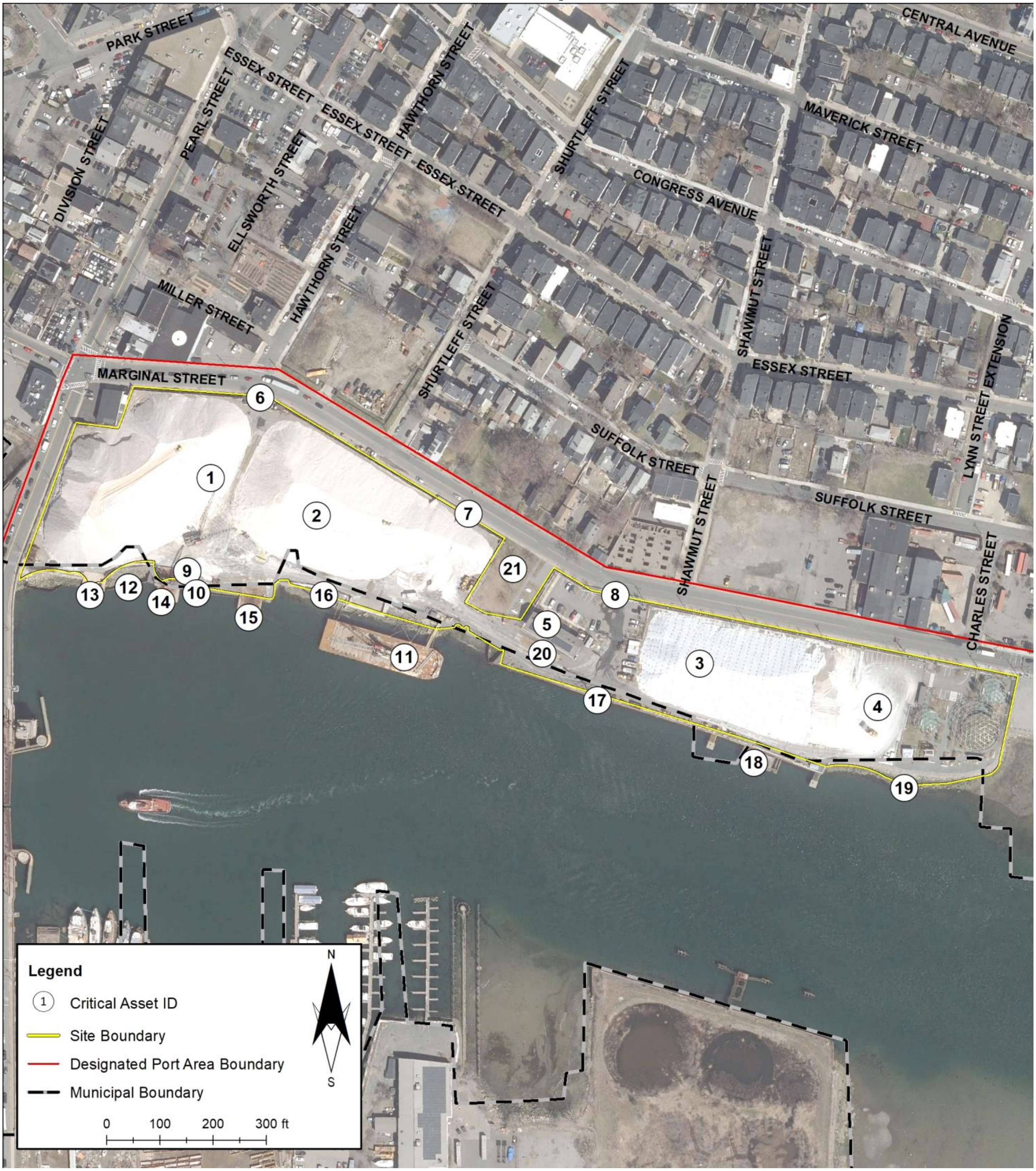
Services: **Salt storage and supply**

Key Adjacencies: **Andrew McArdle Bridge, PORT Park**
(if applicable)

Massachusetts Office of Coastal Zone Management

ARCADIS

Site Map



Asset Inventory: Eastern Minerals									
Map ID #	Asset or System	Description	Critical Elevation (ft-NAVD88)	Ranking Criticality	Loss of Service Consequences	Flood Exposure MMHW	Flood Exposure 1.0% Storm	Flood Type	Recommended Resilience Approaches*
1	Secondary structure	Western salt storage area	10.1	High	Loss of material and waterbody pollution	2030	2020	Fringe	Elevate grade above future monthly high tide, deployable flood barriers
2	Secondary structure	Central salt storage area	9.44	High	Loss of material and waterbody pollution	2030	2020	Fringe	Elevate grade above future monthly high tide, deployable flood barriers
3	Secondary structure	Eastern salt storage area	12	High	Loss of material and waterbody pollution	2070	2020	Fringe	Elevate grade above future monthly high tide, deployable flood barriers
4	Secondary structure	Seasonal salt storage area	13.2	Medium	Loss of material and waterbody pollution	Beyond 2070	2030	Fringe	Elevate grade above future monthly high tide, deployable flood barriers
5	First / Finished Floor	Office building	12.5	Medium	Loss of administration and operations support	2050	2020	Fringe	Dry floodproof structure below future monthly high tide, elevate mechanical systems/utilities
6	Vehicular site access	Marginal St. Entrance 1	11	High	Loss of vehicular access and material distribution	2070	Beyond 2070	Fringe	Raise road/site access above future monthly high tide
7	Vehicular site access	Marginal St. Entrance 2	10.1	High	Loss of vehicular access and material distribution	2070	2030	Fringe	Raise road/site access above future monthly high tide
8	Vehicular site access	Marginal St. Entrance 3	10.2	High	Loss of vehicular access and material distribution	2050	2030	Fringe	Raise road/site access above future monthly high tide
9	Shipping / Receiving	Top of dock / unloading area	9.2	High	Loss of material supply and distribution	2030	2020	Fringe	Elevate grade above future monthly high tide
10	Shoreline	Z-Pile bulkhead	8	High	Increased site erosion and flooding leading to disruption in operations	2020	2020	Fringe	Elevate bulkhead above future monthly high tide
11	Equipment	Floating barge w/ crawler	Water level	High	Equipment damage and loss of material unloading and distribution operations	2020	2020	Fringe	Elevate/adapt mooring and berthing systems to future monthly high tide

*All DFE determinations should consider criticality and be made on an asset by asset basis in consultation with a qualified professional. Accessibility to the waterfront and maintaining waterside functionality are important considerations if implementing any strategy including the elevation of shoreline infrastructure.

Asset Inventory: Eastern Minerals									
Map ID #	Asset or System	Description	Critical Elevation (ft-NAVD88)	Ranking Criticality	Loss of Service Consequences	Flood Exposure MMHW	Flood Exposure 1.0% Storm	Flood Type	Recommended Resilience Approaches*
12	Shoreline	Batter and lagging wall	7.5	High	Increased site erosion and flooding leading to disruption in operations	2020	2020	Fringe	Elevate structure above future monthly high tide
13	Equipment	Crane pad	10.1	High	Loss of material unloading and disruption in distribution operations	2070	2020	Fringe	Elevate structure above future monthly high tide
14	Equipment	Crane pad	10.24	High	Loss of material unloading and disruption in distribution operations	2070	2020	Fringe	Elevate structure above future monthly high tide
15	Equipment	Crane pad	10.5	High	Loss of material unloading and disruption in distribution operations	2070	2020	Fringe	Elevate structure above future monthly high tide
16	Shoreline	Rip-Rap shoreline	9.1	High	Increased site erosion and flooding leading to disruption in operations	2020	2020	Fringe	Elevate shoreline protection above future monthly high tide
17	Shoreline	Z-Pile bulkhead	10	High	Increased site erosion and flooding leading to disruption in operations	2020	2020	Fringe	Elevate bulkhead above future monthly high tide
18	Shipping / Receiving	Marine loading platform	10	High	Loss of material unloading and distribution operations	2020	2020	Fringe	Elevate structure and adapt mooring and berthing systems above future monthly high tide
19	Shoreline	Rip-Rap shoreline	11.7	High	Increased site erosion and flooding leading to disruption in operations	2020	2020	Fringe	Elevate shoreline protection above future monthly high tide
20	Equipment	Truck scales	10.2	Medium	Safety hazard due to potential for overweight distribution vehicles	2070	2020	Fringe	Elevate system above future monthly high tide, relocate to low flood risk location
21	Utility	MWRA subterranean water supply lines and parcel	9.2	High	Loss of water supply	2050	2020	Fringe	Structural stormwater BMPs, assessment of sea level rise impacts to water table

*All DFE determinations should consider criticality and be made on an asset by asset basis in consultation with a qualified professional. Accessibility to the waterfront and maintaining waterside functionality are important considerations if implementing any strategy including the elevation of shoreline infrastructure.

Building Climate Resilience in Massachusetts' Designated Port Areas

Chelsea Creek DPA Property Card

This form is intended to summarize our understanding of the uses, assets, and critical site features of water dependent industrial uses in the Chelsea Creek Designated Port Area. The purpose of this existing conditions data is to inform a flood risk and vulnerability analysis for each site as part of the Building Resilience in Massachusetts Designated Port Areas project led by the Massachusetts Office of Coastal Zone Management. Questions or comments may be directed to Erikk Hokenson at erikk.hokenson@state.ma.us or by calling 617-626-1234

Primary Contact Information

Name: **Christopher Gill**

Phone Number: **339-933-7046**

Email: **CGill@gulfoil.com**

Site Information

Site Name/Business: **Gulf Oil**

Address: **123 - 283 EASTERN AVE, CHELSEA, MA, 02150**

USE (Industrial, Commercial, Mixed Use, etc.): **Industrial**

Site Description: **Liquid bulk terminal**

Services: **Oil and petrochemical storage and supply**

Key Adjacencies: **PreFlight Parking**
(if applicable)

Massachusetts Office of Coastal Zone Management

ARCADIS

Site Map

Massachusetts Office of Coastal Zone Management

ARCADIS

Asset Inventory: Gulf Oil									
Map ID #	Asset or System	Description	Critical Elevation (ft-NAVD88)	Ranking Criticality	Loss of Service Consequences	Flood Exposure MMHW	Flood Exposure 1.0% Storm	Flood Type	Recommended Resilience Approaches*
1	Tanks (outdoors)	Oil storage tank 1	6.59	High	Loss of product and waterbody pollution	2020	2020	Fringe	Deployable flood barriers
2	Tanks (outdoors)	Oil storage tank 2	6.16	High	Loss of product and waterbody pollution	2020	2020	Fringe	Deployable flood barriers
3	Tanks (outdoors)	Oil storage tank 3	7.31	High	Loss of product and waterbody pollution	2020	2030	Fringe	Deployable flood barriers
4	Tanks (outdoors)	Oil storage tank 4	7.31	High	Loss of product and waterbody pollution	2020	2020	Pathway	Deployable flood barriers
5	Tanks (outdoors)	Oil storage tank 5	6.36	High	Loss of product and waterbody pollution	2020	2020	Fringe	Deployable flood barriers
6	Tanks (outdoors)	Oil storage tank 6	6.06	High	Loss of product and waterbody pollution	2020	2020	Pathway	Deployable flood barriers
7	Tanks (outdoors)	Oil storage tank 7	6.16	High	Loss of product and waterbody pollution	2020	2020	Pathway	Deployable flood barriers
8	Tanks (outdoors)	Oil storage tank 8	6.43	High	Loss of product and waterbody pollution	2020	2020	Pathway	Deployable flood barriers
9	Tanks (outdoors)	Oil storage tank 9	6.26	High	Loss of product and waterbody pollution	2020	2020	Pathway	Deployable flood barriers
10	Tanks (outdoors)	Oil storage tank 10	6.69	High	Loss of product and waterbody pollution	2020	2020	Fringe	Deployable flood barriers
11	Tanks (outdoors)	Oil storage tank 11	6.75	High	Loss of product and waterbody pollution	2020	2020	Pathway	Deployable flood barriers

*All DFE determinations should consider criticality and be made on an asset by asset basis in consultation with a qualified professional. Accessibility to the waterfront and maintaining waterside functionality are important considerations if implementing any strategy including the elevation of shoreline infrastructure.

Asset Inventory: Gulf Oil									
Map ID #	Asset or System	Description	Critical Elevation (ft-NAVD88)	Ranking Criticality	Loss of Service Consequences	Flood Exposure MMHW	Flood Exposure 1.0% Storm	Flood Type	Recommended Resilience Approaches*
12	Tanks (outdoors)	Oil storage tank 12	7.41	High	Loss of product and waterbody pollution	2020	2020	Pathway	Deployable flood barriers
13	Tanks (outdoors)	Oil storage tank 13	7.34	High	Loss of product and waterbody pollution	2030	2020	Pathway	Deployable flood barriers
14	Tanks (outdoors)	Oil storage tank 14	6.36	High	Loss of product and waterbody pollution	2020	2030	Fringe	Deployable flood barriers
15	Tanks (outdoors)	Oil storage tank 15	6.52	High	Loss of product and waterbody pollution	2020	2020	Pathway	Deployable flood barriers
16	Tanks (outdoors)	Oil storage tank 16	7.11	High	Loss of product and waterbody pollution	2020	2020	Pathway	Deployable flood barriers
17	Tanks (outdoors)	Oil storage tank 17	6.16	High	Loss of product and waterbody pollution	2020	2020	Pathway	Deployable flood barriers
18	Tanks (outdoors)	Oil storage tank 18	6.82	High	Loss of product and waterbody pollution	2020	2020	Pathway	Deployable flood barriers
19	Shipping / Receiving	Marine loading platform	3.9	High	Loss of product supply to site	2020	2020	Fringe	Elevate structure to DFE, adapt mooring and berthing systems to DFE
20	Vehicular site access	Eastern Ave. Entrance Gate 4	8.0	Low	Loss of vehicular access	2030	2020	Fringe	Raise road/site access to DFE
21	First / Finished Floor	Foam house	8.33	High	Fire suppression failure and waterbody pollution	2030	2020	Fringe	Elevate structure to DFE, dry floodproof structure below DFE, elevate mechanical systems/utilities
22	First / Finished Floor	Motor control center	7.84	Medium	Motor control failure, disruption in product distribution	2030	2020	Pathway	Elevate structure to DFE, dry floodproof structure below DFE, elevate mechanical systems/utilities

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Massachusetts Office of Coastal Zone Management

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Asset Inventory: Gulf Oil									
Map ID #	Asset or System	Description	Critical Elevation (ft-NAVD88)	Ranking Criticality	Loss of Service Consequences	Flood Exposure MMHW	Flood Exposure 1.0% Storm	Flood Type	Recommended Resilience Approaches*
23	First / Finished Floor	Building	8.0	Low	Disruption in site maintenance and operations	2030	2020	Pathway	Elevate structure to DFE, dry floodproof structure below DFE, elevate mechanical systems/utilities
24	First / Finished Floor	Office building	8.62	Low	Loss of administration and operations support	2030	2020	Pathway	Dry floodproof structure below DFE, elevate mechanical systems/utilities
25	Vehicular site access	Eastern Ave. Entrance Gate 3	8.0	Low	Loss of vehicular access	2030	2020	Pathway	Raise road/site access to DFE
26	First / Finished Floor	Garage at Gate 2	8.07	Low	Loss of vehicular access	2020	2020	Pathway	Elevate structure to DFE, dry floodproof structure below DFE, elevate mechanical systems/utilities
27	First / Finished Floor	Garage at Gate 1	8.2	Low	Loss of vehicular access	2020	2020	Pathway	Elevate structure to DFE, dry floodproof structure below DFE, elevate mechanical systems/utilities
28	Vehicular site access	Eastern Ave. Entrance Gate 2	7.05	High	Loss of vehicular access to loading rack, disruption in product distribution	2030	2020	Pathway	Raise road/site access to DFE
29	Vehicular site access	Eastern Ave. Entrance Gate 1	6.59	High	Loss of vehicular access to loading rack, disruption in product distribution	2020	2020	Pathway	Raise road/site access to DFE
30	Secondary structure	Loading rack	7.15	High	Loss of product distribution	2030	2020	Pathway	Elevate structure and system to DFE, deployable flood barriers
31	Secondary structure	Water retention pond	10.2	Medium	Increased site flooding	2070	2030	Fringe	Improve site drainage / runoff management
32	Spill prevention	Chemical spill berms	14.4	High	Chemical spill exposure and waterbody pollution	2020	2020	Fringe	Elevate structure to DFE
33	Spill prevention	Chemical spill berms	16.9	High	Chemical spill exposure and waterbody pollution	2020	2020	Fringe	Elevate structure to DFE

*All DFE determinations should consider criticality and be made on an asset by asset basis in consultation with a qualified professional. Accessibility to the waterfront and maintaining waterside functionality are important considerations if implementing any strategy including the elevation of shoreline infrastructure.

Asset Inventory: Gulf Oil									
Map ID #	Asset or System	Description	Critical Elevation (ft-NAVD88)	Ranking Criticality	Loss of Service Consequences	Flood Exposure MMHW	Flood Exposure 1.0% Storm	Flood Type	Recommended Resilience Approaches*
34	Spill prevention	Chemical spill berms	15.1	High	Chemical spill exposure and waterbody pollution	2020	2020	Fringe	Elevate structure to DFE
35	Shoreline	Z-Pile bulkhead	4.3	High	Increased site erosion and flooding leading to disruption in operations	2020	2020	Fringe	Elevate bulkhead to DFE
36	Shoreline	Rip-Rap shoreline	7.9	High	Increased site erosion and flooding leading to disruption in operations	2020	2020	Fringe	Elevate shoreline protection to DFE
37	Shoreline	Z-Pile bulkhead	7.2	High	Increased site erosion and flooding leading to disruption in operations	2020	2020	Fringe	Elevate bulkhead to DFE
38	Shoreline	Rip-Rap shoreline	5.6	High	Increased site erosion and flooding leading to disruption in operations	2020	2020	Fringe	Elevate shoreline protection to DFE

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Primary Contact Information

Name: **David Gazda, John Scola**

Phone Number: **978-283-3000**

Email: **David.Gazda@Gortons.com, John.Scola@Gorto**

Site Information

Site Name/Business: **Gorton's**

Address: **127 ROGERS ST, GLOUCESTER, MA, 01930**

USE (Industrial, Commercial, Mixed Use, etc.): **Industrial**

Site Description: **Fish/seafood processing facility and cold storage**

Services: **Fishing Industry**

Key Adjacencies: **National Grid Substation, Americold Logistics**
(if applicable)

Massachusetts Office of Coastal Zone Management

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Site Map

Massachusetts Office of Coastal Zone Management

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Asset Inventory: Gorton's									
Map ID #	Asset or System	Description	Critical Elevation (ft-NAVD88)	Ranking Criticality	Loss of Service Consequences	Flood Exposure MMHW	Flood Exposure 1.0% Storm	Flood Type	Recommended Resilience Approaches*
1	First / Finished Floor	Laboratory	8	Medium	Loss of building use and disruption to operations	2050	2050	Fringe	Dry floodproof structure below DFE, elevate mechanical systems/utilities
2	Vehicular site access	Below grade parking lot	8	Low	Loss of vehicular access	2050	2050	Fringe	Raise road/site access to DFE
3	First / Finished Floor	Main office	12	High	Loss of administration and operations support	2070	2050	Fringe	Dry floodproof structure below DFE, elevate mechanical systems/utilities
4	Utility	Transformer	18	High	Loss of electrical supply leading to disruption in production and site operations	Beyond 2070	2070	Fringe	Elevate structure to DFE or deployable flood barriers
5	Vehicular site access	Rogers Street Entrance	18	High	Loss of vehicular access and product distribution	Beyond 2070	Beyond 2070	Fringe	Raise road/site access to DFE
6	Utility	High voltage electrical enclosure	20	High	Loss of electrical supply leading to disruption in production and site operations	Beyond 2070	Beyond 2070	Fringe	Elevate structure to DFE, deployable flood barriers
7	Storage	Storage silos (2)	14	Medium	Loss of material supply leading to disruption in production	Beyond 2070	2070	Fringe	Elevate structure to DFE, deployable flood barriers
8	Utility	Transformer	9	High	Electrical failure and loss of site operations	2050	2030	Fringe	Elevate structure to DFE, deployable flood barriers
9	Utility	Wastewater management system	9	High	Wastewater backup and potential waterbody pollution, disruption in production	2050	2030	Fringe	Elevate system to DFE, deployable flood barriers

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Asset Inventory: Gorton's									
Map ID #	Asset or System	Description	Critical Elevation (ft-NAVD88)	Ranking Criticality	Loss of Service Consequences	Flood Exposure MMHW	Flood Exposure 1.0% Storm	Flood Type	Recommended Resilience Approaches*
10	Utility	Wastewater holding tank	11	High	Wastewater backup and potential waterbody pollution, disruption in production	Beyond 2070	Beyond 2070	Fringe	Elevate structure to DFE, deployable flood barriers
11	First / Finished Floor	Maintenance office	20	High	Loss of administration and operations support	Beyond 2070	Beyond 2070	Fringe	Dry floodproof structure below DFE, elevate mechanical systems/utilities
12	Manufacturing	Manufacturing plant	12	High	Loss of production	2050	2020	Fringe	Dry/wet floodproof structure below DFE, elevate mechanical systems/utilities
13	Equipment	Americold engine room	8	High	Loss of production	2050	2020	Fringe	Elevate structure to DFE, dry floodproof structure below DFE, elevate mechanical systems/utilities, relocate asset
14	Shipping / Receiving	Loading dock	8	High	Loss of shipping and receiving operations	2050	2020	Fringe	Elevate structure to DFE
15	Manufacturing	Americold warehouse	12	High	Loss of production	2050	2020	Fringe	Dry/wet floodproof structure below DFE, elevate mechanical systems/utilities

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Primary Contact Information

Name: **Michael De Koster**

Phone Number: **978-281-0470**

Email: **mdekoster@maritimegloucester.org**

Site Information

Site Name/Business: **Maritime Gloucester**

Address: **19-23 HARBOR LP, GLOUCESTER, MA, 01930**

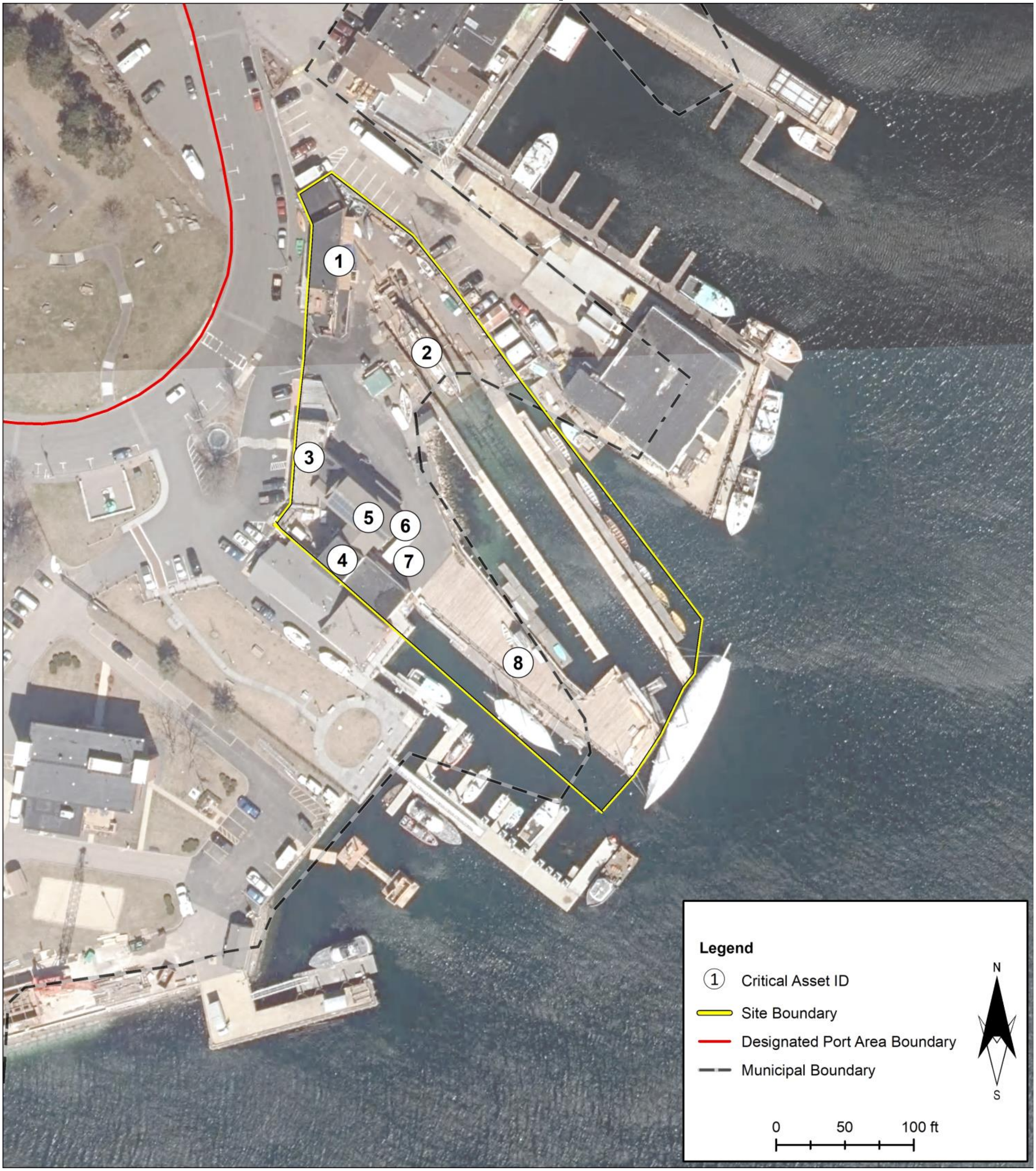
USE (Industrial, Commercial, Mixed Use, etc.): **Other**

Site Description: **Maritime museum, marine railway and boat repair**

Services: **Vessel repair and maintenance, historical and cultural education**

Key Adjacencies: **Office of the Harbormaster, Star Fisheries**
(if applicable)

Site Map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Legend
1 Critical Asset ID
Site Boundary
Designated Port Area Boundary
Municipal Boundary
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Massachusetts Office of Coastal Zone Management

ARCADIS

Asset Inventory: Maritime Gloucester									
Map ID #	Asset or System	Description	Critical Elevation (ft-NAVD88)	Ranking Criticality	Loss of Service Consequences	Flood Exposure MMHW	Flood Exposure 1.0% Storm	Flood Type	Recommended Resilience Approaches*
1	First / Finished Floor	Historic mill building	10	Medium	Loss of building use	2030	2020	Fringe	Dry floodproof structure below DFE, elevate mechanical systems/utilities, fill structure basement,
2	Secondary Structure	Marine railway	1	High	Loss of vessel repair and storage	2020	2020	Fringe	Wet floodproof structure below DFE
3	First / Finished Floor	Museum	12	High	Loss of building use and museum artifacts	2030	2020	Fringe	Elevate structure to DFE or dry floodproof structure below DFE, elevate mechanical systems/ utilities
4	First / Finished Floor	Aquarium	7	High	Loss of access, building use, and safety threat to animals	2020	2020	Fringe	Elevate structure to DFE or dry/wet floodproof structure below DFE, elevate mechanical systems/ utilities
5	First / Finished Floor	Educational classroom	7	Medium	Loss of building use and programs	2030	2020	Fringe	Dry floodproof structure below DFE, elevate mechanical systems/utilities
6	Utility	Motor control center	7	High	Electrical and mechanical failure leading to disruption in operations	2030	2020	Fringe	Elevate structure to DFE , dry floodproof structure below DFE, or relocate system to low flood risk location
7	Secondary Structure	Seasonal tent area	7	Low	Loss of tent utilization	2020	2020	Fringe	Relocate structure/use to low flood risk location
8	Marine Transportation	Pier	0	Medium	Loss of access to ships, potential damage to ships	2020	2020	Fringe	Elevate structure to DFE, elevate / adapt mooring and berthing systems to DFE

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Massachusetts Office of Coastal Zone Management

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Primary Contact Information

Name: **Patrick Scalli**

Phone Number: **617-330-2047**

Email: **pscalli@massdevelopment.com**

Site Information

Site Name/Business: **Jodrey State Fish Pier**

Address: **3 STATE PIER, GLOUCESTER, MA, 01930**

USE (Industrial, Commercial, Mixed Use, etc.): **Mixed**

Site Description: **Multi-use pier**

Services: **Fishing/lobster industry, marine operations and safety**

Key Adjacencies: **Yankee Marine Service**
(if applicable)

Massachusetts Office of Coastal Zone Management

ARCADIS

Site Map

Massachusetts Office of Coastal Zone Management

ARCADIS

Asset Inventory: Jodrey State Fish Pier									
Map ID #	Asset or System	Description	Critical Elevation (ft-NAVD88)	Ranking Criticality	Loss of Service Consequences	Flood Exposure MMHW	Flood Exposure 1.0% Storm	Flood Type	Recommended Resilience Approaches*
1	Vehicular site access	State Fish Pier Entrance	9	High	Loss of vehicular access and product distribution	2070	2030	Fringe	Raise road/site access to DFE
2	Utility	Main transformer	9	High	Electrical failure and loss of production and site operations	2070	2030	Fringe	Elevate structure to DFE, deployable flood barriers
3	First / Finished Floor	Massachusetts Environmental Police building	10	High	Loss of access and safety operations within harbor	2070	2020	Fringe	Elevate structure to DFE or dry floodproof structure below DFE, elevate mechanical systems/utilities
4	Manufacturing	Warehouse for fishing/lobster industry	10	High	Loss of product, equipment, and distribution	2020	2020	Fringe	Wet floodproof structure below DFE, elevate mechanical systems/utilities
5	Marine Transportation	Coast Guard dock	0	High	Loss of access to safety vessels, potential damage to structure	2020	2020	Fringe	Elevate structure to DFE, elevate / adapt mooring and berthing systems to DFE
6	Shipping / Receiving	North warf	0	High	Loss of marine access for shipping and receiving	2020	2020	Fringe	Elevate structure to DFE, elevate / adapt mooring and berthing systems to DFE
7	Marine Transportation	Dock	0	Low	Loss of material supply for production	2020	2020	Fringe	Elevate structure to DFE, elevate / adapt mooring and berthing systems to DFE
8	Manufacturing	Warehouse for fishing/lobster industry	0	High	Loss of product, equipment, and distribution	2020	2020	Fringe	Wet floodproof structure below DFE, elevate mechanical systems/utilities
9	Shipping / Receiving	Loading docks	7	High	Loss of shipping to warehouses and distribution to customers	2020	2020	Fringe	Elevate structure to DFE

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Massachusetts Office of Coastal Zone Management

ARCADIS

Asset Inventory: Jodrey State Fish Pier									
Map ID #	Asset or System	Description	Critical Elevation (ft-NAVD88)	Ranking Criticality	Loss of Service Consequences	Flood Exposure MMHW	Flood Exposure 1.0% Storm	Flood Type	Recommended Resilience Approaches*
10	Marine Transportation	Docks	8	Medium	Loss of access to boats, potential damage to structure	2020	2020	Fringe	Elevate structure to DFE, elevate / adapt mooring and berthing systems to DFE
11	Utility	Electrical enclosure	8	Medium	Electrical failure on docks	2050	2020	Fringe	Elevate structure to DFE, deployable flood barriers

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Building Climate Resilience in Massachusetts' Designated Port Areas

Gloucester Inner Harbor DPA Property Card

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Primary Contact Information

Name: **Rick Kohn**

Phone Number: **978-283-0174**

Email: **rwkohn1@gmail.com**

Site Information

Site Name/Business: **Cape Pond Ice**

Address: **80 - 104 COMMERCIAL ST, GLOUCESTER, MA, 01930**

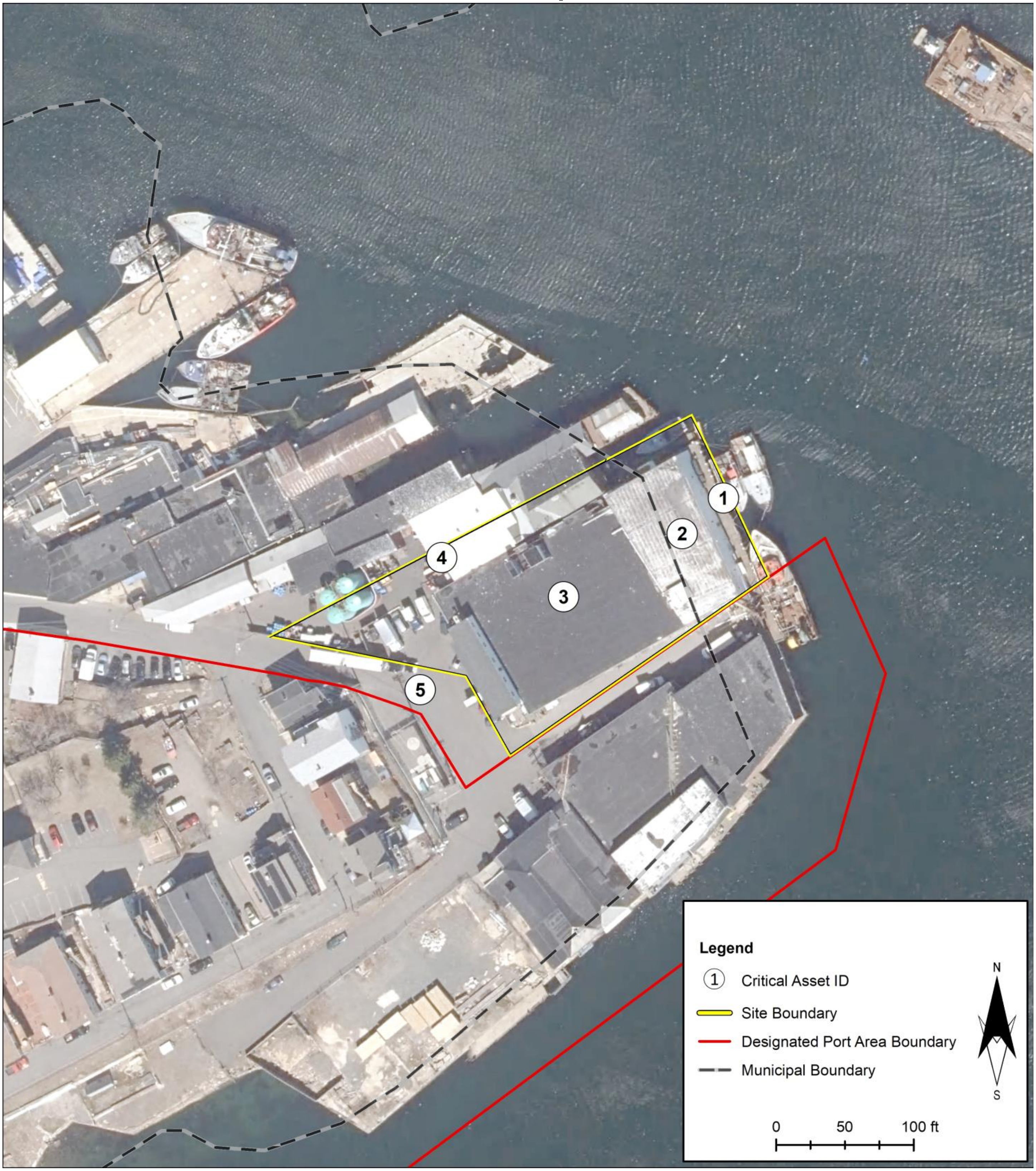
USE (Industrial, Commercial, Mixed Use, etc.): **Industrial**

Site Description: **Ice supply facility, marine supply**

Services: **Fishing Industry**

Key Adjacencies: **Residential Building to the south**
(if applicable)

Site Map



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Critical Asset ID
Site Boundary
Designated Port Area Boundary
Municipal Boundary
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Massachusetts Office of Coastal Zone Management

ARCADIS

Asset Inventory: Cape Pond Ice									
Map ID #	Asset or System	Description	Critical Elevation (ft-NAVD88)	Ranking Criticality	Loss of Service Consequences	Flood Exposure MMHW	Flood Exposure 1.0% Storm	Flood Type	Recommended Resilience Approaches*
1	Shipping / Receiving	Marine loading platform	0	High	Loss of product distribution	2020	2020	Fringe	Elevate structure to DFE, elevate / adapt mooring and berthing systems to DFE
2	Manufacturing	Warehouse and ice storage	0	High	Loss of production, damage to equipment	2020	2020	Fringe	Wet floodproof structure below DFE, elevate mechanical systems/utilities
3	First / Finished Floor	Vacant building	5	Low	Loss of building use and storage	2020	2020	Fringe	Dry floodproof structure below DFE, elevate mechanical systems/utilities
4	Shipping / Receiving	Loading dock	7	Medium	Loss of shipping and receiving access and operations	2030	2020	Fringe	Elevate structure to DFE
5	Vehicular site access	Commercial Street entrance	9	Low	Loss of vehicular access	2050	2030	Fringe	Raise road/site access to DFE

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Primary Contact Information

Name: **TJ Ciarametaro**

Phone Number: **978-325-5750**

Email: **TCiarametaro@gloucester-ma.gov**

Site Information

Site Name/Business: **Harbormaster's Office**

Address: **19-23 HARBOR LP, GLOUCESTER, MA, 01930**

USE (Industrial, Commercial, Mixed Use, etc.): **Other**

Site Description: **Marine support and safety**

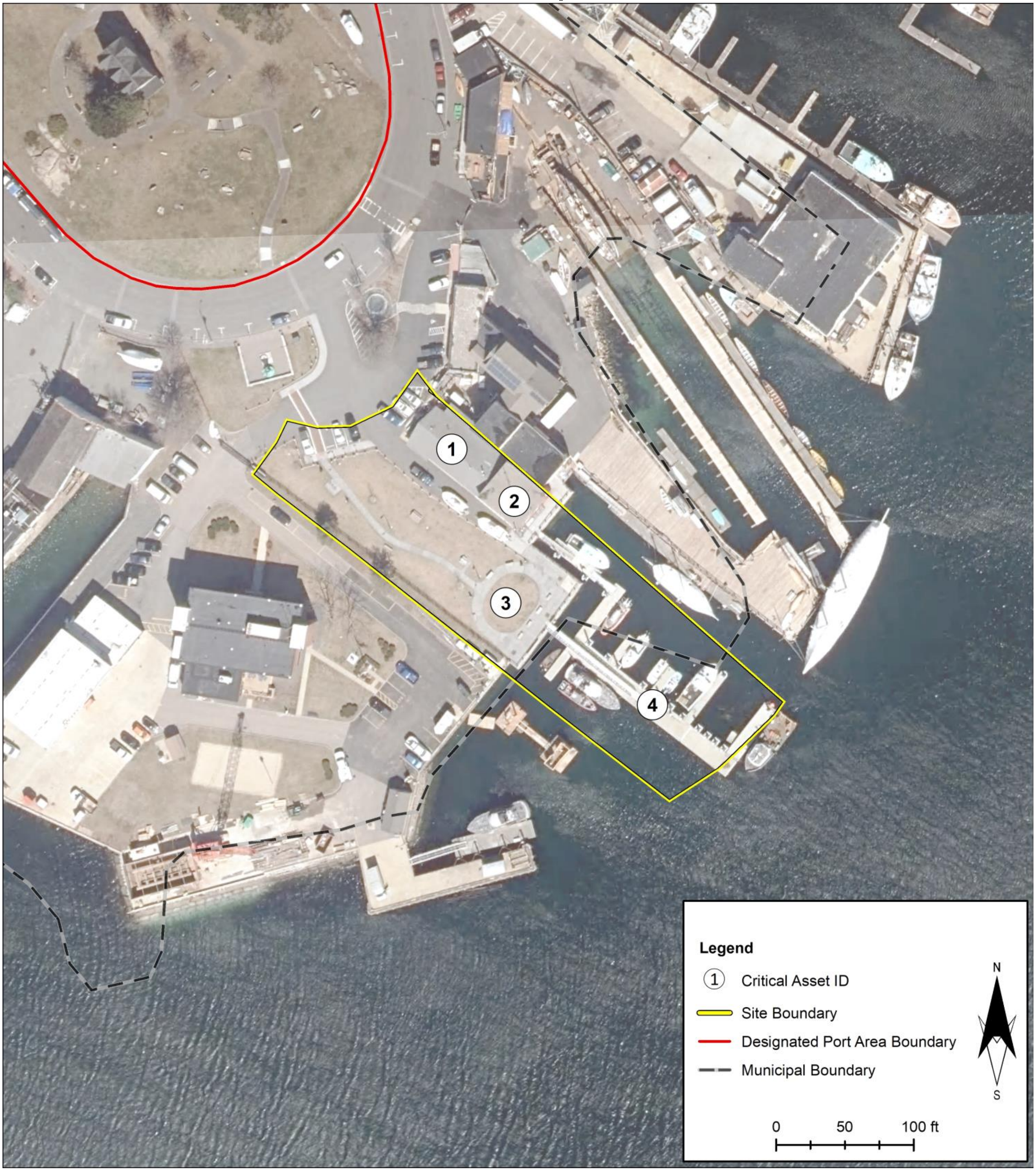
Services: **Gloucester Harbor operations and safety**

Key Adjacencies: **Maritime Museum, U.S. Coast Guard**
(if applicable)

Massachusetts Office of Coastal Zone Management

ARCADIS

Site Map



Massachusetts Office of Coastal Zone Management

ARCADIS

Asset Inventory: Harbormaster's Office									
Map ID #	Asset or System	Description	Critical Elevation (ft-NAVD88)	Ranking Criticality	Loss of Service Consequences	Flood Exposure MMHW	Flood Exposure 1.0% Storm	Flood Type	Recommended Resilience Approaches*
1	First / Finished Floor	Visitors building complex	10	Medium	Loss of facility use	2050	2020	Fringe	None - site designed for flood protection against 100-year storm
2	First / Finished Floor	Harbormaster's office	10	High	Loss of communications and safety support throughout harbor	2030	2020	Fringe	None - site designed for flood protection against 100-year storm
3	Recreation	Public park	9	Low	Loss of park space	2050	2020	Fringe	None - site designed for flood protection against 100-year storm
4	Marine Transportation	Pier	7	High	Loss of access to safety vessels, potential for boats to float away	2020	2020	Fringe	None - site designed for flood protection against 100-year storm

*All DFE determinations should consider criticality and be made on an asset by asset basis in consultation with a qualified professional. Accessibility to the waterfront and maintaining waterside functionality are important considerations if implementing any strategy including the elevation of shoreline infrastructure.

Massachusetts Office of Coastal Zone Management

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Primary Contact Information

Name: **TJ Ciarametaro**

Phone Number: **978-325-5750**

Email: **TCiarametaro@gloucester-ma.gov**

Site Information

Site Name/Business: **I4C2**

Address: **65 ROGERS ST, GLOUCESTER, MA, 01930**

USE (Industrial, Commercial, Mixed Use, etc.): **Other**

Site Description: **Vacant lot and commercial dockage**

Services: **Parking and boat storage**

Key Adjacencies:
(if applicable)

Site Map


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Legend
1 Critical Asset ID
Site Boundary
Designated Port Area Boundary
Municipal Boundary
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Massachusetts Office of Coastal Zone Management

ARCADIS

Asset Inventory: I4C2									
Map ID #	Asset or System	Description	Critical Elevation (ft-NAVD88)	Ranking Criticality	Loss of Service Consequences	Flood Exposure MMHW	Flood Exposure 1.0% Storm	Flood Type	Recommended Resilience Approaches*
1	Shoreline	Sheet pile wall	0	High	Increased site erosion and flooding leading to disruption in operations	2020	2020	Fringe	Elevate shoreline protection to DFE
2	Marine Transportation	Commercial dockage	0	High	Loss of access to boats and use	2020	2020	Fringe	Elevate structure to DFE, elevate / adapt mooring and berthing systems to DFE
3	Vehicular site access	Parking lot	5	Low	Loss of vehicular access and site use	2030	2020	Fringe	Elevate grade to DFE
4	Storage	Commercial dockage storage	0	Low	Loss of equipment and materials	2020	2020	Fringe	Relocate use to low flood risk location

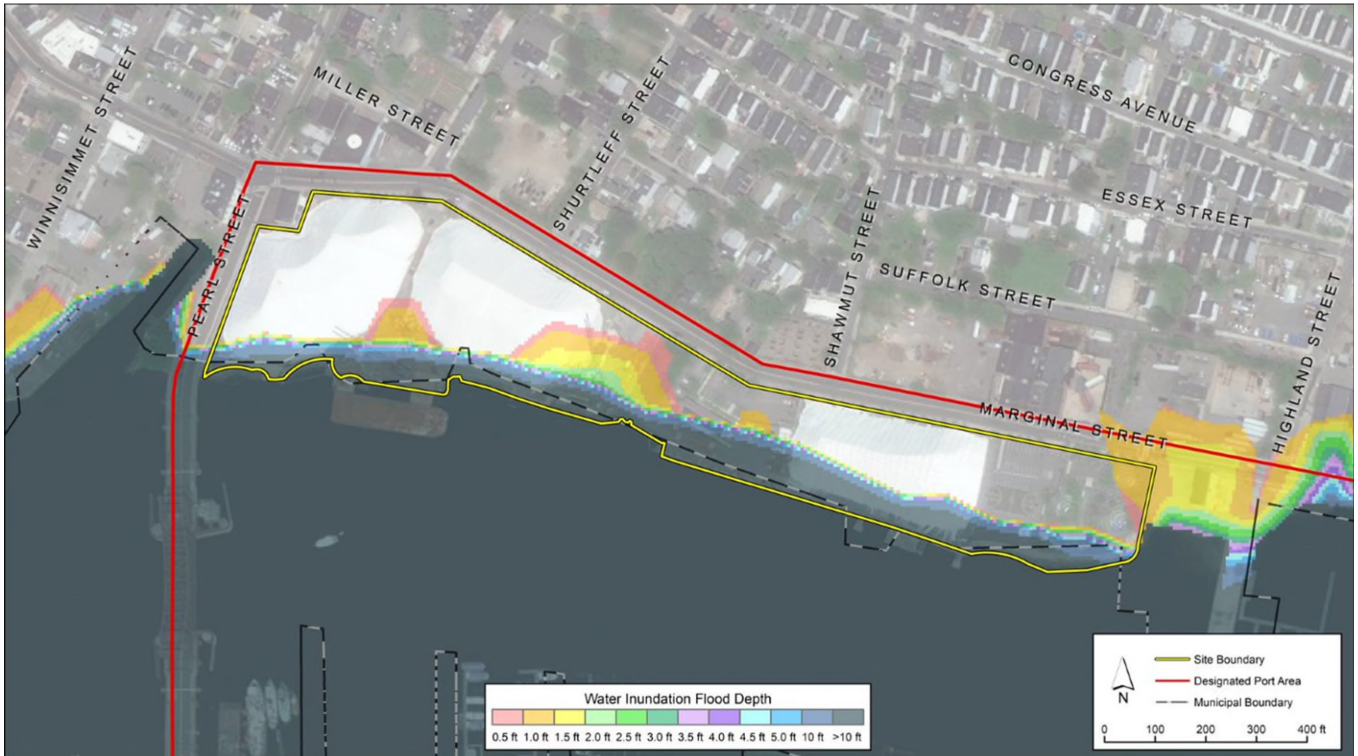
*All DFE determinations should consider criticality and be made on an asset by asset basis in consultation with a qualified professional. Accessibility to the waterfront and maintaining waterside functionality are important considerations if implementing any strategy including the elevation of shoreline infrastructure.

Appendix B – Representative Site Flood Risk Maps

Included as attachment.

Eastern Minerals – Present Day Flood Risk

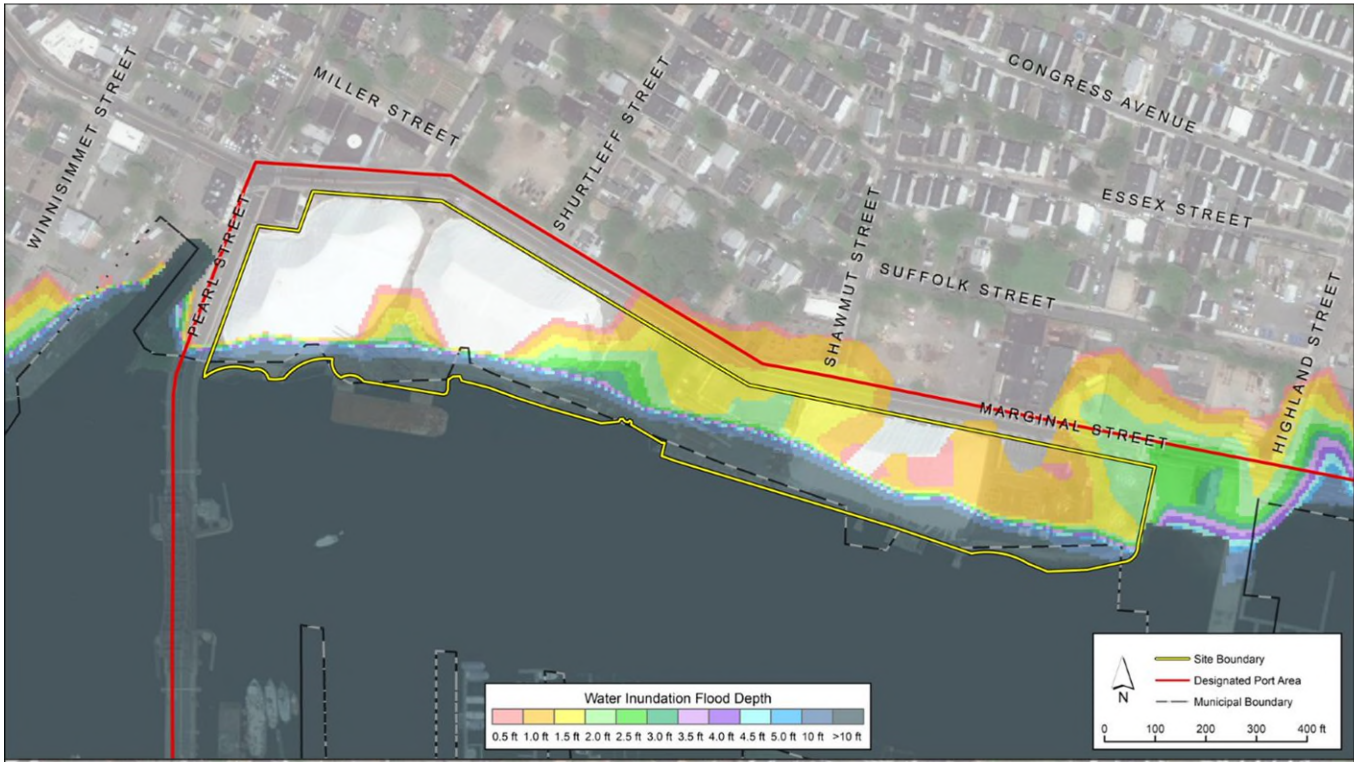
1% Annual Chance or 100-year Storm Flooding



Mean Monthly High Water Tidal Flooding

Eastern Minerals – 2030 Flood Risk

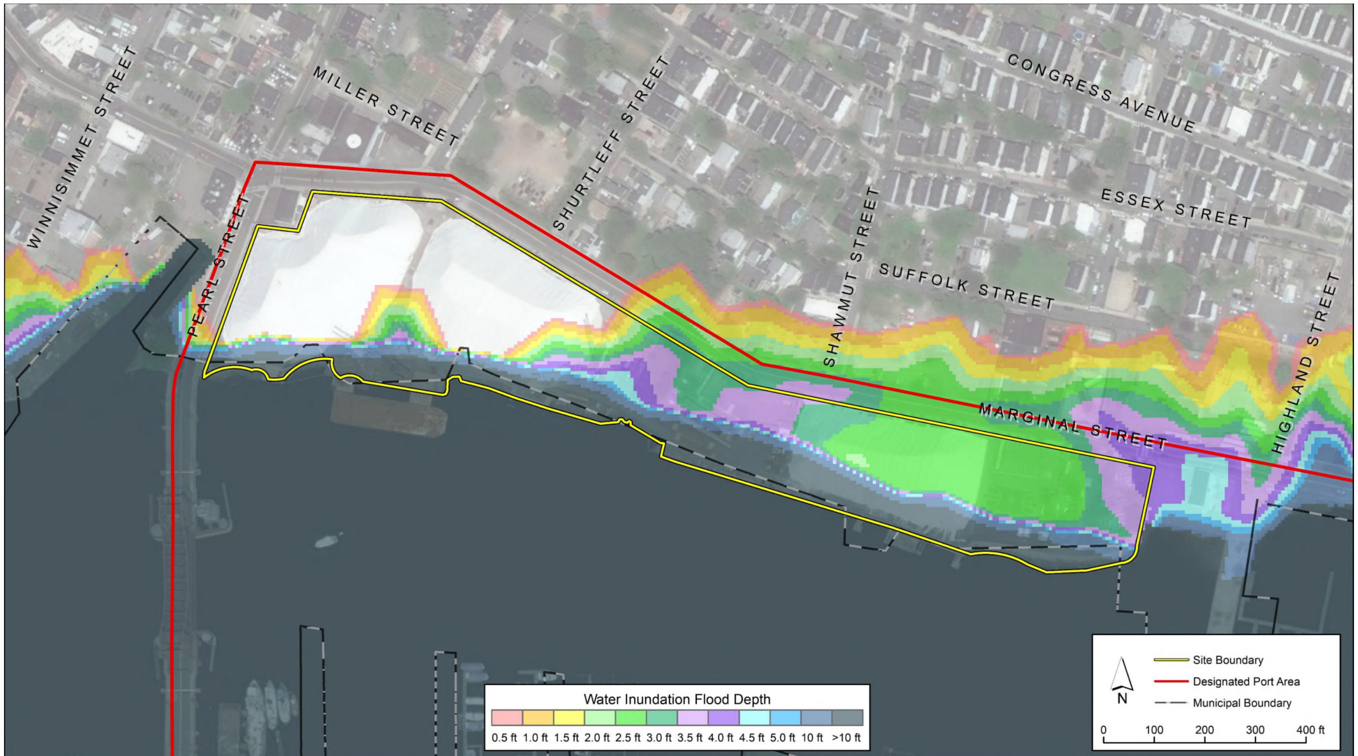
1% Annual Chance or 100-year Storm Flooding



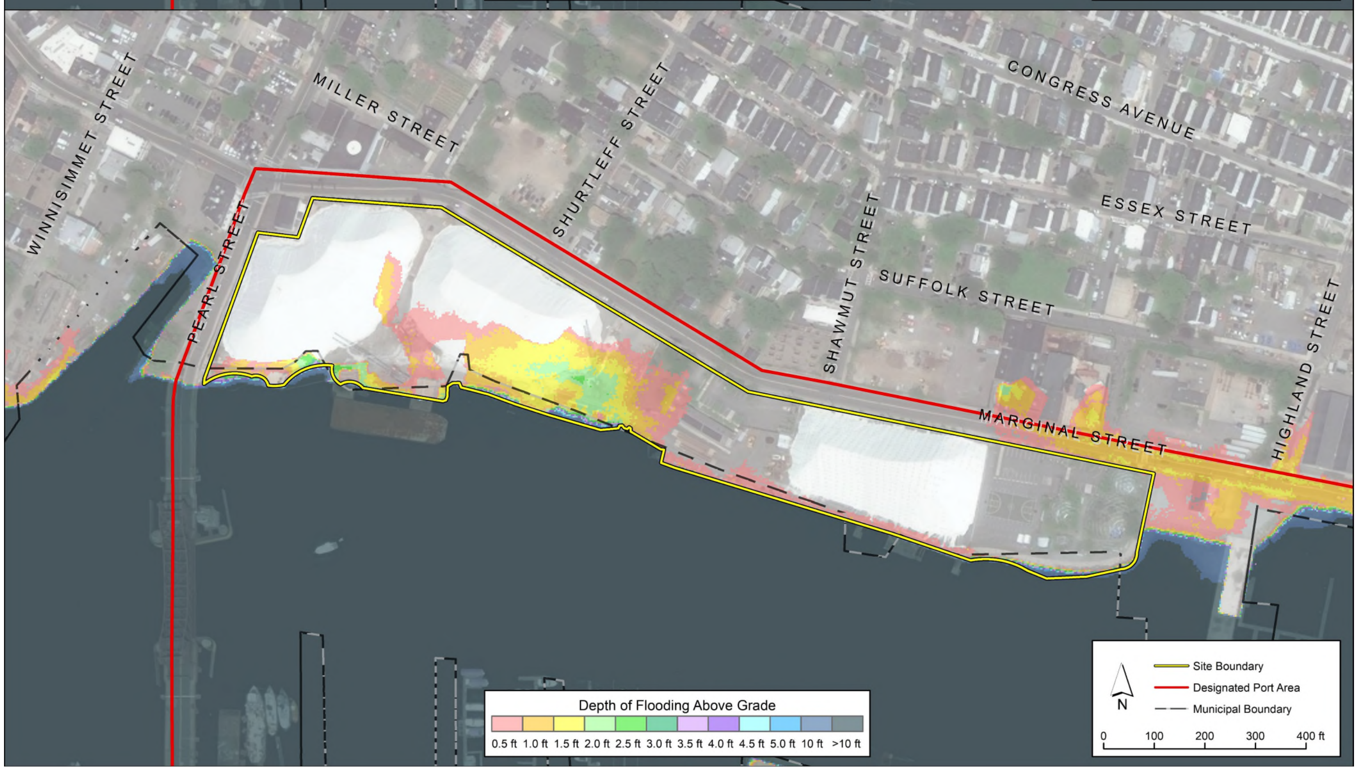
Mean Monthly High Water Tidal Flooding

Eastern Minerals – 2050 Flood Risk

1% Annual Chance or 100-year Storm Flooding

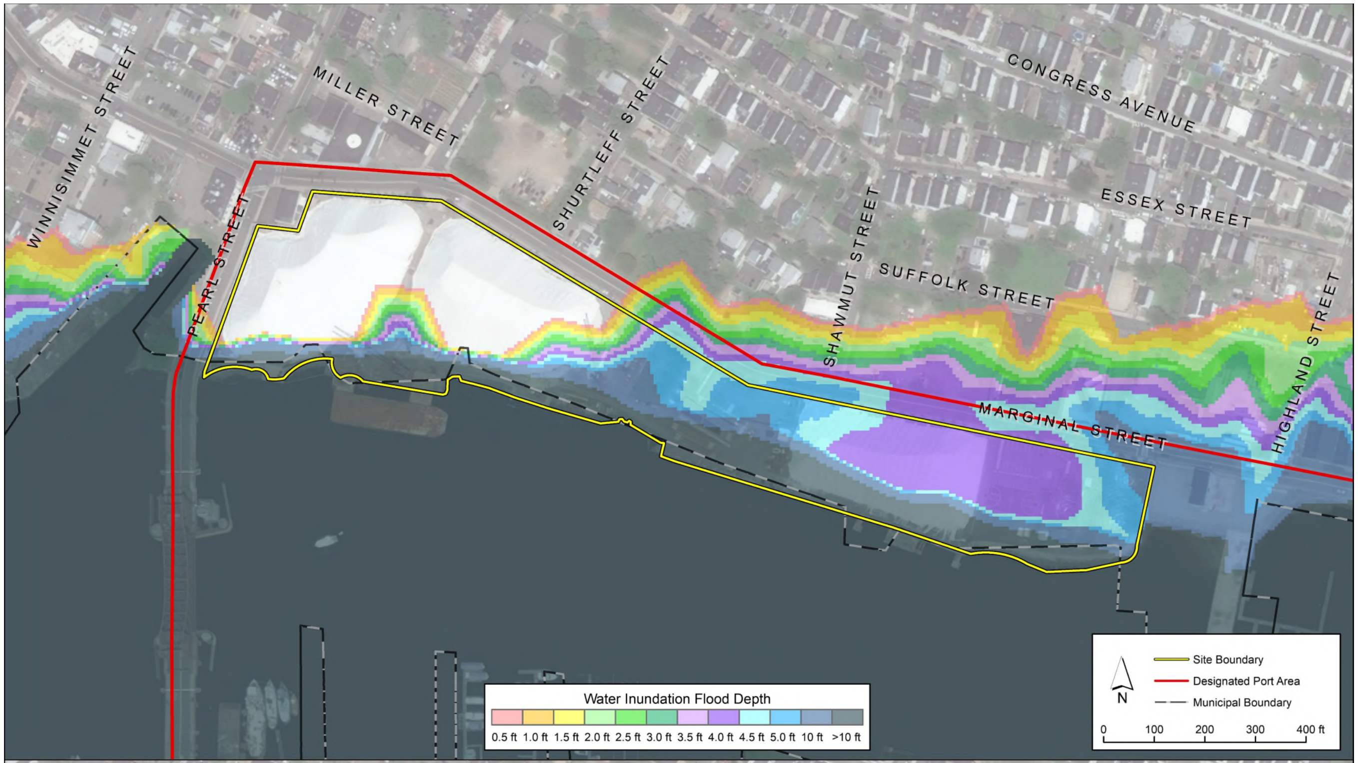


Mean Monthly High Water Tidal Flooding

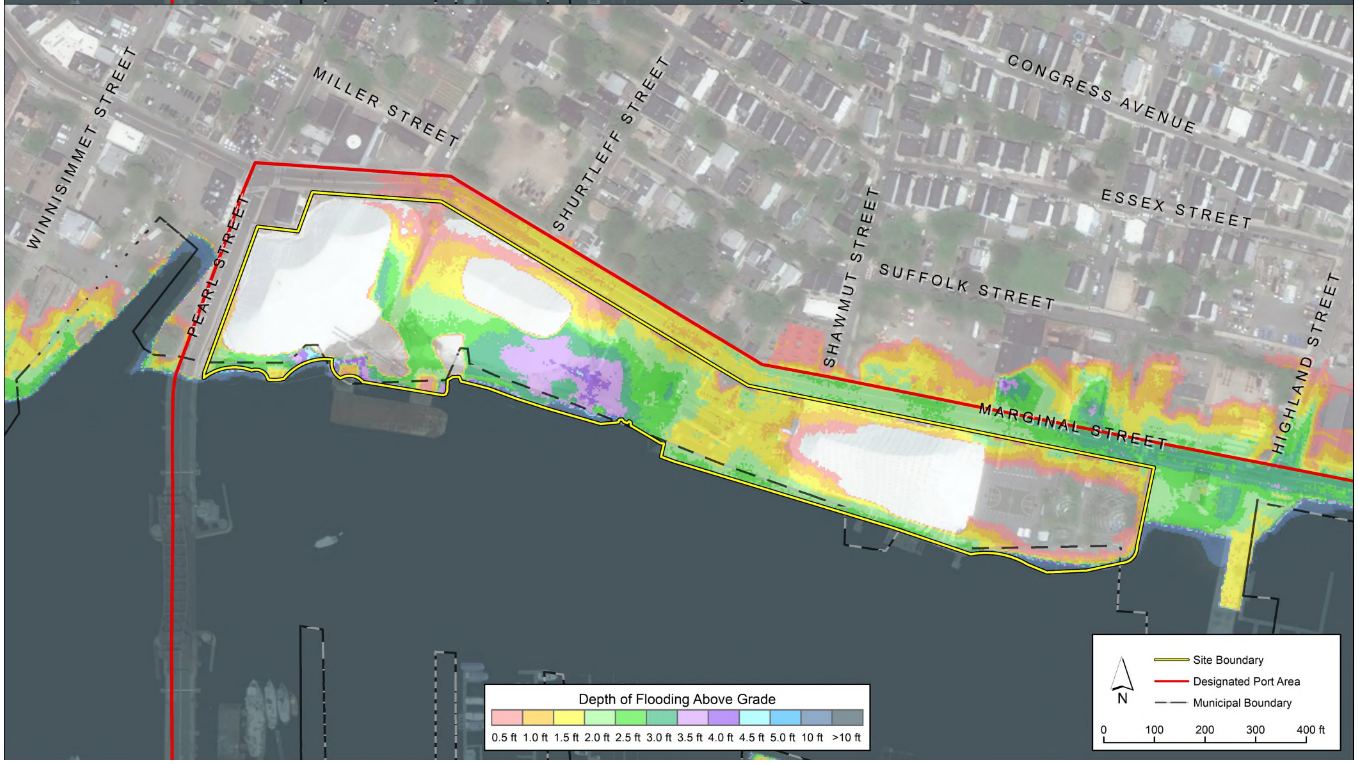


Eastern Minerals – 2070 Flood Risk

1% Annual Chance or 100-year Storm Flooding

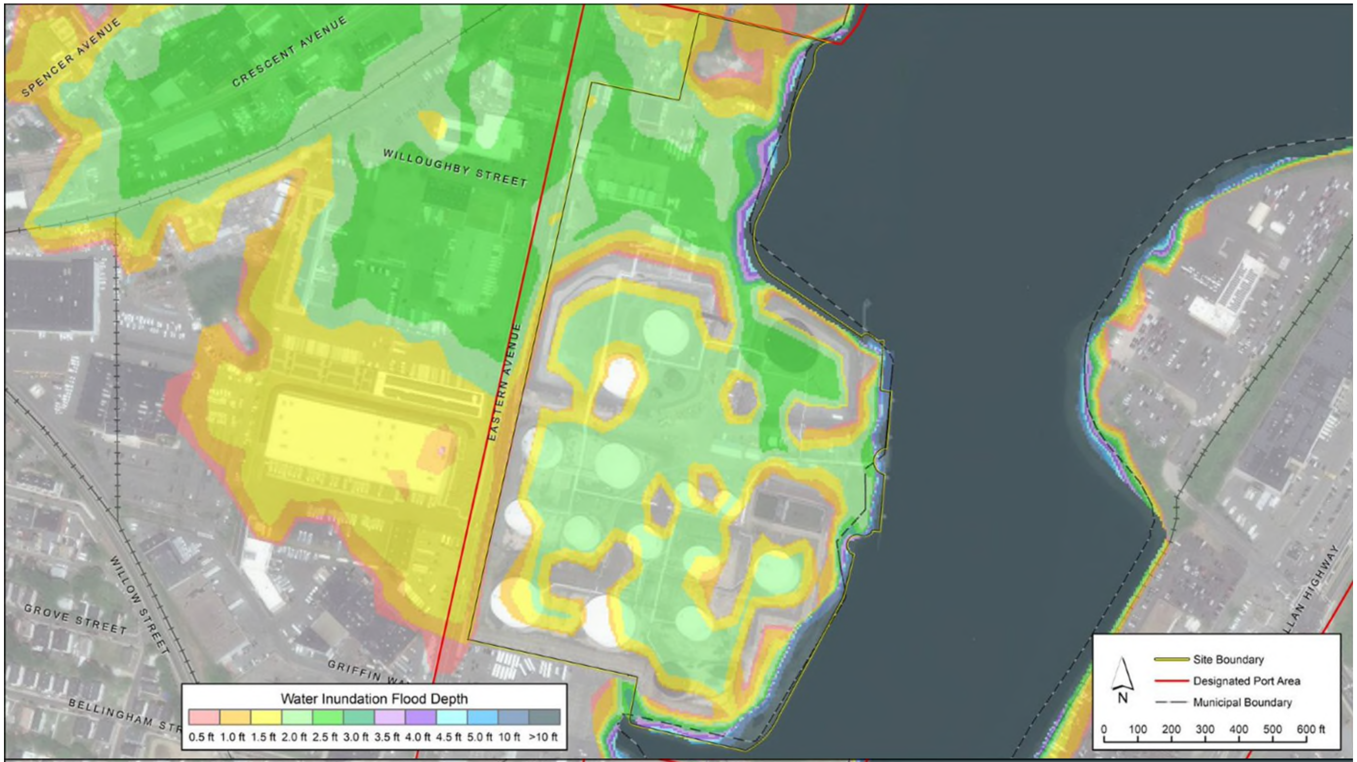


Mean Monthly High Water Tidal Flooding

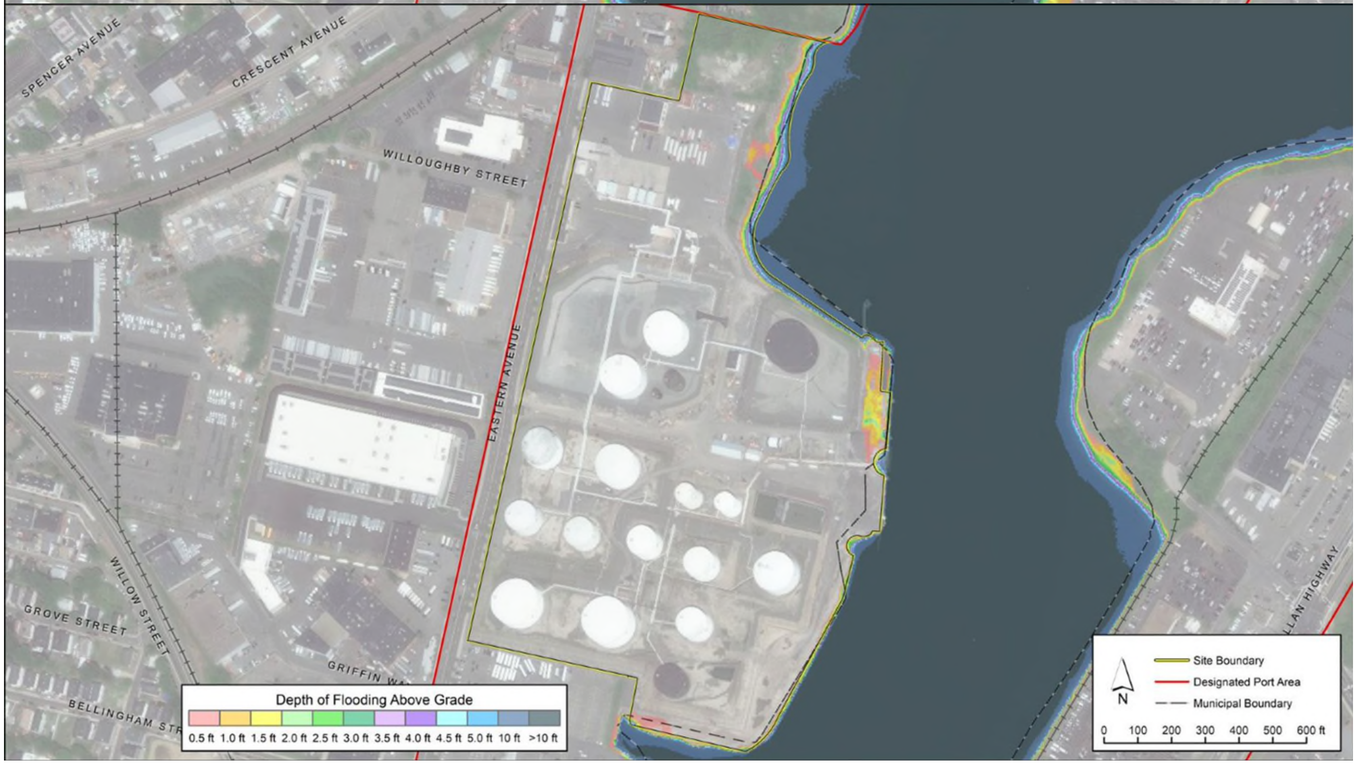


Gulf Oil – Present Day Flood Risk

1% Annual Chance or 100-year Storm Flooding

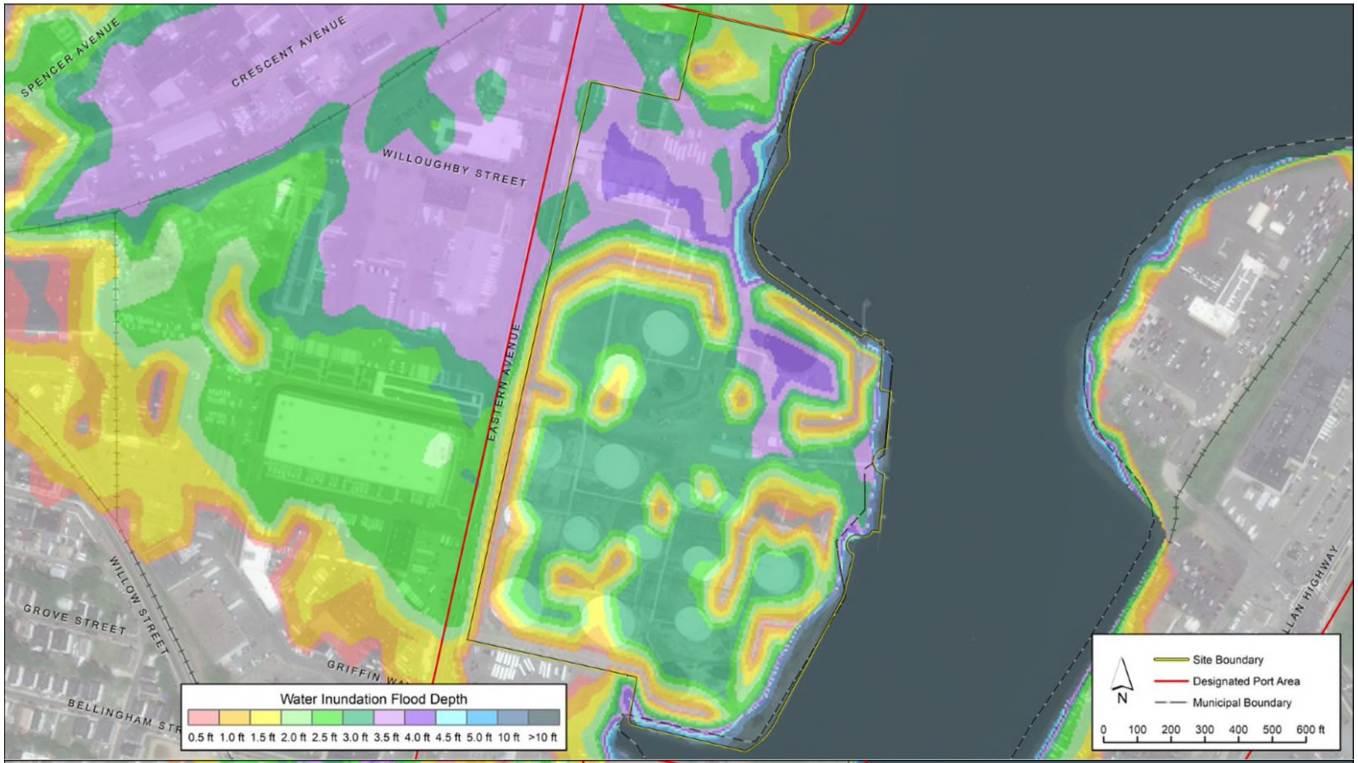


Mean Monthly High Water Tidal Flooding

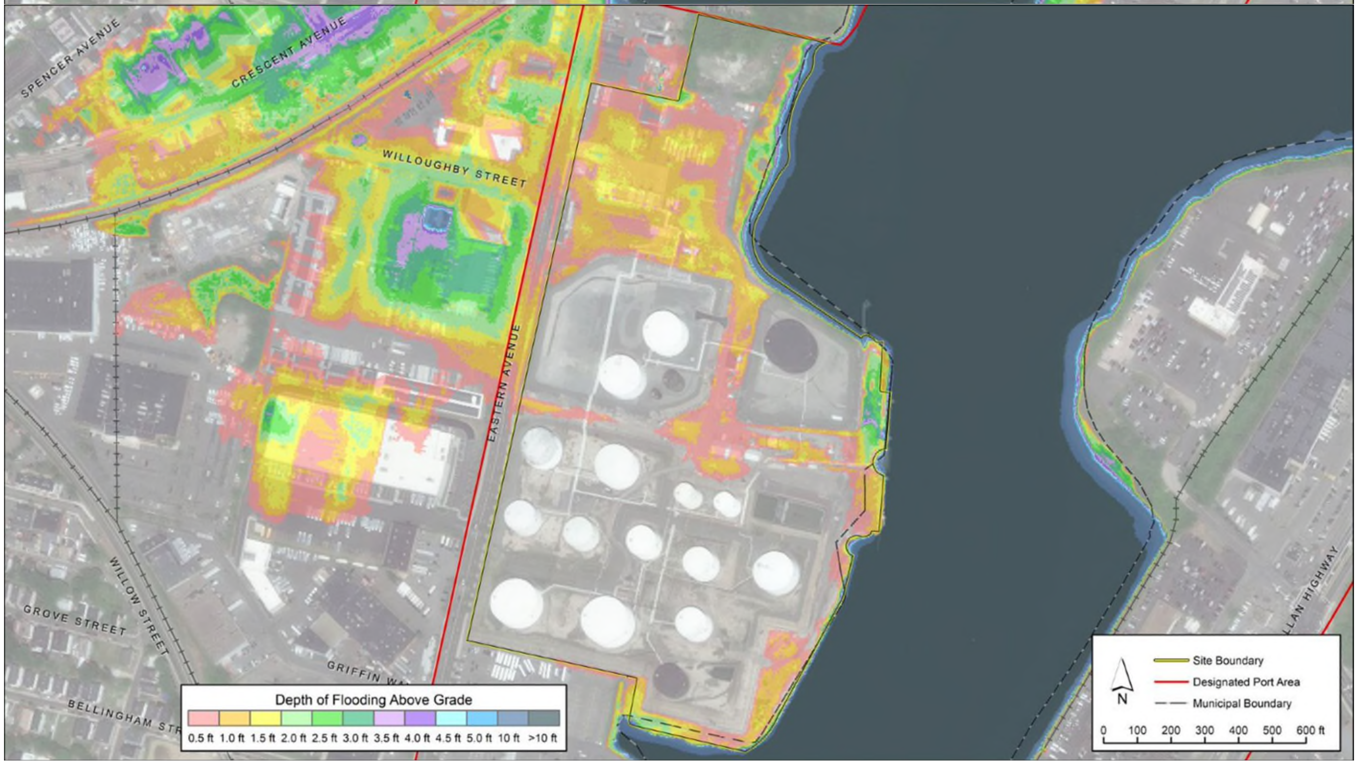


Gulf Oil – 2030 Flood Risk

1% Annual Chance or 100-year Storm Flooding

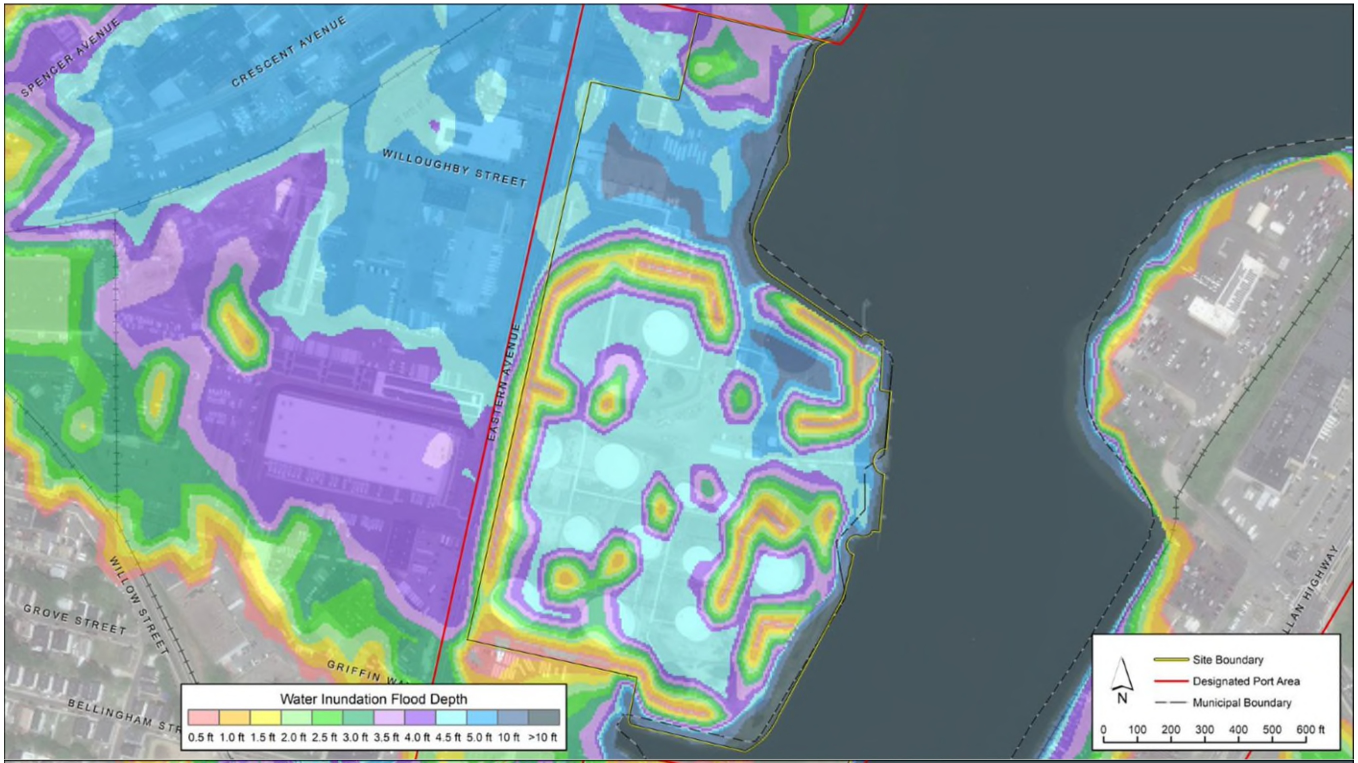


Mean Monthly High Water Tidal Flooding

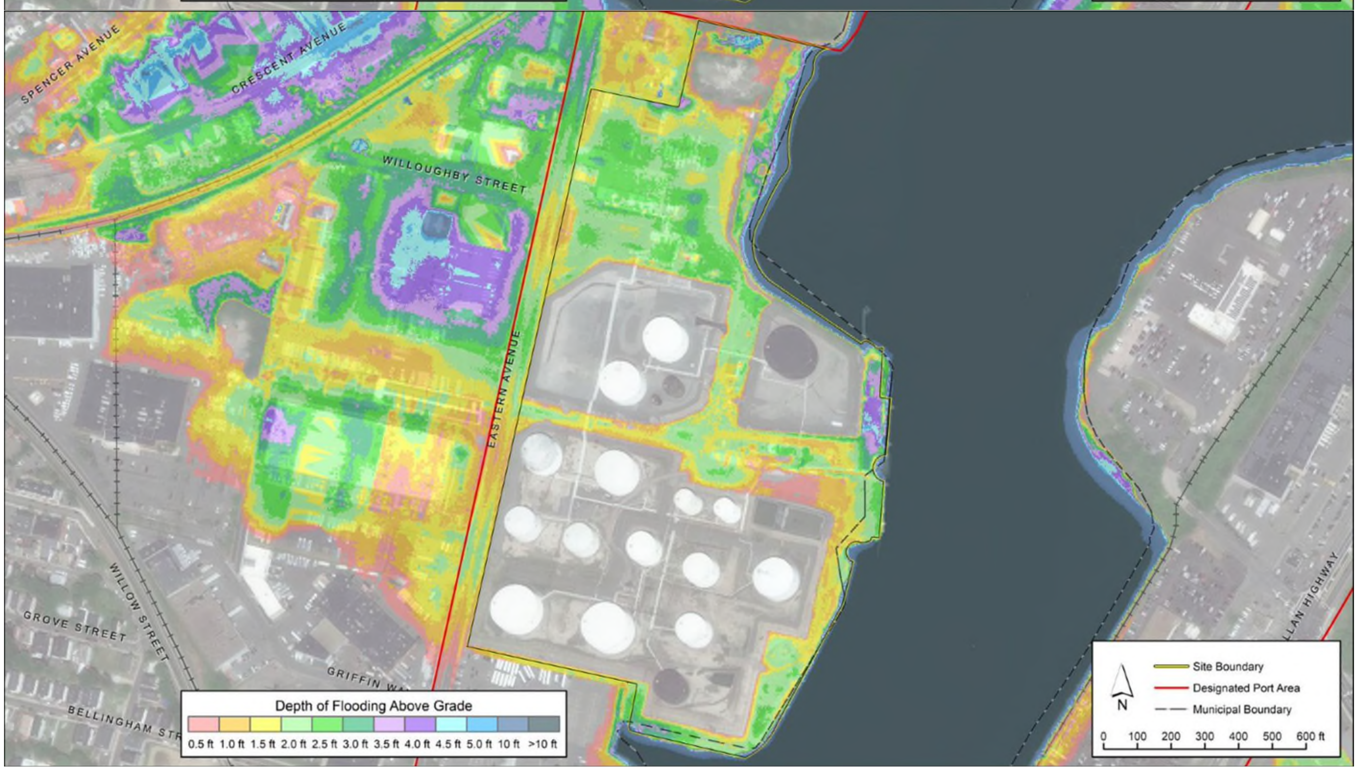


Gulf Oil – 2050 Flood Risk

1% Annual Chance or 100-year Storm Flooding

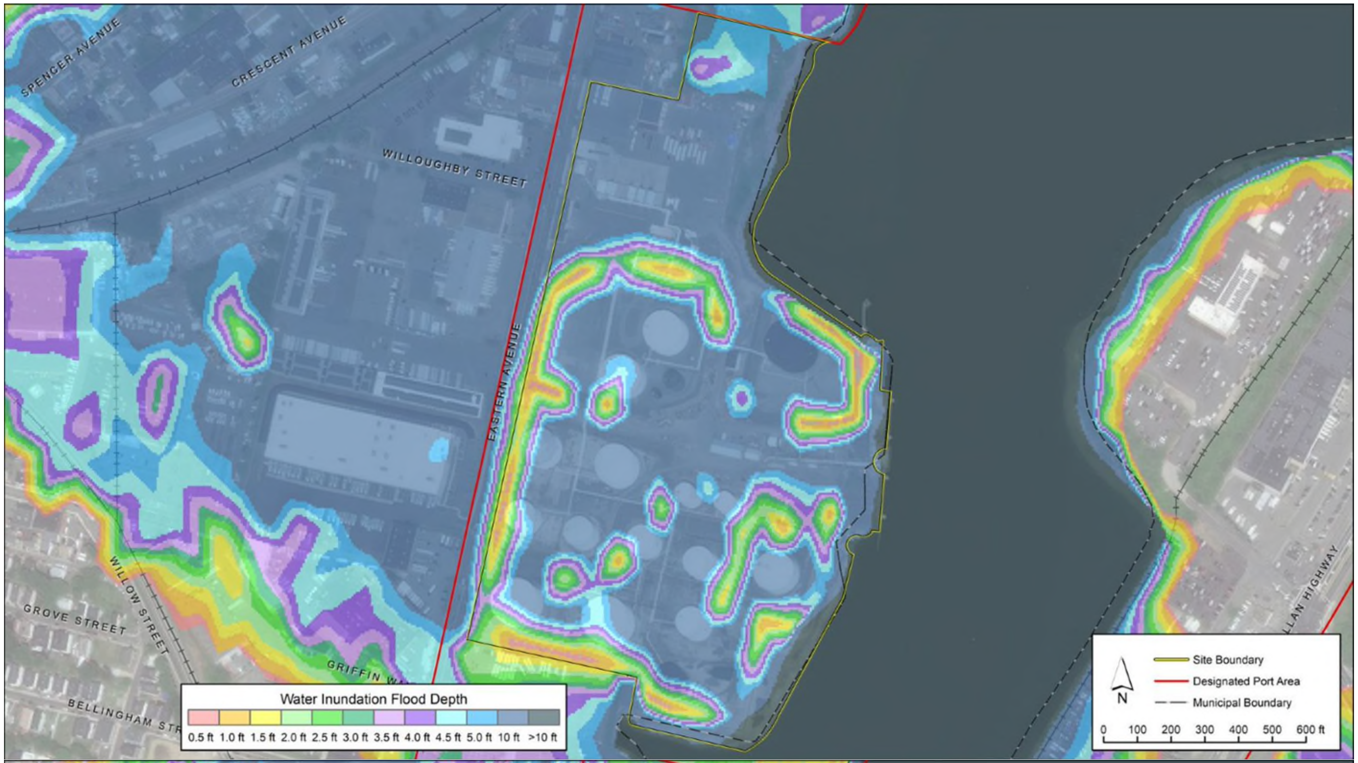


Mean Monthly High Water Tidal Flooding



Gulf Oil – 2070 Flood Risk

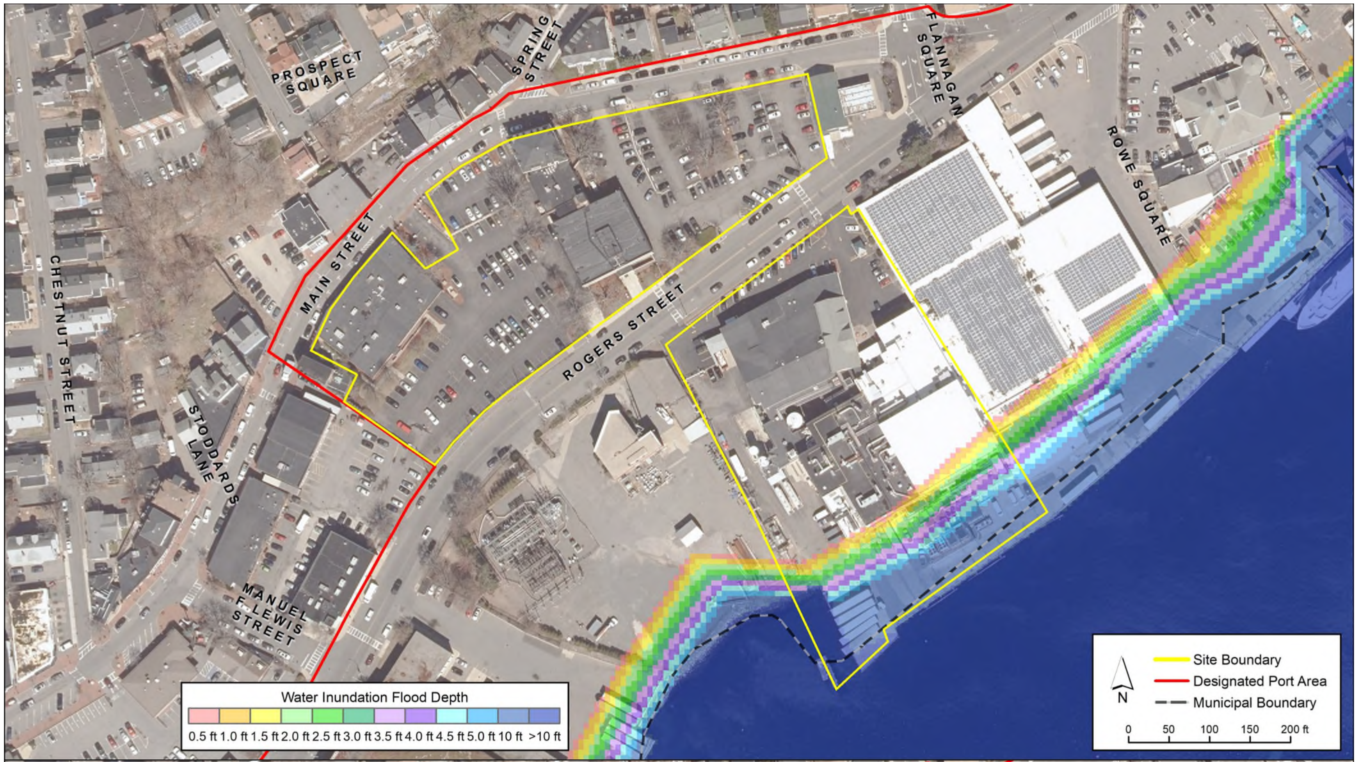
1% Annual Chance or 100-year Storm Flooding



Mean Monthly High Water Tidal Flooding

Gorton's– Present Day Flood Risk

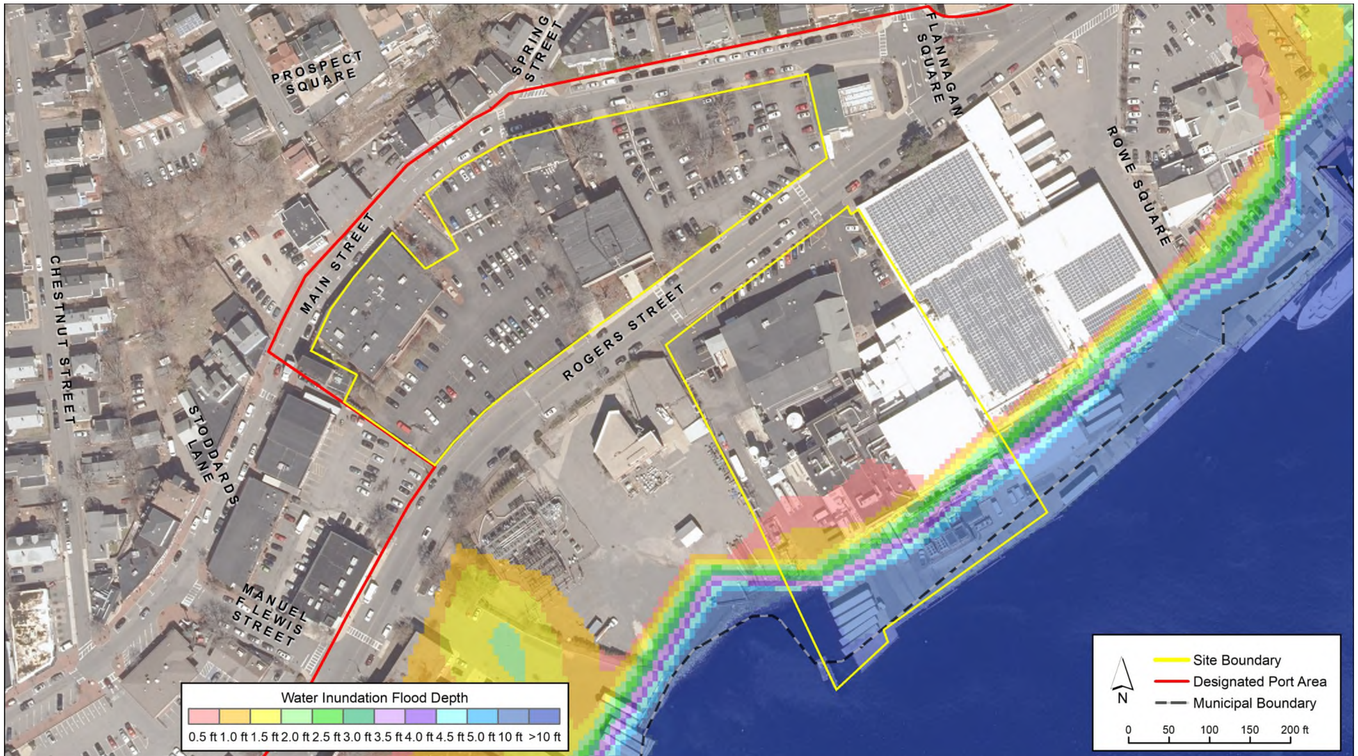
1% Annual Chance or 100-year Storm Flooding



Mean Monthly High Water Tidal Flooding

Gorton's – 2030 Flood Risk

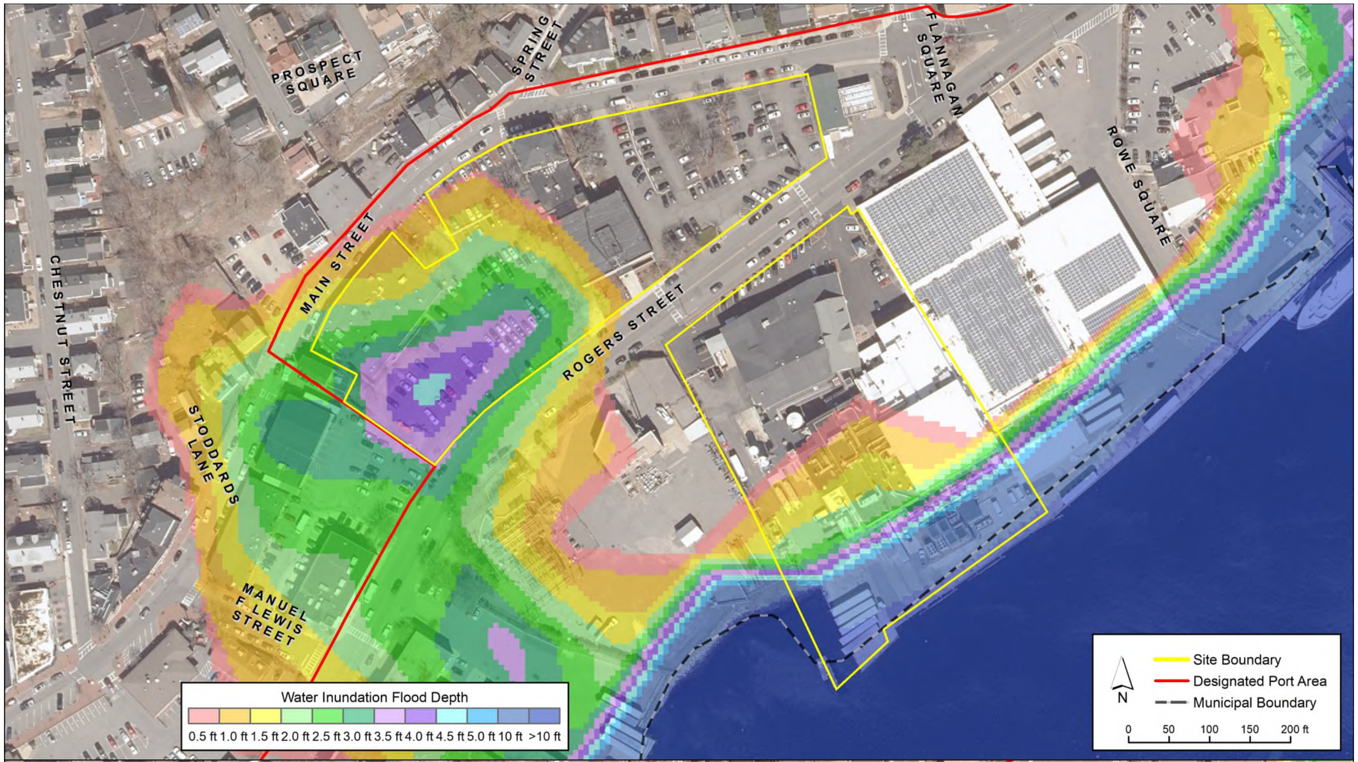
1% Annual Chance or 100-year Storm Flooding



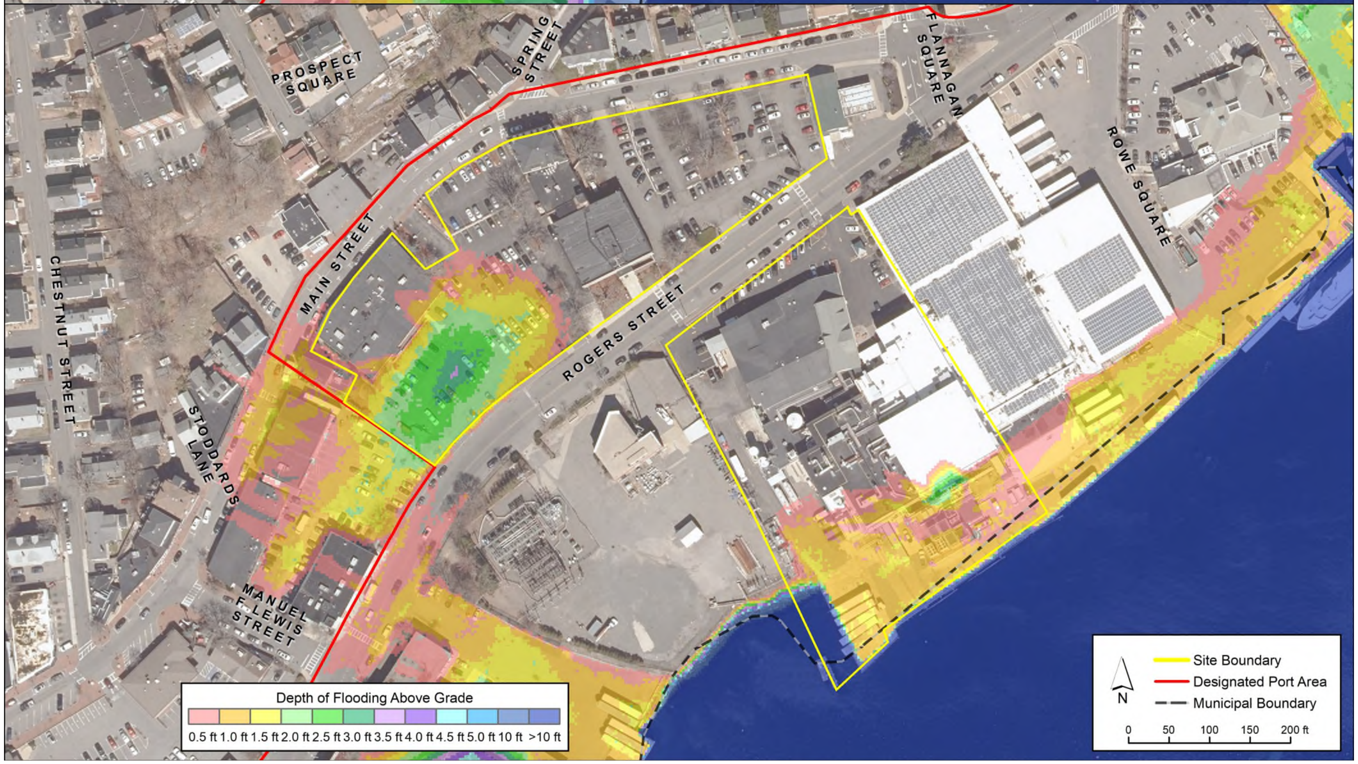
Mean Monthly High Water Tidal Flooding

Gorton's – 2050 Flood Risk

1% Annual Chance or 100-year Storm Flooding

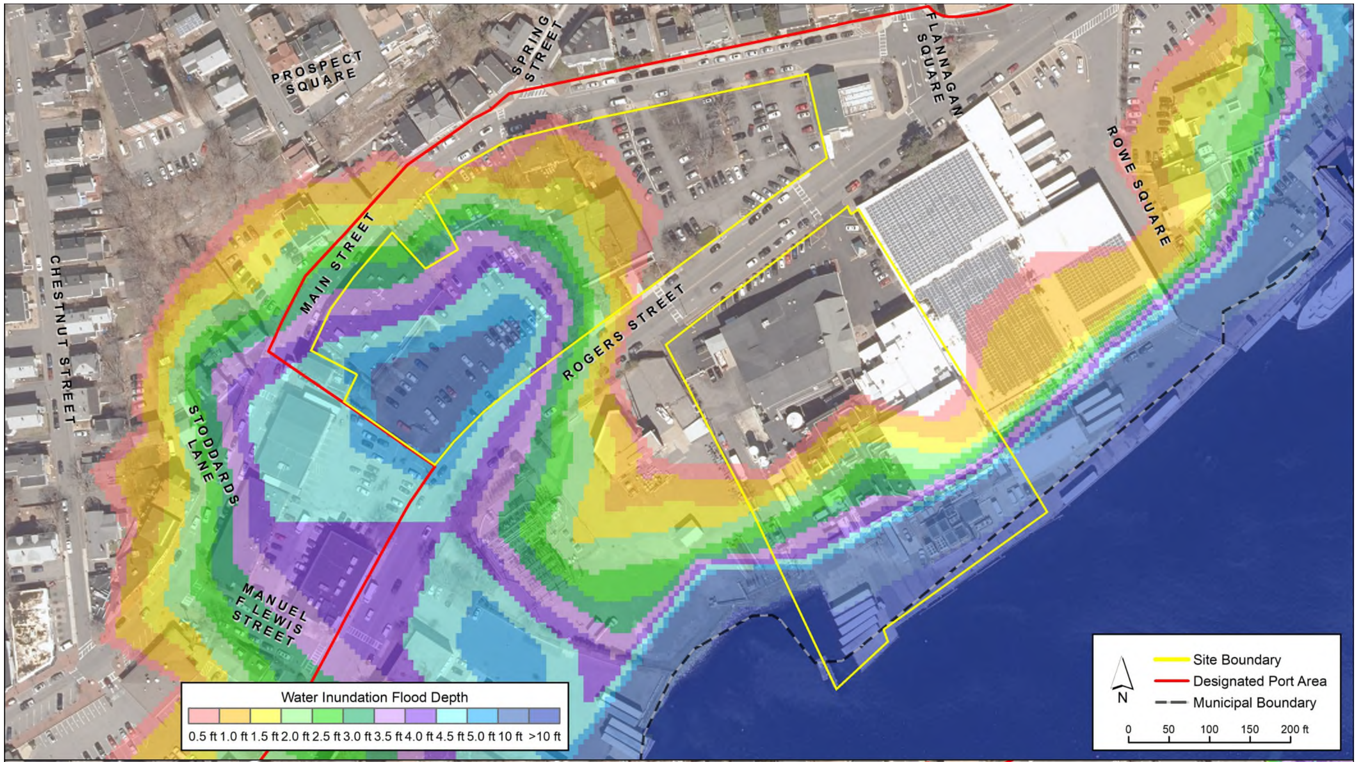


Mean Monthly High Water Tidal Flooding

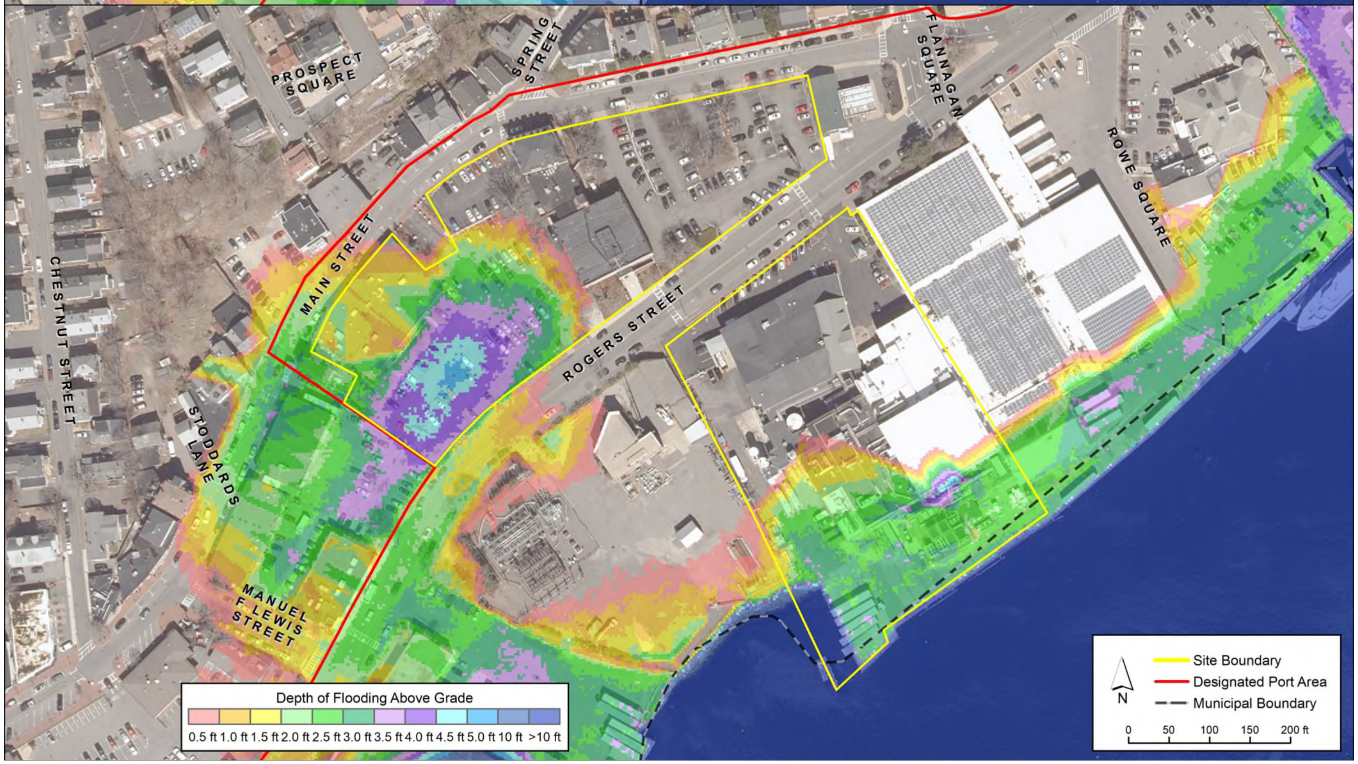


Gorton's – 2070 Flood Risk

1% Annual Chance or 100-year Storm Flooding

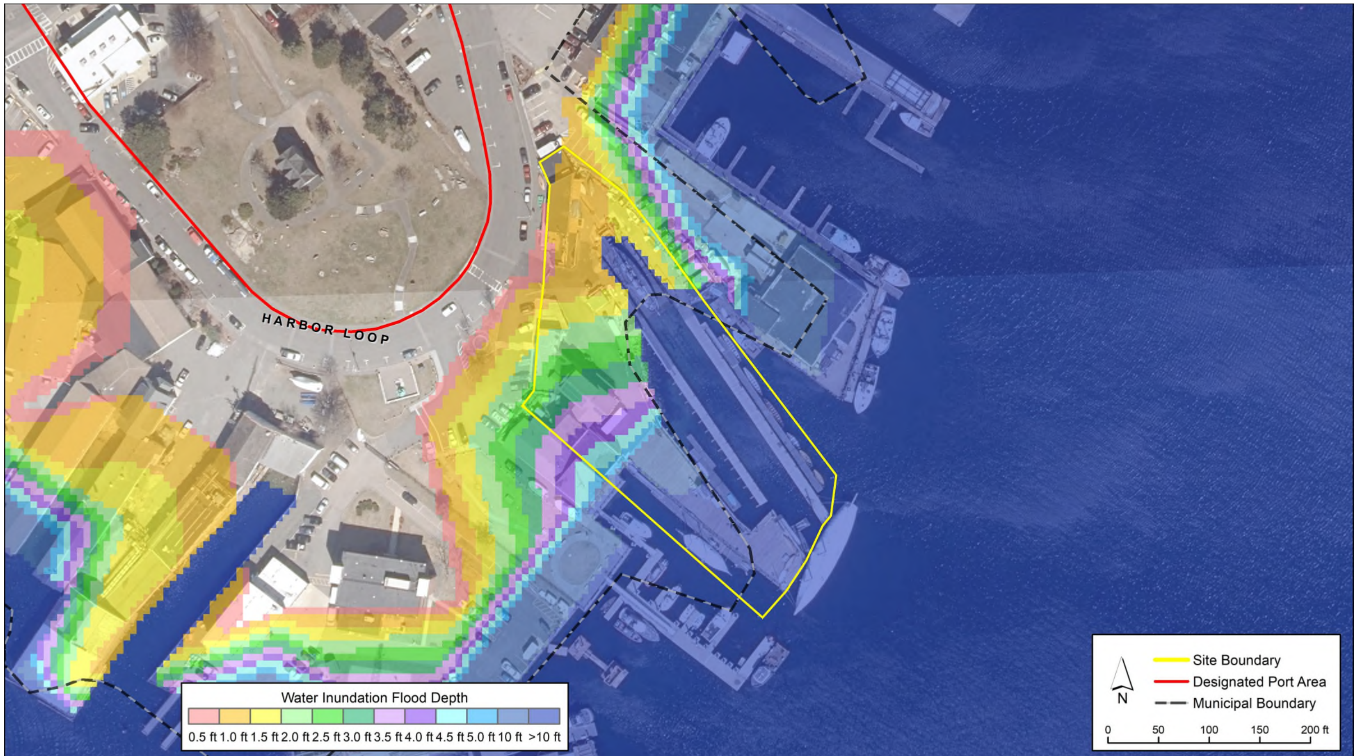


Mean Monthly High Water Tidal Flooding



Maritime Gloucester – Present Day Flood Risk

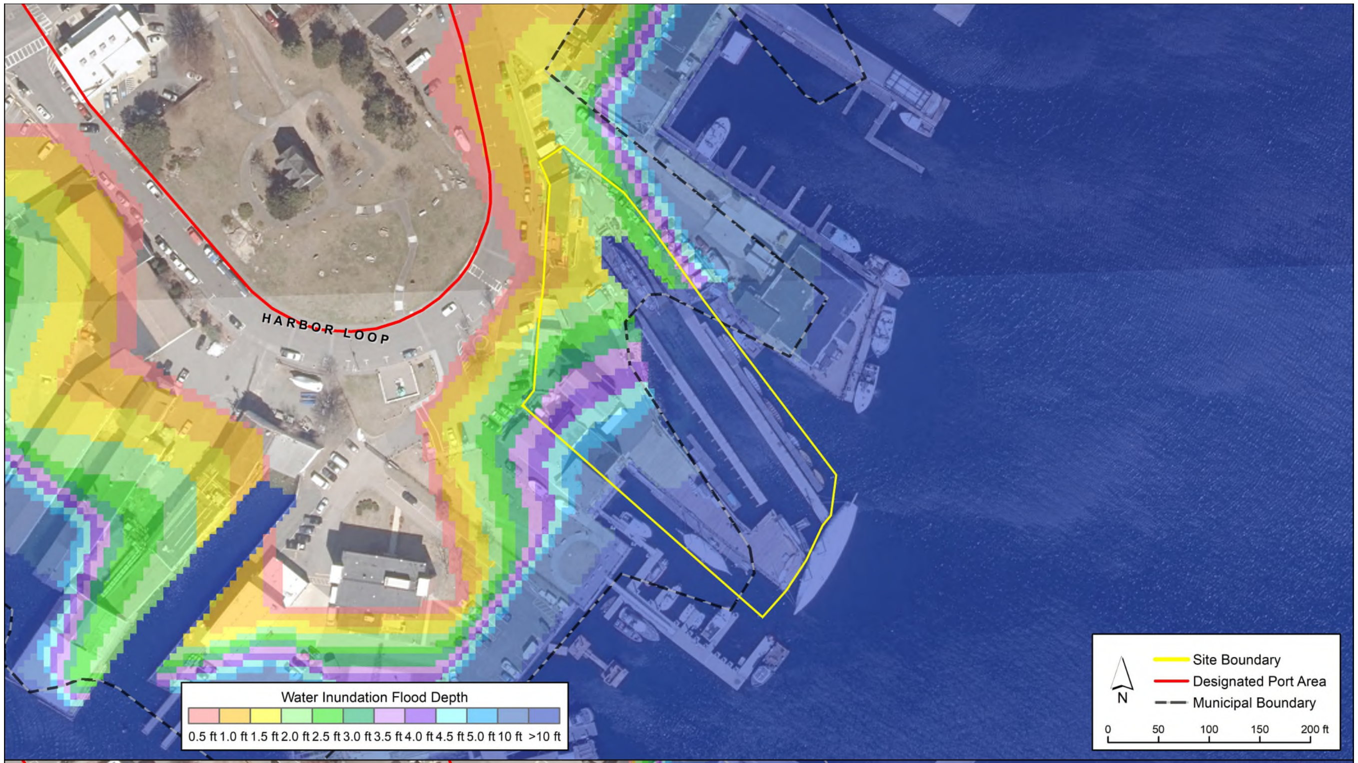
1% Annual Chance or 100-year Storm Flooding



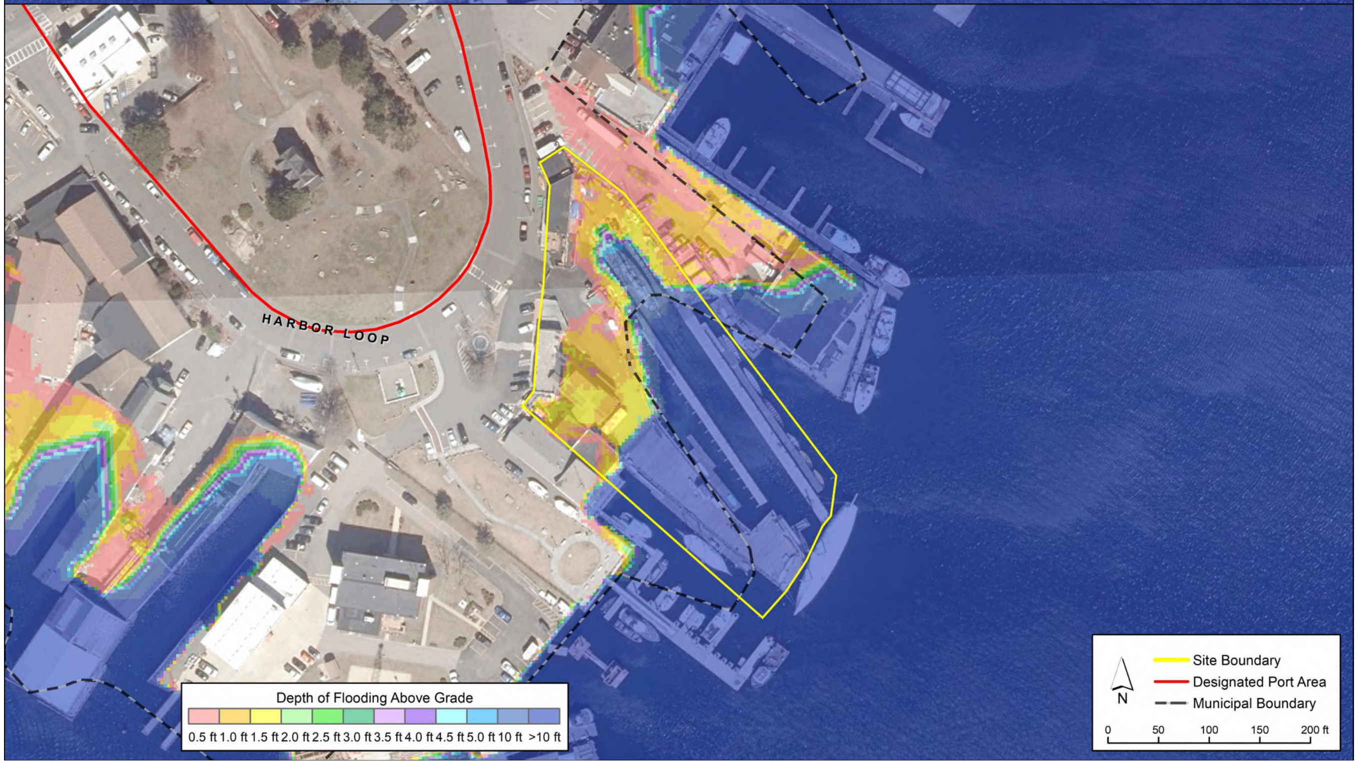
Mean Monthly High Water Tidal Flooding

Maritime Gloucester – 2030 Flood Risk

1% Annual Chance or 100-year Storm Flooding

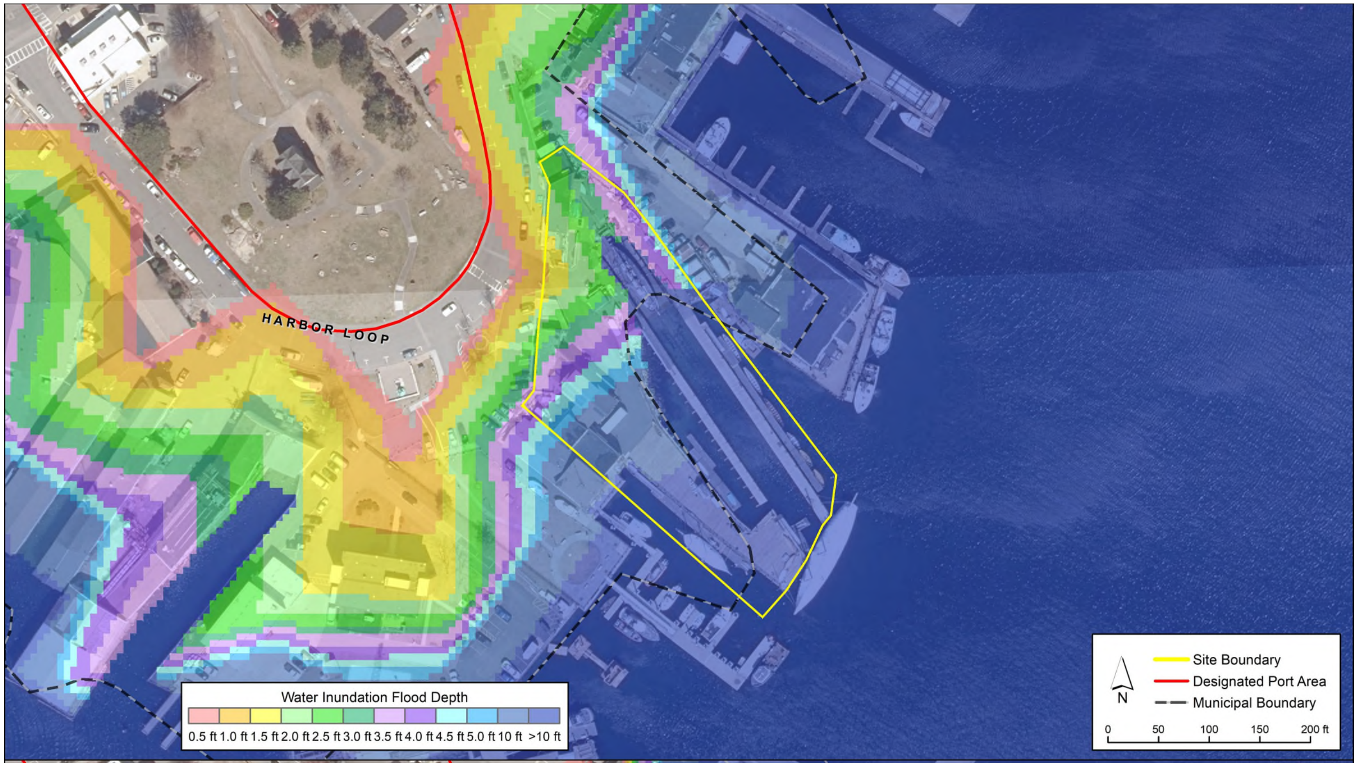


Mean Monthly High Water Tidal Flooding

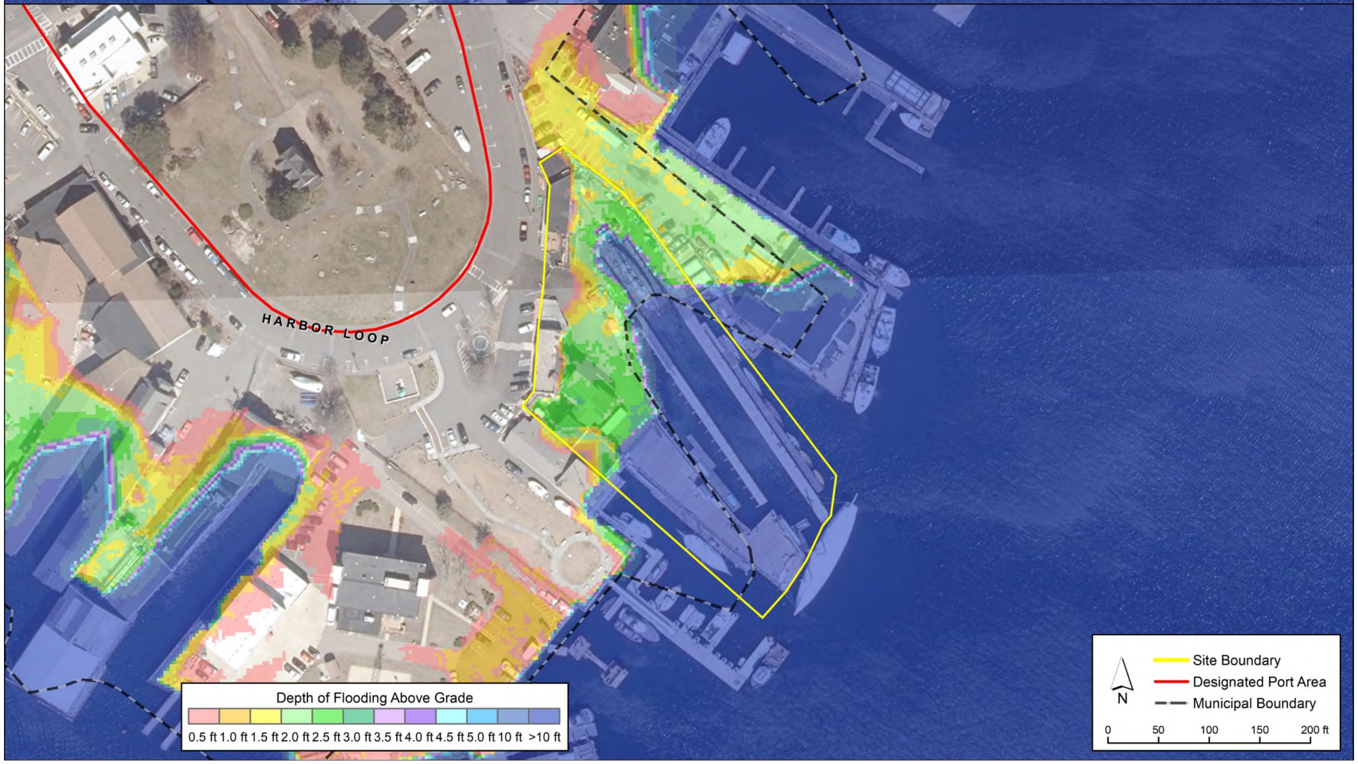


Maritime Gloucester – 2050 Flood Risk

1% Annual Chance or 100-year Storm Flooding

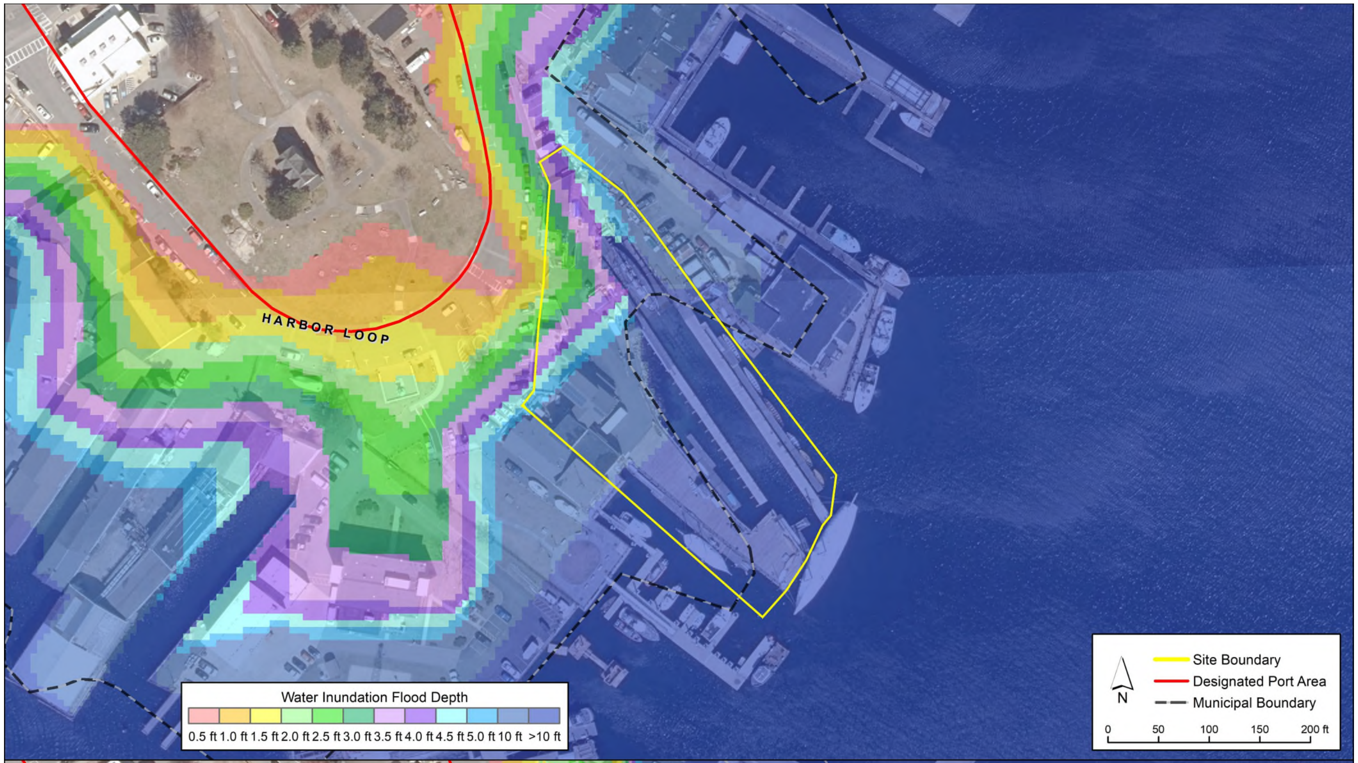


Mean Monthly High Water Tidal Flooding

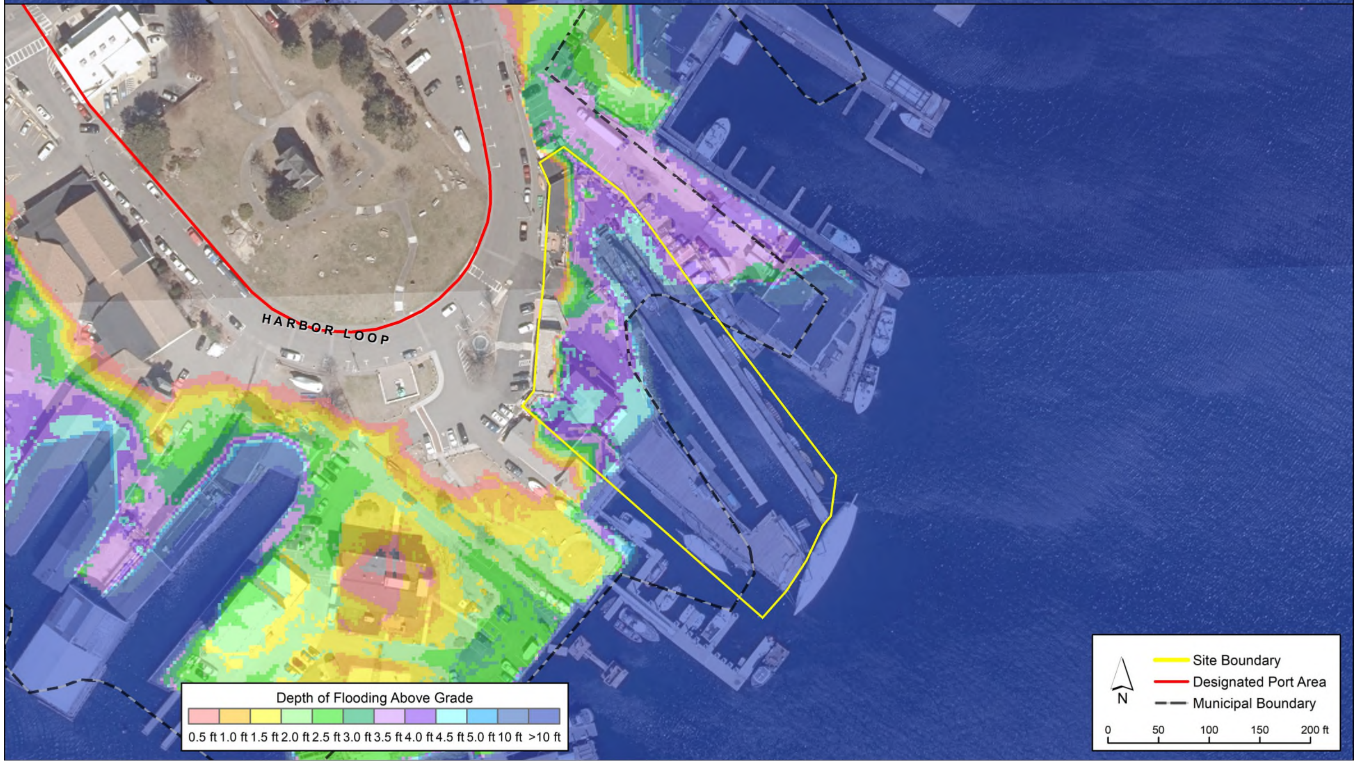


Maritime Gloucester – 2070 Flood Risk

1% Annual Chance or 100-year Storm Flooding



Mean Monthly High Water Tidal Flooding



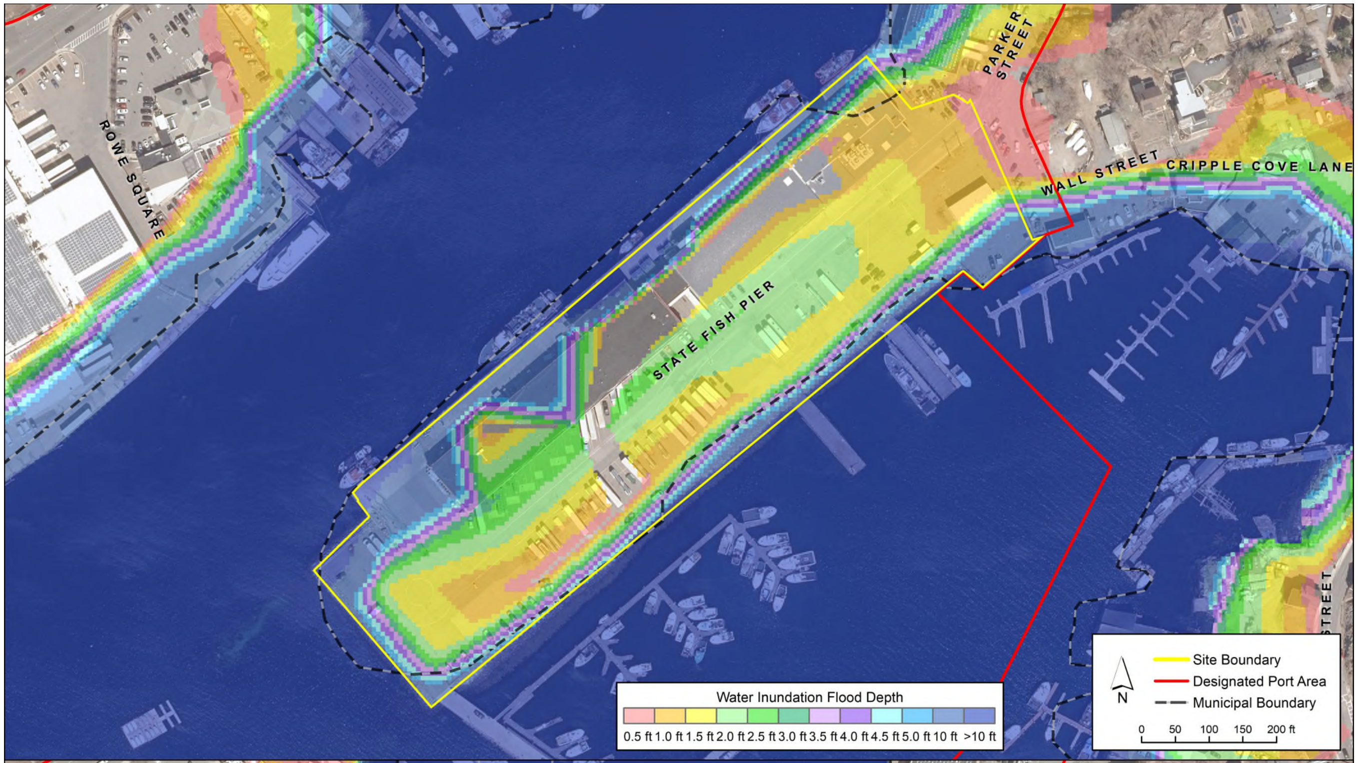
Jodrey State Fish Pier – Present Day Flood Risk

1% Annual Chance or 100-year Storm Flooding

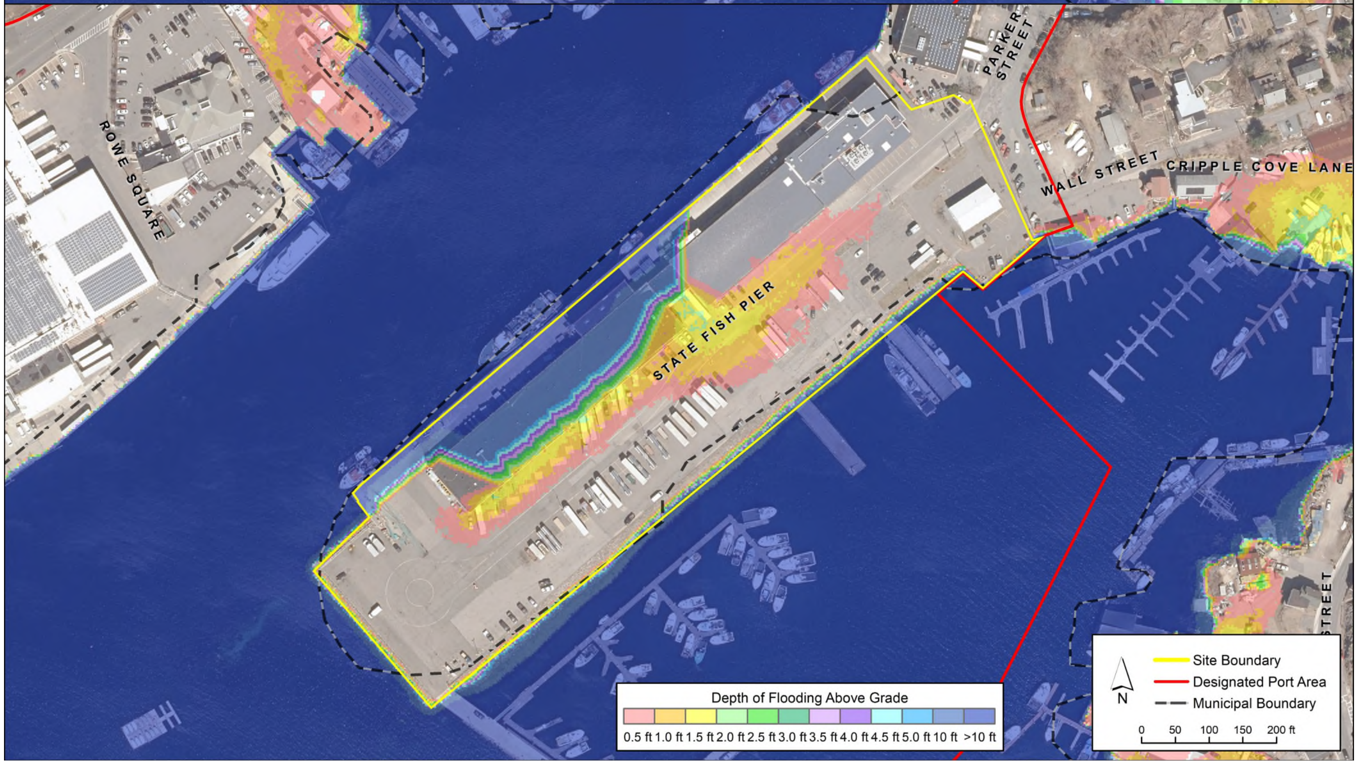
Mean Monthly High Water Tidal Flooding

Jodrey State Fish Pier – 2030 Flood Risk

1% Annual Chance or 100-year Storm Flooding

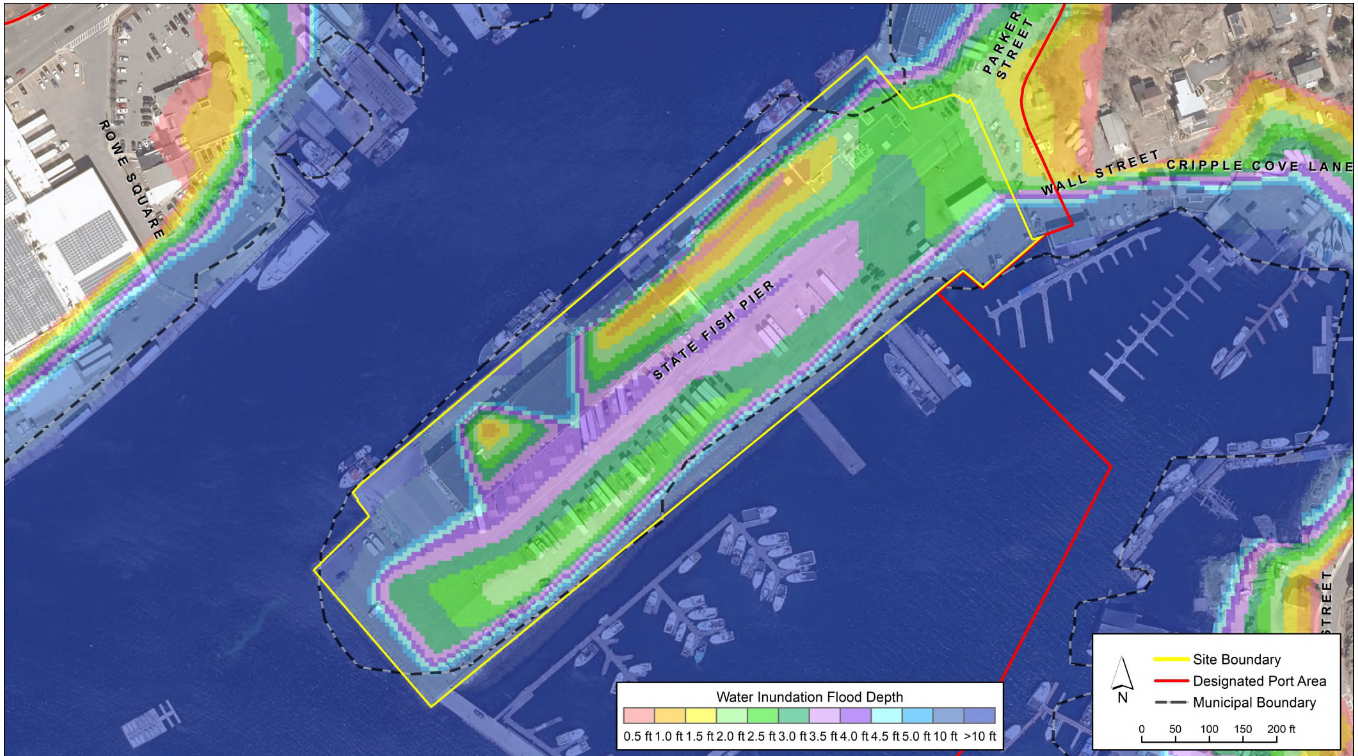


Mean Monthly High Water Tidal Flooding

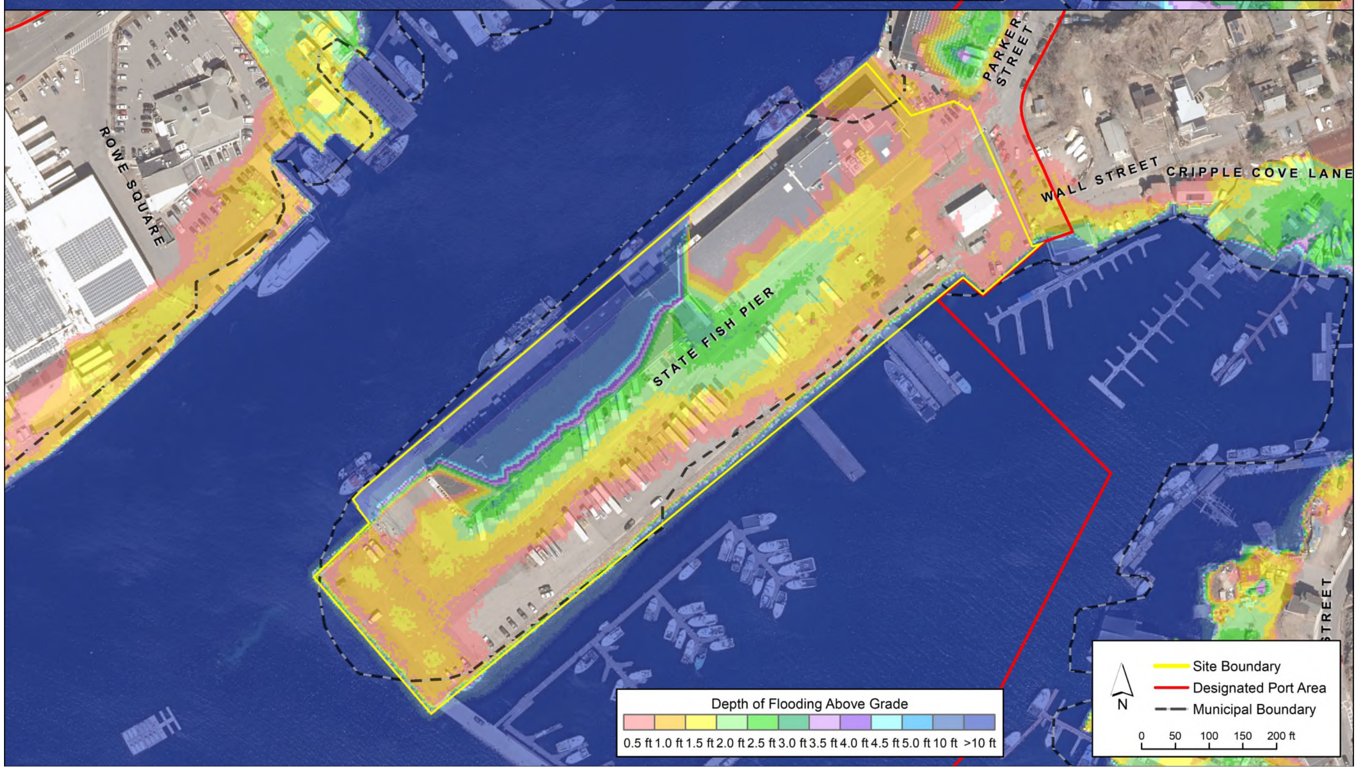


Jodrey State Fish Pier – 2050 Flood Risk

1% Annual Chance or 100-year Storm Flooding

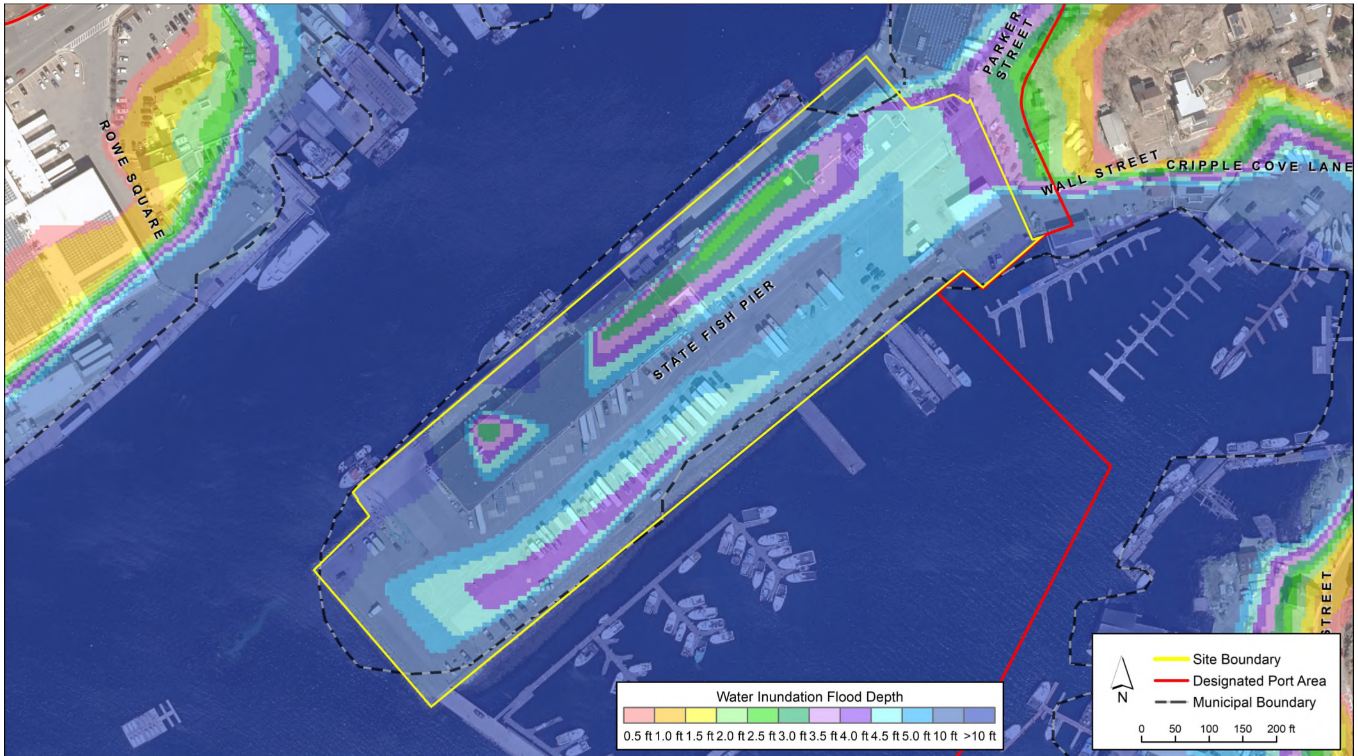


Mean Monthly High Water Tidal Flooding

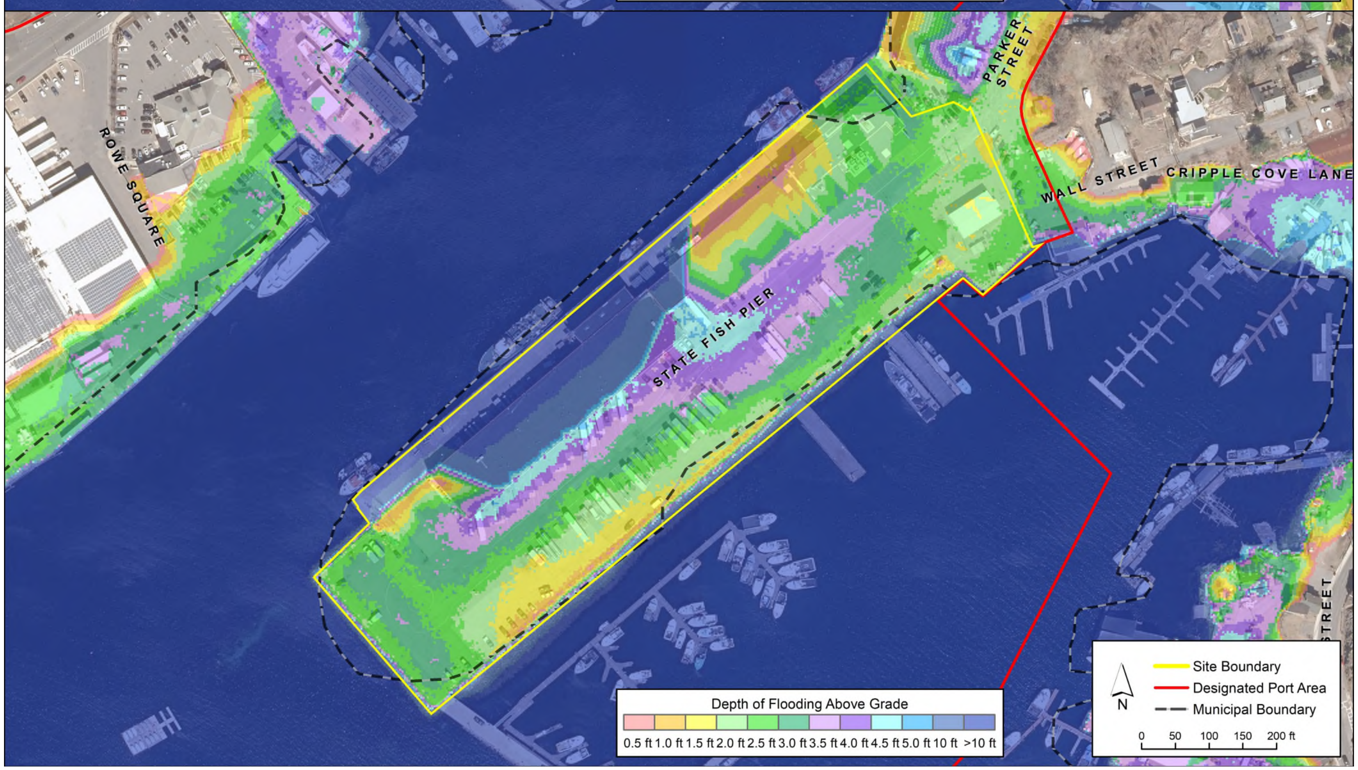


Jodrey State Fish Pier – 2070 Flood Risk

1% Annual Chance or 100-year Storm Flooding

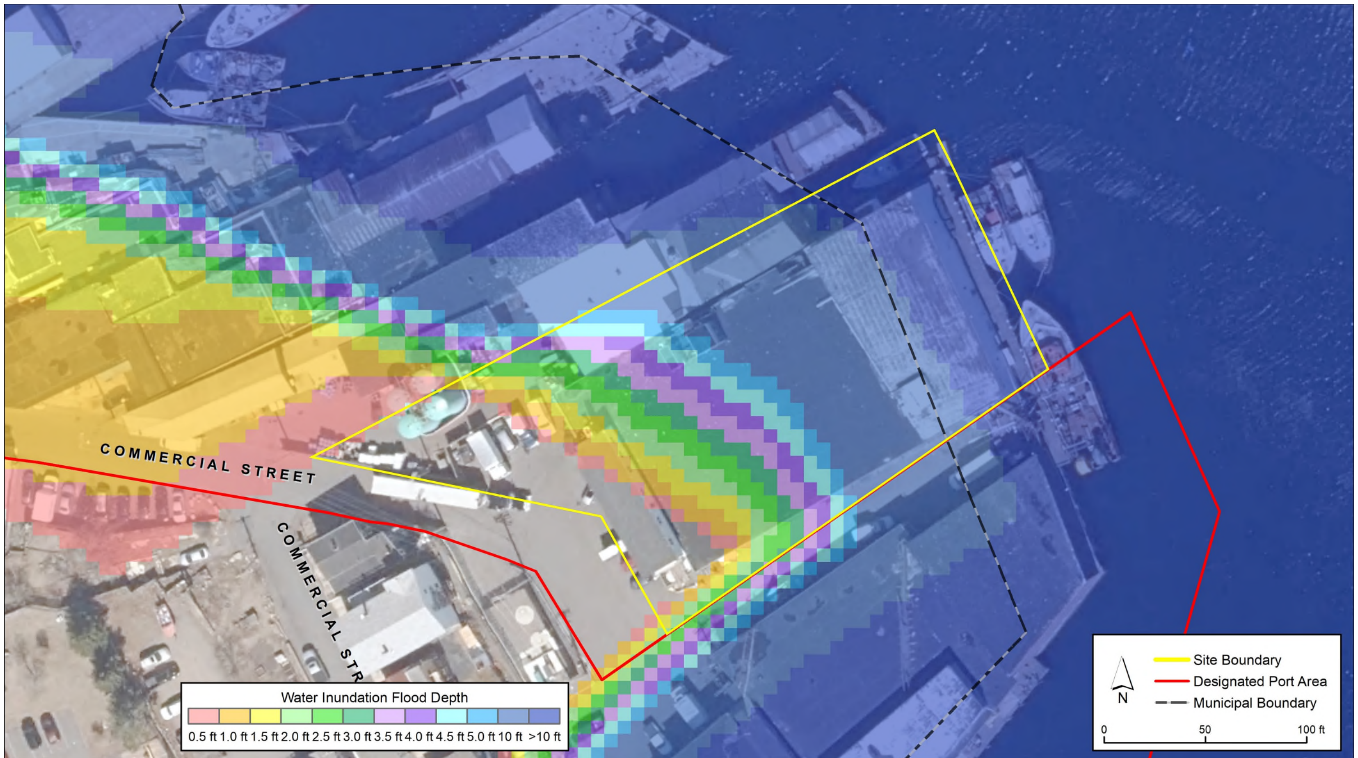


Mean Monthly High Water Tidal Flooding

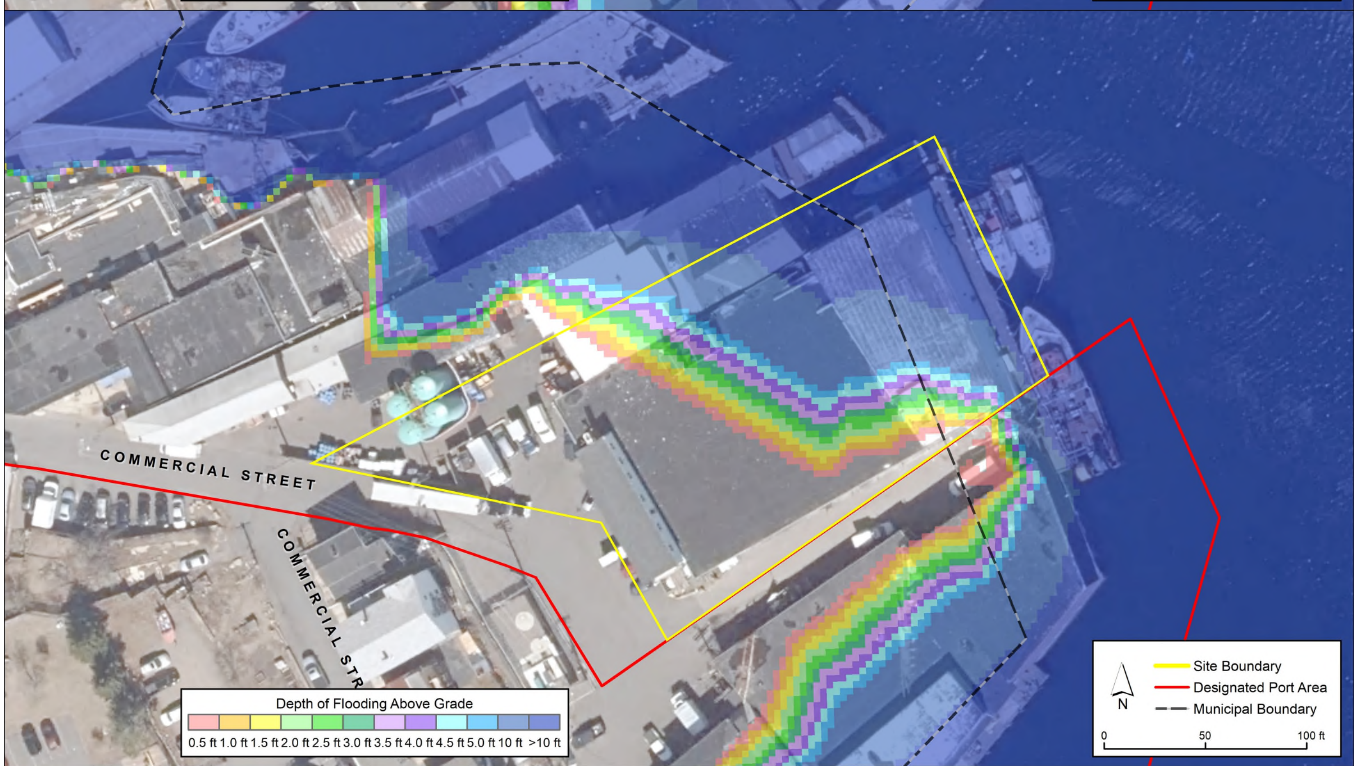


Cape Pond Ice – Present Day Flood Risk

1% Annual Chance or 100-year Storm Flooding

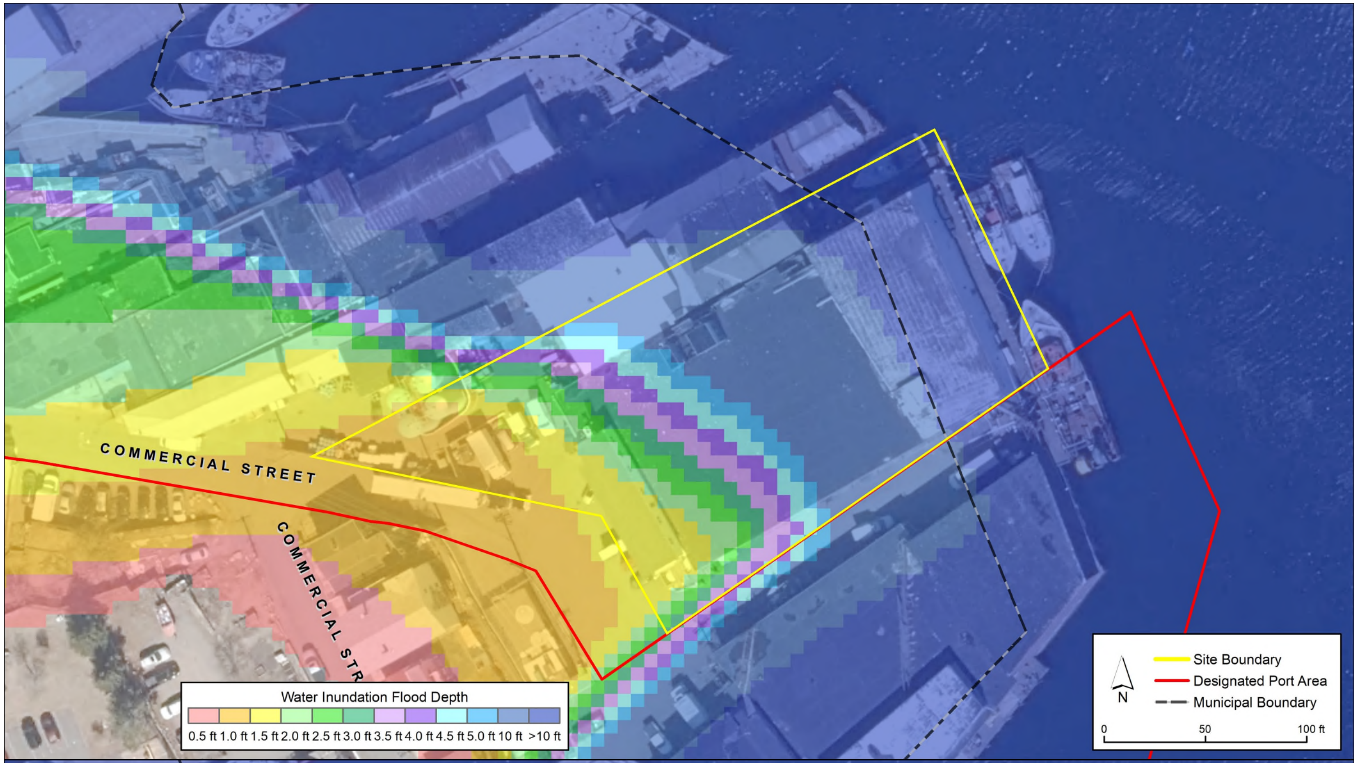


Mean Monthly High Water Tidal Flooding



Cape Pond Ice – 2030 Flood Risk

1% Annual Chance or 100-year Storm Flooding



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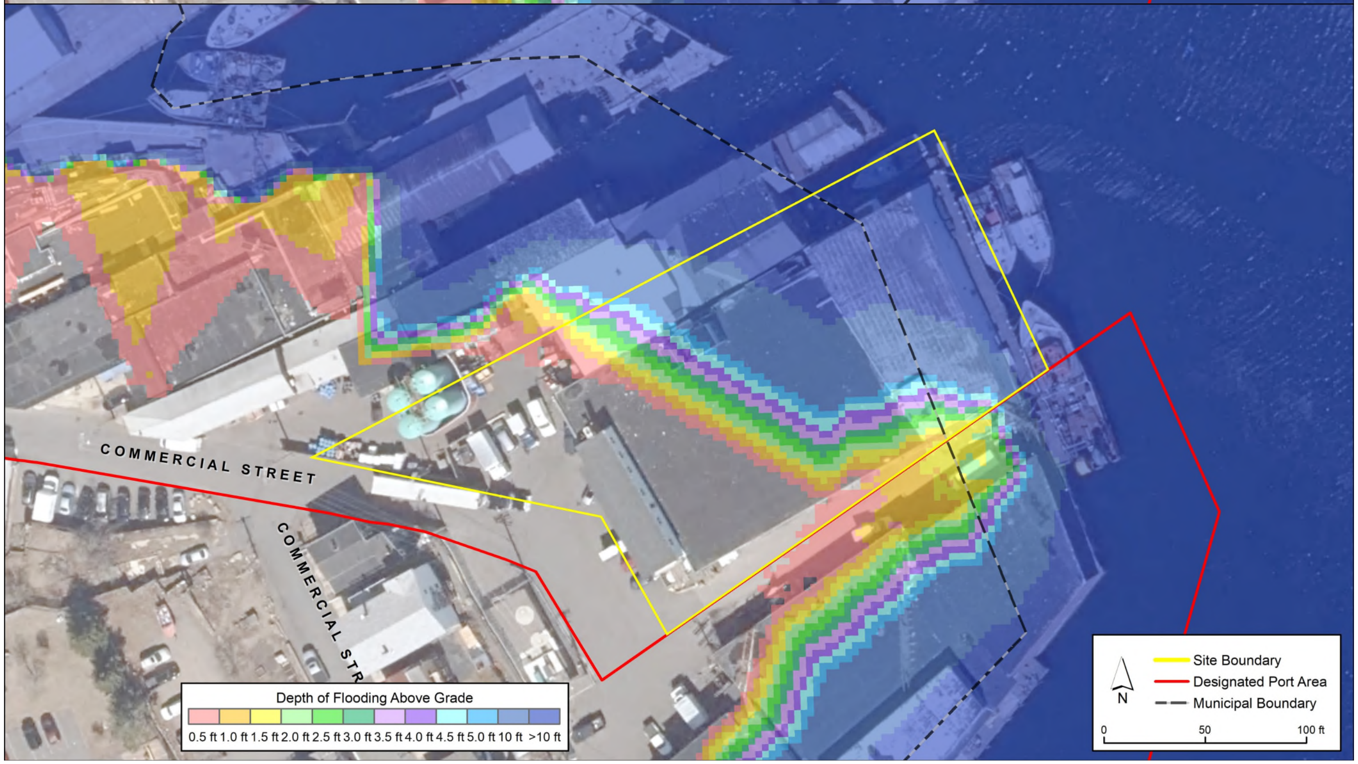
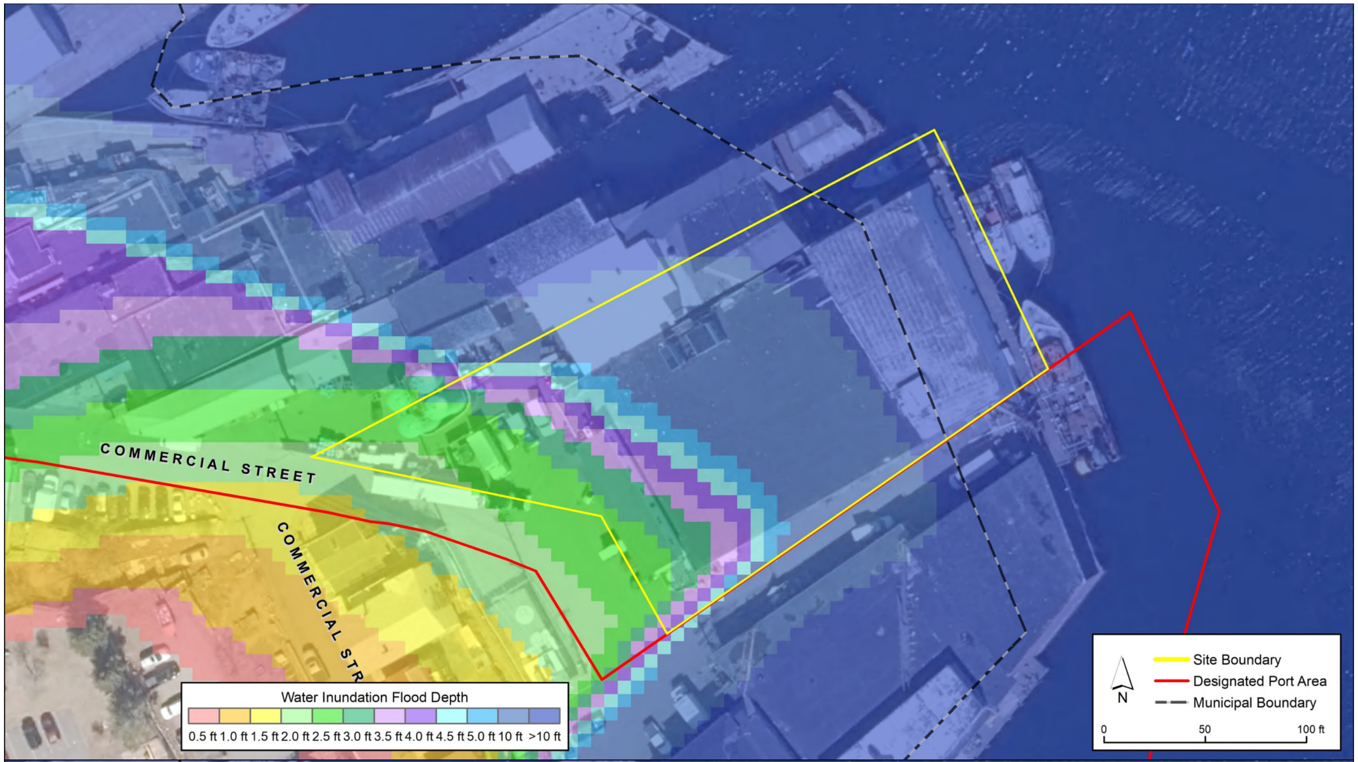


Cape Pond Ice – 2050 Flood Risk

1% Annual Chance or 100-year Storm Flooding



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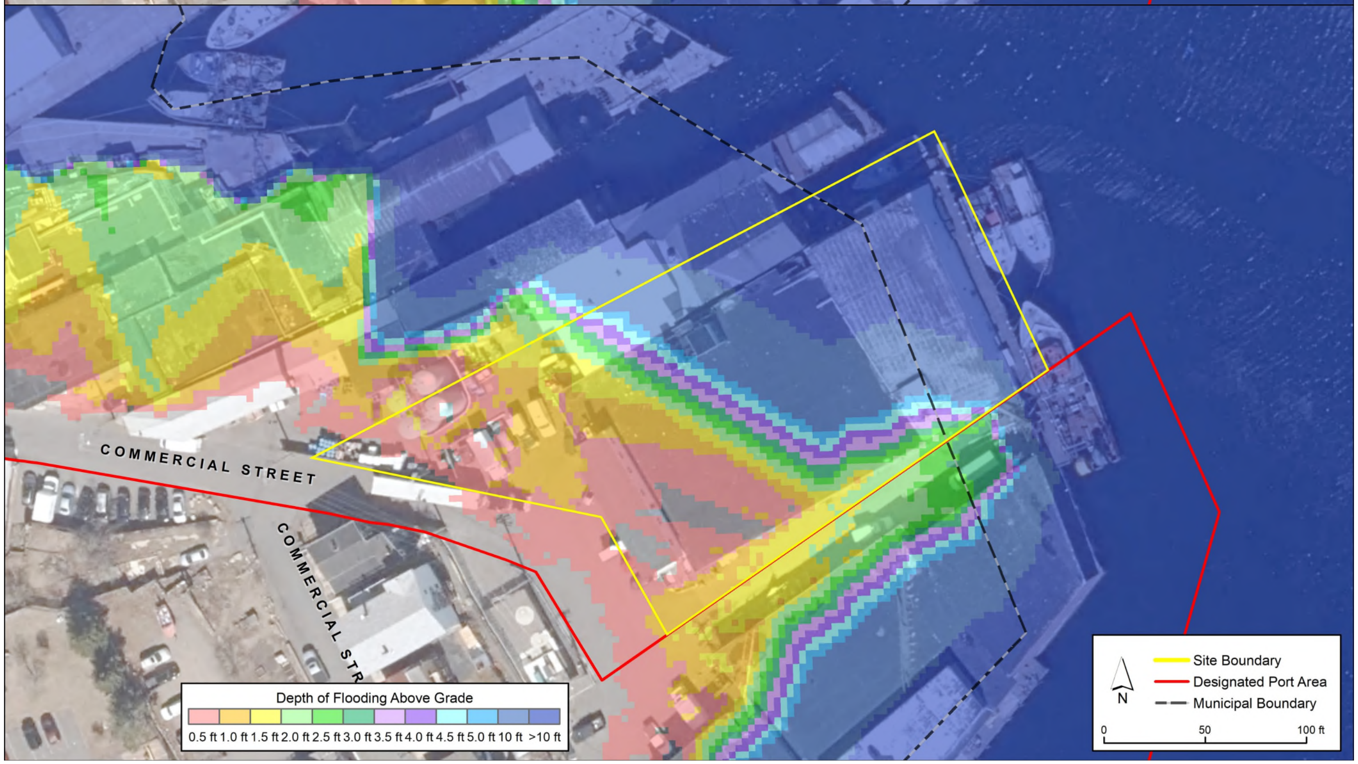
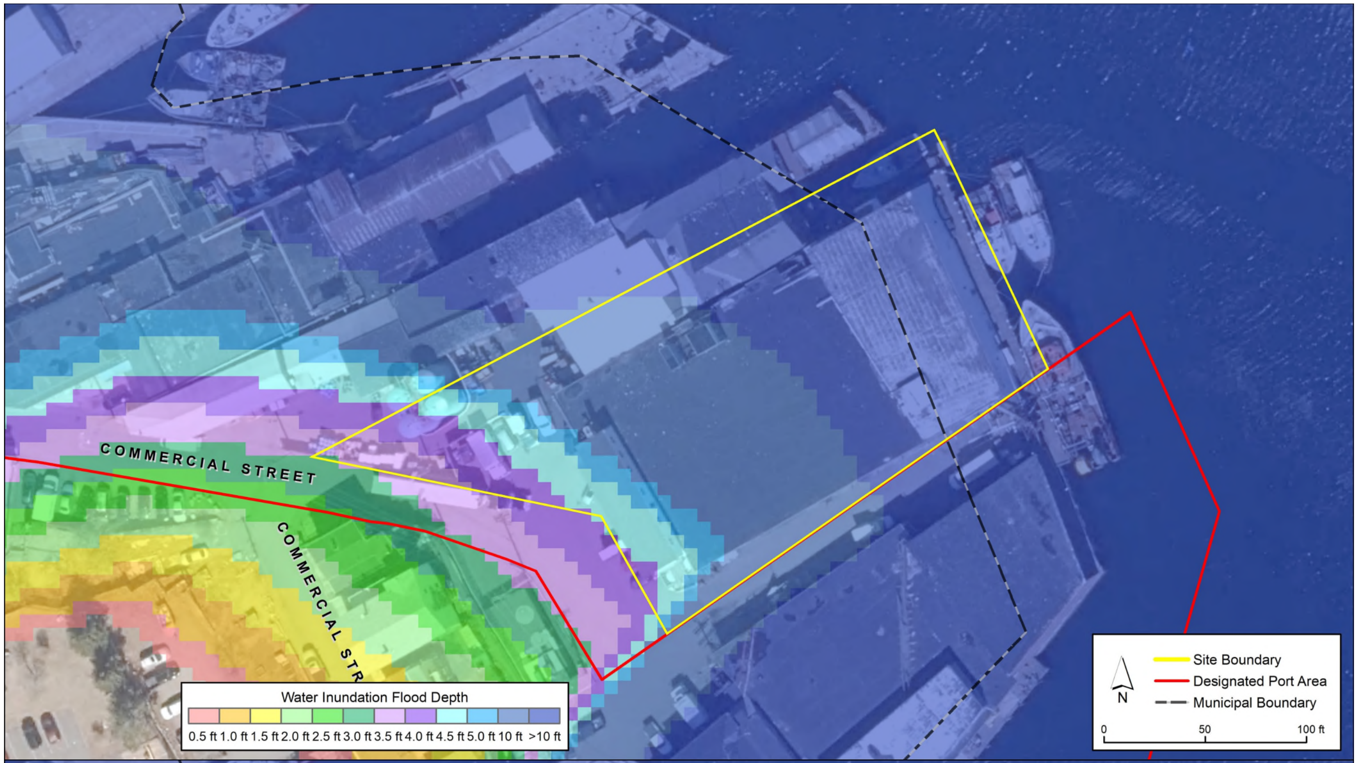
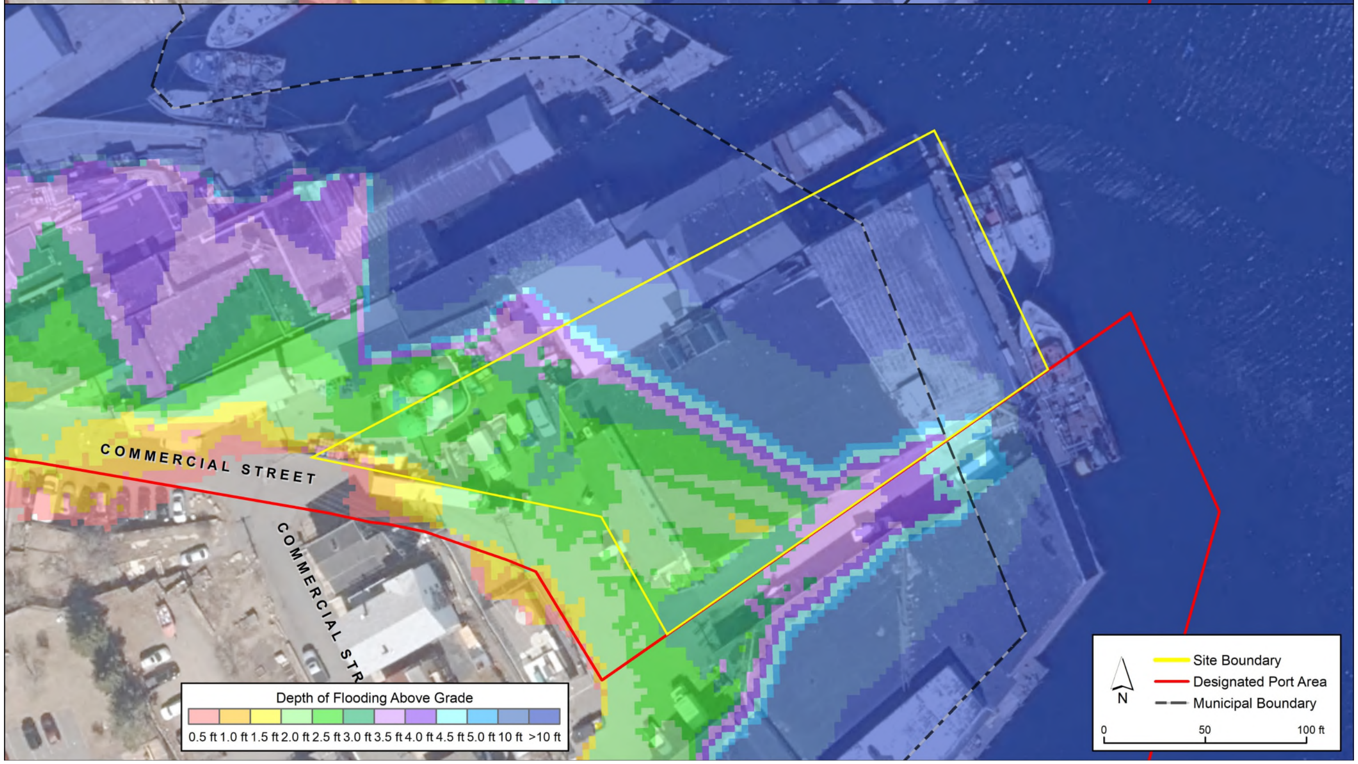


Cape Pond Ice – 2070 Flood Risk

1% Annual Chance or 100-year Storm Flooding

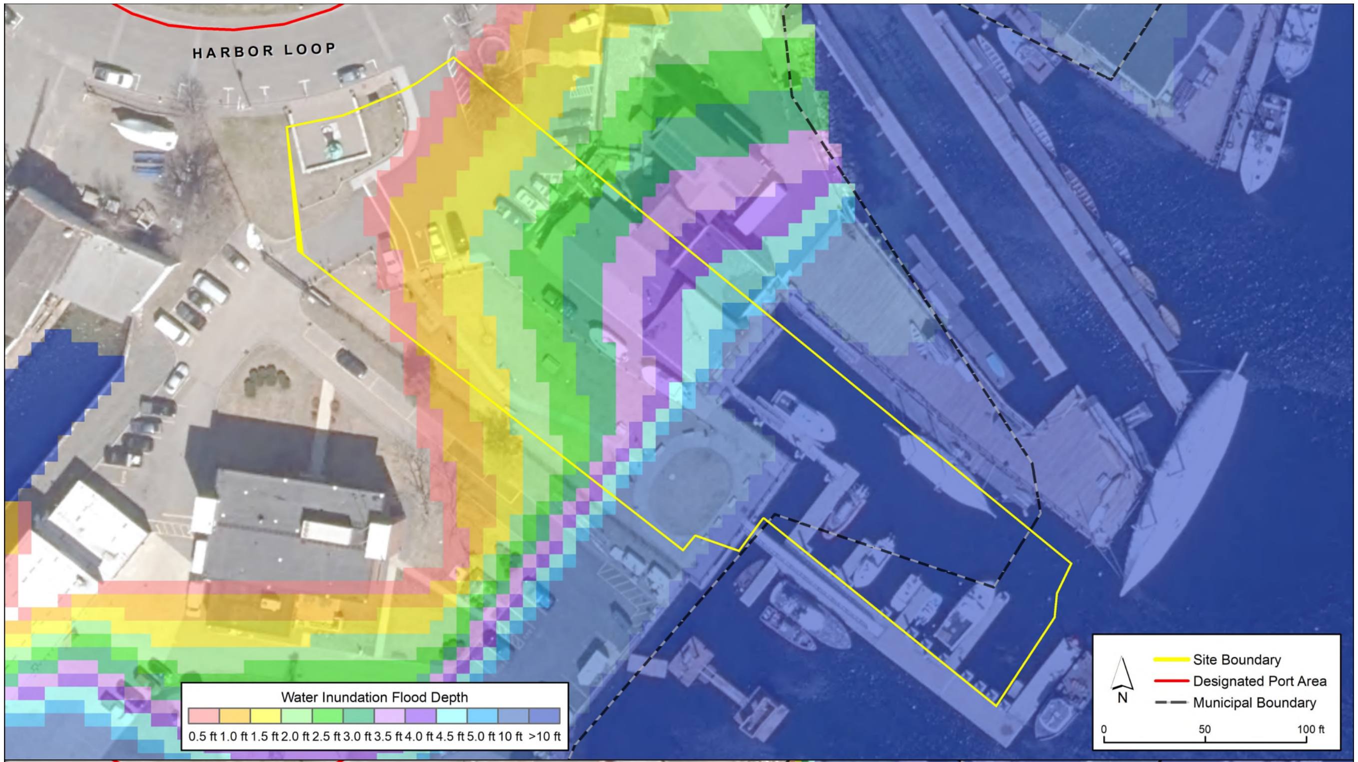


Mean Monthly High Water Tidal Flooding



Harbormaster's Office – Present Day Flood Risk

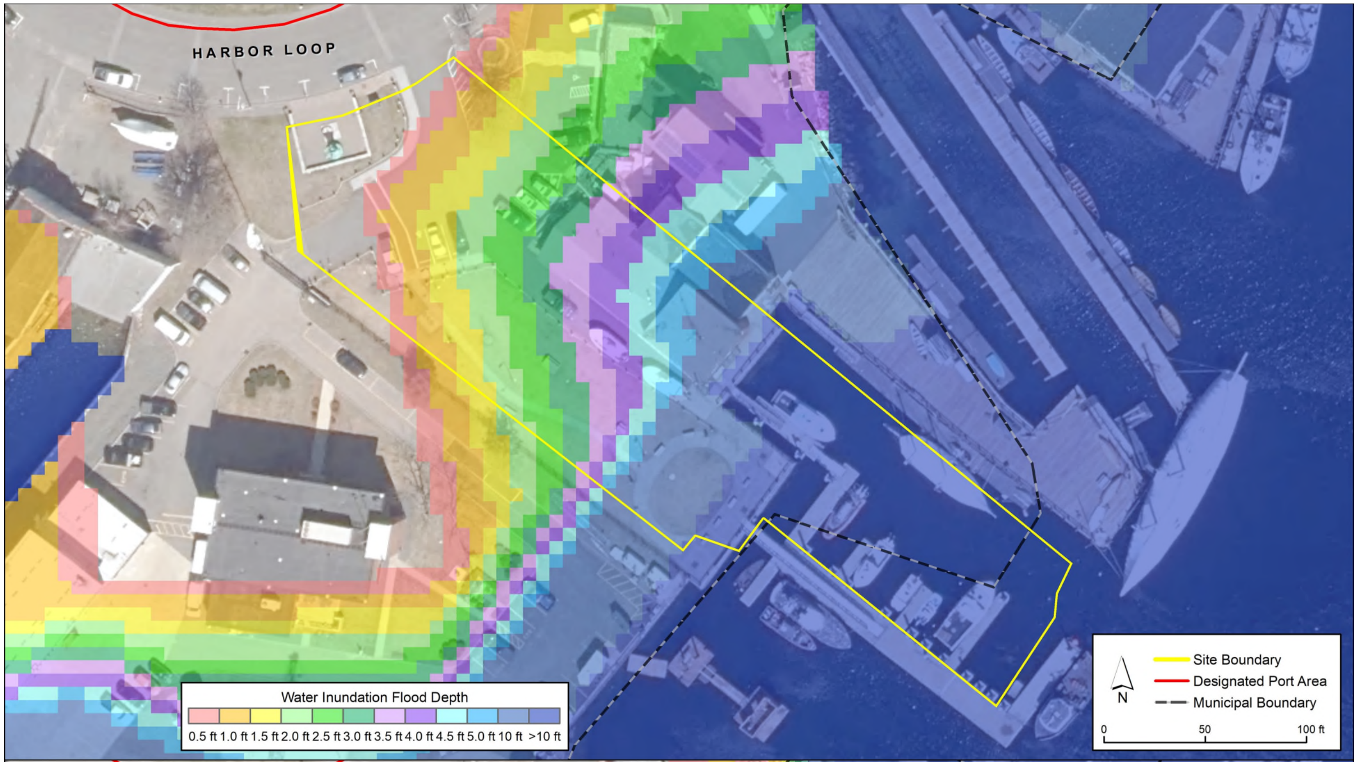
1% Annual Chance or 100-year Storm Flooding



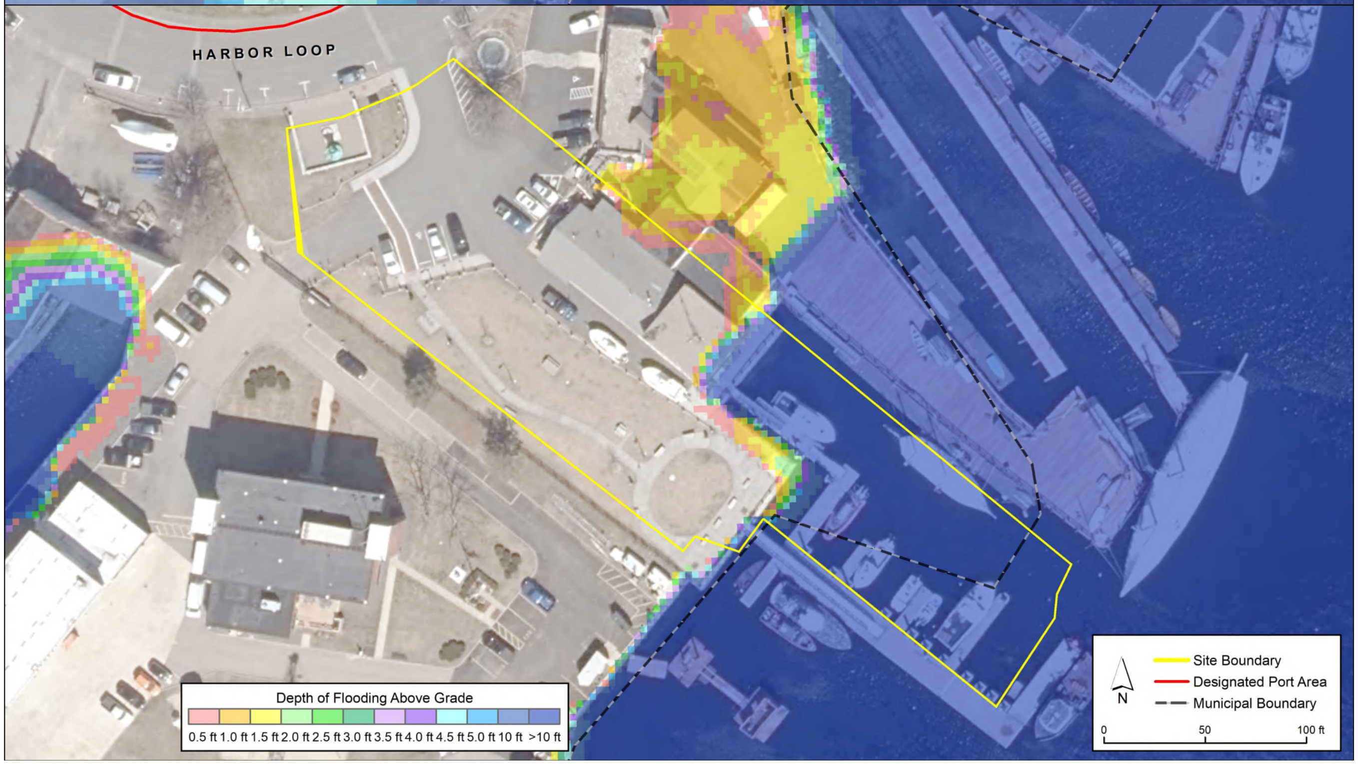
Mean Monthly High Water Tidal Flooding

Harbormaster's Office – 2030 Flood Risk

1% Annual Chance or 100-year Storm Flooding

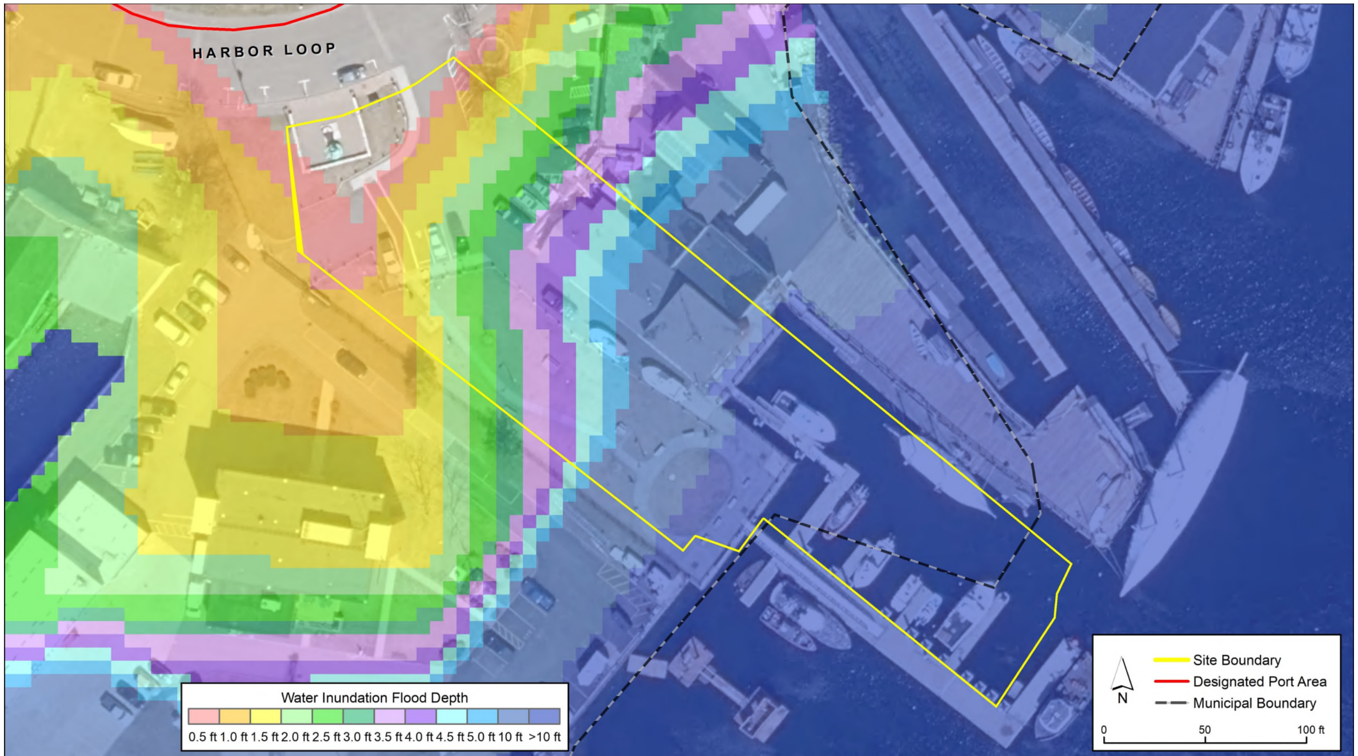


Mean Monthly High Water Tidal Flooding

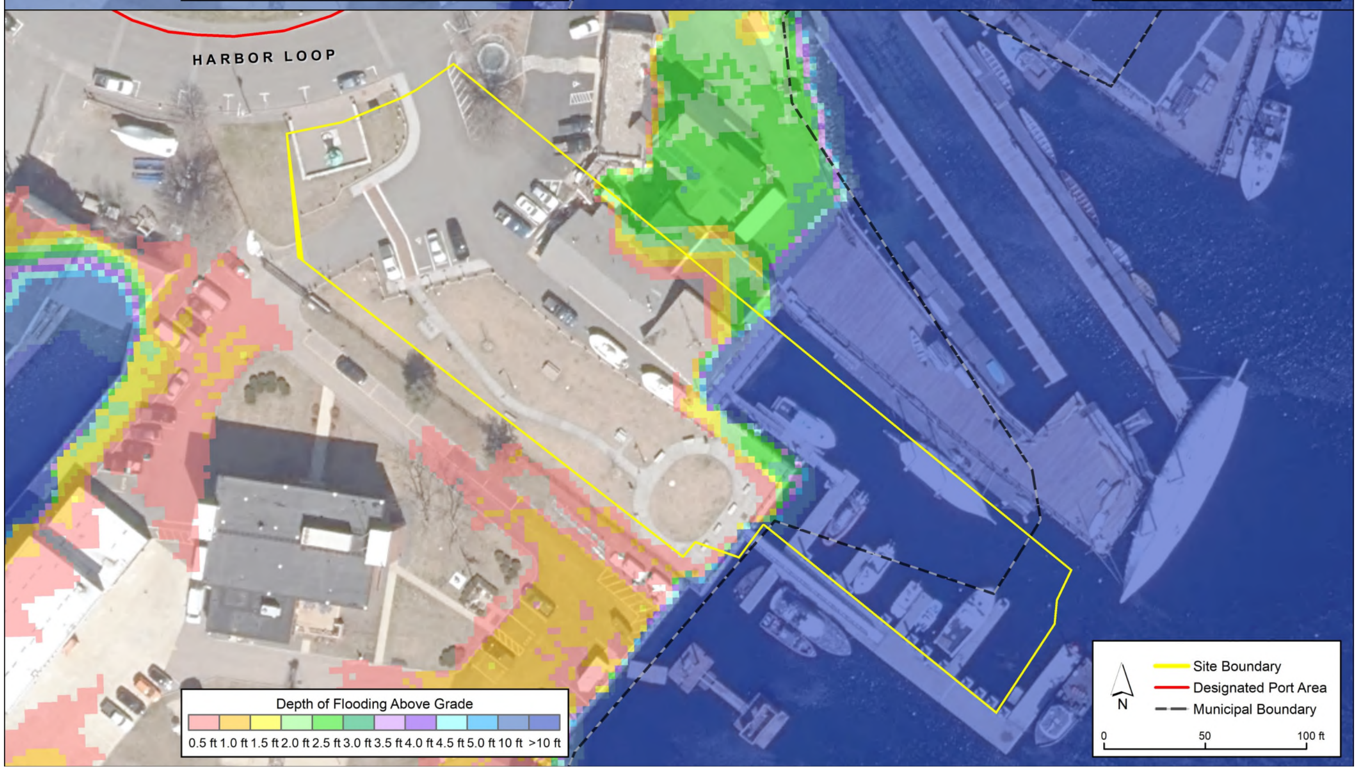


Harbormaster's Office – 2050 Flood Risk

1% Annual Chance or 100-year Storm Flooding

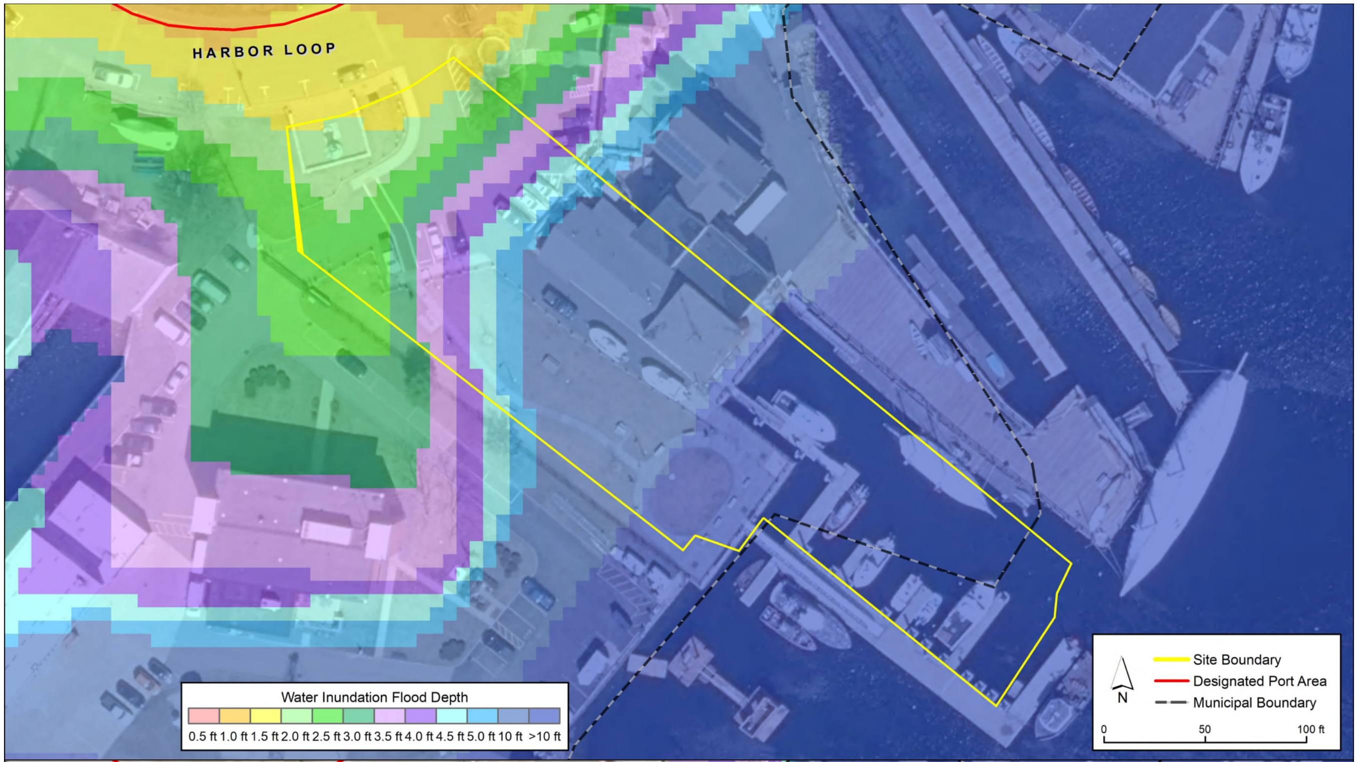


Mean Monthly High Water Tidal Flooding

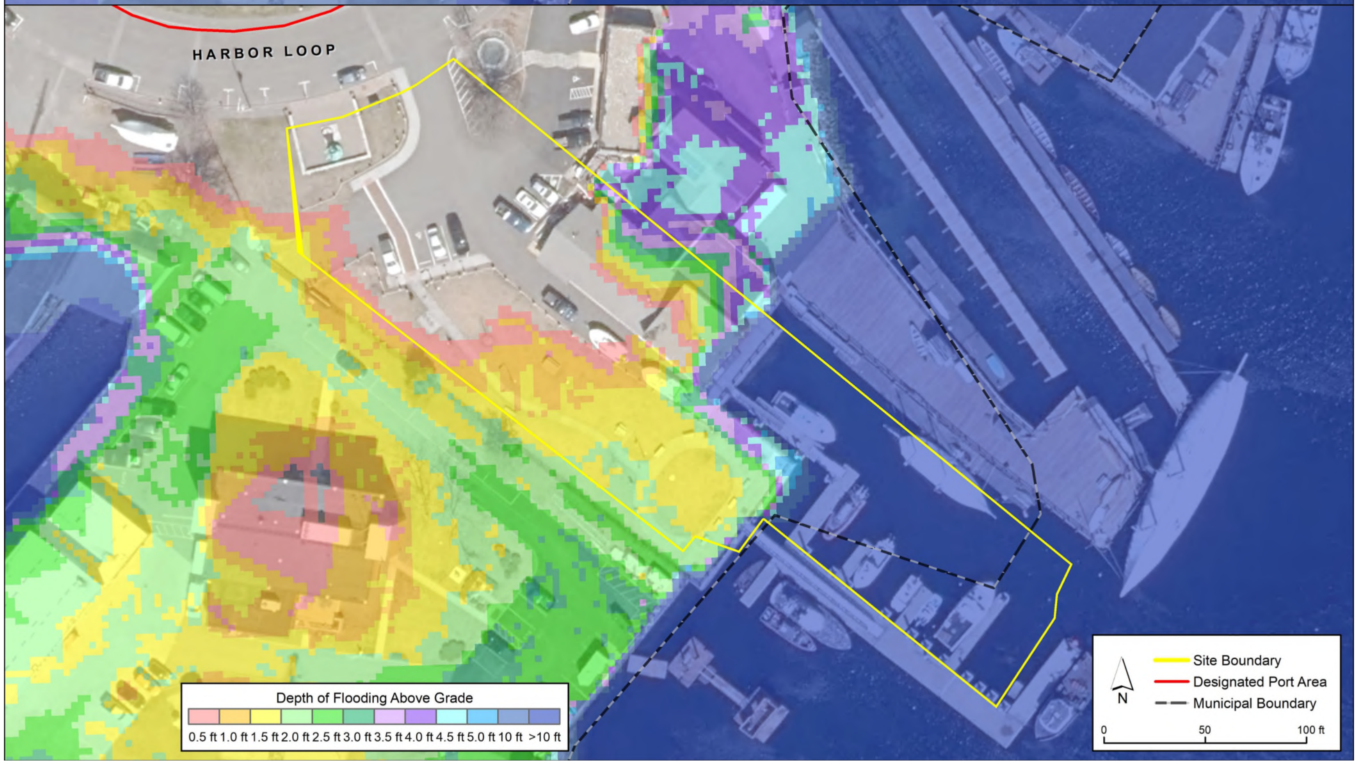


Harbormaster's Office – 2070 Flood Risk

1% Annual Chance or 100-year Storm Flooding

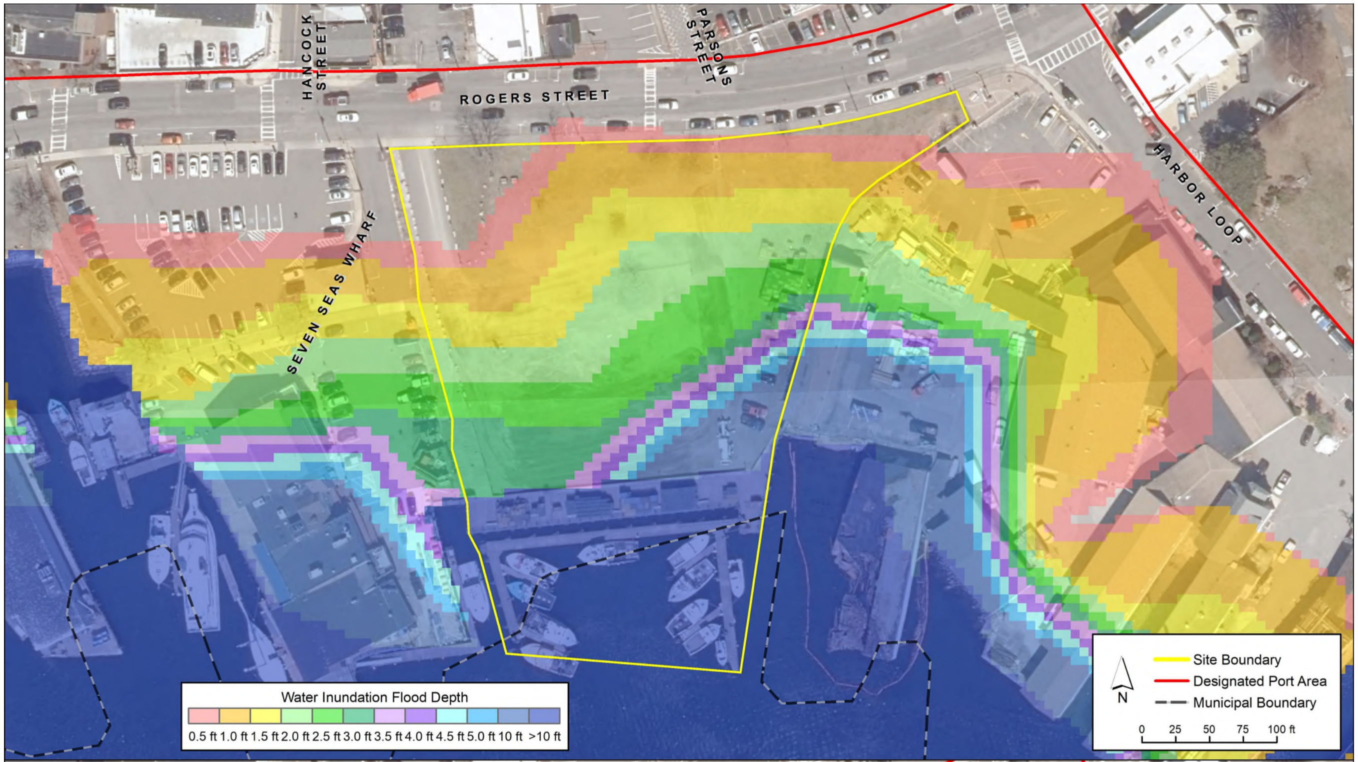


Mean Monthly High Water Tidal Flooding

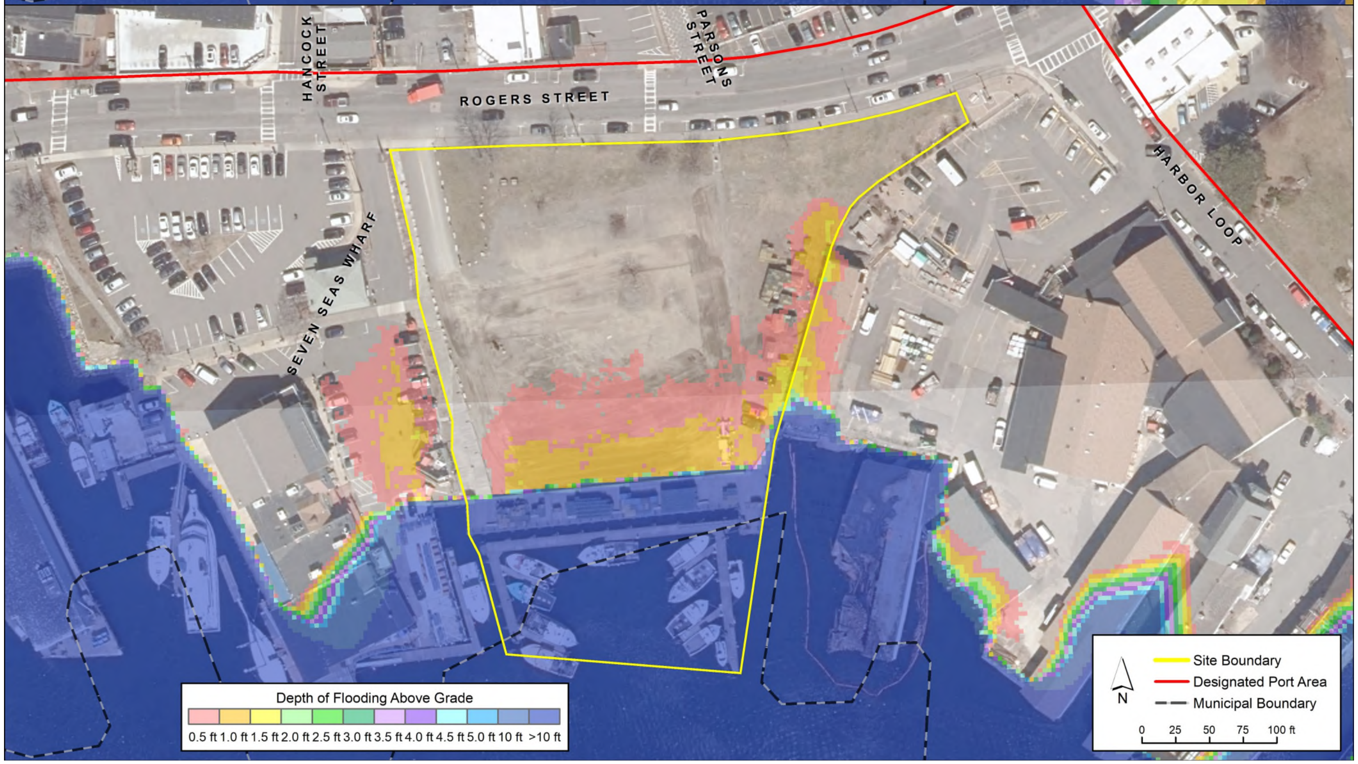


I4C2 Site – Present Day Flood Risk

1% Annual Chance or 100-year Storm Flooding

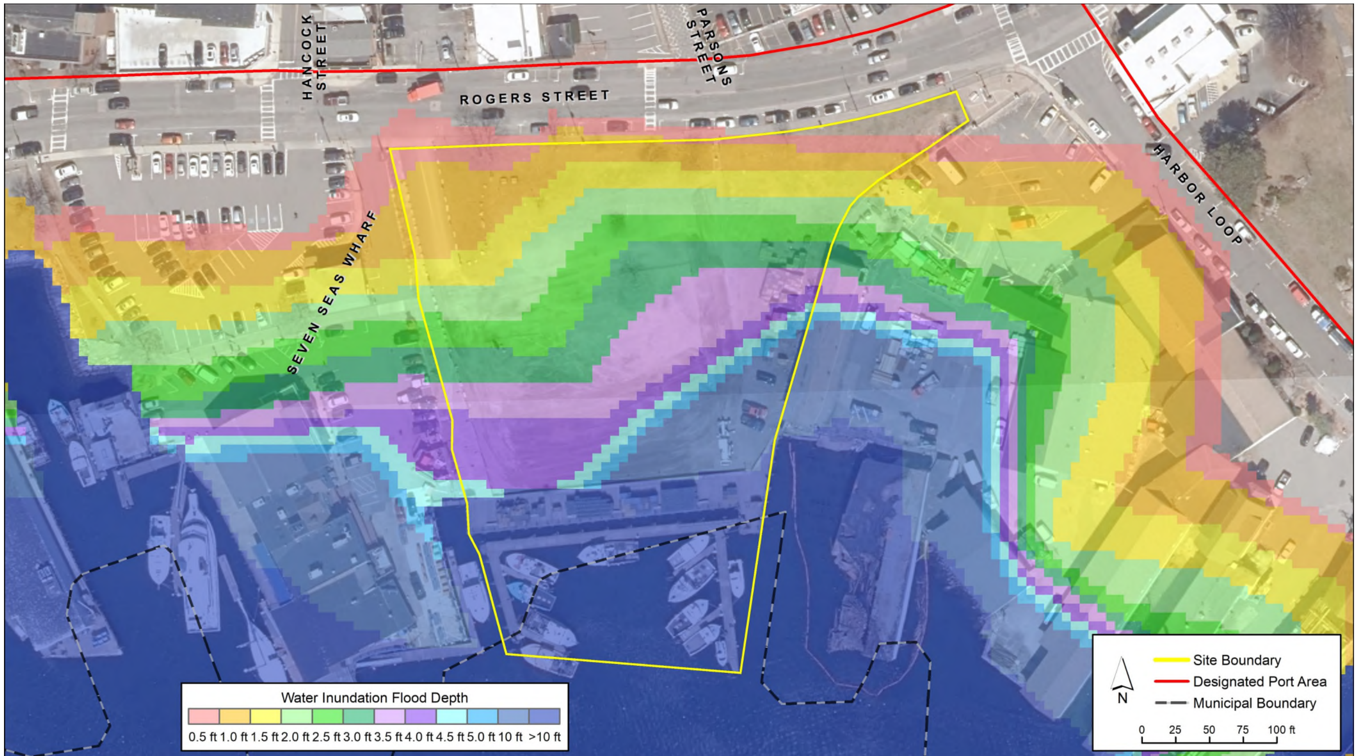


Mean Monthly High Water Tidal Flooding

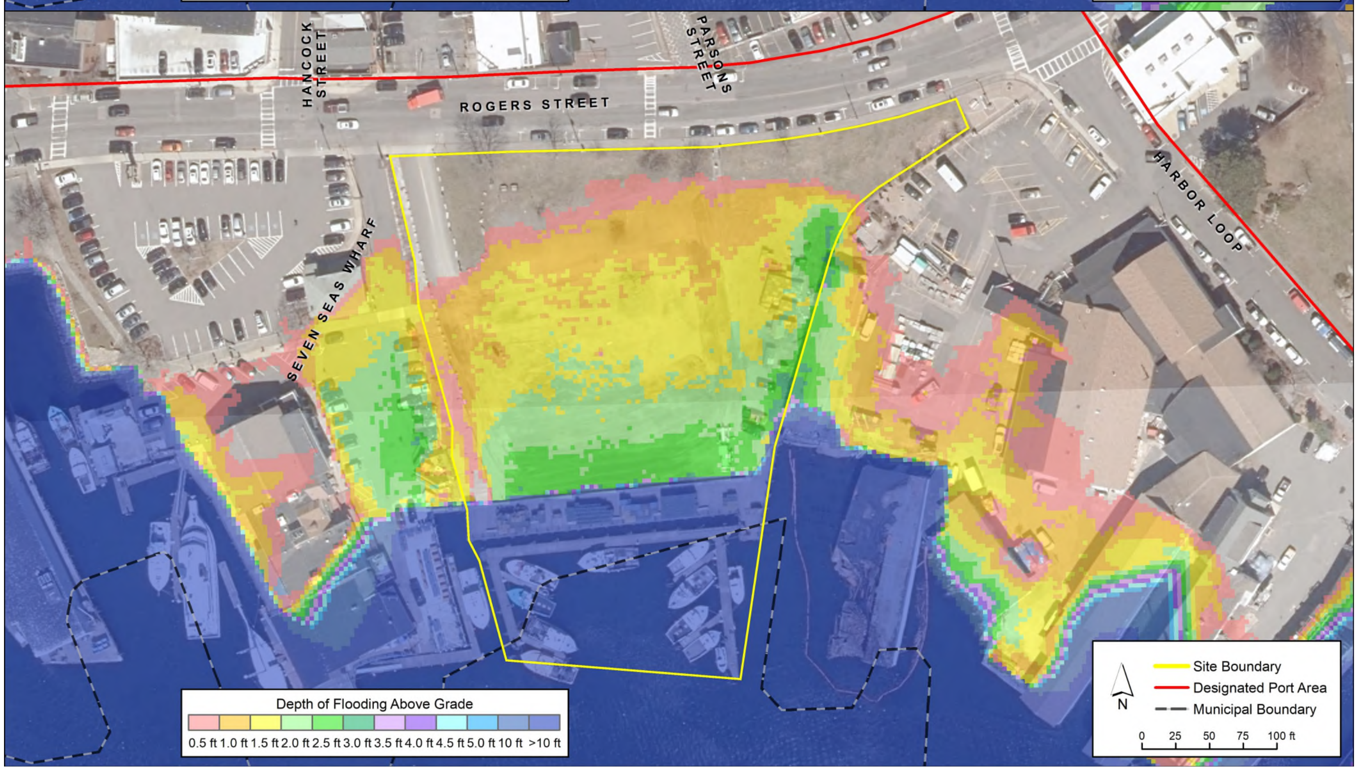


I4C2 Site – 2030 Flood Risk

1% Annual Chance or 100-year Storm Flooding

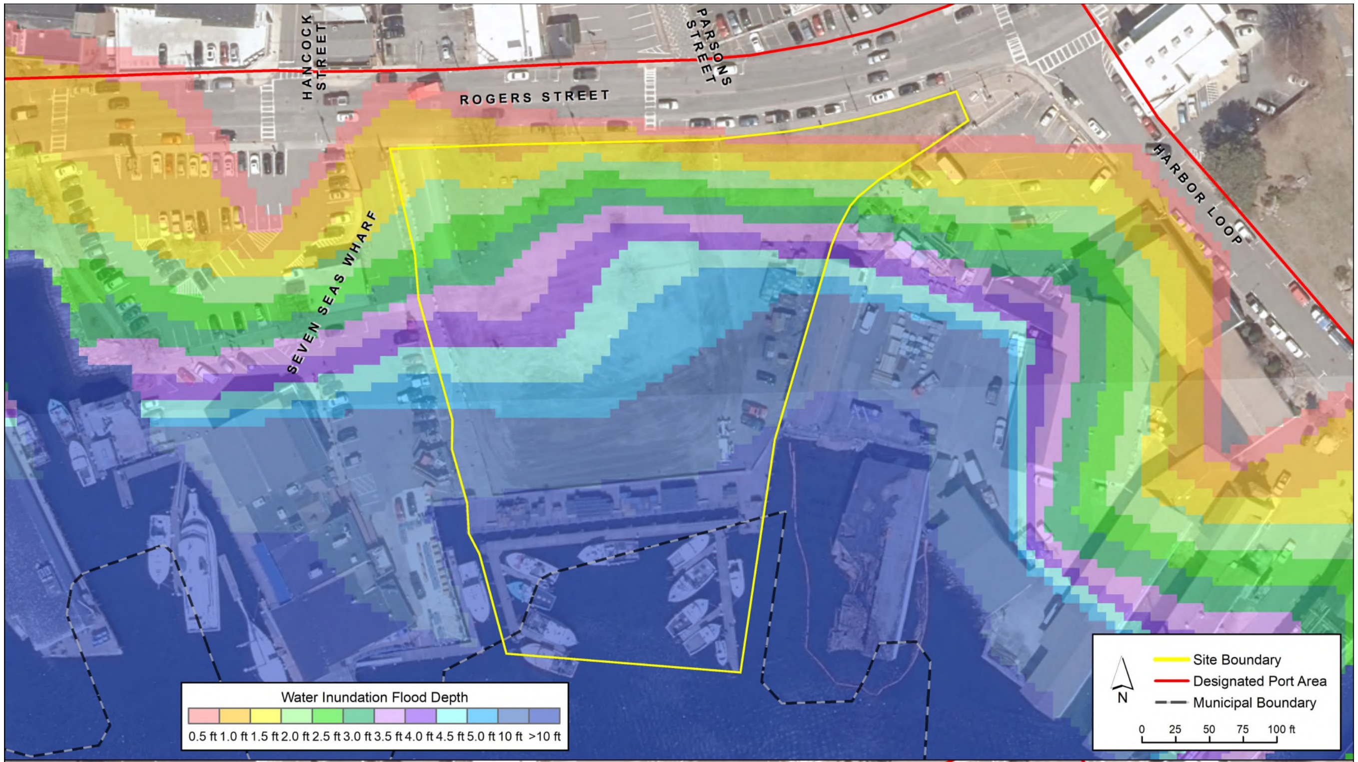


Mean Monthly High Water Tidal Flooding

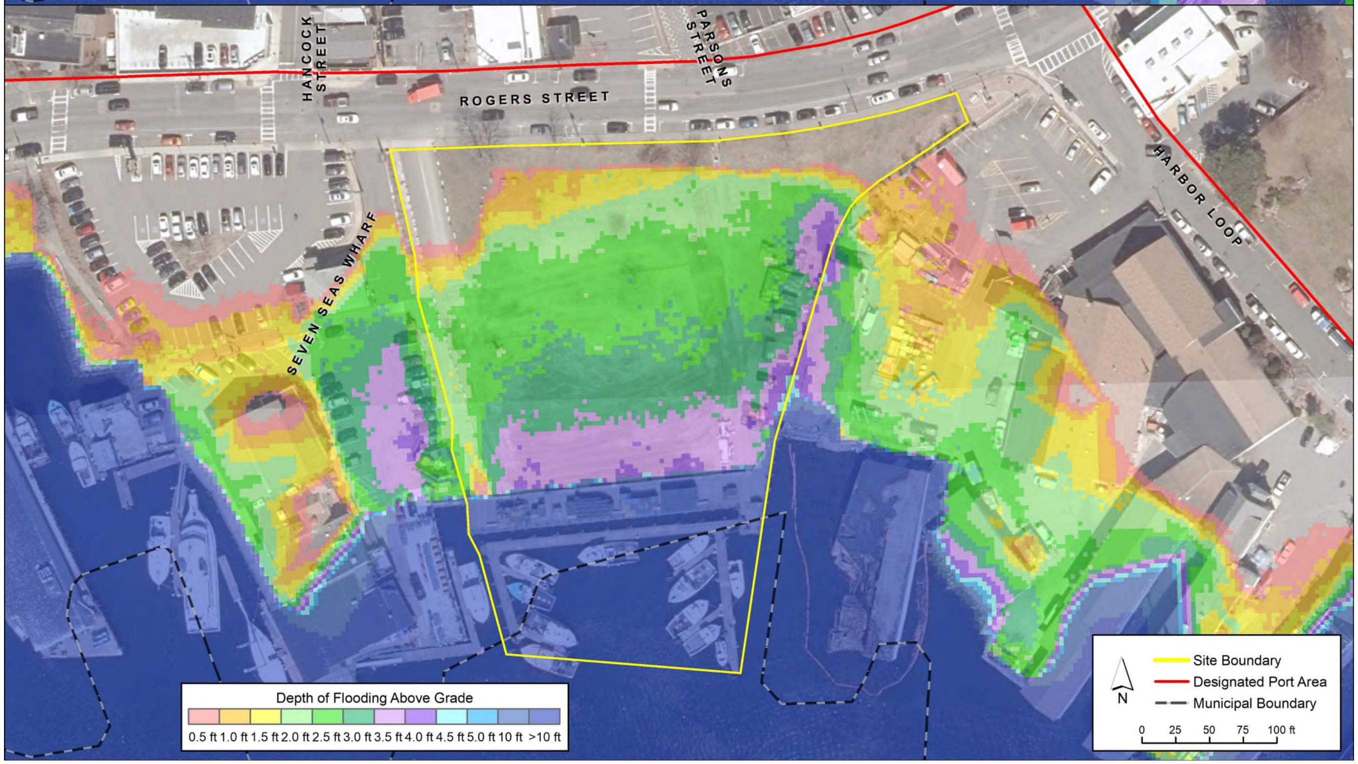


I4C2 Site – 2050 Flood Risk

1% Annual Chance or 100-year Storm Flooding

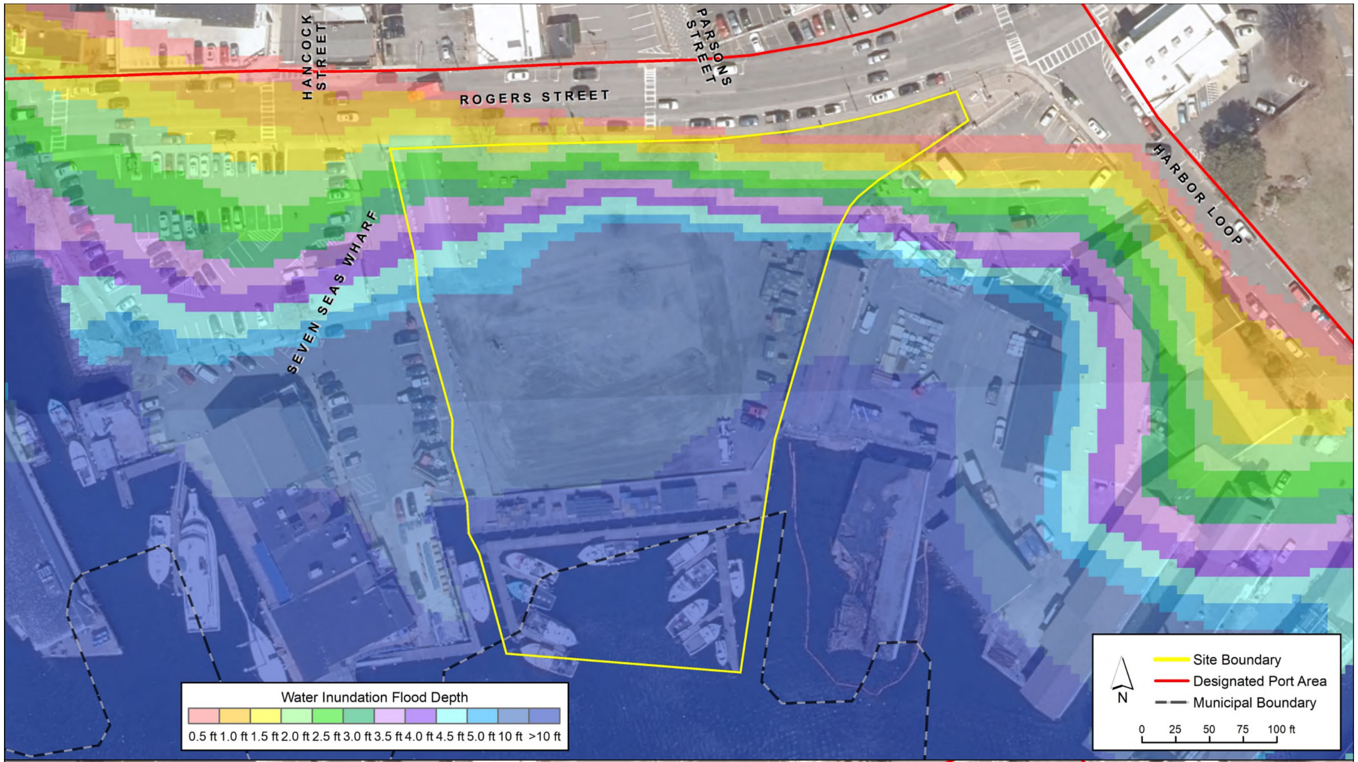


Mean Monthly High Water Tidal Flooding

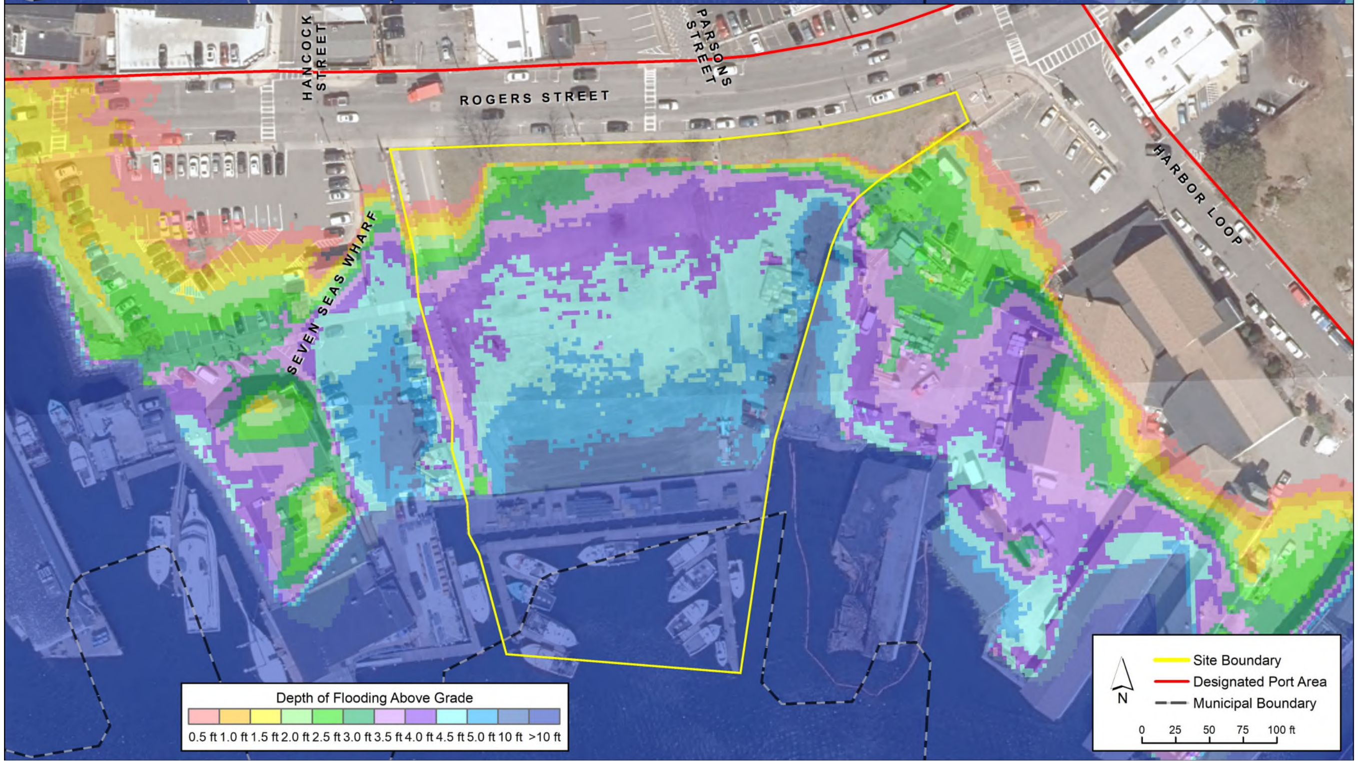


I4C2 Site – 2070 Flood Risk

1% Annual Chance or 100-year Storm Flooding



Mean Monthly High Water Tidal Flooding



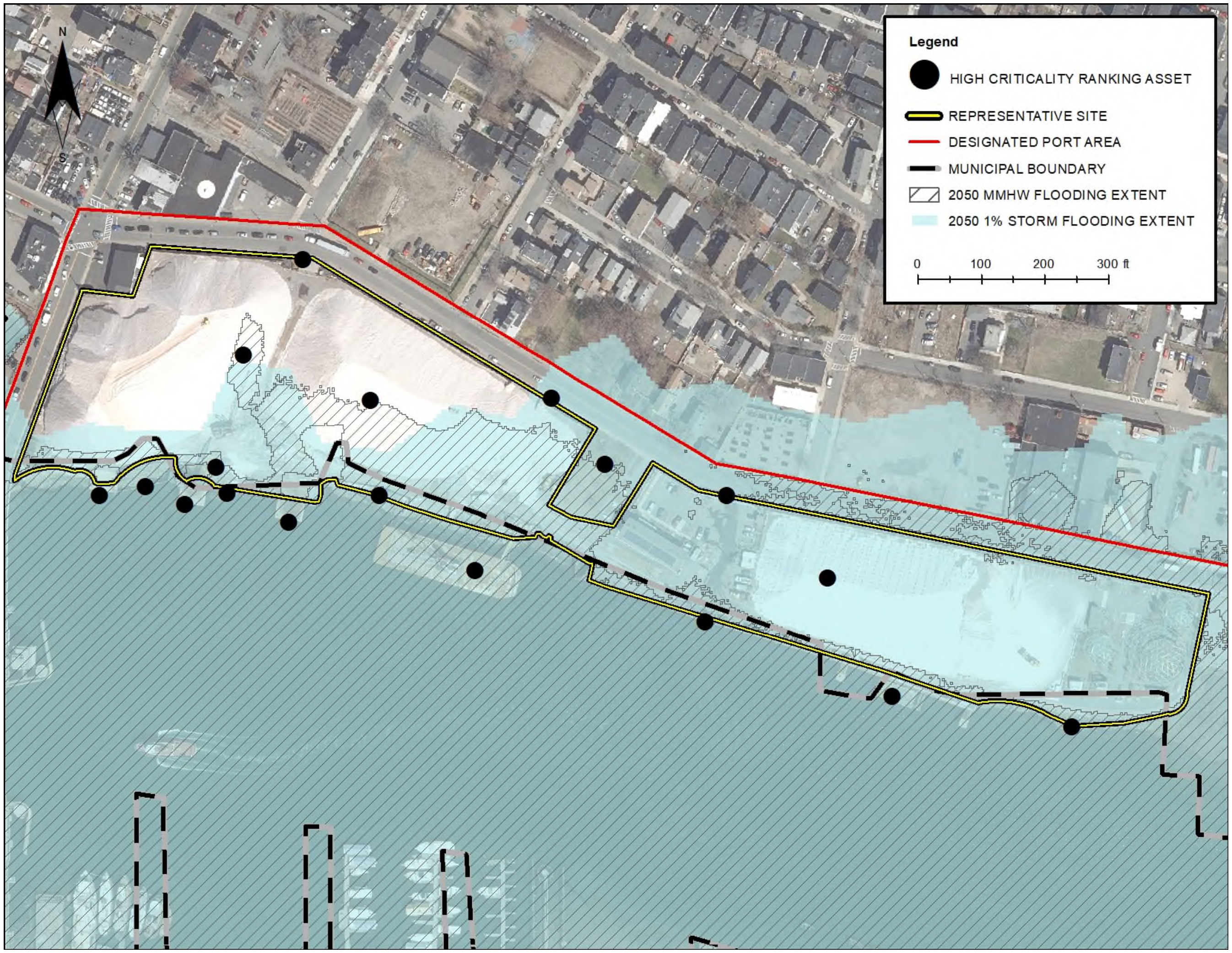
Appendix C – Representative Site Coastal Flood Exposure Profiles

Included as attachment.

Representative Site Flood Exposure Profiles

Eastern Minerals

Eastern Minerals Inc. is a dry bulk terminal located in Chelsea Creek and functions as a site for salt storage and distribution. Track based cranes on the site remove salt from the barges docked at the terminal and the salt is then stored in stockpiles. Salt is then distributed from these stockpiles via trucks to local and regional customers in preparation and during winter storm events.



PRIMARY LOSS OF SERVICE CONSEQUENCES

- Reduced salt supply to local and state agencies and municipalities
- Potential impact to traveling conditions during inclement weather

- Hurricane Sandy storm surge was only major flooding experienced on site
- Cannot operate at full capacity if crane pads are inaccessible and cranes are inoperable
- Salt distribution services cannot be conducted if Marginal St. access is blocked

Eastern Minerals Exposure Summary	
Total Number of Assets	21
Number of Critical Assets	18
Critical Assets Exposed to Coastal Flooding Today	83%
Critical Assets Exposed to Coastal Flooding by 2050	94%
Dominant Flood Type for Critical Assets	Fringe

Gulf Oil

The Gulf Oil terminal is responsible for the handling and storage of oil and other petrochemicals that arrives to the terminal via oil tanker. The site is comprised of a tank farm, berthing system and loading platform for delivery of oil, truck parking, office space, and garages for vehicle and equipment maintenance.

PRIMARY LOSS OF SERVICE CONSEQUENCES

- Loss of oil distribution to nearby locations and potentially to regional level
- Environmental contamination

- Storm surge has never impacted storage tanks closest to waterfront
- During and after storm events, one of the largest obstacles to product distribution is clearing of distribution routes in surrounding area

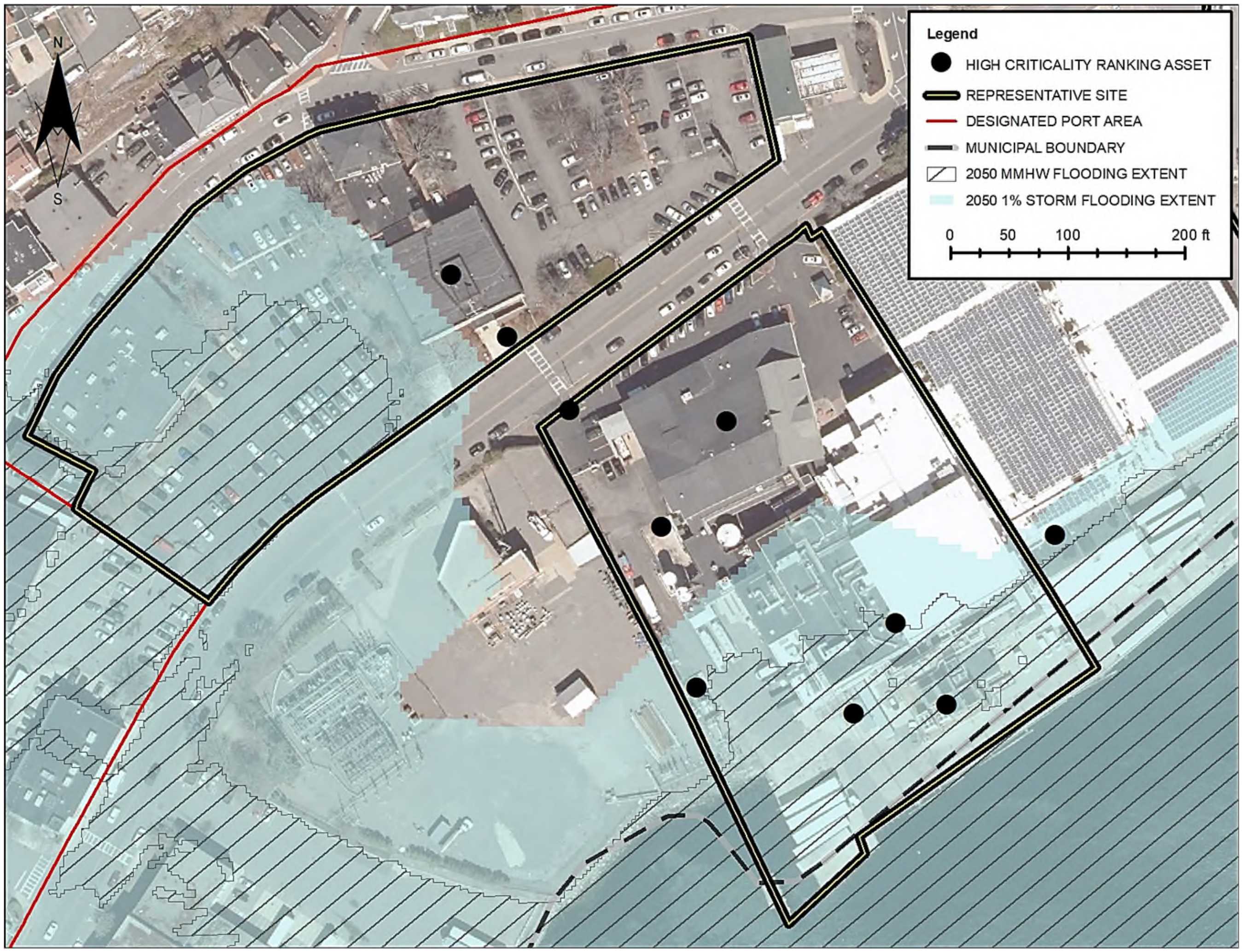
Gulf Oil Flood Exposure Summary	
Total Number of Assets	38
Number of Critical Assets	30
Critical Assets Exposed to Coastal Flooding Today	93%
Critical Assets Exposed to Coastal Flooding by 2050	100%
Dominant Flood Type for Critical Assets	Fringe (50%) and Pathway (50%)

Gorton's

Gorton's is a fish and seafood processing facility and produces fish sticks and other frozen seafood products. The company's products are distributed to food retailers and food service suppliers nationwide. Americold, located adjacent to the Gorton's facility, is responsible for cold storage operations. Gorton's and Americold are no longer dependent on fish stocks landed in Gloucester or on local marine transportation at their waterfront to carry their products to market. The fish and seafood supplies and then products that are and stored now arrive and are shipped out by truck.

PRIMARY LOSS OF SERVICE CONSEQUENCES

- Food retailers and customers experience shortage in frozen fish and seafood products



- Stormwater flooding during major precipitation events has had greatest impact to site, specifically the lab facility and main office
- No present-day storm surge flooding has been experienced on site

Gorton's Flood Exposure Summary	
Total Number of Assets	15
Number of Critical Assets	12
Critical Assets Exposed to Coastal Flooding Today	33%
Critical Assets Exposed to Coastal Flooding by 2050	58%
Dominant Flood Type for Critical Assets	Fringe

Maritime Gloucester

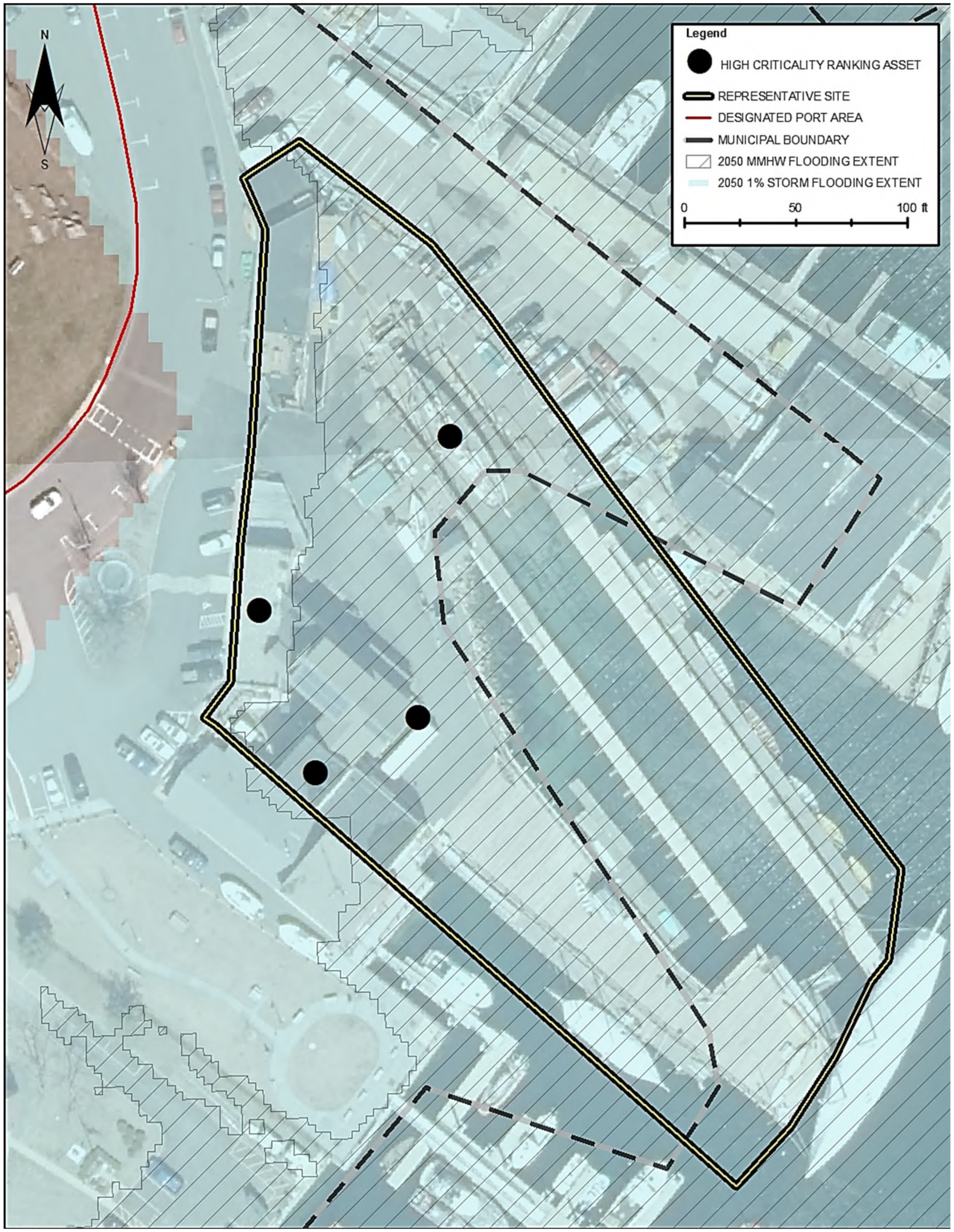
Maritime Gloucester hosts the oldest continuously operating marine railway in the United States, which aids in the maintenance and repair of fishing vessels within the harbor. The site also encompasses the operations and habitats within the historic fishing port through the operations of a museum, aquarium, and educational classroom.

PRIMARY LOSS OF SERVICE CONSEQUENCES

- Marine railway inoperable – cannot conduct out-of-water maintenance and repairs on vessels
- Loss of programming and community engagement

- Present day flooding on site 3-4 times per year
- Due to existing grading, once floodwaters are on site they are funneled towards the buildings

Maritime Gloucester Flood Exposure Summary	
Total Number of Assets	8
Number of Critical Assets	4
Critical Assets Exposed to Coastal Flooding Today	100%
Critical Assets Exposed to Coastal Flooding by 2050	100%
Dominant Flood Type for Critical Assets	Fringe

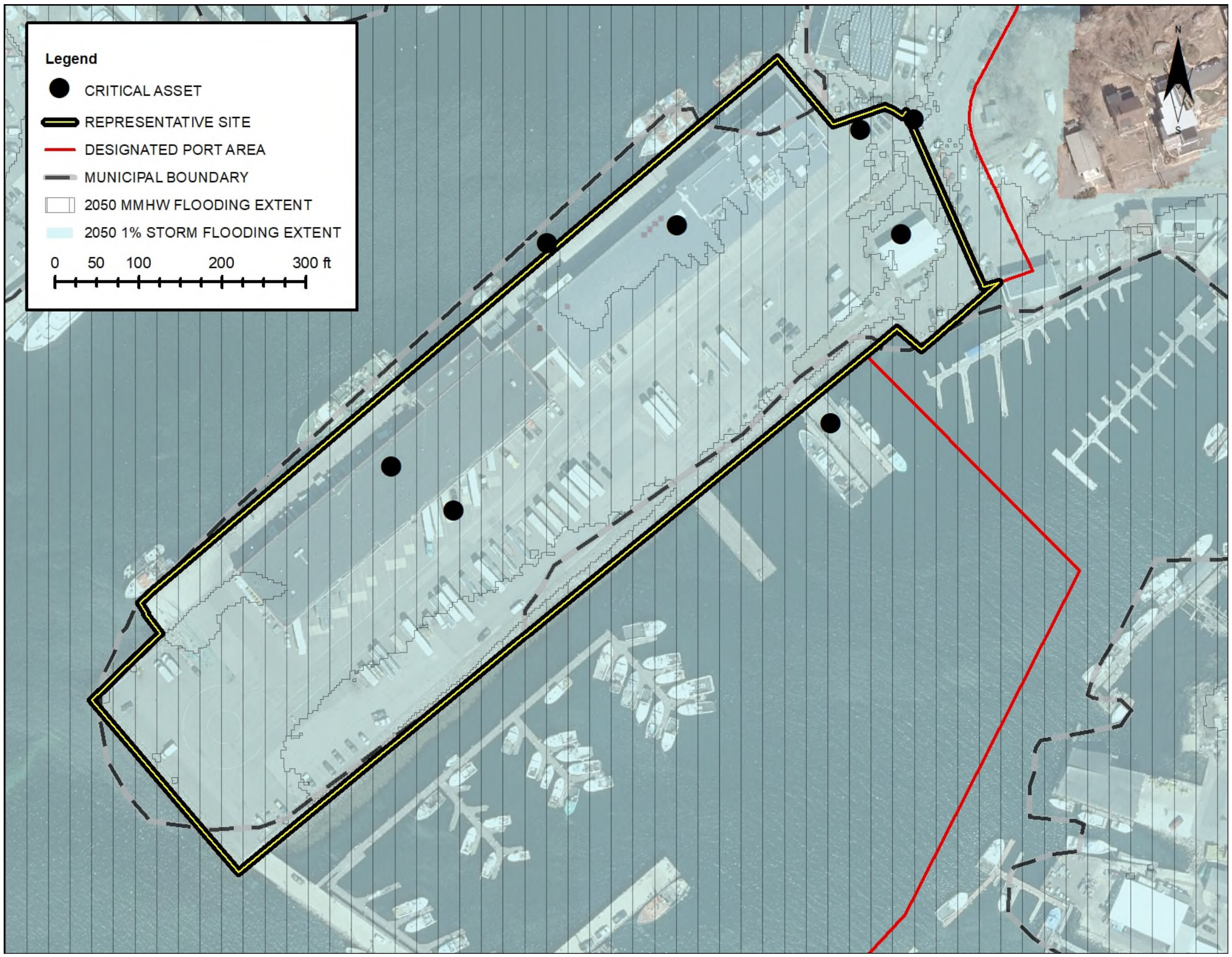


Jodrey State Fish Pier

The Pier, owned and operated by MassDevelopment, supports the local fishing and lobster fleets with warehouses on site for processing, storage, and distribution of seafood products. Numerous docking berths are also located at the pier for commercial fishing vessels. In additional to supporting the fishing industry, the site also hosts Coast Guard vessels and a Massachusetts Environmental Police operations building.

PRIMARY LOSS OF SERVICE CONSEQUENCES

- Decrease in fish and lobster supply to local customers and community
- Loss of maritime safety operations



- Due to existing grade and consistent site elevation, once floodwaters overtop shoreline protection majority of site will become inundated
- No flooding experience on site during major storm surge events

Jodrey State Fish Pier Exposure Summary	
Total Number of Assets	11
Number of Critical Assets	8
Critical Assets Exposed to Coastal Flooding Today	75%
Critical Assets Exposed to Coastal Flooding by 2050	100%
Dominant Flood Type for Critical Assets	Fringe

Cape Pond Ice

The production of ice is a critical business for harbors where fishing is a large industrial presence. At the Cape Pond Ice facility, fishing vessels can pull up directly to the wharf and take anywhere from 300lbs to 30 tons of ice per fishing trip. In addition to supplying the fishing industry with ice, Cape Pond Ice supplies ice to farmers, concrete contractors, custom ice sculptors, and retailers throughout Cape Ann and all-over New England.

PRIMARY LOSS OF SERVICE CONSEQUENCES

- Ships reliant on ice cannot operate – loss of production in fishing and seafood industry

- Ice augers and other production equipment at first floor in the warehouse has been damaged by floodwaters during previous storms
- Stakeholders report that the site currently does not experience tidal flooding

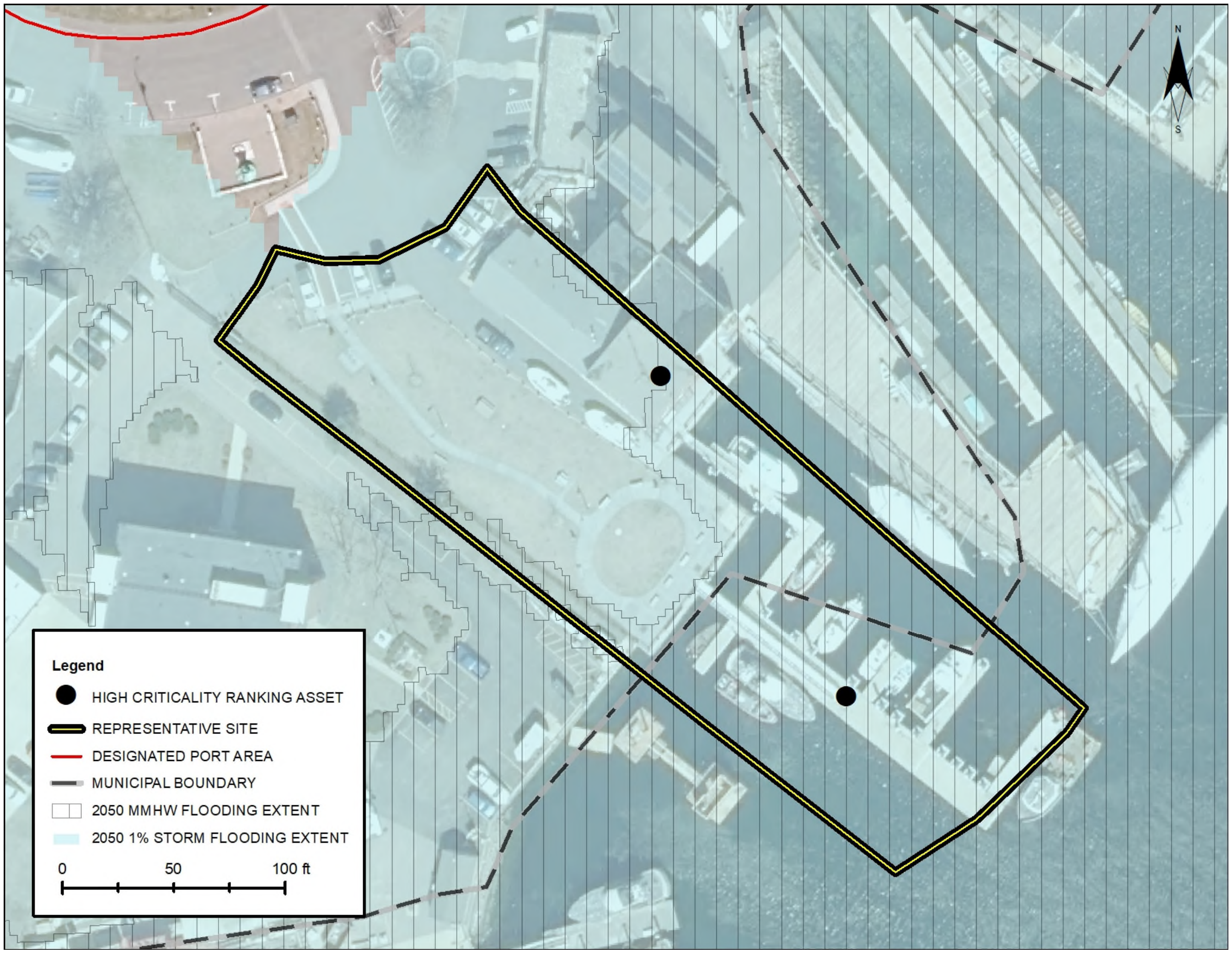
Cape Pond Ice Flood Exposure Summary	
Total Number of Assets	5
Number of Critical Assets	2
Critical Assets Exposed to Coastal Flooding Today	100%
Critical Assets Exposed to Coastal Flooding by 2050	100%
Dominant Flood Type for Critical Assets	Fringe

Harbormaster’s Office

The Harbormaster's Office sites provides the space and resources for the Harbormaster to enforce the responsible use of Gloucester’s waterways and administer local, state, and federal environmental laws.

PRIMARY LOSS OF SERVICE CONSEQUENCES

- Loss of maritime safety and law enforcement operations



- Office has been wet floodproofed with vents and flood gates and contains communication and emergency response controls on the second floor
- Office and pier were designed and constructed in accordance with 100-year storm surge protection

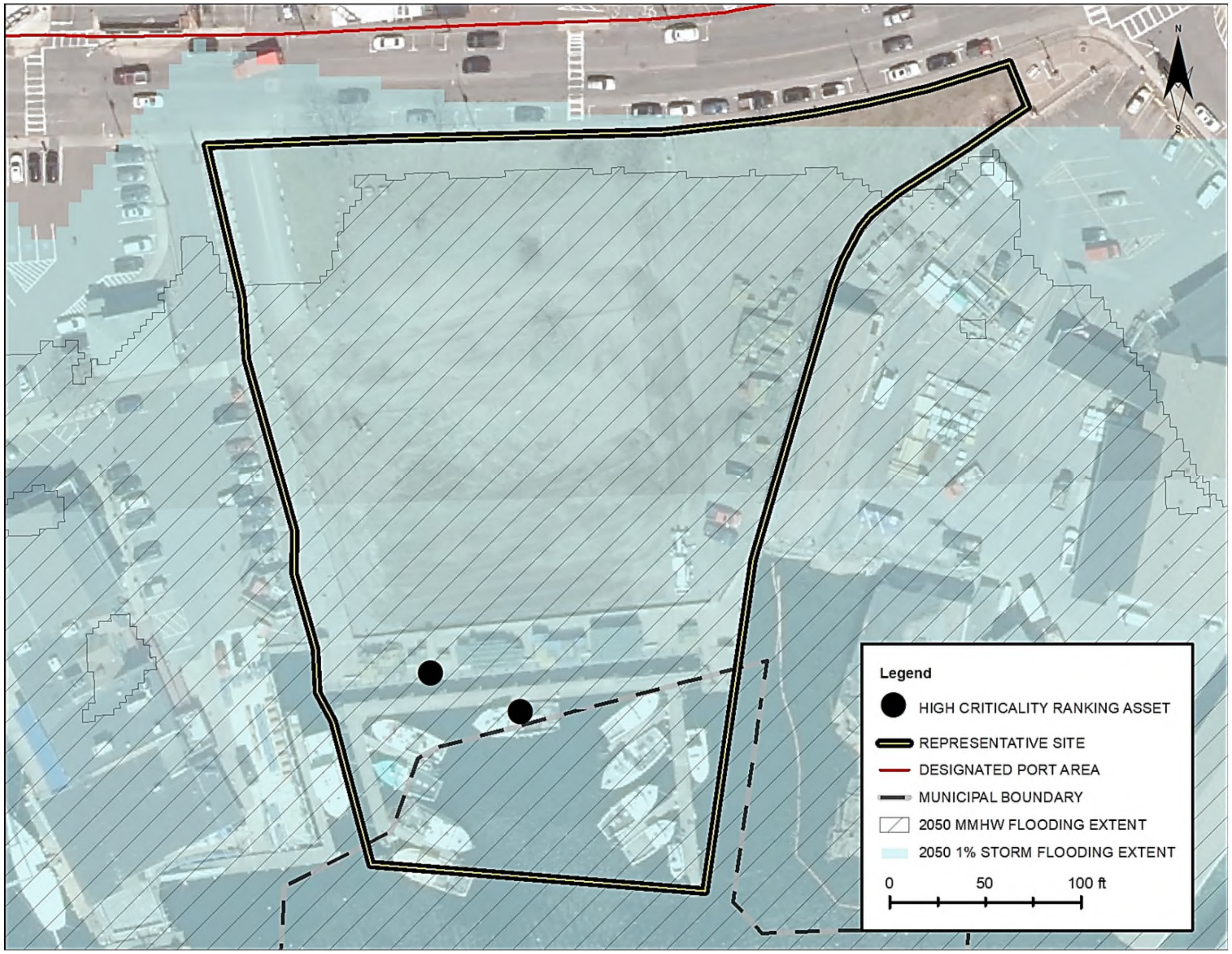
Harbormaster’s Office Exposure Summary	
Total Number of Assets	4
Number of Critical Assets	2
Critical Assets Exposed to Coastal Flooding Today	100%
Critical Assets Exposed to Coastal Flooding by 2050	100%
Dominant Flood Type for Critical Assets	Fringe

I4C2 Site

This city-owned site is the only vacant parcel on Gloucester's Harbor Cove and is currently utilized for parking. The commercial dockage at the site is operated and maintained by the Harbormaster's Office and operates as a storage location for fishing equipment.

PRIMARY LOSS OF SERVICE CONSEQUENCES

- Loss of parking and utilization of commercial dockakge



- Stakeholder reported parking lot receives floodwaters during storm events with 1-2 feet of storm surge and with 11-foot tides

I4C2 Exposure Summary	
Total Number of Assets	4
Number of Critical Assets	2
Critical Assets Exposed to Coastal Flooding Today	100%
Critical Assets Exposed to Coastal Flooding by 2050	100%
Dominant Flood Type for Critical Assets	Fringe

Appendix D – Representative Site Resilient Strategy Profiles

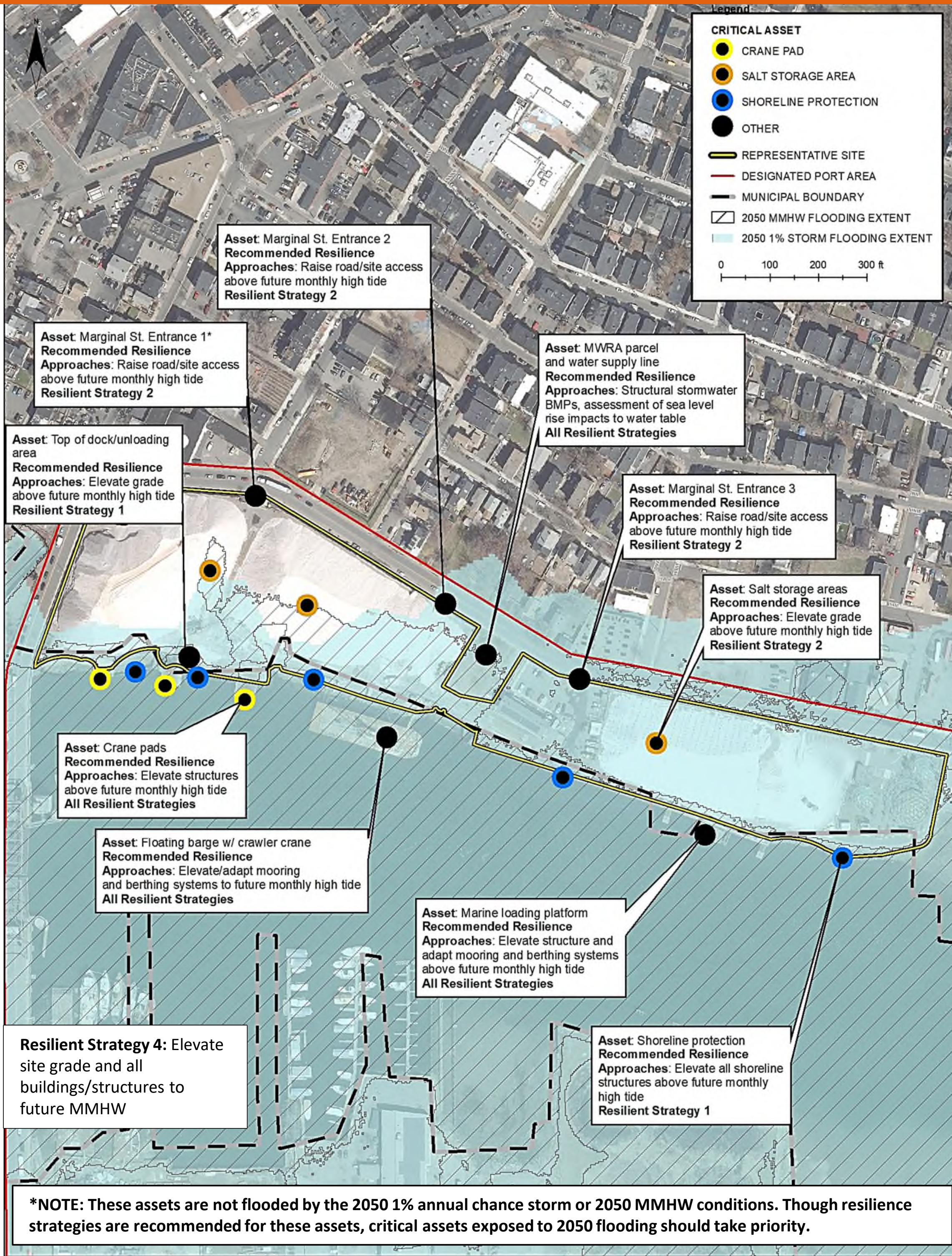
Included as attachment.

Representative Site Resilient Strategy Profiles

Legend
Easy Win Approach (0-1 year)
Larger Investment (1-3 years)
Capital Intensive and Site-Wide (3+ years)

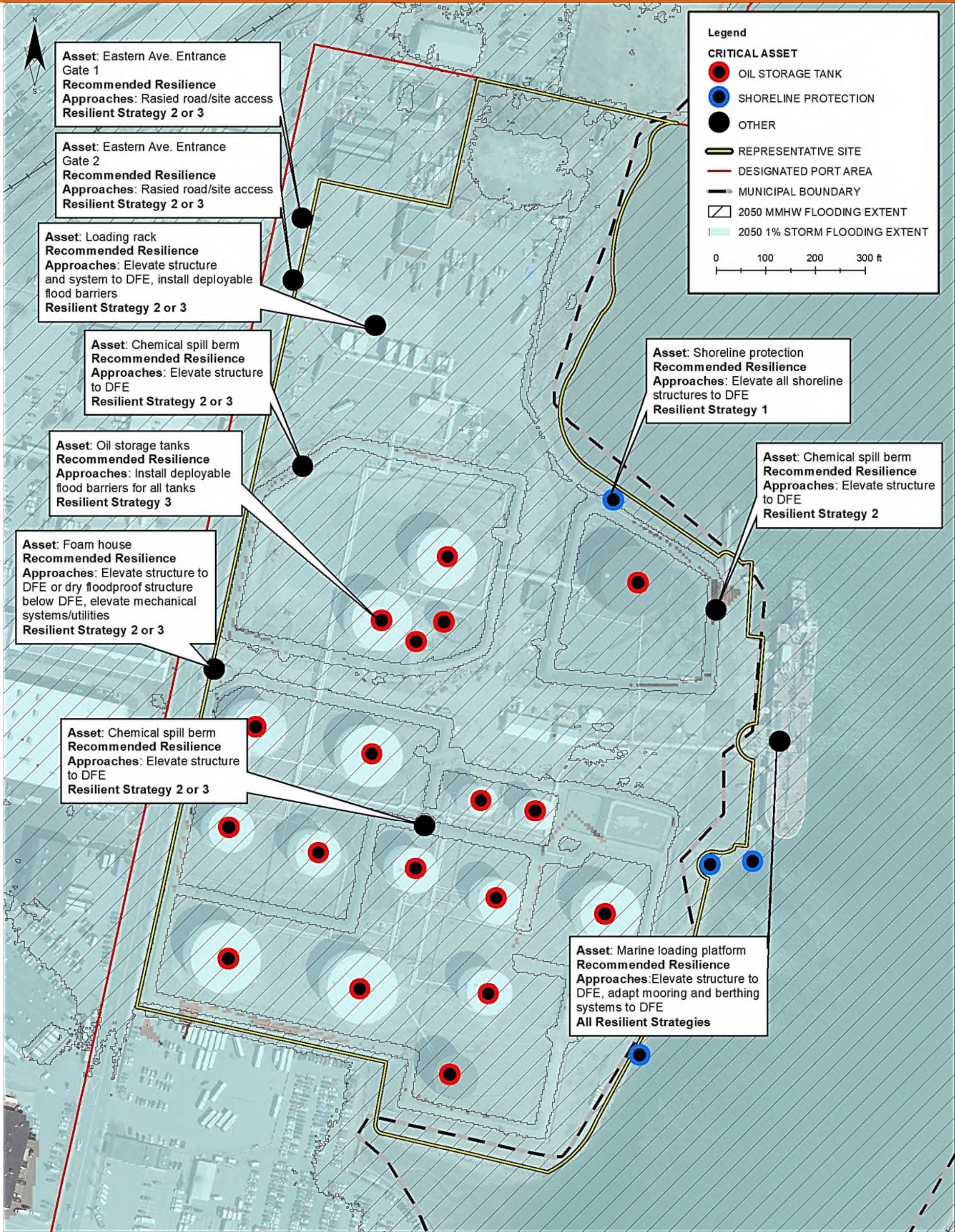
Resilient Strategies – Eastern Minerals

Resilient Strategy	Resilience Approaches	Strategy Description
Applicable to All Strategies	Easy-Win strategies including develop flood preparedness plan, purchase and maintain flood insurance, increase risk awareness, and relocate moveable assets.	It is recommended that all Easy-Win resilience approaches be implemented on site as it provides a foundation for longer-term and larger investment approaches. For this site, two larger investment approaches are also included. These are specific to this site and can be readily implemented.
	Implement structural stormwater best management practices (BMPs) and assess impacts of sea level rise on water table at MWRA parcel	
	Elevate crane pads above future monthly high tide	
Resilient Strategy 1	Elevate dock and unloading area above future monthly high tide	Strategy 1 provides flood protection to the site through elevation of all existing shoreline protection measures. In addition to shoreline protection, crane pads and all berthing systems and marine loading platforms will need to be elevated above the future monthly high tide.
	Elevate shoreline protection above future monthly high tide	
Resilient Strategy 2	Raise Marginal Street, site access points, and elevate grade at location of salt storage areas	Strategy 2 provides protection to critical assets through approaches that establish protection of an asset on an individual basis. No passive flood protection measures or site-wide approaches are recommended with this strategy.
Resilient Strategy 3	Install perimeter flood wall	Strategy 3 delivers flood protection through the construction of a flood wall along the perimeter of the site.
Resilient Strategy 4	Elevate site grade and all buildings/structures to future monthly high tide	Strategy 4 incorporates the asset scale elevation approaches in Strategy 1 and 2 with a site-wide grade elevation to the future monthly high tide.



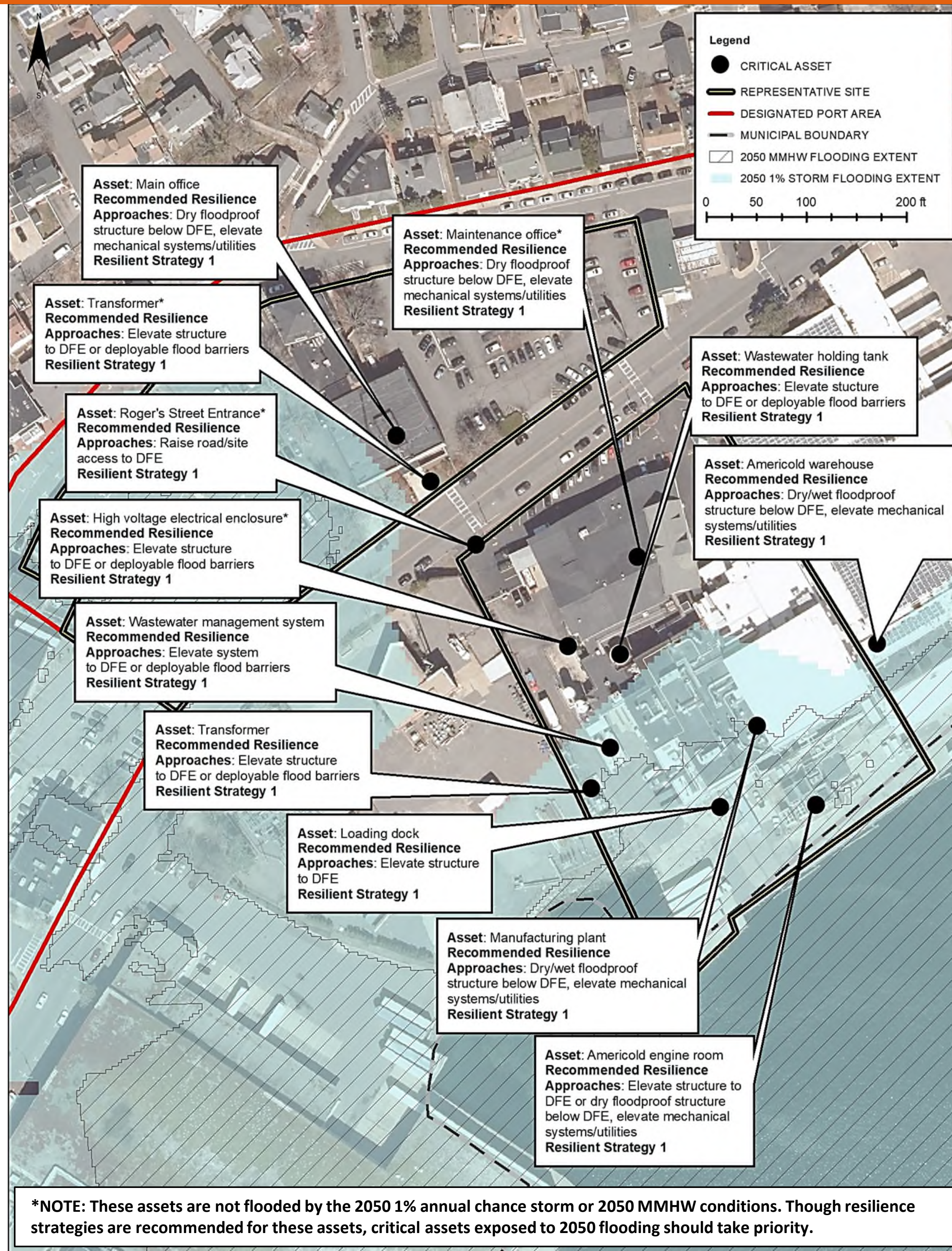
Resilient Strategies – Gulf Oil

Resilient Strategy	Resilience Approaches	Strategy Description
Applicable to All Strategies	Easy-Win strategies including develop flood preparedness plan, purchase and maintain flood insurance, increase risk awareness, and relocate moveable assets.	It is recommended that all Easy-Win resilience approaches be implemented on site as it provides a foundation for longer-term and larger investment approaches. The marine loading platform will need to be elevated regardless of Resilient Strategy implemented.
	Elevate marine loading platform and adapt mooring and berthing systems to DFE	
Resilient Strategy 1	Elevate shoreline protection to DFE	Strategy 1 provides flood protection to the site through elevation of all existing shoreline protection measures. In addition to shoreline protection the marine loading platform and the berthing system needs to be elevate to the DFE.
Resilient Strategy 2	Elevate chemical spill containment berms to DFE	Strategy 2 provides protection to critical assets through approaches that establish protection of an asset on an individual basis. Elevation of the containment berms will provide flood protection for all storage tanks. No passive flood protection measures or site-wide approaches are recommended with this strategy.
	Elevate foam house to DFE or dry floodproof below DFE, and elevate mechanical systems and utilities	
	Raise site entrances at Eastern Avenue street to DFE	
	Elevate loading rack and systems to DFE or install deployable flood barriers	
Resilient Strategy 3	Install deployable flood barriers for oil storage tanks	Strategy 3 incorporates the asset scale protection approaches in Strategy 2 but removes elevation of chemical spill berms. Oil storage tanks will instead be protected with the use of deployable flood barriers.
Resilient Strategy 4	District-scale perimeter flood wall	Strategy 4 delivers flood protection through the construction of a flood wall along the perimeter of the site and adjacent sites.



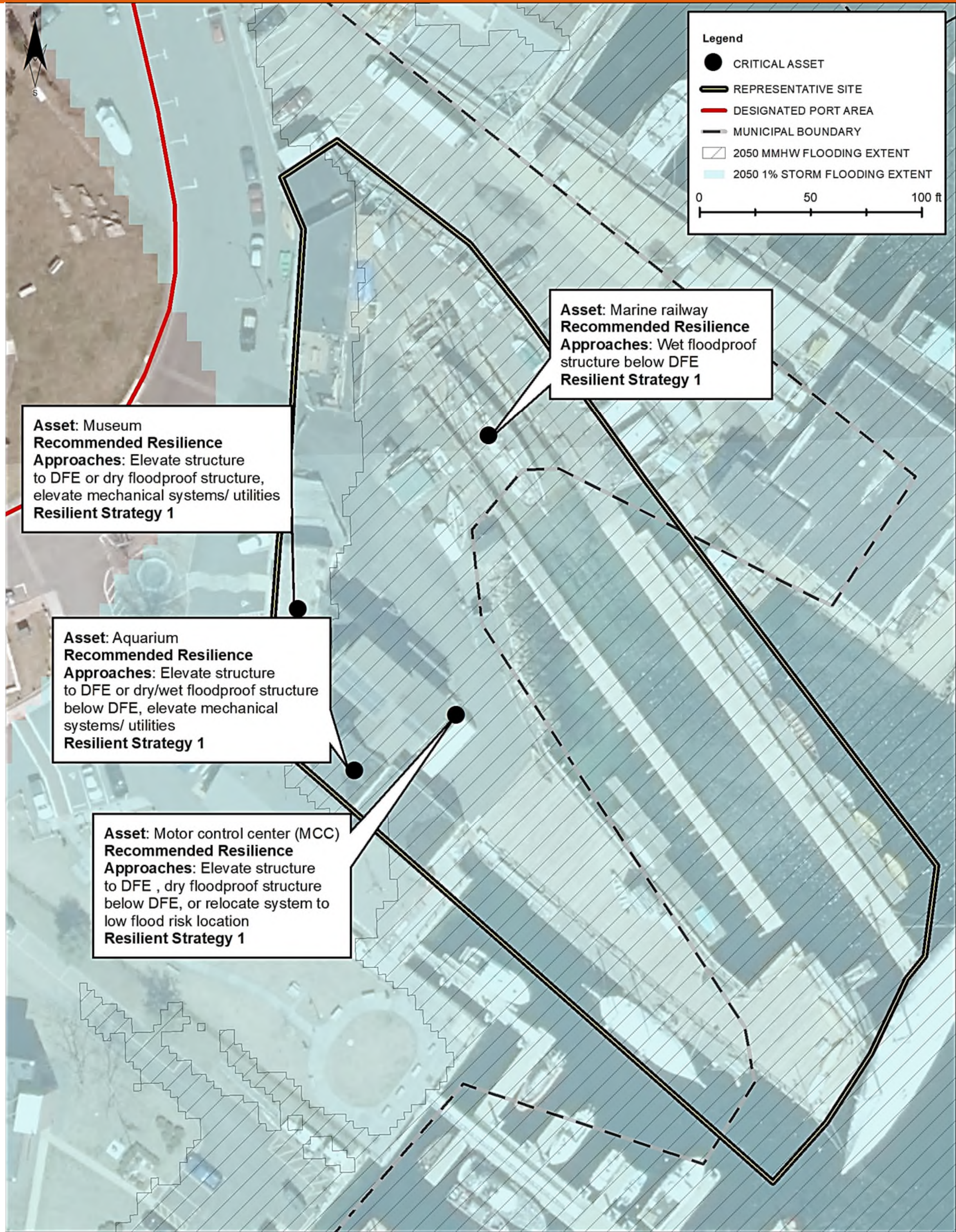
Resilient Strategies – Gorton's

Resilient Strategy	Resilience Approaches	Strategy Description
Applicable to All Strategies	Easy-Win strategies including develop flood preparedness plan, purchase and maintain flood insurance, increase risk awareness, and relocate moveable assets.	It is recommended that all Easy-Win resilience approaches be implemented on site as it provides a foundation for longer-term and larger investment approaches.
Resilient Strategy 1	Elevate Americold engine room to design flood elevation (DFE) or dry floodproof below DFE, elevate mechanical systems/utilities	Strategy 1 provides protection to critical assets through approaches that establish protection of an asset on an individual basis. No passive flood protection measures or site scale approaches are recommended with this strategy.
	Elevate electrical transformers/enclosures and wastewater management system to DFE or install deployable flood barriers	
	Dry floodproof main office below DFE, elevate mechanical systems/utilities	
	Dry/wet floodproof manufacturing plant and Americold warehouse, elevate mechanical systems/utilities	
	Raise site entrance at Roger's Street to DFE	
Resilient Strategy 2	Elevate site grade and buildings/structures to DFE and raise Rogers Street to protect Gorton's property to the north and the interior neighborhood.	Strategy 2 integrates the asset scale elevation approach in Strategy 1 with a site-wide grade elevation to the DFE.
Resilient Strategy 3	Install perimeter flood wall	Strategy 3 delivers flood protection through the construction of a flood wall along the perimeter of the site, with recommended coordination with Americold
Resilient Strategy 4	Relocate engine room, electrical transformers/enclosures, wastewater management system, and additional critical assets and uses to lower flood risk location.	Strategy 4 requires relocation of uses on site, in addition to buildings if feasible, to a lower flood risk area (higher ground across Rogers St.)



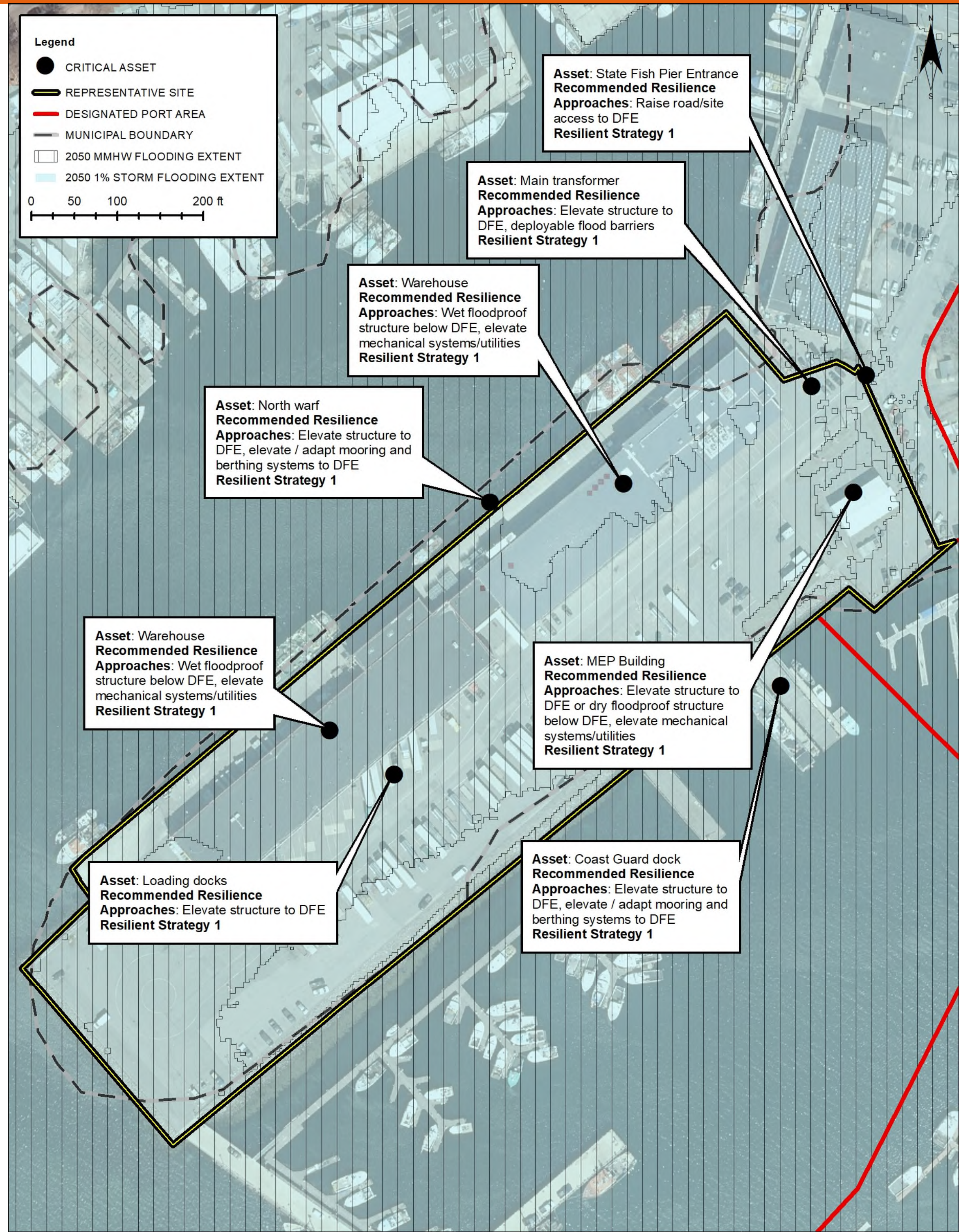
Resilient Strategies - Maritime Gloucester

Resilient Strategy	Resilience Approaches	Strategy Description
Applicable to All Strategies	Develop Flood Preparedness Plan Purchase and maintain flood insurance Increase risk awareness Relocate moveable assets	It is recommended that all Easy-Win resilience approaches be implemented on site as it provides a foundation for longer-term and larger investment approaches.
Resilient Strategy 1	Elevate MCC to design flood elevation (DFE), dry floodproof structure below DFE, or relocate system to low flood risk location Elevate aquarium to DFE or dry/wet floodproof building below DFE, elevate mechanical systems/ utilities Elevate museum to DFE or dry floodproof building below DFE, elevate mechanical systems/utilities Wet floodproof marine railway system	Strategy 1 provides protection to critical assets through approaches that establish protection of an asset on an individual basis. No passive flood protection measures or site scale approaches are recommended with this strategy.
Resilient Strategy 2	Elevate site grade and all buildings/structures to DFE	Strategy 2 integrates the asset scale elevation approach in Strategy 1 with a site-wide grade elevation to the DFE.
Resilient Strategy 3	Install perimeter flood wall	Strategy 3 delivers flood protection through the construction of a flood wall along the perimeter of the site.
Resilient Strategy 4	Relocate uses and buildings to lower flood risk location, potentially to higher ground across Harbor Loop	Strategy 4 requires relocation of uses on site, in addition to buildings if feasible, to a lower flood risk area.



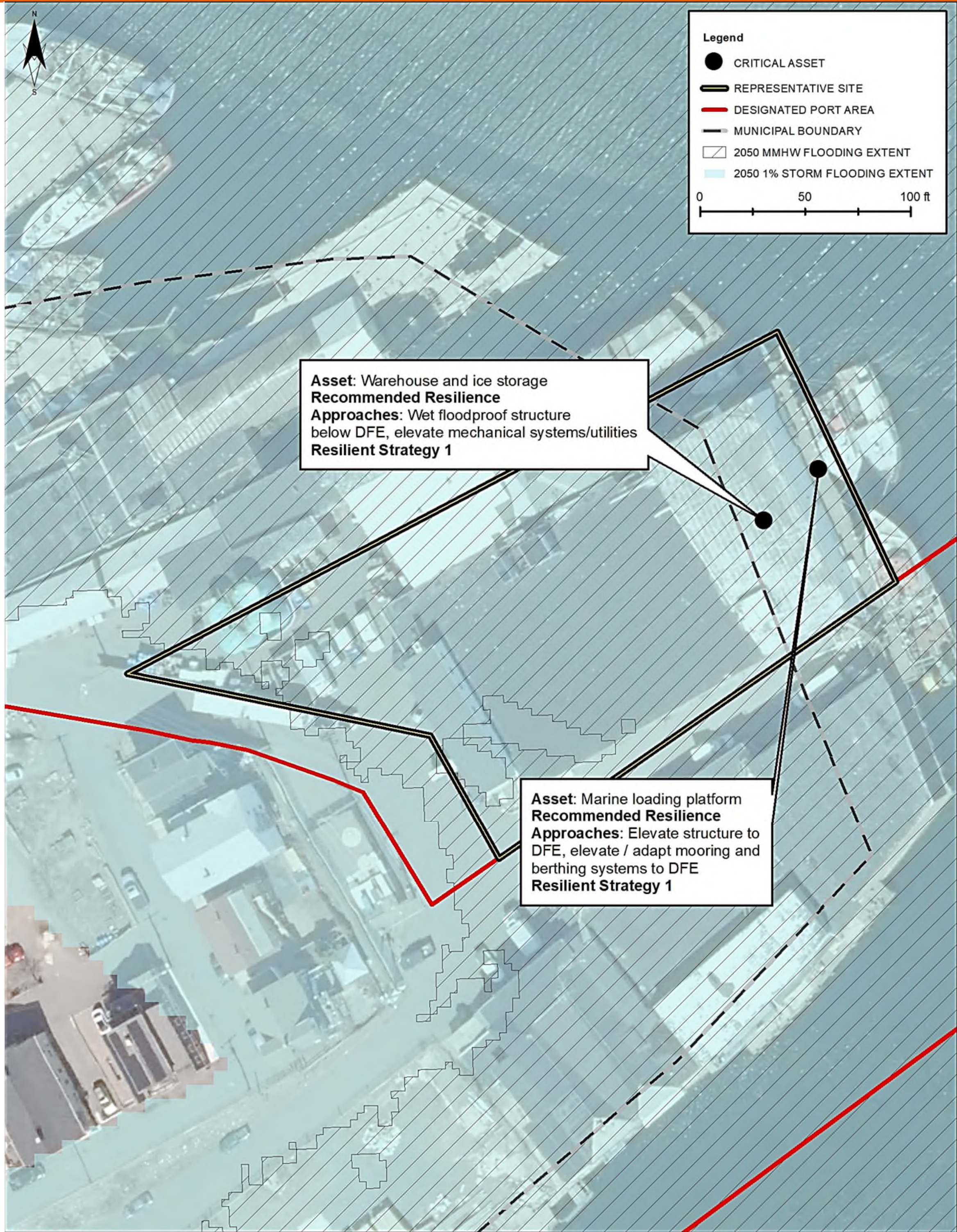
Resilient Strategies – Jodrey State Fish Pier

Resilient Strategy	Resilience Approaches	Strategy Description
Applicable to All Strategies	Develop Flood Preparedness Plan	It is recommended that all Easy-Win resilience approaches be implemented on site as it provides a foundation for longer-term and larger investment approaches.
	Increase risk awareness	
	Relocate moveable assets including vehicles	
	Deployable flood barriers (main transformer)	
Resilient Strategy 1	Wet floodproof warehouses below DFE, elevate mechanical systems/utilities	Strategy 1 provides protection to critical assets through approaches that establish protection of an asset on an individual basis. No passive flood protection measures or site-wide approaches are recommended with this strategy.
	Elevate North Wharf and other fixed docks to DFE, elevate / adapt mooring and berthing systems to DFE	
	Elevate Massachusetts Environmental Police building to DFE or dry floodproof below DFE, elevate mechanical systems/utilities	
	Raise site entrance at Parker Street to DFE	
	Elevate main transformer to DFE	
Resilient Strategy 2	Elevate site grade and all buildings/structures to DFE	Strategy 2 incorporates the asset scale elevation approach in Strategy 1 with a site-wide grade elevation to the DFE.



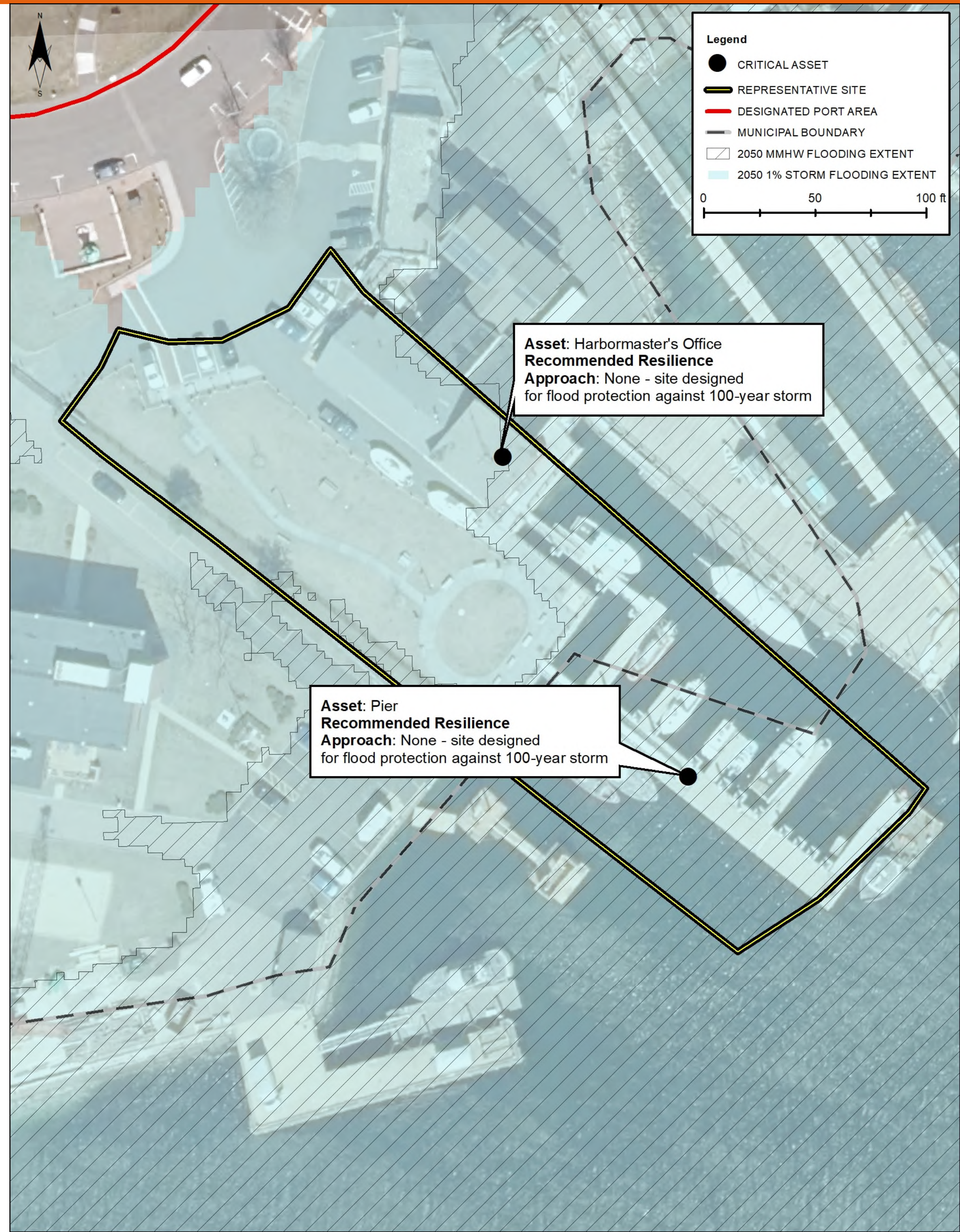
Resilient Strategies – Cape Pond Ice

Resilient Strategy	Resilience Approaches	Strategy Description
Applicable to All Strategies	Develop Flood Preparedness Plan	It is recommended that all Easy-Win resilience approaches be implemented on site as it provides a foundation for longer-term and larger investment approaches.
	Purchase and maintain flood insurance	
	Increase risk awareness	
	Relocate moveable assets including vehicles	
Resilient Strategy 1	Wet floodproof warehouse and ice storage facility below DFE, elevate mechanical systems/utilities	Strategy 1 provides protection to critical assets through approaches that establish protection of an asset on an individual basis. No passive flood protection measures or site-wide approaches are recommended with this strategy.
	Elevate marine loading platform to DFE, elevate / adapt mooring and berthing systems	
Resilient Strategy 2	Elevate site grade and all buildings/structures to DFE	Strategy 2 incorporates the asset scale elevation approach in Strategy 1 with a site-wide grade elevation to the DFE.



Resilient Strategies – Harbormaster's Office

Resilient Strategy	Resilience Approaches	Strategy Description
Applicable to All Strategies	Develop Flood Preparedness Plan	Although this site is designed for flood protection against the present day 1% annual chance storm, it is recommended that all Easy-Win resilience approaches be implemented on site as they aid in building consensus around existing and future resilience approaches.
	Purchase and maintain flood insurance	
	Increase risk awareness	
	Relocate moveable assets including vehicles	
Resilient Strategy 2	Elevation of site and/or relocate of uses and buildings to lower flood risk location, potentially to higher ground across Harbor Loop	Strategy 2 recommends elevation of the site or relocation to lower flood risk locations such as higher ground across Harbor Loop road after the useful life of the existing structures is exceeded.



Resilient Strategies – I4C2 – *Future Development*

Resilient Strategy	Resilience Approaches	Strategy Description
Applicable to All Future Strategies	Develop Flood Preparedness Plan	Although this site is vacant, it is recommended that all Easy-Win resilience approaches be implemented on site in its existing condition and with future development as they aid in building consensus around future resilience approaches.
	Purchase and maintain flood insurance	
	Increase risk awareness	
	Relocate moveable assets including vehicles	
Resilient Strategy 1	Elevate site grade and all future buildings/structures to DFE	Strategy 1 is preferred for this undeveloped site. Before development, elevating the site grade to DFE or future DFE is recommended.
Resilient Strategy 1	Design location of utilities and critical assets at or above 2070 DFE	If Strategy 1 is not feasible, Strategy 2 can be implemented to build resilience of the site to future flood risk.
	Floodproof buildings and assets if 2070 flood exposure is expected	

Appendix E – Data Summary and GIS Database

The following table details the datasets created and altered in the production of this report. All datasets reference NAD 1983 State Plane Massachusetts FIPS 2001. A geodatabase including each of these datasets and complete metadata has been delivered electronically.

Dataset	Description	Source	Date
MMHW 2030	GIS layer approximating the extent of average monthly high tide in 2030	Developed by the project team.	2021
MMHW 2050	GIS layer approximating the extent of average monthly high tide in 2050	Developed by the project team.	2021
MMHW 2070	GIS layer approximating the extent of average monthly high tide in 2070	Developed by the project team.	2021
Chelsea Creek Buildings	GIS layer with building footprints from MassGIS for water-dependent and non-water dependent sites in Chelsea Creek DPA. **1Percent_Exposure_Year:** likely decade of first exposure to 1% annual chance flood **MMHW Exposure Year:** likely decade of first exposure to MMHW flood	Base file modified by the project team.	Modifications in 2021
Gloucester Buildings	GIS layer with building footprints from MassGIS for water-dependent and non-water dependent sites in Gloucester Inner Harbor DPA. **1Percent_Exposure_Year:** likely decade of first exposure to 1% annual chance flood **MMHW Exposure Year:** likely decade of first exposure to MMHW flood	Base file modified by the project team.	Modifications in 2021
Chelsea Creek Asset Inventory	GIS layer mapping assets at Chelsea Creek DPA WDIU sites with criticality defined for assets within the representative sites.	Developed by the project team.	2021

Gloucester Asset Inventory	GIS layer mapping assets at Gloucester Inner Harbor DPA WDIU with criticality defined for assets within the representative sites.	Developed by the project team.	2021
Chelsea Creek Water Dependent User Sites	GIS layer with parcels from MassGIS data for water dependent sites in Chelsea Creek DPA.	Base file modified by the project team.	Modifications in 2021
Gloucester Water Dependent User Sites	GIS layer with parcels from MassGIS data for water dependent sites in Gloucester Inner Harbor DPA.	Base file modified by the project team.	Modifications in 2021

MMHW Mapping Methodology

By examining monthly high water, decision makers are able to understand potential future nuisance issues and address them through mitigation or adaptation actions before the flooding increases in frequency and becomes disruptive. MMHW is typically exceeded 25-35 times a year and is meant to approximate an identified tipping point of 30 floods per year. The table below summarizes the elevations of MMHW and MSL for Boston Harbor based on the NECSC 2018 (State) High projections. These projected future sea levels can be used to determine high tide flood exposure using a bathtub GIS mapping approach. Current high tide water levels can be added to SLR values for a given year to identify locations where land, infrastructure, and structures are below the stillwater level and at risk of nuisance flooding. The analysis of nuisance flooding is based on tidal benchmark data available from the Boston Harbor Tide Station as reasonably representative for Chelsea Creek and Gloucester Inner Harbor.

Year	MSL (ft NAVD88)	MMHW (ft NAVD88)
2020	-0.3	6.61
2030	1.2	8.11
2050	2.4	9.31
2070	4.2	11.11
2100	7.6	14.51

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