Sea-Level Rise Impacts on Drinking Water

A Groundwater Modeling Study in Newmarket, NH

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Notes on Use and Applicability of this Report and Results:

The purpose of this vulnerability assessment report is to provide a broad overview of the potential risk and vulnerability of drinking water resources as a result of projected changes in sea-levels and coastal storm surge. This report should be used for preliminary and general planning purposes and to guide further investigations. The model is a conceptual model that is limited by factors including: a simplified representation of the geology; limited data on material properties, saltwater concentrations, and piezometric heads in groundwater; assumption of a constant pumping rate throughout simulation; a changing coastline was not simulated with sea-level rise scenarios; the uncertainties in sea-level rise projections.

Executive Summary

Project Overview

Strafford Regional Planning Commission (SRPC) partnered with the University of New Hampshire (UNH) to implement a groundwater modeling study to identify existing and potential future locations where public water systems may be vulnerable to sea-level rise impacts on groundwater. With guidance from a Technical Planning Committee, a computer model was developed to analyze potential impacts of saltwater intrusion on groundwater and drinking water in the Town of Newmarket based on three sea-level rise projections.

The objectives of the project were to:

- Better understand how sea-level rise could impact groundwater in the Town of Newmarket
- Develop short and long term strategies to reduce risks to drinking water source contamination associated with saltwater intrusion.
- Utilize groundwater modeling results to identify additional threats to source water that result from changes in groundwater level, such as septic systems or underground storage tanks.
- Provide the Town of Newmarket with information that will support decision making related to its current wells, as well as the location of future wells that will enable both the protection of the quality of drinking water sources as well as human health.
- Identify a menu of adaptation strategies the community can employ to reduce risk and protect its drinking water investments.
- Evaluate the lessons learned, including transferable findings and limitations of this type of analysis.
- Apply innovative academic research in a community.
- Recommend next steps for the Town of Newmarket.

As noted in the New Hampshire Coastal Risk and Hazard's Commission report, efforts to adapt to sea-level rise have primarily focused on identifying and implementing strategies to reduce risk associated with surface water, including flooding and storm surge. This groundwater modeling project was developed out of the recognized gap in understanding and addressing how rising sea-level will impact the level and chemistry of groundwater.

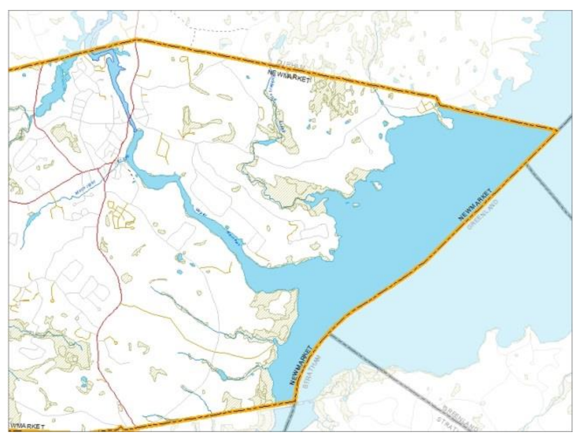


Figure 1. Newmarket's Coastal Shoreline. [SRPC, 2017]

A model was developed for the Town of Newmarket, which is located in Rockingham County on the west side of Great Bay. As the crow flies, the town is approximately 8.5 miles from the Atlantic Ocean. Newmarket has approximately five miles of shoreline along Great Bay, as well as approximately 3.5 miles of frontage on the tidal portion of the Lamprey River (see Figure 1).

Description of the Model

Two models were used to simulate a groundwater flow model to assess effects of sea-level rise from climate change on groundwater levels and saltwater intrusion in Newmarket: USGS MODFLOW2000 and SEAWAT2000. The study modeled a three-dimensional area that includes all of the Town of Newmarket along with portions of Lee, Durham, Newfields, Exeter, Brentwood, and Epping and extends from the water table to a depth of 600 feet below mean sea level. The model uses scenarios developed by the National Oceanic and Atmospheric Administration (NOAA) in the third National Climate Assessment. These scenarios include sea-level rise projections of 1.0, 2.7, 5.2, and 6.6 feet corresponding to the high emission scenario in the early-century (2030), mid-century (2060) and end of the century (2090 and 2100). See Appendix A for a technical description of the model.

Outcomes

Based on the GIS outputs that were produced by UNH's groundwater model, SRPC analyzed the effects of sea-level rise on groundwater levels and saltwater intrusion. The 6.6ft sea-level rise (by 2100) was used for the map set because it represented the maximum potential threats to groundwater and drinking water supplies, and thus encompasses all threats identified in the 1ft, 2.7ft, and 5.2ft scenarios.

Groundwater Rise

Groundwater rise ranging from 1 to approximately 7 feet with 6.6 feet of sea level rise is predicted to occur within 0.8 miles from the coast of Newmarket. The town can expect to see impacts in a range of approximately 565 acres in the lower sea-level rise scenario all the way up to 1,250 acres in the highest sea-level scenario. Moody Point is projected to experience the most groundwater rise due to the influence of the adjacent wetland area to the north and the mouth of the Lamprey River to the south. These plots suggest that the Moody Point wells already may be experiencing some saline water in their wells.

The model may overestimate the concentration saltwater in the wells for several reasons. The Moody Point wells are modeled in the bedrock in layers 14 through 18, corresponding with approximately 400 to 500 feet below mean sea-level. In reality, it is likely that the wells take water from a larger depth interval which would reduce the salt concentrations by mixing the lower concentrations from the layers above. Also, the wells are assumed to be continuously pumping a combined total of 6,256 cubic feet per day from 1992 onwards, which is likely to be an overestimate since the wells are not pumped continuously.

Vulnerable Infrastructure and Potential Contamination

The analysis identified one contamination hazard site, one local potential contamination site, and one sewer pump station. The contaminated hazard site is the former Frank Smas Property (now owned by the Nature Conservancy) on Bay Road, which in 2005 required a Phase I Environment Site Assessment Report to investigate elevated lead and arsenic concentrations collected from a historical farm dump located at the site. The local potential contamination site is the Kevin D. Ernest Revocable Trust Property on New Road, which NHDES lists as supporting vehicle service repair (VSR) activities on the site. It is assumed that these activities are taking place in the outbuilding garage, and are relatively small in scale. The Moody Point sewer pump station was also identified as vulnerable.

It was determined that 30 private drinking water supplies have the potential to be impacted by groundwater rise, including the Moody Point Wells. In the 6.6 foot sea-level rise scenario, over half of the private wells identified in the analysis are projected to be impacted by a 1 to 2 feet of groundwater rise; all four wells with 6 feet groundwater rise are located on Moody Point.

Saltwater Intrusion

The analysis projects that Moody Point may experience an 8-12% increase in salinity concentrations with up to a 16% increase in the immediate vicinity. Inland public water supply wells are not predicted to be affected by saltwater intrusion from sea-level rise. There are, however, approximately 30 domestic wells along the coast and nearby large volume supply wells that may be affected under the 6.6ft of sea-level scenario.

Septic System Risk

An environmental risk analysis was conducted to measure the risk to septic tanks based on soil characteristics and surface water features. A vulnerability map was produced to assist the town in identifying areas of concern for potential septic system failure. Additional information on private septic systems, including: location, age, depth of groundwater, and maintenance records is needed to more accurately determine the most at risk areas.

Climate Change and Sea-Level Rise Projections

Climate change is expected to have significant impacts on human and natural systems in coastal New Hampshire. Over the last century, average temperature and precipitation and the frequency and intensity of heat and precipitation events in the Piscataqua/Great Bay region have increased.[i] Sea level rise and coastal flooding associated with sea-level rise have also increased. Regional and national studies indicate that these trends will continue and intensify in the Northeast.[ii]

Global sea level rise has occurred for decades and is expected to continue throughout this century and beyond.[iii] Sea-level rise is caused by change in both the volume of water in oceans and the amount of water the sea can hold given the height of the land. As temperatures increase, melting land-based ice, including glaciers and ice sheets, and thermal expansion of the ocean cause sea level rise.[iv] At the local level, factors including tectonic uplift and down dropping, isostatic rebound[1] and depression, coastal subsidence, land surface changes from compaction, dewatering, fluid extraction, and diagenetic processes[2] influence vertical land motion and lead to variations in relative sea level rise.[v] In addition to melting ice and land subsidence, changes in ocean circulation may also contribute to the increased sea level rise the Northeast has experienced over the last century.[vi] These factors make New Hampshire particularly vulnerable to sea-level rise.[vii] Sea-level rise will likely pose significant impacts and risks to coastal communities, cultural resources, infrastructure, and ecosystems and fresh water resources.

The extent of future climate change and future sea-level rise depends on the rate that greenhouse gas emissions are reduced. A range of scenarios are used to project future sea-level rise under low, medium, and high emissions scenarios. As shown in Figure 2, projected sea-level rise ranges from 1 foot in 2030 to 6.6 feet in 2100 under a high emissions scenario.

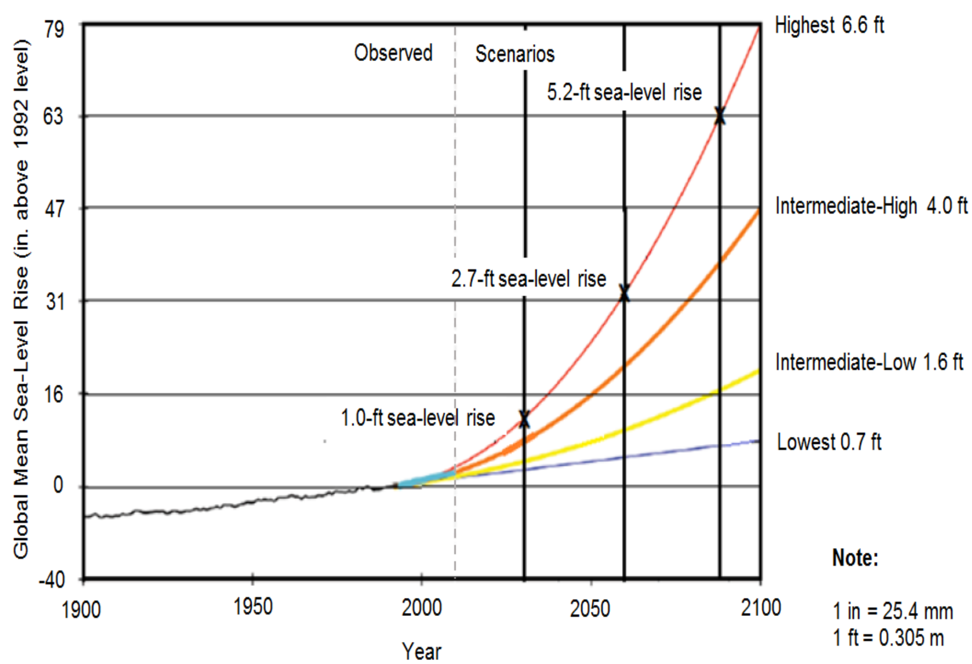


Figure 2. Global mean sea-level-rise scenarios relative to 1992 from the National Climate Assessment. [Parris et al., 2012]

During the timeframe in which the modeling work and the development of this report were being completed, NOAA released a report titled "Global and Regional Sea Level Rise Scenario for the United States" (2017) that indicates sea-level projections under the highest scenario may be in the range of 6.6ft to 8.9ft of rise by 2100. These results take into consideration the instability of the Antarctic ice-sheet and indicate that these higher outcomes may be more likely than previously thought. While these projections are based on models and there is always a high level of uncertainty, it is important to recognize that the trend continues to go up – not down.

[1] Isostatic rebound – The crust of the Earth was depressed underneath the weight of the ice during the last ice age. It is still rebounding north of us. As the crust to the north rebounds, the crust underneath the Northeast Region sinks resulting in a small % of the total SLR in the area.

[2] Diagenesis – The changes (primarily chemical) that occur as sediments, that have been deposited, are converted to rock (over geologic time).

Climate Change Impacts on Drinking Water

Overview

While the impacts of climate change on groundwater storage or flow are not well understood, expected changes in precipitation and land use in aquifer recharge areas, coupled with changes in demand for groundwater, will affect the availability and quality of groundwater.[viii]

Factors including proximity to the coast and Great Bay, location in relation to fresh water bodies, elevation of system components, size of contributing watershed to surface water sources, and geologic settings of groundwater sources will affect the impact of climate change on water systems.[ix] Impacts of flooding, wind, sea-level rise may include damage to infrastructure, water quality impairment, and water availability.

NHDES identified three primary challenges for New Hampshire's Drinking Water Systems in its 2014 Climate Change Resilience Plan:

- Damage to infrastructure
- Water quality concerns
- Water availability concerns

Nearly all coastal aquifers experience some naturally occurring saltwater intrusion. As the elevation of saltwater bodies increases and as coastal flooding continues to occur, the saltwater intrusion may increase. Groundwater withdrawal and pumping of aquifers can increase saltwater intrusion.[x]

Sodium Chloride in Groundwater

In pristine areas of New Hampshire, the levels of sodium and chloride in groundwater are typically less than 20 milligrams per liter (mg/L) and 20 mg/L, respectively. Higher levels of sodium and chloride occur naturally in the immediate seacoast area and typically reach up to 75 mg/L sodium and 150 mg/L chloride.[xi] Substantially higher levels of these elements can indicate that other factors such as road salt storage and usage, discharges from water softeners, human or animal waste disposal, leachate from landfills, or other activities are contributing to groundwater contamination.[xii]

The Environmental Protection Agency does not currently identify a maximum contamination level (MCL) for sodium or chloride under the primary Federal Safe Drinking Water Act. Secondary, advisory (Aesthetic) Drinking Water Standards for these contaminants are 250 mg/L. This is the concentration at which drinking water can taste salty.[xiii]

Key Terms

Aquifer: A geologic formation composed of rock, sand, or gravel that contains significant amounts of potentially recoverable water, or water that could be withdrawn by a well.

Groundwater: The water between the cracks and spaces in soil particles and rock beneath the surface of the land.

Saltwater Intrusion: The movement of saline water into freshwater aquifers.

High levels of sodium and chloride can result in increased treatment costs for water providers and may render groundwater wells unusable. This would require communities to develop new well locations or alternative sources of freshwater.[xiv]

To learn more about sodium chloride in drinking water, see the NHDES factsheet: https://www.des.nh.gov/organization/commissioner/pip/factsheets/dwgb/documents/dwgb-3-17.pdf

Economic Implications

While it is difficult to predict exact dollar amounts, estimating economic impacts associated with climate change needs to be considered at the local level. The purpose of this study and analysis was to strictly look at the impacts of sea-level rise on groundwater resources; however, changes in water supply and demand are influenced by climate change and it can be expected that non-consumptive uses (flow rates and hydropower), as well as consumptive uses (agriculture and drinking water) will be impacted as well.

As a coastal community likely to deal with sea-level rise, Newmarket may face future capital costs that include investments in new water treatment technology to combat salinity concentrations, the replacement of underground pipes that corrode faster submerged under salt water, and the possible extension of municipal water infrastructure to locations such as Moody Point where they are already experiencing high total dissolves salt concentrations. Other more localized costs that may fall on homeowners could include the siting of new private drinking water wells, and the potential to relocate existing septic systems (depending on changes to groundwater levels). Finally, the loss of environmental resources in the Great Bay Estuary (shellfish, saltmarsh, fish species, etc.) and the ecosystem services they provide would have economic implications for Newmarket residents and those residing in the seacoast region.

Climate Resilience Evaluation and Awareness Tool (CREAT)

The EPA's Climate Resilience Evaluation and Awareness Tool (CREAT) defines and identifies the following economic consequences of climate change on water systems:

- Utility Business Impact – Operating revenue loss evaluated in terms of the magnitude and recurrence of service interruptions. Consequences range from long-term loss of expected operating revenue to minimal potential for any loss
- Utility Equipment Damage – Cost of replacing the service equivalent provided by a utility or piece of equipment evaluated in terms of the magnitude of damage and financial impacts. Consequences range from complete loss of the asset to minimal damage to the equipment
- Source/Receiving Water Impacts – Degradation or loss of source or receiving water quality or quantity evaluated in terms of recurrence. Consequences range from long-term compromise to no more than minimal changes to water quality or quantity
- Environmental Impacts – Evaluated in terms of environmental damage or loss, aside from damage to water resources, and compliance with environmental regulations. Consequences range from significant environmental damage to minimal impact or damage.

Vulnerability Assessment of Sea-Level Rise and Coastal Storm Surge Flooding in Newmarket

A recent assessment — Climate Risk in the Seacoast (C-RiSe): Vulnerability assessment of projected impacts from sea-level rise and coastal storm surge flooding — identified the vulnerability of wellhead protection areas and stratified drift aquifers in Newmarket. The mapping assessment found that impacts to these natural resources varies under low, medium, and high sea-level rise scenarios, as well as when storm surge was added to sea-level rise projections. The total acres of wellhead protection areas impacted ranged from 1.10 to 21.24 acres, while the impacted acres of land that overlay stratified drift aquifers ranged from 3.72 to 32.24 acres.[xv] The C-RiSe vulnerability assessment also identified vulnerable water pipes and pump stations. The assessment found that no water pipes were projected to be inundated by sea-level rise; however, the pump station near Creighton Street is projected to be impacted. [xvi]

Newmarket's Drinking Water Supply

Public Water Supply and Groundwater Resources in Newmarket

There are five active public water systems in Newmarket. Approximately 56% of the town's population of 8,936 (2010 Census) is served by the Newmarket Water Works. An additional 475 people are served by condominium community water systems (Table 1). Approximately 39% of the population of the town relies on private wells. Table 2 displays the registered water users and average daily withdrawal in the town. The average annual withdrawal from public water system wells is approximately 392,000 gallons per day (2016).[xvii] This is projected to increase, according to two studies by Metcalf & Eddy (2004) and Underwood Engineers, Inc. (2006) to 671,000 and 533,700 gallons per day, respectively, by 2025.[xviii]

Table 1. Community Water System, Newmarket, NH (Source: NHDES Onestop)

System Name	System ID	System Type	System Category	Population Served	Connections
Newmarket Water Works	1731010	Community System	Major CWS	5,000	1,950
Moody Point	1732010	Community System	Condominiums	215	86
Wade Farm Condos	1732020	Community System	Condominiums	40	16
Great Bay Water System	1732030	Community System	Condominiums	220	87
Great Hill Maples	1738010	Transient Non-Community	Restaurant	60	2

Table 2. Registered Water Users, Newmarket, NH (Source: NHDES Onestop)

Name	Source Destination ID	Source Type	Substrate Type	Average Daily Use (gallons) (2015)	Average Daily Use (gallons) (2016)
BRW 1	20018-S02	GROUNDWATER	BEDROCK WELL	7,954	8,656
BRW 3	20018-S03	GROUNDWATER	BEDROCK WELL	4,827	5,200
Folletts Brook	20057-S01	SURFACE WATER	BROOK	0	0
Bennett Well	20057-S02	GROUNDWATER	GRAVEL WELL	159,758	154,460
Sewall Well	20057-S03	GROUNDWATER	GRAVEL WELL	213,904	226,288
Piscassic River	20057-S04	SURFACE WATER	RIVER	0	0
Lamprey River	20057-S05	SURFACE WATER	RIVER	0	0
NGE-2B	20057-S06	GROUNDWATER	GRAVEL PACKED WELL	0	8,534

There are approximately 657.5 acres of stratified drift aquifer (7.2% of total municipal area) and 3,062.6 acres of till aquifer (33.7% of total municipal area) in Newmarket. The most productive groundwater resource is a stratified drift aquifer known as the Newmarket Plains Aquifer. The surficial area of this aquifer is approximately 410 acres (0.64 square miles) and is about 60 to 80 feet at its deepest point.[xix] This is the primary source of drinking water from the Bennett and Sewall Wells. The Bennet and Sewell Wells are located approximately 2,250 feet apart in the Newmarket Plains Aquifer, which is a sand and gravel aquifer that underlies the towns of Newmarket, Lee, and Durham.[xx] Additional stratified drift aquifer deposits in Newmarket exist along Bald Hill Road in the western portion of town and directly beneath Route 108 on the south side of town. Due to their relatively shallow depths of less than 20 feet, and narrow size, and potential contamination from development along Route 108, neither deposit is considered to have high water supply potential. Studies indicate that the combination of that rate of withdrawal from this source and drought conditions have resulted in the lowering of groundwater levels in the aquifer. [xxi]

One potential drinking water source the Town did consider was located at the Beaudet Farm parcel, consisting of about 162 acres located in the Business (B-2) zoning district in one of the largest commercially zoned parcels in town. Preliminary studies found that the Beaudet Farm contains two bedrock test wells that have potential to provide substantial water supply yields based on preliminary well drilling information from more than 10 years ago. The Town was unable to reach a lease agreement with the owners and that location has been abandoned. The Town has since developed the Macintosh well and acquired a second site, the Tucker Well off Neal Mills Road. While the Town has moved on from the Beaudet Farm parcel, it doesn't mean that in the future there may not be renewed interest in that source of water for both municipal and private use.

Managing and Protecting Drinking Water in Newmarket - Past and Ongoing Planning Efforts

The Town of Newmarket is committed to protecting and managing its groundwater resources and adapting to climate change. The Town recognizes that climate change will have a range of impacts on public and private property, infrastructure, and the Town's residents and businesses. Examples of past and ongoing planning efforts include:

Town of Newmarket Master Plan – Vision Chapter

In 2016, the Town adopted a new Vision Chapter for its Master Plan. The chapter identifies both the goal of protecting water resources and of continuing to become more resilient to change:

- *The integration of climate adaptation measures into municipal programs, policies, and operations reflect Newmarket's commitment to reduce community risk. Smart development has led to a greater resilience against adverse impacts and infrastructure vulnerability associated with climate changes, such as sea- level rise and increased flooding.*

Town of Newmarket Master Plan – Water Resources Chapter

A number of policy statements to guide protection of groundwater resources are included in the Water Resources Chapter, including:

- *Groundwater: Protect the volume and quality of groundwater resources for use as future sources of drinking water and to protect the hydrology of surface waters and wetlands.*
- *Municipal drinking water supply: Comprehensively protect existing and future drinking water sources and manage these resources to accommodate growth while sustaining them for the future.*
- *Potential threat to water resources: Protect water resources from pollution and degradation to maintain critical functions, benefits and ecological integrity of these resources*

Town of Newmarket Zoning Ordinance – Section 5.01 Aquifer Protection Overlay District

The purpose of the Aquifer Protection Overlay District is to:

- *Protect, preserve and maintain existing and potential groundwater supplies and related groundwater recharge areas.*
- *Prevent development and land use practices that would increase risk of contamination or reduce the recharge of identified aquifers.*

- *To provide for future growth and development of the Town, in accordance with the Master Plan, by insuring the future availability of public and private water supplies.*

Town of Newmarket Code of Ordinances –Chapter 14 Article II Water Management

Upon evaluation of information in Chapter 14 Section 20, and declaration of a water supply shortage or other water emergency by the town administrator, the water department shall be authorized and empowered to impose such restrictions necessary to conserve and maintain adequate reserves of the public water supply, including the following stages:

- *Voluntary water conservation*
- *Mandatory odd/even outside water use*
- *Mandatory two-day lawn watering by address*
- *Mandatory outside water ban*

Climate Risk in the Seacoast - Vulnerability Assessment of Projected Impacts from Sea-Level Rise and Coastal Storm Surge Flooding (C-RiSe)

- In 2016, the Town participated in a vulnerability assessment that was conducted by SRPC. The mapping assessment identified and measured the impacts of flooding from sea-level rise and storm surge, including the extent and depth of flooding, on built structures, human populations, and environments.

Water Demand Study and Sewer Capacity Study

- In 2017, the Town hired Wright-Pierce to prepare a water demand study and sewer capacity study, which will include a 20-year build out analysis that will look at the Bennett and Sewell Wells to determine the safe yield.

Building Resilience to Flooding and Climate Change in the Moonlight Brook Watershed

- In 2015, the Town received NOAA funding through their competitive NHDES Coastal Program Resiliency Technical Assistance Grants Program. This grant award funded the Horsley Witten Group, Inc. to study flood risk associated with climate change as well as how future development and build out of the community affect these risks; and to design robust green infrastructure practices within the Moonlight Brook watershed to help reduce risk of flooding while reducing pollutant load into the brook and further downstream into the Lamprey River and ultimately Great Bay.

Climate Change Related Workshops and Trainings

Over the last several years, Newmarket has partnered with a variety of agencies to offer trainings and workshops for both municipal decision-makers and residents. Workshops and trainings include, but are not limited to:

- March 25, 2013 – “Climate Change/Sea-Level Rise Kick-Off Presentation” w/ guest speaker Cameron Wake (UNH) provided the latest data on climate change science and predicted impacts.
- June 25, 2014 – “Newmarket Plans for Municipal Stormwater Impacts” w/ guest speakers: Tim Puls (UNH Stormwater Center), Newton Tedder (EPA-Region1), Barbara McMillan (NHDES), Bill Arcieri (VHB), and Jill Farrell (NROC). More than 25 participants attended the workshop, including members of town government, conservation commissioners, public work employees, planners, and local residents. Many residents offered their thoughts on stormwater management and permitting and were also interested in becoming more actively involved during the next steps. Among the next steps for residents and the community include continuing public outreach and education efforts and identifying creative stormwater management opportunities.

Mapping Results

Based on the GIS outputs that were produced by UNH's groundwater model, SRPC was able to create a series of maps in which the effects of sea-level rise on groundwater levels and saltwater intrusion were analyzed. The 6.6ft sea-level rise (by 2100) was used for the map set because it represented the maximum potential threats to groundwater and drinking water supplies, and thus encompasses all threats identified in the 1ft, 2.7ft, and 5.2ft scenarios. Results from the mapping analysis not shown in the map set are provided in figures and tables, as appropriate. For more information about the modeling process, the report in its entirety is attached in Appendix A.

Limitation of Study

It is important to note that with any model, there are certain associated limitations. For this particular study, key factors and variables to consider include: mapping and data restrictions, scale, assumed pumping rates, and uncertainties. Mapping only shows impacts at select depths/layers of the model, and limited data on material properties, saltwater concentrations, and piezometric heads in groundwater may lead to inaccuracies. The model also contains a simplified representation of the geology within the study area and does not take into account the changing extent of surface water as sea-level increases. In other words, the shoreline doesn't change in the model, but realistically would change over time as sea-level increases – a changing coastline was not simulated with sea-level rise scenarios.

This was a regional study with wide geographic parameters, in which the model used 400x400 foot grid cells; it is not intended to be used on a parcel basis. Another limitation to this study is the analysis did not account for the distance between surface level and current groundwater, which would be needed to identify areas where groundwater rise would already be relatively close to the surface and more vulnerable. The model did not look at the impacts of sea-level rise without well pumping; constant pumping rates were used throughout the simulation, which we know to not be the case as water demands and usage fluctuates throughout the year. There are also uncertainties in the sea-level rise projections that were used and may change over time.

Lastly, this was a one-year project with limited funding and did not allow for further analysis. The model is capable of future runs that can incorporate additional information and inputs if Newmarket wants to build on this effort.

What else can be done with the Model?

In future phases, the model can be used to:

- Map other model layers and spatial scales
- Run the model with sea-level rise and no pumping to determine the relative importance of each to salt-water intrusion
- Conduct a sensitivity analysis on material properties; improve model with more data
- Add or remove wells and change pumping rates to investigate the effect changing demands for drinking water
- Investigate the effects of a changing coastline

Groundwater Rise

Groundwater rise ranging from 1 to approximately 7 feet with 6.6 feet of sea level rise is predicted to occur within 0.8 miles from the coast of Newmarket. Table 3 summarizes the amount of land area (acres) experiencing groundwater rise by each of the four sea-level rise scenarios. Newmarket can expect to see impacts in a range of approximately 565 acres in the lower sea-level rise scenario all the way up to 1,250 acres in the highest sea-level scenario.

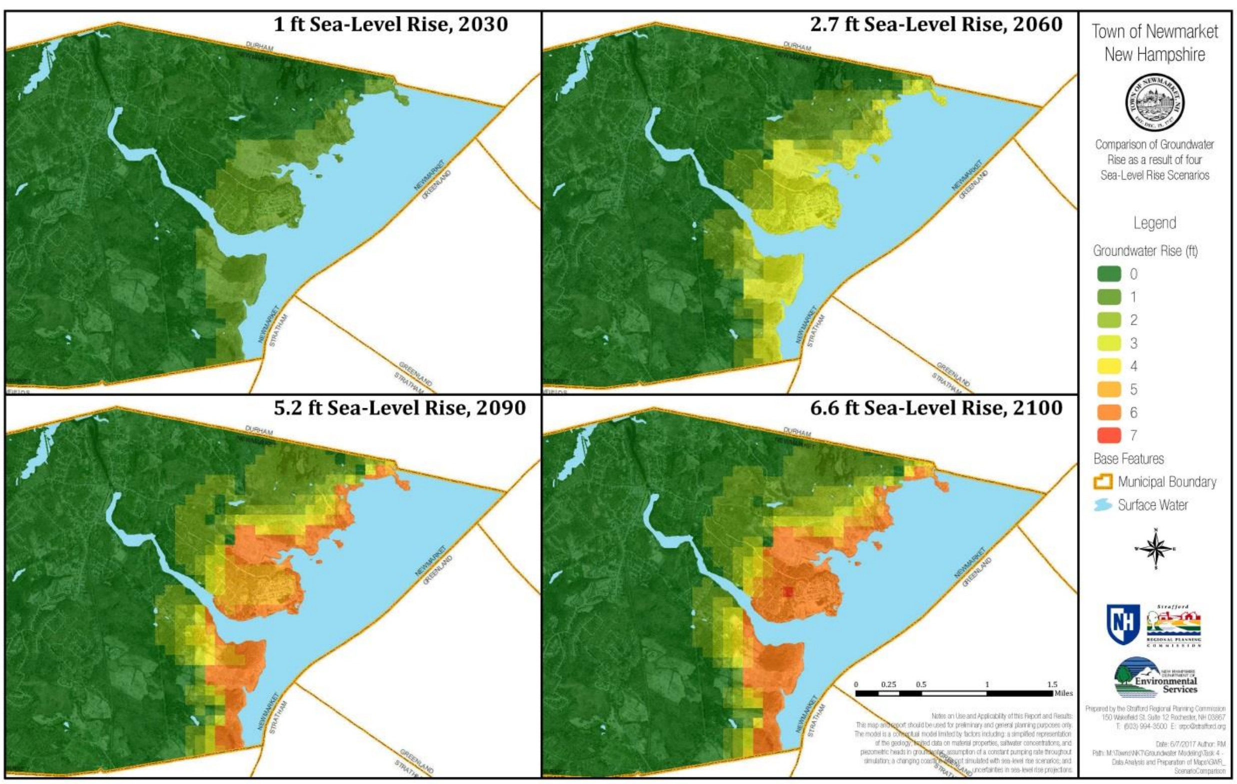
Table 3. Land Acreage Experiencing Groundwater Rise (Source: SRPC, 2017)

Groundwater Rise (ft.)	1ft SLR	2.7ft SLR	5.2ft SLR	6.6ft SLR
1	564.7	318.8	425.0	441.6
2		160.9	118.8	156.7
3		403.9	117.8	90.4
4			55.1	70.1
5			153.2	66.1
6			301.0	421.2
7				3.7
TOTAL (acres)	564.7	883.5	1,170.9	1,249.7
TOTAL (% acres)	3.7%	5.7%	7.6%	8.1%

Moody Point is projected to experience the most groundwater rise due to the influence of the adjacent wetland area to the north and the mouth of the Lamprey River to the south.

Results from the groundwater flow model were used to generate raster datasets representing the increase in groundwater (feet) from current (2016) levels. A 400 foot by 400 foot cell size was used to match the scale of the groundwater model. In the 1 foot sea-level rise scenario, no areas of Newmarket are predicted to experience more than 1 foot of groundwater rise, compared to the 6.6 foot scenario where much of the shore land property is expected to experience 6 feet of groundwater rise with a small area resulting in 7 ft.

Map #1: Comparison of Groundwater Rise by Sea-Level Rise Scenario



Map #1 represents the four different sea-level rise scenarios in incremental timeframes from 2030, which is understood as the short-term planning scenario all the way out to 2100, which is the long-term worst case scenario. The map graphically shows the difference in extent and intensity of groundwater rise over the four scenarios as described in Table 3.

Vulnerable Infrastructure and Potential Contamination Sites

As previously mentioned, the only public water supply in Newmarket projected to experience saltwater intrusion is Moody Point. Changes in concentration are visible deep in the bedrock and in the vicinity of the well. Much smaller changes are predicted in the shallow and mid-depths. These plots suggest that the Moody Point wells are already experiencing some saline water in their wells. The model may overestimate the concentration saltwater in the wells for several reasons.

The Moody Point wells are modeled in the bedrock in layers 14 through 18, corresponding with approximately 400 to 500 feet below mean sea-level. In reality, it is likely that the wells take water from a larger depth interval which would reduce the salt concentrations by mixing with the lower concentrations from the layers above. Also, the wells are assumed to be continuously pumping a combined total of 6,256 cubic feet per day from 1992 onwards, which is likely to be an overestimate since most wells are not pumped continuously.

Map #2 shows the drinking water infrastructure and potential sources of contamination that are vulnerable to increases in groundwater levels. The worst-case scenario (6.6 feet of sea-level rise) was chosen since it encompasses all public and private drinking water wells and potential contamination sites that would be impacted under all scenarios. Three public drinking water supply wells at Moody Point, two potential contamination hazards, one sewer pump station, and 30 private drinking water wells fall within the projected area of groundwater rise under this scenario.

Map #2: Vulnerable Infrastructure and Potential Contamination Sites

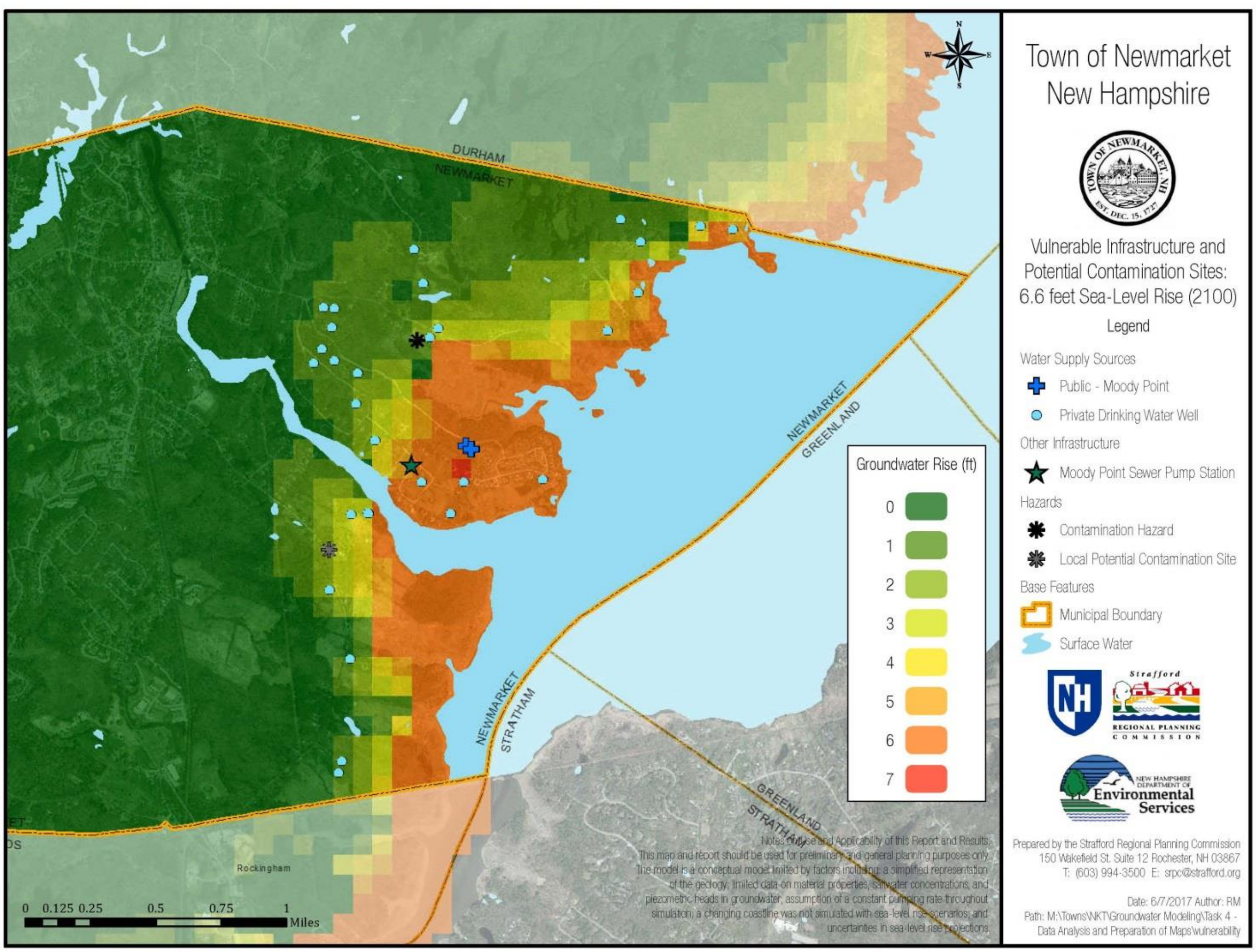


Table 4 summarizes groundwater rise levels for the three Moody Point wells under each of the four sea-level rise scenarios. Due to the close proximity of the wells and the large grid cells, there is no discernable difference in the projected rise levels between the three wells.

Table 4. Groundwater Rise for Moody Point Wells (Source: SRPC, 2017)

Moody Point Wells	Address	Groundwater Rise (ft.)			
		1ft SLR	2.7ft SLR	5.2ft SLR	6.6ft SLR
Well #1 (7819)	Cushing Rd	1	3	5	6
Well #2 (5074)	Cushing Rd	1	3	5	6
Well #3 (5076)	Cushing Rd	1	3	5	6

The mapping analysis identified one contamination hazard site[3] and one local potential contamination site[4]. The contaminated hazard site is the former Frank Smas Property (now owned by the Nature Conservancy) on Bay Road, which in 2005 received a Phase I Environment Site Assessment Report to investigate elevated lead and arsenic concentrations collected from a historical farm dump located at the site. Upon review, the Department of Environmental Services (DES) issued a certificate of no further action as it was demonstrated that the concentrations were reflective of site background concentrations and posed no associated groundwater threat. The state did recommend limiting site exposure to the soils as arsenic is present at concentrations above an established direct contact risk-based level. The local potential contamination site is the Kevin D. Ernest Revocable Trust Property on New Road, which NHDES lists as supporting vehicle service repair (VSR) activities on the site. It is assumed that these activities are taking place in the outbuilding garage, and are relatively small in scale.

Table 5 summarizes groundwater rise levels for each of the two contaminated sites under each of the four sea-level rise scenarios. Neither site is projected to experience any impacts under the 1ft scenario and a maximum of 1 to 2 feet of rise under the worst case scenario of 6.6ft of rise.

Table 5. Groundwater Rise for Contamination Sites (Source: SRPC, 2017)

Contamination Sites	Address	Groundwater Rise (ft.)			
		1ft SLR	2.7ft SLR	5.2ft SLR	6.6ft SLR
F. Smas Property	Bay Rd	0	1	1	1
Ernest Garage	New Rd	0	1	2	2

The mapping analysis identified the sewer pump station, which is owned and maintained by the Moody Point Community Association, as potentially being impacted by the different groundwater rise scenarios. It is unclear as to how potential groundwater rise would impact the overall function of the station, but impacts may include risk from groundwater inundation (if located at a low elevation), seepage into pipes causing increases in treatment volume, and potential corrosion of equipment in the treatment plant that may possibly harm the treatment bacteria. It will be important for the pump station to be properly monitored and maintained by the Community Association.

According to private drinking well data, which was provided by NHDES and developed by the DES Water Management Bureau, it was determined that 30 private drinking water supplies have the potential to be impacted by groundwater rise. The private drinking wells data includes wells installed since 1984 (data prior is not available); however, the coverage is not updated as frequently as the Well Completion Report Data summaries and only approximately 30% have been field-located.

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[3] Contamination hazards sites are existing and potential threats to source water quality including, but not limited to: above-ground storage tanks, CERCLA superfund sites, complaints, leaking bulk fuel storage facilities, groundwater release detection permits, isolated gw sample w/contaminant detection, non-petroleum hazardous waste, non-hazardous/non-sanitary holding tanks, initial spill response, lined landfills, proposed landfills, unlined landfills, leaking above-ground storage tanks, leaking underground storage tanks, lined wastewater lagoons, leaking motor oil storage tanks, old open dump sites, leaking heating oil tanks, rapid infiltration basins, septage lagoons, subsurface wastewater disposal >20,000gal/day, unsolicited site assessments, sludge lagoons, sludge applications, oil spill/releases, spray irrigation, municipal/commercial stump/demo dumps, solid waste transfer stations, underground injection control, unlined wastewater lagoons.

[4] Local potential contamination sites are located by public water system operators as part of the Phase II/V Waiver program including, but not limited to vehicle service/repair shops, general service/repair shops, metalworking shops, manufacturing facilities, waste & scrap processing & storage, laboratories & professional services, salt storage & use, cleaning services, food processing plants, fueling & maintenance of excavation & earthmoving equipment, concrete/asphalt/tar manufacturer, car dealerships, construction sites.

Table 6 summarizes groundwater rise levels for each of the 30 private drinking water supplies under each of the four sea-level rise scenarios. As with public drinking water supply sources, the greatest amount of groundwater rise will be experienced by private wells on Moody Point. In the 6.6 foot sea-level rise scenario, over half of the private wells identified in the analysis are projected to be impacted by 1 to 2 feet of groundwater rise; all four wells with 6 feet groundwater rise are located on Moody Point.

In conjunction with the groundwater rise scenarios, additional factors that play an important role in determining future vulnerability to private drinking water supplies include depth to groundwater, pumping rates, and well depths. Additional model runs and analysis are needed to develop more accurate risk assessments.

Table 6. Groundwater Rise for Private Drinking Water Supplies (Source: SRPC, 2017)

Private Drinking Water Supply Address	Well Depth (ft.)	Groundwater Rise (ft.)			
		1ft SLR	2.7ft SLR	5.2ft SLR	6.6ft SLR
Bay Road	405	1	2	3	4
Cushing Road	263	0	0	1	1
Cushing Road	155	0	0	1	1
Moody Point Drive	220	1	3	5	6
Bayview Drive	120	1	2	5	5
Stevens Drive	162	0	0	0	1
New Road	225	0	0	1	1
Cushing Road	262	0	1	1	1
Bay Road	200	0	0	1	1
New Road	440	0	0	1	1
Bay Road	180	0	1	3	3
New Road	280	0	0	1	1
Moody Point Drive	300	1	3	5	6
Moody Point Drive	305	1	3	6	6
Cushing Road	285	0	0	1	1
Bay Road	260	0	0	1	1
Smith Garrison Road	320	1	2	3	4
Bay Road	220	0	1	2	2
Gonet Drive	425	0	0	1	1
Barberry Coast Road	620	1	2	4	5
New Road	320	0	1	2	3
New Road	305	0	1	2	2
Gonet Drive	400	0	0	1	1
Bay Road	300	0	1	2	2
Cushing Road	510	1	3	6	6
Stevens Drive	425	0	1	2	2
Bay Road	300	1	2	5	5
New Road	320	0	1	3	3
New Road	345	0	1	3	3
Stevens Drive	300	0	0	1	1

Salt water Intrusion

The EPA has identified 250 mg/L as a concentration at which chloride can be expected to cause a salty taste in drinking water. The secondary level of 250 mg/L is based on aesthetic concerns, and is only advisory in the Federal Safe Drinking Water program. Current chloride levels at Moody Point are estimated to be 880 mg/L. This estimation is based off total dissolved salt (TDS) data provided by the Moody Point Community Association.

Elevated levels of sodium and chloride somewhat increase the water's ionic conductance, and thus slightly increase the potential for corrosive water damage to plumbing fixtures. To reduce this damage, a whole-house water treatment system would be needed. Bottled water is also an option to address the health concerns posed by leached lead and copper caused by corrosive water while a long-term treatment solution is being investigated. For further information concerning the layout of a water treatment system and its purchase, see the fact sheet WD-DWGB-2-5 "Considerations when Purchasing a Water Treatment System."
https://www.des.nh.gov/organization/commissioner/pip/factsheets/dwgb/documents/dwgb-2-5.pdf

Moody Point blends their drinking water using water from all three of their wells, allowing the water system to lower their average overall TDS levels. Table 7 shows the three well depths and current TDS levels. One can make the determination that the two deeper wells are experiencing the higher salt concentrations, which would be consistent with the model – wells deeper and closer to the groundwater table are more susceptible to saltwater intrusion.

Table 7. Groundwater Rise for Contamination Sites (Source: SRPC, 2017)

Moody Point Well	TDS (mg/L)	Well Depth (ft.)
Well 1	1,000	610
Well 2	240	510
Well 3	1,400	607

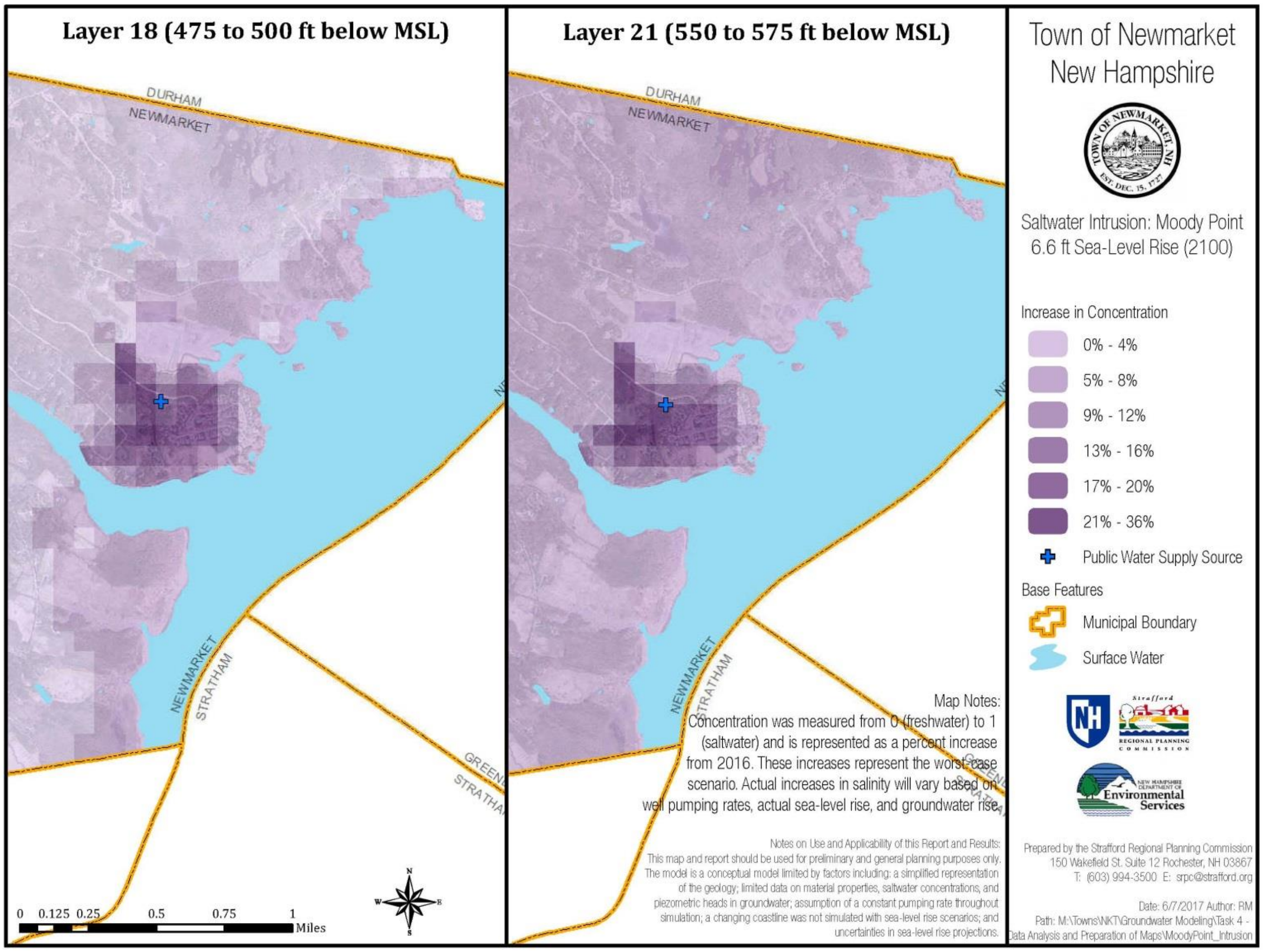
The mapping results project that Moody Point may experience an 8-12% increase (see Table 8) in salinity concentrations, with up to a 16% increase in the immediate vicinity. Inland public water supply wells are not predicted to be affected by saltwater intrusion from sea-level rise. There are, however, approximately 30 domestic wells along the coast and near large volume supply wells that may be affected under the 6.6ft of sea-level scenario.

Table 8. Percent increase in salt concentration from 2016 (Source: SRPC, 2017)

Moody Point Well	Well Depth (ft.)	Model Layer	Salt Concentrations (%)			
			1ft SLR	2.7ft SLR	5.2ft SLR	6.6ft SLR
Well 1	610	21	4.4	10.9	15.3	16.5
Well 2	510	18	2.6	6.0	7.8	8.2
Well 3	607	21	4.4	10.9	15.3	16.5

Map #3 shows the percent increase in salinity of groundwater relative to current (2016) levels. The groundwater flow model used a relative current saltwater concentration (0 being freshwater and 1 being saltwater) to determine the relative concentration in each of the four sea-level rise scenarios. A similar GIS analysis to groundwater rise was performed using 400 by 400 foot cells to find the percent increase in concentration. The worst-case scenario was chosen since it represents the greatest predicted extent of saltwater intrusion and percent increase in salinity. Layers from the model were specifically extracted based on the depths of the individual wells at Moody Point, and cannot be extended to private drinking wells in the area. Future analyses should consider extracting this data from the model in order to determine the impact of saltwater intrusion on private wells. Average depth and pumping rates differ greatly between public and private wells, so conclusions about the percent increase in salinity experienced by private wells cannot be generalized from the estimated impacts to public wells, despite their geographic proximity.

Map #3: Saltwater Intrusion at Moody Point



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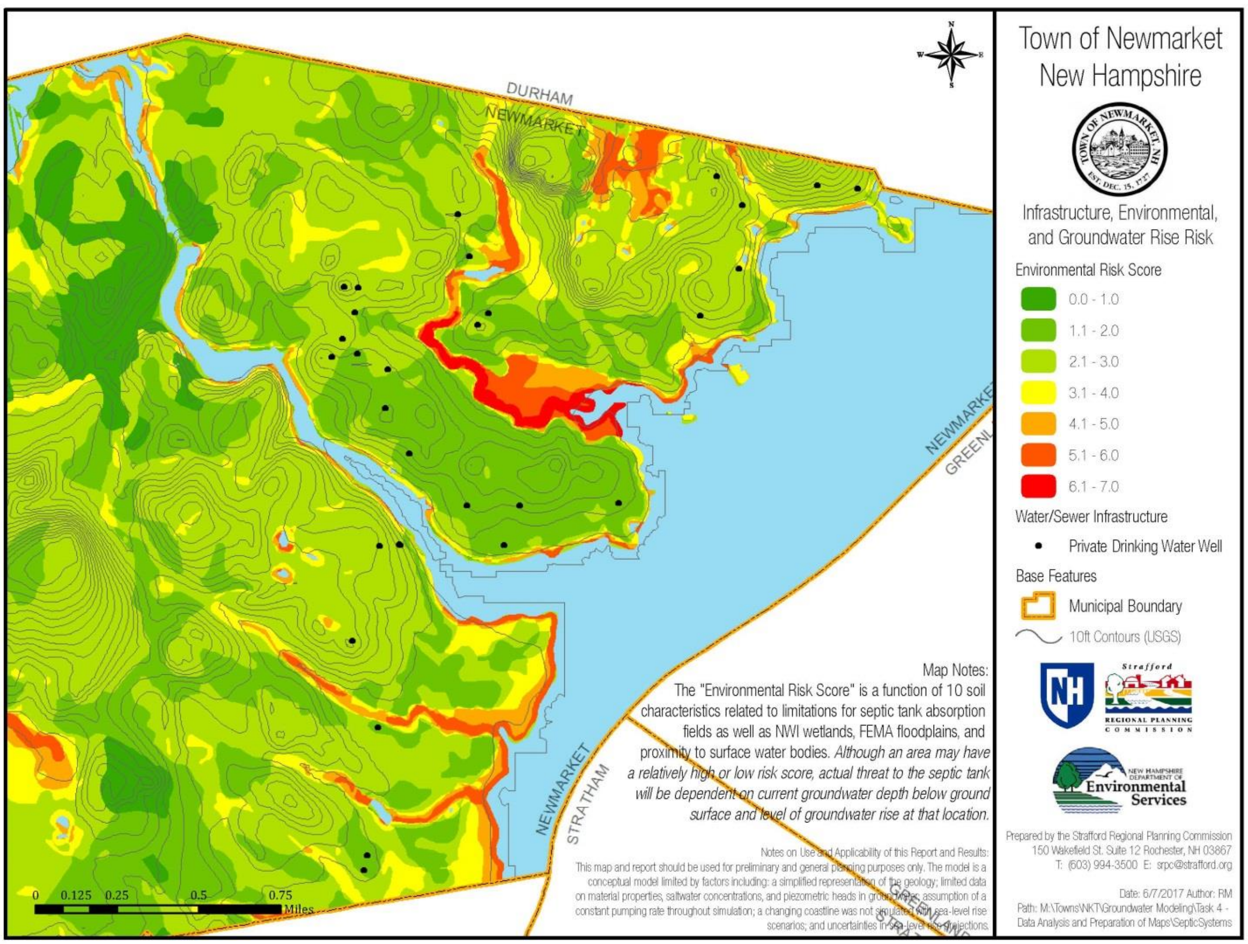
Septic System Environmental Impacts

An environmental risk analysis was conducted to measure the risk to septic tanks based on soil characteristics and surface water features (Map #4). Soils data were obtained from the Natural Resources Conservation Service (NRCS) Web Soil Survey relative to limitations for septic tank leach fields. Ten factors were used to score soil types across Newmarket on a scale from 0 to 1 for each factor. NWI wetlands, FEMA floodplains, and 100 foot buffer of surface water features were also assigned a value of 1 or 0, based on their presence or absence, respectively. These four data layers were overlaid and a composite score calculated (Environmental Risk Score). The Environmental Risk Score can be used to indicate where septic tanks and leach fields are more vulnerable to groundwater rise due to soil type and proximity to surface water features. However, current groundwater levels and distance to surface level were not taken into account and will have significant impacts on the actual risk to a septic tank. In New Hampshire, the depth at which septic tanks must be buried depends on multiple criteria but is generally between 3 to 6 feet (for the top of the tank) https://www.des.nh.gov/organization/commissioner/legal/rules/documents/env-wq1000.pdf. If current groundwater levels are 40 feet below the land surface, the maximum projected groundwater rise of 7 feet will not impact the septic tank, even if the environmental risk score in that area is relatively high.

Map #4: Septic System Risk



Using this map as a preliminary guide for planning purposes, the town can identify vulnerable areas for potential septic system failure. Additional information on private septic systems including location, age, depth of groundwater, and maintenance records is needed to more accurately determine where the most at risk areas are.

Types of Adaptation Strategies

Climate Change Adaptation

Climate change adaptation is action taken to avoid and minimize the negative impacts and take advantage of the positive impacts of a changing and increasingly variable climate.[xxii] Adaptation includes changes in processes, practices, and structures to reduce potential damages associated with climate change.[xxiii]

Adaptation Principles

- Identify vulnerable assets and resources
- Guide planning, regulation, and policies at all scales
- Inform prioritization of state, regional, and private investments in areas at risk to future conditions
- Identify possible strategies and actions that provide economic, social, and environmental benefits
- Protect public health and safety
- Improve community awareness about the region's changing climate
- Preserve regional and community character and ensure sustainable outcomes

(Wake, 2014)

General Federal, State, and Regional Strategies and Recommendations to Increase Resilience

NHDES Drinking Water & Groundwater Bureau developed a draft Climate Change Resilience Plan in June 2014 that provides information and resources about Community Water Systems and climate change. This includes a summary of resilience measures taken to date, strategies water systems can use to become more resilient, and actions NHDES can take to promote resiliency of these important systems.[xxiv] Among the strategies that were identified are:

- Educate customers, municipal officials and the public about the impacts of climate change and expected impacts on public drinking water systems
- Participate in community and regional planning related to climate change adaptation.
- Perform a vulnerability assessment to evaluate the impacts of climate change on a drinking water system and identify system weaknesses.
- Incorporate monitoring of groundwater conditions and climate change projections into groundwater models.
- Maintain an inventory of all assets, including photographs. Pre- and post-event documentation is important to document damages in support of insurance claims and in obtaining FEMA reimbursement, Hazard Mitigation Funding and other public assistance funding.

The Environmental Protection Agency, in its "Climate Ready Water Utilities" Report, identified a number of adaptation options. Many of these strategies are considered 'no regrets' actions that provide benefits to the utility under current and any future changes in climate to address water quality.[xxv] These include:

- Conduct sea-level rise and storm surge modeling. Incorporate inundation mapping estimates of saltwater intrusion into groundwater or estuaries within land use, water supply, and facility planning
- Develop models to understand potential water quality changes (e.g. increased salinity) and costs of resultant treatment changes
- Model groundwater conditions, including saltwater intrusion into aquifers associated with sea-level rise, and evaluate feasibility of implementing intrusion barriers

The New Hampshire Coastal Risk and Hazards Commission Final Report (2016) identified several recommendations for increasing resilience to climate change. Recommendations and action steps from this report that are relevant to drinking water impacts include:

- Identify gaps in scientific information, work to fill existing scientific information gaps, and conduct quantitative analyses detailing coastal risk and hazards. Conduct additional applied research to better understand saltwater intrusion into coastal surface and ground water sources.
- Assess current conditions of groundwater resources and impacts from best available climate science. Assess location, quality and quantity of groundwater under current and future climate conditions.
- Restore or maintain natural flow regimes (groundwater, surface water and wetlands) to increase ecosystem resilience to extreme weather events and other coastal hazards, including floods, drought, and sea-level rise. Comprehensively manage groundwater resources to consider infiltration and recharge, water quality, and changes to groundwater levels and salinity from sea-level rise.
- Identify gaps in scientific information, work to fill existing scientific information gaps, and conduct quantitative analyses detailing coastal risk and hazards. Identify impacts of future drought conditions on groundwater and drinking water sources, natural resources, and other assets.

Diversify the Water Supply

Diversifying options for water supply and expanding current sources can increase resilience.

- Diversifying sources helps to reduce the risk that water supply will fall below water demand. Examples of diversified source water portfolios include using a varying mix of surface water and groundwater, employing desalination when the need arises and establishing water trading with other utilities in times of water shortages or service disruption.[xxvi] Long term adaptation strategies may include using desalinated water to supplement surface and groundwater resources.

TOOL: Increasing Resilience of Utilities

The Climate Resilience Evaluation and Awareness Tool (CREAT) is a risk assessment application, which helps the utilities in adapting to extreme weather events through a better understanding of current and future climate conditions. The tool includes following steps:

- Discover: Find out which extreme weather events pose significant challenges to your utility and build scenarios to identify potential impacts.
- Assess: Identify your critical assets and the actions you can take to protect them from the consequences of extreme weather events on utility operations.
- Share: Generate reports describing the costs and benefits of your risk reduction strategies for decision-makers and stakeholders.

CREAT provides five general threats related to climate conditions for use in the risk assessment, including:

Water Quality Degradation: saline intrusion into aquifers and contaminated or negatively altered surface water quality.

For more information see:

https://www.epa.gov/sites/production/files/2016-05/documents/creat_3_0_methodology_guide_may_2016.pdf

Enhance Drinking Water Treatment

Although it can be costly to remove sodium and chloride from water, there are several options for doing so at the under-the-sink or full-house scale. Examples of effective treatment types identified by NHDES include:

- Reverse Osmosis (RO): This method places water under pressure against a special membrane. The membrane allows water molecules to move through, but retards the passage of salt and other dissolved minerals. RO is not practical for high-volume needs due to the inefficiency associated with the water "reject" rate. For more information on RO, see fact sheet WD-DWGB-2-11 "Reverse Osmosis Treatment of Drinking Water."
- Distillation: This method first boils water to produce steam. The steam is then condensed to produce purified drinking water. Salts and other mineral impurities stay in the boiling chamber. The boiling chamber requires periodic cleaning to remove the accumulated minerals. Distillation is not effective for organic contaminants. Distillation is costly to operate and is only feasible for a few gallons of water produced per day. The reject heat during the summer is objectionable to most people. See fact sheet WD-DWGB-2-15 "Distillation Treatment of Drinking Water."
- De-ionization: This method has similarities to a water softener, but uses strong acids and bases rather than salt to regenerate the system. While it is an effective method, the dangerous chemicals are inappropriate in a residence. See fact sheet WD-DWGB-2-12 "Ion Exchange Treatment of Drinking Water."

Increase treatment capabilities:

- Existing water treatment systems may be inadequate to process water of significantly reduced quality. Major improvement to existing treatment processes or implementation of additional treatment technologies may be necessary to ensure that quality of water supply (or effluent) continues to meet standards as climate change impacts source or receiving water quality. EPA's CREAT tool can help with determining vulnerability and action strategies (see box on next page).[xxvii]

Establish Barriers to Saltwater Intrusion

Injecting fresh water into aquifers can help create a barrier between fresh and saltwater while recharging groundwater resources. See the EPA's factsheet on Injection wells for more information: https://www.epa.gov/sites/production/files/2015-08/documents/fs_salt_intr_wells.pdf.

Use Public Health Regulations and Authorities

NH RSA 147:1 grants municipalities the broad authority to draft regulations for the prevention and removal of nuisances, and such other regulations relating to the public health as in their judgment the health and safety of the people require.[xxviii] The health officer of a town is responsible for implementing these regulations after they are approved by the selectmen, recorded by the town clerk, and published in some newspaper printed in the town, or when copies have been posted in two or more public places in the town.[xxix]

Per RSA 485:33 Testing of water supplies, if a health officer suspects, or is made aware of, a public or private water supply that may be contaminated, they may order testing (at no expense to the owner).

Per RSA 147, when a residential septic system is in failure, creating a nuisance and health hazard, the health officer has the authority to order the system repaired or replaced in accordance with Administrative Rule Env-Wq 1000. It is recommended that the public health officer provide educational materials to all property owners regarding drinking water quality and testing and septic system maintenance.

RESOURCE: Adaptation Strategies from EPA Climate Ready Water Utilities – Saltwater Intrusion into Aquifers

		No Regrets Option	Green Infrastructure	Water Demand Management	Energy Management	Relative Cost
Planning	Conduct seal-level rise and storm surge modeling. Incorporate resulting inundation mapping and estimates of salt water intrusion into groundwater into land use, water supply, and facility planning					$
	Develop models to understand potential water quality changes and costs of resultant changes in treatment	✓				$
	Model groundwater conditions, including saltwater intrusion into aquifers associated with sea-level rise, and evaluate feasibility of implementing intrusion barriers	✓				$
	Conduct training for personnel in climate change impacts and adaptation	✓				$
	Participate in community planning and regional collaboratives related to climate change adaptation		✓			$-$$
Operational Strategies	Finance and facilitate systems to recycle water, including use of greywater in homes and businesses			✓		$$-$$$
	Reduce agricultural and irrigation water demand by working with irrigators to install advanced equipment (e.g. drip or other micro-irrigation systems with weather-linked controls)			✓		$$-$$$
	Practice water conservation and demand management through water metering, leak detection and water loss monitoring, rebates for water conserving appliances/toilets and or/rain harvesting tanks			✓	✓	$-$$
Capital/Infrastructure Strategies	Diversity options to complement current water supply, including recycled water, desalination, conjunctive use[5] and stormwater capture	✓		✓		$$$
	Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage	✓				$$-$$$
	Increase water storage capacity, including silt removal to expand capacity at existing reservoirs and construction of new reservoirs and/or dams	✓				$$-$$$
	Install low-head dams to separate saltwater wedge from intakes upstream, in the freshwater pool[6]					$$$
	Implement barriers and aquifer recharge to limit effects of saltwater intrusion. Consider use of reclaimed water to create saltwater intrusion barriers					$$$
	Increase treatment capabilities and capacities to address decreased water quality due to saltwater intrusion	✓				$$$

Source: EPA, https://www.epa.gov/sites/production/files/2015-04/documents/updated_adaptation_strategies_guide_for_water_utilities.pdf

[5] Conjunctive use – This is a water conservation term referring to the storage of surface water in a groundwater infiltration basin during wet years for withdrawal during dry years. It is a term to describe the coordinated use of surface water and groundwater.

[6] Rising sea levels, combined with reductions in freshwater runoff due to drought, will cause the salt water-freshwater boundary to move further upstream in tidal estuaries. Upstream shifts of this boundary can reduce the water quality of surface water resources. Installation of low-head dams across tidal estuaries can prevent this upstream movement. This refers to a saltwater wedge in an estuary like the Squamscott or the Lamprey Rivers. The low head dam would be placed in the estuary to block the upstream migration of saltwater with SLR.

VI. Recommended Actions and Implementation

The following table contains strategies developed by the Technical Planning Committee, in conjunction with the Strafford Regional Planning Commission, and is intended to provide guidance for the Town of Newmarket on how to address sea-level rise impacts on the town's groundwater resources. Each strategy is associated with the following topic areas:

OE	PR	DW	IE	AR	EM
Outreach & Engagement	Planning/ Regulatory	Long-Term Drinking Water	Infrastructure & Equipment	Additional Research	Emergency Management

Included in the table is a broad planning timeframe category (short-term = 1-5 years; medium-term = 5-10 years; long-term = >10 years) and potential partners/programs and additional needs. It is important to note that in order to successfully implement many of these strategies the town will need to increase staff resources and capacity.

Implementation			
Topic Area	Strategy	Timeframe	Potential Partners/Programs & Additional Needs
OE	Provide education to private homeowners on water conservation measures, water testing, and septic system maintenance	Short-term	NHDES (Soak-up the Rain), EPA (WaterSense)
OE	Encourage private well owners to test their water for salinity levels	Short-term	NHDES; Investigate costs for testing; Potential grant opportunities
PR	Review local regulations for the separation of septic leach fields and wells and wells and sewers and other sources of contamination in potentially vulnerable areas and consider adopting greater standards than the state	Medium-term	Town Planner; Planning Board; Strafford Regional Planning Commission
PR	Consider developing a landscaping ordinance within the town's site and subdivision regulations to better manage water demand and uses; less watering has already shown to be effective in reducing salt concentration at Moody Point	Medium-term	Town Planner; Planning Board; Strafford Regional Planning Commission; NHDES; UNH (Green SnowPro)
PR	Consider additional components to the building permit process to include well-testing requirements for sodium/chloride and total suspended solids	Medium-term	Code Enforcement Officer; Research what other neighboring communities have done
DW	Develop contingency drinking water sources in case one source becomes damaged, contaminated or do not have adequate storage	Long-term	Groundwater investigation consultants would be needed to test potential well yielding
DW	Consider collaborating with adjacent municipalities to develop regional water systems or create formal or informal mutual aid agreements	Long-term	Adjacent communities

DW	Avoid increasing withdrawals from the Moody Point well and wells in coastal areas	Long-term	Moody Point Community Association
DW	Identify opportunities to increase recharge within the Moody Point Wellhead Protection Area	Long-term	Moody Point Community Association; NHDES; Groundwater investigation consultants would be needed
DW	Use existing resources to implement best management practices and strategies to increase resilience of water systems to other hazards	Medium-term	NHDES; Strafford Regional Planning Commission
IE	Consider purchasing groundwater level/salinity monitoring devices for existing or potential future well locations	Medium-term	NHDES; Potential grants may offset initial costs
IE	Identify potential areas to expand municipal water infrastructure	Short-term	Public Works Department; Identifying areas would be short-term, Implementation would be long-term
IE	Identify and repair existing leaks in water infrastructure to decrease withdrawals and avoid potential increased contamination	Medium-term	NHDES; EPA; Public Works Department
AR	Seek grant funding to re-run model to conduct a sensitivity analysis to determine impacts of modifying pumping patterns of withdrawal at Moody Point Wells, incorporate future projected population/capacity, and develop greater confidence with regard to vulnerable areas	Short-term	NHDES Source Water Program; UNH; Strafford Regional Planning Commission
AR	Continue to monitor, track, and map salinity levels within the initial study area.	Short-term	UNH; Strafford Regional Planning Commission
AR	Track migration of tidal influence, and obtain data from state-owned and community wells in the region to assist in future model runs	Medium-term	NHDES; UNH; Strafford Regional Planning Commission
AR	Investigate location, age, and maintenance records for private septic systems located within vulnerable areas identified in the environmental risk analysis map	Short-term	UNH; Strafford Regional Planning Commission
EM	Integrate an emergency response plan for back up water and saltwater intrusion into next Multi-Hazard Mitigation Plan Update.	Short-term	Emergency Management Director; Strafford Regional Planning Commission
EM	Ensure that the Town's Emergency Operations Plan and other relevant planning documents include plans for ensuring drinking water for residents served by Moody Point wells and private wells in coastal areas.	Short-term	Emergency Management Director

APPENDIX A: Groundwater modeling to investigate the effect of sea-level rise on saltwater intrusion and drinking water wells in the Town of Newmarket

Strafford Regional Planning Commission
University of New Hampshire
Groundwater Modeling
April 4, 2017

Introduction

Greenhouse gas emissions have caused an increase in global atmospheric and oceanic temperatures since the mid-20th century. The rate of warming is projected to increase through the 21st century and beyond [*Pachauri and Meyer,* 2014]. Sea level in coastal New Hampshire is projected to rise 3.8 to 6.6 ft by the year 2100 [*Kirshen et al.,* 2014] and can cause erosion, flood coastal communities and damage coastal infrastructure [*Melillo et al.,* 2014]. Sea-level rise has also been shown to raise groundwater levels [*Bjerklie et al.,* 2012] and increase saltwater intrusion in some locations [*Masterson et al.,* 2014]. The causes of sea-level rise are 1) thermal expansion of ocean waters, 2) water transfer between glaciers and oceans, 3) vertical land movement, 4) shifts in the Earth's magnetic field, and 5) ocean dynamics [*Parris et al.,* 2012].

Uncertainties exist in sea-level rise projections due to uncertainties in the rate of greenhouse gas emission reductions that will be adopted globally and uncertainties in the rate and magnitude of ice loss from the Greenland and West Antarctica ice sheets, a process that is not well understood. Regional factors such as changing ocean circulation patterns in the West to Northwest Atlantic may lead to higher than average sea level along northern parts of the eastern United States [*Ezer and Atkinson,* 2014]. For the third National Climate Assessment, the National Oceanic and Atmospheric Administration (NOAA) assessed a large body of sea-level rise studies and produced scenarios of global mean sea-level rise ranging from 0.7 to 6.6 ft by the end of the century [*Parris et al.,* 2012]. The lowest scenario is based on an extrapolation of the historical record. The highest scenario is based on the IPCC AR4 global sea-level rise projections and an estimate of the maximum amount of glacial and ice sheet loss by the end of the century. They recommend that the highest scenario be used to plan for infrastructure where there is little tolerance for risk [*Parris et al.,* 2012]. In coastal New Hampshire sea level rose 5.3 inches during the period from 1927-2001 which is close to the global mean sea-level rise [*Kirshen et al.,* 2014].

The New Hampshire Hazards and Risks Commission have adopted the NOAA scenarios for coastal adaptation planning. These scenarios were used in modeling the effects of rising groundwater on NH coastal road infrastructure [*Knott et al.,* 2017] and are used in this study. The sea-level rise projections are 1.0, 2.7, 5.2, and 6.6 ft corresponding to the high emission scenario in the early-century (2030), mid-century (2060), and end of the century (2090 and 2100), respectively. The goal of this study is to assess the effects of sea-level rise on groundwater levels and the potential for saltwater intrusion in Newmarket, NH. A groundwater flow model was developed and applied using the four SLR projections (Figure 1).

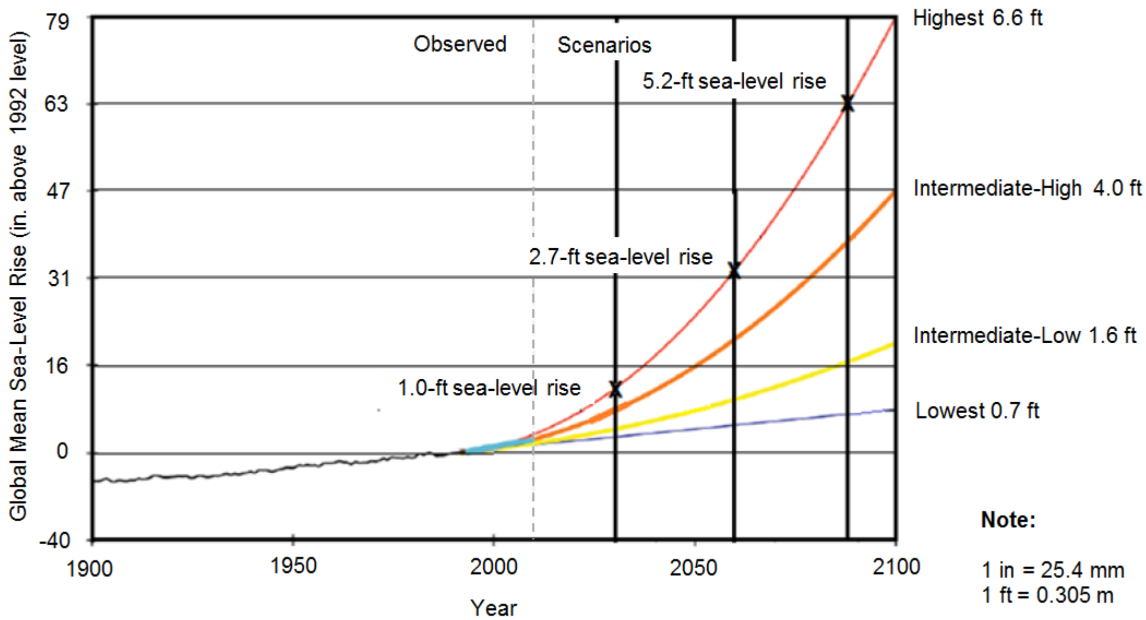


Figure 1. Global mean sea-level-rise scenarios relative to 1992 from the National Climate Assessment. [Parris et al., 2012]

Hydrogeology

The Seacoast Region of New Hampshire is characterized by thin glacial and marine sediments and a topography that generally follows the bedrock surface [*Mack,* 2009]. Land-surface altitude ranges from 4 ft above the North American Vertical Datum of 1988 (NAVD88) at the mouth of the Lamprey River to approximately 280 ft in the southwest corner of Newmarket [*NH Coastal Lidar,* 2011]. The surficial geology consists of fine-grained till and marine silts and clays and coarse-grained stratified drift consisting of sands and gravels in the unconsolidated deposits overlying the bedrock surface. The underlying bedrock consists of crystalline metamorphic rock of sedimentary origin and igneous bedrock [*Mack,* 2009]. The surficial deposits, mapped by [*Moore,* 1990; *Stekl and Flanagan,* 1992] are typically less than 40 ft. thick in the region with deposits of up to 100 ft. thick occurring in the Newmarket Plains Aquifer located along the northern boundaries with Durham and Lee (NH Geological Survey (NHGS).

The coarse stratified-drift sediments are the most permeable with hydraulic conductivities ranging from 50 to more than 200 ft/day. The hydraulic conductivities of the fine-grained sands range from 2 to 15 ft/day [*Ayotte and Toppin,* 1995; *Medalie and Moore,* 1995; *Mack,* 2009]. These sediments form unconfined aquifers bounded above by the water table and laterally by groundwater discharge areas along the Lamprey River and Great Bay. The coarse-grained stratified drift Newmarket Plains Aquifer is the most productive aquifer for water supply [*Town of Newmarket,* 2013] and groundwater in fractured bedrock is also extracted for drinking water. In addition to public water supply wells, there are many domestic wells in Newmarket, most of which have been drilled into bedrock [*Mack,* 2009]. Slightly less than one-half of the precipitation, averaging 40 inches per year from 1896 through 2004 in Durham, recharges the aquifer with the rest being lost to evapotranspiration and runoff [*Flynn and Tasker,* 2004]. Groundwater typically flows from areas of high groundwater altitude toward natural discharge areas in the Lamprey River and Great Bay [*Mack,* 2009].

Groundwater piezometric heads (heads) were compiled over the period of record from several sources including the NH Department of Environmental Services (NHDES) and the NHGS. Average groundwater heads in 144 wells, installed in the unconsolidated deposits, and 240 wells, installed the bedrock, were used to construct groundwater contour maps of the existing groundwater-flow regime and to identify target wells for use in model calibration. Groundwater heads were obtained from GEOLOGs (NHGS) and the water well inventory (NHDES). GEOLOGs are a compilation of boring and well information from NHDES, NH Department of Transportation (NHDOT) and the US Geological Survey (USGS). Groundwater head measurements from these data are available from the early 1900s to the present and were commonly measured only one time, while a few were monitored over time [*Barker,* 2016]. The water well inventory is a database of boring and well information compiled by the NHDES from wells installed for domestic and industrial water supply, exploration, and testing. Groundwater levels in this dataset were recorded by drillers during installation and are the most uncertain (NHDES). The piezometric head along the shoreline of Great Bay was assumed to be mean sea level (MSL) as recorded at the NOAA tidal gauge at Fort Point, Newcastle, NH and converted to NAVD88 [*NOAA,* 2016].

Modeling Process

USGS MODFLOW2000 [*Harbaugh et al.,* 2000] and the variable-density flow package SEAWAT2000 [*Langevin et al.,* 2007] were used to model the effects of sea-level rise on groundwater levels and saltwater intrusion in the Town of Newmarket. The model area includes all of Newmarket and parts of the adjacent communities Lee, Durham, Newfields, Exeter, Brentwood, and Epping (Figure 2).

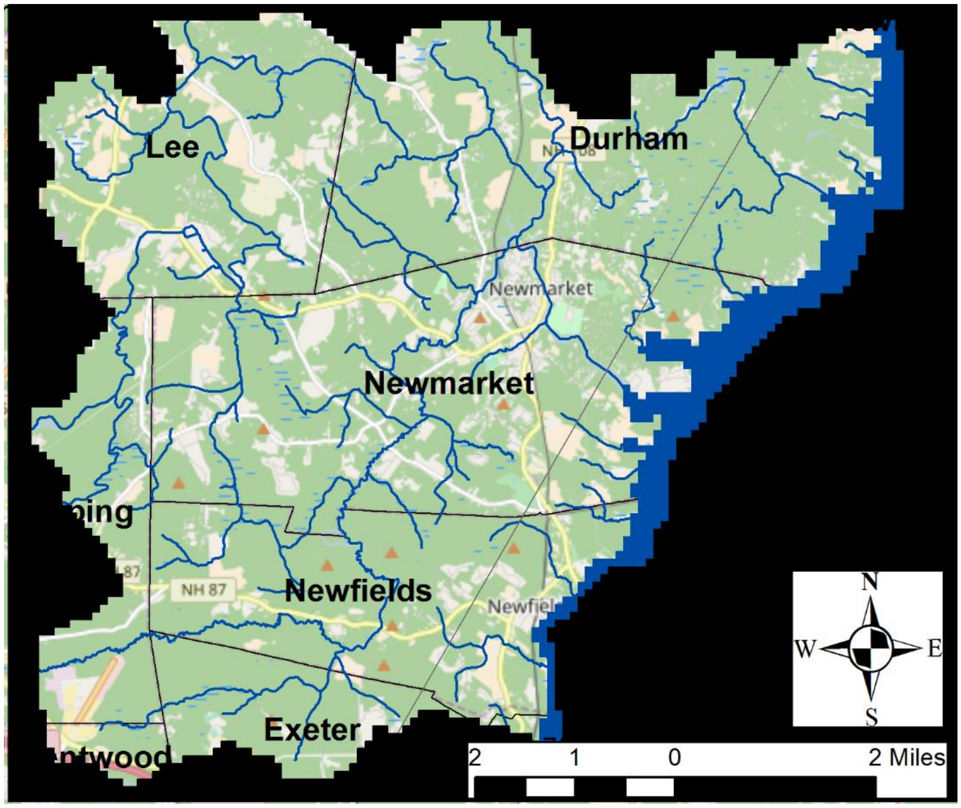


Figure 2. Study area showing streams, constant head (blue) and no flow (black) boundaries [OppenStreetMap contributors, 2016]

The model grid consists of uniformly-spaced cells that are 400 ft. x 400 ft. The grid consists of 105 rows and 125 columns with 22 vertical layers that extend from the water table to a uniform depth of 600 ft. below current MSL. The layer thicknesses vary from 5 to 50 ft. and many layers were used to model the location of the freshwater/saltwater interface. Typically, the bottom of the model is defined by the bedrock surface, but in this area of New Hampshire the bedrock surface is shallow, approximately 40 ft below ground surface, and many of the residential and public water-supply wells remove water from the fractured bedrock. Unconsolidated deposits were simulated in layers 1 through 3 to a depth of 40 ft. below MSL and bedrock was simulated in layers 4 through 22 down to a depth of 600 ft below MSL. This depth was chosen to include pumping wells at Moody Point, the maximum depth of which is approximately 575 ft below mean sea level (NHDES).

The freshwater aquifer receives water from aquifer recharge, the infiltration of precipitation and/or surface water and its percolation through the unsaturated zone to the saturated zone of the soil profile [*Heath,* 1983]. The infiltration rate depends on precipitation, the permeability of the soil, and other factors such as storm intensity, duration, and snow cover. Areal recharge rates used in the groundwater model were calculated by the NHGS using the Dripps model. This is a soil-water model that accounts for interception, evapotranspiration (ET), partitioning of run-off, soil infiltration or snow-pack storage, and soil-moisture partitioning [*Dripps and Bradbury,* 2007]. It is based on the water budget equation and compares favorably with standard base-flow separation techniques (Barker, personal communication).

The lateral boundaries of the model are the drainage divides to the North, South, and West and discharge areas along Great Bay and the Squamscott River to the East. The top four layers are bounded to the East by constant head/concentration cells down to depth of

60 ft. This simulates the constant head of Great Bay in the near term with a MSL of 0.31 ft. below NAVD88. Head-dependent boundaries were assigned to cells in layers 5 to 22 to allow for fresh groundwater discharge to the sea. All coastal boundary cells were assigned an initial relative concentration of 1 for saltwater (1= saltwater and 0 = freshwater). The concentration in the constant-head cells remains constant but the concentration in the head-dependent cells can vary. Cells at the outer edge of the model are assigned constant head/concentration for all 22 layers. This is a requirement of SEAWAT to ensure that enough saltwater is available to meet the simulation requirements [*Langevin et al.*, 2007]. Rivers, streams, and wetlands are also simulated as head-dependent flux boundaries in layer 1 of the model using the river package in MODFLOW [*Harbaugh et al.*, 2000]. Streams in the model area were digitized into 273 stream reaches using the National Hydrologic Dataset and high resolution aerial photographs in GIS [*NH Hydrography*, 2006; *Aerial Photos*, 2011]. Stream stage at the beginning and end of each reach was determined from bare earth LiDAR data and linearly interpolated between points [*NH Coastal Lidar*, 2011].

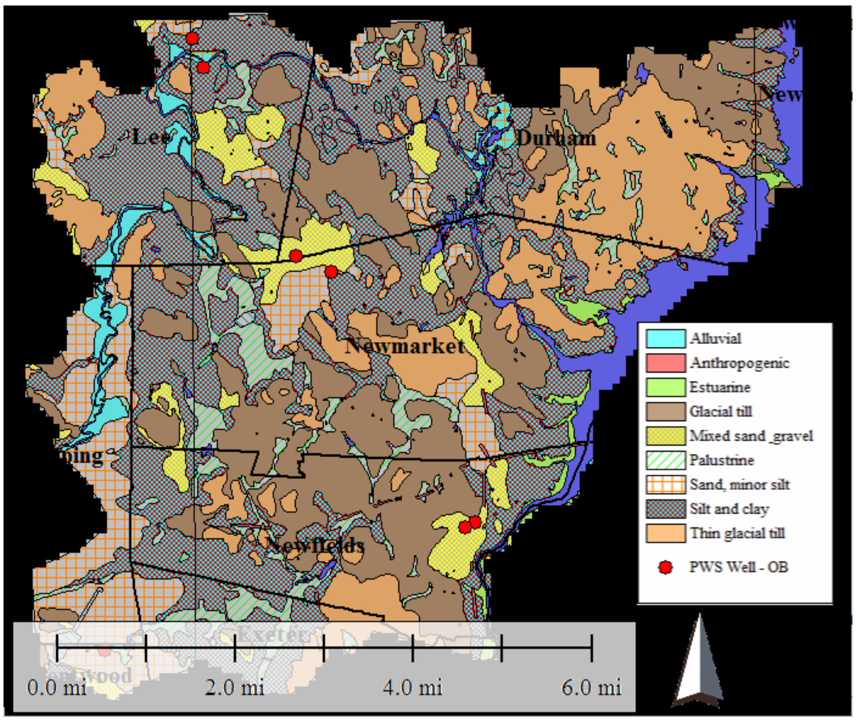


Figure 3. Surficial geology in study area with public water supply wells in overburden for the study area [NH State Geologist, 2004]

The hydrologic properties of the geologic materials include hydraulic conductivity, saturated thickness, storage coefficient, specific yield, and porosity. These were initially estimated using typical values based on surficial and bedrock geology [*Walton*, 1970; *Lyons et al.*, 1998; *NH State Geologist*, 2004; *Mack*, 2009] and then adjusted during the calibration process. Aquifer properties were assigned to 16 zones representing unconsolidated deposits and bedrock formations. The unconsolidated materials are represented by 10 zones consisting of deposits from estuarine (salt marsh) to glacial till (Figure 3).

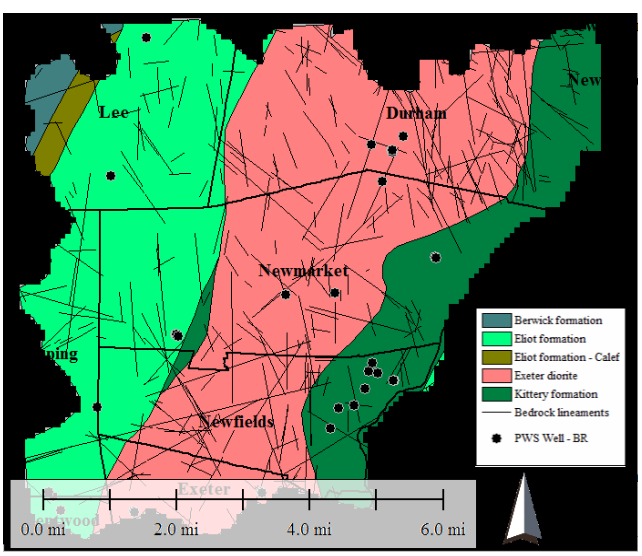


Figure 4. Bedrock geology zones with lineaments and public water supply wells in bedrock. [Lyons et al., 1998]

Bedrock zones represent three geologic formations with three additional zones representing lineaments (indicative of fracturing) within these formations [*Lyons et al.*, 1998; *Mack*, 2009] (Figure 4).

Table 1 lists the aquifer and bedrock property values used in the calibrated model by geologic zone.

Table 1 Aquifer and bedrock properties used in the model

Property Zones in Model		Hydraulic Conductivity (feet/day)			Storage/Porosity		
Zone	Description	K_x	K_y	K_z	Specific Storage	Specific Yield	Porosity
1	Water	13230	13230	5000	-	0.30	0.35
2	Estuarine (saltmarsh)	1.96	1.96	0.50	-	0.30	0.35
3	Palustrine (freshwater wetlands)	3.92	3.92	0.75	-	0.30	0.35
4	Anthropogenic - fill	1.96	1.96	0.50	-	0.25	0.35
5	Mixed sand and gravel	4.41	4.41	0.50	-	0.25	0.35
6	Alluvial - predominantly sand	1.00	1.00	0.01	-	0.30	0.40
7	Sand, minor silt	1.14	1.14	0.02	-	0.30	0.40
8	Silt and clay	0.10	0.10	0.01	-	0.20	0.45
9	Thin glacial till	0.13	0.13	0.05	-	0.20	0.20
10	Glacial till	0.03	0.03	0.03	-	0.20	0.20
11	Kittery formation	0.04	0.04	0.02	1.00E-05	-	0.10
12	Eliot and Berwick formations	0.23	0.23	0.01	1.00E-05	-	0.10
13	Exeter Diorite	0.13	0.13	0.03	1.00E-05	-	0.10
14	Kittery lineaments	0.01	0.01	0.01	1.00E-03	-	0.20
15	Eliot and Berwick lineaments	0.13	0.13	0.13	1.00E-03	-	0.20
16	Exeter diorite lineaments	0.71	0.71	0.71	1.00E-03	-	0.20

Public water supply information including well locations, depths and pumping rates were provided by NHDES. The locations of these wells are shown on Figures 3 and 4. Pumping rates were held constant during the entire simulation and the withdrawal volumes were distributed over all screened (overburden) or open borehole (bedrock) layers.

Model Calibration

The model was calibrated using the automated calibration procedure from Groundwater Vistas [*Rumbaugh and Rumbaugh,* 2011] to groundwater levels measured at 391 wells in the area over the period from 1940 to 2013. This calibration procedure uses inverse methods to determine the model parameters that best fit a set of "target" observations and employs Marquardt's modification to the Gauss-Newton nonlinear least-squares parameter estimation technique [*Levenberg,* 1944; *Marquardt,* 1963]. Approximately 35 percent of the target wells were screened in the overburden and 65 percent were open holes in the bedrock. Average piezometric heads from each target well were verified with the overburden or bedrock contour maps generated from the observations and assigned to the model layer in which the bottom of the well is located. The following statistics were generated for the model. The residual mean is 0.03 ft. The absolute residual mean, a measure of the average error in the model, is 8.7 ft. The residual standard deviation of the fit, a measure of the overall spread of the residuals is 11.4 ft or 8.0 percent of the range of head observations in the model area. A plot of the observations and the residual versus the simulated values is presented in Figure 5.

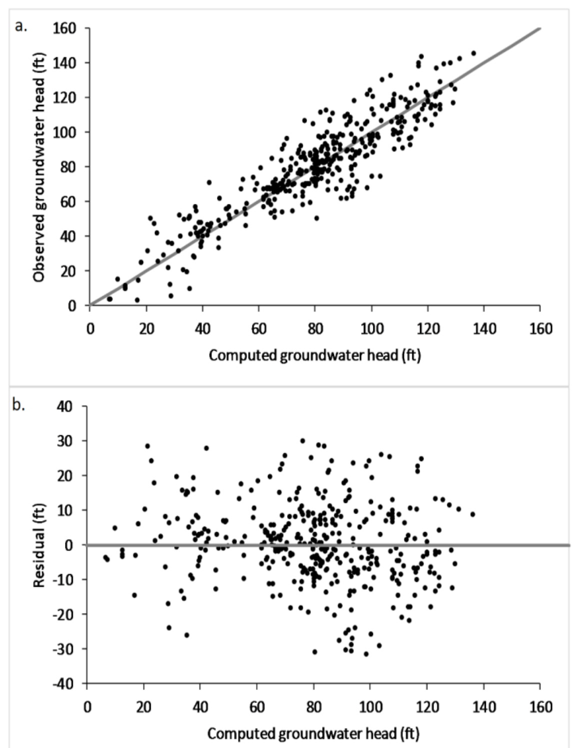


Figure 5. (a) Groundwater heads in observation wells from all 22 layers in the study area versus computed groundwater heads, and (b) groundwater-head residuals (simulated minus observed heads) versus computed groundwater heads.

The top layer of the model, represented by 140 target wells, is primarily where the groundwater table resides near the coast. The residual mean in this layer is 0.3 ft. The absolute residual mean is 5.1 ft. and the residual standard deviation of the fit is 6.6 ft. or 5.2 percent of the range of observations in layer 1.

Sea-Level Rise Scenarios and Model Simulations

The current MSL in coastal New Hampshire is 0.31 ft below NAVD88 [*NOAA,* 2016] and the historical rate of sea-level rise for the region for the period from 1927 through 2001 is 0.072 inches per year [*Kirshen et al.,* 2014]. Using 1992 as the reference year for the sea-level rise scenarios presented in Figure 1, coastal NH sea levels and the annual rate of rise were calculated (Table 2).

The steady-state flow model was calibrated to historical data without pumping. Following calibration, the model was run to quasi-steady state with SEAWAT for approximately 270 years to establish saltwater/freshwater equilibrium in the geologic materials. The very long time scales associated with salt-water intrusion necessitates the initial quasi-steady state run. The concentration output file at the end of the quasi-steady state run was used as the starting concentrations in the transient simulation. The transient simulation was run using the stress periods and the corresponding boundary heads presented in Table 1 for the periods from 1992 to the year 2100. The boundary head is a step function, changing at the beginning of each stress period and remaining constant for the time steps within each stress period. It was assumed that pumping began in 1992 and model output was generated for years 2016, 2030, 2060, and 2100 corresponding to 0, 1.0, 2.7, 5.2, and 6.6 ft of sea-level rise.

Table 2: Groundwater flow stress periods and corresponding coastal boundary head based on the third National Climate Assessment [*Parris et al.,* 2012]

Stress Period	Years	Stress period duration (yrs)	Stress period duration (days)	SLR relative to 1992 sea level (ft)	Sea Level-NAVD88 (ft)	Boundary Head - NAVD88 (ft)
Pumping begins	1992			0.00	-0.45	
1	1992-2016	24	8760	0.14	-0.31	-0.31
2	2016-2020	4	1460			-0.06
3	2020-2030	10	3650	1.00	0.55	0.55
4	2030-2040	10	3650			1.12
5	2040-2050	10	3650			1.68
6	2050-2060	10	3650	2.70	2.25	2.25
7	2060-2070	10	3650			3.08
8	2070-2080	10	3650			3.92
9	2080-2090	10	3650	5.20	4.75	4.75
10	2090-2100	10	3650	6.60	6.15	6.15

Model Limitations

The groundwater model created for this project is a conceptual model to investigate the effects of sea-level rise on groundwater levels and saltwater intrusion. It is not designed to predict groundwater head and/or concentration at individual wells, but to simulate groundwater-flow patterns and trends with sea-level rise and groundwater pumping. Uncertainties are associated with the groundwater measurements, bedrock geology, properties of the geologic materials, salinity distribution at the coast, and sea-level rise scenarios. The location of fracture zones in bedrock, which could have significant effect on saltwater intrusion, are not well known. Pumping is assumed to be at a constant rate throughout the simulation and there is uncertainty in the vertical distribution of withdrawal volumes. Despite these limitations, the groundwater model is useful in identifying the areas that are most at risk from saltwater intrusion (both shallow and deep in the geologic materials) and zones of groundwater rise caused by sea-level rise. This information can be used to direct monitoring programs, target areas for additional studies and data collection, and assist in managing large groundwater withdrawals where saltwater intrusion is predicted to occur.

Next Steps with the Groundwater Level

The groundwater model developed for this study has the potential to provide additional information beyond the scope of this project. It could be used to investigate the sensitivity of the simulated saltwater intrusion on the aquifer parameters used in the model including hydraulic conductivity, porosity, dispersivity, and conductance of the head-dependent flux boundaries. The groundwater model could also be used to investigate individual effects of sea-level rise and pumping on saltwater intrusion. Various pumping rates and pumping schemes can be investigated over time with or without sea-level rise and vice versa. Changes to seasonal and annual aquifer recharge associated with changing precipitation patterns and temperature variation from climate change can also be investigated to determine the impact of these changes on groundwater levels and the sustainability of drinking water sources. The model simulates groundwater and streamflow over a large inland area including all of Newmarket, Newfields, and portions of Durham and Lee. It could be used to investigate other groundwater questions outside the coastal focus of this study.

The groundwater model developed for this study has the potential to be enhanced. Model accuracy could be improved as more hydrogeologic data become available and are incorporated into the model. This study investigated the effect of increasing piezometric head at the coast due to sea-level rise but did not consider changing coastline geometry. Inland migration of the coast could affect saltwater intrusion both at shallow depths and deep in the bedrock. A potential next step is to simulate changes in the location of the coastal boundary as the coastline recedes with rising sea-level.

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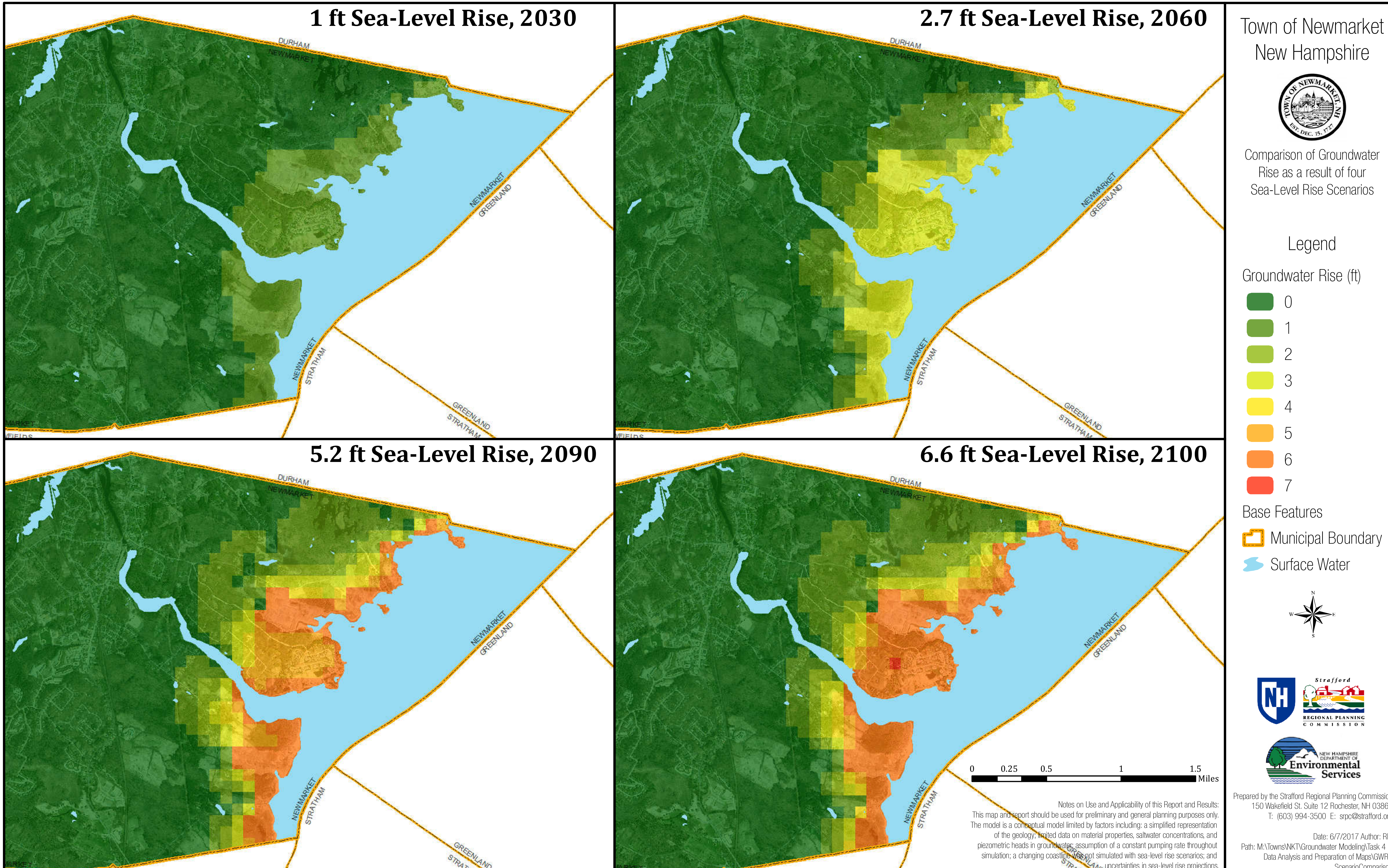
APPENDIX B: Map Set

Map #1: Comparison of Groundwater Rise by Sea-Level Rise Scenario

Map #2: Vulnerable Infrastructure and Potential Contamination Sites

Map #3: Saltwater Intrusion at Moody Point

Map #4: Septic System Risk


1 ft Sea-Level Rise, 2030
2.7 ft Sea-Level Rise, 2060
5.2 ft Sea-Level Rise, 2090
6.6 ft Sea-Level Rise, 2100
DURHAM
NEWMARKET
NEWMARKET
GREENLAND
NEWMARKET
STRATHAM
GREENLAND
STRATHAM
Town of Newmarket
New Hampshire
Comparison of Groundwater
Rise as a result of four
Sea-Level Rise Scenarios
Legend
Groundwater Rise (ft)
0
1
2
3
4
5
6
7
Base Features
Municipal Boundary
Surface Water
0 0.25 0.5 1 1.5 Miles
Notes on Use and Applicability of this Report and Results:
This map and report should be used for preliminary and general planning purposes only.
The model is a conceptual model limited by factors including: a simplified representation
of the geology; limited data on material properties, saltwater concentrations, and
piezometric heads in groundwater; assumption of a constant pumping rate throughout
simulation; a changing coastline was not simulated with sea-level rise scenarios; and
uncertainties in sea-level rise projections.
Prepared by the Strafford Regional Planning Commission
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T: (603) 994-3500 E: srpc@strafford.org
Date: 6/7/2017 Author: RM
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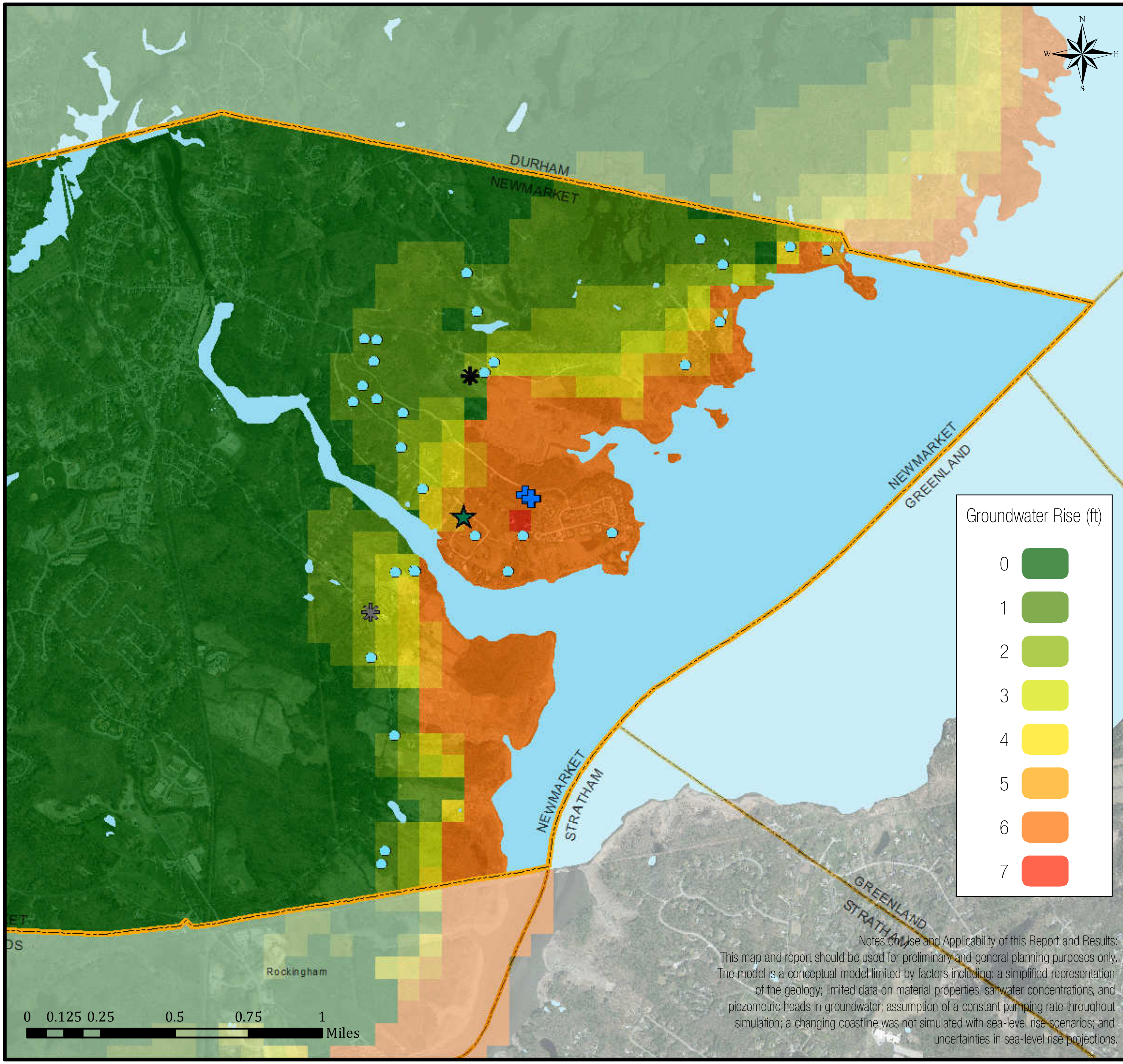
Data Analysis and Preparation of Maps\GWR_
ScenarioComparison



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Town of Newmarket New Hampshire

TOWN OF NEWMARKET, NH EST. DEC. 15, 1727

Vulnerable Infrastructure and Potential Contamination Sites: 6.6 feet Sea-Level Rise (2100)

Legend

Water Supply Sources
- Public - Moody Point
- Private Drinking Water Well

Other Infrastructure
- Moody Point Sewer Pump Station

Hazards
- Contamination Hazard
- Local Potential Contamination Site

Base Features
- Municipal Boundary
- Surface Water

Strafford Regional Planning Commission

New Hampshire Department of Environmental Services

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Date: 6/7/2017 Author: RM
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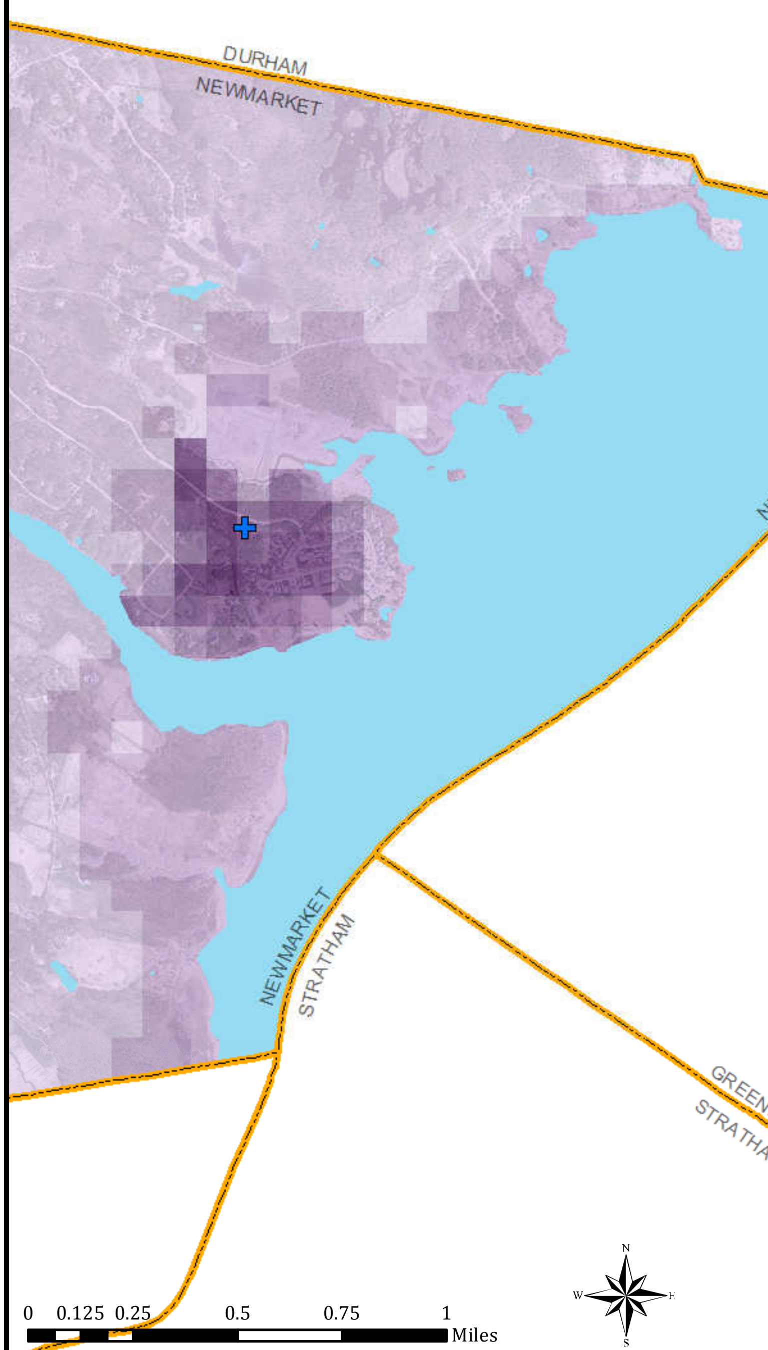
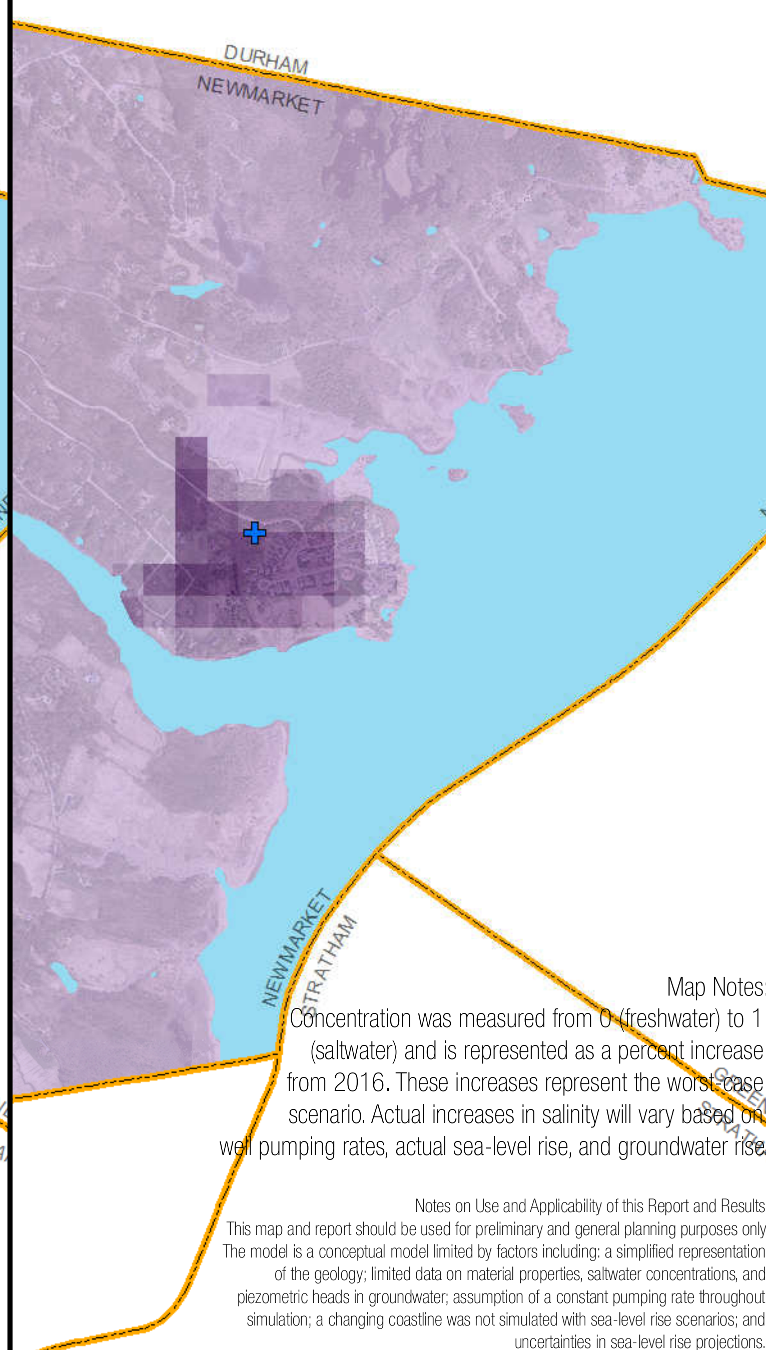
Layer 18 (475 to 500 ft below MSL)



Layer 21 (550 to 575 ft below MSL)



Map Notes:
Concentration was measured from 0 (freshwater) to 1 (saltwater) and is represented as a percent increase from 2016. These increases represent the worst case scenario. Actual increases in salinity will vary based on well pumping rates, actual sea-level rise, and groundwater rise.

Notes on Use and Applicability of this Report and Results:
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Town of Newmarket New Hampshire

Saltwater Intrusion: Moody Point
6.6 ft Sea-Level Rise (2100)

Increase in Concentration
- 0% - 4%
- 5% - 8%
- 9% - 12%
- 13% - 16%
- 17% - 20%
- 21% - 36%
- Public Water Supply Source

Base Features
- Municipal Boundary
- Surface Water

Prepared by the Strafford Regional Planning Commission
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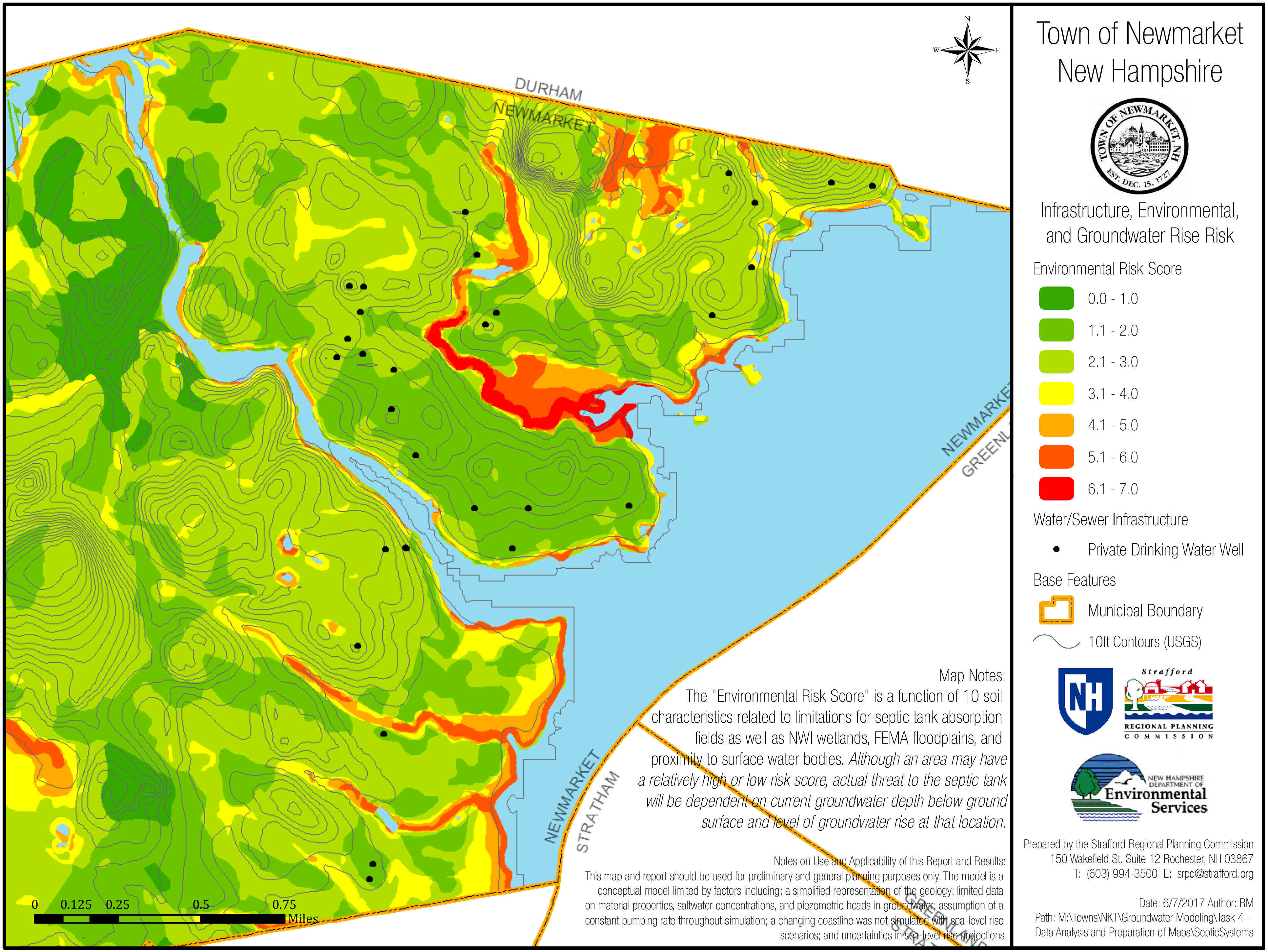

Town of Newmarket
New Hampshire
Infrastructure, Environmental, and Groundwater Rise Risk
Environmental Risk Score
0.0 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
Water/Sewer Infrastructure
Private Drinking Water Well
Base Features
Municipal Boundary
10ft Contours (USGS)
DURHAM
NEWMARKET
NEWMARKET
GREENL
NEWMARKET
STRATHAM
N
W
E
S
0
0.125
0.25
0.5
0.75
Miles
Map Notes:
The "Environmental Risk Score" is a function of 10 soil characteristics related to limitations for septic tank absorption fields as well as NWI wetlands, FEMA floodplains, and proximity to surface water bodies. *Although an area may have a relatively high or low risk score, actual threat to the septic tank will be dependent on current groundwater depth below ground surface and level of groundwater rise at that location.*
Notes on Use and Applicability of this Report and Results:
This map and report should be used for preliminary and general planning purposes only. The model is a conceptual model limited by factors including: a simplified representation of the geology; limited data on material properties, saltwater concentrations, and piezometric heads in groundwater; assumption of a constant pumping rate throughout simulation; a changing coastline was not simulated with sea-level rise scenarios; and uncertainties in sea-level rise projections.
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APPENDIX C: Fact Sheets

NHDES Fact Sheet #WD-DWGB-3-17: Sodium and Chloride in Drinking Water [2010]

NHDES Fact Sheet #WD-DGWB-2-5: Considerations When Purchasing Water Treatment Equipment [2012]

EPA: Saltwater Intrusion Barrier Wells

ENVIRONMENTAL Fact Sheet

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

29 Hazen Drive, Concord, New Hampshire 03301 • (603) 271-3503 • www.des.nh.gov

WD-DWGB-3-17 2010

Sodium and Chloride in Drinking Water

Many people use the word “salt” when they intend to refer to sodium or to sodium chloride. When a salt such as sodium chloride dissolves in water it breaks up into positively- and negatively-charged ions. Sodium chloride breaks up into sodium and chloride ions in water. Every water supply contains some sodium and chloride.

Occurrence of Sodium and Chloride

Typical background levels of sodium and chloride for pristine locations in New Hampshire are less than 20 milligrams per liter (mg/L) and 30 mg/L, respectively. A milligram per liter is the same as a part per million (ppm). In the immediate seacoast area, elevated levels of sodium and chloride occur naturally due to the proximity to sea water and wind-blown sea spray. Concentrations in groundwater in the seacoast area typically range up to 75 mg/L sodium and 150 mg/L chloride, respectively. Substantially higher levels of sodium and chloride tend to imply contamination by human activities, including road salt storage, use of road salt, discharges from water softeners, human or animal waste disposal, leachate from landfills, and other activities.

Normally the chloride concentration of well water exceeds that of sodium by approximately 50 percent due to the difference in their atomic weights. Any judgment relative to water’s salt concentration should be made only after reviewing the results of several samples that have been taken at different times of the year.

Use of Salt for Road Deicing

The application of deicing salts is an important component of maintaining road safety. The environmental impact of deicing salts can be minimized by use of best management practices. For more information concerning road salt management and the effect of road salt on surface water quality, see DES fact sheet WD-WMB-4 “Road Salt and Water Quality” at www.des.nh.gov/organization/commissioner/pip/factsheets/wmb/index.htm.

Health Implications

The following information concerning health implications has been provided by the DES Environmental Health Program. They can be reached at (603) 271-4608.

At present there are no health-based standards for sodium or chloride under the Federal Safe Drinking Water Act. In the mid-1980s, USEPA had listed sodium in a group of contaminants called the Drinking Water Priority List, for which official maximum contaminant levels (MCLs) would be developed. MCLs are health-based standards that must be met by public water systems. A subsequent review of scientific evidence by EPA showed that the vast majority of sodium ingestion was from food rather than drinking water, and that the linkage between sodium and hypertension (high blood pressure) was still not well documented. Consequently in 1988, EPA removed sodium from the Drinking Water Priority List. In March 1998, EPA reissued the list, now known as the Drinking Water Contaminant Candidate List

(DWCCL). That list included sodium. In September 2009, the final version of the third edition of the list was published, and sodium was again off the list. Visit the EPA website at www.epa.gov/ogwdw000/ccl/index.html for details.

When considering the health importance of sodium and chloride, EPA assumed that water users consume two liters of water per day, and found that 10 percent or less of a person's daily sodium intake comes from drinking water. The rest is usually from food. Persons on a sodium-restricted diet should evaluate all sources of sodium when attempting to reduce overall sodium intake. It is often much easier, and less expensive, to make a dietary change than to excessively purify drinking water.

EPA has recommended that sodium levels not exceed 20 mg/L for those persons on a physician-prescribed "no salt diet." This is the same level recommended by the American Heart Association. This is a very stringent level. For comparison purposes, regular milk has a sodium concentration of approximately 500 mg/L. The sodium levels of certain other major foods are listed below.

Food Product	Sodium (mg)[1]
Tomato sauce, 1 cup	1,482
Ham, 2 oz.	810
Bacon, 3 slices	303
Cottage cheese, 1 cup	851
Red or white wine, 3.5 oz.	5
Club soda, 12 oz.	75

Sodium and chloride are generally not major contaminants in the water served by community public water systems in New Hampshire. Such systems typically have concentrations of sodium and chloride that are less than 75 mg/L each in almost all cases.

Secondary (Aesthetic) Drinking Water Standards
EPA has identified 250 mg/L as a concentration at which chloride can be expected to cause a salty taste in drinking water. Water users typically notice the presence of high chloride before an equal amount of sodium. The secondary level of 250 mg/L is based on aesthetic concerns, and is only advisory in the Federal Safe Drinking Water program.

Control of Sodium and Chloride
Normally, the best method to control sodium and chloride in drinking water is to better manage those activities that add salt in the recharge area of the water supply source(s). The following are the most common sources of salt in water supply recharge areas.

Application of road deicing salts. For more information, see the "Road Salt and Water Quality" fact sheet referenced above.

Water softeners. Sodium is added to drinking water directly during the softening process, and indirectly by the discharge of waste brine (salt dissolved in water) into subsurface disposal systems. The amount of salt added by a water softener is most influenced by the water's hardness. High hardness increases the sodium level of the treated water.

The volume of waste brine generated by the regeneration cycle of a softener can be reduced by using a water meter or ion probe to trigger the regeneration cycle. This method is called demand regeneration. Visit the fact sheets webpage at www.des.nh.gov/organization/commissioner/pip/factsheets/dwgb/index.htm and scroll to WD-

[1] University of Maine Cooperative Extension (2008) Sodium Content of Your Food. Bulletin #4059. Accessed 8/3/10 at www.umext.maine.edu/onlinepubs/PDFpubs/4059.pdf

DWGB-2-12, "Ion Exchange Treatment of Drinking Water."

Other Sources. Many water treatment chemicals have sodium as a basic ingredient. These chemicals often perform a valued treatment function.

Sanitary Significance of Sodium and Chloride

Sodium and chloride are also present in domestic sewage. Finding the source of elevated sodium and chloride is important since this may indicate the nearby disposal of sewage. The presence of elevated sodium and chloride must initially be considered as an indication of increased risk of more serious bacterial or chemical pollution until a more detailed analysis identifies the origin of the sodium and chloride.

Drinking Water Treatment to Remove Sodium or Chloride

Sodium and chloride are costly to remove from water. Effective treatment types include:

Reverse Osmosis (RO)

This method places water under pressure against a special membrane. The membrane allows water molecules to move through, but retards the passage of salt and other dissolved minerals. RO is not practical for high-volume needs due to the inefficiency associated with the water "reject" rate. For more information on RO, see fact sheet WD-DWGB-2-11 "Reverse Osmosis Treatment of Drinking Water."

Distillation

This method first boils water to produce steam. The steam is then condensed to produce purified drinking water. Salts and other mineral impurities stay in the boiling chamber. The boiling chamber requires periodic cleaning to remove the accumulated minerals. Distillation is not effective for organic contaminants. Distillation is costly to operate and is only feasible for a few gallons of water produced per day. The reject heat during the summer is objectionable to most people. See fact sheet WD-DWGB-2-15 "Distillation Treatment of Drinking Water."

De-ionization

This method has similarities to a water softener, but uses strong acids and bases rather than salt to regenerate the system. While it is an effective method, the dangerous chemicals are inappropriate in a residence. See fact sheet WD-DWGB-2-12 "Ion Exchange Treatment of Drinking Water."

Where treatment is going to be installed, the size of the device can range from an under-the-sink system to a full-house system. If pure drinking water is the only goal, then an under-the-sink system will suffice.

Elevated levels of sodium and chloride somewhat increase the water's ionic conductance, and thus slightly increase the potential for corrosive water damage to plumbing fixtures. To reduce this damage, a whole-house water treatment system would be needed. Bottled water is also an option to address the health concerns posed by leached lead and copper caused by corrosive water while a long-term treatment solution is being investigated.

For further information concerning the layout of a water treatment system and its purchase, see the fact sheet WD-DWGB-2-5 "Considerations when Purchasing a Water Treatment System."

FOR MORE INFORMATION

Please contact the Drinking Water and Groundwater Bureau and the New Hampshire Water Well Board at (603) 271-2513 or dwgbinfo@des.nh.gov or visit our website at http://www.des.nh.gov/organization/divisions/water/dwgb/index.htm. All of the bureau's fact sheets are on-line at www.des.nh.gov/organization/commissioner/pip/factsheets/dwgb/index.htm.

ENVIRONMENTAL Fact Sheet

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

29 Hazen Drive, Concord, New Hampshire 03301 • (603) 271-3503 • www.des.nh.gov

WD-DGWB-2-5 2012

Considerations When Purchasing Water Treatment Equipment

Water Quality
If you have tested your well water and found that it contains contaminants that are either undesirable due to taste and odor or that pose health risks, you may be considering installing water treatment equipment. You may have tested the water using the Standard Analysis offered by the Department of Health and Human Services' Laboratory, which includes coliform and *E. coli* bacteria, pH, hardness, iron, manganese, sodium, chloride, nitrate/nitrite, fluoride, copper, lead, arsenic and uranium. For bedrock wells, you may wish to test for additional contaminants including beryllium, mineral radioactivity (partially identified by the analytical gross alpha), uranium, and radon gas test along with volatile organic chemicals (VOCs). If affordable, it is a good idea to know as much about your water quality as possible before selecting a treatment system. If you know that your well is very shallow or if it is a dug well, you may wish to consider conducting two water tests over a period of one seasonal change (e.g., summer to winter) to identify changes in pH or certain metals.

Laboratory test services are available at the DHHS Laboratory and also available from independent laboratories, which are listed on-line or in the yellow pages under such listing as "Laboratories" and "Water Analysis." A list of New Hampshire accredited labs is available at http://www2.des.nh.gov/CertifiedLabs/Certified-Method.aspx or by calling (603) 271-3906.

Size of Treatment Equipment
Water treatment devices come in two basic sizes: "point-of-use" or "whole-house." Each type is explained below. The nature of the contaminant dictates which type of treatment should be used. The relative size and cost of the treatment device is related to the water volume processed and the concentration of contaminant(s) present.

"Point-of-use" devices are typically installed in the kitchen and treat only a few gallons of water per day. The purified water is taken from an extra faucet installed at a location of your choice, typically at the kitchen sink. Such a system might be used for contaminants such as arsenic, beryllium, fluoride, uranium, nitrate, or radium where only the water to be directly consumed or used for cooking generally needs to be treated.

"Whole-house" devices typically treat all water used within the home, about 100 to 300 gallons per day depending on family size. This size treatment device might be used for contaminants such as odor, iron, hardness, manganese, and radon gas. **Outside water faucets generally do not need treatment.** The exception is swimming pools that typically require low levels of iron and manganese, which can stain swimming pool linings. Needlessly treating outside water increases the capital and operational costs of treatment for in-house use.

Identifying Treatment Options

It is good practice for consumers to request information from water treatment firms and study each proposed alternative treatment method before making a purchase. Request information from at least two different water conditioning firms. Asking the following questions will help you make the best selection.

- What is the treatment method (not just the marketing name of the device)?
- What are the technical principle(s) governing the process? Specifically, how does it work?
- What other treatment options are available?
- Can plumbing connections be installed for the addition of future treatment devices?
- Why were the other treatment options not recommended?
- Ask your neighbors or co-workers if they have the same problem with their water and which type of equipment they used to correct it.

When choosing a treatment device, identify the following:

- Understand how raw water quality changes can affect the device efficiency.
- What chemicals does the treatment add to the water?
- What desirable chemical(s) does the treatment process inadvertently take out?
- Where do the waste products go?
- What factors would cause this treatment process to malfunction and how are malfunctions detected?
- What maintenance procedures are necessary for efficient operation of the treatment process?
- How much will maintenance cost?

Small System Treatment Contractors

DES provides a list of contractors who provide design services for small water systems and private residential water systems. The list is available at
http://des.nh.gov/organization/commissioner/pip/factsheets/dwgb/documents/dwgb-7-3.pdf.

In choosing a contractor for purchase of services or equipment, we suggest choosing a firm within 30 to 50 miles of your home to facilitate follow-up service. Ask the water treatment firm to provide references of other local customers. Other considerations include:

- Identify the guarantee and the level of “after sale” service provided.
- Ask for a copy of the contract prior to signing.
- Identify what equipment will be provided. Identify precisely what will not be covered.
- Identify the spare parts and instruction documents that will be provided with the equipment.
- Identify both the **purchase cost** and the **projected annual operating cost** for your family’s water use.

Installation of the Treatment Equipment
Some considerations when laying out water treatment equipment include:

- Providing a permanent gated bypass of the treatment device for any outside water faucets.
- For a whole house treatment, have a plumbing bypass to allow convenient repair of the treatment device.
- Place the device in a well lighted, heated area where repair access is good.
- Where cost is not prohibitive and where health factors are being addressed, consider whether it is appropriate to install two devices together to ensure greater treatment. The first device would remove the majority of the contaminant. The second device would take out anything that made it through the first.

Operation of the Treatment Equipment

- Make multiple copies of the operating instructions and store in secure locations.
- Sample treated water periodically to ensure high treatment effectiveness.
- Sample raw water occasionally to determine the whether the contaminant levels have changed.

Third Party Testing, Certification and Professional Associations
New Hampshire operates a voluntary certification program for water treatment technicians. A list of certified technicians is available at https://nhlicenses.nh.gov/MyLicense%20Verification/, selecting "Building Trades" in the "Profession" box and then "Plumber Water Treatment Technician" in the "License Type" box, typing an asterisk (*) in the "Last Name" box and clicking on the "Search" button. For more information, call (603) 223-4289.

The professional trade group of the private home water treatment industry is the Water Quality Association. You may also want to look for their membership seal. The Water Quality Association has developed the "Gold Seal" program to help identify superior water treatment equipment. The certification categories include:

- WQA S-100: Household and Commercial Water Softeners.
- WQA S-200: Household and Commercial Water Filters (In-line).
- WQA S-300: Point-of-Use Reverse Osmosis Drinking Water Systems.
- WQA S-400: Point-of-Use Distillation Drinking Water Systems .

The contact information is: Water Quality Association, 4151 Naperville Road, Leslie, IL 60532-3696; (630) 505-0160; www.wqa.org.

For Additional Information
Please contact the DES Drinking Water and Groundwater Bureau at (603) 271-2513 or dwgbinfo@des.nh.gov or visit http://des.nh.gov/organization/divisions/water/dwgb/index.htm. All of the bureau's fact sheets are available at http://des.nh.gov/organization/commissioner/pip/factsheets/dwgb/index.htm.

Note: This fact sheet is accurate as of June 2012. Statutory or regulatory changes, or the availability of additional information after this date may render this information inaccurate or incomplete."

CLASS V UIC STUDY FACT SHEET
SALT WATER INTRUSION BARRIER WELLS

What is a salt water intrusion barrier well?

Salt water intrusion barrier wells are Class V underground injection control (UIC) wells used to inject water into a fresh water aquifer to prevent the intrusion of salt water. These wells may have secondary purposes, such as to recharge an aquifer with fresh water to be used later or to control land subsidence (reduce ground movement).

What types of fluids are injected into salt water intrusion barrier wells?

Waters of varying qualities are injected to create salt water intrusion barriers, including untreated surface water, treated drinking water, and mixtures of treated municipal wastewater and ground or surface water.

Do injectate constituents exceed drinking water standards at the point of injection?

Available data show that the injectate typically meets primary and secondary drinking water standards and health advisory levels at the point of injection.

What are the characteristics of the injection zone of salt water intrusion barrier wells?

Salt water intrusion barrier wells are drilled to various depths depending on the depth of the aquifer being protected. They inject into fresh ground water aquifers used as drinking water supplies that are in hydraulic connection with an extensive salt water body, such as a sea, a salt lake, or an ocean.

Are there any contamination incidents associated with salt water intrusion barrier wells?

No contamination incidents associated with the operation of salt water intrusion barrier wells have been reported.

Are salt water intrusion barrier wells vulnerable to spills or illicit discharges?

Because protection of drinking water supplies is the major goal of a salt water intrusion barrier well and the injectate typically meets drinking water standards, salt water intrusion barrier wells are unlikely to receive spills or illicit discharges of potentially harmful substances.

How many salt water intrusion barrier wells exist in the United States?

There are 315 salt water intrusion barrier wells documented in the United States. The number of salt water intrusion barrier wells in the nation is estimated to be greater than 609, but unlikely to be higher than 700.

Where are salt water intrusion barrier wells located within the United States?

All documented salt water intrusion barrier wells are located in CA (308), FL (1), and WA (6). In addition, as many as 200 salt water intrusion barrier wells are believed to exist in NY. There also may be some wells in NJ; however, the exact number of such wells in this state is unknown.

How are salt water intrusion barrier wells regulated in states with the largest number of this type of well?

Permit by rule: CA

Individual permit: FL, NY, and WA

Where can I obtain additional information on salt water intrusion barrier wells?

For general information, contact the Safe Drinking Water Hotline, toll-free 800-426-4791. The Safe Drinking Water Hotline is open Monday through Friday, excluding federal holidays, from 9:00 a.m. to 5:30 p.m. Eastern Standard Time. For technical inquiries, contact Amber Moreen, Underground Injection Control Program, Office of Ground Water and Drinking Water (mail code 4606), EPA, 401 M Street, SW, Washington, D.C., 20460. Phone: 202-260-4891. E-mail: moreen.amber@epa.gov. The complete Class V UIC Study (EPA/816-R-99-014, September 1999), which includes a volume addressing salt water intrusion barrier wells (Volume 20), can be found at http://www.epa.gov/OGWDW/uic/cl5study.html.

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