FUTURE HIGH WATER LEVELS IN RYE | MEMORANDUM

TO: Kim Reed, Town of Rye; Deb Loiselle, NHDES
FROM: Magdalyn Kosalek and Cayce Dalton, FB Environmental Associates
SUBJECT: Future High Water Levels in Rye, NH (Task 3)
DATE: March 28, 2024
CC: Matthew Scruton, Becky Bergeron, Jason Rucker, Chuck Marsden, Town of Rye
Deb Loiselle, Sally Soule, Dennis Greene, NHDES
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OVERVIEW

This memo provides an overview of research on of future flooding related to climate change in the Town of Rye, New Hampshire. A changing climate generates high water levels through several effects, including sea level rise, storm surge, groundwater rise, and spring tides. Below, various scenarios and predictions of future surface and groundwater conditions are reviewed, specific scenarios are selected for planning purposes, and geographic areas which will be most affected are identified. This research will be used to inform municipal level planning, outreach, and education in the Parsons Creek watershed, as part of a long-term effort to reduce and prevent fecal pollution to the creek and downstream beaches. This memo is a final deliverable under Task 3 of the New Hampshire Department of Environmental Services (NHDES) Clean Water State Revolving Fund / ARPA-funded project entitled "Restoring Parsons Creek" (Project Number CW-334230-01).

Sea level rise (SLR) is the steady increase in sea levels over time, including mean higher high water (MHHW), due to climate change. It is expected that the northeastern U.S. will experience SLR higher than that of the global average due to factors of changing ocean circulation patterns in the northwest Atlantic Ocean and land subsidence from glacial isostatic adjustment, putting Rye, NH at relatively greater risk than other areas (Knott et al., 2019).

Storm surge is the combination of wave run up and set up as well as wind set up caused by weather events. Storm surge is a main cause of flooding, and with rising sea levels and more severe weather events, the storm surge and subsequent flooding will become more intense and affect more land area.

Groundwater rise (GWR) is the increasing of groundwater levels caused by SLR. GWR is an important risk multiplier in coastal areas as it can affect additional land areas beyond those affected by SLR surface inundation. GWR reduces the life of pavement, compromises the effectiveness of onsite wastewater treatment systems temporarily or permanently, and infiltrates wastewater collection systems (Knott et al., 2019). GWR of one foot (30 cm) has been found to increase the release of fecal bacteria, and nutrient pollution including phosphorus and nitrogen (Cooper et al., 2016). Research on wastewater systems in southern Rhode Island found that 40% of existing systems are compromised by seasonal high water half of the time, and 30% are affected all the time; and the systems' ages were not correlated with this problem (Cox et al., 2020b). While the geology of that study area consisted of coarse, sandy, highly transmissive soils unlike most of Rye, it nonetheless highlights that in some coastal New England areas high groundwater is already a severe problem. GWR also threatens the delicate balance between fresh and salt water in freshwater wetlands and salt marshes (Knott et al., 2019).

“King Tide” is an informal name for extra high tides, which can have a variety of causes. Spring tides are higher high tides which occur when the moon, sun, and earth are aligned during a full or new moon and gravitational pull is maximized. The distance between the earth and moon also goes through an approximately 28 day cycle (not identical to the moon phases cycle). The moon’s closest point to the earth is called “perigee.” On the 6 to 8 times per year when a full or new moon coincides with the perigee, the resulting “perigean spring tides” can be exceptionally high. The highest tides of the year may also depend on other factors such as the seasonal expansion of warmer water or other weather conditions (NOAA, 2022). With rising sea levels, scientists are exploring how tides, mean sea level, and coastal groundwater levels will be impacted. In general, higher mean sea level is expected to exacerbate “king tides,” so that the vertical amount of predicted SLR alone does not fully reflect the risk to infrastructure and safety.

For all of the above reasons, over the coming decades the Town of Rye is predicted to experience increased flooding. Among the many effects of these environmental changes will be damage to existing onsite wastewater treatment systems, which, if not properly managed, will increase fecal-related pollution to Rye’s wetlands, streams, and beaches. Insight into the types of damage possible is described from field inspections of onsite wastewater treatment systems reviewed by Cox et al. (2020a) after superstorm Sandy in Rhode Island. That research found that some damage from coastal flooding to onsite wastewater systems is ephemeral, with wastewater treatment efficacy reduced during the flooding but eventually returning when flood waters recede. An example of ephemeral damage includes reduction in unsaturated treatment area under the drainfield leading to inadequate treatment, which can result in elevated bacteria levels to streams and beaches for several days after the storm event. Other damage is permanent and requires system repairs to restore wastewater treatment. Mechanisms of permanent damage from temporary storm conditions included the following:

- Inundation for several days can disrupt gravity fed systems by dislocating buoyant components (e.g., a distribution box in waterlogged soils could float out of alignment with pipes to the drainfield).
- Sediment could clog void spaces within system components.
- Electrical components critical for advanced wastewater systems could be destroyed.

The following sections summarize SLR, GWR, and other climate effects as researched and presented by the NH Coastal Flood Risk Summary (Part I and II), NOAA, the Rockingham Planning Commission, NH GRANIT (statewide geographic data clearinghouse), and the NH Coastal Adaptation Workgroup on each of these factors.

SEA LEVEL RISE

NH Coastal Flood Risk Summary

The New Hampshire Coastal Flood Risk Summary is a two-part document created in 2019-20 by the Science and Technical Advisory Panel, convened by NHDES. The panel consists of members from the New Hampshire Department of Transportation, Division of Homeland Security and Emergency Management, Office of Strategic Initiatives, NH Fish and Game Department, Department of Natural and Cultural Resources, Department of Administrative Services, Rockingham Planning Commission, Strafford Regional Planning Commission, University of New Hampshire, coastal municipalities, and New Hampshire Coastal Adaptation Workgroup. Part one of the document, published in August 2019, outlines the science behind coastal flood risks, including projections of sea level rise, coastal storms, GWR, precipitation, and freshwater flooding. Part two of the document, published in March 2020, provides guidance for a step-by-step approach to applying the information from part one to mitigation projects.

The New Hampshire Coastal Flood Risk Summary predicts that coastal NH is likely to experience 0.5 – 1.3 feet of uniform sea level rise between 2000 – 2050, likely not reaching 0.9 feet, if global greenhouse gas emissions stabilize. By 2100, it predicts that coastal NH is likely to experience 1.0 – 2.9 feet of uniform sea level rise if global greenhouse gas emissions stabilize. Wake et al. (2019) recommend that the best scenario for predicting SLR in coastal New Hampshire is that greenhouse gas emissions stabilize then begin to decline after 2050. This choice is defined as "Representative Concentration Pathway (RCP) 4.5" and its corresponding SLR values can be seen in Table 1. Figure 1 provides another look at these predictions for coastal New Hampshire. This corresponds to the "Likely Range" column from Table 1 for RCP 4.5. (NH Coastal Flood Risk Science and Technical Advisory Panel, 2020)

Table 1: Values selected by Wake et al. (2019) for projected SLR along coastal NH, as presented by NH Coastal Flood Risk Science and Technical Advisory Panel (2020). All are based on Representative Concentration Pathway (RPC) 4.5.

Year	RCP	Central Estimate 50% probability SLR meets or exceeds:	Likely Range 67% probability SLR meets or exceeds:	1-in-20 Chance 5% probability SLR meets or exceeds:	1-in-100 Chance 1% probability SLR meets or exceeds:	1-in-200 Chance 0.5% probability SLR meets or exceeds:
2050	RPC 4.5	0.9	0.5-1.3	1.6	2.0	2.3
2100	RPC 4.5	1.9	1.0-2.9	3.8	5.3	6.2
2150	RPC 4.5	2.7	1.2-4.6	6.4	9.9	11.7

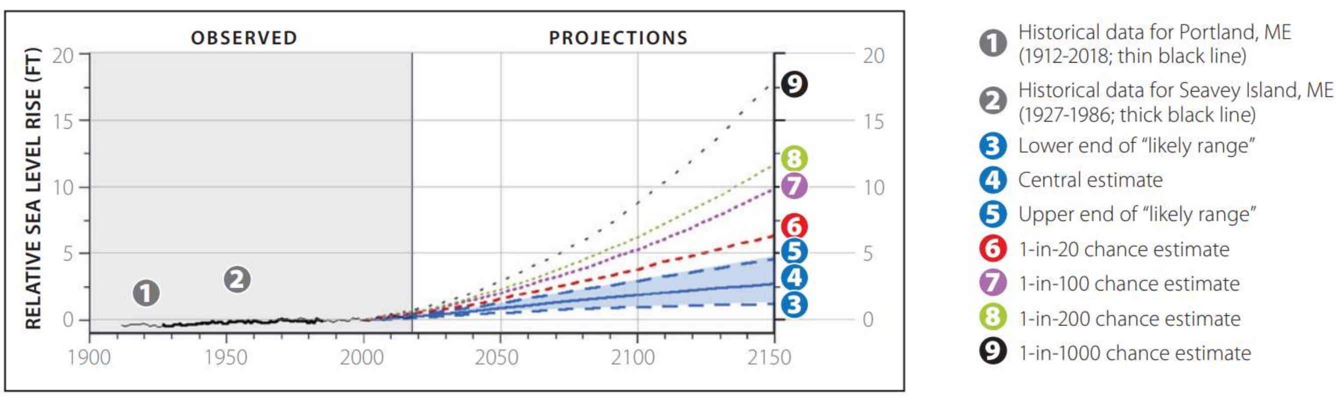

Figure 1: Projected SLR range for coastal NH under RPC 4.5, as presented by NH Coastal Flood Risk Science and Technical Advisory Panel (2020) in the New Hampshire Coastal Flood Risk Summary, Part II: Guidance for Using Scientific Projections (Figure 2 in that report).

NOAA

NOAA released localized SLR predictions in "Global and Regional Sea Level Rise Scenarios for the United States" in February 2022. The predictions in this are based on "dynamic modeling" for SLR scenarios as opposed to tide gauge-based modeling. Tide gauge-based modeling does not consider wave processes or non-linear impacts of SLR, making it less accurate than dynamic modeling which takes these into account along with other factors (Baranes, 2022). The "intermediate-high" predictions made by NOAA for the U.S. Northeast are 1.61 ft by 2050, 5.25 ft by 2100, and 8.86 ft by 2150. These predictions are relative to the baseline year of 2000 (Sweet et al., 2022). Water level baseline datums are typically calculated over a 19-year period to account for cyclical astronomical, oceanic, and atmospheric variability, thus the 2000 datum (1991-2010) is the most recent usable datum (Baranes, 2022). NOAA indicates that they are able to make increasingly accurate predictions for SLR due to longer record lengths including a satellite altimeter record that is nearing three decades in length. These longer record lengths make extrapolation of future predictions more accurate. This is especially true for short term predictions (until 2050). These predictions also take into consideration updated scenarios for the Greenland and Antarctic ice sheet contributions. (Sweet et al., 2022)

Rockingham Planning Commission

The Rockingham Planning Commission (RPC) serves in an advisory role to local governments in Rockingham County to ensure and promote coordinated planning, growth, efficient land use, environmental protection, and transportation access. The RPC created the document "From Tides to Storms: Preparing for New Hampshire's Future Coast" to assess the vulnerability of the towns of Portsmouth, New Castle, Rye, North Hampton, Hampton Falls, and Seabrook to coastal flooding due to expected increase in rates of SLR and storm surge. The RPC also created a draft "Rye Master Plan" in 2016 in which they assess topics including but not limited to coastal hazards and other climate related impacts specific to Rye, NH. The Rockingham Planning Commission used data from the U.S. National Climate Assessment to predict SLR in Rye, as seen in Table 2 (Rye Master Plan 2016). The RPC also provides estimates from Wake et al. (2011) as shown in Table 3.

Table 2: SLR scenarios used by the Rockingham Planning Commission (from Rye Master Plan 2016), based on the National Climate Assessment using mean sea level in 1992 as a reference. Sea level rise and storm surge measured from Mean Higher High Water, which in NH is 4.4 feet, using average of highest tides over 19-year period. Storm surge is defined as the area flooded by the current 100-year (or 1% chance annually) storm event.

Time Period	Intermediate Low	Intermediate High	Highest
Year 2050	0.6 ft.	1.3 ft.	2.0 ft.
Year 2100	1.6 ft.	3.9 ft.	6.6 ft.

Table 3: SLR scenarios based on greenhouse gas emissions from Wake et al. (2011), adapted from Tides to Storms: Preparing for New Hampshire's Future Coast (Rockingham Planning Commission, 2015). Shows estimates of future 100-year flood levels at the Fort Point Tide gauges under two emission scenarios. Estimates are in feet relative to North American Vertical Datum (NAVD) 1988. MHHW: Mean Higher High Water at Fort Point, NH. Total Stillwater Elevation may not equal total of components due to rounding.

	Lower Emissions (B1)		Higher Emissions (A1fi)	
Year →	2050	2100	2050	2100
Current Elevation of MHHW	4.43	4.43	4.43	4.43
100-Year Flood Height	7.78	7.78	7.78	7.78
Subsidence	0.012	0.016	0.012	0.016
Eustatic SLR	1.0	2.5	1.7	6.3
Total Stillwater Elevation	13.2	14.7	13.9	18.5

NH GRANIT

The New Hampshire Geographically Referenced Analysis and Information Transfer System (NH GRANIT) is a cooperative that has created and maintains a statewide geographic database. NH GRANIT created the New

Hampshire Coastal Viewer (www.nhcoastalviewer.org) which allows users to select certain layers to view on a map such as various SLR scenarios, GWR caused by SLR scenarios, beach shoreline change, and much more.

The SLR scenarios database is called Sea Level Rise: New Hampshire Open Coast, Piscataqua River, and Great Bay. The database was curated and published by the Earth Systems Research Center at the University of New Hampshire on June 18, 2019. The curator used methodologies established by AECOM from a prior coastal sea level rise estimation project. Figure 2 displays various SLR scenarios obtained through NH GRANIT Coastal Viewer. Figure 3 shows the same scenarios zoomed to Parsons Creek.

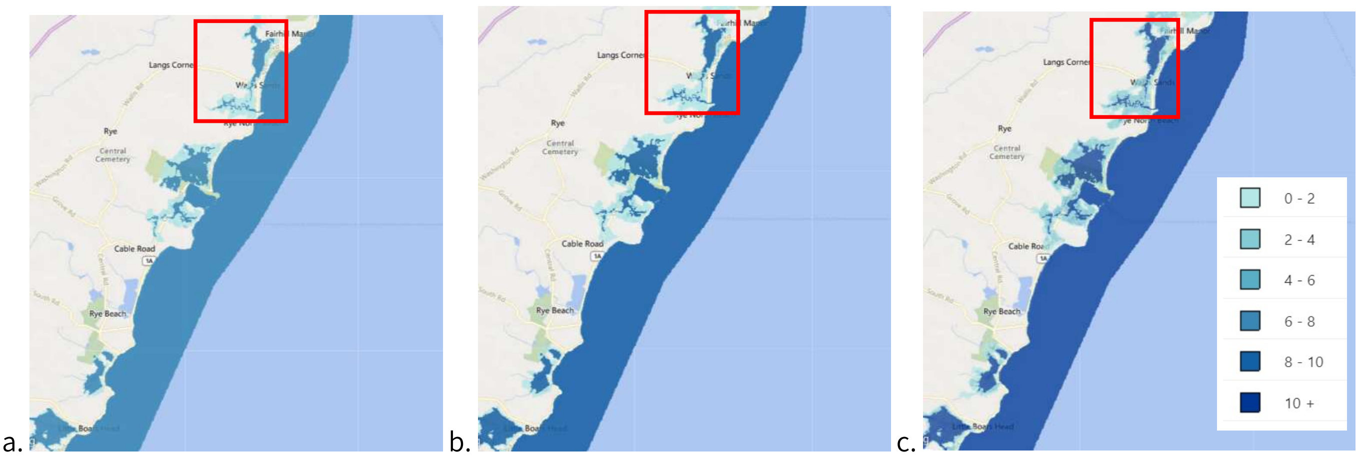

Figure 2: SLR along the Rye coastline of 1 ft (a), 2 ft (b), and 4 ft (c). Parsons Creek is marked by the red box (NH GRANIT, 2021).

Figure 3: SLR at Parsons Creek of 1 ft (a), 2 ft (b), and 4 ft (c) (NH GRANIT, 2021).

NH Coastal Adaptation Workgroup

The NH Coastal Adaptation Workgroup (NH CAW) does not provide its own data; however, it does provide resources about coastal resilience planning that CAW members find useful for municipal decision making. The NH Coastal Viewer and underlying data are accessed at www.nhcoastalviewer.org. Data are categorized under “Oceans and Coasts”, then “Sea Level Rise Scenarios” and “Groundwater Rise (ft) Caused by Sea Level Rise.” The following resources are provided by NH CAW:

- NH Coastal Flood Risk Summary (Part I, 2019 and Part II, 2020; described above)
- NH Flood Hazards Handbook (2019); Federal Funding Opportunities for Flood Resilience

- Climate Risk in the Seacoast (C-RiSe); From Tides to Storms: Preparing NH's Coast, Climate Change in Southern NH
- NH Coastal Risk & Hazards Commission Report; Science & Technical Advisory Panel Report (2014)
- NH Hazard Mitigation Assistance Resource Center; NH Coastal Floodplain Mapping Project; Seabrook Hamptons Estuary Alliance (SHEA)
- Assessing Flood Risk in The Lamprey River Watershed
- The New Hampshire Coastal Viewer
- Data: Extreme Precipitation in New England
- The Infrastructure and Climate Network (ICNET)
- Upper Valley Adaptation Workgroup (UVAW)
- Transportation and Climate Change Clearinghouse
- National Climate Assessment (2014)
- IPCC 5th Assessment Report (2014)
- National Climate Assessment (2018)

The NH Flood Hazards Handbook, developed by the New Hampshire Silver Jackets, provides information and advice regarding actions to take "Before the Flood," "During the Flood," and "After the Flood" (2019). The "Before the Flood" section identifies flood risks including stream crossings, ice jams, dams, and extreme precipitation and high sea levels. The handbook highlights the NH Stream Crossing Initiative which analyzes stream crossings all over the state to determine risk of failure during flooding events. The closest stream crossing to Parsons Creek that was analyzed is near the intersection of TJ Gamester Ave and FW Hartford Dr in Rye (represented by the green dot in Figure 4). This stream crossing was determined to be able to withstand up to 100-year flooding. The flood history reports (represented by the black flags in Figure 4) surrounding the Parsons Creek area briefly describe flood history records from the town hazard mitigation plan. The risk for each flagged area is as follows:

- <u>Flag 1:</u> at risk from ocean flooding and experiences splash over and flooding on the road, which is slow to drain (source: Homeland Security & Emergency Management (HSEM) Meeting 9/5/2017)
- <u>Flag 2:</u> sometimes floods at the crossing from tidal impacts, and it takes four tidal cycles to flush the water out (source: HSEM Meeting 9/5/2017)
- <u>Flag 3:</u> never seen to be flooded during King Tide; however, when it is flooded by tidal action, it also takes four tidal cycles to flush the water out (source: HSEM Meeting 9/5/2017; Rye Hazard Mitigation Plan 2016)
- <u>Flag 4:</u> has been flooded in the past at the intersection of Wallis Road and Brackett Road (source: Storm Damage Reports 1/4/2018)
- <u>Flag 5:</u> has large beaver dams that cause water to back up upstream (source: HSEM Meeting 9/5/2017)
- <u>Flag 6:</u> represents a location on Long John Road that dips in elevation at a stream/wetland crossing and is impassable during a large storm. This culvert has required maintenance due to frequent blockage by the beaver dams downstream (source: HSEM Meeting 9/5/2017; Rye Hazard Mitigation Plan 2016)

Figure 4: Map of the Parsons Creek area from the NH Aquatic Restoration Mapper. The green dot labeled "Pass" (south of Elwyn Park) identifies a stream crossing that was analyzed and determined to be adequate to withstand up to the 100-year storm. Areas identified as "No Rating" are other stream crossings which could not be confirmed as passing. The black flags represent locations where there are flood history reports. Areas north of Washington Road and east of Sagamore Road are in the Parsons Creek watershed. (NHDES, NHDOT, NH Geologic Survey, NH Fish and Game, NH Department of Safety)

Each of these stream crossings are clearly at risk during heavy flooding and thus rising sea levels in the long term (NH Stream Crossing Initiative). The NH Flood Hazards Handbook does not identify any sites at risk for ice jam in coastal NH. The handbook notes that 300 dams in NH are identified as significant or high hazard should they fail; however, it does not give a source to identify where these are. In regard to extreme precipitation and rising sea levels, the handbook uses the NH Coastal Viewer as a resource (previously described above).

The Science and Technical Advisory Panel convened by NHDES as part of the NH Coastal Flood Risk Summary (discussed above) summarizes projected sea level rise from three sources: the National Research Council assessment of sea-level rise, the Intergovernmental Panel on Climate Change assessment of sea-level rise, and global sea-level rise scenarios developed for the National Climate Assessment (2014). These projections are globally based and somewhat dated, so they will not be discussed here. The projections specific to coastal NH, described above, are a more appropriate basis for planning.

STORM SURGE

NH Coastal Flood Risk Summary

Two estimates are highlighted in this summary. FEMA estimates four feet of storm surge for the 100-year return period at the mouth of the Piscataqua River. The North Atlantic Comprehensive Coastal Study predicts 5.3 feet for the 100-year return period (USACE, 2015). Wake et al. (2019) claim that the maximum water levels along the open coast of NH are higher than that at the mouth of the estuary due to wave set-up, wave run-up, and wind set-up directly on the shoreline.

NOAA

The NOAA source provides calculated predictions for minor, moderate, and major flooding levels that are based on FEMA storm surge values and individual tide gauge information. Minor flooding is defined as causing minimal or no property damage but possibly some threats to the public, and triggers a flood advisory. Moderate flooding involves minor inundation near streams of structures and roads requiring some evacuations, and merits a flood warning. Major flooding results in extensive inundation of buildings and roads causing significant damage, requires major evacuation, and also merits a flooding warning. (NWS, 2019; and NWS, undated)

The closest tide gauge to Rye is Fort Point, NH. The predictions for flooding levels in this area are 2.02 ft for minor flooding, 2.84 ft for moderate flooding, and 4.22 ft for major flooding. These predictions are based on the time period from 1983-2001. Annual average event frequencies predicted for 2050 in the Northeast Atlantic are greater than ten events for minor floods, 6 moderate floods, and 0.4 major floods. These are compared to the current (2020) annual frequencies of 4 minor floods, 0.6 moderate floods, and 0.09 major floods. These frequency predictions are the highest of any region in the U.S., showing that the northeast US is at a particularly high flood risk due to SLR impacts. (Sweet et al., 2022)

Rockingham Planning Commission

The RPC states that there is insufficient basis in scientific literature to determine whether or not storm surge will increase in the future. However, they do recognize that storm surge paired with SLR will result in increased flooding and expansion of the coastal floodplain. The RPC analyzed and compared rainfall data from the 1960s to data in 2014 and found that rainfall for the 50-year and 100-year storms has increased 25% and 35%, respectively, in Rye. (Rye Master Plan 2016)

NH GRANIT

The NH GRANIT database for storm surge is included in the same database as the SLR scenarios (Sea Level Rise: New Hampshire Open Coast, Piscataqua River, and Great Bay). Figure 5 and Figure 6 display the NH GRANIT Coastal Viewer scenarios for SLR + storm surge along the Rye coastline. For a more detailed map of SLR in the Parsons Creek watershed, see Figure 10; for storm surge, see Figure 11. “1% storm surge” refers to the storm surge caused by the 1% annual chance flood. This is also referred to as the 100-year flood.

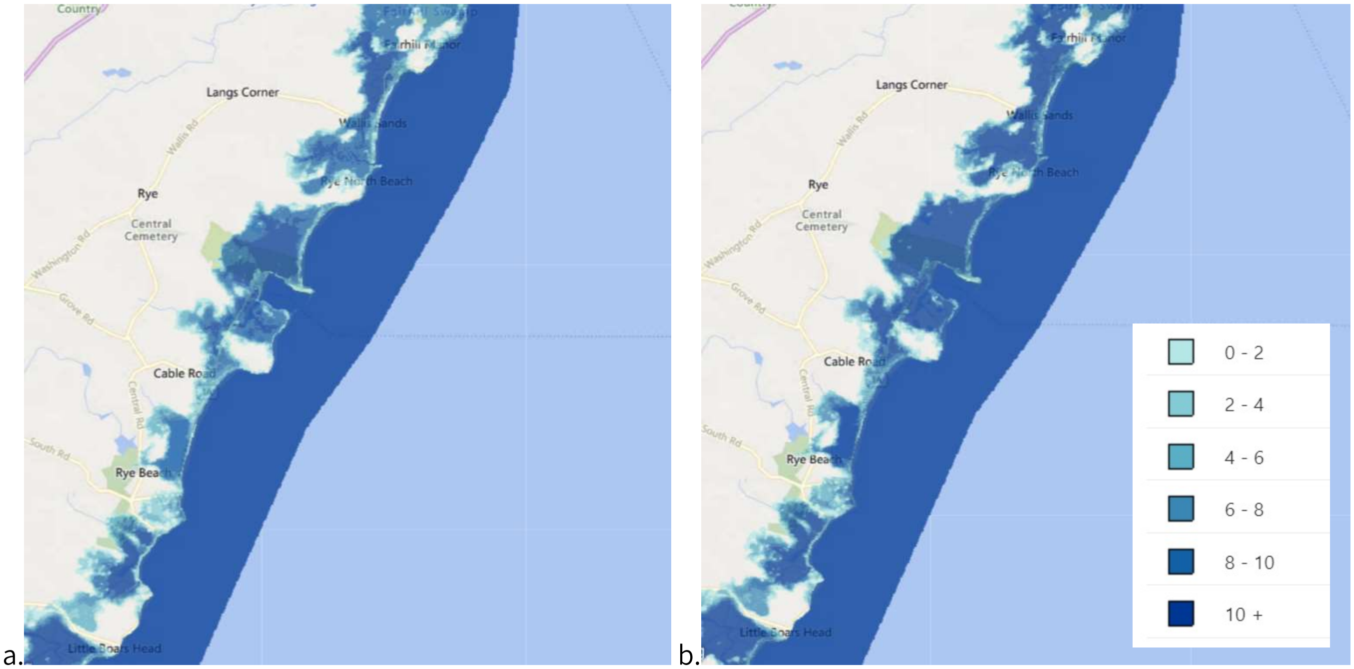

Figure 5: SLR of 2 ft + 1% storm surge (a) and SLR of 4 ft + 1% storm surge (b) (NH GRANIT, 2021).

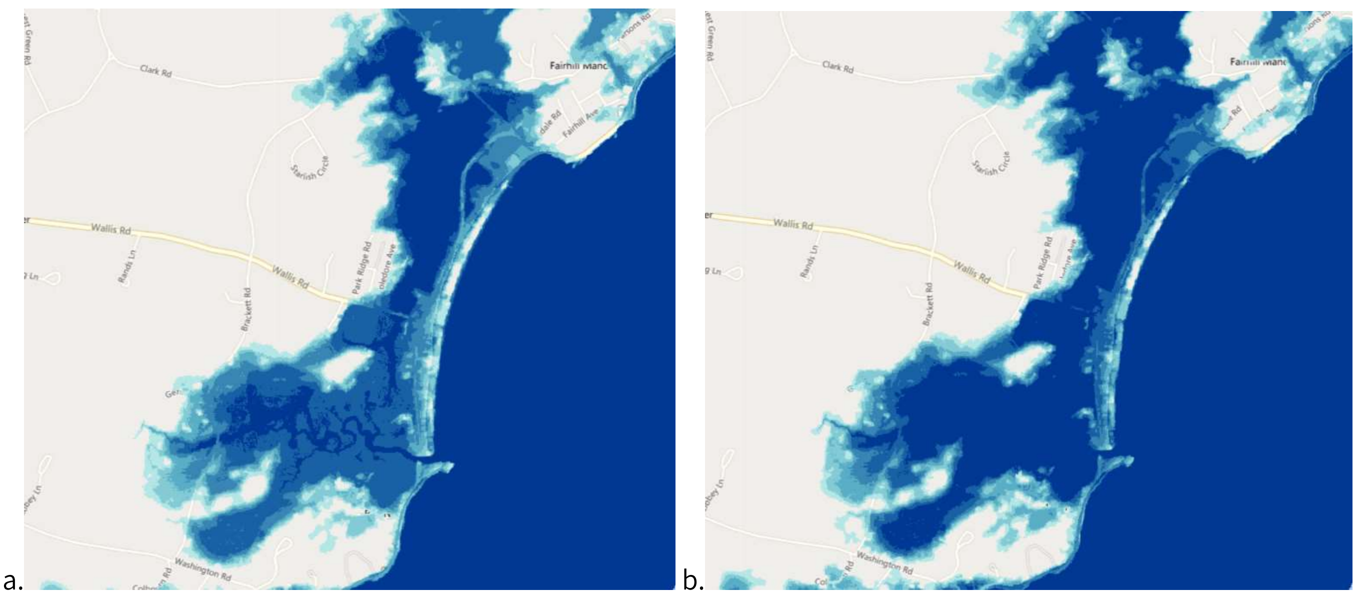

Figure 6: SLR at Parson's Creek of 2 ft + 1% storm surge (a) and SLR of 4 ft + 1% storm surge (b) (NH GRANIT, 2021).

GROUNDWATER RISE

NH Coastal Flood Risk Summary

Wake et al., (2019) predicts the Groundwater Rise Zone extends 2.5 - 3 miles inland from the coast of coastal NH. The mean groundwater levels are predicted to rise 66% of the projected SLR between 0 - 0.6 miles inland of the coast, 34% between 0.6 - 1.2 miles, 18% between 1.2 - 1.9 miles, 7% between 1.9 - 2.5 miles, and 3% between 2.5 - 3.1 miles of the coast.

Rockingham Planning Commission

The RPC does not provide information on GWR.

NH GRANIT

NH GRANIT displays various GWR scenarios in its Coastal Viewer. This GWR database was curated in 2019 by Jayne F. Knott, a PhD candidate at the time advised by Dr. Jennifer Jacobs, professor of Civil and Environmental Engineering at the University of New Hampshire. Knott and colleagues wrote *Modeling Groundwater Rise Caused by Sea-Level Rise in Coastal New Hampshire* (2019) in which they present and discuss the study that generated the data for the NH GRANIT GWR database in the Coastal Viewer. Knott et al. updated an existing USGS groundwater flow model of the NH coast to investigate SLR-induced GWR. The GWR scenarios are relative to the mean sea level measured at Fort Point tide gage in New Castle, NH. They were calculated using USGS MODFLOW2005, a version of the USGS three-dimensional finite-difference ground-water model (Harbaugh, 2005). The GWR predictions are based on the SLR scenarios from the New Hampshire Hazards and Risk Commission's NOAA-derived SLR scenarios for coastal adaptation planning (Knott et al., 2019). To determine GWR, several factors were used as inputs to the model including ground-surface topography, areal recharge, groundwater withdrawals, hydrogeologic properties, surface water, and SLR. Given the variability of these factors (seasonal, annual, etc.), Knott et al. (2019) advises that the model should not be used to predict groundwater head at specific locations but for a general understanding of changing groundwater flow patterns and trends caused by SLR. Knott is currently working on a higher resolution groundwater model in Rye which may form the basis for more precise mapping in the future. Figure 7 and Figure 8 are maps of GWR scenarios as shown on NH GRANIT. For more detailed GWR maps, see Figure 12 and Figure 13 at the end of this memo.

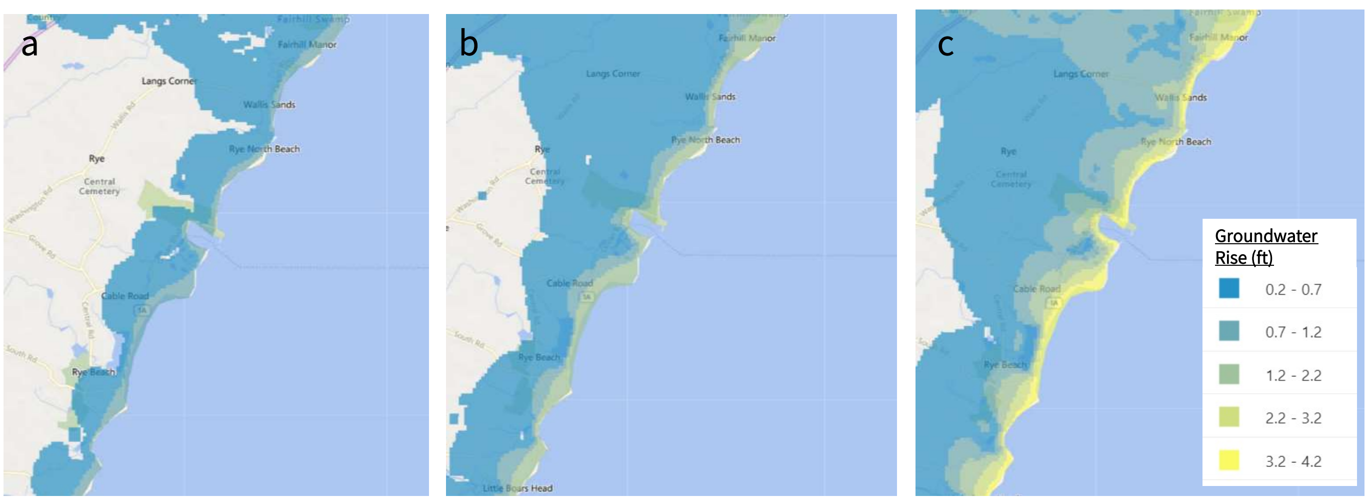

Figure 7: NH GRANIT's map of GWR (ft) caused by (a) 1 ft SLR, (b) 2 ft SLR, and (c) 4 ft SLR (NH GRANIT, 2021).

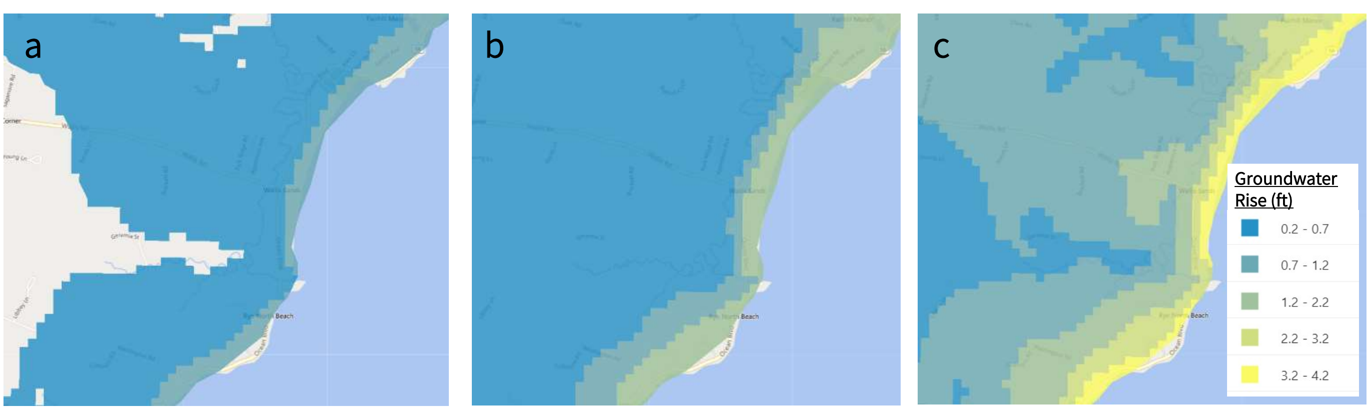

Figure 8: Map of GWR at Parsons Creek caused by (a) 1 ft SLR, (b) 2 ft SLR, and (c) 4 ft SLR (NH GRANIT, 2021).

Knott et al.'s findings predict that under a 2 m (approx. 6 ft) SLR scenario, the farthest extent of surface-water inundation at MHHW will likely be 1 to 1.5 km (approx. 0.6 – 1 mile) inland. This is projected to drive GWR up to 0.2 m (0.7 ft) in magnitude as far as 4 km (2.4 miles) inland, more than twice the distance of the surface-water effects caused by SLR. The combination of 2 m of SLR and GWR is predicted to inundate 9% of Portsmouth land area, 48% of which is attributed to rising groundwater. Knott et al. found that GWR is dampened near streams due to the increased gradients between groundwater and streams leading to more stream flow. As groundwater discharge to streams increases, groundwater discharge to coastal areas will decrease due to SLR. Figure 9 displays four different scenarios of GWR as they correspond to possible values of SLR. (Knott et al., 2019). This figure shows the large variation around the mean GWR predicted near the coast as a result of local hydrogeology.

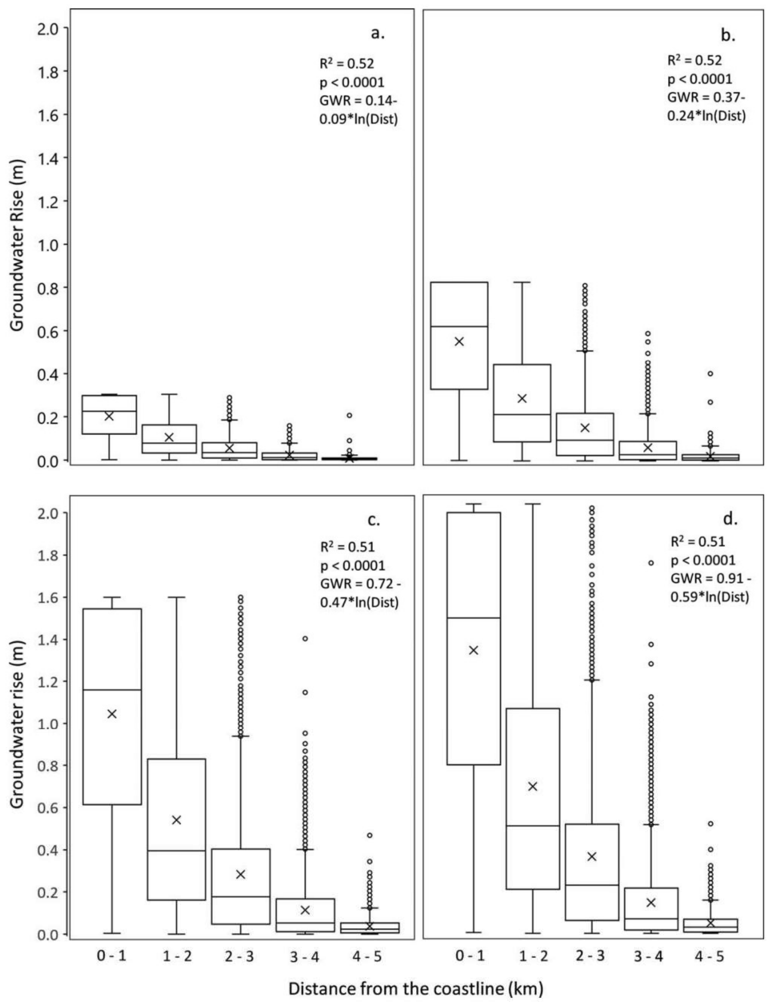

Figure 5. Simulated groundwater rise *vs.* distance from the coast for the four sea-level rise scenarios: (a) 0.3 m, (b) 0.8 m, (c) 1.6 m, and (d) 2 m. Each box shows the mean ($\bar{x}$), median, interquartile range, and outliers for each 1.0-km distance interval from the coast. The R^2 and *p*- values are from a linear fit of groundwater rise and the natural logarithm of the distance.

Figure 9: GWR scenarios for corresponding SLR examples of (a) 0.3 m, (b) 0.8 m, (c), 1.6 m, and (d) 2 m, as presented in Knott et al. (2019) including original caption.

SPRING TIDES

NH Coastal Flood Risk Summary

Wake et al. explains that tide gauge data need more study to understand the how tide levels may change under SLR scenarios, but they do point to evidence of rising tides. This evidence includes the NHCAW King Tide photo contest, and the Hampton town ordinance that allows residents to park their personal vehicles at municipal lots when flooding is expected. (Wake et al., 2019)

Rockingham Planning Commission

The RPC does not provide information on spring tides.

NH GRANIT

NH GRANIT does not provide information on spring tides.

KING TIDES

"King tides" is an informal term used to indicate the highest tides of the year due to any cause. Although it is not a scientific term, this section summarizes the maximum expected tides in coastal NH, as presented in available research.

NH Coastal Flood Risk Summary

The NH Coastal Flood Risk Summary does not include information on king tides; however, it does mention them in a case study highlighted in Part II. This project is Lubberland Creek Culvert Replacement Design, and the king tide was evaluated using the closest tide gauge station data. In this project, they needed to take tide into consideration when designing and constructing a culvert. An electronic data logger was used to measure the current tide elevations at the site, and data from the Fort Point, NH tide gauge station was used to adjust to represent king tide elevations. (NH Coastal Flood Risk Science and Technical Advisory Panel, 2020)

Rockingham Planning Commission

The RPC does not provide information on king tides.

NH GRANIT

NH GRANIT does not provide information on king tides.

PLANNING RECOMMENDATIONS

For this work, we recommend planning for the intermediate-high SLR prediction presented by NOAA (2022) which is 1.61 ft by 2050, 5.25 ft by 2100, and 8.86 ft by 2150. This recommendation is based on the NOAA predictions having the most up-to-date understanding of each factor that influences SLR, including the highly variable Greenland and Antarctic ice sheets.

One-hundred-year storm surge was predicted within a range 4 to 5.3 feet by various sources including the NH Coastal Flood Risk Science and Technical Advisory Panel (2020) and the US Army Corps of Engineers (2015). Wake et al. (2019) predicts it to be even higher than this on the NH coastline, estimating it at 7.78 feet, due to the uniquely open coast. Given this, the recommended one-hundred year storm surge / king tide level value for planning purposes is set conservatively at 7.78 feet.

Groundwater predictions are based on the distance inland from the shore. The recommendation is to use the data presented in the NH Coastal Flood Risk Summary, based on Knott et al. (2019), which predicts GWR of 66% of the projected SLR between 0 - 0.6 miles inland of the coast, 34% between 0.6 - 1.2 miles, 18% between 1.2 - 1.9 miles, 7% between 1.9 - 2.5 miles, and 3% between 2.5 - 3.1 miles of the coast. The specific value of GWR values based on the chosen SLR scenarios is show in Table 4. A summary of total water level changes can be found in Table 5. The current MHHW was retrieved from NOAA's Fort Point datum which is relative to the 1993-2001 datum epoch.

Table 4: Predicted GWR caused by SLR for the NH coastline, based on Knott et al. (2019) as presented by the NH Coastal Flood Risk Summary.

Distance Inland (mi)	GWR by 2050 (ft)	GWR by 2100 (ft)	GWR by 2150 (ft)
0 – 0.6	0.9	1.9	3.0
0.6 – 1.2	0.4	1.0	1.6
1.2 – 1.9	0.2	0.5	0.8
1.9 – 2.5	0.1	0.2	0.3
2.5 – 3.1	0.04	0.1	0.1

Table 5: Summary of predicted future water and flooding levels for the NH coastline. Recommended values for planning purposes are highlighted in yellow.

Year→	2050	2100	2150
Current (1991-2010) MHHW* (feet above datum)	4.70	4.70	4.70
SLR (in feet above current MHHW) Source: NH Coastal Flood Risk Summary (2020); upper end of "likely range"	1.3	2.9	4.6
SLR (feet above current MHHW) Source: NOAA (Sweet et al., 2022)	1.61	5.25	8.86
SLR (feet above current MHHW) recommended for planning purposes, and shown in maps below	2	6	8
Storm Surge / King Tide Source: NH Coastal Flood Risk Summary (2020), based on FEMA and USACE predictions	4 - 5.3	4 - 5.3	4 - 5.3
Storm Surge / King Tide Source: Wake et al. (2019)	7.78	7.78	7.78
Maximum GWR (feet above current groundwater level) occurring within 0.6 miles of the coast Source: Knott et al. (2019)	0.9	1.9	3.0

*retrieved from NOAA's Fort Point datum
(https://tidesandcurrents.noaa.gov/datums.html?datum=MSL&units=0&epoch=0&id=8423898&name=Fort+Point&state=NH)

The maps below show the SLR, GWR, and storm surge scenarios for planning purposes for 2050, 2100, and 2150 within the Parsons Creek watershed. NH GRANIT provides data in intervals of 1, 2, 4, 6, and 8 feet. To match NOAA 2022 predications, the scenarios presented below use 2 ft SLR by 2050, 6 ft SLR by 2100, and 8 ft SLR by 2150. Each storm surge scenario adds 1% storm surge to the corresponding SLR scenario. GWR data also correspond to each SLR scenario. It is important to note that as these changes occur, the coastal geomorphology will change along with it. Wetlands and salt marshes will become inundated and retreat and migrate where possible and beaches will erode, among other changes. These maps provide a planning level guide for the Town of Rye within the Parsons Creek watershed for which areas will be impacted by SLR, GWR, and storm surge, and by what amounts.

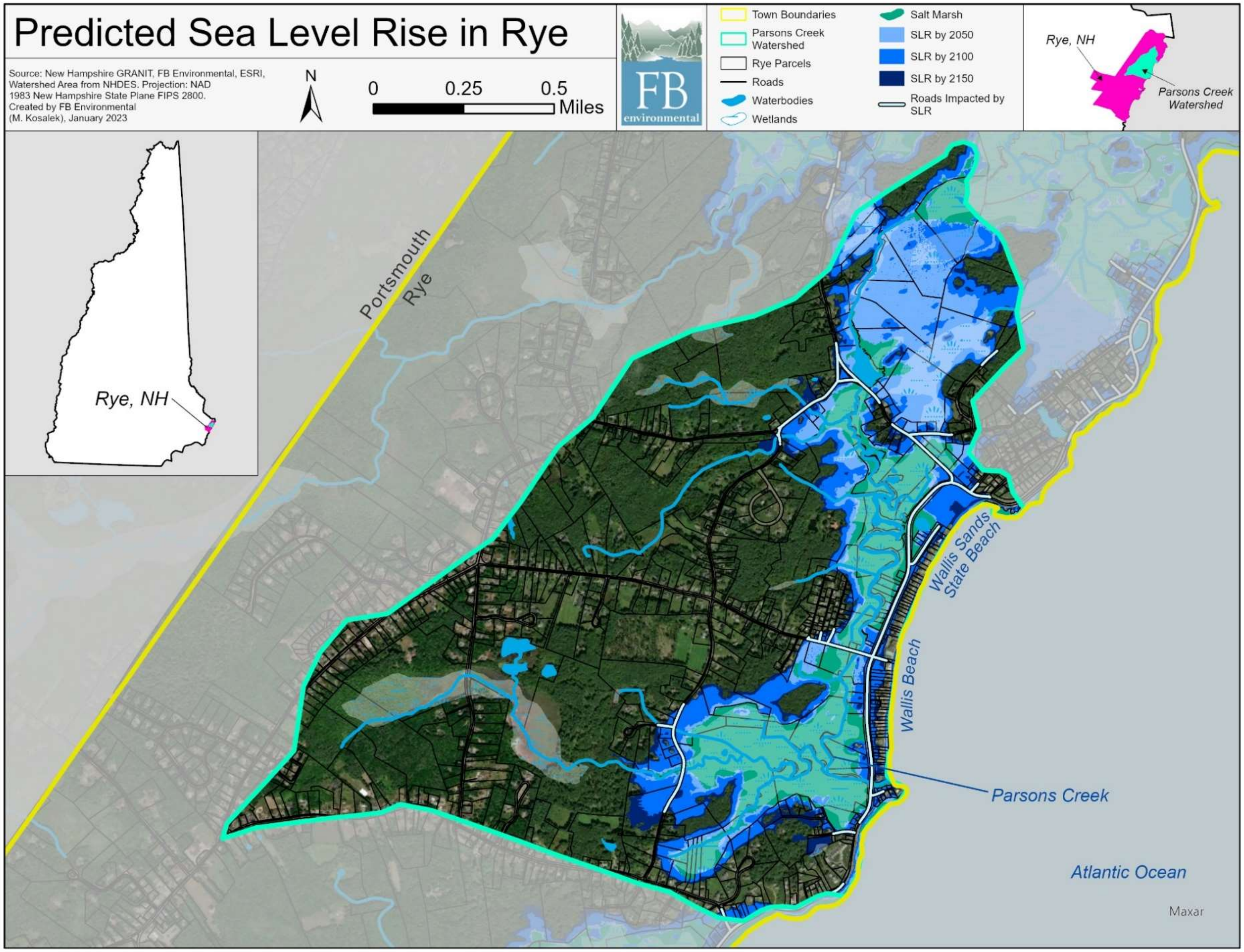

Figure 10: Sea Level Rise scenarios for Parsons Creek watershed, based on the NOAA 2022 predictions.

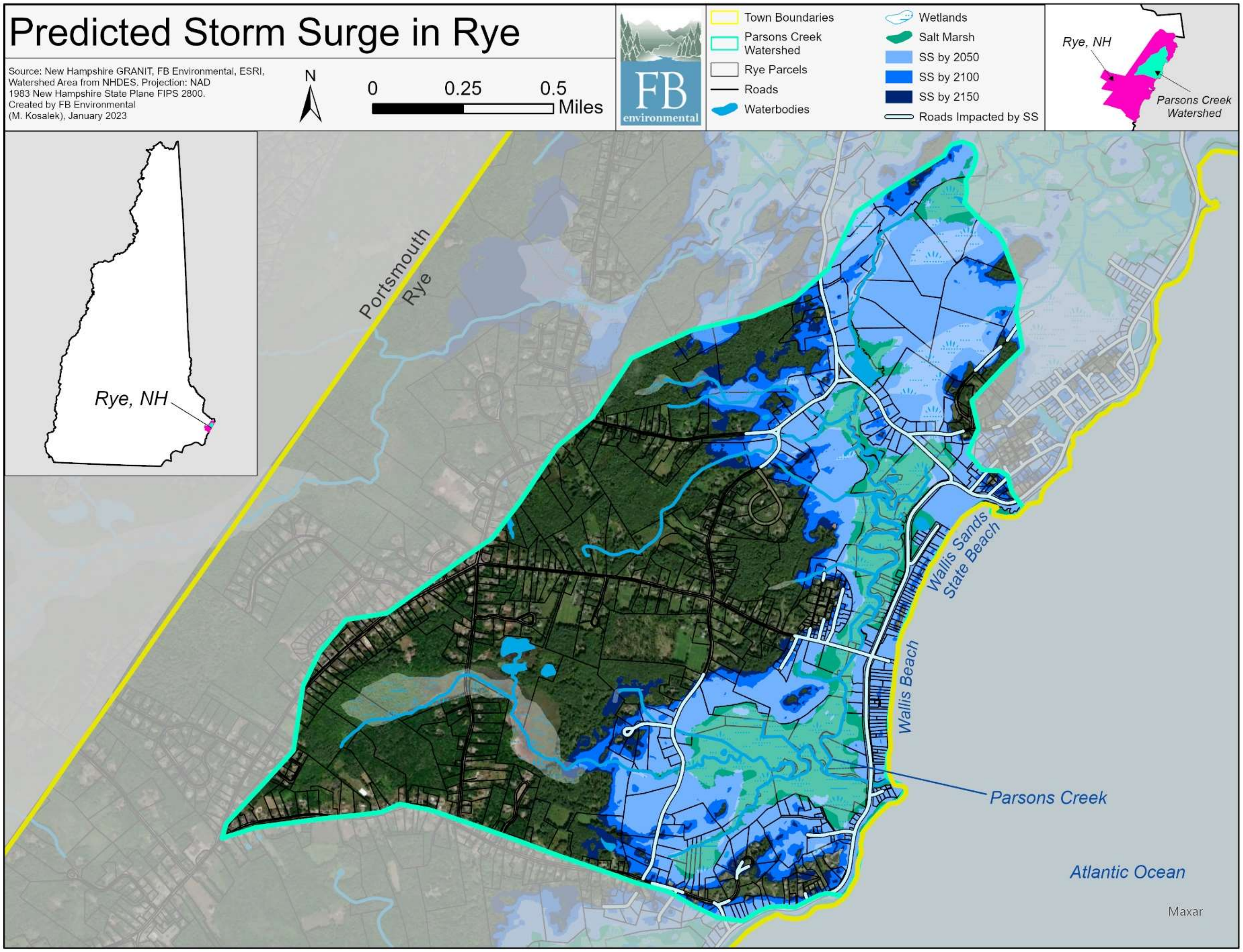

Figure 11: Storm surge scenarios for Parsons Creek watershed, based on the NOAA 2022 predictions.

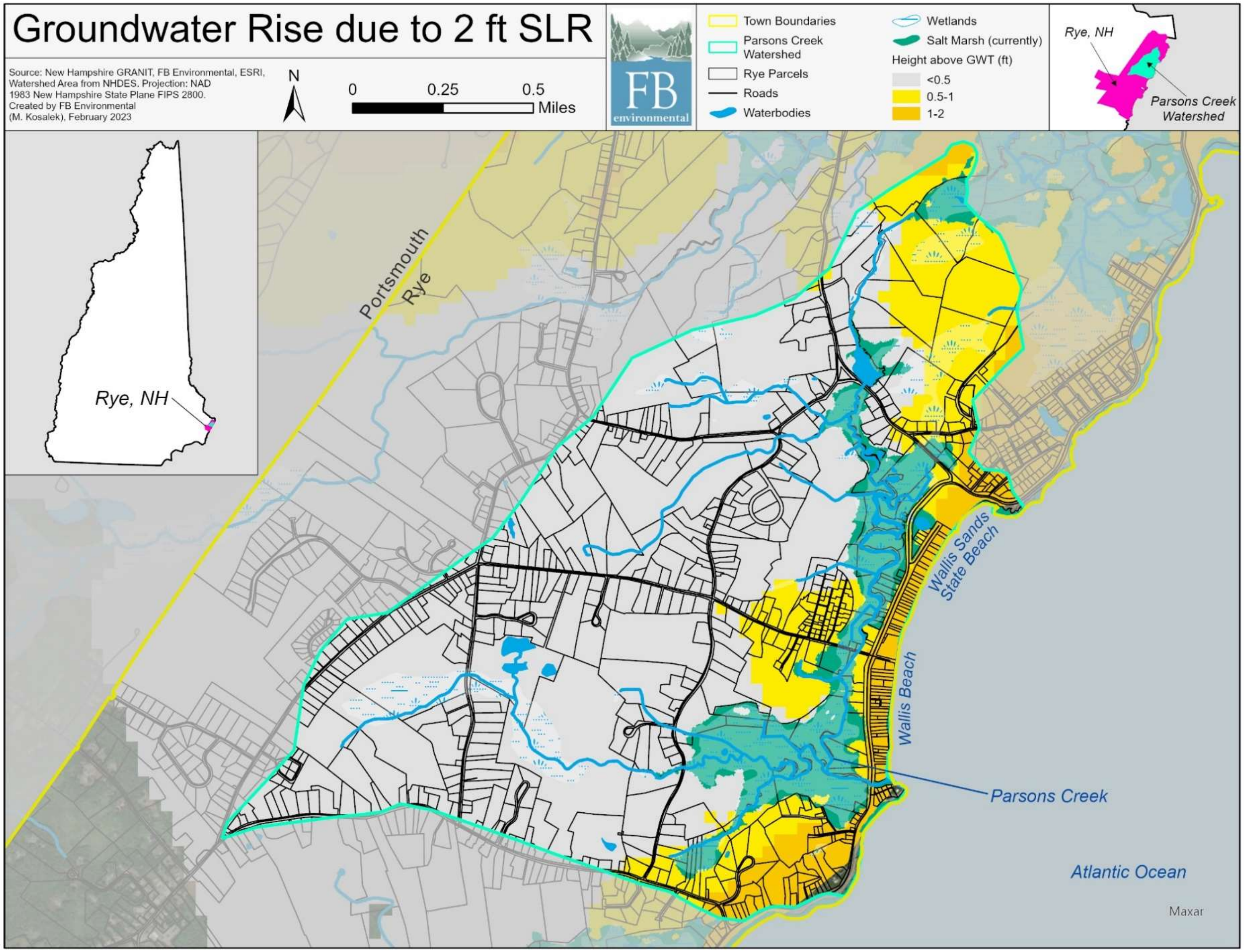

Figure 12: GWR for the 2 ft SLR scenario estimated in 2050 (NOAA 2022), where GWT is the current Groundwater Table.

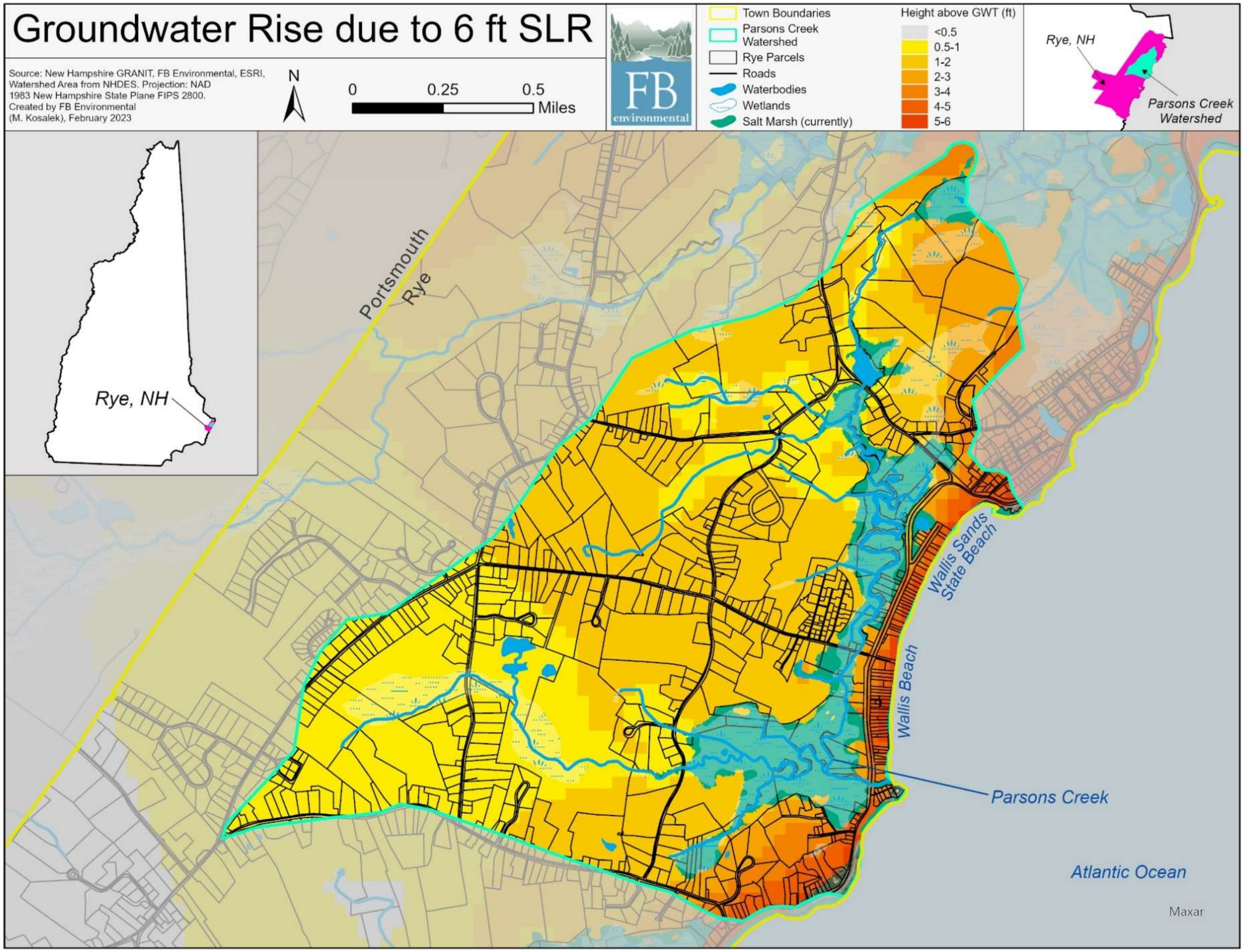

Figure 13: GWR for the 6 ft SLR scenario estimated in 2100 (NOAA 2022), where GWT is the current Groundwater Table.

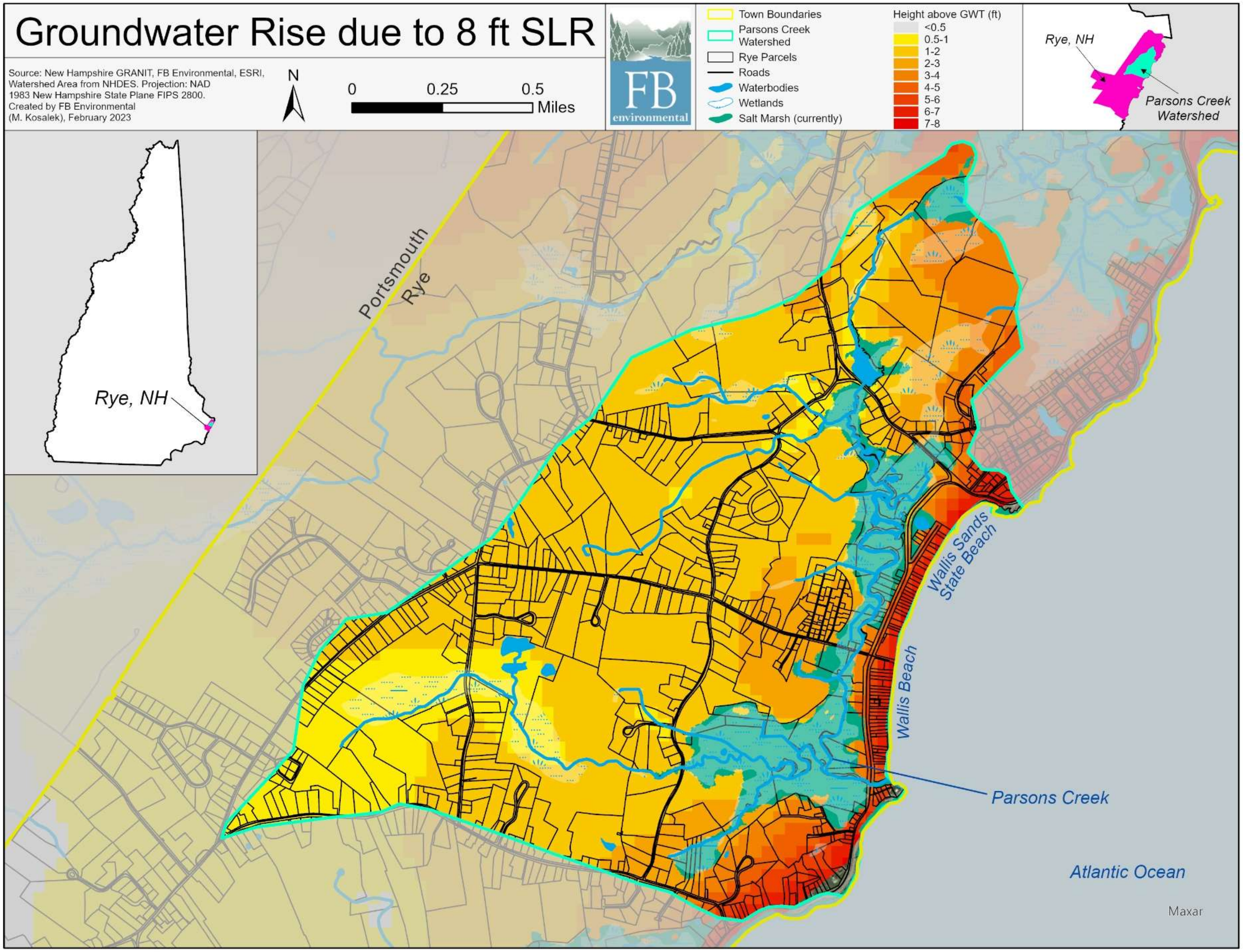

Figure 14: GWR for the 8 ft SLR scenario estimated in 2150 (NOAA 2022), where GWT is the current groundwater table.

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