SITE ASSESSMENT SUMMARY REPORT

South Portland, Maine

September 2025

CITY OF SOUTH PORTLAND

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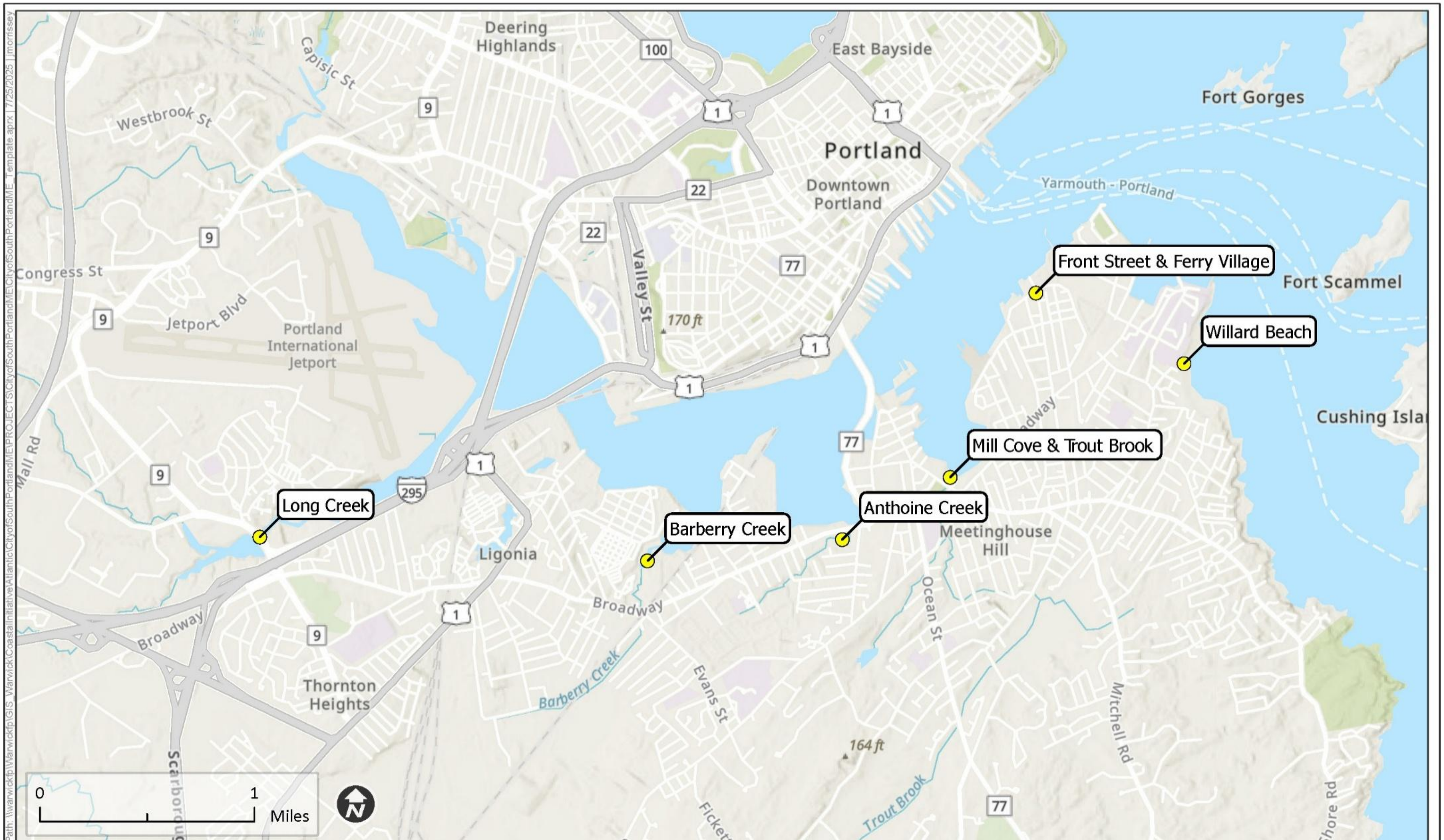
OVERVIEW

The project team of EA Engineering, Science and Technology, Inc., PBC and CMA Engineers was retained to perform a resiliency assessment for six sites in the City of South Portland, ME (City). The six sites were identified as priority locations for implementing coastal resilience solutions based on previous work assessing the impacts of climate change in the City. The goal of this phase of the project is to evaluate the feasibility of hardscaping and/or hybrid green-grey infrastructure at each site, which combines elements of traditional grey infrastructure with nature-based solutions. In the subsequent phase, preferred adaptation strategies for the priority sites will be advanced to conceptual design. To complete this scope, the project team performed field reconnaissance, collected topography of the sites using drone photogrammetry, desktop analysis of previous studies and relevant existing databases, reviewed design guidance for relative sea level rise (RSLR) adaptation, and developed several design alternatives for the sites identified as viable for interventions.

METHODS

The six project sites include Mill Cove and Trout Brook, Front Street and Ferry Village, Long Creek, Barberry Creek, Anthoine Creek, and Willard Beach. These sites were identified as vulnerable to current and future flooding by the City through the South Portland Waterfront Resilience project (City of South Portland, 2024). This project mapped both tidal and storm events under existing conditions and under future conditions incorporating RSLR.



Project Site

Figure 1
Site Overview
Coastal Resilience Solutions Assessment
City of South Portland, ME

Topography and Imagery Collection

The project team performed site assessments to investigate existing conditions, paying particular attention to infrastructure identified as critical and/or vulnerable through previous studies and from City staff. Elevation data was collected using drone photogrammetry to provide more refined data compared to the publicly available LIDAR, and to better identify the vulnerability of infrastructure as it relates to design flood elevations. The elevation data was collected utilizing an EVO II Pro 6k RTK drone with a vertical and horizontal accuracy of ± 1 inch. To achieve high accuracy, the drone position must be tied to a base station utilizing high quality GPS data. The position is collected using GPS equipment tied to multiple Maine DOT operated base stations throughout the state. Additional quality assurance is obtained through placement of Ground Control Points (GCPs) within the project area. For subsequent engineering design phases, a licensed land surveyor should be employed to perform a detailed survey and/or to capture critical spot elevations. Elevation data shown in this report is provided in the North Atlantic Vertical Datum of 1988 (NAVD88), unless otherwise specified. The following deliverables have been transmitted to the City for each site: shape files (to be uploaded into GIS or CAD), drawings (CAD file), 3D model (accessible in adobe), digital elevation models (to be uploaded into GIS or CAD), digital terrain models (to be uploaded into GIS or CAD), and orthomosaic (high-resolution aerial image).

Desktop Analysis

The desktop analysis portion of the site assessment consisted of a review of existing databases with information relevant to the vulnerability assessment and development of design alternatives. Informative findings are discussed with each site’s assessment summary. These databases included:

- FEMA National Flood Hazard Layer
- Maine Department of Inland Fisheries & Wildlife; Beginning with Habitat
- Maine Natural Areas Program Potential Tidal Marsh Migration
- Maine Coastal Program Tidal Restriction Atlas
- City GIS

Site and Adaptation Strategy Prioritization

Sites where the preferred adaptation design was determined to impact private property or were determined to be low priority for adaptation have abbreviated sections within this report, while sites identified as high priority warranting further analysis receive more robust discussion on design alternatives. Based on discussions with the project team, the Mill Cove and Trout Brook and Front Street and Ferry Village sites are discussed in greater detail and include the development of design alternatives, while the Long Creek, Barberry Creek, Anthoine Creek, and Willard Beach sites are analyzed with the simplified approach excluding the development of design alternatives.

To help compare and weigh adaptation strategies, the project team developed a multi-criteria decision analysis (MCDA) tool. The initial matrices were prepared by the consultant team to provide a structured evaluation of design alternatives across multiple criteria. The City then convened an internal working session to review these matrices in detail, adjusting scores and weights where appropriate to better reflect local priorities and community considerations. Following this internal review, the City and consultant team met together to walk through the revised results, discuss differences in perspective, and confirm the updated scoring as the basis for evaluation in this report. The criteria used in the MCDA include:

- **Community Acceptance:** The degree to which local stakeholders (residents, businesses, institutions, and City departments) are likely to support the strategy, considering visibility, disruption during construction, and alignment with community priorities. Higher scores reflect stronger support and fewer potential objections.
- **Coastal Hazard Protection**: Expected effectiveness at reducing coastal erosion, wave energy, and storm-surge impacts on at-risk assets. Higher scores indicate greater protection across a range of flood scenarios (including DFE-based events).
- **Freshwater Flooding Mitigation**: Ability to lower frequency, extent, and duration of rainfall-driven flooding. Higher scores indicate better performance.
- **Capital Cost**: Relative magnitude of up-front design and construction cost. Higher scores indicate lower capital burden for achieving comparable resilience outcomes.
- **Operating Costs**: Anticipated lifecycle O&M needs (inspection, sediment/vegetation management, repairs, etc.). Higher scores indicate lower, more predictable O&M effort and cost.
- **Co-benefits**: Positive environmental and community outcomes beyond flood risk reduction—e.g., habitat enhancement, water quality, public access, aesthetics, recreation, and educational value. Higher scores reflect broader, durable co-benefits.
- **Adaptability**: Flexibility to be modified, scaled, or implemented in phases over time as conditions and guidance evolve (e.g., updated SLR projections, asset criticality, funding windows). This criterion also reflects how implementation-ready a measure is in the near term — strategies with fewer technical or logistical barriers, clearer precedents, and existing momentum score higher, while those requiring extensive new analysis, coordination, or enabling actions score lower. Higher scores indicate both easier phasing over time and stronger potential for near-term readiness.
- **Permitting Feasibility**: Focuses on likelihood a project is likely to obtain the necessary approvals (e.g., NRPA, USACE Sections 404/10, FEMA floodway coordination, local zoning). A high score means there is a clear, achievable path to permits. It is noted that this criterion was assigned the lowest weight in the MCDA, recognizing that permitting challenges alone should not prevent otherwise high-value strategies from advancing.
    - **When all options appear permit-able**: We differentiate scores by the practical burden of obtaining permits—timeline, level of interagency coordination, extent of avoidance/minimization/mitigation, and likelihood of special conditions. This doesn't "stop" a project, but it affects schedule risk, cost, and delivery certainty, so options with simpler, faster pathways or fewer sensitive-resource impacts receive modestly higher scores.
    - **When feasibility is uncertain:** Options with significant permitting challenges (e.g., new shoreline hardening where statutes constrain it, substantial floodway fill without clear compensatory measures) score lower due to the risk that approvals may not be obtainable within a reasonable scope or timeline.

Coastal Hazards and Design Flood Elevation

The City's current Floodplain Management Ordinance requires the lowest floor elevation of buildings to be at least one foot above the 100-year flood level in FEMA Zone AE, which most of the projects locations are sited in. This Ordinance does not incorporate RSLR. The City's ongoing Climate Resilience Zoning project may result in alterations to zoning regulations that do incorporate RSLR, specifically as it relates to design flood elevations (DFE).

ASCE 24 is the industry standard for flood-resistant design and construction and is either directly or indirectly adopted by most building codes. ASCE 24-14 (the version referenced by the City's building code) includes freeboard in the calculation of the DFE, however it is not explicit if this freeboard is intended to account for RSLR and this value is not site specific (Ayyub, 2018). It is worth noting that a new addition, ASCE 24-24, has been released and does now factor in climate change considerations related to future sea levels.

Given the absence of relative sea level rise (RSLR) consideration from current local ordinances and adopted building code standards, the methodology in this assessment utilizes regional guidance from the Maine Coastal Program's CoastWise Approach and New Hampshire Coastal Program's Coastal Flood Risk Summary for deriving a resilient, site-specific DFE for infrastructure at the project sites. The project teamed determined that these guidance documents were appropriate to use because they account for RSLR and more accurately reflect the risk of coastal hazards at the project sites. The two methodologies share many similarities and frequently cite each other, and these references have been successfully applied by the project team on other, similar projects in the coastal environment. It is noted that following this guidance, which incorporates RSLR into the DFE calculation, is not currently a requirement of state permitting agencies, however it aligns with the project team's stated goal of accounting for RSLR in the development of adaptation strategies for the project sites.

To determine the DFE for infrastructure, the first step is to assess the given infrastructure's risk consequence from flooding. Given the range of predictions for RSLR by global climate models, especially at more distant timeframes, climate adaptation guidance for infrastructure considers the consequence of flooding for the infrastructure and then assigns an appropriate RSLR scenario, rather than assuming a blanket RSLR value for every piece of infrastructure. For instance, a walkway has a low consequence from flooding and therefore corresponds to the lowest RSLR scenario, while critical infrastructure like an emergency services station has a very high risk consequence from flooding and corresponds to the highest RSLR scenario. This first step is summarized in **Table 1.**

TABLE 1. Framework for determining risk and assigning corresponding sea level rise scenarios (adapted from Moore et al., 2023 and NH Coastal Flood Risk Science and Technical Advisory Panel, 2020).

Risk Consequence:	Low	Medium	High	Very High
Value of assets	Low	Medium	High	Very high
Ease or likelihood of adaptation	Easy or likely	Moderately easy or somewhat likely	Difficult or unlikely	Very difficult or very unlikely
Public function or safety implications	Few to none	Moderate	Substantial	Critical
Inundation Sensitivity	Low	Moderate	High	Very high
Examples of site-specific asset types	Conserved or working land, minor storage, temporary or accessory structure, walking path	Residential, light commercial, or industrial building, local culvert	School, community center or recreational facility, care or childcare facility, commercial hub	Hospital, public safety, drinking water supply, emergency shelter, power generating facility
Corresponding RSLR Scenario	Intermediate	Intermediate	Intermediate High	High

Table 2 displays the RSLR values corresponding to timeframes and RSLR scenario estimates. The bold values (Sweet et al., 2017) are currently recommended by the Maine Climate Council and the newer, italicizes values (Sweet et al., 2022) are derived from a more recent study that was not available at the time. The 2017 values are utilized in this assessment because of their adoption by the Maine Climate Council and they are more conservative.

TABLE 2. RSLR projections (in feet above 2000 levels) based on project timeframe and risk consequence. 2017 NOAA estimates (bold text) are based on Sweet et al. 2017. 2022 NOAA estimates (italicized text in parentheses) are based on Sweet et al. 2022. (adapted from Moore et al., 2023).

	Low Risk Consequence	Medium Risk Consequence	High Risk Consequence	Very High Risk Consequence
	Corresponding Sea Level Rise Scenario Estimates (FT) Compared to Sea Level in the year 2000			
Timeframe	Intermediate	Intermediate	Intermediate-High	High
2050	**1.5** (*1.2*)	**1.5** (*1.2*)	**2.2** (*1.3*)	**3.0** (*1.4*)
2070	**2.4** (*1.9*)	**2.4** (*1.9*)	**3.5** (*2.4*)	**5.0** (*2.9*)
2100	**3.9** (*3.6*)	**3.9** (*3.6*)	**6.1** (*4.6*)	**8.8** (*5.9*)

Considering the level of consequence from flooding selected in step 1 and the corresponding RSLR from step 2, the third and final step in calculating the DFE is selecting the appropriate equation from **Table 3** below.

TABLE 3. RSLR-adjusted DFE based on risk consequence (adapted from NH Coastal Flood Risk Science and Technical Advisory Panel, 2020).

	Low Risk Consequence	Medium Risk Consequence	High Risk Consequence	Very High Risk Consequence
If project area is located in:	RSLR-Adjusted DFE =			
A, AO, or AE Zone not identified as Coastal A Zone	[BFE] + RSLR	[BFE + (required freeboard ≥ 1 ft) + RSLR	[BFE + (required freeboard ≥ 1 ft)] + RSLR	*Whichever is greater:* [BFE + (required freeboard ≥ 2 ft)] + RSLR *or* 0.2% annual chance flood elevation + RSLR
VE Zone and Coastal A Zone			[BFE + (required freeboard ≥ 2 ft)] + RSLR	

The base flood elevation (BFE) is the foundation of each equation. The BFE is the water surface elevation resulting from a flood that has a 1% chance of equaling or exceeding that level in any given year (also called the 100-year flood) and is calculated based on hydrological and hydraulic analysis taking into account local bathymetry, topography, and historic weather data. It is noted that the BFE does not account for RSLR, and as such may underrepresent the risk at the site. Because of climate change, the historic 100-year flood is not the same as this year's 100-year flood, which is also not the same as the future's 100-year flood. The 100-year flood is essentially a statistically moving target based on all historic flood data available at the time of the analysis. As sea levels increase the impacts of flooding will also increase and in turn affect the 100-year flood estimate. While FEMA does do a good job of trying to assess and show the impact of a 100-year flood to an area, the BFEs can quickly become outdated and rely on old data. At the time of this assessment, FEMA released new effective BFE values in June 2024 for South Portland.

FEMA Flood Insurance Rate Maps, or flood maps, depict the flood zones resulting from the 100-year storm and include V zones (subject to wave heights greater than 3 ft), Coastal A zones (subject to wave heights between 3 ft and 1.5 ft), and A zones (subject to wave heights below 1.5 ft). Maps may also depict areas subject to the 0.2% annual chance storm event (also called the 500-year flood). Most of the sites assessed in this project are sited in Zone AE, with Willard Beach and Ferry Village being a notable exception located in the Zone VE. It is often impractical or infeasible with respect to cost or site constraints to rigorously meet these standards. For the purposes of this report, the DFE for each piece of infrastructure will be determined first. The feasibility of rigorously meeting this standard is then described, as well as suggested design alternatives.

The DFE is based on a 2100 timeframe for planning purposes in this assessment, and all elevations are given in elevation NAVD88. The year 2100 was selected as the most reasonable timeframe for these recommendations because it corresponds to the most common design life, 50-75 years, of grey infrastructure, it aligns with discussions with the City to date, and it aligns with the mapping resulting from the South Portland Waterfront

Resilience project. The time frame, and resulting calculation of the DFE, can easily be altered in subsequent project phases as design alternatives are selected and advanced. The time frame will need to be reevaluated for nature-based solutions particularly, as those tend to have a nearer planning horizon. Some of the design alternatives can be implemented in phases to spread costs, minimize disruption, and allow adaptation to RSLR gradually, while others, such as roadway raising, are far more challenging to phase and would likely require full implementation at once. Given the scale of these interventions, major projects often require many years from concept through permitting, funding, design, and construction—meaning that solutions recommended for the near term should begin advancing toward implementation soon, while those intended for conditions expected 20–50 years from now can be timed to align with observed sea level rise and evolving community priorities.

Assessing RSLR with respect to non-storm tidal levels, such as mean higher high water (MHHW) and highest astronomical tide (HAT) is also noteworthy for less critical infrastructure or when it is infeasible to achieve DFEs based on storm scenarios. For instance, a walkway may not be expected to withstand future extreme flood events, but it should be situated above future MHHW in such a way that it will not be submerged on a daily basis. Flood mapping from these scenarios (MHHW/HAT) is available from the South Portland Waterfront Resilience Project. The nearest National Oceanic and Atmospheric Administration (NOAA) station with tidal datums is in Portland, ME. The following table summarizes datums for the station:

TABLE 4. Tidal datums (in feet) from Portland, ME NOAA station, referencing NAVD88.

Mean Lower Low Water (MLLW)	-5.26
Mean Low Water (MLW)	-4.91
Mean Sea Level (MSL)	-0.32
Mean High Water (MHW)	4.21
Mean Higher High Water (MHHW)	4.65
Highest Astronomical Tide (HAT)	6.71

Establishing site-specific datums, especially if nature-based concepts are incorporated or if the site is influenced by restricting infrastructure (such as a bridge or culvert), may be necessary in subsequent phases. The initial phase of this project does include the establishment of site-specific tidal datums at the Mill Creek site through the deployment of pressure transducers measuring water levels over a study period. Additionally, these site-specific tidal datums will be more representative of actual site conditions compared to the Portland, ME NOAA station value due to proximity and also through incorporating RSLR that has occurred. The Portland, ME tidal datums are tied to the National Tidal Datum Epoch (NTDE), which covers the period of 1983 to 2001, and has a baseline year (mid-point) of 1992. The NTDE covers a 19-year period to ensure that an 18.6-year astronomical cycle that includes all significant variations in the distances from Earth to the moon and sun, which produce slowly varying changes in the tidal range, is accounted for in the epoch (Sweet et al. 2017). The current NTDE is more than 20 years old, and it is NOAA's policy to consider revising the NTDE every 20 to 25 years. The NTDE needs to be regularly revised to account for changes in tidal constituents, SLR, and vertical land movement. Tidal constituents describe the effects that the cyclical motion of the earth, sun, and moon have on the tides by breaking these motions down into mathematical constants that essentially form the "building blocks" of the tides, allowing for the prediction of future tides. Currently NOAA is working on revising the NTDE to cover the period of 2002 to 2020, and it is anticipated to be released in 2025.

This means that the tidal datums currently published at the Portland, ME station do not include any RSLR that has occurred since 2001, which results in an underestimate of the actual water levels. This is true for all NOAA stations until the new NTDE is published, noting that at a few stations water levels are actually decreasing.

The tidal datums derived from pressure transducer measurements will support the next phase of the project. These calculations are essential for integrating nature-based elements into the design. Additionally, the data will help the project team assess the extent of existing tidal restrictions at the site and predict potential changes in upstream water levels resulting from their removal.

Potential Adaptation Design Alternatives

The design alternatives presented in this assessment for the priority sites were developed through an iterative process that combined professional experience, lessons learned from similar projects, engineering judgment, and targeted discussions with the project team. In some cases, the alternatives build directly on previous planning or design efforts completed for the City, allowing this assessment to refine, expand, or reframe those earlier concepts in light of updated RSLR projections and site-specific conditions documented during this phase.

Once a list of possible strategies was developed for each location, the project team used qualitative screening to identify the most viable concepts for further evaluation. The alternatives were then entered into the MCDA matrix to evaluate their performance relative to each other using consistent scoring criteria.

The top-ranked alternatives emerged because they provided a balanced combination of technical feasibility, alignment with community and environmental goals, potential for significant flood risk reduction, and realistic pathways for implementation. In some cases, lower-scoring alternatives were retained in the report if they offered unique co-benefits or could serve as supplemental measures to the preferred strategies. The results of this process are reflected in the site-specific Design Alternatives and Design Alternatives Evaluation sections that follow.

In addition to the strategies evaluated in detail, the project team also considered a broader set of hardscape interventions at both Mill Cove/Trout Brook and Ferry Village. These concepts were screened out early because of prohibitive cost, severe natural resource impacts, or a low likelihood of being permittable:

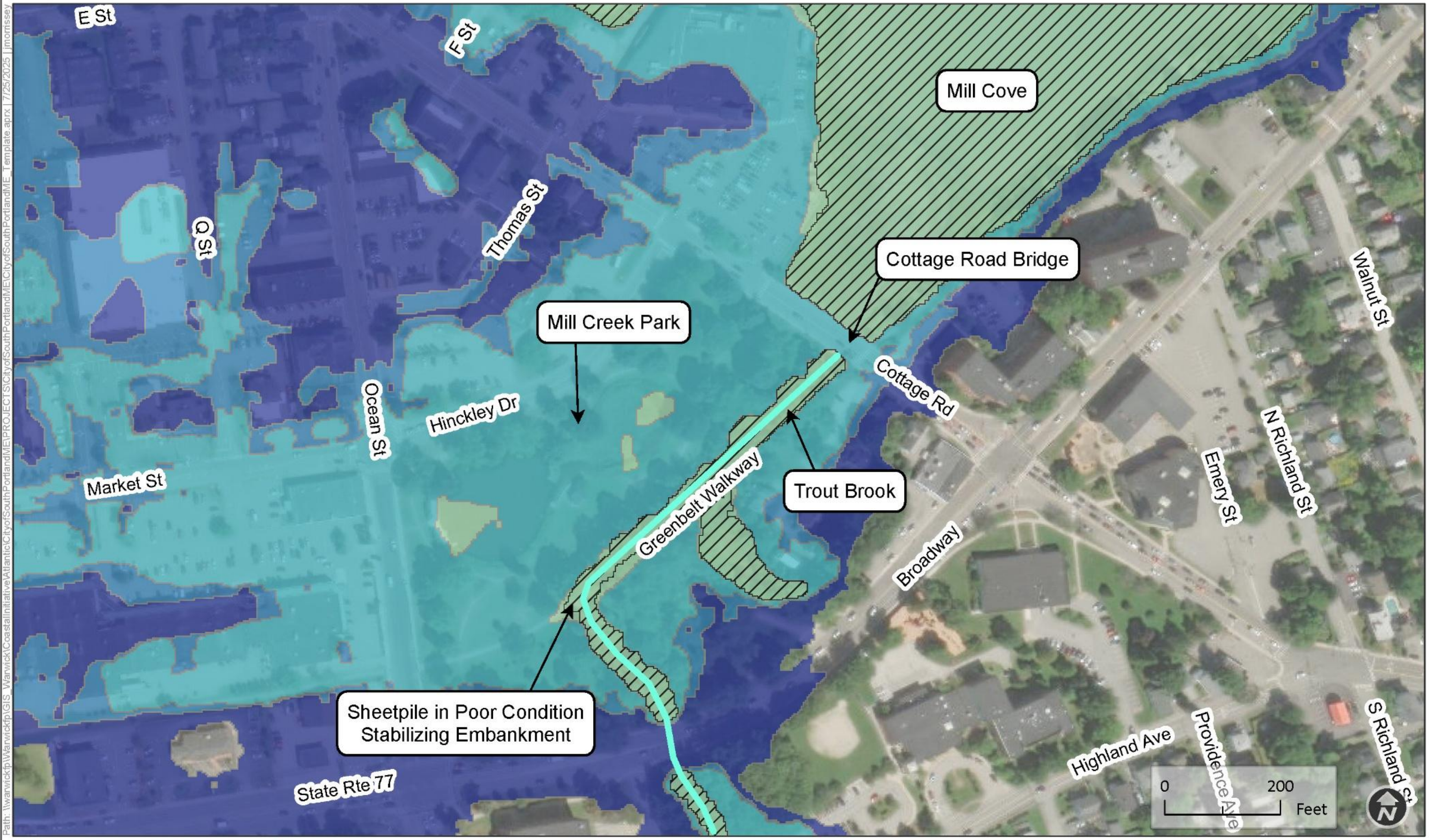
- **Mill Cove/Trout Brook:** Continuous seawalls or bulkheads along the Mill Cove shoreline were considered but not advanced. Beyond their cost and disruption to intertidal habitat, new seawalls are generally not permittable in Maine, making them an impractical option for long-term resilience. Similarly, construction of a large tidal gate or pumping station at Cottage Road was identified as technically possible but incompatible with project goals, given their ecological impacts and low feasibility of approval.
- **Ferry Village:** A gated storm surge barrier on the main drainage outfall was considered conceptually, but it would not address freshwater flooding issues, which are a primary vulnerability in the neighborhood. Instead, the necessary backflow prevention function is better incorporated into the Subsurface Stormwater Detention System alternative.

SITE ASSESSMENTS

1. Site Assessment: MILL COVE AND TROUT BROOK

- Site Description: MILL COVE AND TROUT BROOK

  Mill Cove has a heavily developed shoreline, with several commercial and residential properties vulnerable to flooding under both existing and future conditions. This assessment focuses on the Mill Cove area, seaward of the Cottage Road bridge, and upstream Trout Brook along Mill Creek Park.



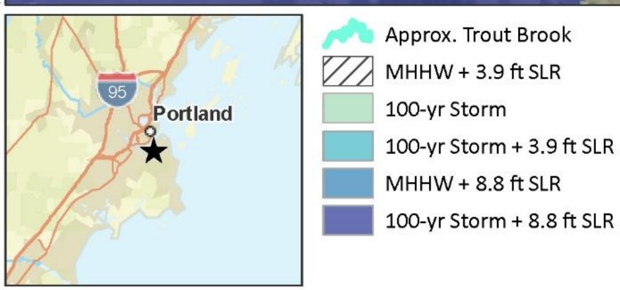


Figure 2
Mill Cove and Trout Brook Site Overview
Coastal Resilience Solutions Assessment
City of South Portland, ME

Trout Brook is one of five urban impaired streams in the City. The stream is a present-day brook trout habitat. The City is in the final design stage for the replacement of five culverts upstream along Trout Brook, with the goals of habitat restoration, water quality improvements, flood protection, and protecting roadways and utilities from overtopping. It is also understood that the replacement of the Cottage Road bridge is currently under design by MaineDOT. The Cottage Road bridge was observed to be in poor structural condition, and the Maine Tidal Restriction Atlas indicates the crossing is a tidal restriction.

A high degree of scouring and erosion along the banks of Trout Brook was observed on the site visit. Several trees appear undermined and susceptible to being washed away (see **Figure 3**).

FIGURE 3. Erosion along Trout Brook embankment.

Additionally, there is a short section of sheet pile wall at the first bend downstream of the Greenbelt crossing that has rusted through in many spots allowing backfill material to be eroded (see **Figure 4**).

FIGURE 4. Erosion of backfill behind sheet pile along Trout Brook.

A review of historical USGS topographic maps, as seen on the subsequent page, indicates the section of Trout Brook between Broadway and Cottage Road has been heavily disturbed by manmade activities. The 1891 map depicts a bridge significantly wider than what is there today and a large, ponded area encompassing the present-day Mill Creek Park. Under these conditions, it is likely the present-day Mill Creek area was salt marsh. The 1941 map depicts a smaller bridge span consistent with the span size that is there today, though the section of Trout Brook between Broadway and Cottage Road shows a large, ponded area and the streamline has a high degree of sinuosity. By 1956, the area is depicted as it appears today, with the pond in Mill Creek Park separated from Trout Brook and Trout Brook artificially straightened along the Greenbelt.

FIGURE 5. Clip from 1891 USGS topographic map

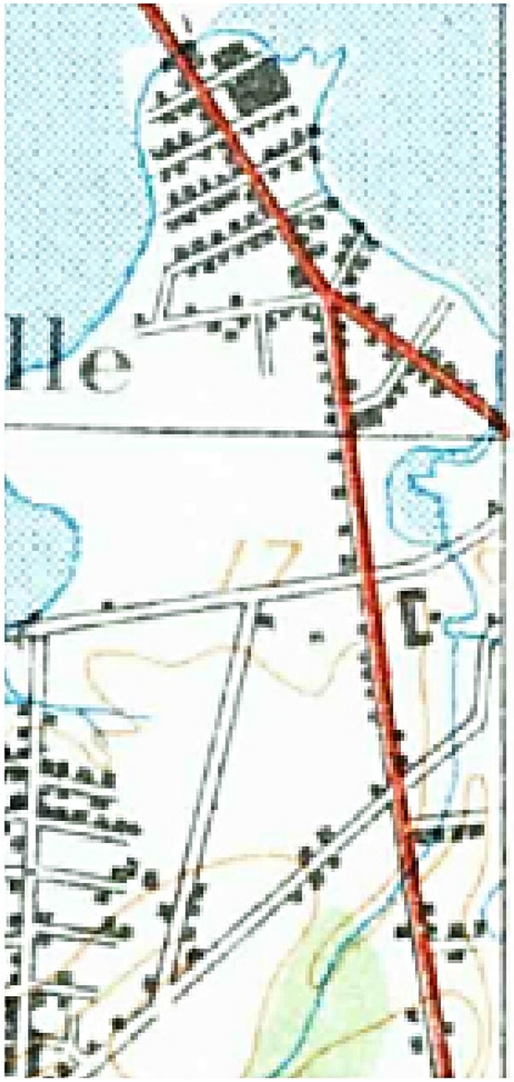


FIGURE 6. Clip from1946 USGS topographic map

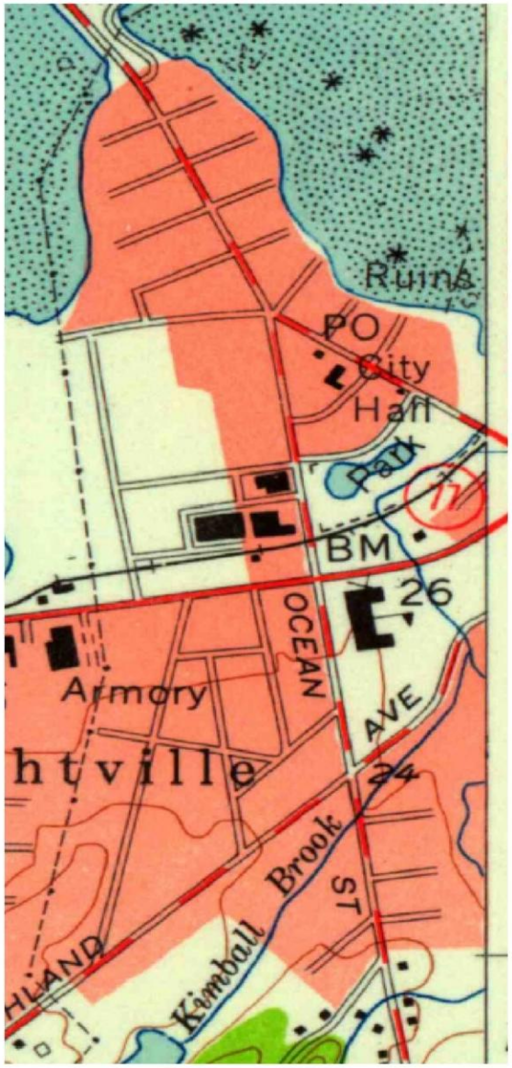


FIGURE 7. Clip from 1956 USGS topographic map

- Vulnerability Assessment: Mill COVE AND TROUT BROOK

  The BFE is 9 feet upstream of Cottage Road and 10 feet downstream of Cottage Road (see Attachment 2). The difference in elevation is possibly due to the tidal restriction imposed by the Cottage Road bridge. The bridge is assigned a 'medium' tolerance for flooding because it is a minor arterial and the detour in the event of inundation is relatively short.

TABLE 5. Inputs and resulting DFE for Cottage Road.

	Cottage Road
Existing Elevation (ft)	12.0 (low point)
FEMA BFE	10 (seaward of bridge)
Risk consequence	Medium
RSLR Estimate (ft)	3.9
DFE (ft)	14.9

Achieving the DFE at this site through roadway raising is likely a significant undertaking. The shoreline along Mill Cove going west from the bridge varies from 9-13 feet in elevation, indicating hardscaping, such as a seawall, would be needed along the entire length of the shoreline to prevent inland flooding as an alternative to roadway raising. This seawall would likely need to be sited across several private properties, further decreasing the concept's feasibility. A hybrid green/grey alternative to a seawall or bulkhead is a living shoreline with vegetation and structural measures. This concept would combine vegetation with rock sills for added stability. Living shorelines reduce erosion, attenuate wave energy, and provide high-value habitat. It should be noted that while a living shoreline can decrease damage from storm events, it may not prevent damage/flooding during all storms.

Separate from the issue of inundation during present and future storm events, interventions are also likely needed along Trout Brook to reduce erosion and compound flooding impacts, assuming Trout Brook maintains its current alignment. The planned upsizing of several upstream crossings may exacerbate already present erosion by increasing stormwater runoff. Further hydraulic analysis, which is outside the scope of the current project, is needed to confirm if the observed erosion is driven by storm surge, or by freshwater flooding. Hardscaping or biostabilization techniques are likely needed along the banks of the existing channel, especially at the corner where the current sheet pilling is failing.

Alternatively, there is an opportunity to rewild the section of Trout Brook between the Greenbelt and Cottage Road. Rewilding the system to something similar to 1941 conditions would provide flood storage (both tidal and freshwater), reduce erosion, improve water quality, and provide valuable habitat.

Based on the site assessment and desktop analysis, the following design alternatives have been developed for this site:

- Rewilding Trout Brook and Mill Creek Park
- Trout Brook Stabilization
- Mill Cove Living Shoreline
- Cottage Road Raising and Bridge Replacement
- Mill Creek Park Berm

- <u>Design Alternatives</u>*:* **MILL COVE AND TROUT BROOK**

Alternative 1: Rewilding Trout Brook and Mill Creek Park

Rewilding this reach of Trout Brook involves restoring the stream and floodplain to a more natural state, resembling the conditions seen in a historical map from 1941. This would include reintroducing sinuosity to the stream channel and reconnecting it to its former floodplain (now Mill Creek Park). Key steps for implementation would include:

- **Stream Channel Realignment**: Remove the straightened section of the stream between Broadway and Cottage Road, replacing it with a sinuous channel to reduce flow velocities and erosion.
- **Floodplain Excavation and Grading**: Lower areas within Mill Creek Park to allow for tidal inundation and stormwater storage, improving both flood attenuation and habitat function.
- **Salt Marsh Restoration**: Seed or plant native marsh vegetation in newly excavated intertidal areas. This would support marsh migration as sea levels rise.
- **Tidal Connectivity**: It will be essential to coordinate with the MaineDOT Cottage Road bridge replacement. The new bridge span must be designed to restore tidal flow and minimize restriction.
- **Green Infrastructure**: Incorporate bioswales, rain gardens, and native riparian buffers along park pathways and around parking to manage stormwater and improve water quality.

This rewilding strategy would reduce peak stormwater flows, lower erosion risk, increase flood storage, improve habitat, and provide passive recreation benefits. This strategy will require significant public engagement, as Mill Creek Park and the Greenbelt are well used by residents for recreational purposes, and this design concept would likely alter the Greenbelt alignment and the use of the pond for wintertime skating.

Pros:

- Restores natural stream and floodplain function, increasing tidal and stormwater storage capacity.
- Improves habitat and water quality while reducing erosion.
- Enhances passive recreation and educational opportunities.
- Increases resilience to both tidal and freshwater flooding.

Cons:

- Significant change to existing park layout and recreational uses (e.g., Greenbelt trail, skating pond)
- Requires complex permitting due to wetland and floodway modifications.

Alternative 2: Trout Brook Stabilization

In the event that Trout Brook retains its current alignment between the Greenbelt crossing and Cottage Road, targeted stabilization of the stream banks will be essential to mitigate the risks of scour and erosion. These processes, if left unaddressed, could undermine the integrity of the stream corridor and adjacent infrastructure, degrade water quality, and negatively impact aquatic habitats.

To protect the stream banks, two broad categories of stabilization techniques are typically considered: structural stabilization methods and biostabilization techniques.

Structural approaches primarily rely on inert materials such as rock or concrete to armor the stream bank. Examples include:

- **Riprap**: Large, angular stones placed along the bank to resist erosive forces
- **Gabions**: Wire mesh baskets filled with rock that are stacked and anchored to form retaining structures

While effective in increasing resistance to erosive flows, these methods do little to dissipate the stream's hydraulic energy. Moreover, they often lack ecological value and may create hard edges that disrupt natural stream function.

Biostabilization incorporates living vegetation—particularly deep-rooted woody plants—either alone or in combination with structural elements (USDA NRCS, 2021). These methods serve a dual purpose: reducing the velocity and energy of stream flows while enhancing the soil's resistance to erosion through root reinforcement and surface cover. Biostabilization also offers ecological benefits by improving habitat complexity and promoting biodiversity. Examples include:

- **Live Stakes**: Dormant woody cuttings, such as willow or dogwood are driven directly into the streambank where they root and grow into erosion-resistant vegetation.
- **Live Stakes and Riprap:** A hybrid approach where live stakes are installed above a rock toe. The rock provides immediate structural stability, while vegetation establishes over time for long-term reinforcement.
- **Coir Fiber Roll**: Biodegradable rolls made from coconut fiber are installed at the base of the slope. These rolls trap sediment, reduce flow velocity, and provide substrate for vegetation to grow

FIGURE 8. Live stakes in stream embankment (USDA Natural Resources Conservation Services, 2021).

- **Stream Terraces**: Engineered step-like features carved into the streambank that reduce slope gradient, slow runoff, and provide planting zones for vegetation.

Given the unique hydrologic setting of this reach of Trout Brook—where it receives freshwater input from upstream and is influenced by tidal backwater conditions from Mill Cove—particular attention must be paid to the selection of vegetation. Any plant species used for biostabilization must be tolerant of both freshwater and brackish conditions, as well as periodic inundation and drying cycles.

To ensure the selected stabilization approach is appropriately designed and effective under varying hydraulic conditions, detailed hydraulic and hydrologic modeling is necessary in future design phases. This modeling will guide the sizing and configuration of stabilization features and help predict their performance over time.

It is important to recognize that while bank stabilization measures are critical for preserving channel form and reducing localized erosion, they will not eliminate or significantly reduce the risk of present or future flooding in the broader surrounding area. Flood mitigation would require elevating the top of the stream banks.

Pros:

- Directly addresses ongoing erosion and bank instability.
- Can be implemented in targeted locations without major reconfiguration of the channel.
- Potential for hybrid approaches that balance structural stability and ecological benefits.

Cons:

- Does not reduce broader flooding risk to surrounding areas.
- Limited benefit for sea level rise adaptation.

Alternative 3: Mill Cove Living Shoreline

To address shoreline erosion and flooding while improving ecological conditions, a hybrid living shoreline should be considered along Mill Cove. The Maine Geological Survey Living Shorelines Decision Support Tool, which displays the potential suitability for living shoreline approaches based on factors such as nearshore bathymetry, landward shoreline type, seaward shoreline type, aspect, and slope, scores Mill Cove as having a moderate-to-highly suitable shoreline for this practice (Maine Geological Survey, 2023). This concept would be constructed in the intertidal zone when possible, limiting impacts to private property. Implementation steps include, but are not limited to:

- Site Survey and Sediment Analysis: Assess substrate and wave energy conditions along the shoreline to design appropriate stabilization measures.
- Vegetative Stabilization: Install native salt marsh grasses (e.g., *Spartina alterniflora*, *Spartina patens*) on gentle slopes or planted terraces.
- Rock Sills or Fiber Rolls: Place low-profile, segmented rock sills or coir fiber rolls in the intertidal zone to attenuate wave energy and anchor sediment.
- Bank Grading: Where feasible, regrade steep slopes to more stable angles for planting and resilience against slope failure.
- Private Property Coordination: Since portions of the shoreline traverse private parcels, this effort would require a collaborative framework

FIGURE 9. Living shoreline with rock sill at Wagon Hill Farm in Durham, NH

It should be noted that this intervention provides less protection to inland properties from extreme storm surge compared to interventions that elevate structures and likely would not alter the projected flood mapping significantly.

Pros:

- Provides erosion control while enhancing intertidal habitat.
- Moderate-to-high site suitability per Maine Geological Survey tool.
- Visually integrates with natural shoreline.

Cons:

- Less protective against extreme storm surge compared to hard infrastructure.
- Requires coordination with private property owners.

Alternative 4: Cottage Road Raising and Bridge Replacement

This dual-purpose intervention seeks to both protect transportation infrastructure and provide flood protection to inland areas. While a full build-out to 14.9 feet may not be feasible, partial elevation could still provide significant resilience benefits. This should be coordinated with MaineDOT's replacement of the Cottage Road bridge.

The existing elevation of Cottage Road does not reach 15 feet until ~1,045 feet northwest along the road. The alternative to achieving the design elevation with roadway raising is by constructing shoreline flood barriers (i.e. seawalls and revetments). Ignoring the 1 foot of freeboard in the DFE, raising the roadway to accommodate the 100-year BFE plus 3.9 feet of RSLR scenario (el. 13.9 feet) would tie-in to existing grade ~625 feet to the northwest along Cottage Road (see **Figure 11**), a more feasible scenario than either of the previous two. Further discussion on the DFE is needed with all relevant stakeholders. Raising Cottage Road not only maintains access along Cottage Road during these scenarios but would double as a berm to prevent flooding of inland properties. However, this would not alleviate flooding for the private properties north of Cottage Road. It is critical that the Cottage Road bridge replacement should balance environmental considerations and the desire to promote salt marsh migration inland, while ensuring an enlarged crossing does not pose adverse impacts to upstream properties with respect to flooding.

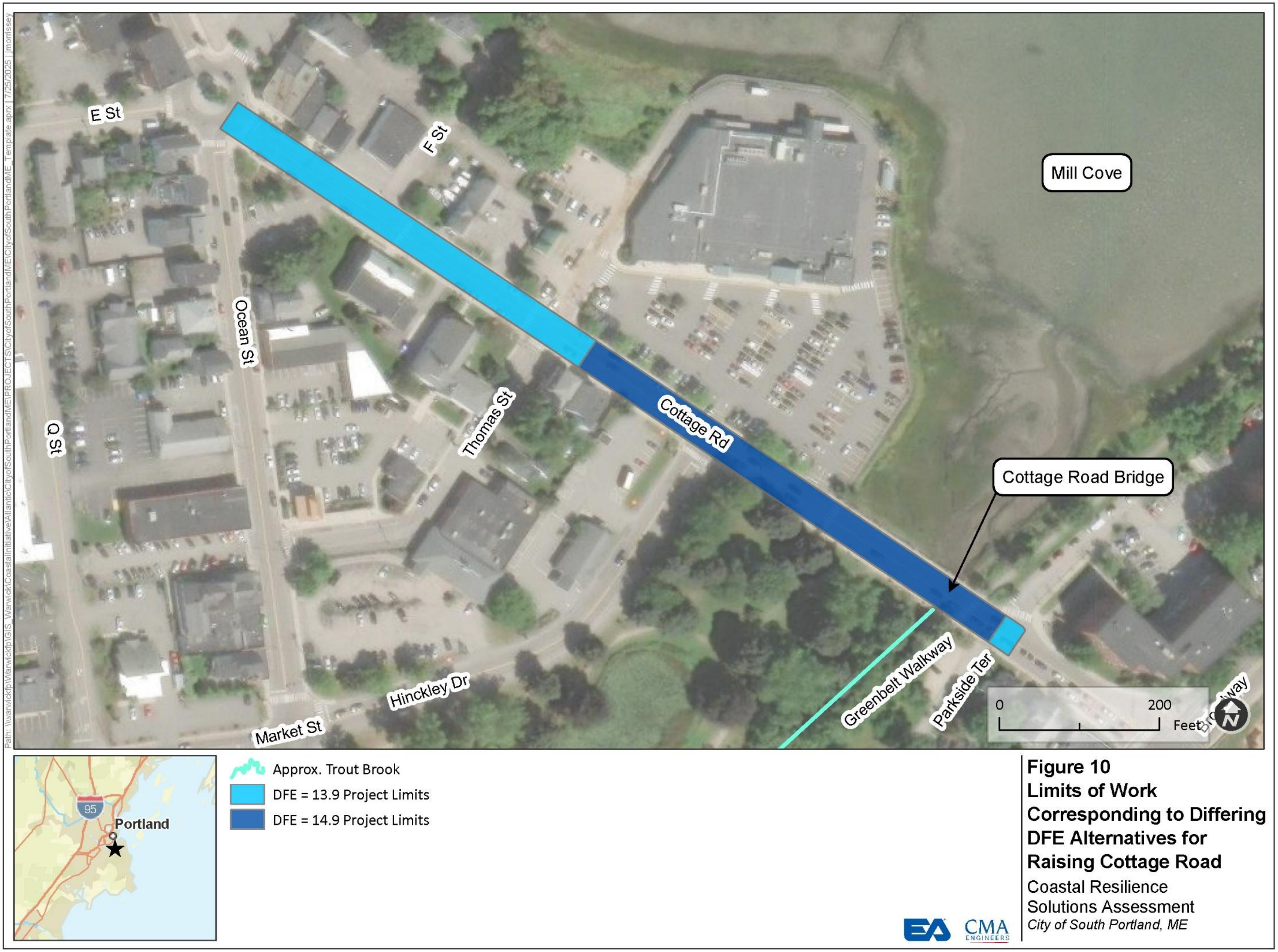


Figure 10
Limits of Work Corresponding to Differing DFE Alternatives for Raising Cottage Road

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The bridge Replacement (MaineDOT Project) should ensure the new span does not impede tidal exchange and allows salt marsh migration while preventing increased flood risk to upstream properties. This design alternative addresses both access and flood mitigation for the surrounding neighborhood. As part of this project, water level data is being collected to understand the severity of the existing tidal restriction, which could subsequently be compared to post-construction conditions when the bridge is replaced.

Pros:

- Maintains critical transportation access during flood events.
- Provides flood barrier effect for inland properties.
- Can be coordinated with MaineDOT bridge replacement project.

Cons:

- High capital cost and construction complexity.
- Difficult to phase due to continuous grade tie-in requirements.
- Potential impacts to private property and utility adjustments.

Alternative 5: Mill Creek Park Berm

To complement any of the three proposed design concepts for the Trout Brook area, a low-profile flood protection feature, such as an earthen berm or vegetated levee, could be strategically implemented along the boundary of Mill Creek Park. This linear feature would serve as a flood barrier that helps safeguard the adjacent residential neighborhoods from episodic flooding events.

The proposed berm would run parallel to the edge of Mill Creek Park and be graded to align with the elevation of Cottage Road. This alignment is critical because the low point of Hinckley Drive lies at an elevation below 10 feet, making the area vulnerable to overland flooding during storm events or extreme tidal conditions.

By elevating the berm to match the roadway elevation of Cottage Road, the structure would act as a passive defense, redirecting or containing floodwaters during specific flood scenarios. If future design alternatives include raising Cottage Road, the berm should be designed to match that new design grade, maintaining continuity in the protective barrier.

The berm would be constructed as a subtle, landscape-integrated feature, potentially vegetated with native grasses and low-maintenance plantings to promote both ecological resilience and visual appeal. In addition to its flood mitigation function, the berm could be designed with a multi-use path along its crest, offering opportunities for walking, biking, and passive recreation. This path would not only serve as a community amenity but also promote public engagement and support for the broader flood resilience strategy.

If the Greenbelt pathway is realigned as part of the rewilding or ecological restoration concept, the alignment of the berm could be modified accordingly to accommodate the new trail routing. The top of the berm could serve as a natural corridor for the Greenbelt trail, blending recreational infrastructure with climate adaptation and stream restoration goals.

This multipurpose use enhances the berm’s value, turning a purely functional flood mitigation structure into a community-focused feature that contributes to park access, connectivity, and open space aesthetics.

Pros:

- Offers targeted flood protection for adjacent properties.
- Can be integrated into park landscaping and recreational paths.
- Lower cost than large-scale roadway raising

Cons:

- Provides protection only up to berm elevation.
- Still requires complementary measures for broader flood resilience.

- Design Alternatives Evaluation: MILL COVE AND TROUT BROOK

The MCDA analysis (Attachment 3) shows that the Mill Creek Park Berm achieved the highest weighted score, reflecting its strong performance in adaptability, community acceptance, and cost-effectiveness. The next highest-ranking option was Cottage Road Raising with Bridge Replacement, which scored well for its ability to provide significant coastal hazard protection and maintain access during flood events, but was moderated by higher capital costs and construction challenges. It is important to note that the capital cost reflected in the MCDA for this alternative does not include the cost of replacing the Cottage Road bridge itself, as that work is being undertaken by MaineDOT. The roadway raising costs are considered separately as the City's responsibility. Trout Brook Stabilization also performed well, with strong scores in addressing erosion and streambank stability and relatively straightforward implementation, though it provides more localized benefits than neighborhood-scale flood protection.

Other alternatives scored more moderately. The Rewilding and Berm combination and the No Action scenario produced mid-range results, with the former offering ecological and storage benefits but lower overall protection compared to top-scoring strategies, and the latter serving primarily as a baseline for comparison. The Rewilding and Road Raising combination, the Mill Cove Living Shoreline, and Rewilding alone received the lowest overall scores in this update, reflecting either cost challenges or more limited effectiveness in reducing flood risk during extreme events.

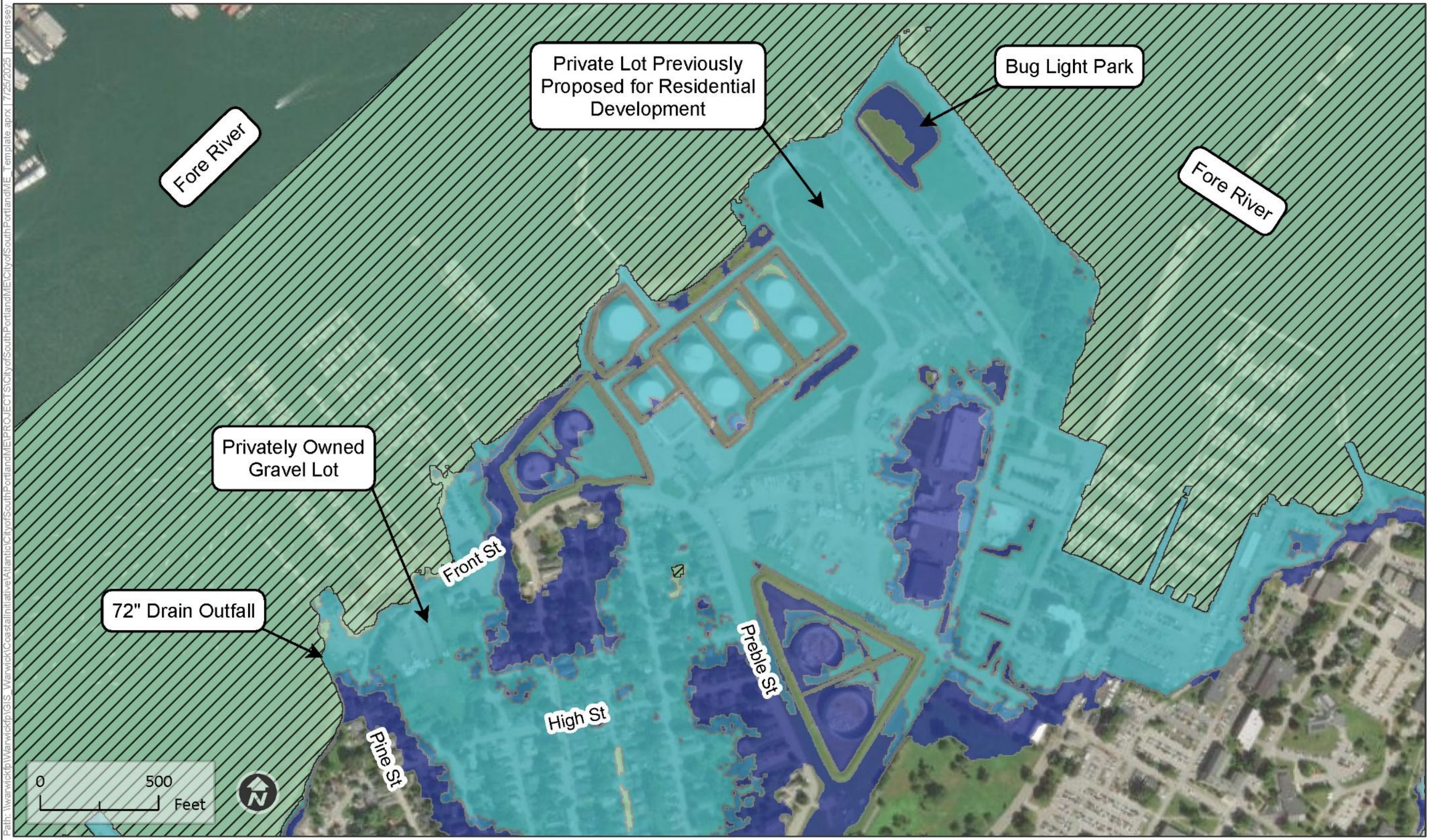
Taken together, the results suggest that the Mill Creek Park Berm offers the strongest near-term opportunity for implementation, with Trout Brook Stabilization providing an effective complementary measure. The Cottage Road Raising and Bridge Replacement option remains an important long-term strategy to advance in coordination with MaineDOT, but its scale and complexity indicate it will require more extensive planning and resources to implement.

2. Site Assessment: FRONT STREET AND FERRY VILLAGE

- Site Description: FRONT STREET AND FERRY VILLAGE

Ferry Village is a low-lying neighborhood along the eastern waterfront. Flood mapping from the South Portland Waterfront Resilience project indicates numerous commercial and residential properties are vulnerable to inundation under various future storm and non-storm scenarios.

The City has already carried out a study of infrastructure adaptation measures in this neighborhood to increase resiliency to coastal flooding. Infrastructure interventions evaluated included raising Front Street, shoreline interventions (including seawalls and living shorelines), redeveloping the waterfront into a resiliency park and public access parcel, and raising High Street.



MHHW + 3.9 ft SLR
100-yr Storm
100-yr Storm + 3.9 ft SLR
MHHW + 8.8 ft SLR
100-yr Storm + 8.8 ft SLR

Figure 11
Ferry Village and Front Street Site Overview

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In addition to coastal flooding, the neighborhood is highly vulnerable to freshwater flooding due to the bathtub-like topography of the neighborhood and the submerging of outfalls during high tides and storm surge. If a freshwater storm occurs during high tide and the outfall pipes are submerged, drainpipes will be surcharged until the tide recedes. This issue will only be exacerbated by raising Front Street, which will further impound water in the neighborhood. Additional storage may be needed in the drainage system to reduce overland flooding.

- Vulnerability and Assessment: FRONT STREET AND FERRY VILLAGE

Front Street is assigned a 'medium' tolerance for flooding because it is a minor arterial, but it acts as a berm to prevent flooding to many inland residences.

TABLE 6. Inputs and resulting DFE for Front Street.

	Front Street
Existing Elevation (ft)	9.1 (low point)
FEMA BFE	13
Risk consequence	Medium
RSLR Estimate (ft)	3.9
DFE (ft)	17.9

It is highly unlikely that raising Front Street nearly nine feet, as required to meet the DFE presented in **Table 6**, would be feasible. The previous study considered raising Front Street four feet, which is likely the most reasonable elevation change given development adjacent to the roadway and right-of-way constraints.

Raising the road presents a more practical and effective strategy for enhancing flood resiliency compared to implementing shoreline interventions. The neighborhood is vulnerable to flooding from two main directions: the northeast (at the corner of Front Street and Preble Street) and the northwest (near the corner of Front Street and Pine Street). The northwest flood path is particularly complex due to the presence of multiple private property owners and varied existing shoreline conditions, making the design and construction of a unified shoreline solution difficult. In contrast, the northeast flood path involves fewer private properties, making shoreline interventions in that area more feasible and potentially effective.

Based on the site assessment and desktop analysis, the following design alternatives have been developed for this site:

- Front Street Road Raising
- Shoreline Flood Protection Measures
- Deployable Flood Barriers
- Subsurface Stormwater Detention System

- <u>Design Alternatives</u>: FRONT STREET AND FERRY VILLAGE

Alternative 1: Front Street Road Raising

This design alternative is the centerpiece of adaptation in Ferry Village. The crux of the design process will be stakeholder collaboration on a DFE, and the design elevation will significantly impact the scale of the project. For example, a target design elevation of 13 feet, bringing the roadway to a minimum of matching the current FEMA BFE would require ~1,900 linear feet of roadway work. A target design elevation of 17.9 FEET would require ~3,285 linear feet of roadway work (see **Figure 12**), plus significant impacts to abutting parcels. The design of associated curbing, sidewalk, and intersections would also need to be incorporated to ensure ADA compliance and acceptable roadway geometry.

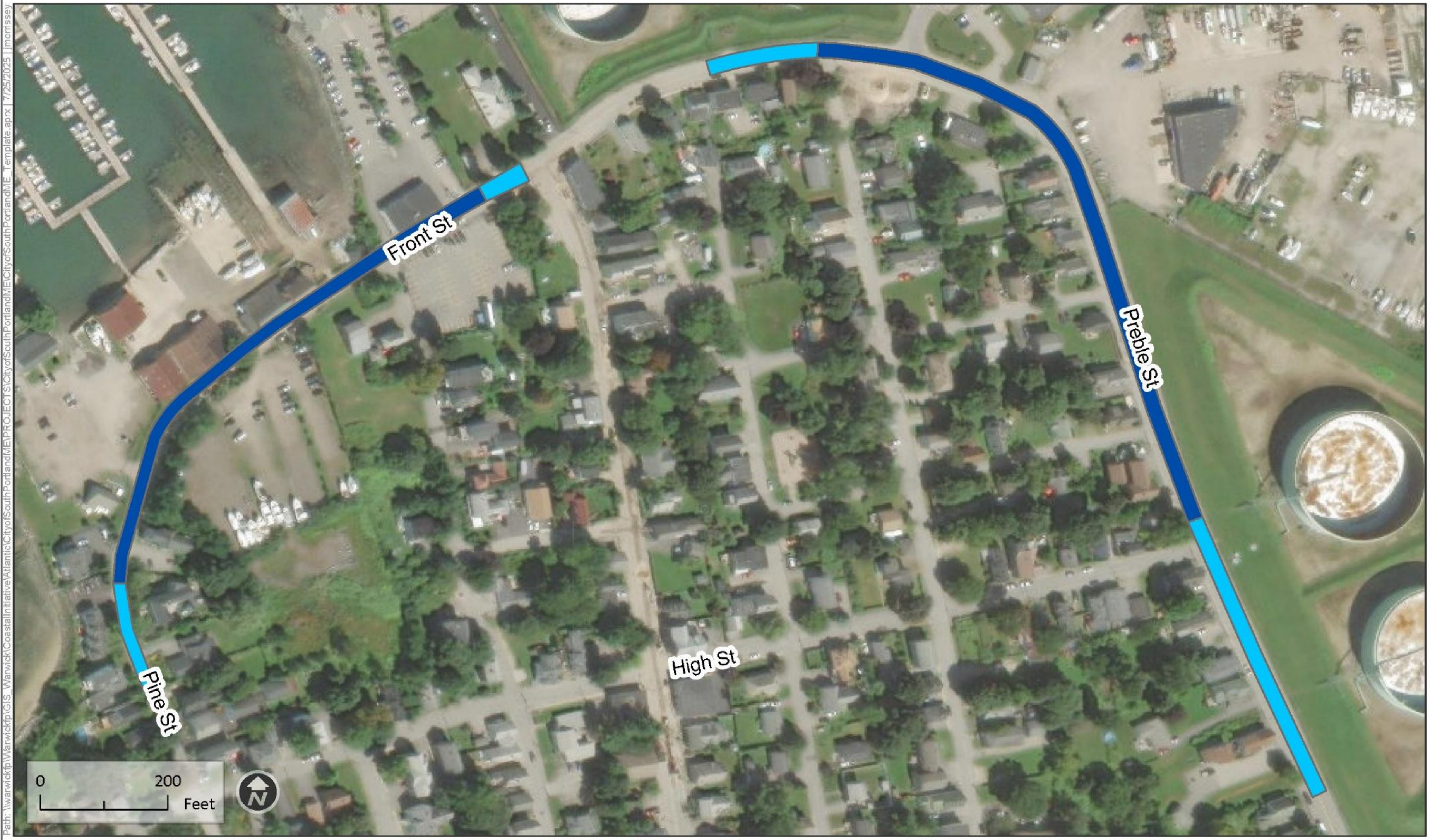
This alternative provides a flood barrier effect, reducing inundation risk from tidal flooding to many low-lying parcels that are vulnerable to future flooding. However, raising the roadway would further impound stormwater runoff and likely exacerbate inland flooding during freshwater flooding, if not accounted for simultaneously.

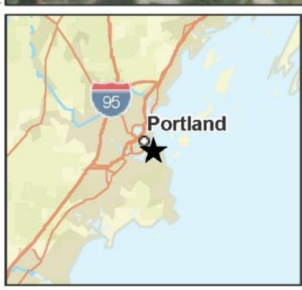
Pros:

- Acts as a flood barrier for inland properties.
- Long-lasting protection if built to target DFE.
- Can be combined with stormwater improvements.

Cons:

- Large-scale construction with significant disruption.
- May exacerbate freshwater flooding without additional drainage measures.
- Limited phasing potential.





DFE = 17.9 Project Limits

DFE = 13.0 Project Limits

Figure 12
Limits of Work Corresponding to Differing DFE Alternatives for Raising Front Street

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Alternative 2: Shoreline Flood Protection Measures

As an alternative or supplement to roadway elevation, constructing elevated shoreline structures can serve to mitigate coastal flooding impacts to inland properties. However, this strategy presents significant implementation challenges, particularly along the northeastern flood path.

The northwest flood pathway crosses six privately owned parcels, each with varying existing shoreline features such as docks, piers, boat ramps, and seawalls. These site-specific constraints, along with the need to preserve access to critical features like the boat ramp, make it difficult to design a continuous and cohesive flood barrier. Achieving effective flood protection in this area would require extensive coordination among multiple property owners, detailed site design, and likely regulatory hurdles—making this approach complex and potentially infeasible in the near term.

Conversely, the northeast flood path poses fewer property-related challenges. This pathway appears to affect primarily parcel 6-2H, with some potential influence from adjacent parcel 6-3, which contains petroleum storage infrastructure. A flood barrier, such as a seawall or levee, constructed along the perimeter of parcel 6-2H could significantly reduce coastal flood risk for inland areas.

Parcel 6-2H is privately owned and was recently the subject of a now-withdrawn proposal for a 1,000-unit housing development. As the lot currently remains undeveloped, there may be a strategic opportunity for the City to collaborate with current or future developers to integrate robust shoreline flood protection measures into the site's design. Such a partnership could simultaneously facilitate resilient development and protect vulnerable inland properties.

Pros:

- Protects shoreline directly, potentially reducing need for road elevation.
- More feasible along northeast flood path with fewer property owners.

Cons:

- Complex implementation along northwest flood path due to multiple private owners.
- Regulatory challenges and possible NRPA limitations for hardscaping.
- Does not address freshwater flooding.

Alternative 3: Deployable Flood Barriers

For additional protection during extreme events, temporary modular barriers along key segments of the roadway could be deployed. Example of an applicable barrier is the 'big bag' (bags typically filled with sand to create a temporary levee) or inflatable water dams (see **Figure 13**)

FIGURE 13. Tiger Dams flood barrier (courtesy of Tiger Dams).

This concept requires City DPW staff to develop a deployment plan. Bags could be staged at key locations, such as the City owned lot near the pump station, and deployed when a king tide or extreme storm surge is forecasted. This method is likely more applicable in the northeast corner of Front Street, where the floodpath into the neighborhood is narrower. The deployable flood barrier could connect the two outer tank berms that abut the road. While not a permanent solution, deployable barriers provide a flexible defense layer when raising infrastructure is not feasible. This adaptation strategy does pose additional risk compared to permanent features, though, as incorrect or untimely deployment poses additional failure mechanisms.

Pros:

- Flexible, can be deployed only when needed.
- Lower capital cost than permanent structures.
- Minimal visual or physical footprint between events.

Cons:

- Dependent on timely deployment and trained staff.
- Provides no protection if not deployed or if deployment fails.
- Requires ongoing storage, maintenance, and training

Alternative 4: Subsurface Stormwater Detention System

To mitigate freshwater flooding in Ferry Village, considering the impacts of RSLR increasing the duration of the tidal cycle where outfall pipes are surcharged and possible exacerbation of this issue if roadway raising is advanced, subsurface detention systems can be installed under roadways or on parcels the City obtains easements to store runoff during high tides when outfalls are submerged. The major stormwater outfall pipe for the neighborhood, a 72” reinforced concrete pipe, passes under a gravel lot at 262 Front Street that appears to be a viable site to install such a system.

FIGURE 14. StormTech Subsurface Stormwater Management System (courtesy of Advanced Drainage Systems).

The system would require a tide gate or other backflow prevention device to prevent storm surge from backing up into the system and allow for discharge of stormwater once the tide recedes. Other storm drains in the neighborhood can also benefit from the installation of check valves or other backflow prevention devices. Further hydrologic and hydraulic analysis is needed to evaluate sizing requirements.

Pros:

- Mitigates freshwater flooding during high tides when outfalls are surcharged.
- Can be installed under existing lots or roadways.
- Minimal impact to above-ground aesthetics and land use.

Cons:

- Does not protect against tidal flooding.
- Requires backflow prevention and regular maintenance.

- Design Alternatives Evaluation

The MCDA analysis (Attachment 3) indicates that the combined alternative of Road Raising and Subsurface Stormwater Detention achieved the highest weighted score. This reflects its ability to provide a balanced package of coastal hazard protection and freshwater flooding mitigation, addressing both primary vulnerabilities in the neighborhood. The combination also scored well on permitting feasibility, given that both measures have clear precedents.

Among the single-strategy alternatives, the Deployable Flood Barriers and the Subsurface Stormwater Detention System scored next highest. Deployable barriers performed strongly in terms of flexibility, cost, and community acceptance, providing targeted protection during extreme events with limited permanent footprint. The detention system also ranked highly due to its effectiveness in reducing freshwater flooding during high tides, relatively straightforward permitting, and limited surface disruption.

Lower-scoring options included Front Street Road Raising and Shoreline Flood Protection Measures. Road raising continues to show strong potential for coastal hazard reduction, but its score was moderated by high cost, construction disruption, and freshwater flooding tradeoffs if not paired with drainage improvements. Shoreline protection, particularly along the northwest flood path, remains challenging due to property ownership fragmentation and permitting complexity, resulting in the lowest overall score. The No Action scenario also scored in the lower range, as expected, serving as a baseline for comparison.

3. Site Assessment: LONG CREEK

- Site Description: LONG CREEK

  Long Creek is another one of the five urban impaired streams in the City. An EPA report (Zigler et al., 2007) identified five probable causes of poor biological indicators in Long Creek: decreased dissolved oxygen, altered flow regime, decreased large woody debris, increased temperature, and increased toxicity. The highly developed watershed with a large portion of impervious cover results in flashy flows, reduced infiltration, elevated temperatures, and increased pollutant runoff. The Long Creek Watershed Management District has implemented several projects in recent years with the goal of improving water quality, including the South Branch Gravel Wetland, Blanchette Brook Stream Restoration, and the Main Stem Restoration Project.

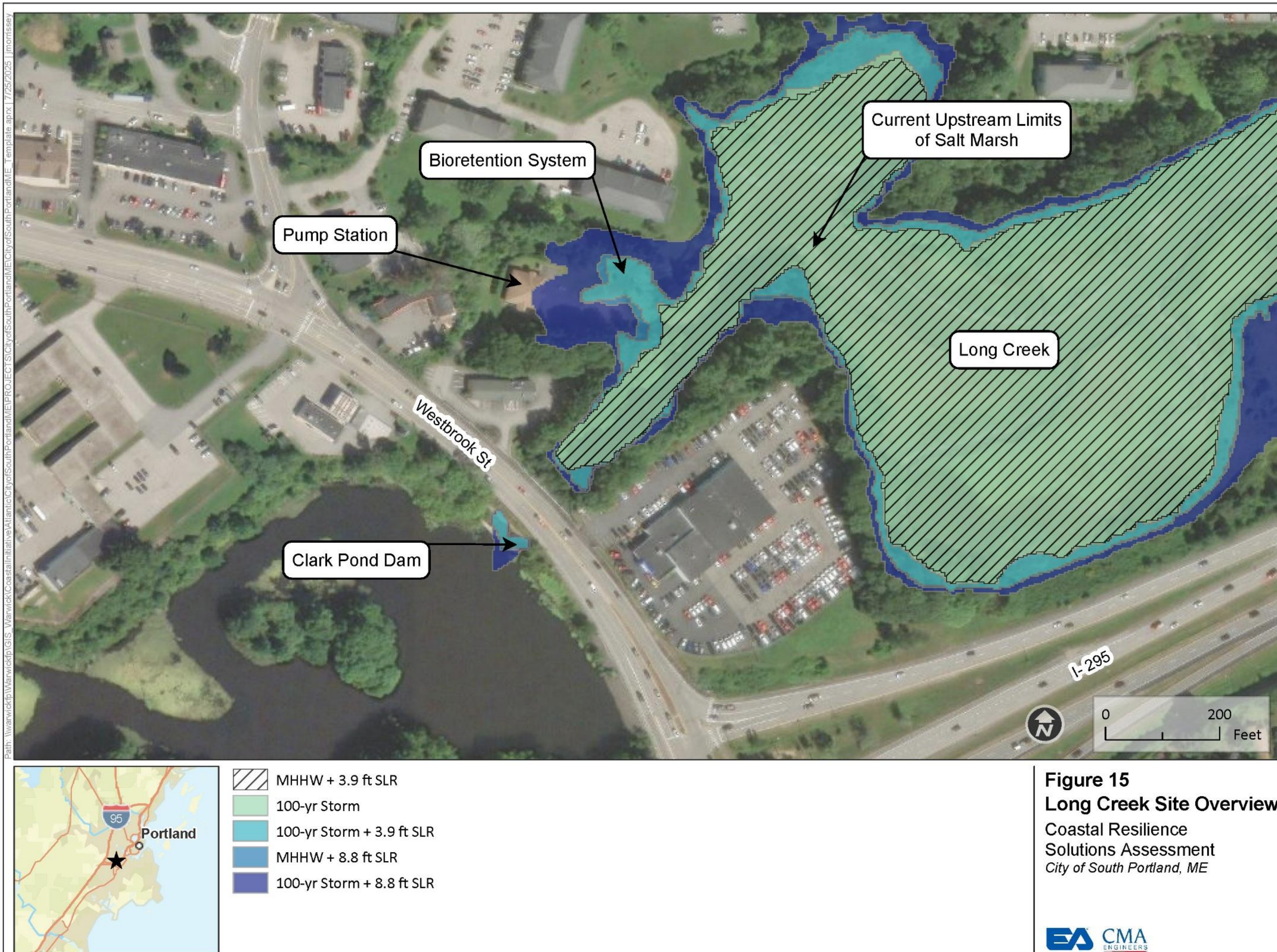

Figure 15
Long Creek Site Overview

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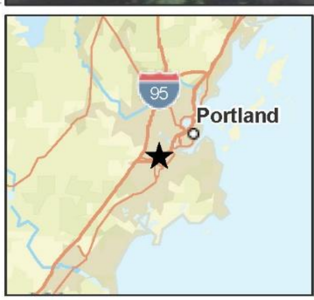
The infrastructure in this area that is the primary focus of this assessment is the Long Creek Pump Station. The Long Creek Pump Station was upgraded in 2009 to increase capacity. Upgrades included construction of a new pump station, demolition of an abandoned pump station and an active pump station, addition of a public parking area with permeable pavers, and construction of a bio-retention system for stormwater management. The bio-retention system discharges to a swale that drains to Long Creek.

The Clark Pond Dam, ~525 feet upstream of the Pump Station along Long Creek, was also assessed as part of the site visit and assessment. The dam was built sometime before 1900 and allowed the Cumberland County Ice Company to harvest ice from the pond. After the cessation of ice harvesting, the pond was stocked with trout and recreationally fished until the declining water quality due to commercial and residential development in the watershed threatened the viability of trout habitat. The Dam was assessed solely based on its apparent impact on the environmental and hydrologic impacts on the project setting; a structural assessment was not included in the scope of this project.

Mapping from the Maine Department of Agriculture, Conservation, and Forestry Potential Tidal Marsh Migration Map (see Figure 16) indicates the current extent of tidal marsh terminates ~225 feet downstream of the Pump Station along Long Creek, and that marsh migration with 3.9 feet of RSLR (the intermediate projection for 2100) will reach the Clark Pond Dam.



Current Tidal Marshes

Marsh Migration 1.6 ft Sea Level Rise

Marsh Migration 3.9 ft Sea Level Rise

Figure 16
Potential Salt Marsh Migration Under Various RSLR Scenarios at Long Creek

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- <u>Vulnerability Assessment</u>: **LONG CREEK**

  The Long Creek Pump Station is assigned a 'very high' consequence from flooding because failure of such a facility can lead to raw sewage overflow and subsequent public health hazards.

TABLE 7. Inputs and resulting DFE for the Pump Station.

	Pump Station – odor control room and screening room first floor elevation	Pump Station – generator room and electrical room first floor elevation
Existing Elevation (ft)	17.0	19.7
FMA BFE	9	9
Risk consequence	Very high	Very high
RSLR Estimate (ft)	8.8	8.8
DFE (ft)	19.8	19.8

The Pump Station is vulnerable to flooding under the 100-year storm surge in the year 2100, with the station suffering damage and access issues under the DFE, as shown in **Table 7**. It is recommended to evaluate adaptation measures, such as elevating the doorways or installing watertight barriers around openings. Also, it is unknown if the outfall pipe exiting the CSO diversion structure has a tide gate or valve downstream. Most likely, a gate or valve will be needed to prevent storm surge from backing up into the wet well. These are long-term adaptation measures to consider and are likely not a high priority in the near future, given the existing structure elevations relative to current flood elevations.

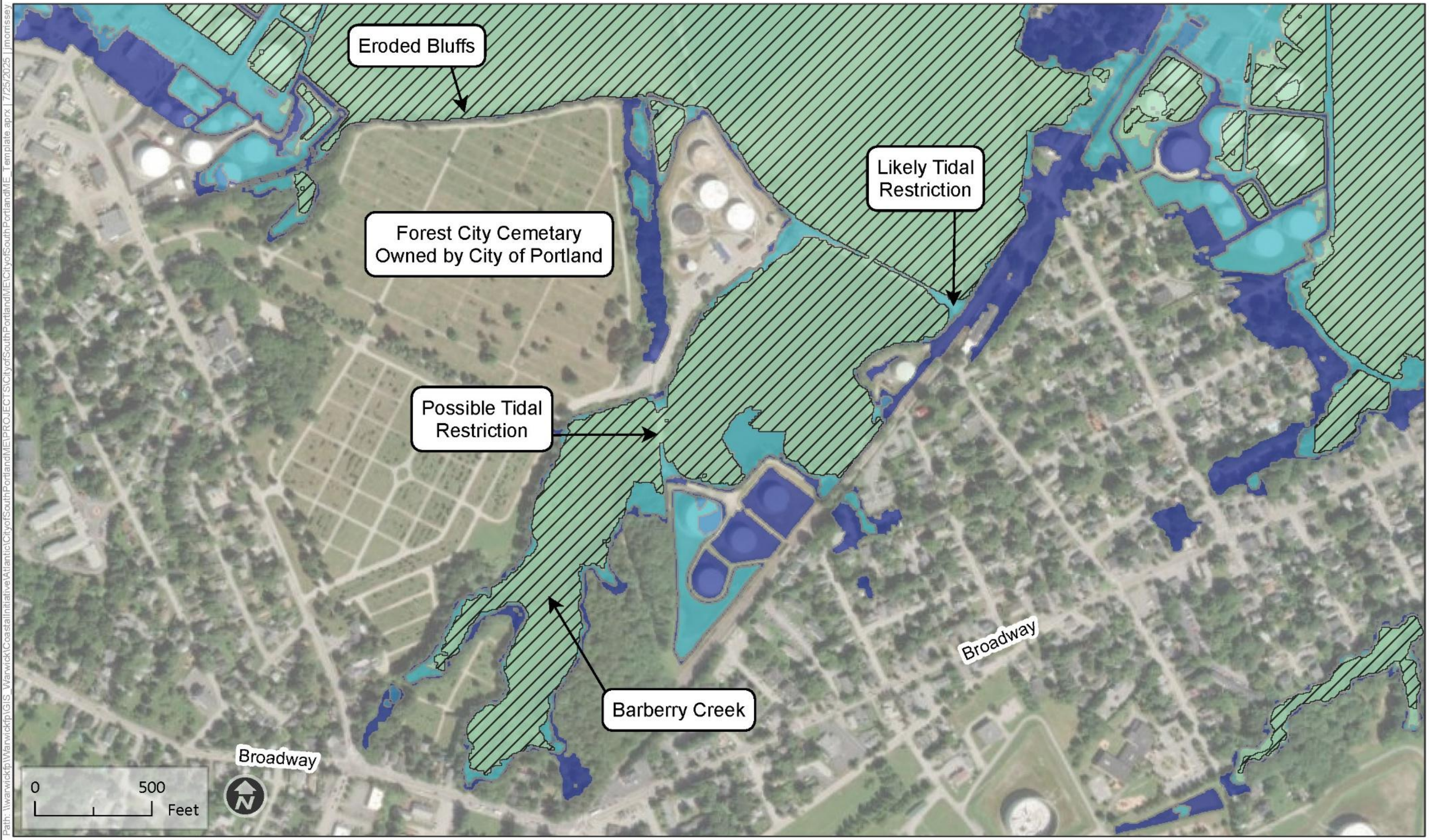
It is noted that the bioretention system spillway elevation (11.0 feet) is below the future BFE under modest RSLR scenarios. The area is planted with Siberian iris, winter berry, and mission arborvitae, all of which are considered salt tolerant, thus the system's ability to treat stormwater runoff is unlikely to be adversely impacted in the long term if inundated by a pulse of saltwater from storm surge. The spillway elevation is above all but the most conservative MHHW plus RSLR scenarios, indicating hydraulic performance of the bioretention system is unlikely to be adversely impacted under normal conditions in the future.

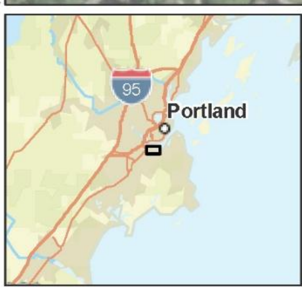
The Clark Pond Dam is a likely contributor to the current degraded water quality in Long Creek and is a future barrier to salt marsh migration. In general, dams can adversely impact water quality in streams by increasing temperature, decreasing dissolved oxygen levels, and impounding sediment and particulate nutrients. Furthermore, mapping described above indicates that the dam will impede future salt marsh migration inland. The removal of a tidal restriction is an example of a hybrid green/grey engineering intervention, where grey infrastructure is improved to create or enhance natural features, such as salt marsh. Salt marsh is considered a high value habitat because it attenuates wave action, absorbs flood waters from storm surge, improves water quality, and increases biodiversity. Further analysis with comprehensive hydrologic, hydraulic, and water quality modeling is needed to investigate the viability and effectiveness of this intervention.

4. Site Assessment: BARBERRY CREEK

- Site Description: BARBERRY CREEK

  Barberry Creek is another one of the five impaired streams in the City. The focus area for this project is the ponded area adjacent to the Forest City Cemetery.





MHHW + 3.9 ft SLR
100-yr Storm
100-yr Storm + 3.9 ft SLR
MHHW + 8.8 ft SLR
100-yr Storm + 8.8 ft SLR

Figure 17
Barberry Creek
Site Overview

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The site visit identified areas of significant erosion along the Cemetery shoreline (see **Figure 18**); however, it is noted the Cemetery is owned by the City of Portland.

FIGURE 18. Erosion along Forest City Cemetery shoreline observed during site visit.

The ponded areas south of the petroleum causeway were observed at both high and low tide, and the difference in water elevation was negligible. This indicates that the culverts under the causeways are impounding water and restricting the daily tidal exchange. This is corroborated by the Maine Department of Marine Resources Tidal Restriction Atlas, which denotes both causeways as tidal restrictions. The project team was unable to access the causeways and assess the culverts up-close

Additionally, Broadway was identified as an area potentially vulnerable to future flooding and its elevation relative to flooding scenarios is assessed.

- Vulnerability Assessment: BARBERRY CREEK

  The causeways are assigned a 'high' consequence from flooding because damage to these pipelines would have significant, adverse environmental consequences if the pipeline should rupture. Broadway over Barberry Creek is also assigned a 'low' tolerance for flood risk because Broadway is a major arterial and the shortest detour is 7.2 miles (via Highland Ave, Pleasant Hill Rd, and Route 1).

TABLE 8. Inputs and resulting DFE for Site around Barberry Creek.

	Northern causeway	Southern causeway	Broadway over Barberry Creek
Existing Elevation (ft)	6.0	5.0	21.0
FEMA BFE	9	9	9
Risk consequence	High	High	High
RSLR Estimate (ft)	6.1	6.1	6.1
DFE (ft)	16.1	16.1	16.1

The petroleum causeways are highly vulnerable to RSLR, as shown in **Table 8**. Even under non-storm conditions, the causeways are predicted to be overtopped daily by 2050 in the MHHW plus RSLR scenarios. It is again worth noting these are privately owned and not the responsibility of the City. However, reconstructing the causeways, by raising them while replacing the culverts with structures that do not impose tidal restrictions, would be a hybrid green-grey infrastructure solution that increases the resilience of infrastructure while restoring degraded wetlands in this impaired stream. This scheme also mirrors the Mildred Street culvert replacement. A public-private partnership could be pursued to this end.

Broadway over Barberry Creek is sited well above the DFE. Even under the most conservative RSLR scenario, the roadway is not threatened with inundation under storm or non-storm scenarios. Additional intervention is not warranted at this location.

5. Site Assessment: ANTHOINE CREEK

- Site Description: ANTHOINE CREEK

  The focus of the Anthoine Creek site is the Broadway bridge. The bridge itself, adjacent Anthoine Street, and upstream residences abutting Anthoine Creek, have all been identified as vulnerable to flooding under various scenarios.

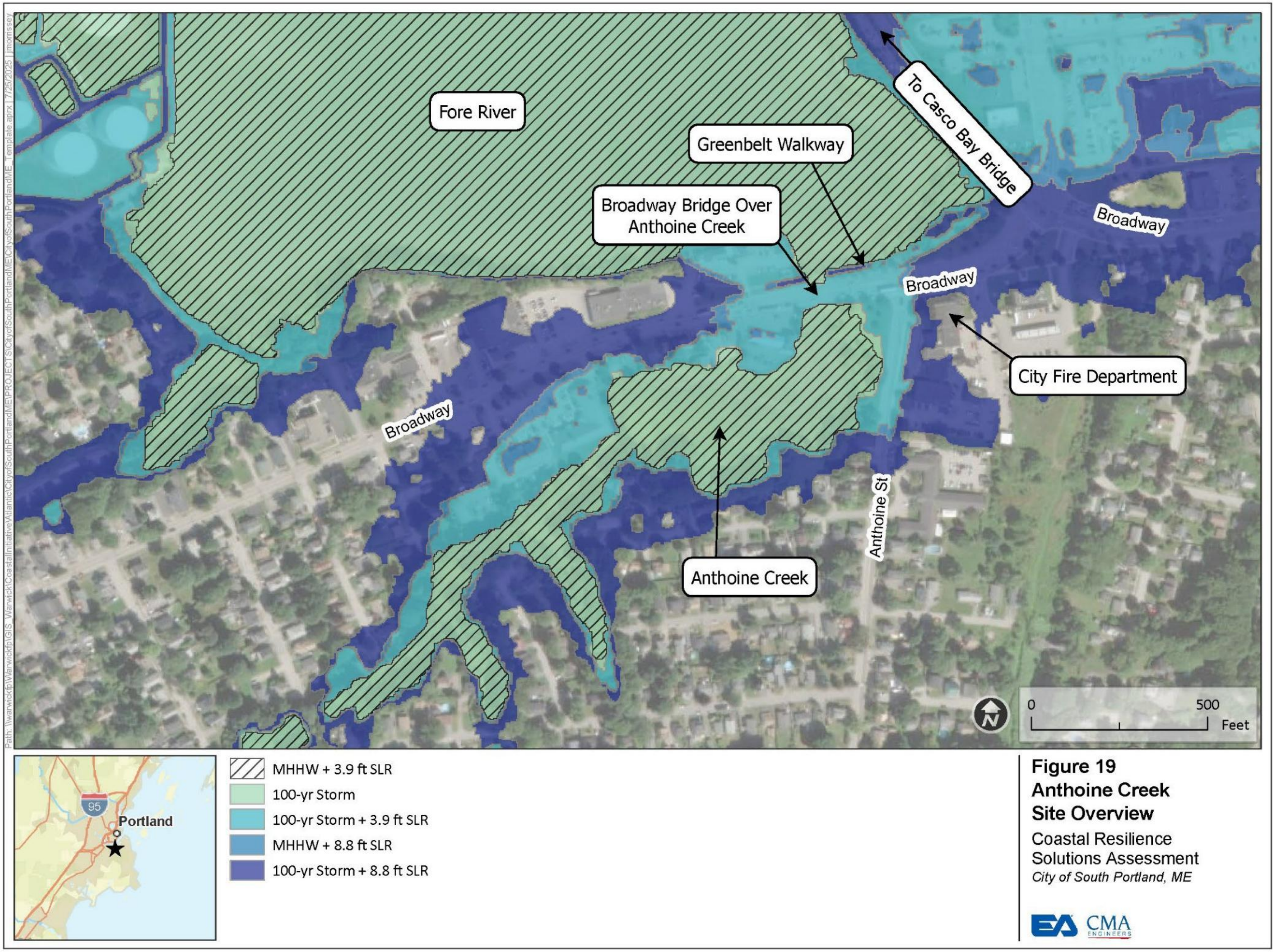

Figure 19
Anthoine Creek Site Overview

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During the site visit, it was observed that protective ducts encasing subsurface utilities through the bridge crossing are extensively deteriorated.

FIGURE 20. Exposed conduit under Broadway bridge observed during site visit.

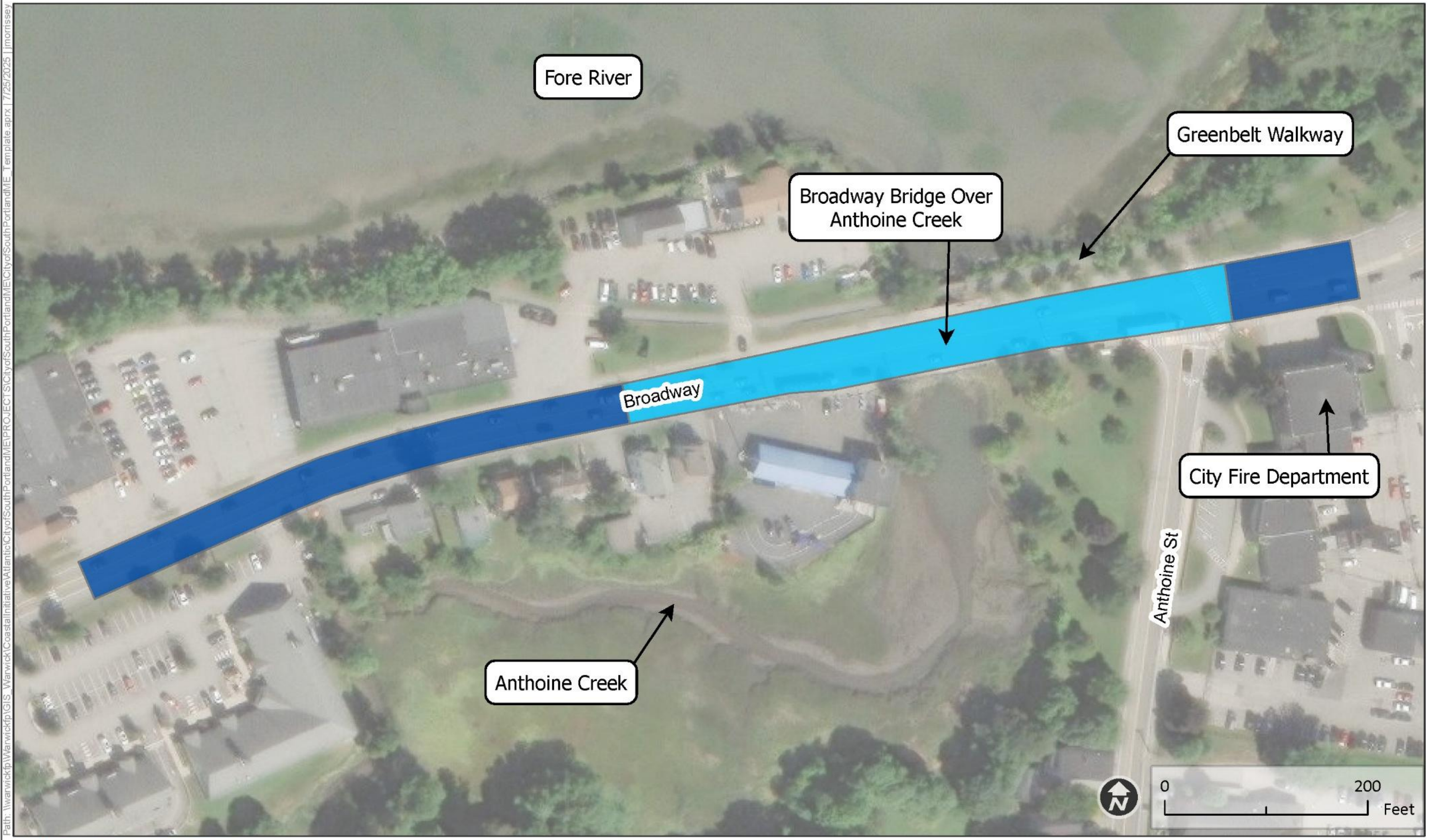
- Vulnerability Assessment: **ANTHOINE CREEK**

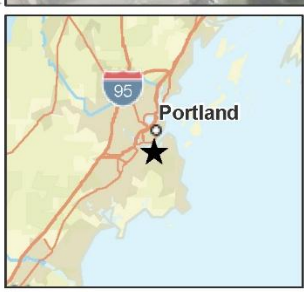
  The Broadway bridge is assigned a 'high' consequence from flooding because it is a major arterial and the likeliest detour is 2.6 miles (there is a shorter detour via Osborn Ave and Kelley St, though this street is projected to flood under the same scenarios).

TABLE 9. Inputs and resulting DFE for Broadway Bridge.

	Broadway Bridge over Anthoine Creek
Existing Elevation (ft)	9.4
FEMA BFE	9
Risk consequence	High
RSLR Estimate (ft)	6.1
DFE (ft)	16.1

Though the FEMA map shows Broadway as inundated, the topography generated for this study indicates the low point of the road is above the BFE. However, the crossing is still vulnerable to future flooding. The derived DFE, shown in **Table 9,** is also approximately equal to HAT plus 8.8 feet of RSLR (el. 15.5 feet), indicating the roadway elevation is significantly lower than future flood elevations in both storm and non-storm scenarios. In reviewing the site topography, it is noted Broadway does not reach elevation 16 feet until ~915 feet west of the bridge, indicating raising the roadway to the DFE is a significant undertaking. Raising the roadway to match the elevation of the Greenbelt bridge (el. 14 feet) would match existing roadway elevations ~360 feet west of the bridge (see **Figure 21**), indicating a more feasible alternative. Further discussion on the DFE is warranted with all relevant stakeholders.





DFE = 16.1 Project Limits

DFE = 14.0 Project Limits

Figure 21
Limits of Work Corresponding to Differing DFE Alternatives for Raising Broadway

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The Maine Tidal Restriction Atlas denotes the crossing as a tidal restriction. Further evaluation is needed to determine if the crossing is adversely impacting upstream marsh health. It was observed during the site inspection that the channel substrate within the bridge is primarily coarse riprap and not consistent with the marsh substrate. Consequently, it appears the bridge has altered sediment transport dynamics and resulted in a higher channel elevation within the bridge than upstream, impounding water at low tide and adversely impacting marsh health. Regrading or reconstructing the channel within and abutting the bridge with substrate more consistent with the marsh may be beneficial to upstream marsh health.

Figure 22. Upstream of Broadway bridge inlet at low tide, noting the difference in channel substrate and lower channel elevation upstream of bridge.

Raising the roadway will also require replacement of the bridge itself. It is noted the bridge is owned by MaineDOT. The bridge was originally built in 1930 and reconst ructed in 1994, though it appears the reconstruction only replaced the superstructure (concrete deck), not the substructure (granite blocks supporting the deck). Both the superstructure and substructure received a rating of 6 (designating minor deterioration) in its most recent inspection, indicating the bridge's replacement is possible in the near future. Coordination with MaineDOT will be needed to ensure an appropriate span size is proposed for the replacement, though it is possible the City could address the channel modifications in the nearer term.

6. Site Assessment: WILLARD BEACH

- Site Description: WILLARD BEACH

  Willard Beach is a small sand beach that has high recreational and cultural value to the City and its residents. The area is a well-known flood hazard, as evidenced by the January 2024 storms that washed away the iconic fishing shacks at Fishermans Point. The area has several complete or ongoing projects executed with the goal of increasing the resiliency of various aspects of the site, including Willard Beach Master Plan, a USACE-led breakwater study, Willard Beach Force Main Replacement, a resilience assessment for the Willard Beach pump station, a project to reconstruct the Deake Street stairway, and Willard Beach Scraping.

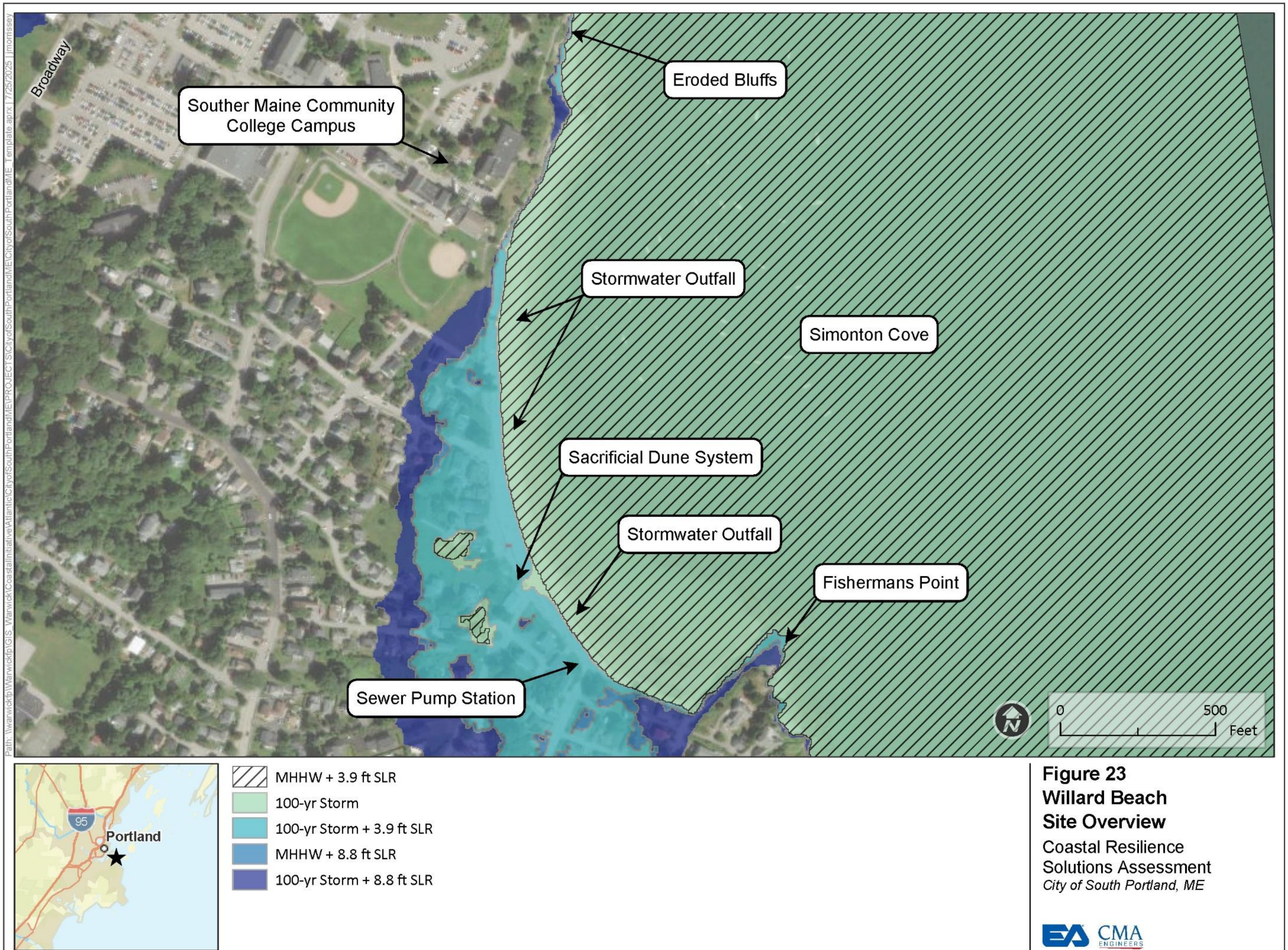

Figure 23
Willard Beach
Site Overview

Coastal Resilience
Solutions Assessment
City of South Portland, ME

There are two distinct shoreline characterizations at the site: sandy beach and rocky bluffs. The site visit occurred a couple of weeks after the completion of the dune scraping project, where the beach was manually regraded and a three-foot tall sacrificial dune was constructed between Willard Beach and Myrtle Avenue. The project noted that current DEP regulations limited the volume of sand that was permitted to be utilized. Flood mapping from the City indicates the neighborhood behind this sacrificial dune is vulnerable to future flooding.

The erosion along the rocky bluffs is severe. There are areas of exposed manholes (**Figure 24**), light pole foundations, and utility pipes that have not been shored up since the 2024 storms. It is noted this area of shoreline is owned by Southern Maine Community College (SMCC).

Figure 24. Exposed manhole along eroded coast observed during site visit.

Another hazard to the Willard Beach area, separate from the flooding and shoreline erosion issues, is poor water quality. Willard Beach is classified as impaired due to elevated bacteria levels. The City notes that 41% of the catchment area to Willard Beach is impervious, and the City's GIS indicates six stormwater outfall pipes between Fishermans Point and Fort Preble.

- Vulnerability Assessment: **WILLARD BEACH**

TABLE 10. Inputs and resulting DFE for sites at Willard Beach.

	Sacrificial dunes	Walkway along bluffs
Existing Elevation (ft)	~9.0	18.5-23.0
FEMA BFE	11	22
Risk consequence	Low	Low
RSLR Estimate (ft)	3.9	3.9
DFE (ft)	14.9	25.9

The large discrepancy in BFE, shown in **Table 10**, at this site is due to the exposure to wave action in the north, while the main beach is sheltered from the largest impacts of wave action by Fishermans Point. The main beach and footpath along the bluffs are assigned a 'low' consequence from flooding because of their recreational use and the lack of critical infrastructure adjacent to them.

If the sacrificial dunes are intended to serve as a long-term measure to increase the resiliency of the neighborhood to flooding, they will likely need to be reconstructed to a significantly higher elevation. Sacrificial dunes, by their nature, will erode over time and require reconstruction, so presumably there will be opportunities over the next decade to achieve a higher top of berm elevation. The most recent projects noted that DEP permitting limited the volume of sand utilized and thus limits the ability to build to a higher elevation. This permitting issue will need to be resolved in the future. There are several additional nature-based or hybrid green-/grey design measures that can be incorporated into the dunes to increase their stability, including planting salt-tolerant plants with extensive root systems, coir envelopes placed in terraces along the beach and covered in sand, and fiber or coir rolls placed in the center of dunes and filled over with sand. As of now, it is understood the City does not intend to plan or develop flood resiliency or shoreline stabilization measures along the sandy beach; it is to be the responsibility of homeowners.

The bluffs likely require hardscaping, such as a revetment, to reinforce the eroding coastal banks, given the steep slopes, rocky complexion and presence of bedrock, high grade differential between the toe of slope and the walkway, and the high exposure to severe wave action, as reflected in the FEMA maps. The bluffs are owned by SMCC, and therefore it is not the responsibility of the City to reinforce this eroding area.

The USACE initially recommended a breakwater in its study in the 1980s. That recommendation has since been walked back, likely due to cost and scale, and there is currently no plan to construct one. An alternative that warrants further investigation is a living breakwater. These submerged features are constructed by creating oyster reefs or utilizing reef balls (**Figure 25**) to serve as natural breakwaters that attenuate wave energy. Living breakwaters are significantly less impactful to sediment dynamics than a hardscaped emerged breakwater, which is likely a concern driving the recommendation against the USACE breakwater. Additional analysis would be required to determine the most viable living breakwater option and the reef balls in **Figure 25** are provided as a general example.

FIGURE 25. Reef ball designed to support growth of oysters, used in construction of living breakwaters (Eternal Reefs, 2020).

The green space around the SMCC sports fields is a viable location for green stormwater infrastructure. There is a large area of grassed space that is seemingly not utilized for recreational activities (see **Figure 26**), and the outfall pipe for the stormwater network collecting Fort Road, Benjamin W Pickett Street, Breakwater Dr, Madison Street, and parts of Front Street runs directly under this parcel.

FIGURE 26. Grassy area adjacent to SMCC sports fields, a potential site for stormwater BMP.

The area presumably has shallow bedrock based on proximity to rocky bluffs, which could limit the viability of infiltration practices. Possible stormwater BMPs (Best Management Practices) include a rain garden, stormwater wetland, or subsurface treatment system. Further site investigation is needed to assess the viability of these alternatives. Because this parcel is owned by SMCC, a partnership between SMCC and the City would be needed to advance this concept.

CONCLUSIONS

This assessment has identified a range of vulnerabilities and proposed interventions for six high-priority coastal locations within South Portland, each with unique characteristics and considerations. Four of the sites identified as lower priority were assessed with a simplified approach that did not include the development of design alternatives, while the two high priority sites did include this additional step. Using a combination of field reconnaissance, drone-based topographic data collection, and DFE calculations based on state and regional guidance, this study provides a foundation for advancing site-specific resiliency improvements.

The design adaptations evaluated for the sites included both traditional grey infrastructure and hybrid green/grey design adaptations. Hybrid solutions combine the more robust stabilization of hardscaping with green elements that provide a wider array of co-benefits than grey or green infrastructure in isolation.

The project team identified Long Creek, Anthoine Creek, Barberry Creek, and Willard Beach as the lower priority sites based on the risk to public infrastructure. Consequently, they were assessed with the simplified approach and the discussions on these four sites ended in addressing the vulnerability of infrastructure and the recommended adaptation measure, including with respect to DFEs.

The assessments for Mill Cove/Trout Brook and Ferry Village sites concluded by recommending several possible design alternatives that will be advanced for discussion and subsequent conceptual design as part of this project. The interventions at these two sites will likely occur primarily on City-owned land, and these proposed public infrastructure improvements increase the resilience of adjacent private properties to current and future flooding.

The feasibility of these interventions will depend on future climate conditions, available funding, permitting constraints that can be better identified with agency pre-application meetings, and the willingness of local and state partners to collaborate. As the City moves toward implementation, two elements will be essential: (1) continued refinement of these alternatives through analysis and conceptual design, and through hydrologic and hydraulic modeling; and (2) stakeholder engagement. The subsequent phase of the current project involves advancing the preferred adaptation strategies to conceptual design.

Based on the collaborative MCDA process and coordination between the City and the consultant team, the selected alternatives to be advanced to conceptual design are:

- Trout Brook Stabilization
- Cottage Road Raising with Bridge Replacement
- Mill Creek Park Berm
- Rewilding Trout Brook and Mill Creek Park Berm
- Deployable Flood Barriers along Front Street
- Front Street Road Raising and Stormwater Detention System

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Attachment 1

Site Photos

March 2025

Photo 1: Long Creek Pump Station bioretention system outlet – March 2025

Photo 2: Clark Pond Dam – March 2025

Photo 3: Southern petroleum causeway along Barberry Creek at low tide – March 2025

Photo 4: Southern petroleum causeway along Barberry Creek at high tide – March 2025

Photo 5: Broadway Ave bridge over Anthoine Creek – March 2025

Photo 6: Anthoine Creek upstream of Broadway at low tide – March 2025

Photo 7: Dune plantings at Willard Beach – March 2025

Photo 8: Erosion along Spring Point Shoreway Trail – March 2025

Photo 9: Mill Cove shoreline– March 2025

Photo 10: Trout Brook upstream of Cottage Street bridge – March 2025

Photo 11: Erosion along Trout Brook – March 2025

Photo 12: Sheet pile along Trout Brook– March 2025

Photo 13: Drainage outfall from Front Street– March 2025

Photo 14: Shoreline along Front Street– March 2025

Photo 15: Shoreline along Front Street– March 2025

Photo 16: Erosion along parcel west of Bug Light Boat Ramp– March 2025

Attachment 2

FEMA National Flood Hazard Layer FIRMettes

National Flood Hazard Layer FIRMette

FEMA

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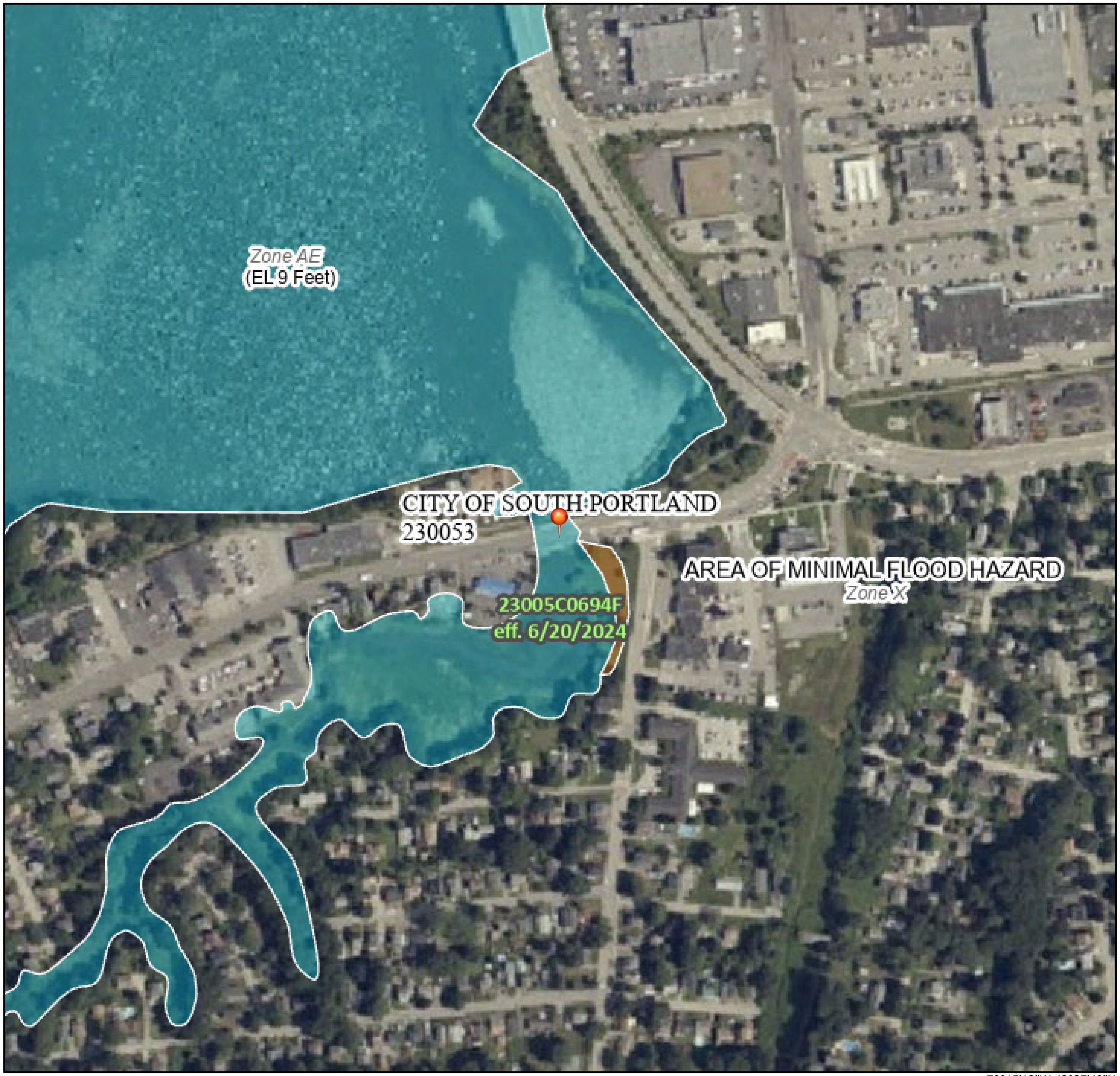

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1:6,000

Basemap Imagery Source: USGS National Map 2023

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 / 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation
- 8 Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

N

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

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National Flood Hazard Layer FIRMette

FEMA

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70°16'17"W 43°37'44"N

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Basemap Imagery Source: USGS National Map 2023

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

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National Flood Hazard Layer FIRMette

FEMA

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1:6,000

Basemap Imagery Source: USGS National Map 2023

Legend

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National Flood Hazard Layer FIRMette

FEMA

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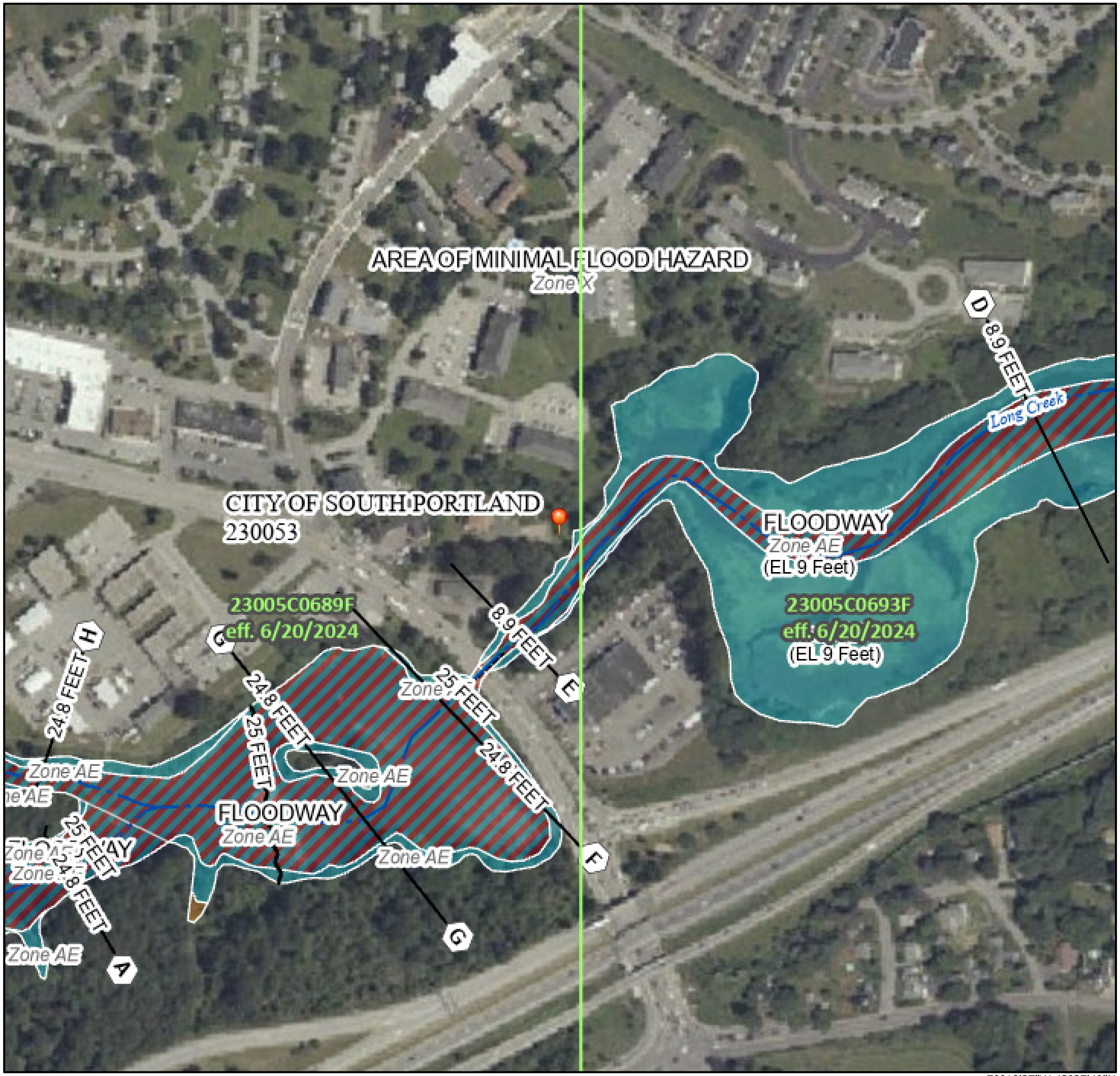

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Basemap Imagery Source: USGS National Map 2023

Legend

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National Flood Hazard Layer FIRMette

FEMA

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Feet

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1:6,000

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Basemap Imagery Source: USGS National Map 2023

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

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MAP PANELS
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- No Digital Data Available
- Unmapped

N

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 2/20/2025 at 1:04 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

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National Flood Hazard Layer FIRMette

FEMA

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70°13'20"W 43°38'22"N

Feet 0 250 500 1,000 1,500 2,000

1:6,000

Basemap Imagery Source: USGS National Map 2023

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

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MAP PANELS
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Attachment 3

MCDA Matrices

Front Street and Ferry Village MCDA Model

Criteria Values (0 to 100) and Weights (0 to 100%)				Alternatives and Scores (1 to 5)					
Criterion ID	Description	Criterion Values	Criterion Weights	No Action	Front Street Road Raising	Shoreline Flood Protection Measures	Deployable Flood Barriers	Subsurface Stormwater Detention System	Road Raising and Stormwater Detention System
1	Community Acceptance	75	14%	3	3	1	5	5	4
2	Coastal Hazard Protection	100	19%	1	4	4	3	1	4
3	Freshwater Flooding Mitigation	100	19%	1	1	1	1	5	4
4	Capital Cost	75	14%	5	1	2	4	2	1
5	Operating Costs	75	14%	2	5	4	1	3	3
6	Co-Benefits	25	5%	1	1	1	1	1	3
7	Adaptability Ready in the near-term	75	14%	5	2	3	5	2	2
8	Permitting Complexity	5	1%	5	4	1	5	4	4
Summation and FINAL WEIGHTED SCORES		530	100%	**2.59**	**2.58**	**2.42**	**2.97**	**2.92**	**3.10**

NOTES:

General MCDA Procedure:

1. Define the set of criteria and assign each a value ranging between 0 and 100 with 0 indicating the criterion has no importance and 100 indicating the criterion is the most critical criterion for consideration. Sum the values for all criteria and calculate relative weights for each.
2. List the set of alternatives and score each alternative for its performance against each criterion. Scores range from 1 to 5 according to the following definitions:

    Score of 1- least favorable performance (highlighted light green)
    Score of 2- below average performance
    Score of 3- average performance
    Score of 4- above average performance
    Score of 5- most favorable performance (highlighted dark green)

3. Multiply the alternative scores and the criteria weights to calculate a weighted score. Sum the weighted scores to find a final weighted score for each alternative. This final weighted score for each alternative considers the alternative's scores and relative criteria weights.
4. The highest final weighted score indicates the alternative that is most desirable with the given inputs (highlighted blue). The lowest final weighted score indicates the alternative that is least desirable with the given inputs (highlighted red).
5. Adjust criteria values and alternative scores in an iterative process based on feedback received from the client, project partners, community members, etc until a final outcome is achieved.

Mill Cove and Trout Brook MCDA Model

Criteria Values (0 to 100) and Weights (0 to 100%)				Alternatives and Scores (1 to 5)							
Criterion ID	**Description**	**Criterion Values**	**Criterion Weights**	**No Action**	**Rewilding Trout Brook and Mill Creek Park**	**Trout Brook Stabilization**	**Mill Cove Living Shoreline**	**Cottage Road Raising with Bridge Replacement**	**Mill Creek Park Berm**	***Rewilding Trout Brook and Mill Creek Park Berm***	***Rewilding Trout Brook and Road Raising***
1	Community Acceptance	75	14%	3	2	5	5	4	5	2	2
2	Coastal Hazard Protection	100	19%	1	2	1	2	4	4	5	4
3	Freshwater Flooding Mitigation	100	19%	2	4	4	1	3	4	4	5
4	Capital Cost	75	14%	5	2	3	2	3	4	2	1
5	Operating Costs	75	14%	4	3	3	3	5	4	3	3
6	Co-Benefits	25	5%	1	3	3	4	4	1	3	4
7	Adaptability Ready in the near-term	75	14%	5	1	5	4	4	5	1	1
8	Permitting Complexity	5	1%	5	2	4	3	4	5	2	2
Summation and **FINAL WEIGHTED SCORES**		530	100%	**3.07**	**2.42**	**3.39**	**2.76**	**3.81**	**4.15**	**2.99**	**2.90**
				7	**3**	**8**	**5**	**4**	**6**	**2**	**1**

NOTES:

General MCDA Procedure:

1. Define the set of criteria and assign each a value ranging between 0 and 100 with 0 indicating the criterion has no importance and 100 indicating the criterion is the most critical criterion for consideration. Sum the values for all criteria and calculate relative weights for each.
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