GREATER PORTLAND
COUNCIL OF GOVERNMENTS

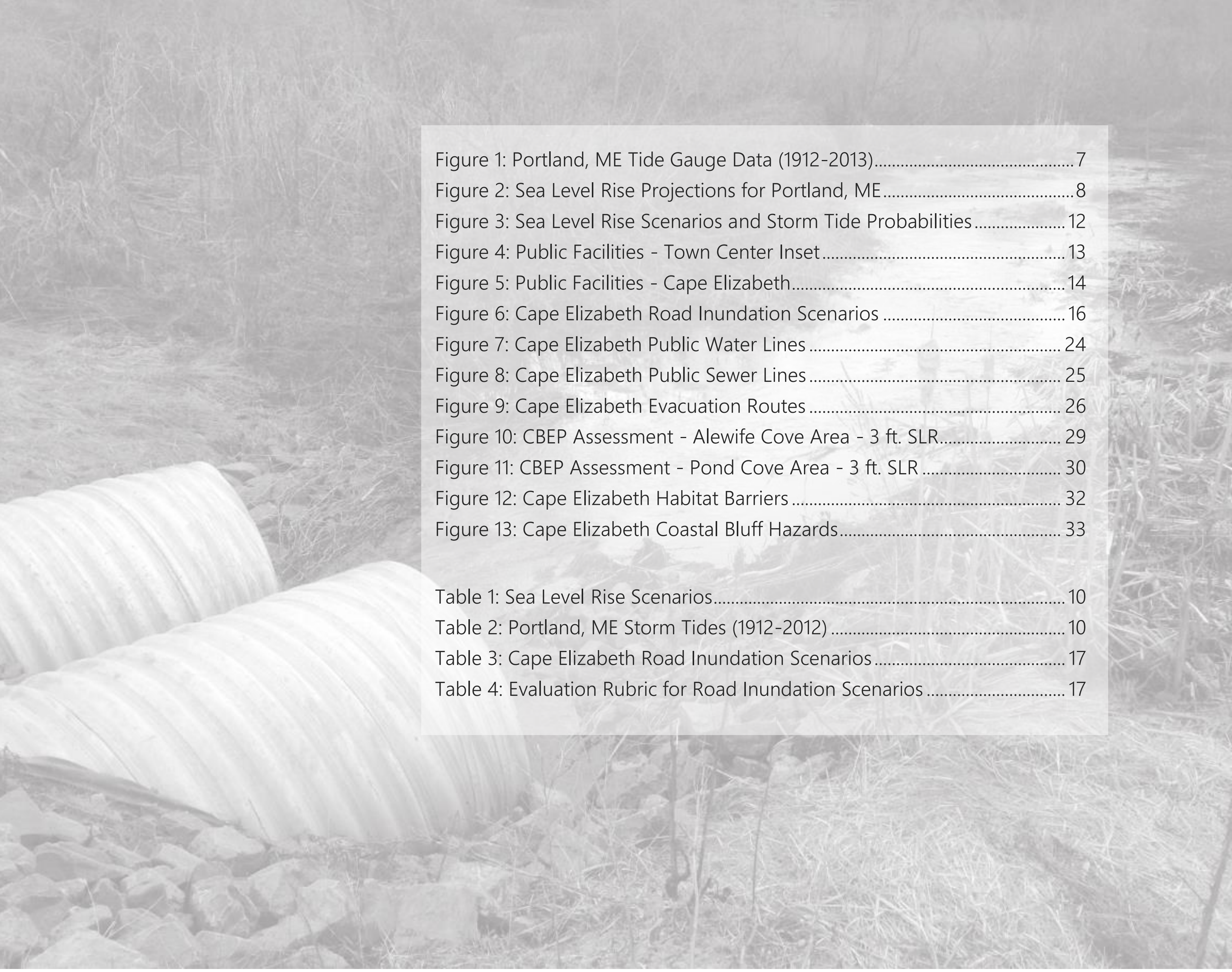
CAPE ELIZABETH | SEA LEVEL RISE VULNERABILITY ASSESSMENT

*Image courtesy of Google Earth

June, 2015

TOWN OF CAPE ELIZABETH:

SEA LEVEL RISE VULNERABILITY ASSESSMENT



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GREATER PORTLAND COUNCIL OF GOVERNMENTS

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EXECUTIVE SUMMARY

For several reasons, Cape Elizabeth is uniquely situated to be more resilient than most communities to the effects of sea level rise, coastal flooding, and storm surge.

First and foremost, the Town's **rocky coastline** severely limits the area that is vulnerable to sea level rise and coastal flooding. According to the Maine Geological Survey's (MGS) Coastal Bluff Maps, most of Cape Elizabeth's coastline is considered "stable," with little risk of landslide or erosion.

In addition to this natural fortification, the town has adopted several **strict policies to regulate development in low-lying, environmentally sensitive areas**. For example, roughly one-third of the town is regulated by local wetlands zoning; the Town recently amended its shoreland zoning regulations to consider the implications of three feet of sea level rise; and new structures in flood-prone areas are required to be raised *at least* two feet above "**base flood elevation**" in most zones. *(Click on any orange term to access the glossary).*

Lastly, the majority of Cape Elizabeth's **public buildings and facilities are located a safe distance inland from any coastal flooding hazards**. The Town office, police and fire departments, schools, and library are all clustered together in the Town Center, and by all appearances out of harm's way.

However, this is not to say Cape Elizabeth is immune to the impacts of sea level rise. This assessment has identified several *potentially* vulnerable areas. In particular, key elements of the Town's transportation and public sewer infrastructure, including Sawyer Rd., Shore Rd., Spurwink Ave., Starboard Dr., and a pumping station on Spurwink Ave. *(Discussed in greater detail in the report).*

Private property in Cape Elizabeth may also be at risk – mainly coastal residences and private access roads. However, this report focuses solely on impacts to public infrastructure.

This report does not provide an exhaustive list of every action the town could take to prepare for sea level rise; rather, it highlights the **top projects and strategies** believed necessary to protect public infrastructure and increase public safety. For Cape Elizabeth, these are:

- Evaluate risk to PWD's wastewater pumping station on Spurwink Ave.
- Raise Sawyer Rd. and minor span.
- Raise Shore Rd. and improve culvert.
- Raise Spurwink Ave. and improve culvert.
- Review capacity and design of culverts Town-wide.
- Coordinate with PWD and South Portland to evaluate risk to underground utilities.
- Improve accuracy of GIS layer for "Normal High Water Line" (HAST+3ft).
- Include sea level rise language in next comprehensive plan update.
- Revise septic ordinance to consider impacts of sea level rise.
- Incorporate Low Impact Development (LID) techniques in land use ordinances.

BACKGROUND

Sea level rise (SLR) has been recognized as a significant threat to low-lying coastal areas around the world. A large and growing body of scientific literature now exists on the subject, and the past few years have seen a proliferation of interactive tools, web maps, and planning materials to help communities understand the risks associated with rising seas.

The scientific consensus is clear, **during the coming decades sea level will continue to rise, bringing with it the following primary impacts:**

- **Flooding and inundation of coastal areas;**
- **Amplified storm surges;**
- **Increased beach, cliff, and bluff erosion;**
- **Salt water intrusion into aquifers and surface waters; and**
- **Wetland habitat conversion or loss.**

While the extent of these impacts will vary by location, they are likely to have considerable human, environmental, and economic consequences, and pose major challenges for many coastal communities.

The Role of Local Governments

While government entities at all levels are responding to sea level rise, most adverse effects will be felt locally, at the community-level (i.e., a local road is washed out, the sewer system malfunctions, local wells are infiltrated with salt water, etc.). Accordingly, local governments will bear the largest burden of responsibility. To their credit, many Maine communities are already taking the necessary steps, and having the conversations needed, to address the issue.

Maine communities are also fortunate to have many resources to draw upon. Local efforts – *like this one* – are often aided by government entities at all levels, including the National Oceanic and Atmospheric Administration (NOAA), the Maine Geological Survey (MGS), the Maine Municipal Planning and Assistance Program at the Maine Department of Agriculture, Conservation, and Forestry (DACF), and Regional Planning Organizations (RPOs).

Cape Elizabeth

In 2013, the Greater Portland Council of Governments (GPCOG) and the MGS held an informational meeting with the Town's Planning Board, in which sea level rise data and trends (developed by the MGS) were presented and discussed.

This led to a request that GPCOG conduct a more detailed assessment of the town's vulnerabilities. In particular, the impacts of sea level rise on publicly-owned infrastructure such as roads, bridges, buildings, sewer, and water.

While this report is the first of its kind prepared for Cape Elizabeth, the town has taken several proactive measures to increase its resiliency to sea level rise. A more detailed description of these efforts can be found in the section, *"Town Response to Sea Level Rise Trends."*

THE SCIENCE

Determining exact sea level, and the extent to which it is rising from year-to-year, is a precise and technical discipline. This section provides a brief overview of the current science and observed trends in sea level rise.

Since this section includes a few technical terms and acronyms, a glossary is included in the Appendix. *(If you are reading this report in digital format, click on any orange term in the document and you will be directed to its full definition in the glossary; click the term again in the glossary, and you will return to where you were last reading).*

Trends in Sea Level Rise

In Maine, there is a clear historical pattern of sea level rise which began about 11,000 years ago, and which is still occurring today. For the past several thousand years, this rise has been slow and incremental, at a rate that allowed today's beaches, sand dunes, and marshes to form from the sediment carried by rivers and re-worked by waves.

Modern-day measurements, however, indicate the rate of rise is accelerating. Core samples, tide gauges, and satellite measurements tell us that over the past century, **Global Mean Sea Level (GMSL)** has risen by approximately 8 inches (.07 inches/1.8 millimeters per year). By all accounts, this is much faster than any time in the past 5,000 years. What's more, the annual rate of rise over the past 20 years has been .13 inches/3.3 millimeters a year – *roughly twice the average speed of the preceding 80 years.*[1]

Causes of Sea Level Rise

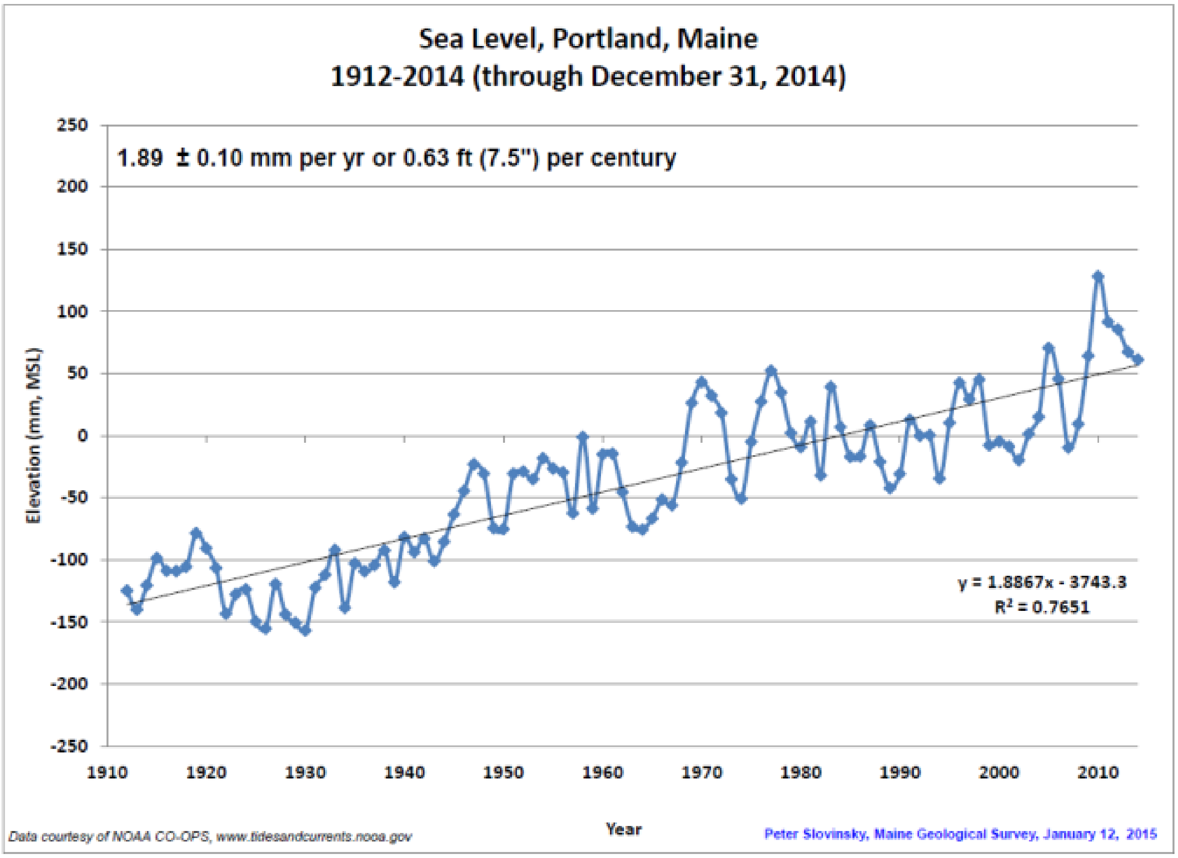
The rise in sea level is linked to two main factors – thermal expansion, and the melting of land-based ice – both a direct result of climate change.

- **Thermal expansion:**
  Rising temperatures are warming ocean waters, which expand as temperature increases. Much of sea level rise is attributable to warmer oceans simply occupying more space. A 2014 study by the Gulf of Maine Research Institute found the Gulf of Maine is warming at a rate faster than 99 percent of the world's oceans.
- **Melting of Land-Based Ice:**
  Higher temperatures have also led to greater-than-average melting of land-based ice, such as glaciers and polar ice caps, adding water to the world's oceans.

It is important to note, sea level rise for any particular location can vary significantly from the global average. The reasons for this variability include other factors such as local topography, changes in ocean circulation, **land subsidence**, and geographic variations in rates of ice melting.

[1] National Geographic. 2015 ***Sea Level Rise: Ocean Levels Are Getting Higher-Can We Do Anything About It?***

Figure 1: Portland, ME Tide Gauge Data (1912-2013)



Local Sea Level Rise Data

Figure 1, above, shows **Mean Sea Level (MSL)** data from Portland's tide gauge dating back to 1912.[2] The data shows that over the last 100+ years, sea level has been rising at a rate of 0.07 inches/1.9 millimeters per year, for a total of approximately 7.5 inches over the time period. Statistically similar results are found up and down the Maine coast, and these figures generally mimic global ocean changes for the same time period.

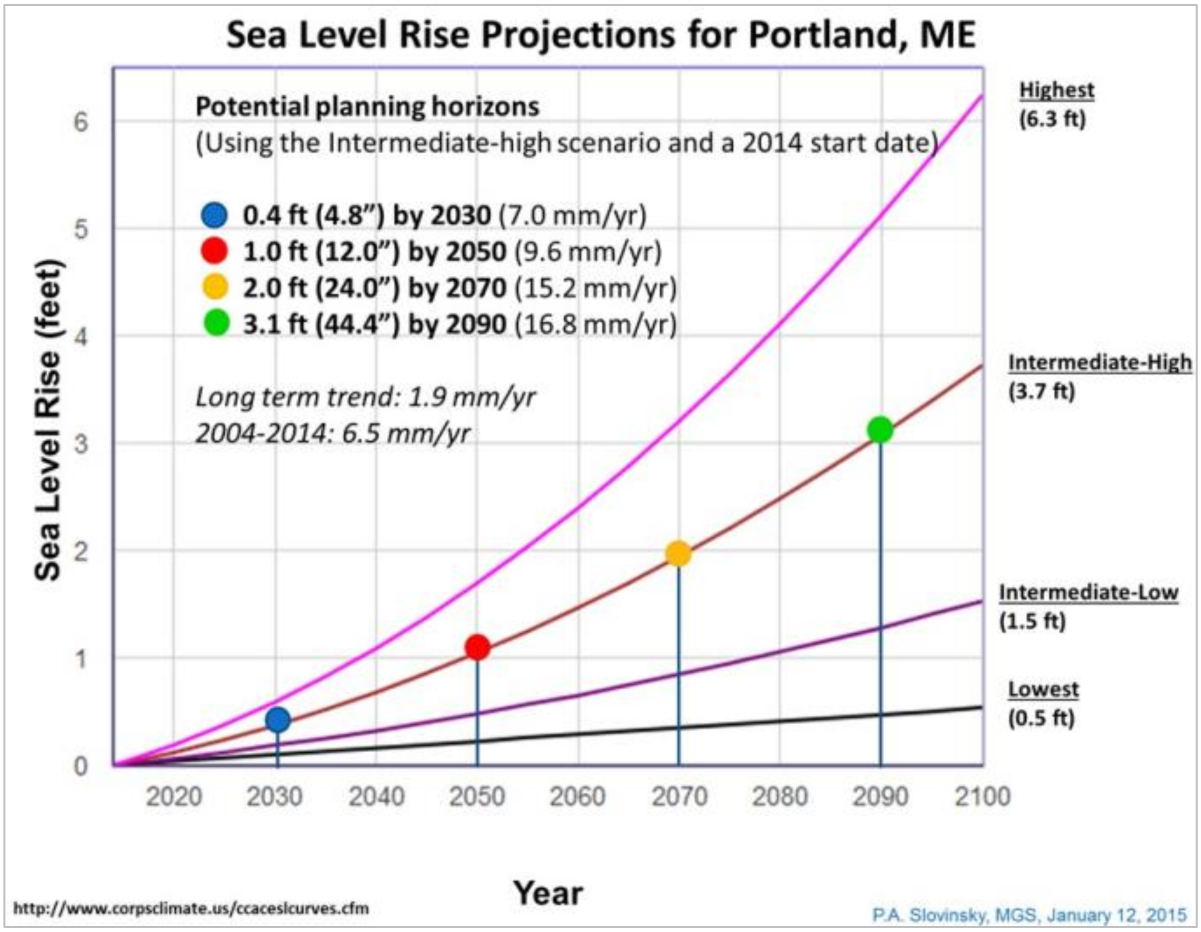
As the Portland data illustrates, sea level is never static. For any given year, we may be experiencing a spike, or dip, in mean sea level. For example, a recent study by scientists at the University of Arizona found that during 2009-2010, sea level off Portland rose by five inches.[3] Described as an "unprecedented" two-year spike, the phenomenon is being attributed to changes in ocean circulation. These abrupt, short-term sea level changes are happening on top of the long-term upward trajectory of sea level rise, and can have significant impacts on flooding and beach erosion.

While research about sea level rise is ongoing, and new data generated by these studies continues to improve our predictions, it seems clear we are in the midst of a long-term, upward trajectory in the rate of sea level rise.

[2] Graph courtesy of the Maine Geological Survey

[3] Nature Communications. 2015. ***An Extreme Event of Sea-Level Rise Along the Northeast Coast of North America in 2009-2010.***

Figure 2: Sea Level Rise Projections for Portland, ME



Sea Level Rise Projections

In planning for sea level rise, a "one-size-fits-all" approach is not realistic. There are simply too many scientific variables, risk perceptions, and political implications unique to each location to consider.[4] For this reason a scenario-based approach is the widely accepted "best practice," as suggested in the U.S. National Climate Assessment.[5]

Considering a range of possibilities lends itself to the flexible management style needed to respond to a changing environment. Moreover, having a range of scenarios on-hand should help communities reduce the need to frequently revise rates or retool the planning framework.

Figure 2, above, was created by the Maine Geological Survey, using Portland's historic sea level rise rate of 1.9 millimeters per year (based on the 1912-2014 data shown in **Figure 1**).

The MGS entered the data into the U.S. Army Corps of Engineer's "Change Curve Calculator" (referenced in the figure's lower left corner), to determine four potential sea level rise scenarios.

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[4] NOAA. 2012. ***Incorporating Sea Level Change Scenarios at the Local Level.***

[5] U.S. Global Change Research Program. ***U.S. National Climate Assessment.***

Coastal Bluffs in Cape Elizabeth

Cape Elizabeth's rocky coastline helps protect it from the combined effects of sea level rise and storm surge. However, a number of low-lying areas in town are potentially vulnerable. These are described in detail throughout the report.

Over the last decade (2004-2014), Portland has seen a local sea level rise rate of about 6.5 millimeters per year. When this is taken into account, it appears that sea level rise in Portland currently fits the "Intermediate-High" scenario.

Thus, at this time, the MGS is recommending that communities use the intermediate-high scenario as the basis for their sea level rise planning. This scenario projects 1 foot of sea level rise by 2050, 2 feet by 2070, and about 3.7 feet by 2100.

Why it Matters

For a number of reasons, even small increases in sea level can have devastating effects. In many flat, low-lying areas, like marshes or beaches, any vertical rise can create a much longer, and larger, horizontal footprint.

Additionally, the projections in this report use a static-approach to simulating sea level rise, or what is called a "**bathtub model**." That is, the data does not account for the combined effects of wind and waves, or other hydraulic features. When large storms hit land, higher sea levels – coupled with storm surge – will result in higher overall water levels. Recent storms, like Hurricane Sandy, are a clear example of this.

Lastly, it is widely accepted that sea level will continue to rise for centuries to come. Even if the global community is able to curb emissions, and reduce the amount of carbon dioxide in the atmosphere, scientists predict the earth will continue to warm for centuries. Accordingly, the main drivers of sea level rise (thermal expansion, and the melting of land-based ice) are also likely to continue unabated.

Scenarios Used for this Report

Table 1, below, lists the various sea level rise scenarios used for this assessment, along with their respective height above **Mean Lower Low Water (MLLW)**.

Table 1: Sea Level Rise Scenarios

Sea Level Rise (SLR) Scenario	Approx. Height
Highest Astronomical Tide (HAST)	11.6 ft.
HAST +1 ft. SLR	12.6 ft.
HAST +2 ft. SLR	13.6 ft.
HAST +3 ft. SLR	14.6 ft.
Highest Annual Tide (HAT) +2m SLR	18.5 ft.

*Data provided by the MGS

Highest Astronomical Tide (HAST) is the elevation of the highest astronomical tide expected to occur at a specific tidal station over a 19-year period (the **National Tidal Datum Epoch**, 1983-2001). The three HAST scenarios were chosen due to the town's recent adoption of HAST+3 ft. as the **Normal High Water Line (NHWL)** for its shoreland zoning ordinance.

Highest Annual Tide (HAT) is the highest predicted tide for any given year. HAT is reached within several inches numerous tides a year and the value changes slightly each year. The HAT+2m scenario was developed several years ago by the MGS for emergency management purposes. It is included in this report to represent an extreme weather event.

Using tide records dating back to 1912, **Table 2** shows the probability of various storm tide scenarios occurring in Portland, as measured against mean lower low water.

Table 2: Portland, ME Storm Tides (1912-2012)

Recurrence Interval (Years / %)	Storm Tide (MLLW)
1 (100%)	11.7 ft.
5 (20%)	12.6 ft.
10 (10%)	12.9 ft.
25 (4%)	13.4 ft.
50 (2%)	13.7 ft.
100 (1%)	14.1 ft.

*Data provided by the MGS.

To help explain the table above, a recurrence interval of "10" indicates the "10-year storm," or an event that has a 10% likelihood of occurring in any given year. A recurrence interval of "100," by contrast, represents a "100-year storm," or a storm that has a 1% chance of occurring in any given year. *Thus, it is possible to have two "100-year storms" occur in consecutive years, or even the same year, although this would be statistically unlikely.*

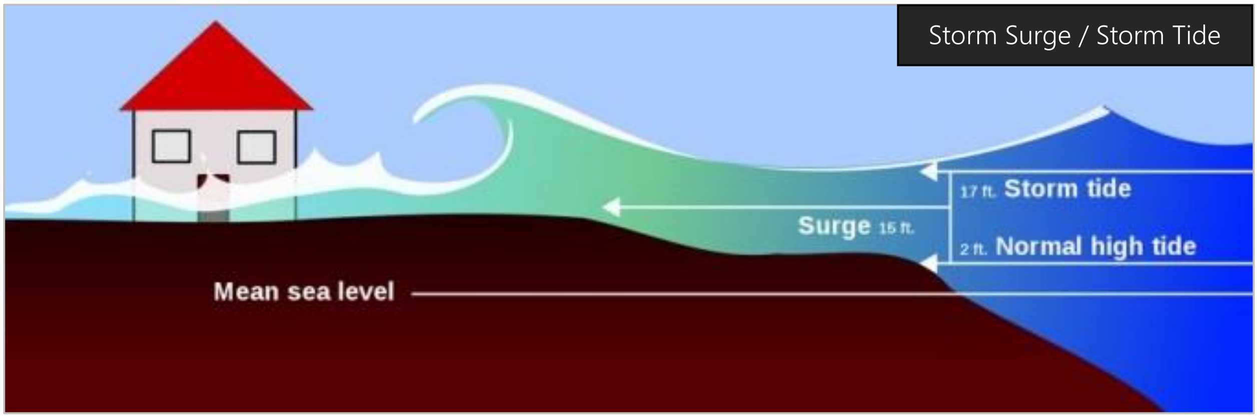


**Image courtesy of NOAA*

The storms of today are the tides of tomorrow…

It should also be noted, there is a difference between the terms "storm tide" and "storm surge." To clarify, **Storm Surge** is the abnormal rise of water generated by a storm, over and above the predicted tide. **Storm Tide** is the overall rise due to the combination of storm surge and tide.

Using the illustration above as an example, if the predicted tide was 2 feet, and storm surge was 15 feet, the storm tide would be 17 feet.

Putting it in Perspective

Portland's current highest astronomical tide is 11.6 feet. Adding one-foot of sea level rise (what communities are being told to plan for by 2050) brings it to 12.6 feet. As **Table 2** illustrates (previous page), 12.6 feet is the same inundation likely to occur from storm tide during a "5-year storm."

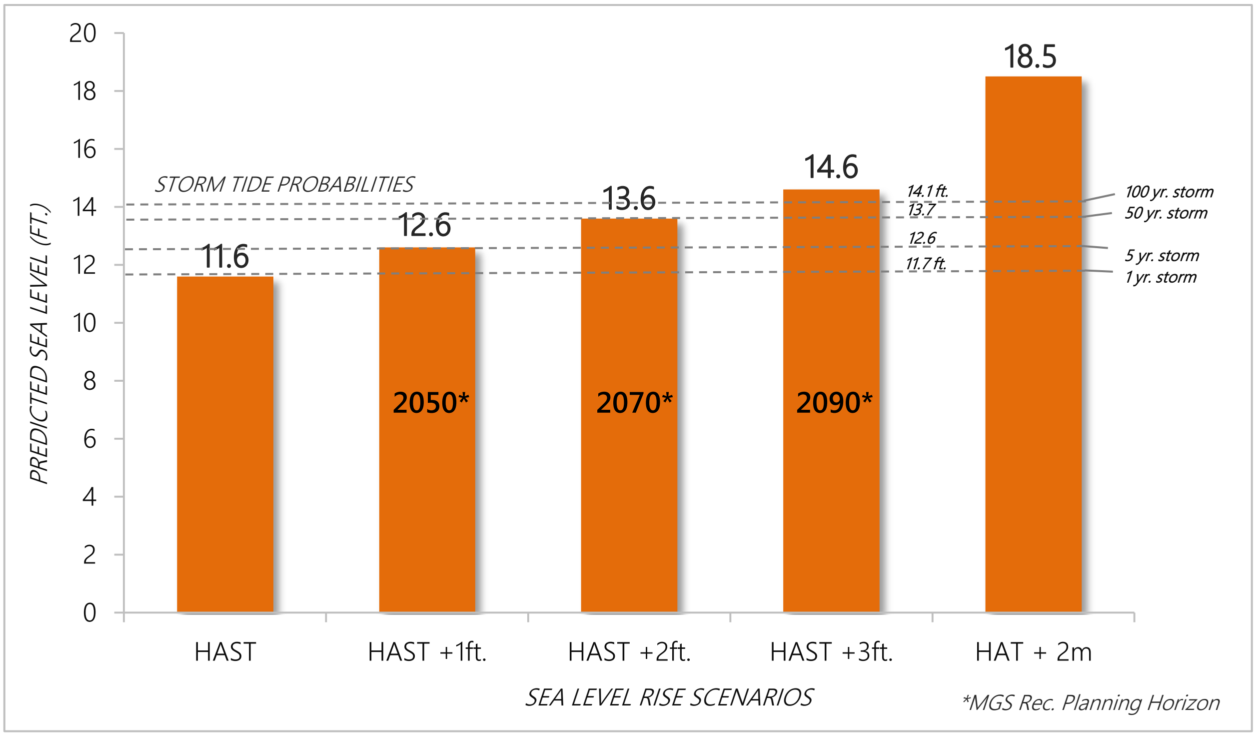
In short, the inundation we get from our current "5-year storm" is what we can expect high tide to look like in 2050, lending credence to the expression, *"The storms of today are the tides of tomorrow."*

Similarly, sea level rise scenarios can also be used as proxies for current disaster planning. For example, we could have a storm event that coincides with highest astronomical tide with an added 3 feet of storm surge today (the HAST+3ft. scenario).

Figure 3, on the next page, shows the sea level rise scenarios used for this report, with storm tide probabilities (dashed lines) superimposed in front. It also includes labels showing projected sea level rise for key time horizons (2050, 2070, and 2090). The graph helps illustrate a few points:

First, it provides a better visual for showing that, as previously mentioned, HAST+1ft. of sea level rise (12.6 ft.) is identical to the predicted storm tide for the "5-year storm" (12.6 ft.).

Figure 3: Sea Level Rise Scenarios and Storm Tide Probabilities



Second, it shows that HAT+2m is truly an extreme event, surpassing the predicted "100-year storm" by over 4 feet.

(It should be noted, however, that Hurricane Sandy is now considered by many scientists to be a 1-in-700 year storm,[6] and research suggests that, due to climate change, such storms could make landfall far more frequently. A 2012 study by researchers from MIT and Princeton found the "500-year flood" could, with climate change, occur once every 25-240 years.[7])

Elevating a road, or structure, just six inches to one foot higher could have a profound impact on the lifetime of the asset.

Lastly, the graph shows the relatively tight grouping of predicted storm tides. For example, the difference between the "50-year storm" and the "100-year storm" is less than a foot. For planning purposes, this means elevating a road, or structure, just six inches to one foot higher could have a profound impact on the lifetime of the asset.

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[6] LiveScience. 2013. ***"Hurricane Sandy Was 1-in-700 Year Event."***

[7] MIT News. 2012. ***"Storm of the Century? Try Storm of the Decade"***

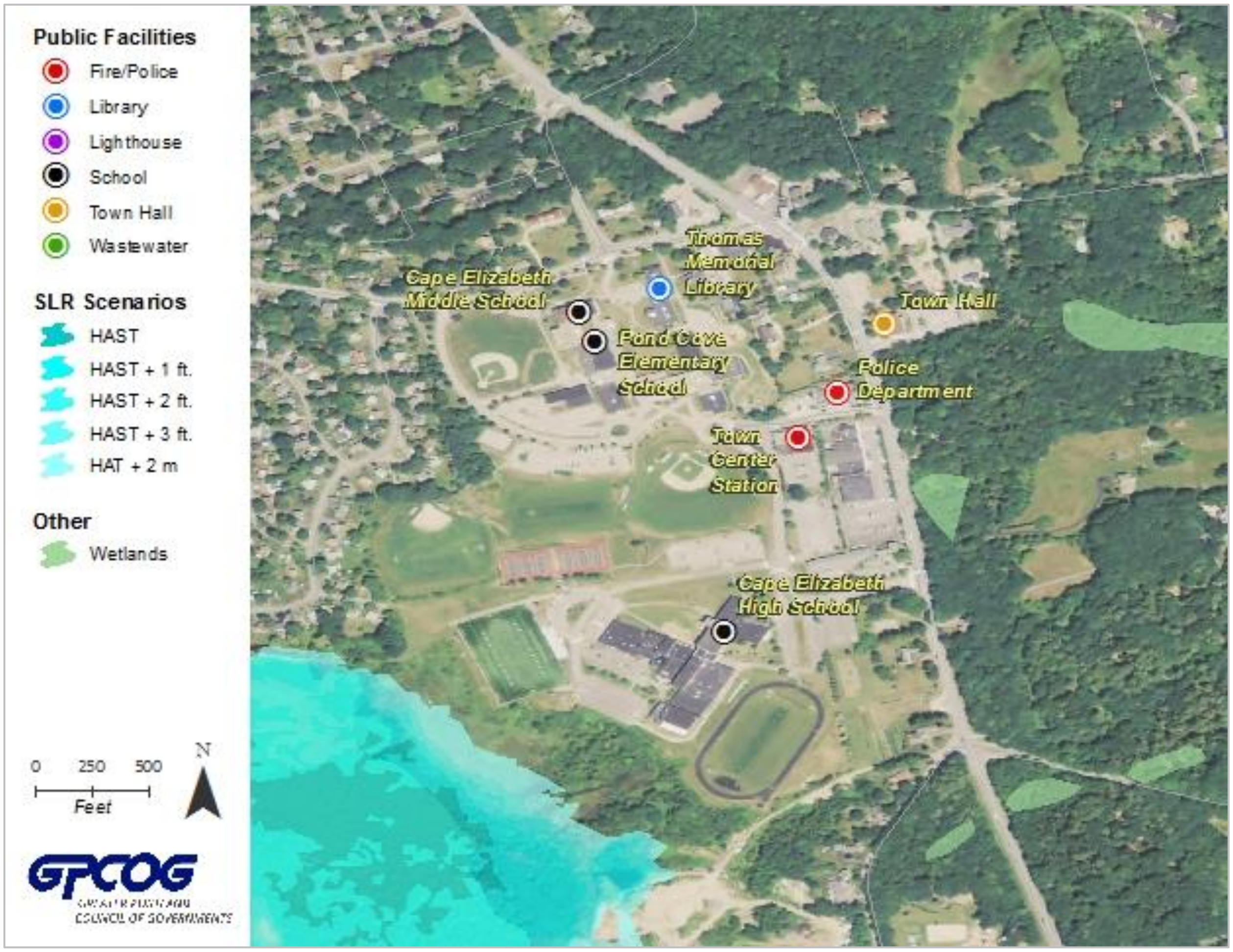
PUBLIC INFRASTRUCTURE IMPACTS

Compared to other municipalities in Maine, Cape Elizabeth is fortunate in that relatively few impacts to public infrastructure were observed, even in the more extreme scenarios. However, a few key areas in town merit further study and careful review. *(Disclaimer: the sea level rise scenarios included in this report should be used for general planning purposes only, actual conditions may vary substantially).*

Buildings and Facilities

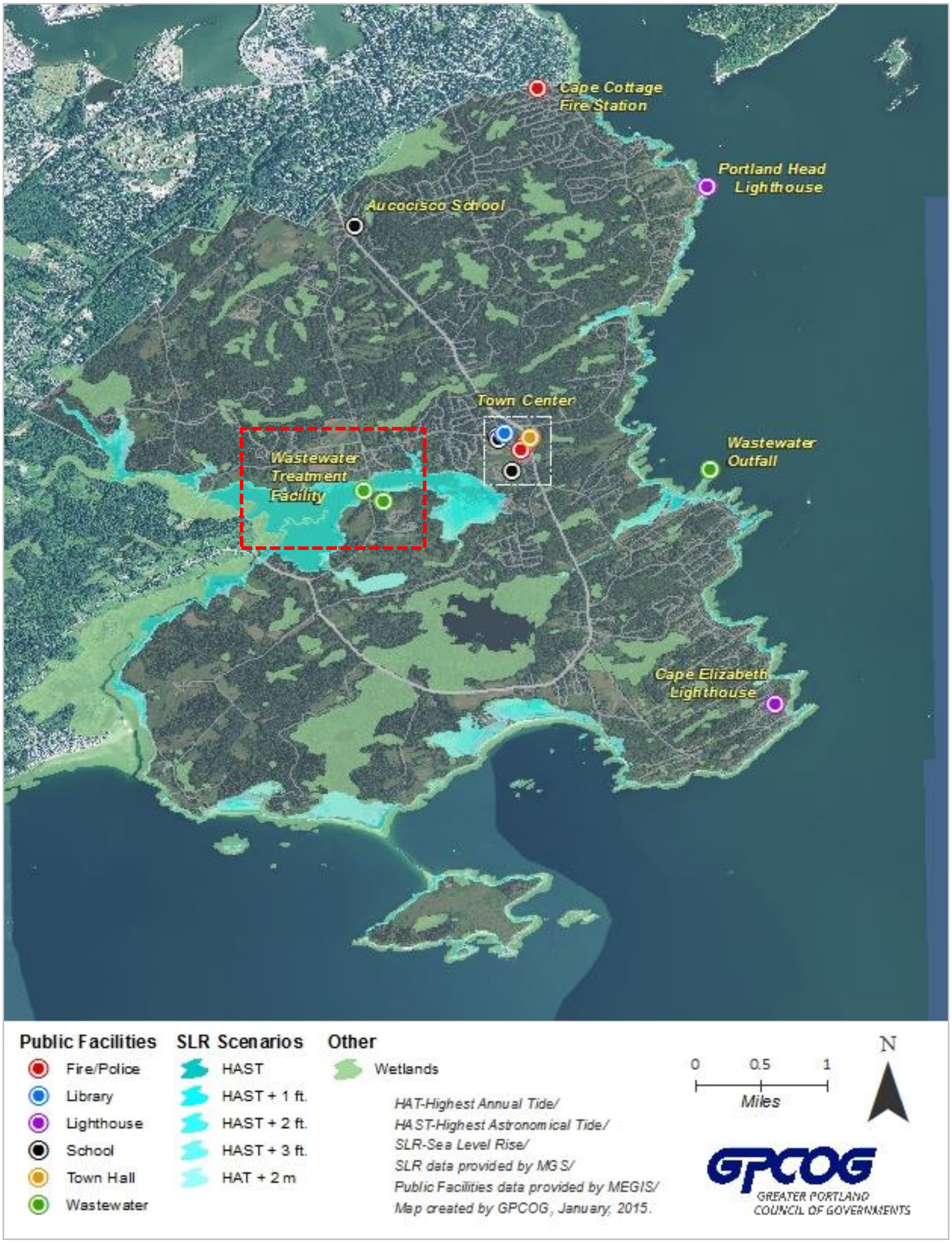
As **Figure 4** illustrates, most of Cape Elizabeth's publicly-owned buildings are located in the town center, in close proximity to one another. This is particularly good news, since the town center is inland, and by all appearances not at any great risk for coastal flooding.

Figure 4: Public Facilities - Town Center Inset



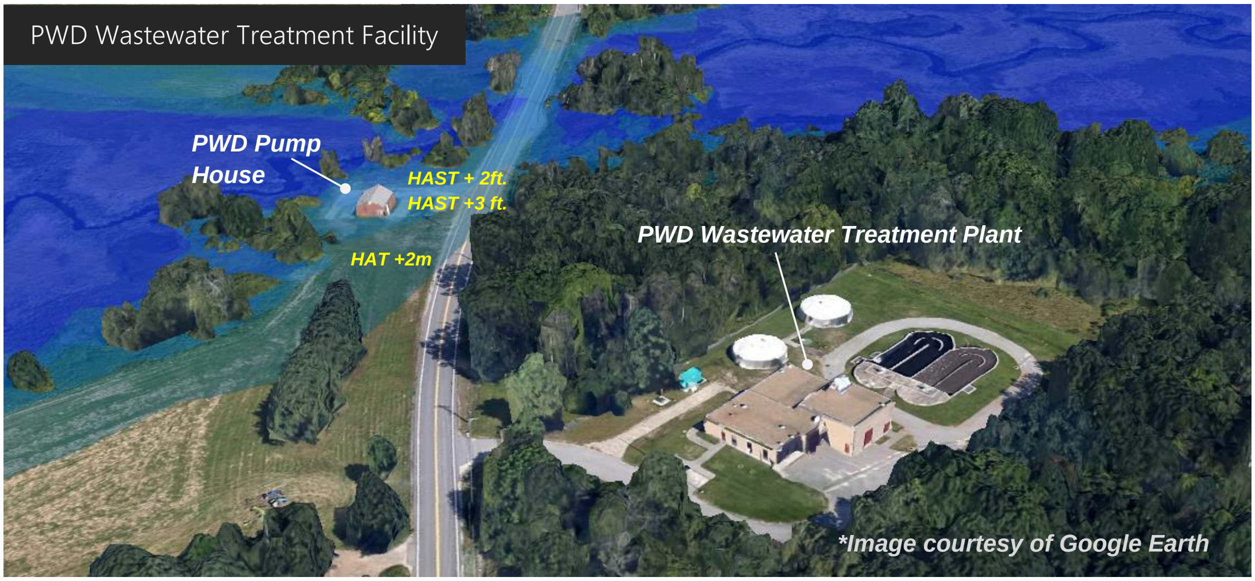
However, as **Figure 5** shows (next page), the Portland Water District's (PWD) wastewater treatment facility on Spurwink Ave. *is* potentially at risk under certain scenarios.

Figure 5: Public Facilities - Cape Elizabeth



There are actually two wastewater facilities in this location – a pump station, and the wastewater treatment plant.

Fortunately, as the aerial image below shows, the larger treatment plant is elevated such that it does not appear to be at risk, even in the most extreme scenario of HAT+2m. The pump station, on the other hand, is quite close to the flood zone of Spurwink Marsh. Our data suggests that at the HAST+2 ft. scenario, water would likely be lapping at the building, and at HAST+3 ft. (and higher) the building would likely be inundated.



Roads

Overall, the impact of sea level rise on Cape Elizabeth's roads does not appear severe. As **Figure 6** shows, many of the "at risk" roads are privately owned, and often dirt or gravel. Additionally, in most cases the impacts are not present until a considerable amount of SLR, or storm surge, occurs. There are, however, a few areas of concern among the Town-owned roads – in particular Sawyer Rd. (#15), Starboard Dr (#18), Shore Rd. (#16), and two sections of Spurwink Ave. (#17).

Figure 6: Cape Elizabeth Road Inundation Scenarios

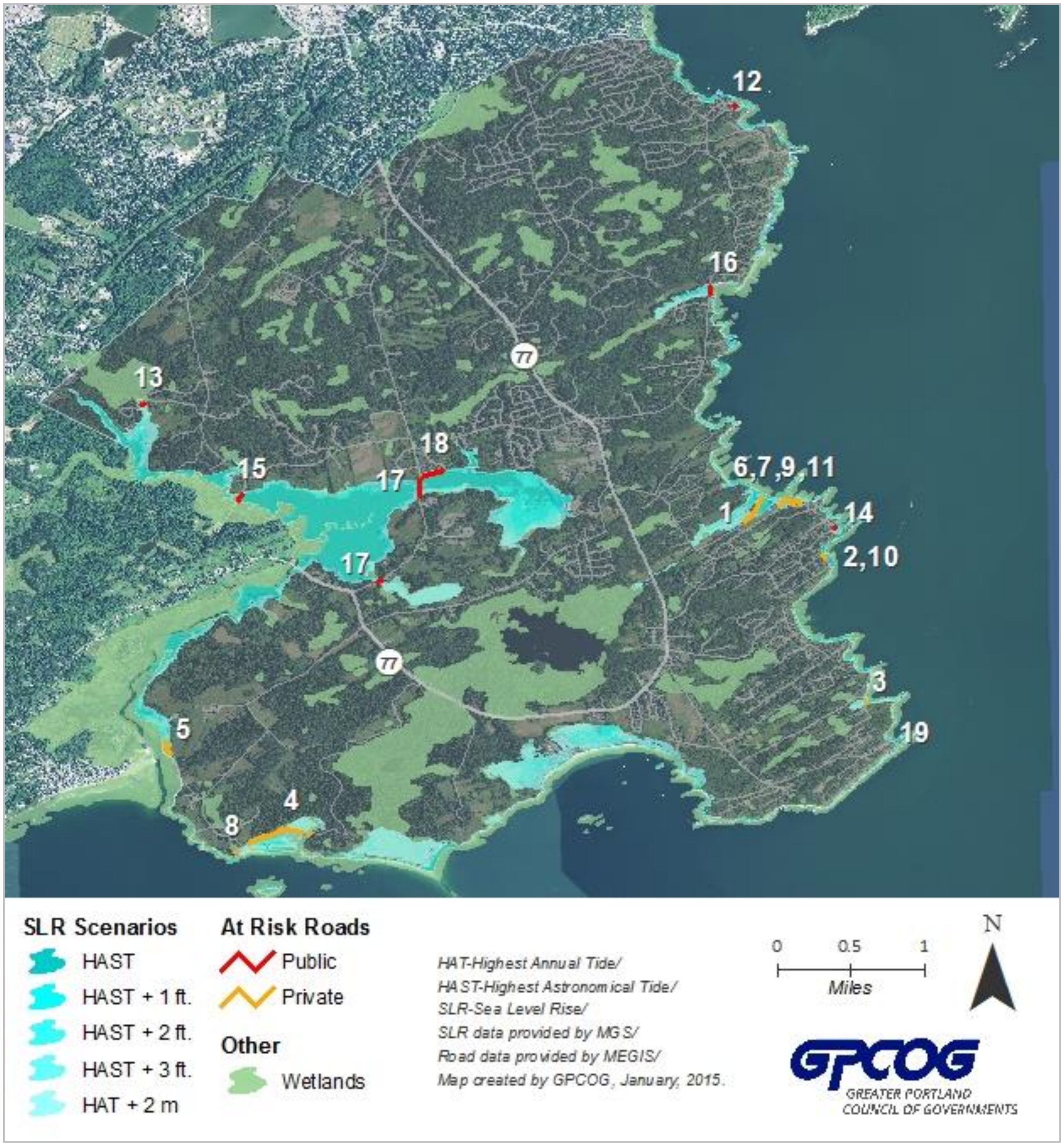


Table 3: Cape Elizabeth Road Inundation Scenarios

Label	Street Name	Road Class	HAT + 2m	HAST + 3ft.	HAST + 2ft.	HAST + 1ft.	Probability	Consequence
1	Alewife Cove Rd.	Private	**1,015 ft.**	**625 ft.**	**31 ft.**	0 ft.	**Medium**	**Low**
2	Algonquin Rd.	Private	**15**	0	0	0	**Low**	**Low**
3	Cunner Ln.	Private	**102**	0	0	0	**Low**	**Low**
4	Little Pond Ln.	Private	**1,513**	0	0	0	**Low**	**Low**
5	Lower River Rd.	Private	**493**	**463**	**69**	0	**Medium**	**Low**
6	Peabbles Cove Rd.	Private	**327**	0	0	0	**Low**	**Low**
7	Ram Light Ln.	Private	**104**	0	0	0	**Low**	**Low**
8	Rams Head Rd.	Private	**23**	0	0	0	**Low**	**Low**
9	Shipwreck Cove Rd.	Private	**357**	0	0	0	**Low**	**Low**
10	Surf Side Ave.	Private	**26**	0	0	0	**Low**	**Low**
11	Tucker Ln.	Private	**37**	0	0	0	**Low**	**Low**
12	Garden Ln.	Local	**182**	**182**	0	0	**Medium**	**Low**
13	Park Cir.	Local	**57**	0	0	0	**Low**	**Low**
14	Reef Rd.	Local	**60**	0	0	0	**Low**	**Low**
15	Sawyer Rd.	Local	**251**	**128**	**73**	**41**	**High**	**Medium**
16	Shore Rd.	Collector	**272**	0	0	0	**Medium***	**High**
17	Spurwink Ave.	Collector	**740**	**335**	**204**	**21**	**High**	**High**
18	Starboard Dr.	Local	**577**	**431**	**118**	0	**Medium**	**Medium**
19	Two Lights Rd.	Local	**6**	0	0	0	**Low**	**Low**
--	***Totals***	--	*6,157 ft.*	*2,164 ft.*	*495ft.*	*62 ft.*	--	--

Table 3 provides a more detailed look at the various road inundation scenarios. The figures refer to the length of road likely to be inundated under each scenario – *the analysis does not consider depth of inundation*.

The "probability" and "consequence" columns are an attempt to help the town attach priority, and relative level of urgency, to the data. Orange colors are used for private roads, while red colors indicate public roads. The rubric used to determine the probability and consequence columns is shown in **Table 4** below:

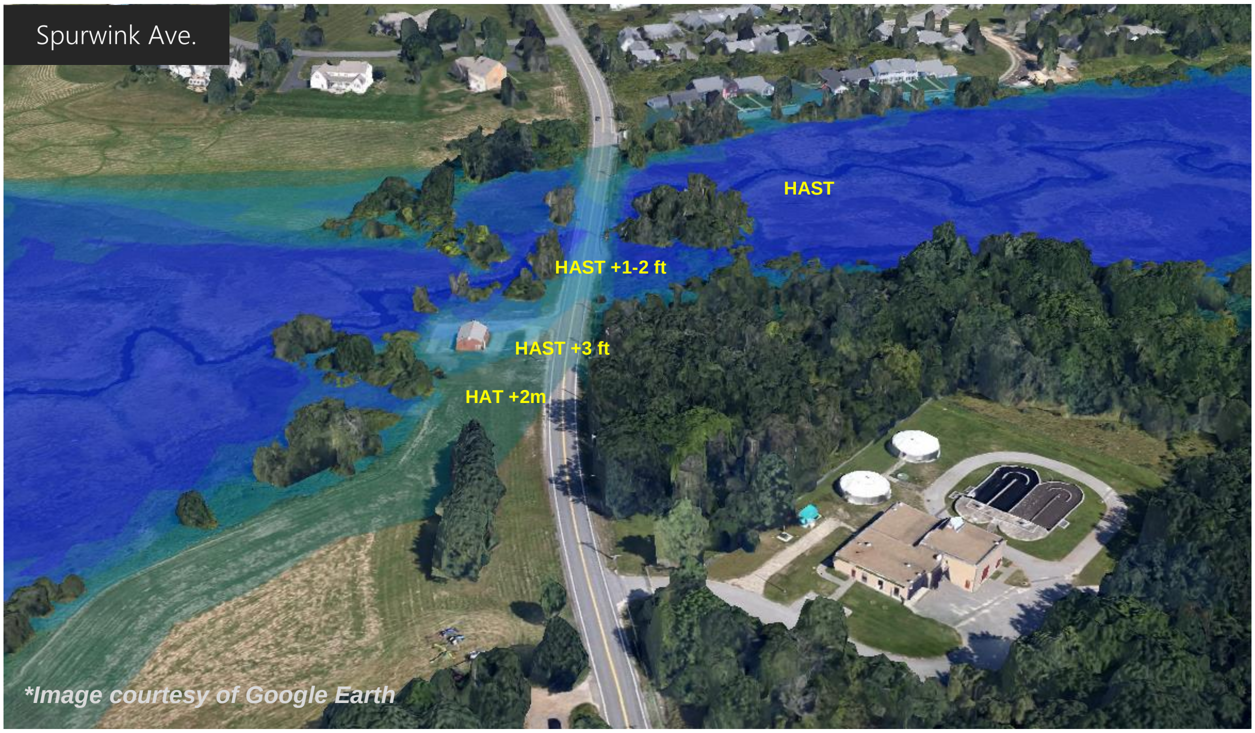
Table 4: Evaluation Rubric for Road Inundation Scenarios

	Probability	Consequence
Low	Impacts starting at HAT+2m only	Private road or low volume public road (dead end, cul de sac, etc.)
Medium	Impacts starting at HAST+2-3ft.	Higher volume public road with thru-way traffic
High	Impacts starting at HAST+1ft. or more	Public collector road / potential evacuation route

Sawyer Rd. (#15), on the west side of town, travels north-south through the Spurwink Marsh where it also crosses over the town line into Scarborough. In several areas it appears to be only marginally higher (perhaps a foot or less) than the water level of the marsh at high tide.

Shore Rd. (#16) is a scenic road that curves its way around the town's eastern shoreline. In technical terms, it is considered by MaineDOT to be a "collector" road, and it experiences approximately 3,500 vehicles per day. While the GIS analysis indicates the road is only vulnerable at HAT+2m (the most extreme scenario), the road's exposure to storm surge and wave action, along with anecdotal evidence from community members, suggests it should remain on the town's "watch list."

Spurwink Ave. (#17) is a major thoroughfare traveling north-south through the center of town, as well as through Spurwink Marsh. It is also considered a "collector" road, and experiences roughly 2,000 vehicles per day. The GIS analysis shows inundation is possible at two locations, but the most acute impacts are likely to occur just south of the road's intersection with Starboard Dr.

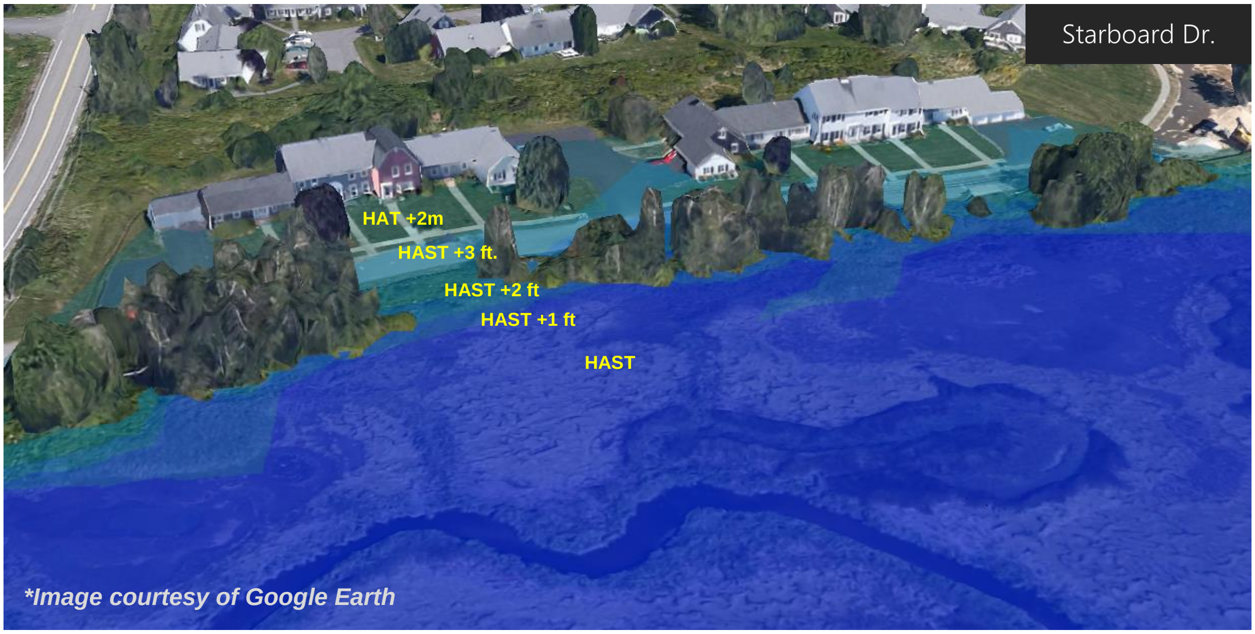


As the pictures below show, the culvert at this location appears to be at, or near, its capacity at high tide. Add normal winter/spring obstructions, like ice chunks, debris, and snow melt, and the culvert may lose even more of its functionality. These pictures were taken at high tide in November, January, and March, 2014-2015



Starboard Dr. (#18) parallels the northern boundary of the Spurwink Marsh, and intersects at a perpendicular angle with Spurwink Ave. It is a low-lying road, with relatively dense residential development. In certain places, the road is quite close to the high tide line of the marsh.

As shown in the image below, the road becomes inundated at HAST+2 ft. and higher, with residential development likely vulnerable at HAST+3 ft. and higher.

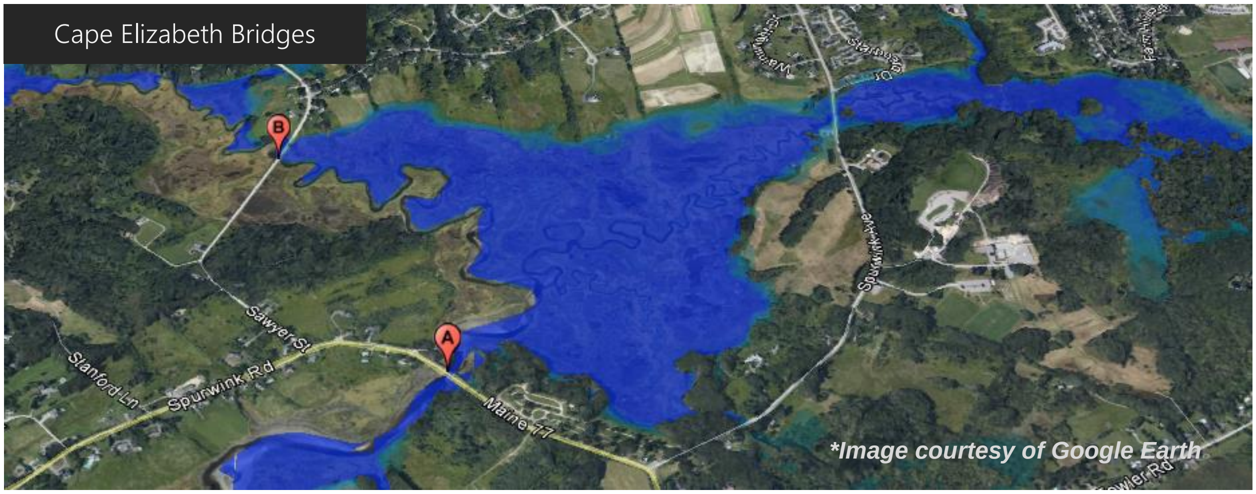


Garden Ln. (#12) is a public way that ends in a low-lying cul-de-sac along the waterfront in the northeast part of town. The cul-de-sac, and area immediately surrounding the cul-de-sac, currently experiences ponding and flooding during major storm events that happen to coincide with abnormally high tides.

The town recently worked with Wright Pierce to study the issue, and determined structural fixes to the solve problem were simply not cost effective. In 2015, the Portland Water District installed a new pump station and replaced the catch basin. These fixes will likely mitigate the issue, but are not considered to be a permanent solution.

Bridges and Culverts

There are two bridges in Cape Elizabeth, as identified by MaineDOT. These are shown as "A" and "B" in the image below.



Bridge #2796 ("A"), is the larger, and more significant of the two bridges. It is located on Route 77 and spans the Spurwink River. Owned and maintained by MaineDOT, the bridge straddles the Cape Elizabeth/Scarborough town line, and was built in 1988. The bridge is 80 ft. long, and considered by MaineDOT to be in "good" condition. The picture below, taken at high tide, shows the bridge appears to be elevated high enough to withstand several feet of sea level rise and/or storm surge. However, a more detailed analysis, conducted by a certified bridge engineer, would be needed to truly determine the bridge's capacity and exposure to risk.

Bridge #6014 ("B"), the smaller of the two bridges, is technically considered by MaineDOT to be a "minor span" – *minor spans are structures between 10 and 20 ft. in length*. Located on Sawyer St., the minor span also crosses the Spurwink River, and is owned and maintained by the Town. Built in 1997, it is 11 feet long and consists of one large culvert.

While the culvert itself appears to be in good condition, there is evidence of deterioration in certain places along the edge of the road (below-left). Since this section of Sawyer Rd. is a particularly low-lying area, this minor span merits close, regular inspection.

Culverts: In addition to the two bridges, numerous culverts are present at river, stream, and wetlands crossings throughout town. The condition, capacity, and degree to which these culverts represent habitat barriers, varies considerably by location and in some cases remains unknown.

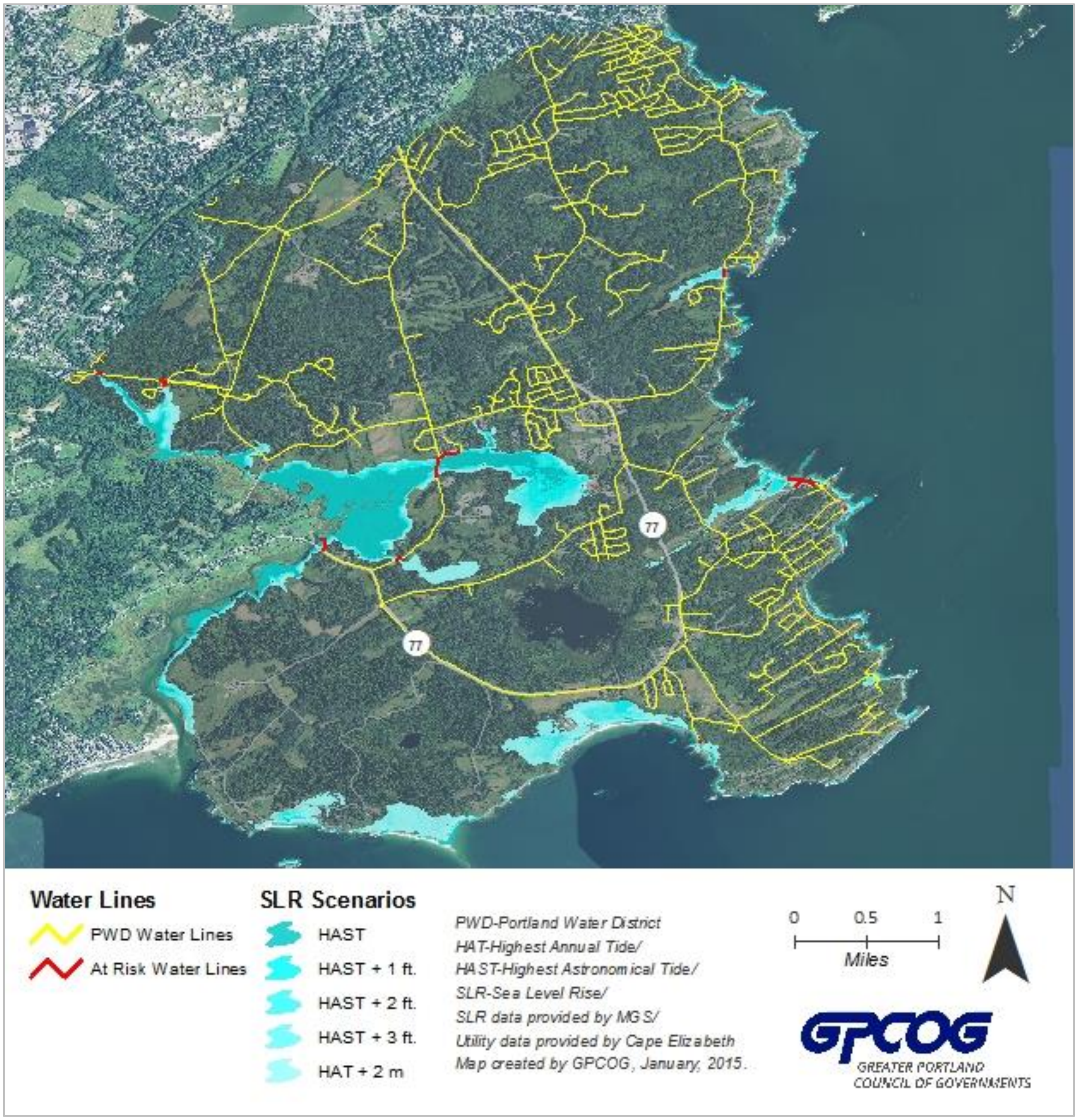
In order to meet **MS4** requirements, the Public Works Department is currently conducting a detailed inventory of the town's culverts and stormwater infrastructure. Once completed, the Department will develop an improvement plan for their eventual upkeep and replacement. *(Additionally, some culverts have been identified as habitat barriers by the Casco Bay Estuary Partnership, and are discussed in the "Environmental Impacts" section of this report).*

Underground Utilities

Many roads in Cape Elizabeth carry public water and sewer lines beneath them. Sea level rise is a very real threat to these utilities, since they are typically not designed to be saturated by saltwater. Flooding and inundation of buried lines can increase deterioration rates, and cause lines to shift, subjecting them to stress levels they were not designed to withstand.

Figure 7, below, shows the extent of water lines in Cape Elizabeth, including those that might be at risk from sea level rise or extreme weather events.

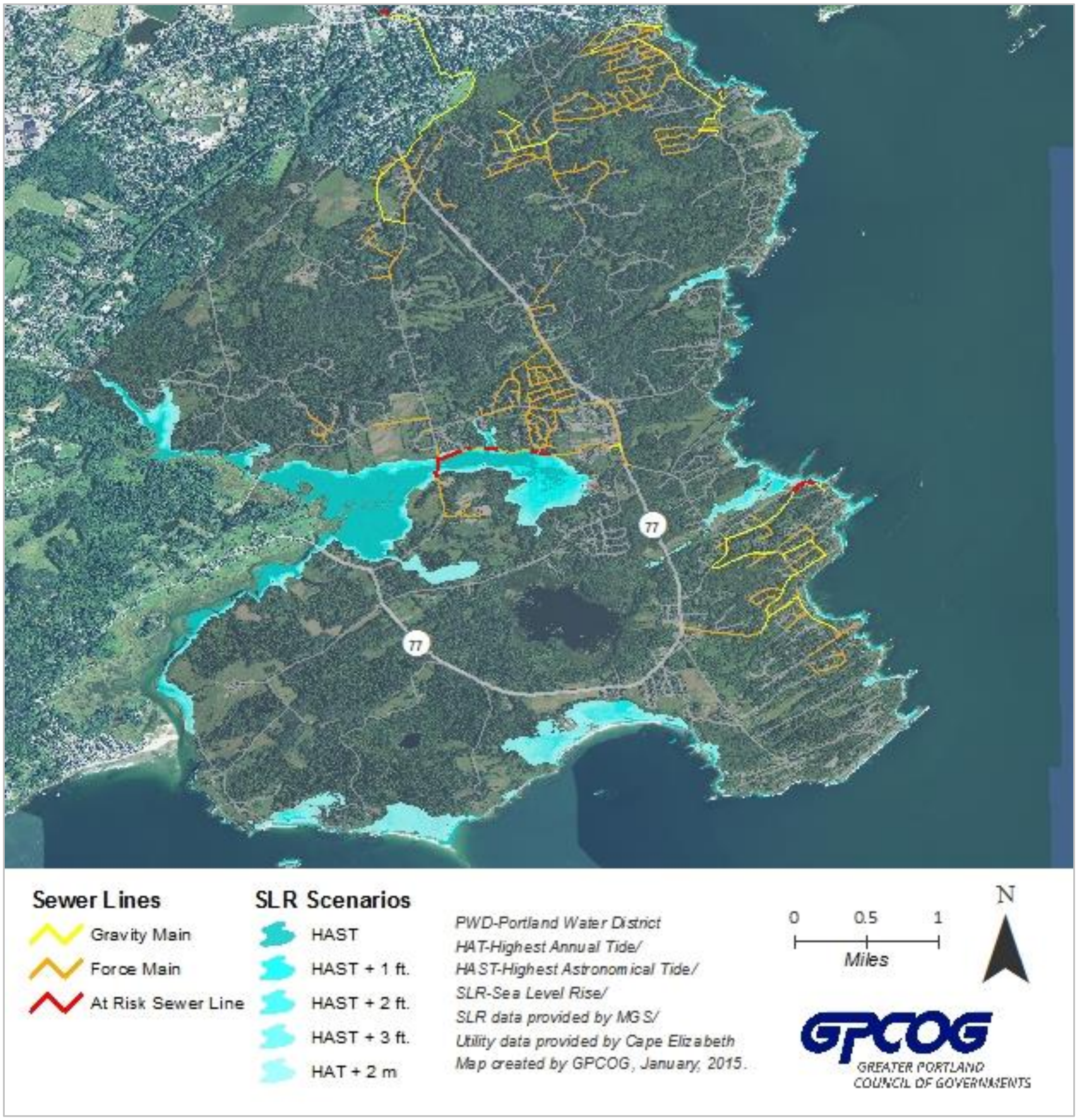
Figure 7: Cape Elizabeth Public Water Lines



It is important to note, these maps provide only a general sense of where utilities are "at risk." *In most cases, these are in the same locations as the roads identified earlier*. The maps do not show the depth or condition of buried lines, nor do they predict whether a line will continue to function.

Figure 8, below, shows the extent of sewer lines in Cape Elizabeth, including those that might be at risk from sea level rise or extreme weather events. ***Areas not served by public sewer are likely on private septic systems. Rising sea levels could make septic systems adjacent to the coast noncompliant, potentially causing breakout and contamination.***

Figure 8: Cape Elizabeth Public Sewer Lines

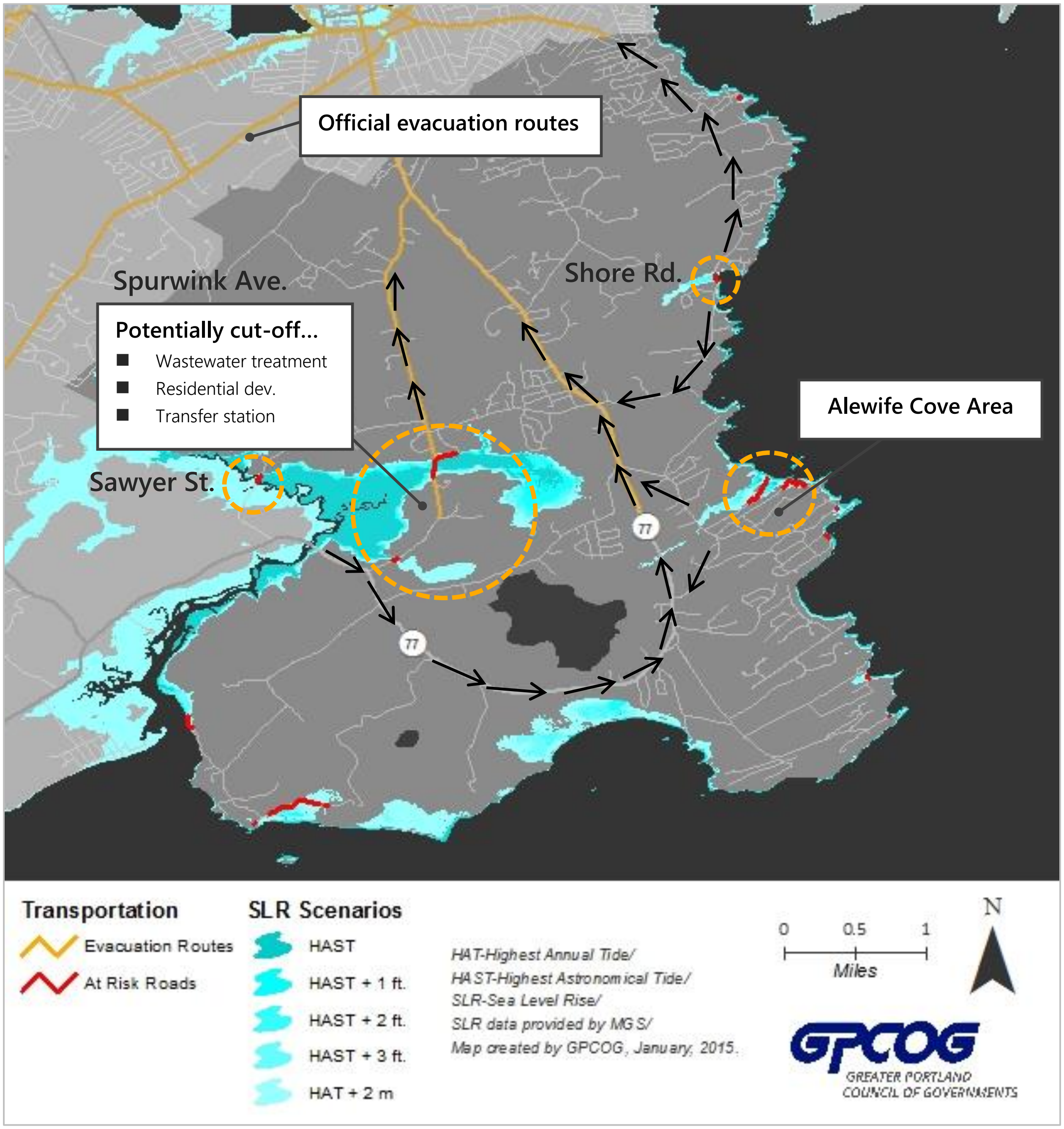


PUBLIC SAFETY IMPACTS

Evacuation Routes

The evacuation routes shown in **Figure 9**, below, were developed by the Cumberland County Emergency Management Agency in 2010. As you can see, there are only a few locations in Cape Elizabeth where extreme coastal flooding could potentially impede evacuation routes.

Figure 9: Cape Elizabeth Evacuation Routes



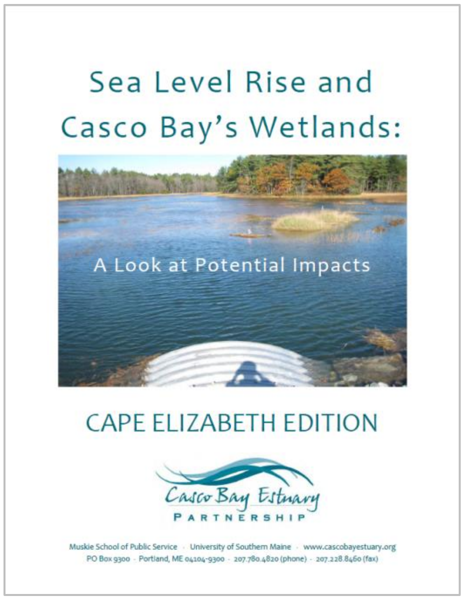
Most importantly, Route 77 – the main evacuation route – should remain clear and does not appear to be affected in any significant way. The chief areas of concern are circled in **Figure 9**, and described briefly below:

1. **Spurwink Ave**: The primary area of concern appears to be a segment on Spurwink Ave. where a handful of residences, and the Portland Water District's wastewater treatment plant, could be isolated if the Spurwink Marsh over-tops the road at either end. The remaining land uses in the area, the town's transfer station and the Gull Crest fields and trails, are not high priorities for emergency planning purposes.
2. **Shore Rd**: For residents along Shore Rd., the Pond Cove area could be a pinch point. However, since Shore Rd. is a thru-road, residents should be able to evacuate north or south to access established evacuation routes.
3. **Sawyer Rd**: The low-lying section of Sawyer Rd. may also get inundated during a storm event. If this is the case, Cape Elizabeth residents should be able to evacuate east along Sawyer Rd. to Spurwink Ave. without too much difficulty.
4. **Alewife Cove:** This area shows potential evacuation conflicts with flooding and nearby residential development. However, as the image below illustrates, only a few residences closest to the coast are affected, and the inundation occurs on small, private roads. With some forewarning, residents should be able to make it to Route 77 via Old Ocean House Rd. without too much trouble.

ENVIRONMENTAL IMPACTS

The main environmental impacts of sea level rise include the potential loss of tidal wetlands, intensified coastal erosion, and an increase in the number of habitat barriers. This section provides a brief assessment of these impacts in Cape Elizabeth.

Tidal Wetlands and Marsh Migration



In 2013, the Casco Bay Estuary Partnership (CBEP) reviewed ten of the fourteen municipalities that line Casco Bay to identify potential areas of marsh migration and possible impacts to existing developed areas due to tidal inundation from sea level rise.[8]

The report looks at, "places where roads, railroads, trails, dams, and other structures cross tidal wetlands." In most cases, the report notes, "these structures alter the way water is passed from one side of the wetland to the other. When tidal exchange is restricted, even if it is restricted only during astronomical spring tides, long-term impacts to wetlands can develop that reduce ecosystem resiliency to respond to impacts such as sea level rise."

By and large, Cape Elizabeth's rocky coastline limits the loss of existing wetlands due to sea level rise. However, the CBEP assessment did identify two primary wetland areas in Cape Elizabeth where conflicts may occur between rising seas and developed areas. These are:

1. Alewife Cove Area
2. Pond Cove Area

Alewife Cove Area

The report notes that existing developed areas at the end of Alewife Cove Rd. are projected to be in conflict with rising seas. As **Figure 10** illustrates (next page), further upstream along Alewife Brook undeveloped low lying areas are suitable for marsh migration inland to occur. Extensive low-lying areas downstream of Old Ocean House Rd. are also suitable elevations for tidal wetlands to form.

The presence of a dam on Alewife Brook (dam not shown in map), could affect the extent of wetland that develops, and the dam itself could be impacted by sea level rise.

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[8] Casco Bay Estuary Partnership. 2013. ***Sea Level Rise and Casco Bay's Wetlands: A Look at Potential Impacts, Cape Elizabeth Edition***

Figure 10: CBEP Assessment - Alewife Cove Area - 3 ft. SLR

Figure 11: CBEP Assessment - Pond Cove Area - 3 ft. SLR

Pond Cove Area

As **Figure 11** (previous page) shows, elevations are generally not suitable for marsh migration inland in the Pond Cove area, except where Shore Rd. crosses over Pond Cove Brook. Shore Rd. restricts tidal water from flowing into the wetlands upstream, except during astronomical high tides and storm events. If sea level rises by 3 ft., elevations upstream of Shore Rd. would be suitable for tidal wetlands to migrate and form.

There is often considerable overlap between the interests of those who own the structure, and those working for the recovery of stream-dependent species.

Habitat Barriers

Over the past several years, the Maine Stream Connectivity Work Group has led an extensive, largely volunteer effort to inventory habitat barriers throughout the state. Habitat barriers are typically undersized culverts, aging dams, or other man-made impediments to stream crossings. A full inventory of stream barriers throughout the state can be found at "Maine Stream Habitat Viewer," available at the following link: **http://mapserver.maine.gov/streamviewer/index.html.**

Habitat barriers can impede, or entirely block, fish access to habitats upstream of the structure, as well as interrupt stream processes that build and sustain habitat. Additionally, habitat barriers often comprise a public safety risk and maintenance liability. Sea level rise, amplified storm surges, and extreme precipitation events only exacerbate these risks and liabilities. For these reasons, there is often a considerable overlap between the interests of those who own the structure, and those working for the recovery of stream-dependent species.

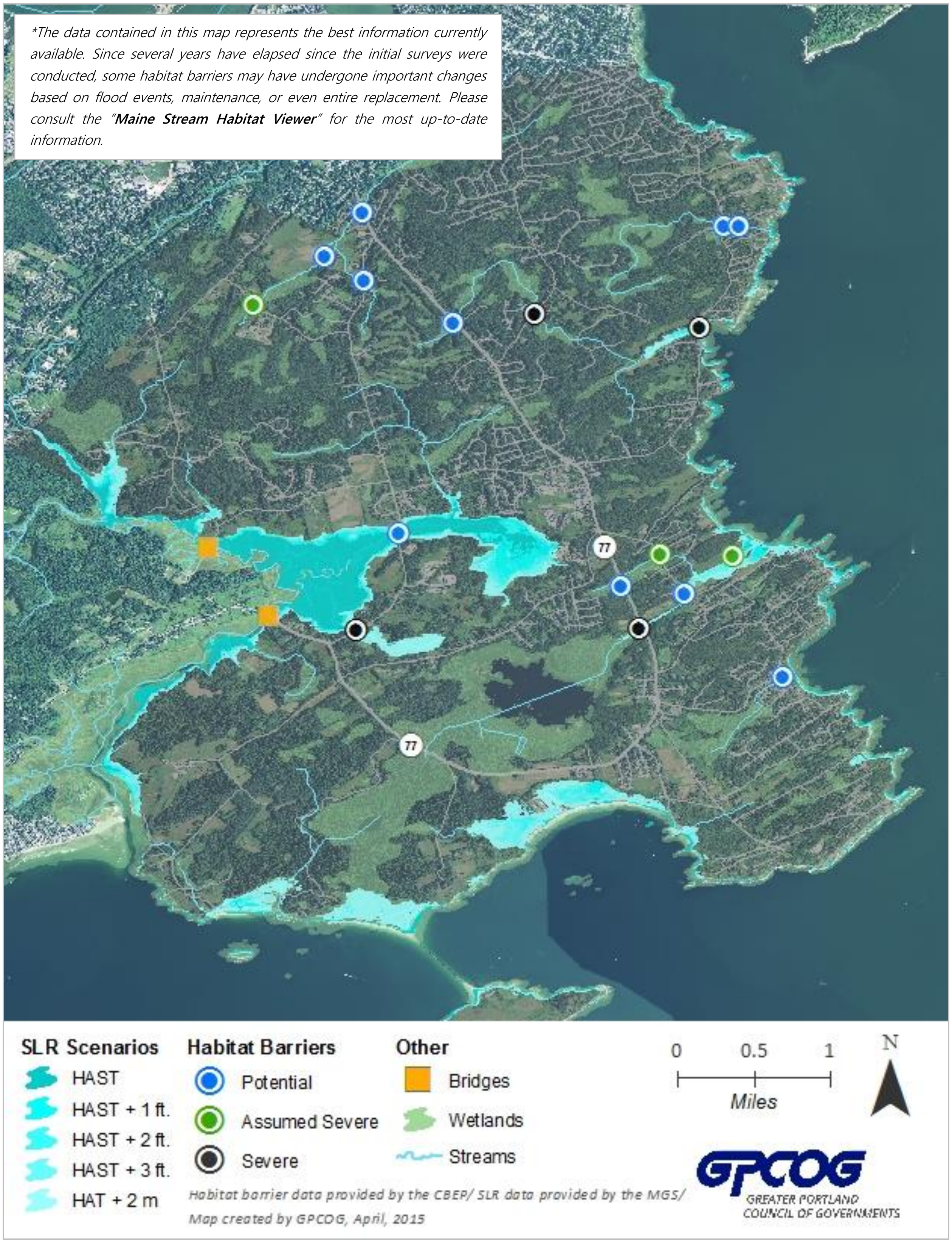
In the Casco Bay watershed, the Casco Bay Estuary Partnership has surveyed over 900 habitat barriers. Of these, roughly 40% are considered barriers because they are perched above the stream and/or blocked. The barriers identified in Cape Elizabeth are shown in **Figure 12** (next page).

This "perched" culvert requires a swimming or leaping ability that not all fish or wildlife have.

The barrier shown in the picture to the left, located on Route 77 in Cape Elizabeth where the road crosses Alewife Brook, is an example of a perched culvert. The Maine Habitat Viewer indicates this culvert blocks roughly 1.41 miles of upstream habitat, and 170.7 acres of Alewife Pond habitat.

While it does not appear to be a flood risk, the culvert does cross below Route 77, the primary evacuation route for the town.

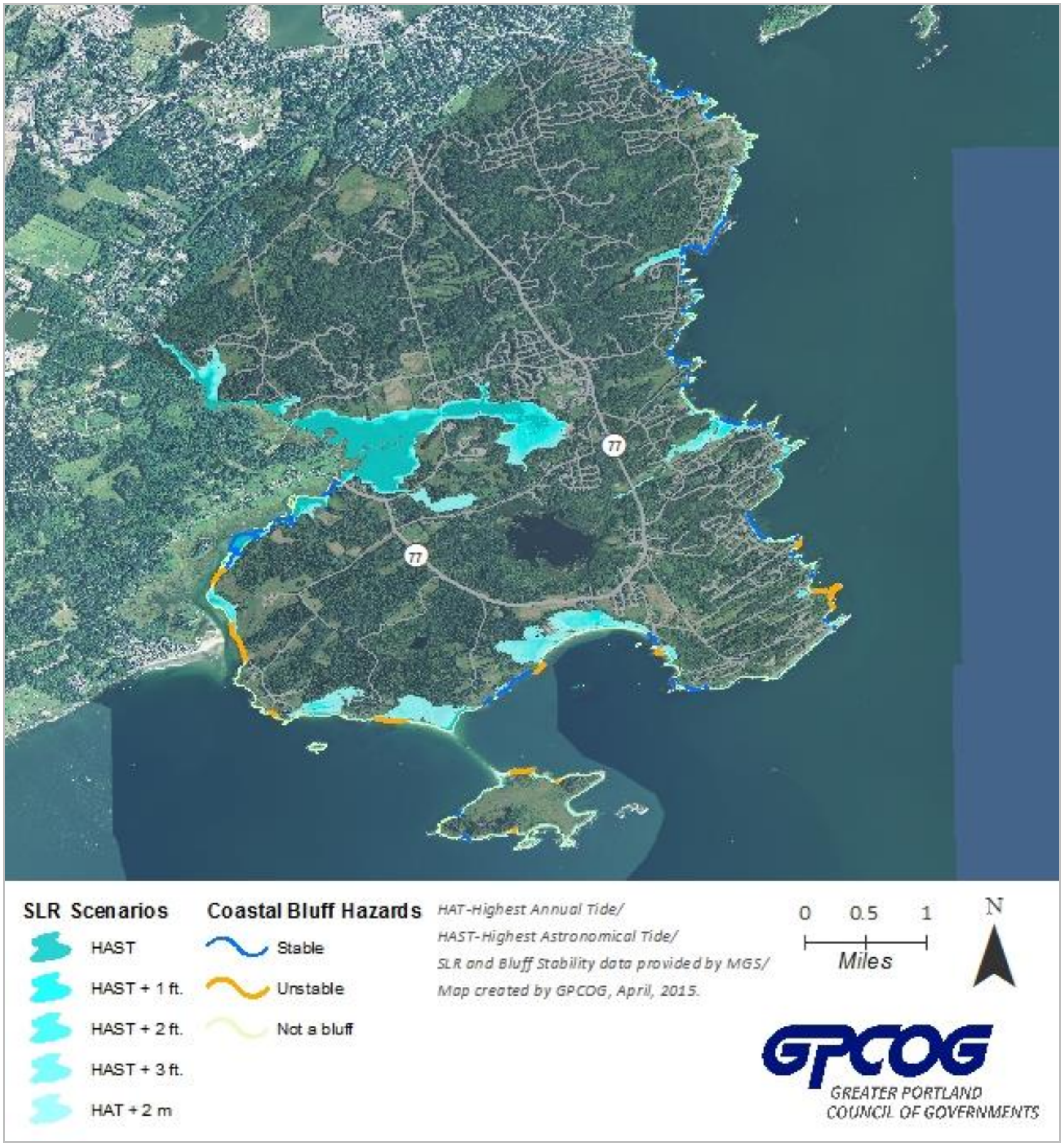
Figure 12: Cape Elizabeth Habitat Barriers



Bluff Stability

Sea level rise and subsequently higher storm tides will exacerbate issues with coastal erosion and bluff stability. Several years ago, the Maine Geological Survey (MGS) mapped unstable bluffs and potential landslide areas for each community along the Maine coast. Fortunately, Cape Elizabeth's coastline is comprised primarily of rocky ledges and bluffs, which are quite formidable. However, as **Figure 13** shows, there are a few areas the MGS has deemed "unstable" and at risk for erosion.

Figure 13: Cape Elizabeth Coastal Bluff Hazards



Of the areas the MGS has deemed unstable, most are located on private property or along conservation/open space parcels. The aerial image below shows a potentially unstable, and privately owned, bluff on Staples Point.

With respect to public property, the image below shows two potentially unstable bluffs on state park property. The bluff in the top left is located on the western end of Crescent Beach State Park, while the bluff in the lower right is part of Two Lights State Park.

Overall, unstable bluffs and landslides do not appear to be a major hazard in Cape Elizabeth. Only a few private residences are impacted, and no town-owned buildings or properties are at risk.

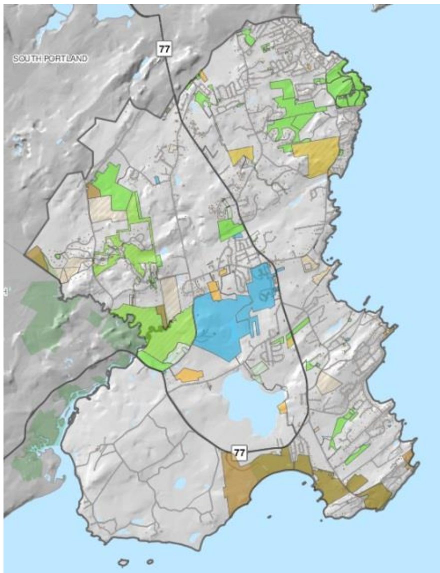
GENERAL ADAPTATION STRATEGIES

It is now widely accepted that strategies for adapting to sea level rise tend to fall into three main categories: Retreat, Accommodate, and Protect.[9] Each strategy has its pros and cons, which are often situational. Below is a brief description of each:

Protect: Protection strategies try to **prevent damage by creating a barrier between rising seas and infrastructure**. Examples include traditional "coastal hardening" techniques, such as the construction of sea walls, bulkheads, tide gates, and saltwater barriers. To be truly effective over the long term, these structures need to be massive, and/or maintained frequently, to withstand the forces of the sea. Protection strategies are often very costly and difficult to get permitted under our current regulatory system. *Sea walls are a common sight along the coast in Cape Elizabeth.*

A sea wall protecting a private residence in Cape Elizabeth.

Accommodate: Accommodation strategies **allow flood waters to reach developed areas, but try to minimize or control the damage.** Typical examples include flood proofing and elevating structures, raising the grade of roads and bridges, designing stormwater facilities to handle larger volumes of water, and prohibiting future development in hazardous areas. *The Town's stringent resource protection policies are a good example of restricting development in flood-prone areas, and using natural buffers to accommodate flooding and storm surge.*



A large portion of land in Cape Elizabeth is either conserved, or in a resource protection zone. The map above, available on the Town's website, shows conserved lands in Cape Elizabeth by type of ownership (i.e., town-owned, state-owned, land trust, etc.). Conserving flood-prone areas is one of the best ways to reduce the impacts of sea level rise and storm surge.

Retreat: The main intent for retreat strategies is to **move development out of harm's way in a planned and controlled manner**. Retreat recognizes that in some areas it may be too costly, or impractical, to prevent damage from rising seas and storm surge. Specific policy tools for retreat include buy-outs, rolling easements, and transfer of development rights (TOD's). *Cape Elizabeth has a TOD policy in place, which can be used as needed, and the Town has purchased conservation lands on several occasions.*

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[9] ***Intergovernmental Panel on Climate Change (IPCC)***

TOWN RESPONSE TO SEA LEVEL RISE TRENDS

Cape Elizabeth is known for its strict environmental regulations. In many instances, the town's policies are *more* restrictive than those of its surrounding communities, or state requirements. The Town's commitment to the environment, along with a predominantly rocky shoreline, has helped lessen the burden of planning for sea level rise. The following are a few highlights of existing policies that help reduce conflicts between rising seas, development, and sensitive areas.

Shoreland Zoning

The Town has adopted shoreland zoning standards consistent with state requirements. This includes a 250 ft. buffer along the coastline, rivers, and ponds, and a 75 ft. buffer along major streams.

Additionally, in August 2014, the Town Council agreed to amend the ordinance's definition of Normal High Water Line to the value of the Highest Astronomical Tide + 3ft. (HAST+3ft.). The new HAST+3ft. definition brings more clarity to the policy, and the additional three feet provides a more appropriate buffer for rising seas and higher storm tides.

Wetland Regulations

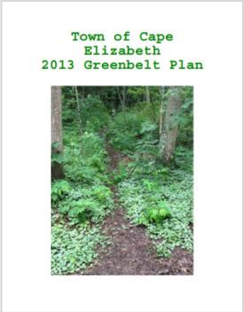
The Town currently has some of the most stringent wetland policies in the state. According to the 2007 Comprehensive Plan, "Threats to wetlands in Cape Elizabeth have been almost eliminated by local wetland regulations that are more restrictive than state wetland protection ... Consequently, what limited growth occurs in Cape Elizabeth is aggressively directed away from wetland areas."[10]

Floodplain Management Ordinance

The Town regulates hazardous areas with a floodplain management ordinance consistent with federal regulations. Of particular note, Cape Elizabeth's ordinance ***requires buildings in most zones to be elevated two feet above base flood elevation, with three feet required in flood zones where depth numbers are not specified.*** These standards are more stringent than most communities, and comply with "best practices" encouraged by FEMA, the Maine Floodplain Management Program, the MGS, and other experts.

Land Conservation

Land conversation is perhaps the single best strategy a community can take to reduce its exposure to coastal flooding hazards.



Fortunately, open space and trails are highly valued by Cape Elizabeth residents. The Town has used municipal bonds to purchase open space in the past, and several organizations actively pursue open space goals, including the Town's Conservation Commission, and the Cape Elizabeth Land Trust (CELT). The recent ***2013 Greenbelt Plan*** has further helped prioritize open space, as well as build support for a town-wide greenbelt trail network.

[10] Pg. 127, ***2007 Cape Elizabeth Comprehensive Plan***

RECOMMENDATIONS

This report does not provide an exhaustive list of every action the town could take to prepare for sea level rise. Rather, it highlights the **top projects and strategies** believed needed to protect public infrastructure and increase public safety in Cape Elizabeth. No timeline is included, as it is understood the Town will make improvements as opportunities and resources allow. Several of the following recommendations are also referenced in the ***Cumberland County Hazard Mitigation Plan***, these are denoted with an asterisk (*).

Buildings and Facilities

- ◻ **Evaluate Risk to PWD's Wastewater Pumping Station:** Coordinate with the Portland Water District regarding the pumping station on Spurwink Ave. Its location should be further evaluated to determine its vulnerability to flooding and inundation. If warranted, the PWD should consider flood-proofing, or elevating, the station to improve its overall resiliency.

Roads, Bridges, and Culverts

- ◻ ***Raise Sawyer Rd. and Minor Span:** Actively monitor the condition of Sawyer Rd. and the minor span where it crosses Spurwink Marsh. Future improvements should be coordinated with the Town of Scarborough, and consider sea level rise, storm surge, and the importance of improving habitat connectivity in Spurwink Marsh.
- ◻ **Raise Shore Rd. and Increase Culvert Capacity:** Actively monitor Shore Rd. along Pond Cove. Future road construction should consider sea level rise, storm surge, the road's exposure to breaking waves, and the importance of the Pond Cove Brook crossing for habitat connectivity.
- ◻ ***Raise Spurwink Ave. and Increase Culvert Capacity:** Consider elevating the road segment that crosses Spurwink Marsh (near Starboard Dr.). Future improvements should consider sea level rise, storm surge, the road's importance as an evacuation route, and the impact the crossing has on habitat connectivity in Spurwink Marsh.
- ◻ **Review Capacity and Design of Culverts Town-wide:** As part of the "MS4" designation, the Town's Public Works Department is currently inventorying the location and condition of all culverts. Once complete, the Department should develop a management plan to prioritize the phased replacement of poorly functioning/undersized culverts. Replacements should be sized to consider the impacts of sea level rise, the potential for increased precipitation events, and the implications the crossing may have on habitat connectivity. *(The MGS recommends using Cornell's updated TP-40 precipitation data for engineering guidance – found here:* ***http://precip.eas.cornell.edu*** *– until NOAA Atlas 15 data is available).*

Underground Utilities

- **Evaluate the Risk to Underground Utilities:** It is unclear to what extent underground utilities are impacted by sea level rise and storm surge. Generally speaking, the utilities identified in this report were located below at-risk roads. The Town should coordinate with the PWD, and the South Portland Public Works Department, to determine if the magnitude of this risk bears future study.

Planning and Policy

- **Improve Accuracy of the GIS layer for Normal High Water Line (HAST+3ft):** The current GIS layer used to visualize the HAST+3ft. line is not accurate enough for conveyance purposes. The Town should hire a GIS consultant to use LIDAR data, or site specific surveying, to clearly delineate where the HAST+3ft. line should be.
- **Include Sea Level Rise in Next Comprehensive Plan Update**: Consider Including language and/or policies regarding the projected impacts of sea level rise and storm surge in the next Comprehensive Plan update. This could be a stand-alone chapter, or included as a topic in a pre-existing chapter. The Towns of York and Bowdoinham have already done this, and can be used for reference. *(Note: at the time of this writing, LD 408, "An Act to Help Municipalities Prepare for Changes in Sea Level"[11] is currently making its way through the Maine legislature. If enacted, it would require coastal communities to, "plan for the impacts of changes in sea level on buildings, transportation infrastructure, sewage treatment facilities, and other relevant state, regional, municipal, or privately held infrastructure, property or resources").*
- **Revise Septic Ordinance to Consider Impacts of Sea Level Rise:** Consider the implications of sea level rise in future updates to the septic system ordinance. If necessary, revise the ordinance language to require stricter standards for the placement of new septic systems in vulnerable areas.
- **Incorporate Low Impact Development (LID) Techniques in Land Use Ordinances:** LID includes a variety of practices that mimic or preserve natural drainage processes to manage stormwater. LID techniques typically retain rain water and encourage it to soak into the ground. This reduces the burden on storm drains and ditches, and helps alleviate damage to

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[11] *The following is a brief, legislative summary of **LD 408, An Act to Help Municipalities Prepare for Changes in Sea Level:** "This bill requires that if a coastal municipality or multimunicipal region that includes a coastal municipality adopts a growth management program under the State's growth planning and land use laws, its comprehensive plan must include information on and a plan to address the impacts of changes in sea level on buildings, transportation infrastructure, sewage treatment facilities and other relevant municipal, multimunicipal or privately held infrastructure or property. This bill also amends the State's growth planning and land use laws to reflect that addressing the impacts of sea level rise is a state planning and regulatory goal. This bill amends the laws regarding the State's coastal management policies to reflect a new state policy of addressing and planning for the impacts of sea level rise."*

infrastructure and habitat. The Town should consider amending its site plan review ordinances to require a certain number of LID stormwater techniques are used for any new development or redevelopment.

APPENDIX

A. Glossary of Terms

Base Flood Elevation (BFE)

The elevation to which floodwater is anticipated to rise during the "base flood" (i.e., the "100-year storm" or a flood having a one percent change of being equaled or exceeded in any given year). Base Flood Elevations are shown on Flood Insurance Rate Maps (FIRMS) and on various flood profiles. The BFE is the regulatory requirement for the elevation or flood proofing of structures. The relationship between the BFE and a structure's elevation determines the flood insurance premium.

Bathtub Model

The sea level rise scenarios used in this report are based on the bathtub model, which solely takes into account rising water levels. It does not factor in the destructive power of storm surge, large waves, and wind, which are much more difficult to predict.

Global Mean Sea Level (GMSL)

GMSL is the globally averaged height of the oceans measured by a network of satellites to sub-millimeter precision. It is sometimes referred to as the "eustatic sea level." The eustatic sea level is not a physical sea level (since the sea levels relative to local land surfaces vary depending on land motion and other factors), but it represents the level if all of the water in the oceans were contained in a single basin.

Highest Annual Tide (HAT)

The highest predicted water level for any given year. The highest annual tide corresponds to the full moon, and is reached within several inches numerous tides a year. The value changes slightly each year.

Highest Astronomical Tide (HAST)

The elevation of the highest predicted astronomical tide expected to occur at a specific tidal station over a 19 year period (the National Tidal Datum Epoch, 1983-2001). HAsT is referenced to Mean Lower Low Water at the Portland Head Light tide prediction station, and occurs during the spring tide when the sun and moon are closest to the earth during an 18.6 year tidal cycle. HAsT accounts for all significant variations in moon and earth orbits, and is recalculated every 20-25 years.

Land Subsidence

Land subsidence is the sinkage or lowering of the land surface. Most land subsidence is caused by human activities (typically intensive groundwater withdrawals). Land subsidence can increase flooding, alter wetland and coastal ecosystems, and damage infrastructure and historical sites.

LIDAR

LIDAR is an acronym that stands for "**Li**ght **D**etection **A**nd **R**anging." LIDAR is a remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light. The technology can be used to make high-resolution maps with great accuracy and precision.

Mean Lower Low Water (MLLW)

The average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch.

Mean Sea Level (MSL)

The average level of the sea surface over a long period, normally 19 years, or the average level which would exist in the absence of tides.

MS4 Communities (MS4s)

The Clean Water Act authorizes the EPA, and individual states, to regulate point sources that discharge pollutants into waters of the United States through the National Pollutant Discharge Elimination System (NPDES) permit program. In Maine, this program is administered by MaineDEP.

MS4 stands for "Municipal Separate Storm Sewer Systems." According to the language of the law, an MS4 is a publicly-owned "conveyance, or system of conveyances (roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, storm drains, etc.)." The MS4 General Permit is designed to reduce the amount of sediment and pollution that enters surface and ground water from storm sewer systems to the maximum extent practicable.

National Tidal Datum Epoch (NTDE)

The specific 19-year period adopted by the National Ocean Service as the official time segment over which the tide observations are taken and used to obtain mean values (i.e., mean lower low water, etc.). The present NTDE is 1983 through 2001 and is actively considered for revision every 20-25 years.

Normal High Water Line (NHWL)

The outermost boundary of the shoreland zone. Development is limited within 250 feet of the boundary, and none is allowed within 75 feet. Cape Elizabeth is using Highest Astronomical Tide, plus three feet to account for rising sea levels and storm surge, as its Normal High Water Line, which was adopted by the Town Council (August, 2014).

Shoreland Zone

The Mandatory Shoreland Zoning Act (MSZA) requires municipalities to adopt, administer, and enforce local ordinances that regulate land use activities in the "shoreland zone." The shoreland zone is comprised of all land areas within 250 feet, horizontal distance of the normal high-water line of any great pond or river; upland edge of a coastal wetland, including all areas affected by tidal action, and upland edge of defined freshwater wetlands; and all land areas within 75 feet, horizontal distance, of the normal high-water line of certain streams.

Storm Surge

Storm surge is an abnormal rise of water generated by a storm, over and above the predicted astronomical tides. Storm surge is typically caused by extreme winds and low pressure associated with an atmospheric front.

Storm Tide

Storm tide refers to the overall rise in water level due to the combination of storm surge and astronomical tide. (For instance, if the predicted tide was 11 feet, and storm surge was 3 feet, the storm tide would be 14 feet).

B. Additional Resources

Specific references to data, quotations, news articles, etc. are cited in footnotes throughout the report. Below is a list of additional resources that might be useful for the Town's future planning efforts. *(Click on any of the resources in **bold** to access their content online).*

- Casco Bay Estuary Partnership, **"Sea Level Rise and Casco Bay's Wetlands – Cape Elizabeth Edition"** (report).
- Cumberland County, Maine, **"Hazard Mitigation"** (webpage).
- Greater Portland Council of Governments, **"Casco Bay Environmental Planning Assessment 2013"** (report).
- Maine Climate Change Institute, **"Maine's Climate Future – 2015 Update"** (report).
- Maine Coastal Program, **"Coastal Erosion and Sea Level Rise"** (webpage).
- Maine Stream Connectivity Work Group, **"Maine Stream Habitat Viewer"** (webmap).
- NOAA, **"Digital Coast"** (webpage).
- NOAA, **"National Sea Grant Resilience Toolkit"** (webpage).
- NOAA, **"U.S. Climate Resilience Toolkit"** (webpage).
- Town of Bowdoinham, **"Comprehensive Plan - Sea Level Rise and Climate Change Adaptation Goals and Strategies"** (report).
- Town of York, **"Adaptation to Sea Level Rise Chapter – Comprehensive Plan Inventory and Analysis, 2013"** (report).
- Urban Land Institute, **"Waterfronts of Portland and South Portland Maine"** (report).
- U.S. Global Change Research Program, **"U.S. National Climate Assessment."** (report and interactive website).