Modeling the Effects of Climate Change and Sea-Level Rise on Groundwater Levels with Implications for Road Infrastructure in Coastal New Hampshire

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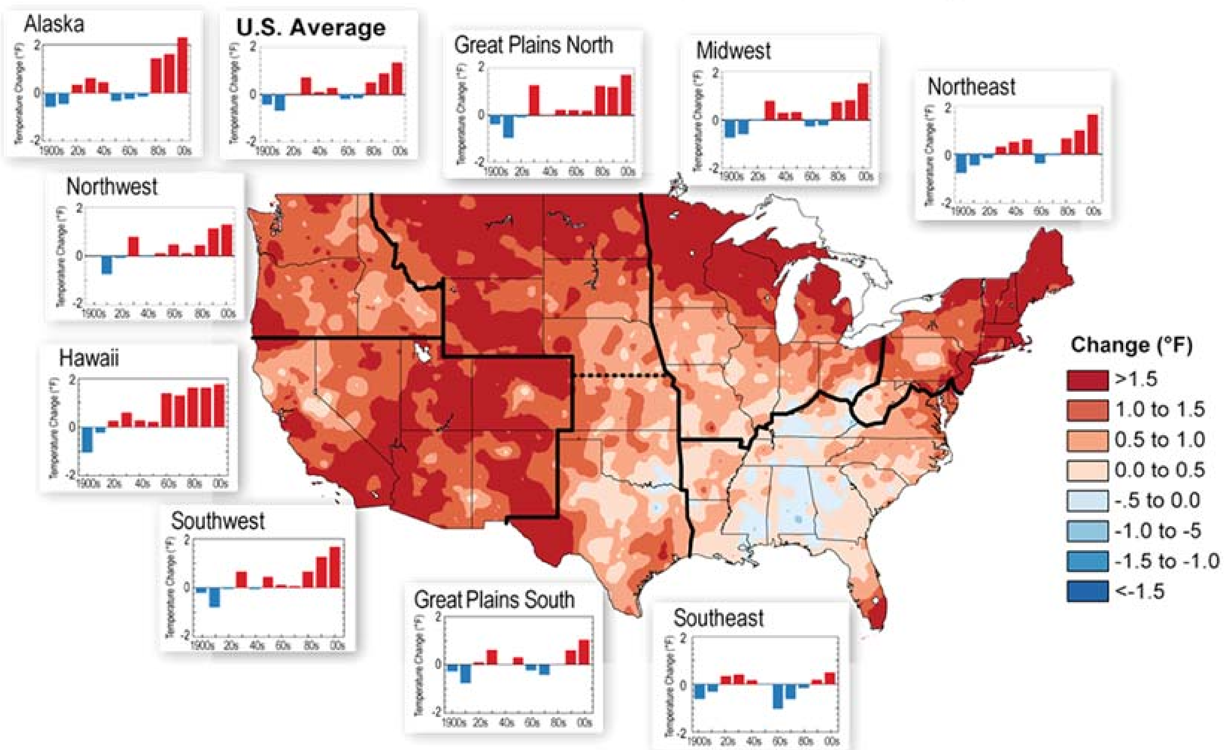
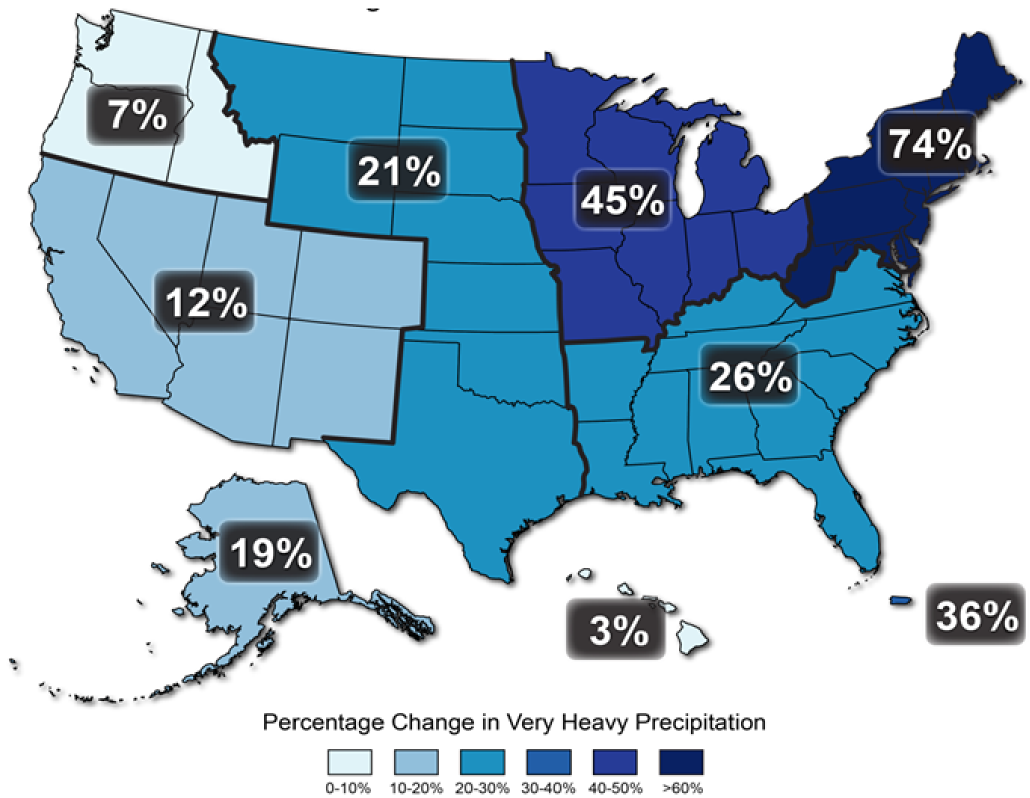
Climate Change Overview

Climate Change in the Northeast Temperature



Source: 2014 National Climate Assessment

Climate Change in the Northeast
Precipitation



Source: 2014 National Climate Assessment

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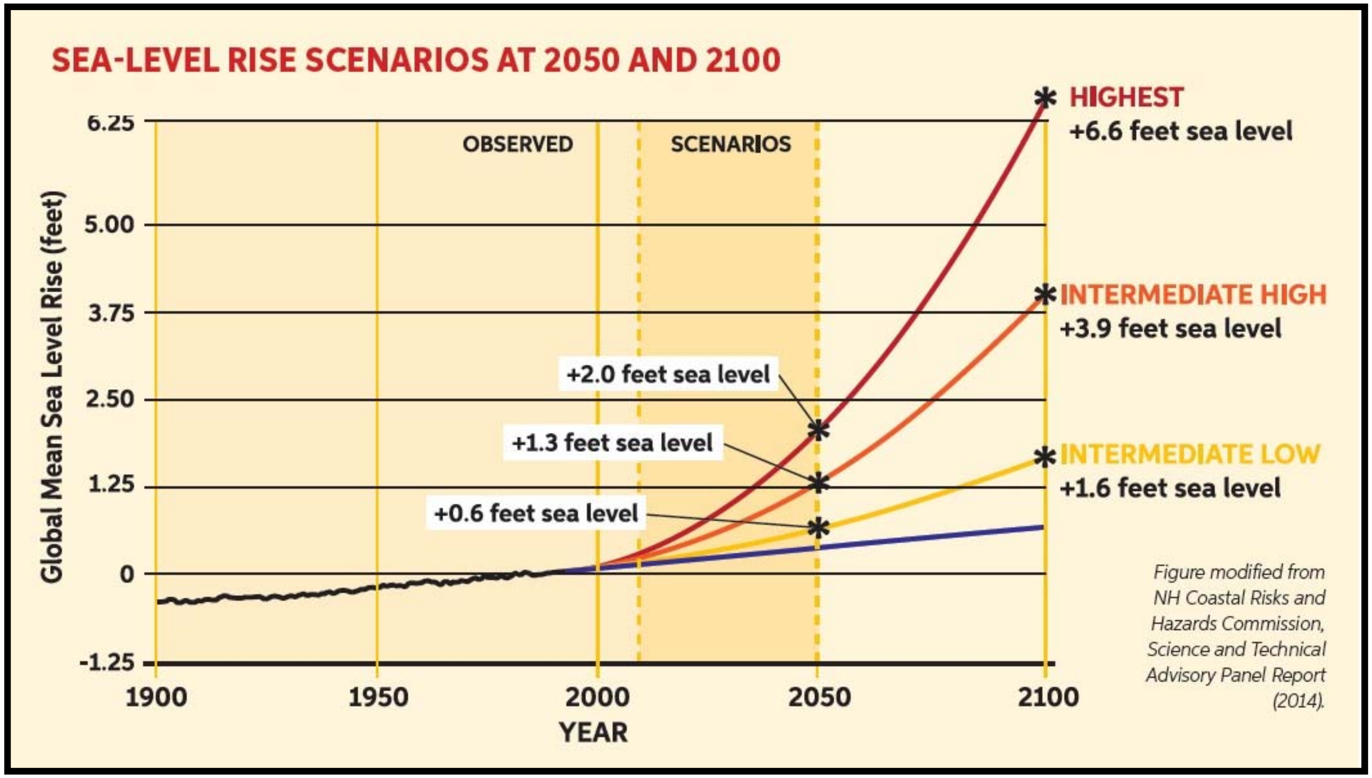
Climate Change in the Northeast
Sea-Level Rise



Source: 2012 National Climate Assessment

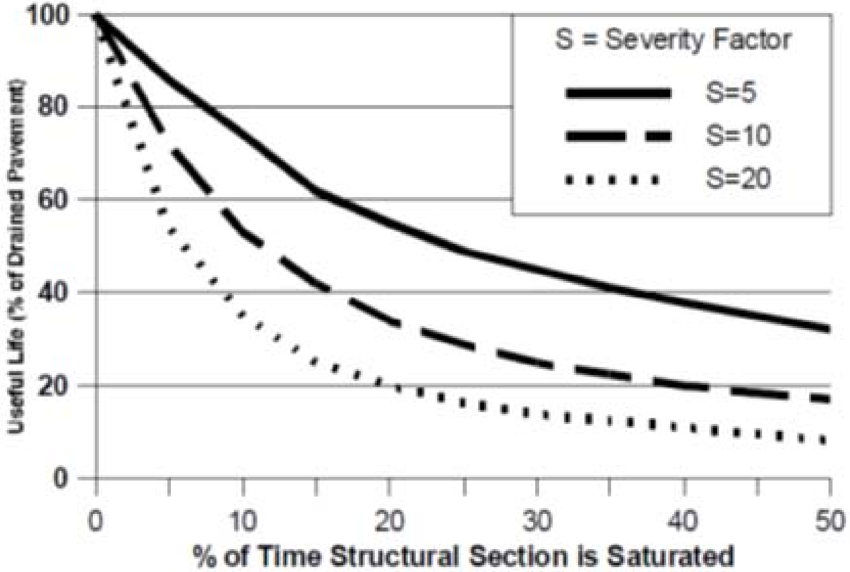
Climate Change in the Northeast
Sea-Level Rise

Coastal NH – Winter storm 2/8/2016

Motivation for this study

Water is a major cause of damage to roads

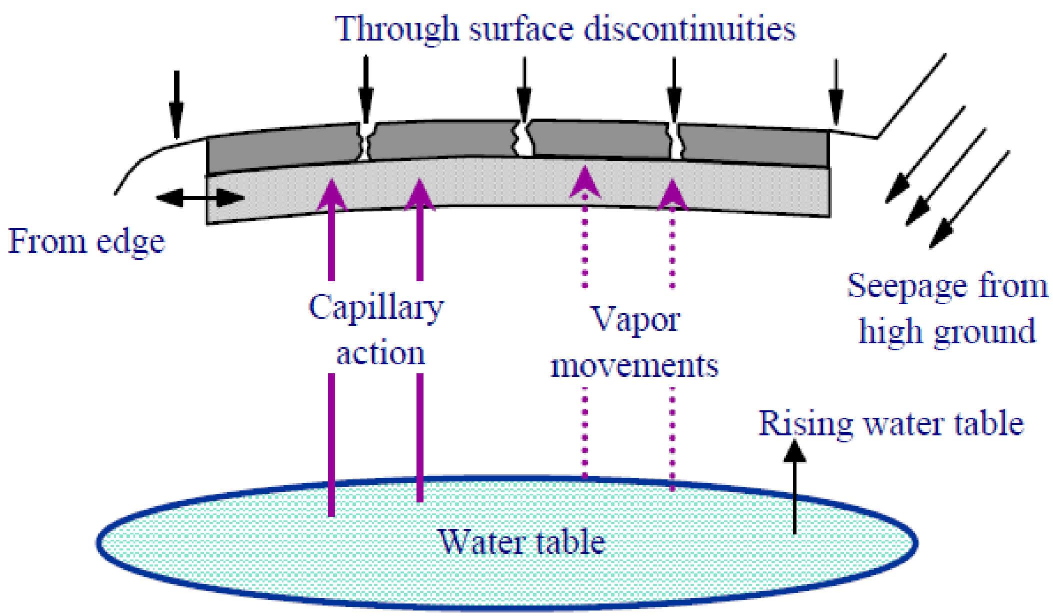
The useful life of the pavement structure decreases with an increase in the percent of time the structure is saturated



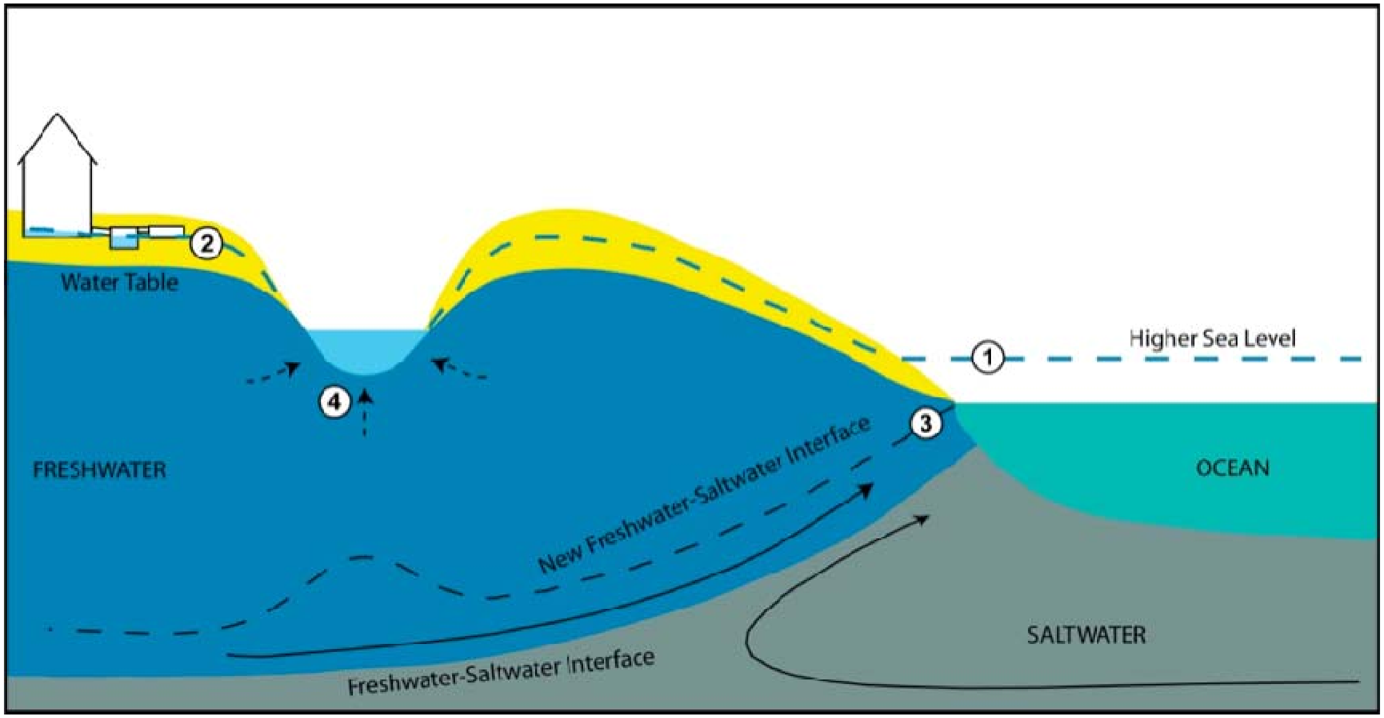
Source: Cedergren, 1987

High moisture content weakens the unbound layers

How does water get into pavement systems?



What does sea level have to do with groundwater?



Source: U.S. Geological Survey

Project Objectives

1. Create a NH Seacoast Transportation Climate Working Group
2. Identify roads that may be vulnerable to damage from rising groundwater
3. Determine the effects of climate change and sea-level rise on coastal groundwater levels
4. Conduct pavement performance evaluations
5. Demonstrate the value of adaptation through case study

Methods

- Update the USGS groundwater flow model of the Seacoast Region of NH (Mack, 2009) using MODFLOW-2005

- Identify areas where the groundwater is less than 10-feet deep using current and historical groundwater observations

- Simulate various sea-level rise scenarios to identify areas where groundwater is predicted to rise

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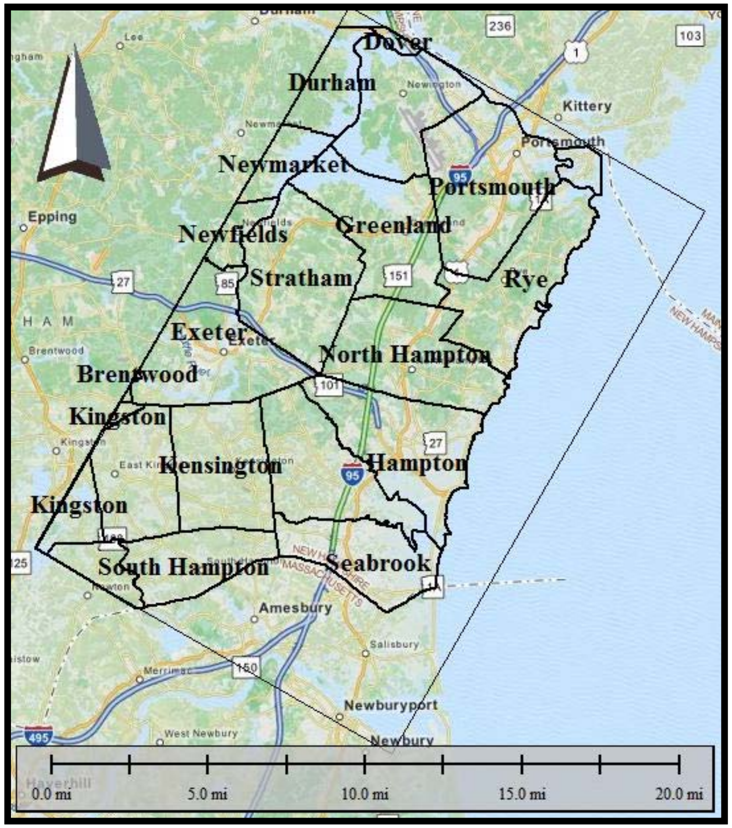
Groundwater Model Construction

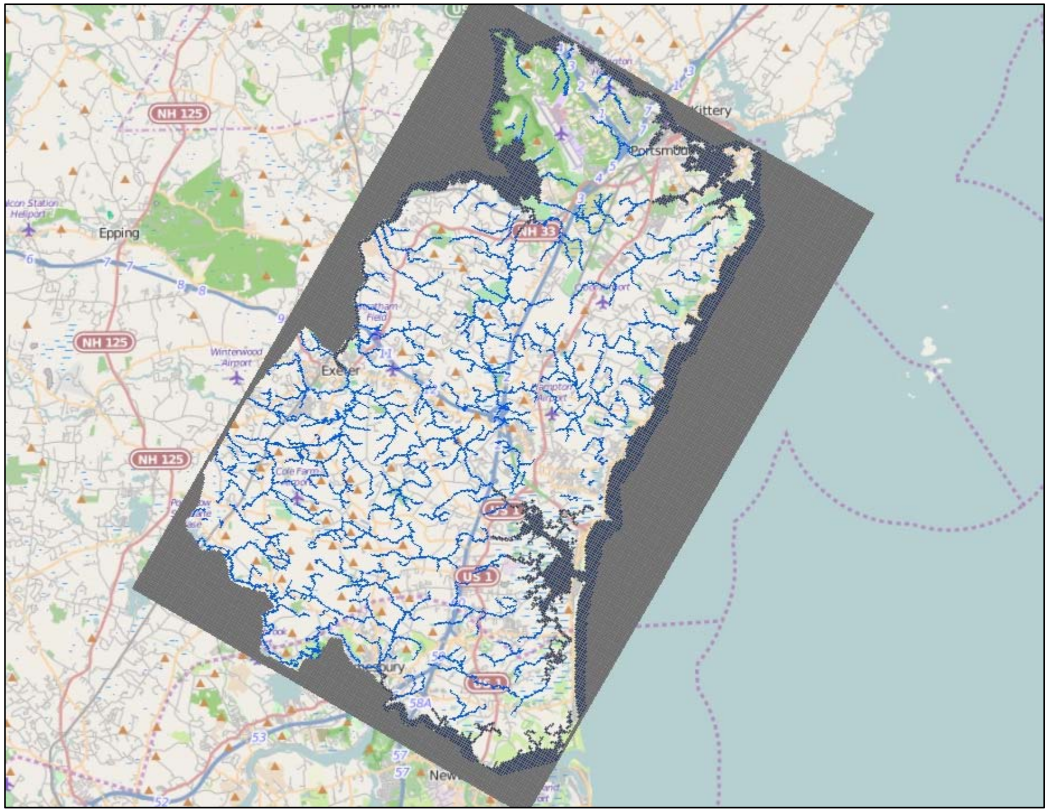
Political Map of Study Area



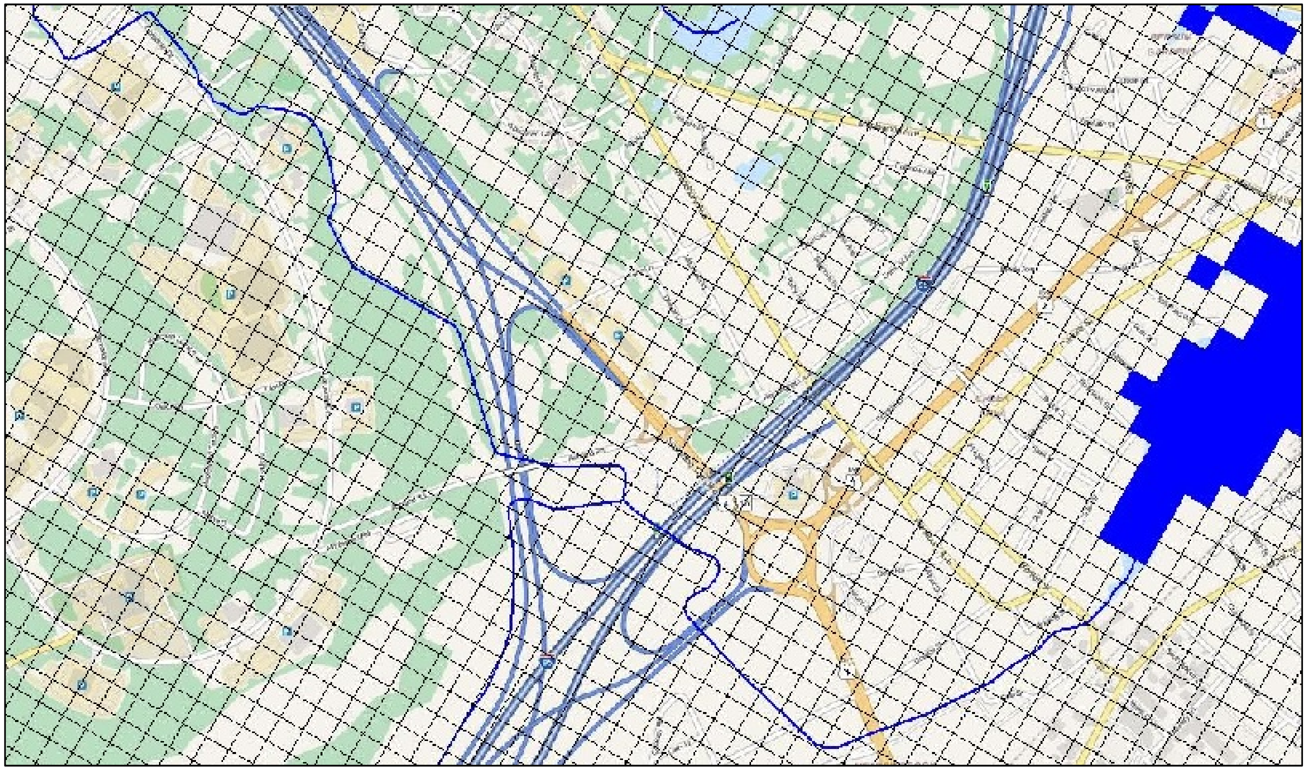
Groundwater Model

- Calculates the groundwater flow equation for many small areas, or cells, within the model domain
- Hydraulic properties of surficial and bedrock geology
- Groundwater recharge
- Streamflow
- Public and private water withdrawals and returns

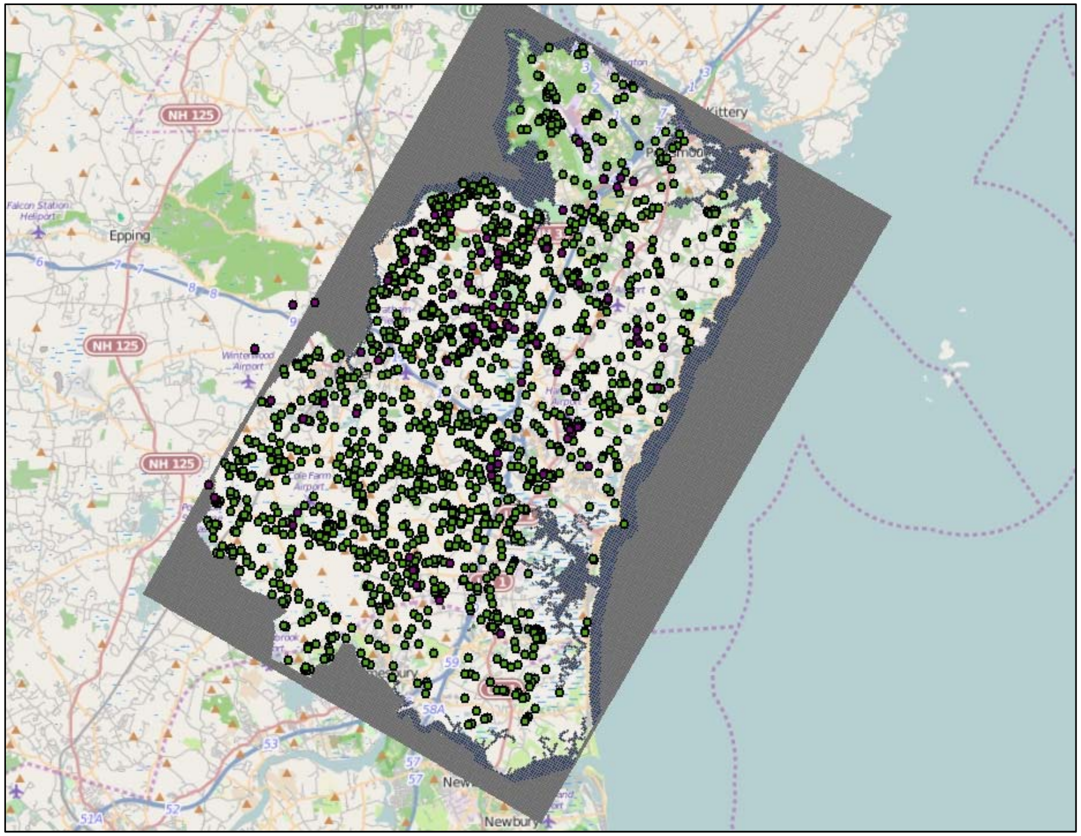
GW model domain and boundary conditions



Model grid is 535 rows and 350 columns, each grid cell is 200' x 200'

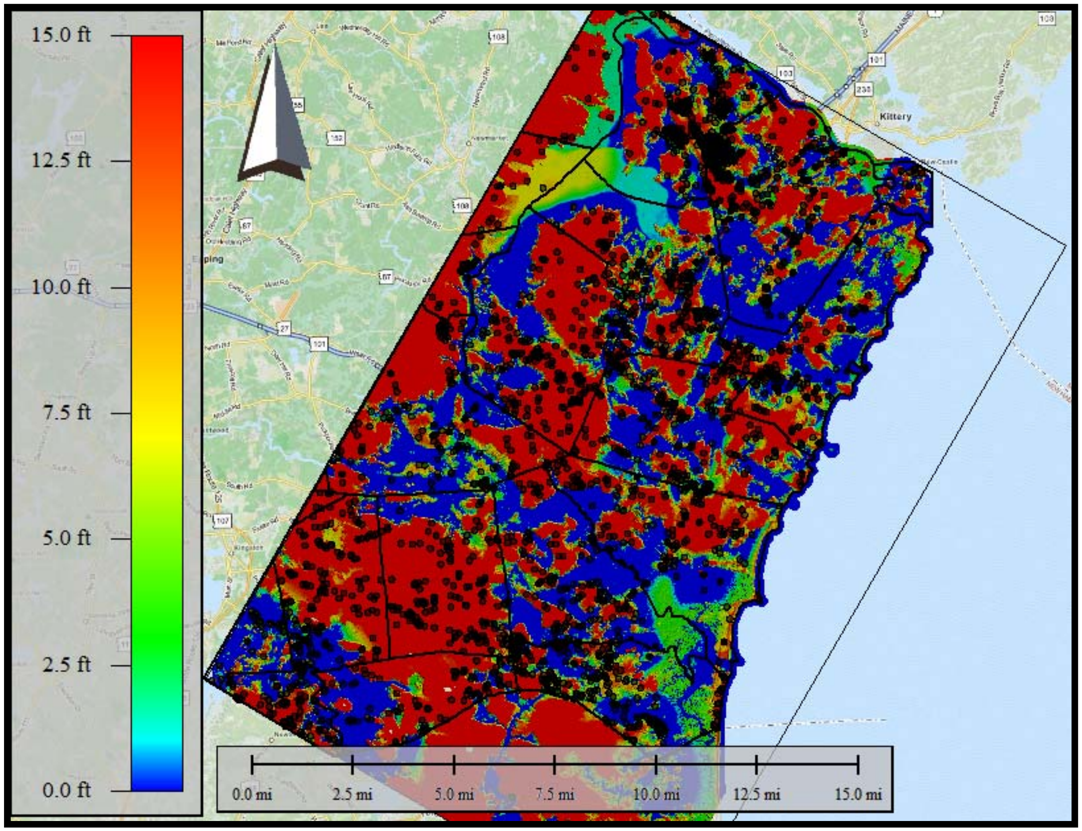


Observation wells and CSWs



Results – Groundwater Observations

Depth to GW from observations (1960-2015)

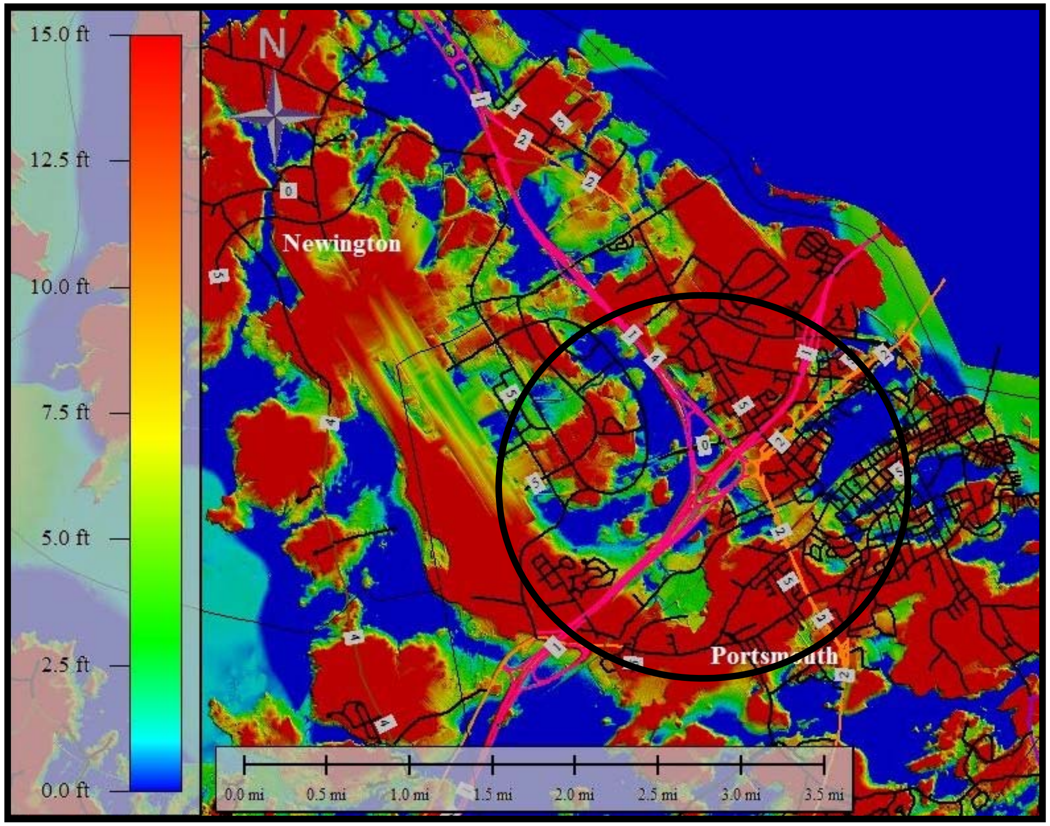


GW table is greater than or equal to 15-ft. below the ground surface.

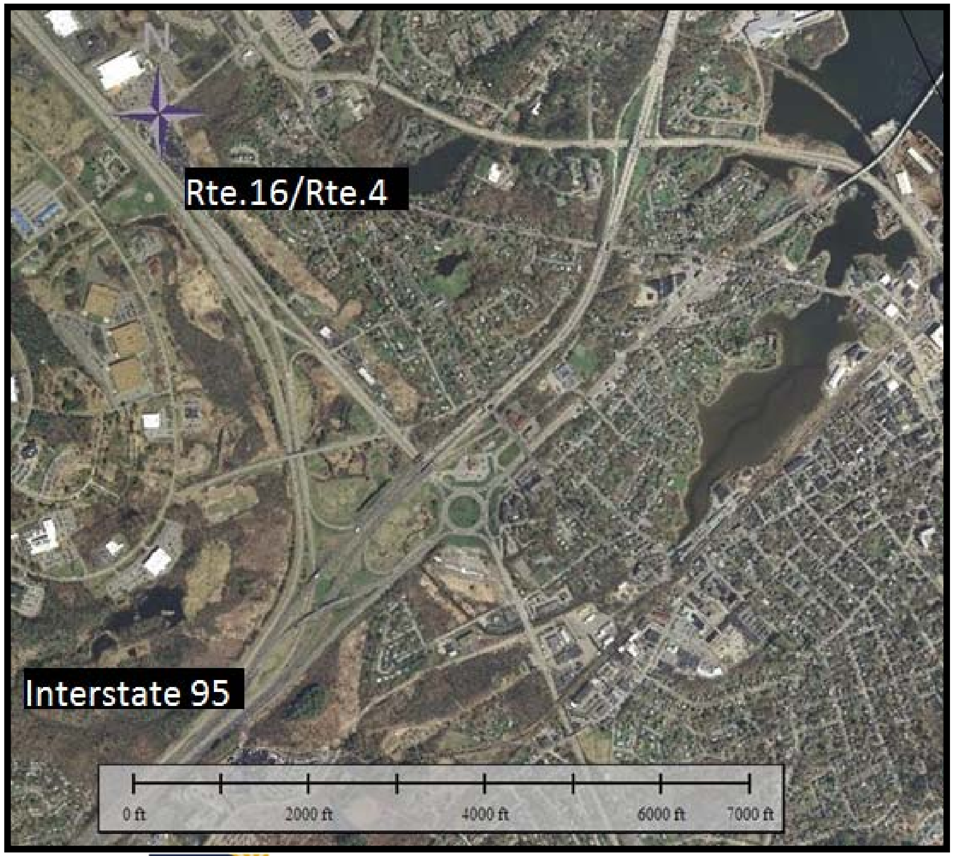
GW table is very close to the ground surface

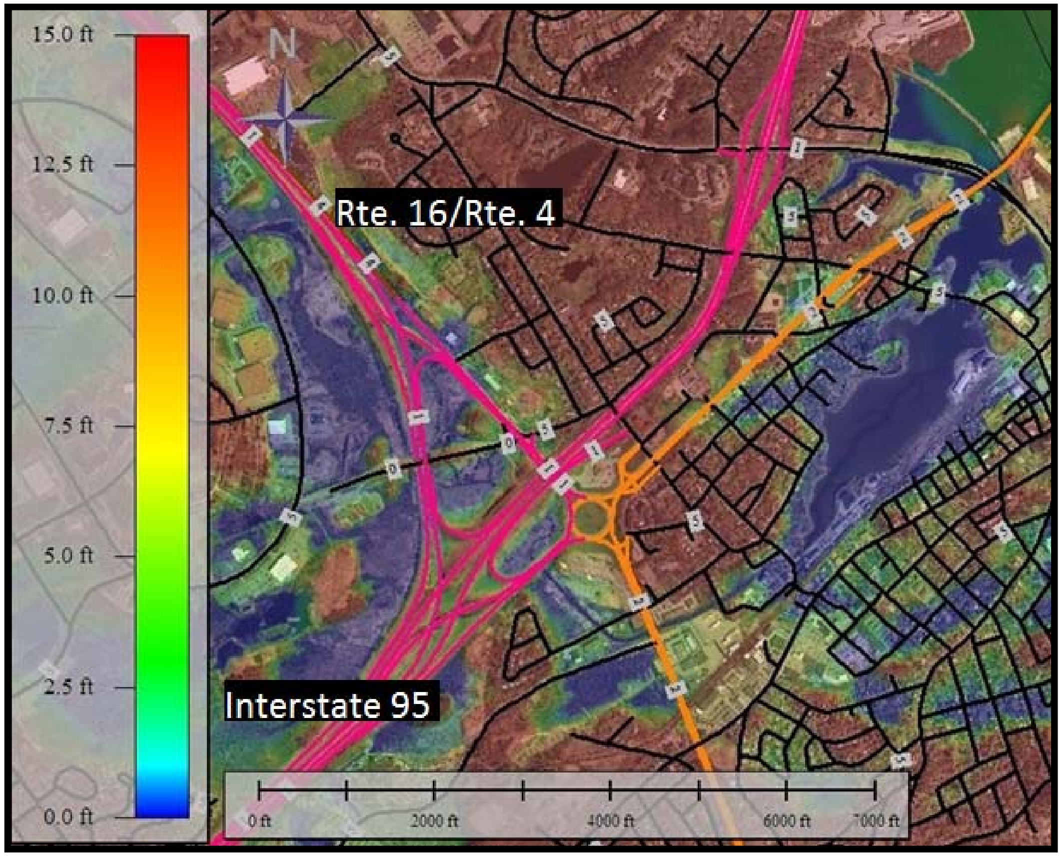
Observation wells

Depth to GW in Portsmouth, NH



Depth to groundwater near the I-95/Rte. 16 Interchange in Portsmouth, NH





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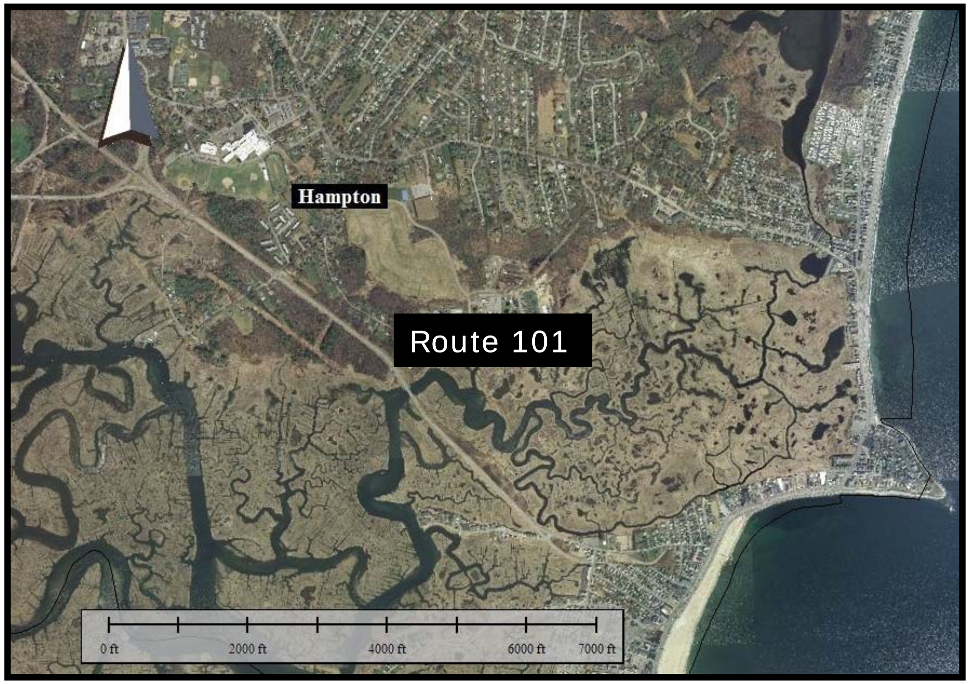
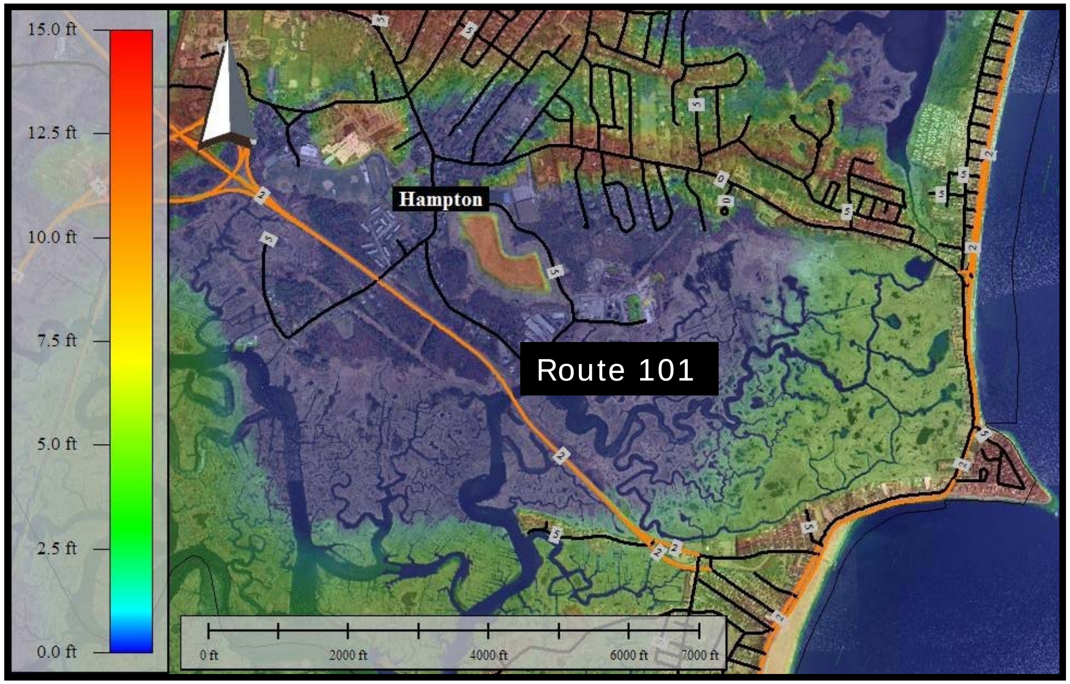
Depth to groundwater near Route 101 in Hampton– Evacuation Rte. From Hampton Beach





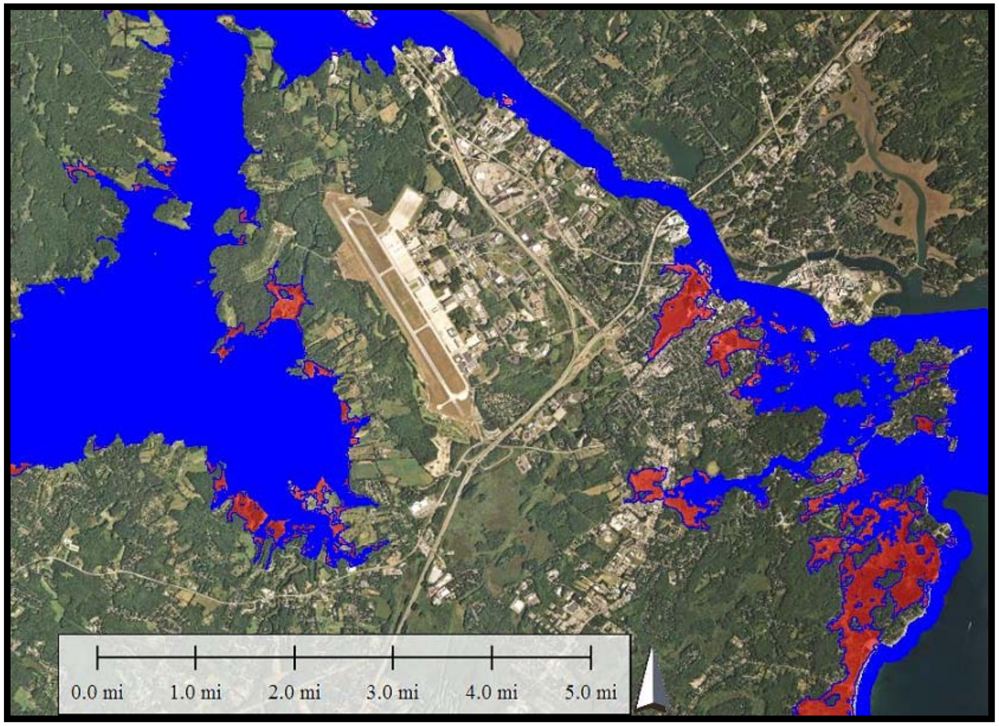
Preliminary Results – Groundwater Modeling

Sea-level rise scenarios

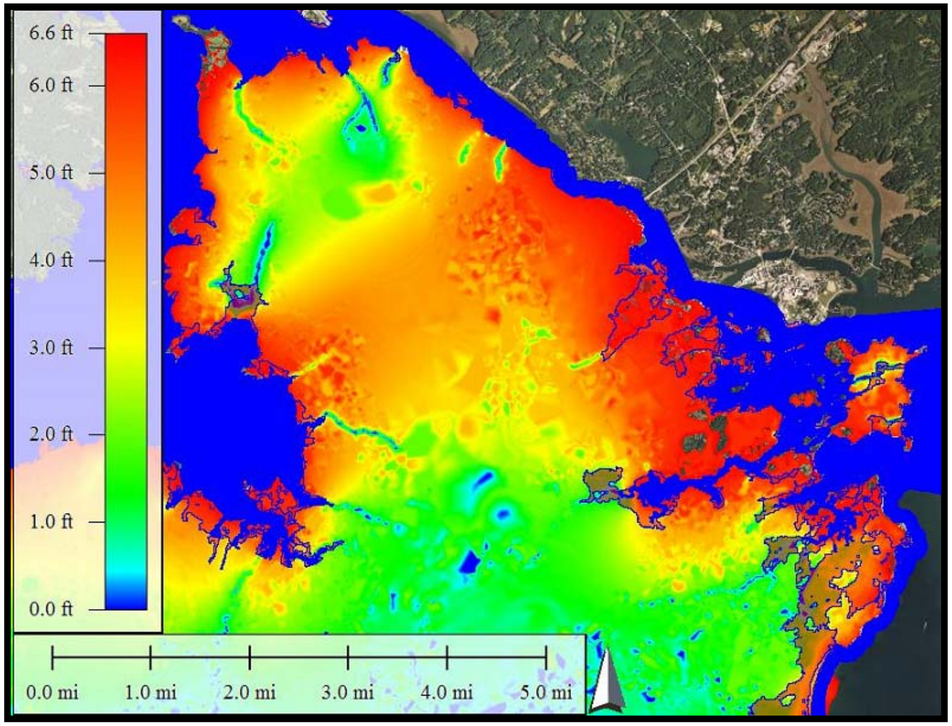
Time Period	2050	2100
Intermediate low	0.6 ft.	1.6 ft.
Intermediate high	1.3 ft.	3.9 ft.
Highest	2.0 ft.	6.6 ft.

From: National Climate Assessment (Parris et al., 2012) using MSL as a reference

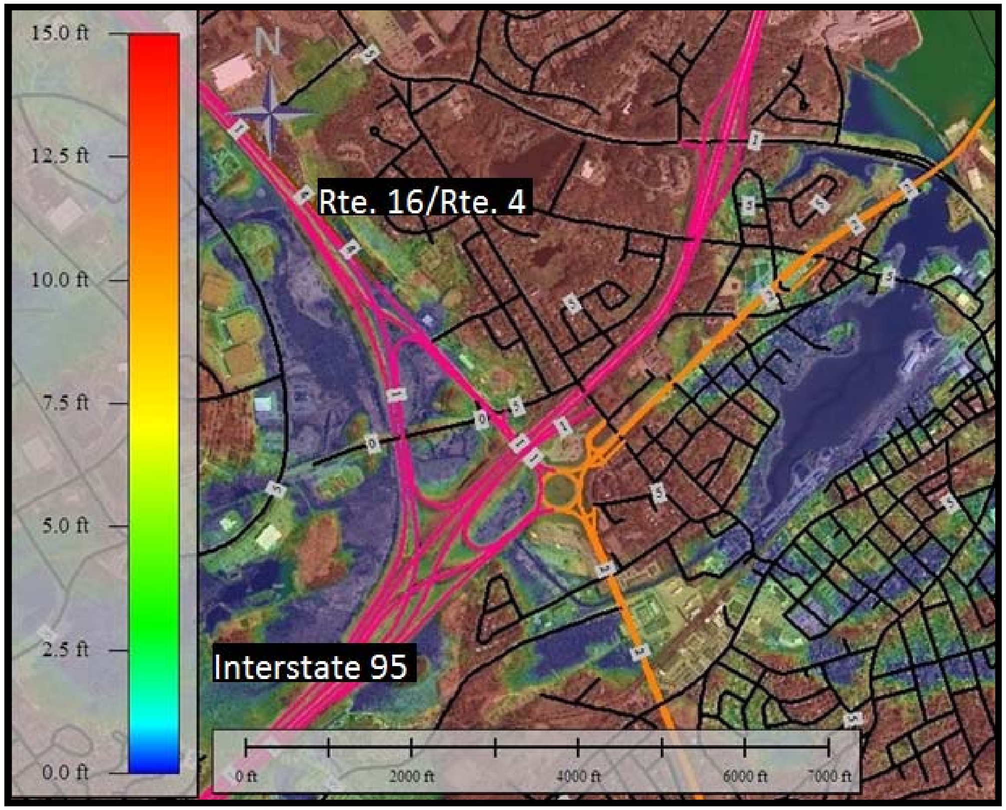
Surface water inundation with 6.6 feet of SLR

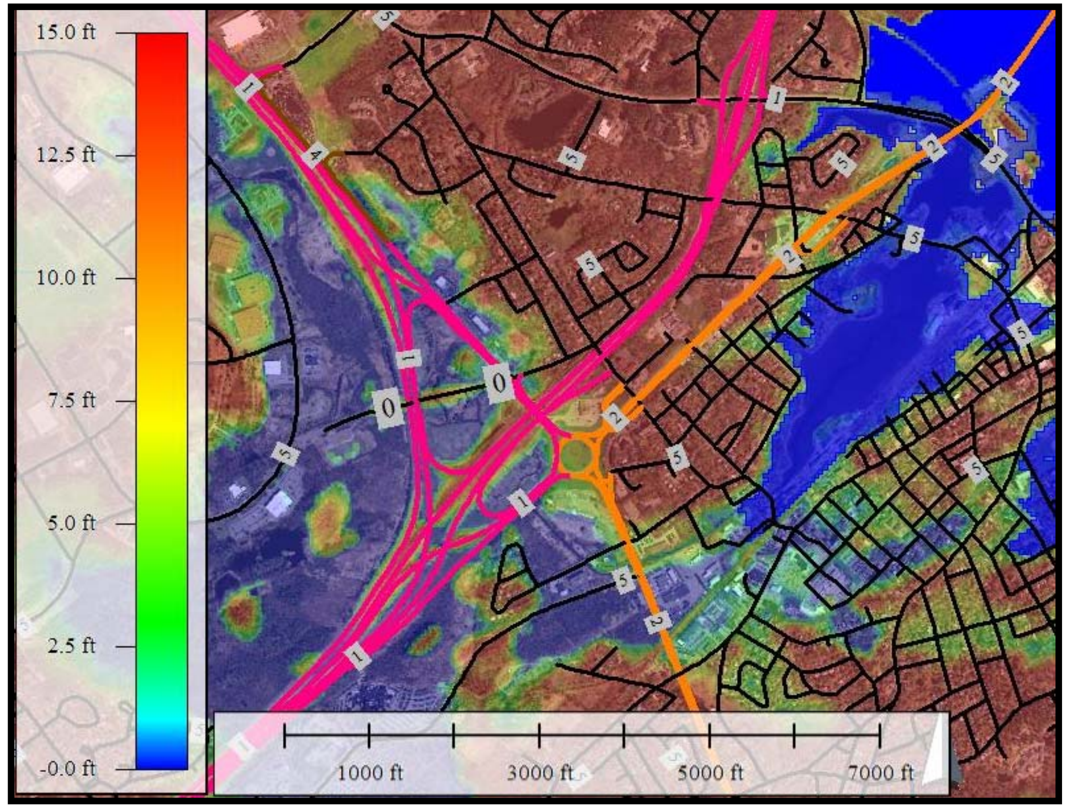


Groundwater rise with 6.6 feet of SLR

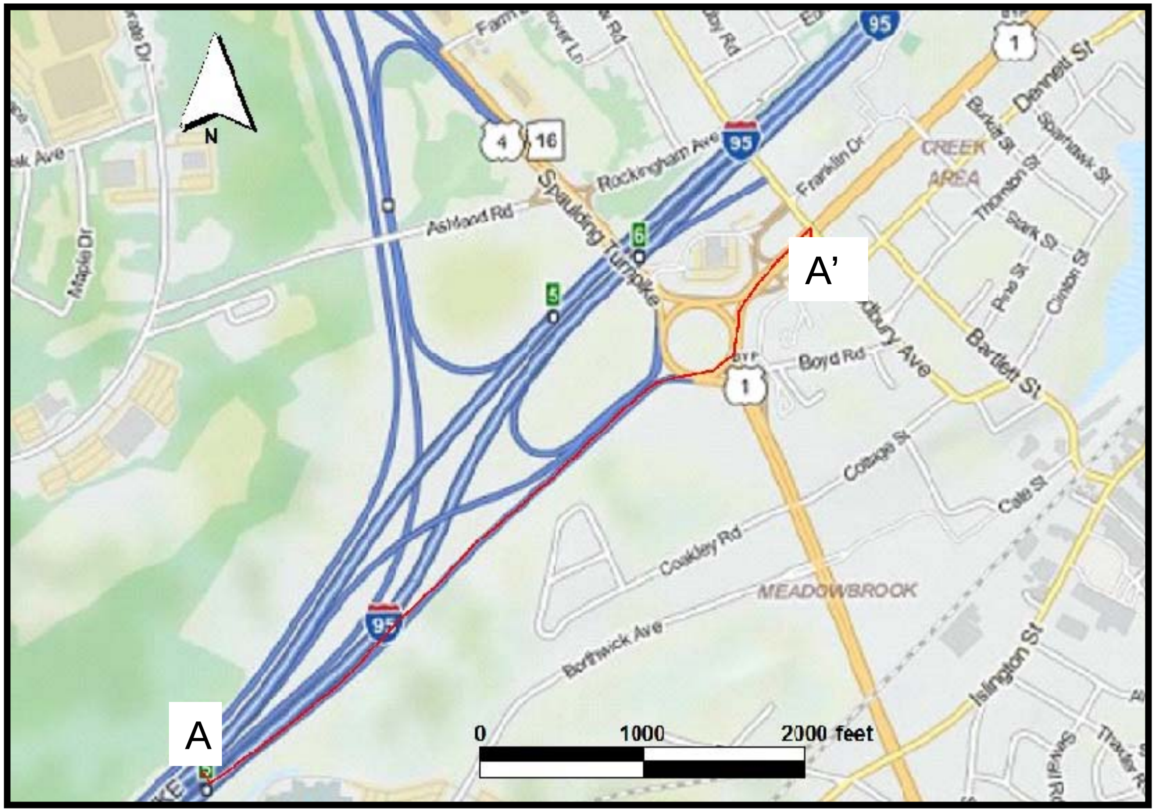


Observed depth to gw and simulated depth to gw with 6.6 feet of sea-level rise

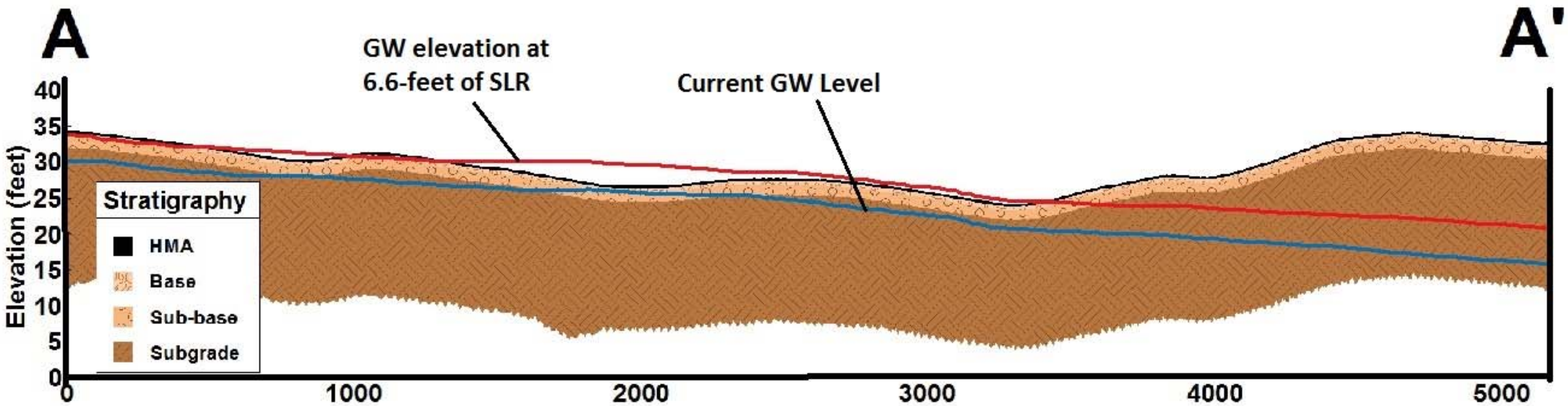




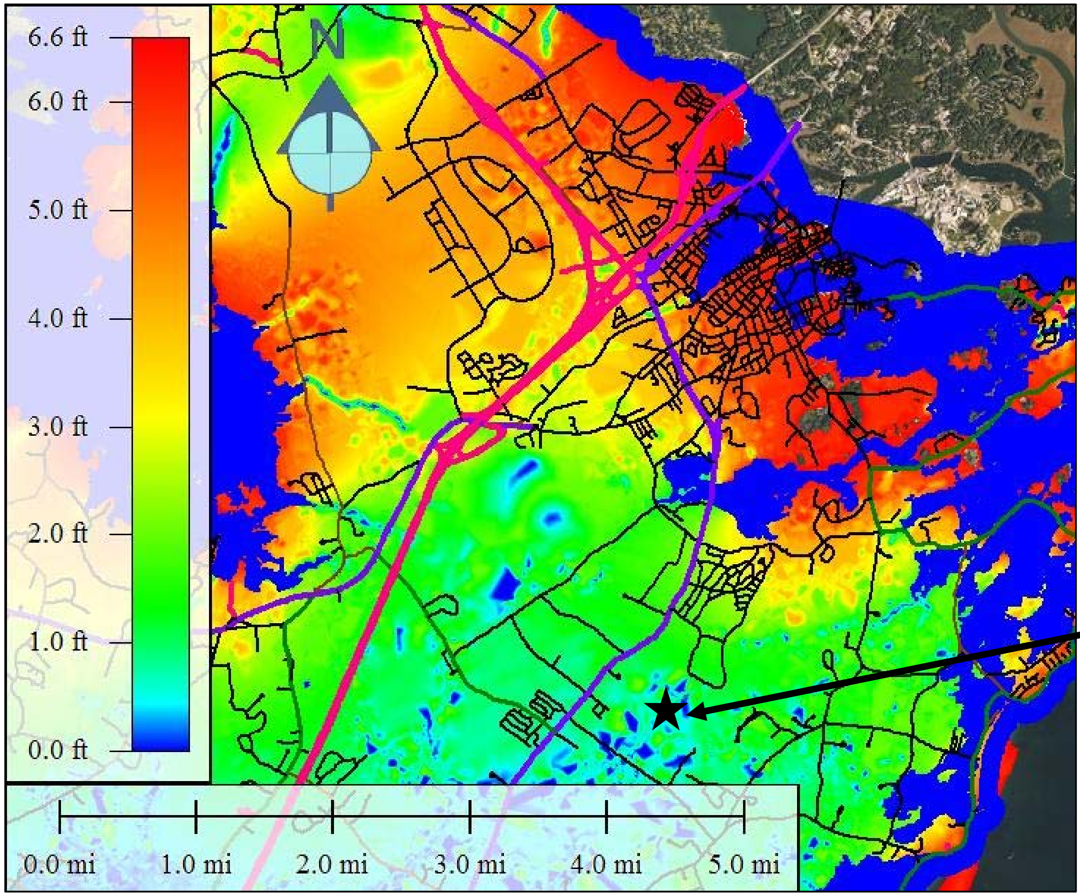
Transect of the off-ramp from I-95 through the Portsmouth Circle



The groundwater is predicted to rise approximately 4-5 feet along this section of road

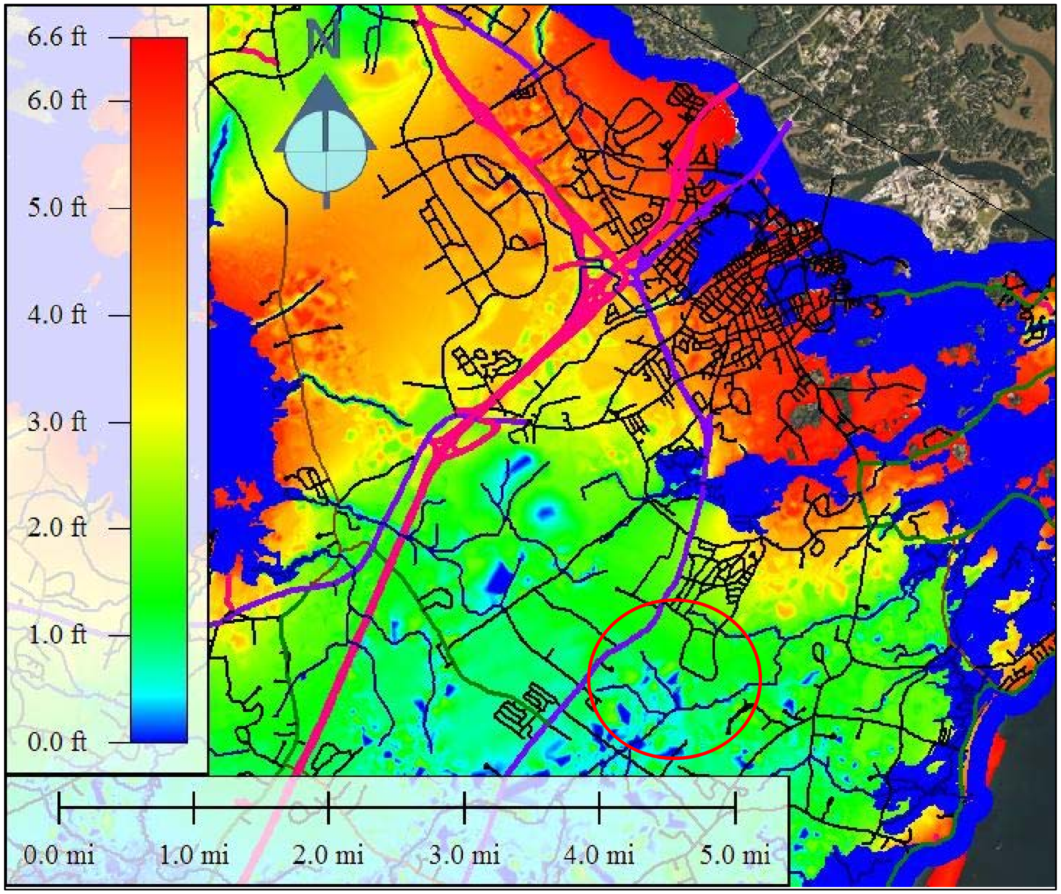


Rise in GW with 6.6 feet of SLR



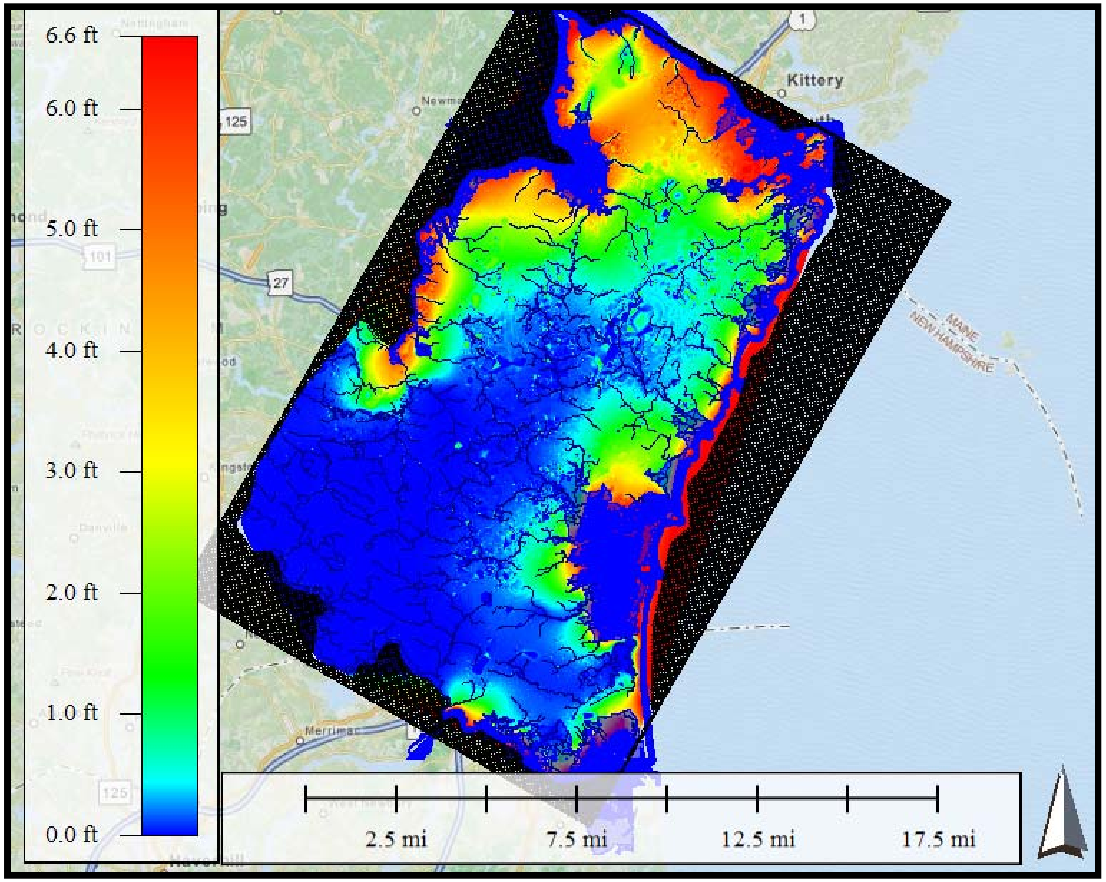
Why doesn't the GW rise as much here?

Increase in GW level is reduced in the proximity of streams, but. . .



- Streamflow will increase.
- The freshwater/salt water interface may move further inland.

Increase in GW levels with 6.6-feet of SLR



What factors make coastal road infrastructure vulnerable to changes in climate?

- Proximity to the ocean
- Locations where groundwater is near the ground surface *and* where groundwater is projected to rise
- Inadequate stream crossings now or in the future
- Subgrade soil types that weaken with increasing moisture content

Conclusions

- Groundwater modeling is an effective tool for investigating spatially variable hydrologic changes resulting from climate change.

- Rising groundwater and changing flow patterns will have important consequences for the structural integrity of infrastructure, water supply and water quality, stream base flow, and the health of natural ecosystems.

- Adaptation strategies must consider potential damage from rising groundwater in addition to surface water impacts.

Future research

- Investigate how groundwater recharge and levels are influenced by changing precipitation patterns and temperature due to climate change

- Model pavement performance with changing groundwater levels, temperatures, and precipitation

- Conduct case studies for adaptation planning

- Use groundwater modeling to investigate the potential for seawater intrusion and the degradation of groundwater quality with sea-level rise in the Town of Newmarket

Acknowledgements

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- NH Department of Environmental Services (NHDES)
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- Gregory Barker, NH Geological Survey

Thank you

Questions?

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