

KITTERY MUNICIPAL WORKING WATERFRONT SEA LEVEL RISE AND COASTAL FLOODING VULNERABILITY STUDY

An assessment of the present and future flood hazard to Kittery's working waterfront in the face of sea level rise and more severe and frequent coastal flooding.

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Kittery Municipal Working Waterfront Sea Level Rise and Coastal Flooding Vulnerability Study

This report assesses the vulnerability of Kittery's municipal-owned working waterfront to coastal flooding under both current conditions and future sea level rise. This study aims to provide essential information for Kittery's decision-makers to enhance preparedness and resilience of working waterfronts against sea level rise-driven increases in coastal flooding risk.

Key points:

- Relatively new construction of piers at Pepperrell Cove and the Government Street Wharf makes it likely that the structures themselves will be durable to sea level rise-driven increase in coastal flooding events for several decades.
 - We highlight several key low-lying utility fixtures at both sites that have a greater near-term risk to flooding impacts that should be prioritized for adaptation measures such as protection or elevation.
 - The Traip Academy Boat Launch is unlikely to be severely impacted by flooding for the next several decades due to limited dockside utilities and infrastructure
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Glossary

Mean higher high water (MHHW): The average of the higher high water height observed each day (the Gulf of Maine has two high tides per day) over a 19-year period (19 years includes the longest-period lunar cycle that significantly influences tide range)

Mean lower low water (MLLW): The average of the lower low water height observed each day over a 19-year period

Highest astronomical tide (HAT): The highest predicted astronomical tide (or the rise in water level from tides alone, without the influence of weather) expected to occur at a location over a 40-year period. Due to wind and currents, water levels exceed HAT roughly 2-10 times per year.

Stillwater Elevation (SWEL): The sustained high-water level resulting from the combined influence of sea level, the tide, storm surge, and wave setup, but not considering the periodic rise and fall or inland uprush of water from wave runup and overtopping.

1% annual chance stillwater elevation (1% SWEL): The peak stillwater water level that has a 1% chance of occurring annually (commonly called the “100-year” water level).

North American Vertical Datum of 1988 (NAVD88): The land-based reference point, assigned a value of zero, relative to which elevations of structures and coastal water levels can be measured.

Mean Sea Level (MSL): The average level of water, typically averaged over a minimum of 1 year to account for seasonal variation

FEMA AE Zone: FEMA Zone designation for an area that is exposed to a 1% annual chance flood, and where wave heights are likely to be less than 3 feet.

FEMA VE Zone: FEMA Zone designation for an area that is exposed to a 1% annual chance flood, with the additional hazard of wave action with wave heights greater than 3 feet.

FEMA Base Flood Elevation (BFE): The peak water level during the 1% annual chance flood event, including the impacts of wave run-up and overtopping (waves traveling inland).

1. Overview

As sea level rise drives more frequent and severe coastal flooding in Kittery, there is a need for quantitative flood hazard assessments to support near-term preparedness and long-term prioritization and planning of adaptation measures. Section 3 of this report describes resources for enhancing near-term flood preparedness, and Section 4 provides a detailed assessment of present and future flooding impacts to three municipal working waterfront sites, conducted in collaboration with the Town of Kittery: Pepperrell Cove, the Government Street Wharf, and the Traip Academy Boat Launch.

In considering flooding impacts to working waterfront sites, we examine the elevations of wharf/pier decking and fixed utilities such as power meters, outlets, crane controls, and power conduits relative moderate and extreme high-water levels under both present-day and future sea levels. We use Highest Astronomical Tide (see Glossary), which is exceeded 2 to 10 times per year, to assess inundation from moderate high-water events, and the 1% annual chance stillwater elevation (see Glossary) to assess inundation from extreme events. *Inundation* describes prolonged flooding over minutes to hours caused by the stillwater level. In Section 4, the water surface elevation reached by wave runup and overtopping, or the periodic rise and fall or inland uprush of water over seconds, is shown on top of the stillwater level. In some cases, it may be useful to consider inundation separately from wave impacts; for example, waves may not be hazardous to a sheltered dumpster or ice machine, but inundation may cause them to become buoyant.

To assess future flood risk, we consider Highest Astronomical Tide and the 1% annual chance flood on top of future sea level rise under both the Intermediate and High sea level rise scenarios from the US Interagency Sea Level Rise Task Force.¹ The state of Maine has adopted these two scenarios for planning and rulemaking at the recommendation of the Maine Climate Council's Scientific and Technical Subcommittee.^{2,3} Use of the Intermediate versus High scenario should depend on the severity of consequences associated with flooding for the asset under consideration and the cost of protecting it against higher water levels.

Detailed information on sea level rise scenarios and determining high water levels can be found in the Appendix.

2. Background

Sea level rise is driving more frequent coastal flooding globally.⁴ Since 1910 when Maine's oldest tide gauge was installed in Portland, sea level has risen 7.5 inches (or 0.6 feet) along the Maine coast, and the rate of rise has doubled in the past two decades.^{2,3} Although a change in sea level of less than one foot is small relative to Kittery's tidal range (which is, on average, 8.9 ft), small increases in sea level can drive rapid increases in the frequency and severity of flooding as more routine high tides and storms begin to exceed flood thresholds. Kittery's town-owned wharfs, private waterfront properties and low-lying portions of Rte. 103 are already threatened by the most extreme storm tides. Recent flooding in December 2022 and January 2024 closed Rte. 103 for a period of several hours and caused moderate damage to working waterfront sites along Kittery's coast through extreme wave action.

The back-to-back storms that impacted Maine’s coast on January 10th and 13th, 2024 were extreme events that led to record-breaking water levels, high waves, and extreme winds, resulting in damage to coastal properties and infrastructure along Maine’s entire coastline. The extreme storm tide resulted from a large surge impacting the coast during monthly high tides on both days. With rising sea level, less extreme combinations of surge and tides will be needed to reach the same high-water mark. Figure 1 shows the future sea level rise-driven increase in frequency of a January-13th-level event using the NASA Flooding Analysis Tool.⁵ Note that while Portland and Kittery have slightly different tidal and storm tide conditions, the sea level rise-driven increase in flooding frequency will be similar between the two sites. The transition of a January-13th level event from a rare extreme to occurring 49-80 days per year in 2100 (statistically likely range) under the Intermediate sea level rise scenario or potentially to a near-daily phenomenon in 2100 under the High scenario demonstrates the need for proactive planning and adaptation.

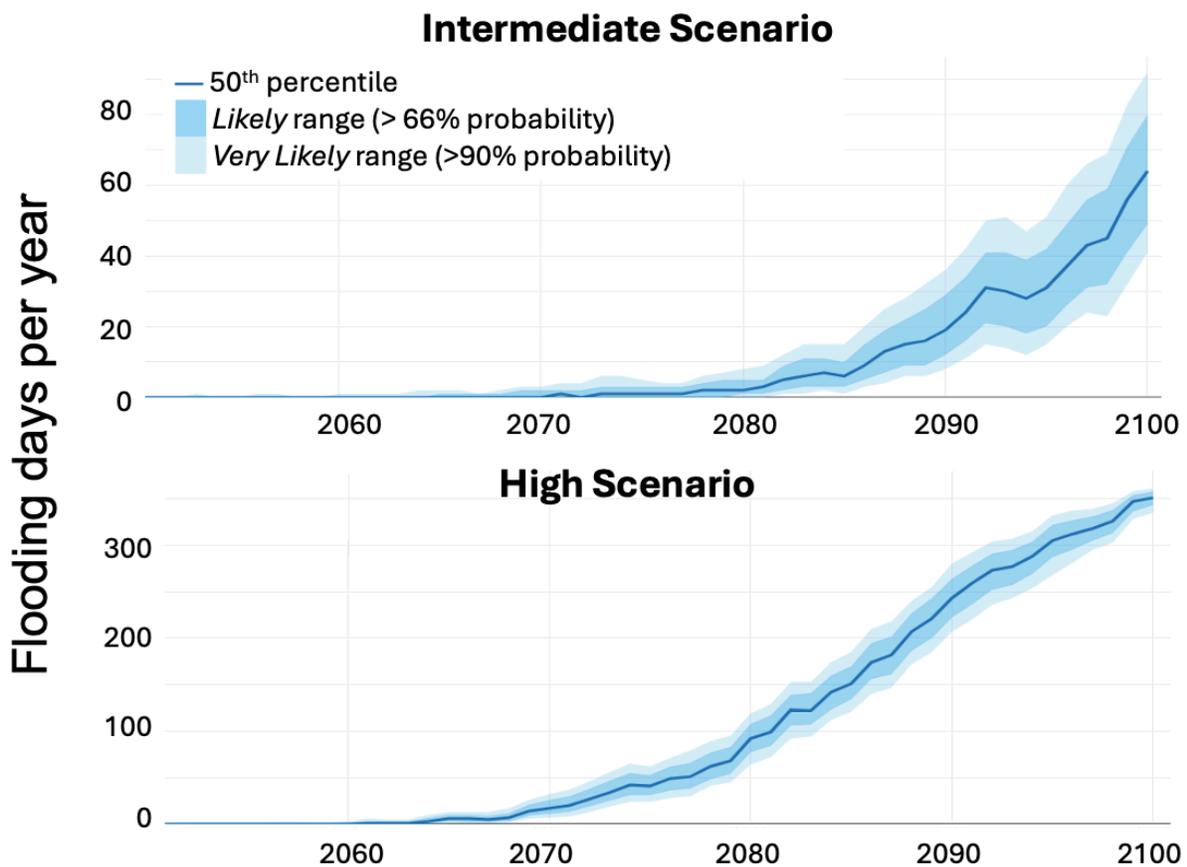


Figure 1: Future frequency of the January 13th, 2024 water level at the Portland tide gauge (4.66 ft above MHHW) under Intermediate (top panel) and High (bottom panel) sea level rise scenarios. Produced by the NASA Flooding Analysis Tool.⁵ *Note differing Y-axis scales between the two panels.

3. Near-term Storm Preparedness

The National Weather Service (NWS) office in Gray (KGYX) issues 72-hour total water level forecasts for the NOAA tide station at Seavey Island (Station #8419870). These forecasts can be accessed online: <https://water.noaa.gov/gauges/seim1>. It is crucial that working waterfront property managers and users do the following:

1. Monitor the total water level forecast, particularly during the winter storm season and around the highest predicted tides of each month. Consider the forecasted water level relative to elevations of key assets at their properties. and
2. Develop an understanding of the relationship between water level and local impacts so that they can take the proper preparedness measures in response to the forecast. For example, at what water level does the parking lot begin to flood and cars need to be moved? How close did a high tide come to flooding an electrical panel?

Tables in Section 4 provide elevations of some of the key assets at Pepperrell Cove, the Government Street Wharf, and the Traip Academy Boat Launch in feet above NAVD88 (a land-based vertical datum). Total water level forecasts are issued relative to the Mean Lower Low Water (MLLW) datum, which is 4.71 ft below NAVD88 at the Seavey Island tide station. Subtracting 4.71 ft from the total water level forecast will convert the water level from feet above MLLW to feet above NAVD88 for comparison to asset elevations

Documenting the impacts of coastal flooding during high tides and storms also improves near-term preparedness and prioritization of adaptations strategies. The Gulf of Maine Research Institute has developed a protocol in collaboration with NWS for the public to photograph and describe coastal flooding impacts. Community-collected photographs and data sheets are uploaded to an online platform and incorporated into a data viewer where observations are associated with water levels recorded at the Seavey Island tide station. The viewer is open-access and can be used by municipal and regional officials, practitioners, and emergency personnel to prepare for flooding. There are newly established monitoring sites at Pepperrell Cove, Fort Foster, and the PNSY Gate 2 entrance. Visit https://investigate.gmri.org/project/coastal_flooding to participate.

Note, working waterfront property managers and users can also independently develop flood thresholds on their properties by photographing or noting water levels relative to key assets, noting the time of the photo/observation, and comparing it to measured water level at the Seavey Island NOAA tide gauge at that time: <https://tidesandcurrents.noaa.gov/waterlevels.html?id=8419870>.

Finally, the Kittery Port Authority has published a set of storm-preparedness guidelines for mariners and for Pepperrell Cove in the event of an extreme coastal storms.⁶ This resource provides important guidance on actions that can enhance safety and reduce exposure of vulnerable assets to incoming storms.

4. Working Waterfront Site Profiles



Image: Frisbee Pier at Pepperrell Cove, Kittery Point, ME, looking southwest, October 12th, 2023. Credit: GMRI

4.1: Pepperrell Cove

Pepperrell Cove is a popular, multi-use site located at Kittery Point, Maine. The wharf provides transient berthing space, long-term moorings, a boat launch, and a public restroom. The Kittery Harbormaster maintains an office at Pepperrell Cove along with one at the Traip Boat Launch. Pepperrell Cove is an earth-filled wharf with two wooden piers: Pepperrell Pier and Frisbee's Pier. Both piers provide access to the floats and Frisbee's pier provides access to a shoreside crane. The surface of the wharf serves as the parking area for 30+ cars in the summer months and is a storage area for the floats in the winter. In 2013, the Kittery Port Authority and Town of Kittery successfully acquired a Boating Infrastructure Grant through the U.S. Fish and Wildlife Service that funded the reconstruction of Frisbee Pier and the enhancement of the transient mooring float system. Per the building plans, the new pier was designed to last at least 30 years, constructed to withstand 3-foot waves and 100 mph, hurricane-force winds.

Pepperrell Cove suffered severe damage during the December 2022 and January 2024 storms. Most impacts occurred from waves moving the stone rip rap around the edge of the wharf and damaging the exterior power conduits that run along the bulkhead of the wharf. Waves also deposited large amounts of detritus on the wharf and adjacent pavement area, jostled the

gangways on the piers, crashed into floats stored for winter on the wharf, and broke against the bulkhead of the wharf. As coastal storms that drive the most severe flooding typically happen in the winter when the floats are removed, there is a risk in storing them on the wharf where floodwaters may move or damage them.

Observations during the recent storms and newly adopted FEMA flood maps (effective July 17, 2024) can be used to assess inundation and wave hazard on the wharf. Pepperell Pier, Frisbee's Pier, and the Pepperell Cove wharf and parking lot are at an elevation of 9.5 feet **NAVD88** (Table 1). The Pepperell Cove wharf and piers are in a **VE zone** with a **base flood elevation** of 15 ft NAVD88. The **1% annual chance stillwater elevation** is estimated at 8.1 ft NAVD88 (note: see Glossary for definitions of bolded terms). Water surface elevations and flood zone designations assume 2017 mean sea level,⁷ and the average rate of sea level rise over the past 30 years in Portland has been 0.12 feet/decade, or 3.6 millimeters/year.³

The **Base Flood Elevation (BFE)** of 15 feet at the Pepperell Cove wharf likely overestimates the impact of waves at the wharf and piers during the 1% annual chance flood event. The difference between the 8.1-foot 1% stillwater elevation and the 15-foot BFE indicates that waves raise water levels roughly 7 feet above the stillwater level. However, during recent coastal storms with strong southeast winds in January 2024 (southeast winds generate the largest waves in Pepperell Cove due to its orientation), the maximum observed waved heights were estimated to be around 3 feet at the wharf and piers—enough to bring water over the bulkhead and on to the wharf. The Pepperell Cove BFE is likely so high because wave contributions to BFE account for wave momentum moving water inland and upslope, e.g. into the parking lot and up Bellamy Ln, up to an elevation of 15 feet NAVD88. **In summary, waves may “push” seawater inland to an elevation of 15 ft, but at the Pepperell Cove wharf and piers, a stillwater elevation of 8.1 ft NAVD88 plus 3-foot waves (i.e. a total water level of 11.1 ft NAVD88) is likely representative of a 1% annual chance flood event under 2017 mean sea level conditions.**

We also note that although the landward side of the wharf is not classified as being within floodplain in the final effective FIRM (Figure 2 inset), this area did flood in January 2024. Wave impacts are considerably damped on the landward side of the wharf, but high stillwater levels can still lead to inundation of the wharf, boat ramp, and adjacent parking lot.

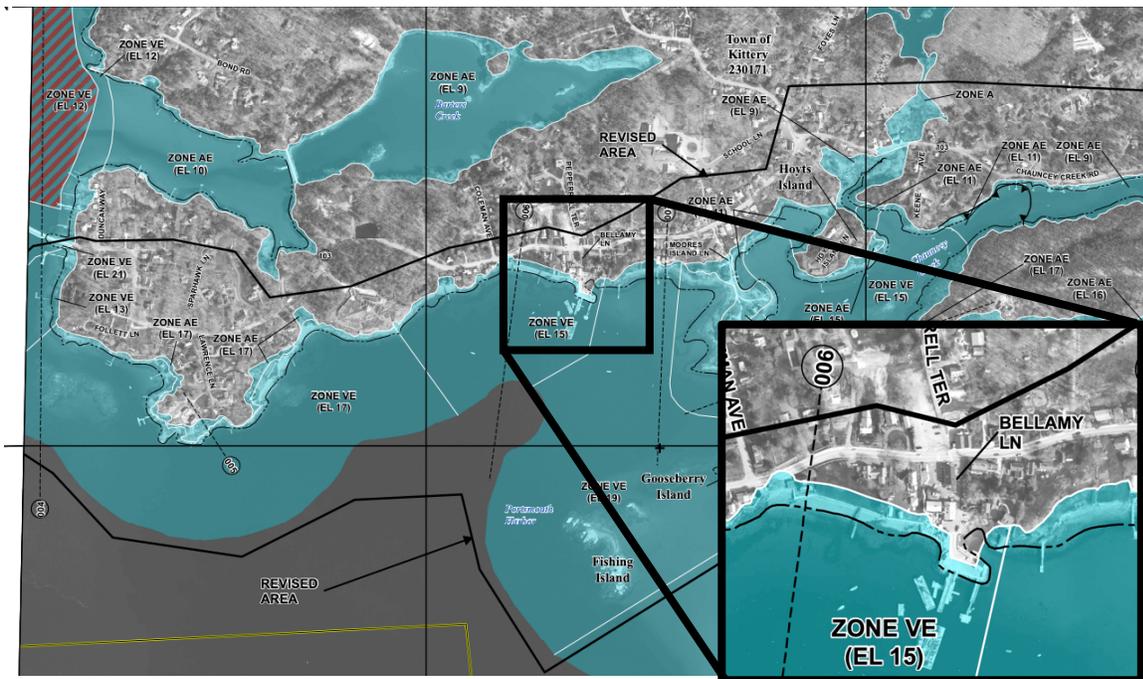
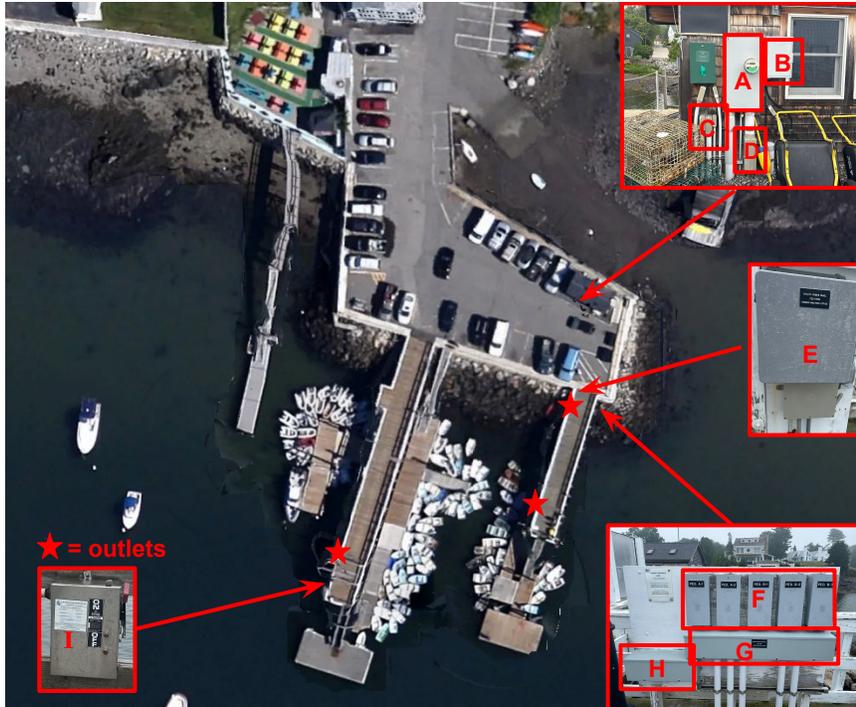


Figure 2: FEMA Flood Insurance Rate Map (FIRM) for Pepperrell Cove, effective July 18, 2024. Note that this FIRM panel was produced as a result of a 2017 Letter of Map Revision (LOMR) process that revised the flood hazard elevations in the demarcated areas above. The inset expands the area around Pepperrell Cove.

Figure 3 and Table 1 show the assets and utility fixtures with their elevations above the NAVD88 reference datum and the surface of the piers. Note that utility box elevations mark the bottom edge of each utility box. The left panel in Figure 2 shows the heights of the assets relative to the FEMA **1% annual chance stillwater level plus 3-foot waves** and the **highest astronomical tide** assuming 2017 mean sea level. The middle and right panels show the same but under 1.5 and 4 feet of sea level rise, which are the “Commit to Manage” sea level rise targets adopted by the Maine Climate Council for 2050 and 2100³. These targets are representative of the Intermediate sea level rise scenario and relative to 2000 mean sea level. Under the High sea level rise scenario, 1.5 feet remains likely by 2050, and 4 feet of sea level rise can be expected as soon as the 2080s. See Table A1 in the Appendix for more information on sea level rise projection for Kittery. Figure 3 also shows the impact of 3-foot periodic waves. Waves crashing against the bulkhead may create additional splashing, though many utilities are tolerant of wave splashing (as opposed to inundation).

Examining utility elevations relative to these water levels can guide the prioritization of adaptation measures on the wharf in the near-to-medium term. The lowest elevation utilities are power conduits that supply electricity to the piers and outlet boxes. These fixtures should be prioritized for protection or elevation measures to alleviate the possibility of flooding damage. Most of the other utilities on the wharf are above stillwater inundation levels for extreme storms through 2050, but as sea level continue to rise, they will become vulnerable to flooding before 2100; thus, adaptation measures should be incorporated into normal repair and replacement cycles to avoid undue burden in elevating and protecting them on a shorter notice. We do not quantitatively assess the durability of assets like the gangways or float systems in this report.



Pepperrell Cove Utility Elevations Relative to Water Level

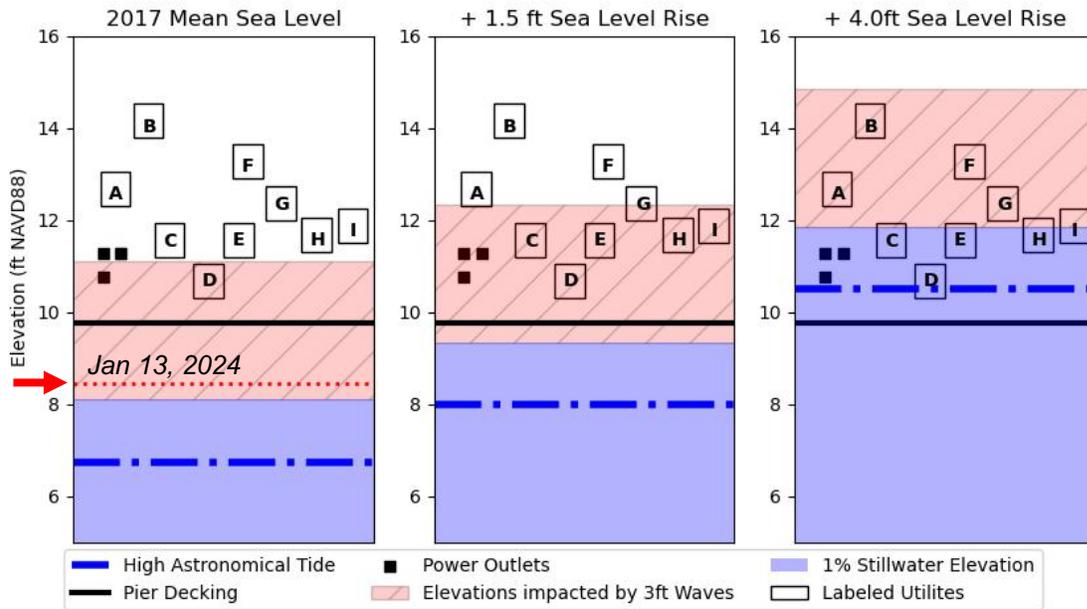


Figure 3: Elevations of Pepperrell Cove utilities and infrastructure relative to present and future flood levels. The upper panel shows locations of utilities, and the lower three panels show pier decking and utility heights relative to the modeled 1% annual chance stillwater elevation under 2017 conditions (FEMA mapping reference year), + 1.5 ft of sea level rise, and +4 ft of sea level rise. 1.5 feet of sea level rise (relative to 2000 mean sea level) is expected around 2050 under both the Intermediate and High scenarios. 4 feet of sea level rise is expected by 2100 under the Intermediate scenario and in the 2080s under the High scenario. The height of the January 13th, 2024 storm tide measured at the Seavey Island tide gauge, the highest on record in Kittery, is noted in the first panel by the red arrow and line. Adjusting the 2017 FEMA 1% stillwater elevation to 2024 sea levels would bring it to within 0.1 ft of January 13th.

Location	Structure/Utility	Height above wharf surface (inches)	Elevation (ft NAVD88)	Potential to be impacted by a flood in the 2020s	Sensitivity (potential for damage if flooded)
	Pepperrell Pier	0	9.5		Wave damage to pier decking, gangways, and hinges
	Frisbee's Pier	0	9.5		Wave damage to pier decking, gangways, and hinges
	Pepperrell Wharf + parking lot	0	9.5		Potential for fill wash-out underneath the wharf during extreme tides, leading to settlement and minor sinkholes.
	Harbormasters Shed	6"	10		Minor interior flooding during future extreme events
HM Shed	A: Power meter	33"	12.3		
HM Shed	B: Comcast box	51"	13.8		
HM Shed	C: Conduits	20-24"	11.2		
HM Shed	D: Power meter conduit box	9"	10.3		
Pepperrell Pier	E: Utility Power Panel box	20"	11.2		
Pepperrell Pier	F: Pedestal Power Conduits	41"	12.9		
Pepperrell Pier	G: Pedestal Power box	30"	12		
Pepperrell Pier	H: Pedestal Conduit	22"	11.3		
Frisbee Pier	I: Crane power box	24"	11.5		
Frisbee Pier	J: Outlet boxes	12-18"	10.5-11		Most have splash guards

Table 1: Utility elevations at Pepperrell Cove relative to wharf surface and NAVD88. The "Near-term exposure" column categorizes the current level of exposure to extreme events in the

2020s. Utilities categorized as **red** are currently lower than the elevation reached by wave crests during the 1% annual chance flood event. Utilities in **yellow** are located within 0.5 feet of the 1% annual chance stillwater plus wave height. We select 0.5 feet because seasonal-to-decadal variability in sea level and tides can increase flood hazard by about 0.5 feet during the most extreme combination of these factors. Utilities in **green** are elevated greater than 0.5 feet above the 1% annual chance total water level for the near-term (2020s). The “Sensitivity” column categorizes how damaging the inundation of each utility would be to wharf operations, based on conversations with local officials.

Shoreline Erosion

The Maine Geological Survey (MGS) publishes Coastal Bluff surveys⁸ that categorize the shoreline into typologies (ledge, armored, salt marsh, beach/flat, and no bluff) and stability (stable, unstable, highly unstable). The most recent survey for the Kittery shoreline was published in 2002. The shoreline around Pepperrell Cove is armored shoreline with no bluffs present. Additional rip rap placed in recent years contributes to the low risk of erosion at this site.

Flood mapping under future sea level rise scenarios

Figure 3 maps the extent and depth of inundation during the 1% annual chance event stillwater elevation occurring on top of 2024 mean sea level (8.5 ft NAVD88, adjusted to 2024 mean sea level using the 0.4-foot difference in annual mean sea level between 2017 and 2023 measured at the Portland tide gauge). *Note that this does not include the impact of wave action which may cause additional periodic inundation.* Figures 4 through 8 show inundation from the present-day 1% annual chance stillwater elevation with an additional 1, 2, 3, 4, and 5 feet of sea-level rise. Under the Intermediate sea level rise scenario, 1 foot of sea level rise occurs in the 2060s, 2 feet in the 2080s, 3 feet in the 2100s, 4 feet in the 2110s, and 5 feet in the 2120s. These amounts of sea level rise occur earlier under the High scenario, with 1 foot occurring in the 2050s, 2 feet in the 2060s, 3 feet in the 2070s, 4 feet in the 2080s, and 5 feet in the 2090s.



Figure 3: Pepperrell Cove: Inundation at 8.5ft NAVD88

2024 1% stillwater elevation

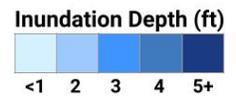


Figure 4: Pepperrell Cove: Inundation at 9.5ft NAVD88

2024 1% stillwater elevation + 1 foot of sea level rise, which occurs in the 2060s under the Intermediate scenario and 2050s under the High scenario

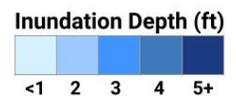




Figure 5: Pepperrell Cove: Inundation at 10.5ft NAVD88

2024 1% stillwater elevation + 2 feet of sea level rise, which occurs in the 2080s under the Intermediate scenario and 2060s under the High scenario

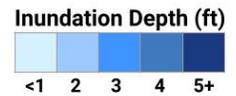


Figure 6: Pepperrell Cove: Inundation at 11.5ft NAVD88

2024 1% stillwater elevation + 3 feet of sea level rise, which occurs in the 2100s under the Intermediate scenario and 2070s under the High scenario



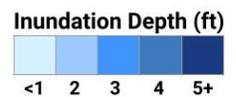
Figure 7: Pepperrell Cove: Inundation at 12.5ft NAVD88



2024 1% stillwater elevation + 4 feet of sea level rise, which occurs in the 2110s under the Intermediate scenario and 2080s under the High scenario



Figure 8: Pepperrell Cove: Inundation at 13.5ft NAVD88



2024 1% stillwater elevation + 5 feet of sea level rise, which occurs in the 2120s under the Intermediate scenario and 2090s under the High scenario

2.2 Government Street Wharf



Image: Government Street Wharf, Kittery, ME, looking south, October 12th, 2024. Credit: GMRI

The town-owned Government Street Wharf is a primary access point with an operating crane in Kittery Foreside for commercial fisherman to load and unload bait and catch. Located in Kittery Foreside, along the Piscataqua River across from Seavey Island, Government Street Wharf was constructed in 2019, replacing a wharf that was constructed in 1955 and deemed unsuitable for long-term investment in 2017. The new wharf is constructed from timber and abuts a stone-block embankment. The location of the site, with limited fetch along the river (the distance wind can travel unimpeded over water) diminishes the likelihood of large waves in the channel. From local knowledge, the largest observed wave heights along at the site are around 1 foot. The Wharf's new and durable construction ensures its protection from wave impacts associated with coastal storms. There is also limited exposure to erosion concerns as the shoreline at the site is stable ledge or stone embankment.

The sheltered nature of the site along the Piscataqua River limits the damage from wave impacts during extreme flooding events, though inundation can stress the wharf decking, leading to uplift and exposed bolts and nail heads. According to the updated FEMA FIRMs, Government Street Wharf is in a **FEMA AE zone** with a **Base Flood Elevation** of 10 feet. The lower BFE compared to Pepperrell Cove derives from the less extreme wave action in Kittery Foreside (see figure 9).

Figure 10 and Table 2 illustrate vulnerability of Government Street wharf structures and utilities under current and future conditions, following the same format as the Pepperrell Cove figures in the previous section. The elevation of the Government Street wharf is approximately 9.0 ft NAVD88 and the lowest elevation utilities are the power and control conduits for the crane at the southeastern edge of the pier (labeled E,F,G in the figure below). The stillwater elevation was below the wharf decking by about 0.5 feet on January 13th, though the periodic rise and fall of waves may have impacted the decking. By 2050, it is likely that extreme storm tides will inundate the wharf and surrounding pavement areas. The utilities were not impacted by the recent storms, though sea level rise will lead to higher extreme water levels that could damage these fixtures over the next 30 years. The impact of wave action on the Crane Phase Converter is of the highest risk. These low lying utilities should be elevated through their normal replacement or maintenance cycles. The power panel utilities (labeled A-D) are sufficiently high so as to be rendered above extreme water levels through the end of the century, likely through the life of the wharf itself.

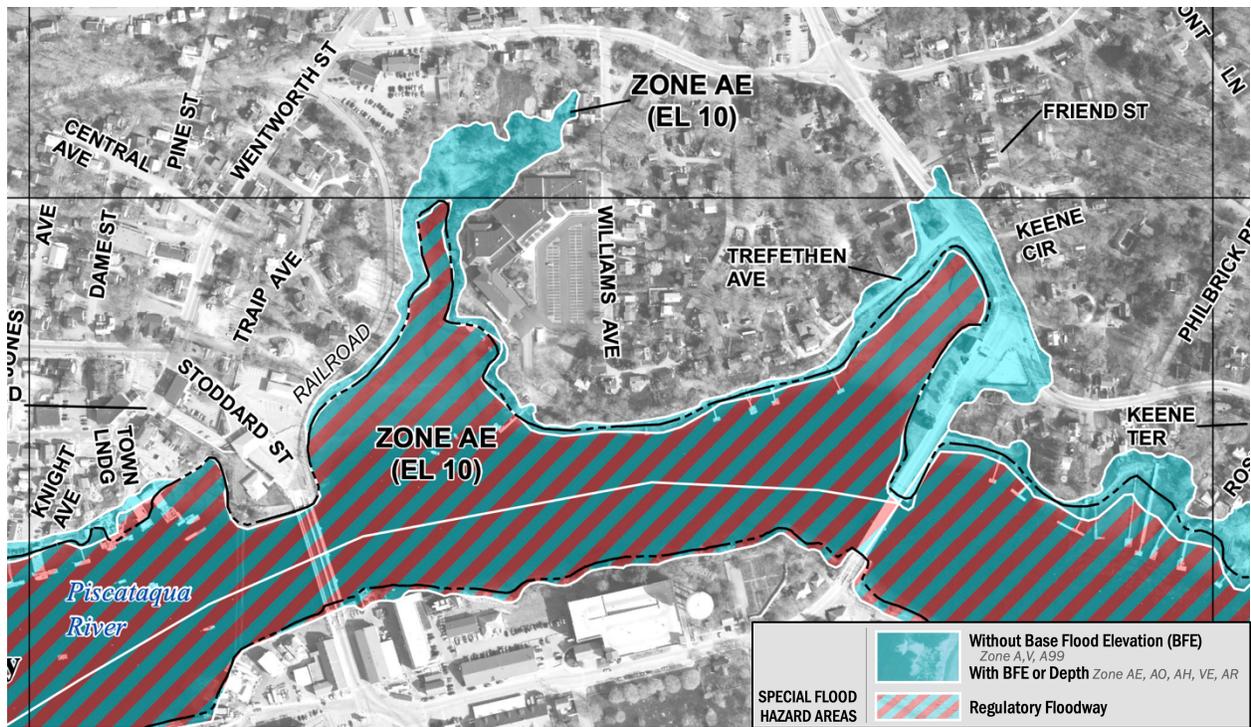


Figure 9: FEMA Flood Insurance Rate Map (FIRM) for Kittery Foreside, effective July 18, 2024.



Government Street Wharf Utility Elevations Relative to Water Level

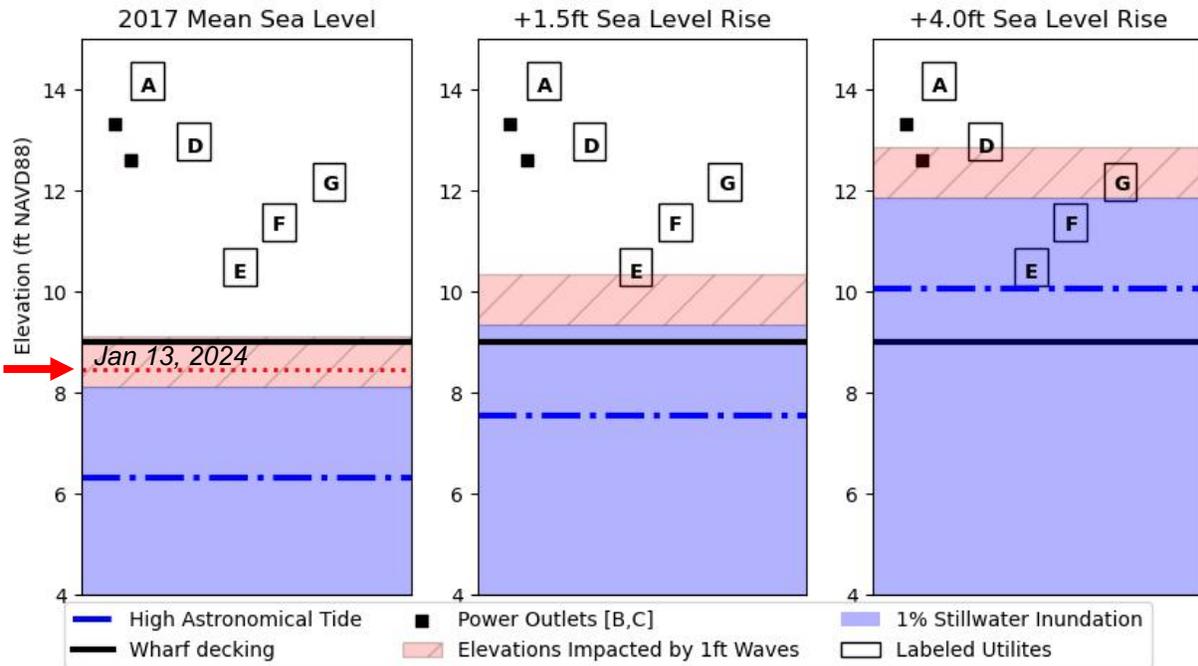


Figure 10: Utility fixture mapping at Pepperrell Cove. The upper figure depicts the location of the utilities, the lower three panels show the utility heights relative to the modeled 1% annual chance flooding event under 2017 conditions (FEMA mapping reference year), + 1.5 ft of sea level rise, and +4 ft of sea level rise. The height of the January 13th, 2024 storm tide, the highest on record in Kittery, is noted in the first panel. Adjusting the 2017 1% stillwater tide to 2024 sea levels would bring it to within 0.1ft of January 13th.

Structure/Utility	Elevation above wharf surface	Elevation height (ft NAVD88)	Near-term Exposure (2020s) (potential to be impacted by a flood)	Sensitivity (potential for damage if flooded)
Wharf decking	0"	9.00		New construction
A: Power Meter	58"	13.8		
B: Plug	52"	13.3		
C: Plug	44"	12.6		
D: Power panel	44"	12.6		
E: Crane Phase Converter	13"	10.1		
F: Crane switch	24"	11.0		
G: Conduit + sea pump breaker	33"	11.8		

Table 2: Utility elevations at Government Street Wharf relative to wharf surface and NAVD88. The "Near-term exposure" column categorizes the current level of exposure to extreme events in the 2020s. Utilities categorized as red are currently lower than the elevation reached by wave crests during the 1% annual chance flood event. Utilities in yellow are located within 0.5 feet of the 1% annual chance stillwater plus wave height. We select 0.5 feet because seasonal-to-decadal variability in sea level and tides can increase flood hazard by about 0.5 feet during the most extreme combination of these factors. Utilities in green are elevated greater than 0.5 feet above the 1% annual chance total water level for the near-term (2020s). The "Sensitivity" column categorizes how damaging the inundation of each utility would be to wharf operations, based on conversations with local officials.

4.3 Traip Academy Boat Launch

The Traip Academy Boat Launch is a popular summertime access point for recreational and commercial boaters. The physical assets at the Traip Academy Boat Launch include the boat ramp and adjacent concrete and floating pier, parking area, and harbormaster’s office. There are no electrical equipment or utilities near the water at the site, limiting its sensitivity to extreme water levels. During these extreme events, the accessibility of the site may be limited depending on how high up the boat ramp water reaches, though this is unlikely to impact users as these events typically occur during the winter when the site sees less traffic.

Currently the concrete pad that anchors the floating pier is just above the height of the Highest Astronomical Tide—5.9 feet NAVD88—which means it may be inundated on a yearly basis. Particular attention should be paid to the durability of the floating pier system to withstand inundation above the elevation of the base. The site itself is sloped above the boat ramp, reaching up to 11 feet NAVD88 at the crest of the ramp, meaning that it is unlikely to be inundated and unusable on a regular basis through the 2060s. The biggest threat is occasional winter storms that drive large storm tides, but the ramp would unlikely be in use during such events.

Structure/Utility	Elevation height (ft NAVD88)	Near-term Exposure (2020s) <i>(potential to be impacted by a flood)</i>
Harbormasters Office	16.2	
Boat Launch Parking Area	12.5 – 14	
Concrete pier base	6.8*	

Table 3: Asset elevations at the Traip Academy Boat Launch relative to NAVD88. The “Near-term exposure” column categorizes the current level of exposure to extreme events in the 2020s. Assets categorized as red are currently lower than the elevation reached by wave crests during the 1% annual chance flood event. Utilities in green are elevated greater than the 1% annual chance total water level for the near-term (2020s).

*The elevation for the concrete pier base was acquired using LIDAR elevation data, which, because the base is so small and the presence nearby obstacles such as trees and poles, may not be entirely accurate. This elevation could be confirmed by comparing to a high tide line and referencing the Seavey Island tide gauge.

Shoreline Erosion

The Traip Boat Launch is the only town-owned site that has a moderate risk of shoreline erosion. The adjacent shoreline to the northwest of the site is categorized as “Unstable, Salt Marsh”, the shoreline to the east of the site is categorized as “Unstable, Armored.” where the level of stability can be classified as “stable, unstable, or highly unstable.” See the MGS Coastal Bluffs Map for more information.⁸ Shoreline erosion rates are difficult to quantify, though rising sea levels will likely increase erosion rates. A recommendation would be to record and document the current shoreline profile and monitor changes in the profile over the coming years, especially following extreme water level events.

Floodplain Mapping for Kittery Foreside



Figure 11: Kittery Foreside: Inundation at 8.5ft NAVD88

2024 1% stillwater elevation



Figure 12: Kittery Foreside: Inundation at 9.5ft NAVD88

2024 1% stillwater elevation + 1 foot of sea level rise, which occurs in the 2060s under the Intermediate scenario and 2050s under the High scenario

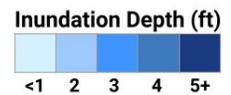




Figure 13: Kittery Foreside: 10.5ft NAVD88 SWEL.
 2024 1% stillwater elevation + 2 feet of sea level rise, which occurs in the 2060s under the Intermediate scenario and 2080s under the High scenario



Figure 14: Kittery Foreside: Inundation at 11.5ft NAVD88
 2024 1% stillwater elevation + 3 feet of sea level rise, which occurs in the 2070s under the Intermediate scenario and 2100s under the High scenario



Figure 15: Kittery Foreside: Inundation at 12.5ft NAVD88

2024 1% stillwater elevation + 4 foot of sea level rise, which occurs in the 2110s under the Intermediate scenario and 2080s under the High scenario



Figure 16: Kittery Foreside: 13.5ft NAVD88

2024 1% stillwater elevation + 5 feet of sea level rise, which occurs in the 2120s under the Intermediate scenario and 2090s under the High scenario

Appendix:

A.1 Drivers of Coastal Flooding Hazard in Kittery

The combined impacts of rising sea level, high tides, storm surge, and waves all contribute to coastal flooding (Figure 1). Natural planetary cycles cause tidal range to vary over daily-to-decadal timescales, and the highest tides can cause minor flooding, even in the absence of stormy weather. In Kittery, the average greater diurnal tidal range (the distance between mean higher high and mean lower low water) is 8.89 feet, but the highest astronomical tide (HAT) can raise water level an additional 1.7 feet above mean higher high water. Storm surge is the prolonged rise in water level above the predicted tide, caused by strong and persistent winds driving ocean water toward land. Storm surges from extratropical cyclones rather than tropical cyclones (hurricanes) have driven the vast majority of extreme coastal floods in the Gulf of Maine because they are more common and larger, slower-moving storms that cause longer-duration surges more likely to intersect with high tide.^{9, 10} There is also not statistically significant evidence that climate change will drive higher or more frequent storm surges in the Gulf of Maine in the future.^{11,12} Storms with southeasterly winds, such as the recent January 10 and 13 storms in 2024, drive the largest storm surges in Kittery and along most of Maine's coast due to the open-ocean exposure of the coastline in the southeast direction.³ It is currently unknown whether climate change is causing storms with southeasterly winds to become more common.¹³

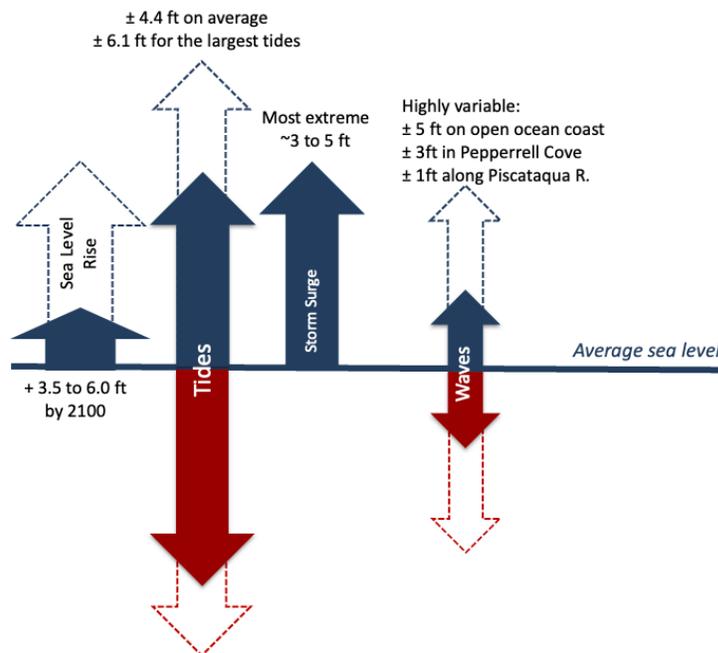


Figure A1 Processes that raise and lower water level in Kittery

A.2 Recent Sea Level Rise and Future Projections

In 2020, the Maine Climate Council's Scientific and Technical Subcommittee (MCC STS) recommended that Maine "Commit to Manage" 1.5 feet of sea level rise in 2050 and 4.0 feet in 2100.² These values are relative to mean sea level in the year 2000. Subsequently, Public Law Ch. 67 *Resolve, To Analyze the Impact of Sea Level Rise* was enacted June 16, 2021, and it directs seven state agencies to incorporate consideration of 1.5 and 4.0 ft of sea level rise into administration of their laws and rules. The "Commit to Manage" values selected by the MCC STS correspond to statewide averages for Intermediate sea level rise scenario developed by the National Oceanographic and Atmospheric Administration (NOAA) in 2017.¹³

The MCC STS released an updated assessment in 2024 indicating that these targets remain valid for the purposes of public law.³ However, they recommend using updated localized Intermediate and High scenario sea level projections from the 2022 U.S. Interagency Task Force report "for planning applications at specific locations over specific time periods," where the choice of the Intermediate versus High scenario should depend on the "risk associated with flooding the asset under consideration".¹³

Table 1 provides sea level projections for Kittery for the updated Intermediate and High scenarios. These projections are referenced to 2000 mean sea level, which is calculated as average sea level over the 19-year period centered on the year 2000 (1991-2009). It is difficult to quantify exactly how much sea level has risen since 2000 because there is significant year-to-year variability in sea level due to currents and broader climate patterns such as the North Atlantic Oscillation (see inset in Figure A2). Using the average rate of SLR over the past 30 years in Portland (0.12 ft/decade, or 3.57 mm/year), sea level rose 0.29 ft between 2000 and 2023 (present).¹² However, 2023 mean sea level was 0.7 ft above 2000 mean sea level in Portland (this contributed to the two extreme flooding events in January 2024; see Figure 2 inset. Note that we use the Portland gauge because it has a longer record and fewer data gaps than Seavey Island, and although tides and surge vary slightly between Kittery and Portland, mean sea level is roughly consistent between the two sites.

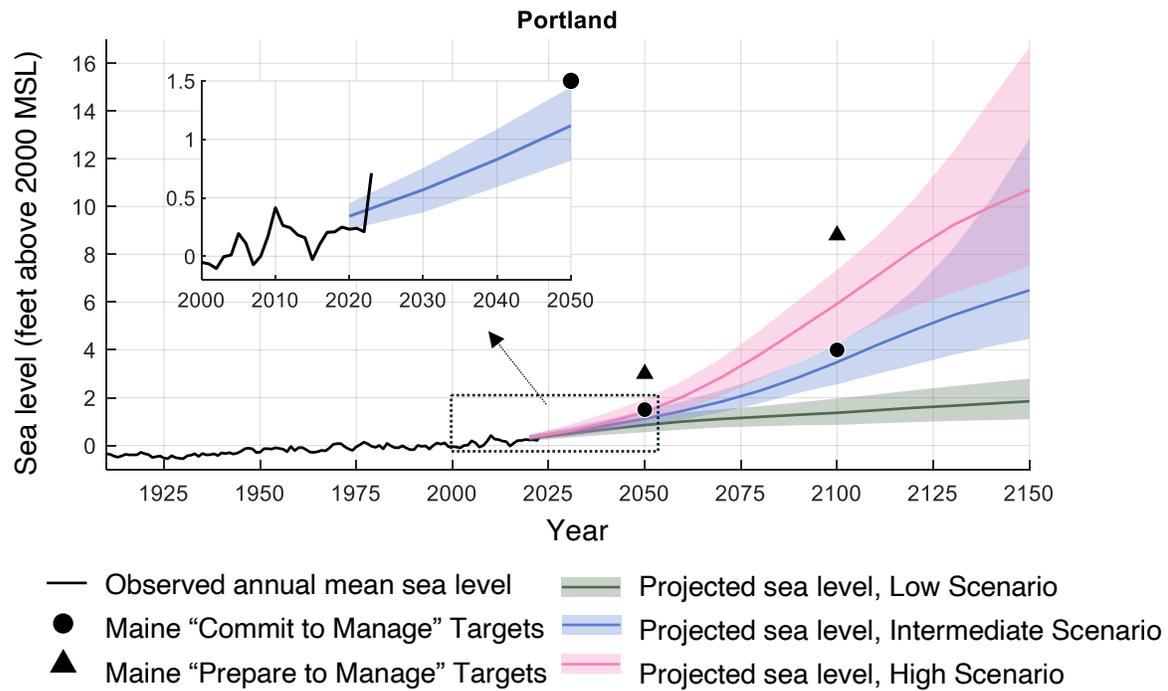


Figure A2. Observed and projected sea level rise in Portland (Maine Climate Council STS Report, 2024, p. 7).¹² The black line shows measured annual mean sea level from 1912 through 2023. Green, blue, and pink lines and shading show projected future sea level rise 2020 through 2150 for the Low, Intermediate, and High scenarios, respectively, from the 2022 U.S. Interagency Task Force report (see table below for tabulated values by decade)¹³. Lines show median estimates, and the shaded regions show the statistically likely range (17th to 83rd percentile) for each scenario. Black circles on each panel mark Maine’s “Commit to Manage” targets of 1.5 ft of sea level rise in 2050 and 4 ft in 2100. Black triangles show the high-end “Prepare to manage” targets of 3 ft and 8.8 ft. The inset in the upper-left corner shows a close-up view of measured and Intermediate scenario projected sea level rise between 2000 and 2050.

Sea Level Rise Projections (Feet relative to 2000 MSL, valid Kittery – Freeport)					
	Intermediate <i>Med (17th, 83rd)</i>	High		Intermediate	High
2030	0.58 (0.39, 0.78)	0.61 (0.40, 0.86)	2100	3.49 (2.59, 4.23)	5.98 (4.40, 7.35)
2040	0.85 (0.60, 1.11)	0.97 (0.64, 1.36)	2110	4.21 (3.02, 5.22)	7.18 (5.19, 8.78)
2050	1.13 (0.83, 1.47)	1.42 (1.01, 1.95)	2120	4.86 (3.42, 6.48)	8.22 (5.94, 10.30)
2060	1.46 (1.09, 1.87)	2.06 (1.50, 2.69)	2130	5.45 (3.80, 8.20)	9.29 (6.45, 12.40)
2070	1.84 (1.41, 2.33)	2.88 (2.12, 3.68)	2140	5.95 (4.16, 10.30)	10.10 (6.95, 14.47)
2080	2.30 (1.79, 2.85)	3.84 (2.83, 4.83)	2150	6.51 (4.49, 12.82)	10.82 (7.5, 16.74)
2090	2.87 (2.21, 3.48)	4.93 (3.60, 6.15)			

Table A1. Projected sea level rise in Portland for the Intermediate and High scenarios from the 2022 U.S. Interagency Task Force report.¹³ Estimates include the median estimate, as well as the 17th and 83rd percentiles.

A.3 Extreme Water Levels

Estimates of present and future extreme water levels driven by the combination of high tides, surge, and waves are useful for coastal planning. Local knowledge of recent extreme events and Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRMs) can both be used to characterize present-day extreme flood hazard. In participating communities, the FEMA National Flood Insurance Program requires properties to purchase flood insurance if they are located within the area that has a 1% annual chance of being flooded (colloquially called the “100-year flood zone”), and FEMA publishes Flood Insurance Rate Maps (FIRMs) delineating these areas.

Updated FEMA FIRMs became effective on July 17th, 2024, in Kittery. These maps show the combined effects of tides, storm surge, and waves on top of 2017 mean sea level. Accompanying FEMA Flood Insurance Studies (FIS) delineate extreme value statistics for coastal transects in Kittery. Extreme stillwater levels are the same along all coastal transects in Kittery, but wave impacts vary. Table A2 provides the FEMA estimate of the 1% annual chance stillwater elevation, the NOAA CO-OPS estimate derived from fitting a statistical distribution to the Seavey Island tide gauge record, as well as the water level recorded by the gauge on January 13th, 2024. Adjusting the NOAA CO-OPS estimate from the 1992 mean sea level baseline to 2017 mean sea level and the January 13th event from 2024 mean sea level to 2017 mean sea level aligns all these estimates around 8.1 feet NAVD88.

	FEMA LOMR	NOAA CO-OPS Seavey Island statistical estimate	January 13, 2024 observed at Seavey Island
1% SWEL (ft, NAVD88), adjusted to 2017 mean sea level	8.1	8.1	8.1
1% SWEL (ft, NAVD88), relative to original varying baseline sea level years	8.1 (2017 MSL)	7.78 (1992 MSL)	8.46 (2024 MSL)

Table A2: The 1% annual chance SWEL in Kittery from the updated 2024 FEMA Flood Insurance Study (based on modeling by Ransom Consulting, LLC)⁶, the estimate of the 1% annual chance stillwater elevation from the tide record at Seavey Island, and the water level measured at the Seavey Island tide gauge on January 13, 2024.

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