GROUNDWATER SUSTAINABILITY STUDY
CHEBEAGUE ISLAND, MAINE

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KEY FINDINGS

Groundwater wells are the sole source of potable water for Great Chebeague Island's year-round and seasonal residents. Great Chebeague Island is a **sole source aquifer** meaning that there are no reasonable alternative water supplies other than groundwater on the island. Consequently, the sustainability of the island community is dependent on the protection and sustainable management of the island's groundwater resources.

All the homes on Great Chebeague Island rely on **groundwater wells** as their source of potable water Over 90 percent of the homes on Great Chebeague are served by wells drilled into the fractured bedrock aquifer. Based on records from 389 wells on Great Chebeague, the median well depth is 200 feet, the median well yield is 5 gallons per minute (gpm) and the median casing length is 20 feet. These values are similar to the median values statewide of 200 feet for well depth, well yield of 5 gpm and overburden thickness/casing length of 10 feet.

All households utilize **individual wastewater systems** for treatment and disposal of sewage. Oner 90 percent of the wastewater systems are septic systems with septic tanks and leachfields. Based on the survey 73 percent reported that they had pumped their septic tank in the last 5 years.

Bedrock aquifers are complex and difficult to characterize. The quality and quantity of groundwater available from bedrock aquifers is influenced by a number of factors including bedrock lithology and structure, fracture patterns, overburden materials and thickness, recharge rates, slope of the ground surface, vegetation, land use development and water use. Consequently, groundwater availability and vulnerability to contamination and climate related impacts varies considerably from place to place across the island. This inherent variability makes it difficult to generalize how the aquifer will respond to certain stresses, including climate change.

Quantification of groundwater recharge is extremely challenging, especially as it applies to fractured bedrock aquifers in island and coastal settings in Maine. In order to accurately assess groundwater availability, aquifer recharge must be determined. Consequently, **the lack of data on recharge rates** in fractured bedrock aquifers severely limits our ability to determine groundwater availability and carrying capacity under existing and future conditions. More research is needed to reliably measure bedrock aquifer recharge rates and determine groundwater availability and sustainability in fractured bedrock aquifers in Maine.

A very **simplified water balance calculation** indicates, when averaged across the island, sufficient water exists to support existing and some future development. Based on an estimated annual recharge of **300 million gallons per year** to the island overall, the total household groundwater withdrawal is estimated to be on the order of **40 million gallons per year** or less than 15% of the overall annual recharge. Almost all of the groundwater withdrawn for household use is returned back into the aquifer through wastewater system discharge so the net loss to the aquifer system is small.

In coastal Maine, low water table and drought conditions typically coincide with peak demand during the late summer which can magnify the impacts. Residents of Great Chebeague Island have reported problems with **dry wells,** especially during the summer or periods of drought. In bedrock wells the susceptibility of the well to go dry varies from well to well and is a function of the fractures, yield and depth of the well and water usage.

Water quality is in many aspects the limiting factor when considering the sustainability of the aquifer on Great Chebeague Island. In groundwater studies conducted over the past two decades, water sampling has revealed consistent problems with E. coli detections in 5 to 10% of the island water supplies tested. It is likely that some if not all of this bacterial contamination is the result of septic system impacts. These studies also provide evidence that saltwater intrusion is occurring along the shore near Division Point, Waldo Point, Roses Point, Deer Point and Central Landing.

The impacts of changes in temperature and precipitation as the result of **climate change** on Great Chebeague's groundwater resources are difficult to predict. Average annual rainfall is expected to increase between 5-15% by 2100 and that this may lead to higher groundwater levels. In contrast, warmer temperatures and more intense rainfall events may result in less groundwater recharge counteracting these effects. **Sea level rise** is expected to lead to the landward migration of the freshwater/saltwater interface. This will likely exacerbate existing issues in the areas of Division Point, Waldo Point, Roses Point, Deer Point and Central Landing and may expose more wells to saltwater intrusion.

Assuring there is adequate quantity and quality of groundwater in the future requires active and thoughtful **long-term planning** by the town. The effectiveness of the Town of Chebeague's existing groundwater protection is limited by the fact that the majority of the development on the island is construction of **residential single-family homes**. This type of development is generally not subject to the subdivision and site plan ordinances which address groundwater. Consequently, groundwater protection is not reviewed or incorporated into the majority of the development on the island. Of particular concern on the island are the siting of well and wastewater disposal systems, construction along the shore, and the size of homes and overall household water use.

Effective stewardship of the Town's groundwater resources needs to include 1) monitoring of the resource over time; 2) ongoing data collection and updates and 3) implementation of groundwater protection strategies.

1 INTRODUCTION

This report summarizes the results of the Groundwater Sustainability Study conducted by the Chebeague Island Climate Action Team for the Town of Chebeague Island, Maine. This study was funded by a Community Action Grant (CAG) from the Community Resilience Partnership (CRP), which is part of the Governor's Office of Innovation and the Future (GOPIF). Carol White, hydrogeologist with C. A. White and Associates, LLC (CAW), provided technical oversight on the data collection and analysis in the project. CAG funds were used to pay for the water quality testing, monitoring equipment, outreach activities and materials and a portion of our GPCOG Resilience Fellow (Fellow) stipend. Chemical analysis of well water samples was provided by Maine Environmental Laboratory in Yarmouth, Maine. Chris Halstead, Director of Earth Resources Mapping at the Maine Geological Survey, provided recommendations on the data compilation and geodatabase design and Jessie Meeks, Hydrogeologist, provided valuable technical assistance with the specifications for the aquifer monitoring instrumentation.

1.1 Background

The Town of Chebeague Island, Maine was established in 2007 and is comprised of Great Chebeague Island and 14 outer islands. Great Chebeague Island, the largest island in Casco Bay, is the home of 400 year-round residents. In the summer months the population swells to about 1,200 with the influx of tourists and seasonal residents. Access to the island is by passenger ferry from either Portland or Yarmouth. Great Chebeague Island has a single store, a two-room schoolhouse, a library, a golf course, and a recreation center. Map 1 depicts the location of the Town of Chebeague Island in Casco Bay and Map 2 highlights Great Chebeague Island, the focus of this study.

During the town's Community Resilience Partnership Workshop held in September 2022, islanders ranked the protection and sustainability of groundwater on the island as their highest priority. Of particular concern were the risks of saltwater intrusion due to sea level rise and the impacts of development and climate change on groundwater availability. In 2022 the town applied for a Community Acton Grant which included a groundwater vulnerability assessment to assess these climate related impacts on the town's groundwater supply. The project was designed to build on previous town wide groundwater studies completed in 1992, 2002 and 2005 by Carol White, Bev Johnson and Sevee and Maher Engineers.

1.2 Purpose and Scope

Groundwater wells are the sole source of potable water for all Great Chebeague Island residents. All groundwater on the island originates as precipitation – rain and snow that falls onto the island. Most of the precipitation that falls on Chebeague is lost to surface runoff, evaporation or is taken up by plants and only a small percentage seeps into the ground to become groundwater. Great Chebeague Island is a *sole source aquifer* meaning that there are no reasonable alternative water supplies other than groundwater on the island. Consequently, the sustainability of the island community is dependent on the protection and sustainable management of our island's groundwater resources.

What do we mean by **sustainable groundwater management?** It is the development and use of groundwater in a manner that can be maintained for indefinite time without causing unacceptable environmental, economic or social consequences. Sustainable groundwater management on Great Chebeague requires that we monitor and assess changes on an ongoing basis to protect the quality and quantity of groundwater now and into the future.

The objectives of this study are to **update the 20-year-old well dataset, obtain information on current water quality** and **assess the potential climate-related impacts on the aquifer**. The project also sought to re-establish a long-term monitoring program to identify adverse trends in the water levels and water quality.

The Chebeague Climate Action Team (CCAT) was given the responsibility of implementing the CAG, including the community wide groundwater study. The study scope was limited to Great Chebeague Island and did not include data collection or testing of water supplies on the outer islands. Each of the outer islands is supplied by separate, sole-source aquifers. Additionally, most of the outer islands are uninhabited or support a few seasonal residents. Hope Island is the exception. The entire 86-acre island is privately owned and was purchased by a new owner in 2021. There is significant development activity on the island, including a golf course. Although understanding the potential impacts of these activities on Hope Island's aquifer is an important consideration for the town, it could not be included in the scope of this study. This Groundwater Sustainability Study included the following elements:

- A town wide **well and wastewater survey** to update the 20-year-old well dataset from previous studies. The survey also included questions about wastewater disposal systems to begin to build a local dataset.
- A free, town-wide **water quality testing program** designed to assess septic system and saltwater intrusion impacts on homeowner's wells.
- Compilation of the **historical well data and new well and water quality data** into a GIS-compatible database for mapping and analysis and that could be incorporated into the State's water well database.
- An update of current **water supply and water quality status** on the island.
- An assessment of the potential **climate-related impacts** to the bedrock aquifer.
- Reestablishment of a **long-term monitoring program** to identify adverse trends in the water levels and water quality, in particular saltwater intrusion.
- Evaluation of the **best methods to provide information and guidance** on groundwater related risks and vulnerabilities in the community.
- Delivery of a series of meetings, programs and materials designed to **engage and educate** the community about climate related impacts on the groundwater resource that serves as the community's water supply.

2 DATA COLLECTION AND COMPILATION

2.1 Well and Wastewater Disposal Survey

In April 2023, CCAT initiated a community-wide well and wastewater disposal system survey to gather information from property owners on their well type, construction, performance, water quality and quantity. The survey also asked if well owners have experienced problems such as wells going dry or becoming salty. Information on wastewater disposal systems including location, size, age, and maintenance was also collected. The survey was offered in both online and paper format to residents and was deployed in spring of 2023. Approximately half the residents filled out the survey online, and the other half opted to fill out the paper form. To be eligible for the sampling program, we asked that the resident first fill out the survey – even if they didn't know anything about their water supply or wastewater system.

2.1.1 2023 Well Survey Results

A **total of 162 survey responses** were received out of an estimated 400 well owners, representing approximately 40 percent of all well owners on the island. About half of the well survey responses were from seasonal residents.

- Approximately 93 percent of wells reported were drilled bedrock wells and the remaining 7 percent are either dug wells or well points. Many of the properties with dug wells also reported drilled wells on their property. Most of the dug wells are used as a back-up water supply or garden water source.
- 6 percent of the survey respondents reported periodic dry wells.
- 62 percent reported water quality issues.
- 38 percent of the respondents do not drink their water.
- 40 percent of respondents have some form of water treatment system with iron treatment being the most common.
- 35 percent of respondents have never had their water tested.
- 99 percent of respondents wished to have their water tested free of charge.
- 93 percent of people who initially indicated they would like their water tested were sampled in the 2023 program.

2.1.2 2023 Wastewater Disposal Survey Results

We received a total of 149 responses to the survey questions related to wastewater disposal systems. The survey results indicate that:

- 93 percent of the respondents utilize septic systems and leachfield for wastewater disposal.
- 5 percent of the respondents had cesspools.

- The remaining respondents relied on engineered systems, outhouses or did not know what type of waste disposal system they had.
- Based on the installation dates provided, about 25 percent of the systems are more than 30 years old.
- 5 percent reported that they had a separate graywater system.
- 10 percent reported that they had a garbage disposal that sent waste to their septic system.
- An encouraging 73 percent reported that they had pumped their septic tank in the last 5 years; 16 percent reported that they did not know when the system was last pumped and 4 percent reported that as far as they knew their system had never been pumped.

2.2 2023 Water Quality Sampling

The water quality testing program was conducted during the months of August and September 2023. A total of 146 wells were sampled and analyzed for bacteria and chloride. A subset of the wells was also analyzed for iron, manganese and arsenic.

To obtain samples that were useful for the study, bacteria samples were collected from the kitchen tap but chloride samples were collected prior to treatment in order to assess the in-situ groundwater quality. To accomplish this task CCAT opted to have members visit each property individually to ensure that the samples were properly collected. Due to capacity limitations, the lab could only accept about 40 samples per week. Since the bacteria test method requires that the lab receive the samples within 30 hours of collection, we developed a detailed schedule for sample drop off and delivery that was implemented by CCAT members and additional volunteers. Sample locations were separated into groups of 10 based on their geographic locations. CCAT members and teammates were assigned a set of samples in their neighborhood. Samplers were responsible for coordinating with well owners to collect their sample during the specified week. A refrigerator was installed outside the town office for sample storage since bacteria samples had to be kept cold prior to delivery to the lab.

The tax map and lot number were used as the well and sample identifier. Individual chain of custody (COC) forms with the name of the property owner, address and tax map and lot number and sample parameters were created for each well sample. COC forms are required by the lab in order identify and track the sample. Two COCs were created for each sample site, one for bacteria and one for chloride. A few select wells were also analyzed for iron, manganese and arsenic. The COCs were color coded to match the bottle labels to avoid confusion. CCAT prepared individual sample kits for each sampling site, and these were distributed to the appropriate team member for collection.

Following completion of the sampling program, each participant was emailed the laboratory report of their well water test results. Explanatory materials were provided along with the sample report that described the range and significance of the test results and relevant public health information.

CAW individually contacted property owners who received a positive *Escherichia coli (E. coli)* bacteria detection. Each property owner was briefed and counseled on corrective actions to take. Homeowners were provided with information about health concerns related to *E.coli* and how to shock chlorinate their water supply as per Maine Drinking Water program guidance. When requested, CCAT followed up with repeat testing of the water supply until the *E. coli* result was negative.

The results of the 2023 testing program indicated that **44 percent of the wells tested positive for total coliform bacteria** and **4 percent were positive for *E. coli.*** Elevated levels of chloride and iron and manganese were also detected in a number of wells tested. The significance of the water test results are discussed in section 3.6 of this report.

2.3 Data Compilation

Following completion of the survey, the 2023 data was compiled and combined with historical data from previous studies to create a comprehensive town well geodatabase that could be used for GIS analysis. The geodatabase was constructed using the information collected during the 2023 well survey, previous groundwater studies and well records shared by Jon Rich, Great Chebeague's resident plumber. Currently there are 389 records in the well data set. We estimate that this data represents at least 90 percent of the wells on the island.

During the project, CAW initiated discussions with staff at the Maine Geological Survey (MGS) about the best method for archiving and maintaining the well and water quality data for the future. MGS offered that the Town well dataset could be incorporated into the MGS maintained water well database to ensure long term maintenance and public access. A benefit of this approach is that the data will be maintained in perpetuity by the State and new well information, as required by law, will be added to the dataset. These GIS data files will be accessible to the town through the MGS and/or Maine Office of GIS (MEGIS) and can be exported as stand-alone GIS files if desired. After discussions with CCAT and consultation with Viewshed (the town's GIS vendor), we agreed to adopt this approach.

2.4 GIS Mapping

The 2023 well data was georeferenced using a combination of parcel data provided by Viewshed, town assessor's records and E911 address files obtained from the MEGIS. Water quality and waste disposal system data from the 2023 study were maintained in tabular format. The water quality and septic data were linked to the well geodatabase via the key field of concatenated tax map and lot number. The comprehensive data set was used to analyze questions related to water supply, geology, and septic and saltwater impacts for this study. Publicly available digital data on geology, hydrogeology, and land use were downloaded from the MGS and MEGIS for map construction and spatial analysis in Ersi's ArcGIS Pro software.

3 GROUNDWATER RESOURCES ON CHEBEAGUE ISLAND

3.1 Surficial Geology

Surficial deposits are the unconsolidated deposits – clay, silts, sands, and gravels - that were deposited during the advance or retreat of the last major glacier to cover Maine. These materials rest on the bedrock surface. Surficial deposits are distinct, deeper units of earth materials that lie between the soil zone and the underlying bedrock. Soils commonly develop by weathering of the uppermost foot to eighteen inches of surficial materials. Surficial deposits are classified according to differences in the size, shapes and mixtures of mineral grains and rock fragments that they contain, and in the geologic processes by which they are created. As shown on Map 3, as mapped by the Maine Geological Survey, surficial deposits on Great Chebeague Island include: glacial till (Pt), thin till (Ptd), marine nearshore deposits (Pmn), and glaciomarine silt clay of the Presumpscot Formation (Pp). Younger more recent deposits include Wetlands (Hw) and Marine shore deposits (Hms). The characteristics of the surficial units are summarized below:

Glacial Deposits

Marine nearshore deposits - Deposits of sand and or gravel and silt. Occurs as a thin cover over bedrock or older glacial deposits.

Presumpscot Formation - Fine-grained, gray to bluish-gray silt and clay. Deposited during the late-glacial marine submergence of the coastal zone.

Till - Poorly sorted sediments deposited directly by the glacial ice. Till consists of a heterogeneous mixture of clay, silt, sand, gravel and boulders.

Thin drift - Patchy cover of till and/or nearshore deposits overlying bedrock and less than 10 feet thick.

Recent Deposits

Wetland - Silt clay, sand, muck and/or peat. Deposited in poorly drained areas.

Marine shoreline deposits -Modern beach deposits consisting of sand and pebbles. and cobbles. Formed by reworking of older surficial sediments

Groundwater is contained in surficial deposits in the voids and openings - pore spaces - between the silt, sand and stones that make up these deposits. Although all surficial deposits have some capacity to supply groundwater, the presence of groundwater in surficial deposits is driven by topography, the type of material, and hydrology. The type and characteristics of the surficial materials on Great Chebeague Island affects how much groundwater is available for use and how effective the materials are in treating subsurface wastewater. To function properly, septic systems must have sufficient overburden thickness and separation from the water table to treat contaminated effluent. Unlike other islands in Casco Bay, the surficial deposits on Chebeague are relatively thick in some places, ranging from 5-10 feet in lowland areas to greater than 100 feet in the central portion of the island.

3.2 Bedrock Geology

Underlying the surficial deposits is bedrock or ledge that forms the backbone of the islands. Different types of bedrock are classified according to their mineral composition, textures and geologic origin. As shown on Map 4, the bedrock on the island consists of five different geologic formations. On Great Chebeague Island the rocks, which are part of the Casco Bay group mapped by Hussey (1999), include the Jewell Formation (Je and Jef), Spurwink Formation (Sk), Scarboro Formation (Sc), Cape Elizabeth Formation (Ce), and Cushing Formation (Cu). These metamorphic rocks, classified as gneiss, schist, phyllite and meta limestone, are interpreted to be between 450 to 500 million years old.

Groundwater in these metamorphic rocks moves through the foliation and fractures that comprise the "fabric" of the rock. The foliation forms narrow separations along micaceous layers, creating discrete hydrogeologic zones parallel to the steeply dipping, northeasterly-oriented layering (Hussey, 2020). Groundwater also moves through discrete fractures which cut through rock to create narrow passageways that can transmit water within the aquifer. The degree of fracturing varies across the island. In most cases, the greater the fracturing, the greater the well yield. Fractures can also provide a conduit for contaminant movement and saltwater intrusion. The orientation and interconnectedness of these structural features of the bedrock – foliation and fractures – influences the rate and direction of groundwater flow in the bedrock, well yield and the susceptibility of bedrock wells to contamination.

3.3 Groundwater Recharge

Groundwater recharge is defined as the downward percolation of water that has infiltrated into the ground and moved through the root zone to add to the groundwater storage at the water table (Healy, 2010). All groundwater on Great Chebeague Island originates as precipitation – rain and snow - that falls directly on the island's land surface. The amount of groundwater recharge that occurs at any given location is influenced by the vegetation, soil type, nature and thickness of surficial deposits, slope and land use conditions. The type and thickness of overburden affects the amount of water that can infiltrate and replenish the groundwater. In general, coarse gravelly soils allow more water to percolate into the ground and fine clay soils allow less Infiltration. The type of land cover also influences the amount of rain or snowmelt that can replenish the groundwater. In paved areas, buildings and areas of exposed ledge essentially all the precipitation runs off the surface and cannot percolate into the ground. In contrast, undeveloped vegetated areas such as forests and fields can absorb a portion of the precipitation, which can then replenish the groundwater aquifer. Map 5 depicts the mapped landcover on the island that influences groundwater recharge.

To complete a reliable evaluation of groundwater availability and sustainability, aquifer recharge must be quantitatively described spatially, temporally and volumetrically. Groundwater recharge is a complex process, and reliable quantification is extremely challenging and is often based on indirect measurements.   This is especially true for fractured bedrock aquifers in island and coastal settings in Maine.

Few data are available on groundwater recharge rates in Maine. Studies to date suggest that most of the precipitation is lost as runoff (50-60 percent) into surface water or the ocean or is returned to the atmosphere as evaporation or transpiration from plants (30-40 percent). A small portion of the annual precipitation becomes groundwater as it seeps into soil and bedrock. The USGS has calculated median annual potential recharge across the State at 7.5 inches, representing about 12 percent of average annual precipitation. Across the state, rechange rates are estimated to range from a low of about 2 inches per year to over 30 inches per year. Recharge rates for glaciomarine silt/clay soils ranged from 2 to 12 in/yr and rates for sandy glacial outwash were reported as high as 27 in/yr. The USGS estimates that in areas of shallow or exposed bedrock in Maine, infiltration or recharge to the bedrock aquifer is only 2–6 inches per year, only about 5 to 10 percent of total annual precipitation (Nielsen and Westenbroek, 2019).

On Great Chebeague Island, it's likely that recharge is the greatest in the central portion of the island where the overburden is the thickest, moderately permeable and the land is less developed. Areas along the shore where overburden is thinner, and the land surface is more developed likely have lower recharge. Map 6 is derived from the 2019 USGS recharge study of Maine which incorporated soil type, vegetation, slope, land use and historical precipitation data to derive average annual recharge rates across the state. The USGS study calculated recharge rates on Chebeague ranging from 5 to 25 inches per year. In their study, the USGS acknowledges that the accuracy of the recharge estimates are highly uncertain in coastal areas in Maine and in areas of thin overburden and that much lower rates of 2 to 6 inches per year are more likely. Nevertheless, the general pattern of highest recharge along the central axis of the island with lower recharge along the shore is supported by the results of this study.

The range of recharge values is not known for Great Chebeague Island, but given the geology and land use it's reasonable to expect that it may vary from essentially 0 percent to more than 15 percent of annual precipitation across the island. Applying a conservative average annual recharge rate of about 5 percent of total precipitation or 0.3 gallons per minute (gpm)/acre the average annual recharge across the entire island is estimated to be approximately **300 million gallons per year** - but this recharge is not equally distributed across the island or during the months of the year.

3.4 Household Water Use

In general, estimates of water use in Maine vary from about 60 to 100 gallons per day per person, depending on the household. A value of 90 gallons per day per bedroom, or 270 gallons per day for an average home, is often used as an estimate of household water use for wastewater disposal design and water supply calculations. On Great Chebeague Island, an average use of 270 gallons per day would translate to about 100,000 gallons of water per year per household. Applying the conservative assumption that all 400 homes are occupied year-round, Great Chebeague Island's average annual groundwater withdrawal is estimated to be approximately **40 million gallons per year** for the entire island.

3.5 Analysis of Well Characteristics

Based on the combined dataset of 389 wells, approximately 95 percent of Great Chebeague Island's wells are drilled bedrock wells. Map 7 shows the location of these wells. Not all wells in the dataset have values for well depth, well yield and casing length, but based on the available data the characteristics of the wells are:

- Reported drilled well depths vary between 27 ft to a maximum of 465 ft with a median depth of about 200 ft. A reported well depth of 700 feet was considered erroneous and was removed from the well data set.
- Well yields vary from less than a gallon to a maximum of 120 GPM. The median yield of all island wells is 5 GPM. This value similar to the average well yield across the state of 5.5 gpm.
- Well casing lengths reportedly range from 4 to 215 feet with a median length of about 20 feet. A reported casing length of 450 feet was considered erroneous and was removed from the well data set

Table 1 is a summary of the range of drilled well characteristics based on all the records the well database.

Table 1 Drilled Well Characteristics

Chebeague Island Well Data	Minimum	Maximum	Median
Drilled Well Depth, feet	27	465[1]	200
Yield, gallons per minute (GPM)	0.5	120	5
Casing length, feet	4	215[1]	20

Note: [1] Eliminated spurious and likely erroneous data from data set

Drilled well depth is the depth from the top of the well to the bottom of the well boring in the bedrock. Yield is a measure of how much water the well can produce. A steel well casing is typically installed through the overburden extending from the ground surface into the bedrock to provide access to the bedrock through the unconsolidated overburden and prevent surface water and contamination from entering the well. The length of casing can be used as a rough indication of the overburden thickness/bedrock elevation at each well location. Casing length and integrity is also important because domestic septic systems are typically installed in the overburden and shallow depths to bedrock or poorly sealed well casing can increase the risk that a well can become contaminated by septic effluent or other pollutants.

A review of the data suggests that deeper wells and longer well casings are generally located in the interior of the island, likely because the overburden is thicker in this area. No additional relationships were identified between the island's bedrock geology and well characteristics.

3.6 Analysis of Water Quality

The results of the 2023 well survey and sampling program, and findings of previous studies indicate that the quality of groundwater on Great Chebeague Island is influenced by a combination of naturally occurring characteristics and human activities.

3.6.1 Bacterial Contamination

All water samples collected in the 2023 study were analyzed for both total coliforms and *Escherichia coli (E. coli)* bacteria. These bacteria were tested to help assess the potential impacts of wastewater systems on the groundwater quality and to assess overall aquifer water quality.

Total coliforms and *E. coli* bacteria may be present in the natural environment, or they may be introduced by human activity. Coliform bacteria make up a large group of bacteria that are found in soils, on plants, and in surface water. It is assumed that most bacteria in wells come from surface water directly entering the well. The water may be contaminated by bacteria that are naturally in the soil, decayed plants or from human activities. As surface water seeps downward through the overburden to the water table, these bacteria may die off or be naturally removed by the soil. The extent of removal depends on the depth and character of the soil and the distance of wells from the source. In general, shallow wells and springs are more likely to be contaminated than deep wells due to the limited filtering capacity and travel time in the soil. Wells must be properly located, constructed, and maintained to prevent surface water contamination from entering the well.

Total coliforms are commonly used for assessing the bacterial quality of drinking water. It is not practical to test for the numerous species of pathogenic bacteria that can be found in the environment. Instead, the potential presence of pathogens is determined with indirect evidence by testing for an "indicator" organism such as coliform bacteria. Total coliforms are used because this group of organisms is abundant in the environment, are easy to identify, are present in larger numbers, and respond to water treatment the same way as many harmful bacteria and biological pathogens.

On their own, the presence of total coliform bacteria does not imply an imminent health risk. If total coliform bacteria are present in well water, it is an indication (not a certainty) that a pathway may exist for disease organisms to enter a water supply. When a drinking water sample is positive for total coliform bacteria, the water should also be tested for *E. coli* bacteria. When *E. coli* bacteria are detected in well water, confirmation testing (a retest for bacteria) and an inspection of the wellhead are recommended to evaluate how these organisms may have entered the water supply.

E. coli bacteria is a subgroup of total coliform bacteria that live in the intestines of humans and animals. The detection of *E. coli* bacteria in a water sample means there is a chance that human waste or sewage, or animal waste may be impacting the well. Not all *E. coli* bacteria detected by a water test are necessarily harmful, but the presence of *E. coli* indicates the potential for other disease-causing organisms to be present. Consuming water containing *E. coli* can cause intestinal upset or even severe illness; children under five years of age, those with compromised immune systems, and the elderly are particularly vulnerable. The Maine Center for Disease Control (CDC) recommends that if *E. coli* is detected in your well water, you should boil your water for at least one minute or disinfect it before consumption or use bottled water.

Table 2 Bacteria Water Quality Results from the 2023 Well Testing Program

Bacteria (2023)	Percent Positive
Total coliform bacteria	44%
Escherichia coli bacteria	4%

Table 3 Bacteria Water Quality Results from all Well Testing Programs

Bacteria (2001, 2005 and 2023)	Number of Samples	Number of Positive Tests	Percentage of the Samples
Total Coliform	245	108	44%
E. coli	245	12	5%

As shown on Table 2 in the 2023 study, total coliform bacteria were detected in 44 percent of water samples tested, and *E. coli* bacteria were detected in 4 percent of the water samples tested. Map 8 shows the general location of the *E. coli* positive test obtained in the 2023 sampling program. These results are consistent with previous testing programs conducted in 2001 and 2005. As shown on Table 3, when the water quality data from the testing programs over the last 20 years was combined and analyzed, almost half the wells have tested positive for total coliform and 5% tested positive for *E. coli* bacteria.

In a few wells, bacterial contamination persisted despite repeated chlorination. Further investigation revealed that in some cases this was due to well construction deficiencies and in other cases it appeared to be due to septic system effluent. Areas of shallow bedrock appear particularly susceptible to bacterial contamination related to septic effluent. On one property the homeowner is now planning to replace their well with a new well located further from the leachfield and with additional casing to help protect their well from impacts of the septic system.

3.6.2 Naturally-occuring Water Quality

The inherent quality of the groundwater on Great Chebeague Island is a function of the mineralogy of the bedrock. Throughout southern coastal Maine, groundwater in the bedrock is commonly rich in iron and manganese, resulting in high dissolved iron and manganese in the groundwater. In some areas of

Maine, naturally occurring arsenic is also found in high concentrations. Iron, manganese and arsenic occur naturally in the minerals of the rock and are released into groundwater as water passes through the bedrock. Iron and manganese are very common in well water in Maine, especially along the coast. Concentrations in groundwater vary depending on the geology, from barely detectable levels of 0.05 milligrams per liter (mg/L) or less, to greater than 1.0 mg/L of manganese or greater than 10 mg/L of iron. Arsenic concentrations in groundwater vary across the state, but some wells have high levels of arsenic that can be a health concern.

Iron and manganese are classified as secondary or aesthetic “contaminants” because they can cause staining of plumbing fixtures and laundry, and a metallic taste. The federal and state secondary standards are iron at or below 0.30 mg/L and manganese at or below 0.05 mg/L. Iron and manganese are the most commonly reported water quality constituents of concern on Great Chebeague Island. No comprehensive town-wide testing program for iron and manganese has been conducted, but periodic testing over 3 decades has detected elevated iron in concentrations in excess of 10 mg/L and manganese in excess of 1 mg/L. Although these constituents are not considered health concerns at these concentrations, many people find them undesirable due to staining and taste issues. The 2023 survey results indicate that 40 percent of the respondents have installed water treatment for iron removal as the most common reason.

The primary federal and state drinking water standard for arsenic is 0.01 mg/L or 10 parts per billion (ppb). The MGS estimates that 1 in 10 wells in Maine have arsenic above the drinking water standard of 0.01 mg/L. We tested 10 wells on the island for arsenic in 2023 study, and no arsenic was detected in any of the water samples sent to the laboratory.

3.6.3 Chloride

Chloride, a common element, dissolves easily in water. Chloride occurs naturally in concentrations of a few milligrams per liter in groundwater and originates from trace amounts which are present in rocks and soils. Slightly elevated levels of chloride occur naturally in coastal areas due to air-blown marine spray. High levels of chloride are usually associated with contamination by environmental and human activities, including saltwater intrusion (ocean water mixing with groundwater), road salt storage/use, discharges from water softeners, human or animal waste disposal, septic systems, and other activities.

Consuming drinking water containing chloride is not considered harmful to health. High amounts of chloride, above 100 mg/L can give water a salty taste and can corrode pipes, pumps and plumbing fixtures. The federal and state secondary drinking water standard for chloride of 250 mg/L and is set to indicate these water quality problems and not health effects. It’s important to note that high levels of sodium may occur in association with high levels of chloride. If elevated levels of chloride are detected, it is recommended that homeowners check their water for sodium. Individuals on a low sodium diet due to high blood pressure or other health problems may be advised to consume water with a concentration of 20 mg/L or less sodium.

3.6.4 Inorganic Water Quality Results

Table 4 Inorganic Water Quality Results from the 2023 Well Testing Program

Inorganic Parameters (2023)	Number of samples	Minimum	Maximum	Median
Chloride mg/L	146	5	190	16
Iron mg/L	20	<0.05	13	0.05
Manganese mg/L	20	<0.05	0.77	<0.05
Arsenic mg/L	10	*none detected <0.02*		

Table 5 Inorganic Water Quality Results from all Well Testing Programs

Inorganic Parameters (2001, 2005 and 2023)	Number of samples	Minimum	Maximum	Median
pH units	101	5.7	8.9	7.4
Chloride (mg/L)	270	5	6,010	22
Iron (mg/L)	100	<0.05	13	0.2
Manganese (mg/L)	20	<0.05	1	<0.05
Nitrate (mg/L)	150	<0.02	6.5	0.5
Arsenic (mg/L)	9	*none detected <0.02*		

As shown on Table 4, in the 2023 study and in previous studies, iron concentrations in the groundwater on Great Chebeague range from non-detectable levels to greater than 10 mg/L. As a result, many households have installed softener systems to remove iron from their well water. Based on a limited number of water test results, manganese concentration in the groundwater on Chebeague range from no detectable levels up to 1 mg/L. The median concentration of manganese in the groundwater is less than 0.05 mg/L, indicating overall manganese concentration is low. Arsenic was only sampled during the 2023 study, and no arsenic was reported above the detection limit of <0.05 mg/L.

Chloride was analyzed to evaluate the potential of saltwater intrusion impacting the well. As shown on Table 4, chloride concentrations range from 5 mg/L to greater than 200 mg/L in the water samples tested in the 2023 study. As shown in Table 5, chloride concentrations in previous studies were in excess of 6,000 mg/L and have been reported from wells along the shore. As shown on Map 9 and Map 10, in both the 2001 and 2023 sampling programs elevated levels of chloride (above 100 mg/L) have been detected along the shore of Great Chebeague Island in the vicinity of:

- Division Point,
- Waldo Point,
- Roses Point
- Deer Point
- Central Landing

In 2023, elevated levels of chloride are also present in groundwater samples from the interior of the island along South Road at the East End. In this area, chloride impacted groundwater is likely the result of road salt impacts or some other anthropogenic source of contamination.

3.6.5 Other Groundwater Contaminants

Great Chebeague has a history of petroleum spills due to leaking fuel, kerosene and gasoline tanks. Many of these resulted in groundwater contamination and impacted wells. According to Maine Department of Environmental Protection (DEP) records, at least six spills have occurred since 2000. The DEP remediated these spills by excavating the contaminated soils, pumping and treating the contaminated groundwater or installing household treatment systems.

In 2022, PFAS contamination was discovered in the Chebeague Island School well and the Chebeague Island Recreation Center well, both located on Schoolhouse Road at the southern end of the island. Water treatment systems have been installed on both wells to remove the PFAS. The source of the PFAS is not known. The school is currently investigating to determine the source and to evaluate the feasibility of a replacement water supply.

4 VULNERABILITY ASSESSMENT

4.1 Projected Climate Impacts

As outlined in the recently updated 2024 Scientific and Technical Subcommittee (STS) report, *Scientific Assessment of Climate Change and Its Effects in Maine*, the impacts of climate change are:

- Maine's climate is getting warmer.
- Maine's climate is getting wetter, with more high-intensity precipitation.
- Precipitation variability is increasing, and winter snowpack is decreasing.
- Winter storms are projected to become more intense.
- Sea levels are rising and are expected to continue to rise.

4.2 Potential Impacts on Groundwater Availability

Groundwater availability depends on surface and subsurface geology as well as the local climate, especially precipitation available to recharge the aquifer. Consequently, changes in climate including increasing temperatures, more intense rainfall, reduced snowpack and sea level rise can all impact the availability of groundwater on Great Chebeague Island. Our inability to accurately quantify aquifer recharge makes a reliable determination of groundwater availability extremely difficult. For Great Chebeague Island, quantifying groundwater availability and sustainability is further confounded by the complexity and difficulty of characterizing groundwater storage and movement in a fractured bedrock aquifer. Groundwater availability varies markedly across the island as a function of the variable geology, recharge conditions and use.

A simplified island wide assessment of current **groundwater availability** can be derived using the average hydrogeologic characteristics of Great Chebeague Island. As described in section 3.3, the island's average annual recharge is estimated to be about 300 million gallons per year. If we assume all 400 homes on the island are occupied year-round (the number is closer to about 100 year-round and 300 seasonal households) that translates to almost 40 million gallons of water used by islanders per year. Consequently, household water use represents only **13 percent of the total estimated recharge** to the groundwater aquifer per year.

The impact of climate change on the frequency and severity of droughts in Maine remains uncertain. Maine's climate is getting wetter on average, however extreme precipitation conditions are intensifying with wet periods becoming wetter and dry periods becoming drier. Precipitation patterns are also shifting with more high intensity rainfall events that result in increased runoff and less aquifer recharge. Overall precipitation is shifting to more rain and less snow, and reductions in winter snowpack may also result in reduced recharge and drought conditions.

Although the average annual precipitation is about 46 inches per year on Great Chebeague Island it varies seasonally and from year to year. Groundwater levels generally reach their lowest position in late summer due to reduced recharge during the summer months. On Chebeague, low water table and drought conditions typically coincide with peak demand during the late summer which can magnify the impacts. Even under current climatic conditions, wells periodically go dry and we expect that may increase in the future. Residents of Great Chebeague Island have reported problems with dry wells, especially during the summer or periods of drought. In fractured bedrock aquifers, the susceptibility of the well to go dry varies from well to well and is a function of the fractures, yield and depth of the well and water usage. In addition to causing wells to run dry, drought conditions can also exacerbate or induce water quality issue such as elevated iron concentrations or saltwater intrusion.

4.3 Sea Level Rise Impacts

Islands are especially vulnerability to the impacts of sea level rise because they are surrounded by salt water. Groundwater is derived from precipitation and due to density differences, the fresh groundwater floats as a lens on the denser saline ocean water. The position and thickness of the freshwater lens can vary seasonally, due to variations in precipitation, or it can vary over the long term due to the impacts of climate change and sea level rise.

4.3.1 Saltwater Intrusion

Saltwater intrusion occurs when **saltwater is drawn into a freshwater aquifer**. Saltwater intrusion can be the result of natural processes like sea level rise or as the result of human activities such as pumping – or both. Typically, measurements of specific conductance and/or chloride in groundwater are used to evaluate if saltwater intrusion is occurring.

As noted in the spatial analysis of the chloride data, there are several areas of elevated chloride in wells near the shore. In most cases, data from only one well was available in a particular area, limiting the delineation of areas where multiple wells or points may be impacted. Based on the results of this study, and previous studies, saltwater intrusion is impacting the groundwater quality in at least five locations on the Island: **Division Point, Waldo Point, Rose’s Point, Deer Point and Central Landing**. Four drilled wells on Rose's Point/ Waldo Point, two wells at Division Point, and one well on Deer Point have consistently elevated levels of chloride, indicative of saltwater intrusion, as well as one well near Central Landing. Concentrations of chloride in excess of 6,000 mg/L were reported for a well from the Rose’s Point area in the 2001 study. A few residents in these areas have installed water filtration systems to treat for hardness and chloride.

Maine Geological Survey Sea Level Rise projections were used to assess the vulnerability of existing wells and undeveloped coastline to saltwater intrusion. As shown on Map 11, this analysis indicates that about 10 existing wells may be inundated in future sea level rise scenarios. Particularly vulnerable are the homes in the **low-lying areas east of Springettes Road**. On Map 12, overlaying sea level rise on the map of chloride impacted wells indicates that saltwater intrusion impacts in the areas of Division Point, Waldo Point and Rose's Point will likely increase in the future, potentially exacerbating existing issues and exposing new wells to saltwater intrusion.

4.3.2 Groundwater Rise

Sea level rise induced groundwater rise refers to the rise in the freshwater surface – or water table - as the sea level rises and moves landward. Evaluating groundwater rise was out of the scope of this project due to limited data and resources, but it may occur in areas on Great Chebeague Island, especially in low lying areas. Rising groundwater tables pose a risk to septic systems which can translate into water quality degradation. Groundwater rise can also result in road and drainage impacts and basement flooding in certain conditions.

5 GROUNDWATER SUSTAINABILITY

5.1 Aquifer Monitoring Program

Aquifer monitoring is crucial for understanding how climate change impacts groundwater levels, availability and water quality. Monitoring networks provide an early warning system to detect aquifer changes and can help to inform adaptation strategies to manage water resources effectively. The effects of climate change on an island bedrock aquifer are controlled by site specific features such as bedrock lithology and porosity, fracture patterns, recharge rates, local slopes and groundwater gradients, shoreline geometry, land use patterns and water use. Consequently, it is difficult to translate conditions observed in one location to another making collection of site-specific data essential.

Based on input from the MGS, CCAT purchased an AquaTROLL monitoring instrument to track groundwater level and conductivity in the bedrock aquifer. We collaborated with MGS on the instrumentation and site selection and the Town of Chebeague's monitoring site will be incorporated into MGS's saltwater intrusion monitoring network. In collaboration with MGS, we are in the process of completing the software installation to access the data remotely using the manufacturer's data dashboard. Once the connection is established, the town can provide a link to the dashboard on their website. The instrumentation was installed in a well on Great Chebeague Island but due to signal strength issues, CCAT may relocate it to a different well with better exposure to improve reception.

5.2 Groundwater Protection Strategies

Concerns related to water quality and quantity have been a long-standing issue on Great Chebeague Island. There are several options for the island to consider in order to safeguard the aquifer that serves as the island's sole water supply now and into the future. Development and climate impacts will continue to increase the risks to the quantity and quality of groundwater on the island. Ensuring there is adequate quantity and quality of groundwater for future generations requires active, long-term planning by the town

The town has an important role in groundwater protection. It controls land use planning, and zoning, ordinance development and enforcement, and implementation of site law and subdivision permits. To date, groundwater protection on the island has focused on outreach and education delivered by the planning board and through ad hoc community programs. The town has not taken any action to strengthen or adopt specific development guidelines or groundwater-related ordinances or practices. There is currently no system to understand the cumulative impacts of individual wells drilled. There are a number of issues that may impact the quality and quantity of groundwater such as:

- Development and land use practices
- Septic system siting and maintenance
- Changes in precipitation and recharge
- Changes vegetation cover
- Saltwater intrusion due increased withdrawal and/or sea level rise
- Periodic droughts
- Groundwater contamination

Some of these are development driven and some are climate driven, but their impacts on the island aquifer need to be considered collectively to develop an effective sustainability strategy. It's also important to understand that the protection of the groundwater aquifer is significantly easier than finding alternative water sources on the island. That said much of what will make the difference will not necessarily come from regulations, but from the community behavior that supports sustainable water use practices.

Over the past 30 years, the Town of Chebeague has conducted a number of groundwater studies to assess conditions in the aquifer and has compiled a valuable dataset of well and water quality information. These studies have identified persistent water quality issues related to **septic system impacts and saltwater intrusion**. The results of this study demonstrate that projected climate change impacts on groundwater resources may exacerbate and accelerate these water-related problems. Consequently, understanding and protecting the island's water supply is a priority and will become increasingly important as the island continues to develop and as the impacts of climate change progress.

5.2.1 Potential Groundwater Protection Strategies

Groundwater protection strategies follow a spectrum from voluntary practices to regulatory requirements. At the local level on the Town of Chebeague, groundwater protection is addressed in the Comprehensive Plan. The Planning Board is tasked with identifying and implementing protection strategies and the Code Enforcement Officer (CEO) is tasked with enforcing the land use ordinances. Groundwater protection is addressed to a limited degree in the town's subdivision and site plan requirements. The effectiveness of these protections is limited by the fact that the majority of the development on the island is construction of **residential single-family homes** that are not subject to these rules. Consequently, groundwater protection is not considered for the majority of the development on the island. Of particular concern on the island are the siting of well and wastewater disposal systems, development along the shore, and the size of homes and water use.

Table 6 presents a summary of groundwater protection strategies that the town can consider.

Table 6 Groundwater Protection Strategies

STRATEGY DESCRIPTION	IMPLEMENTATION APPROACH
EDUCATION AND OUTREACH	
Town can offer and/or sponsor **Community Outreach programs about groundwater resources.**	Local presentations, webinars, surveys, newsletter or include in town report, community conversations, mailings, multi-board collaboration.
Provide **Septic Smart r**esources to residents and visitors.	Town website and provide print copies at town office or via mailing
Provide **well-owner resources** to residents and visitors.	Town website and provide print copies at town office or via mailing
Educate residents about **efficient outdoor water use.**	Town website; garden club
Continue to partner with CCLT on outreach related to **water resource protection and land conservation.**	Combined community events and communications.
Provide free periodic town-sponsored collection of **hazardous waste** and **unused pharmaceuticals**.	Town organized collection
DATA COLLECTION AND ASSESSMENT	
Conduct a targeted **sampling program** to assess **road salt impacts.**	Identify sites, collect samples.
Compile town **septic system permit** data and incorporate into Town GIS.	Compile data from public sources
Assess groundwater vulnerability to **contamination from septic systems.**	Conduct a GIS analysis using septic system and existing data
Establish a **local water level and water quality monitoring network** distributed across the island and expand sites in **MGS saltwater intrusion monitoring network.**	Select site(s), purchase and install instrumentation with guidance from a hydrogeologist and MGS.
Collect data on local residential, commercial and agricultural water use. Encourage voluntary water metering to obtain information on annual **water consumption**.	Homeowner or other to install meter; read quarterly or manually; could develop online data submittal form
Partner with MGS and/or USGS to collect field data to quantify and **verify groundwater recharge rates;** construct a **groundwater flow model** and assess **groundwater rise** impacts.	Requires qualified technical assistance in collaboration MGS and/or USGS

STRATEGY DESCRIPTION	IMPLEMENTATION APPROACH
PROMOTE BEST PRACTICES - ADVISORY ONLY	
Encourage residents to **report** new or replacement **well information** to Town.	Provide with building or occupancy permit.
Encourage **200' setback** or more for **wells** from septic and shoreline.	Info at Town Office and on town website.
Encourage residents to **install low flow fixtures** and appliances to promote water conservation.	Info at Town Office and on town website.
Encourage **reporting of dry wells** on MEMA website.	Link to MEMA website on town website.
Encourage homeowner **septic system inspection and maintenance**; provide reminder notices to homeowners.	Info on Town website; DHHS presentation on septic systems.
Promote **organic gardening** to reduce the use of pesticides and fertilizers.	Link on Town website; SWCS presentation
Promote **Low Impact Development** to enhance groundwater recharge quantity and quality.	Info on Town website; DEP presentation; PB workshop
REGULATION AND ORDINANCES	
For new **wells/septic** systems adopt a minimum **200' separation**; increase the **minimum setback** for wells and septic systems from the shore. Could limit to just areas with known problems.	Ordinance change with Town Meeting approval
Require **submittal of well information** in order to obtain building permit for new residential home.	Ordinance change with Town Meeting approval
Modify existing local ordinances to require low impact development; use of water conservation fixtures and appliances; permits for irrigation systems, etc.	Ordinance change with Town Meeting approval
Require **evidence of adequate quantity and quality of potable wate**r prior to issuing an occupancy permit; also for Site Plan and Subdivision Ordinance.	Ordinance change with Town Meeting approval
Require **increased groundwater protection** for any storage and use of chemicals such as registration, double containment, spill kits, spill response plans.	Ordinance change with Town Meeting approval
Prohibit or limit use of **certain chemicals**, pesticides etc. in entire town or in certain sensitive areas.	Ordinance change with Town Meeting approval
Apply for **Sole Source Aquifer Designation** through EPA	Application to US EPA
Adopt an **Aquifer Protection Overlay or Ordinance** limiting certain activities or requiring certain practices in order to protect the quality and quantity of groundwater.;	Ordinance change with Town Meeting approval
Adopt a **Groundwater Resiliency Overlay** to identify areas susceptible to saltwater intrusion.	Ordinance change with Town Meeting approval

6 DISCUSSION

6.1 Next Steps

Effective stewardship of the Town's groundwater resources needs to include:

- monitoring of the resource,
- ongoing data collection and updates
- implementation of groundwater protection strategies.

In 2025 the Town plans to initiate an update to its Comprehensive Plan which was completed in 2011. The findings of this Groundwater Sustainability Study should be incorporated into the updated Comprehensive Plan and specific groundwater protection strategies should be included into the Implementation Plan. The Town received a Resilient Communities grant through the Casco Bay Estuary Partnership (CBEP) to develop a climate resilience vision for the Town and conduct a review of Town ordinances to identify opportunities to incorporate resilience considerations into municipal policies. It's envisioned that this effort will happen in tandem with the update to the Town's Comprehensive Plan. The expected outcome of this effort will be suggested practices/ ordinances to protect and improve the resiliency of town's groundwater aquifer to the impacts of development and climate change.

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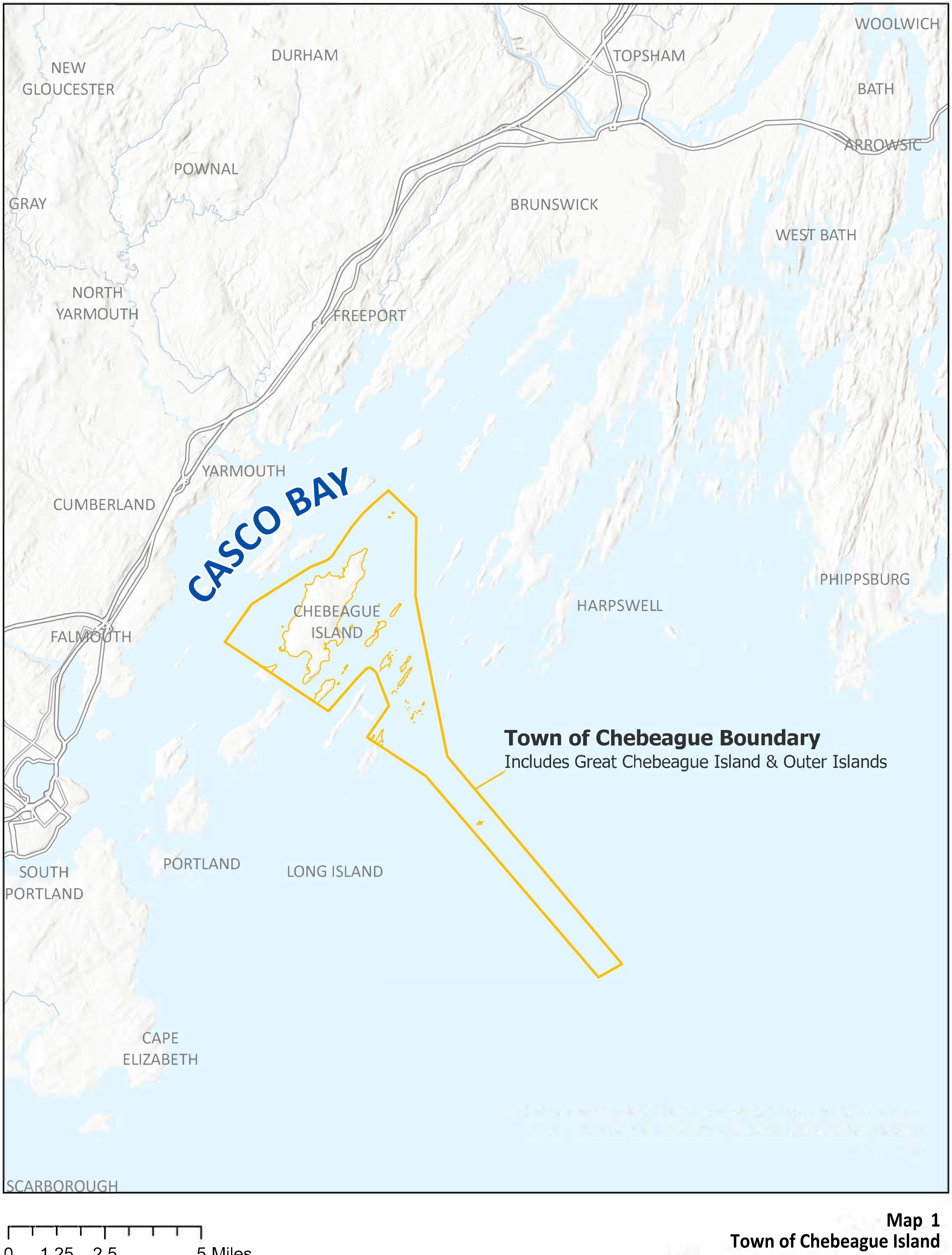
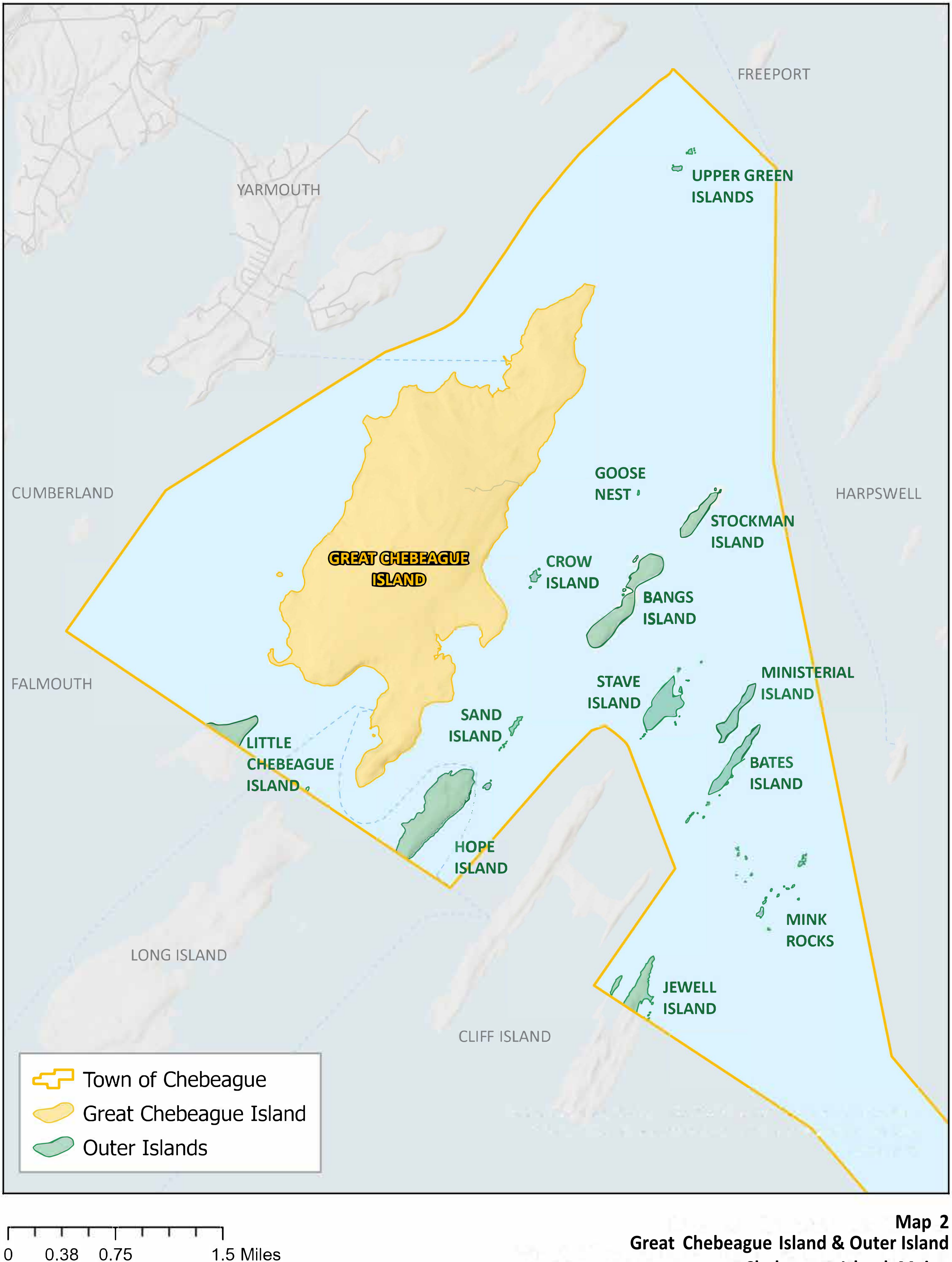
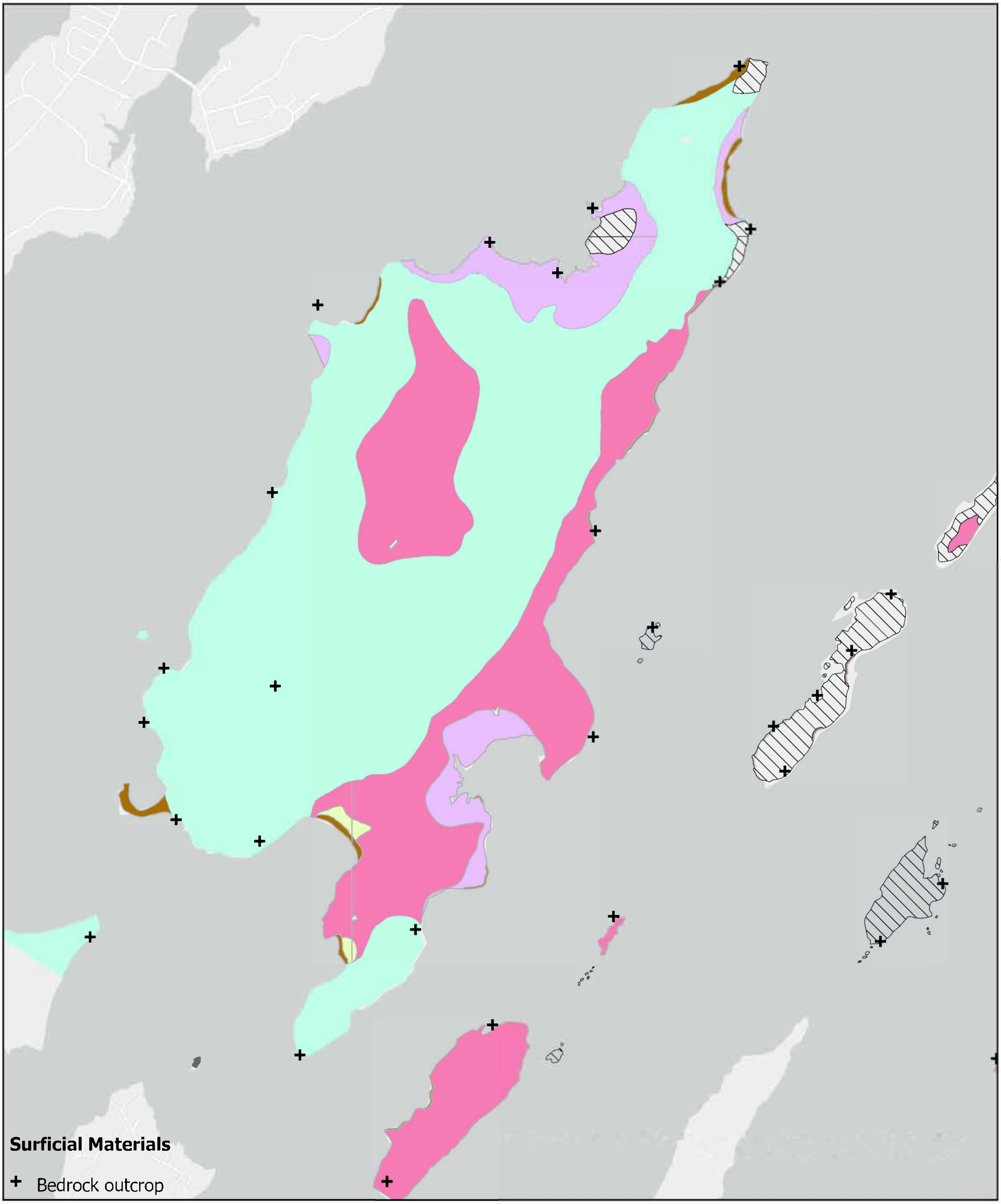
MAPS



Map 1
Town of Chebeague Island
Casco Bay, Maine



Map 2
Great Chebeague Island & Outer Island
Chebeague Island, Maine



Surficial Units

Marine Shoreline (Hms)

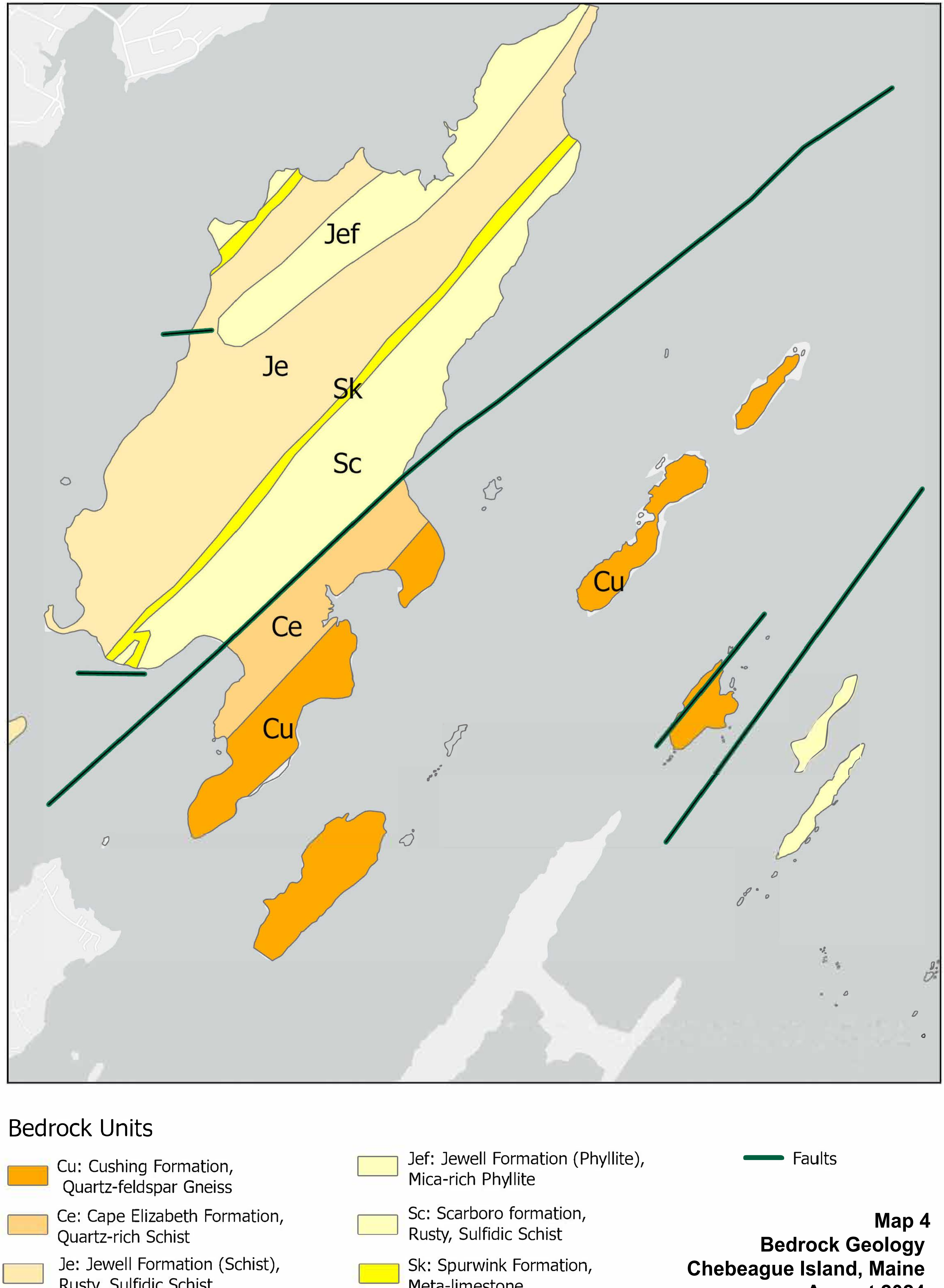
Presumpscot Formation (Pp)

Till (Pt)

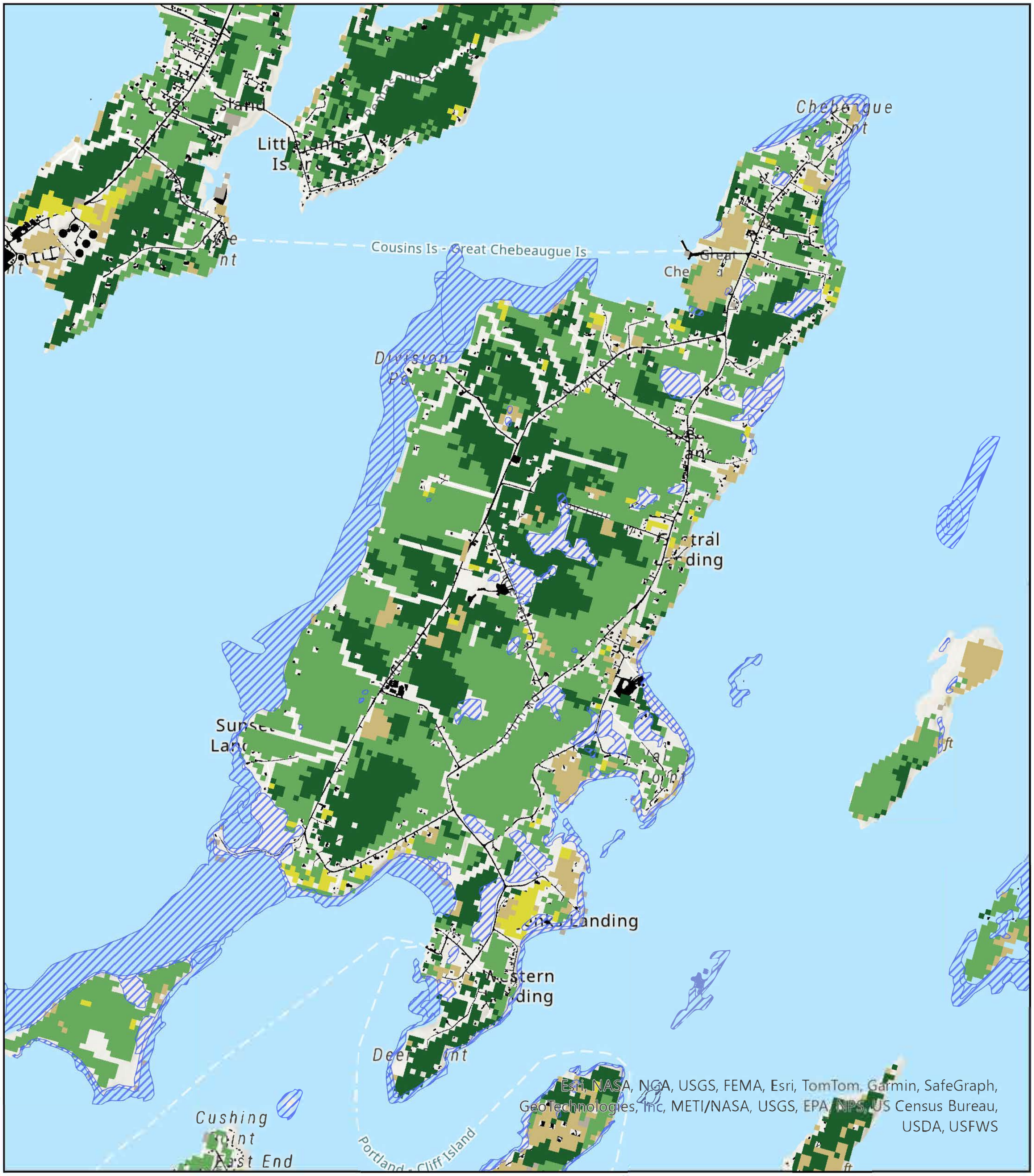
Marine Nearshore Deposits (Pmn)

Thin till (Ptd)

Map 3
Surficial Geology
Chebeague Island, Maine
August 2024



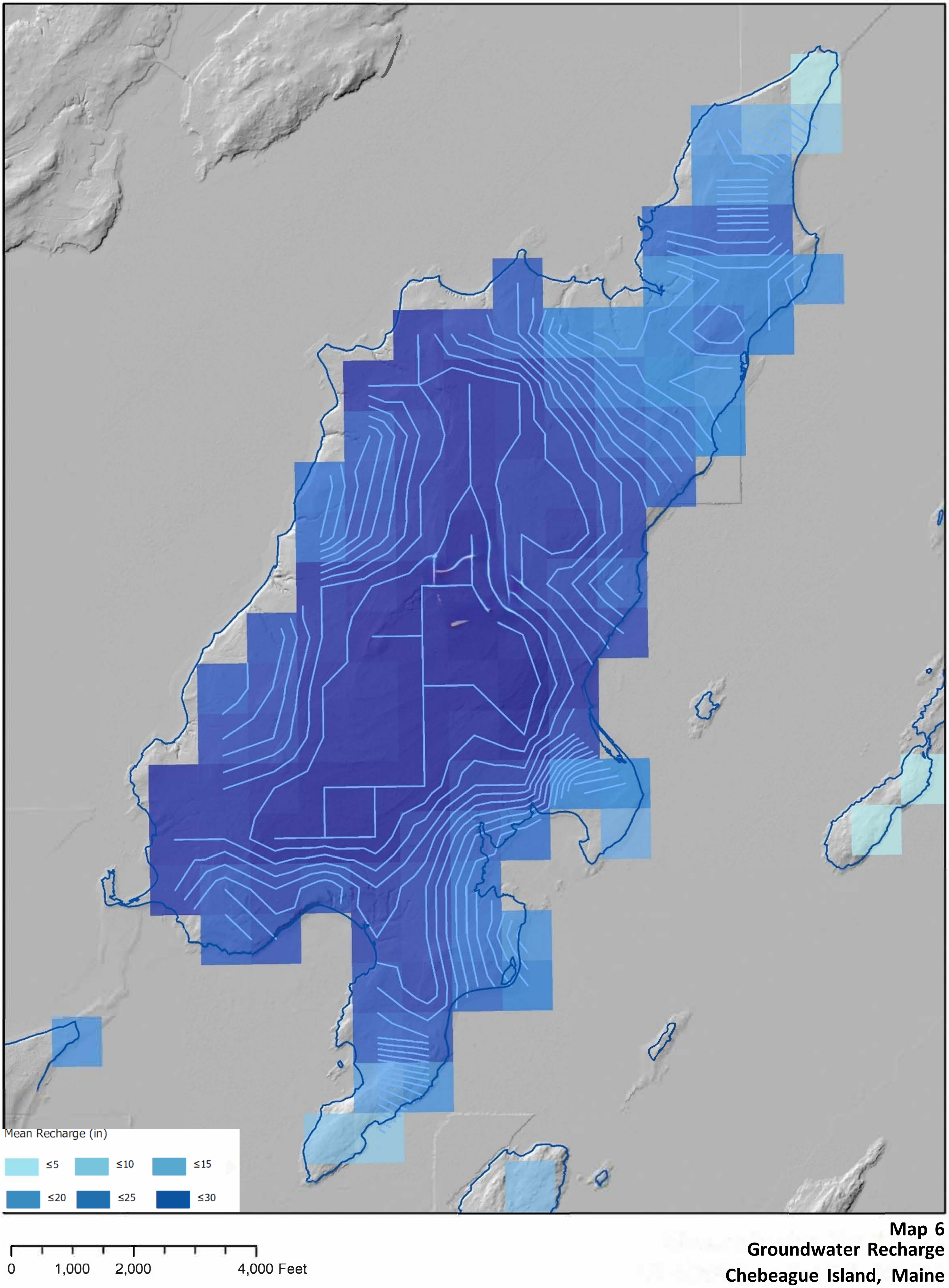
Map 4
Bedrock Geology
Chebeague Island, Maine
August 2024



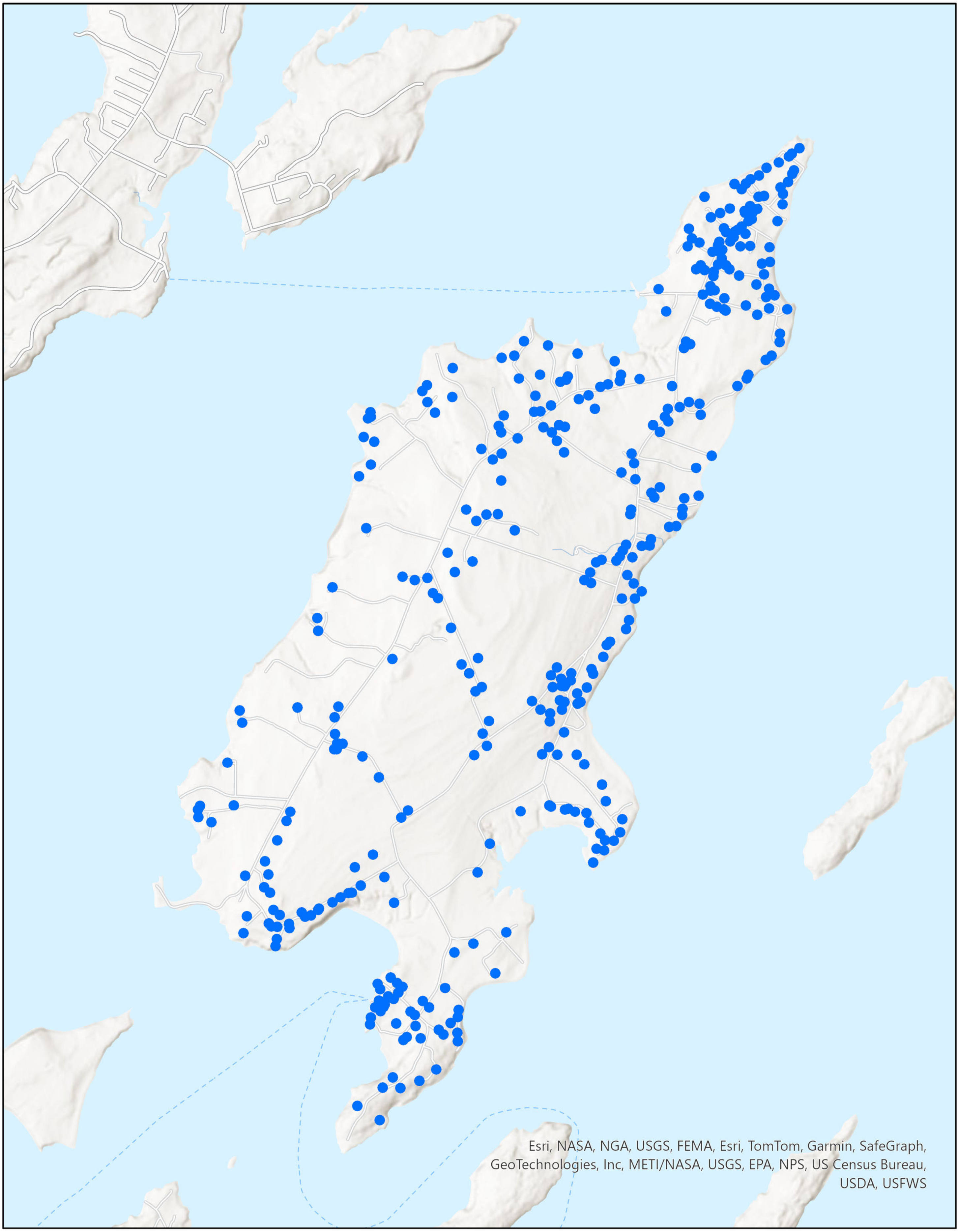
Land use class

- Evergreen Forest
- Mixed/ Deciduous Forest
- Shrub/ Scrub/ Grassland
- Barren Land (Rock/Sand/Clay)
- Wetlands
- Pasture/ Crops
- Developed
- Impervious

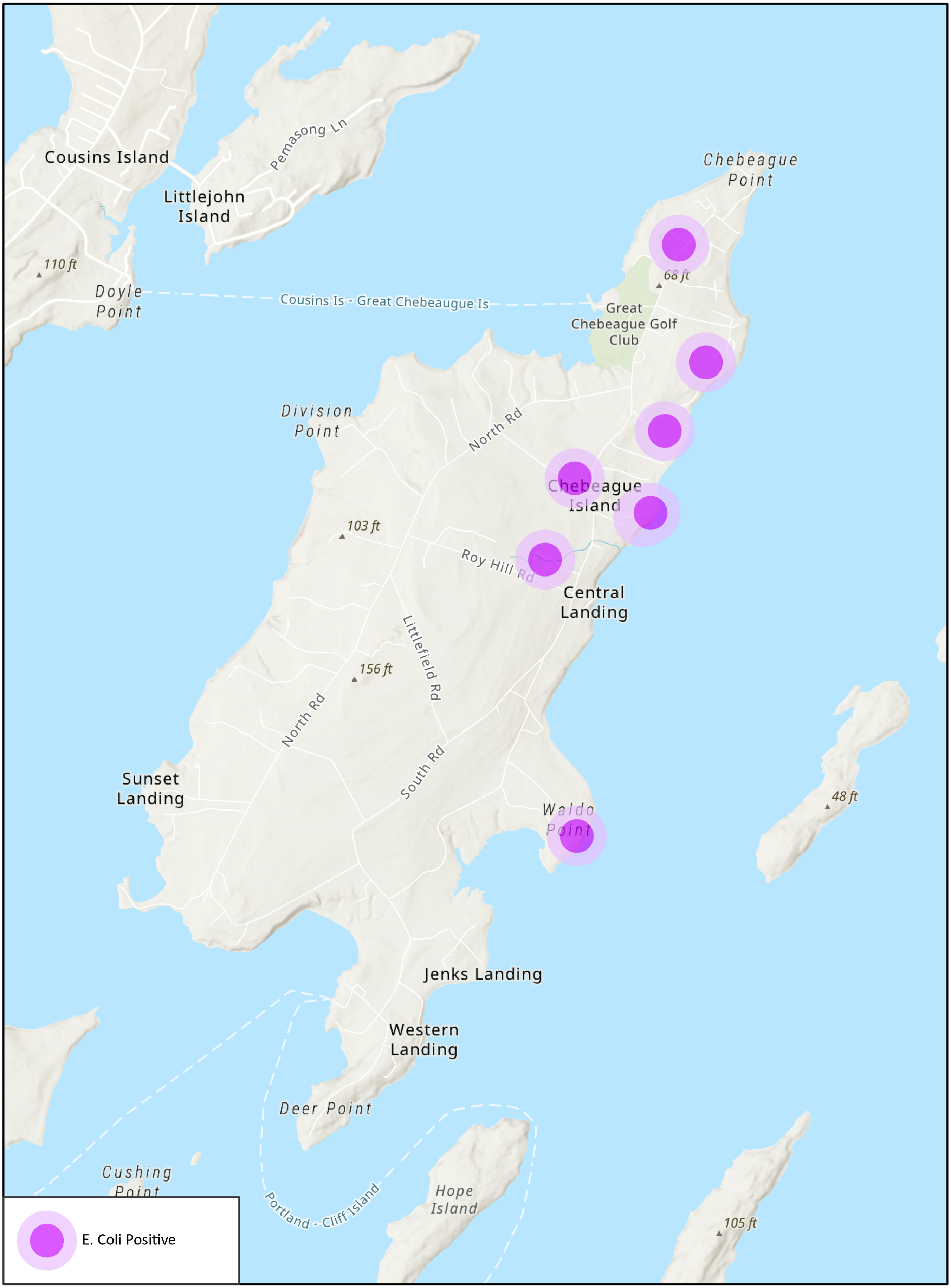
Map 5
Land Cover
Chebeague Island, Maine
August 2024



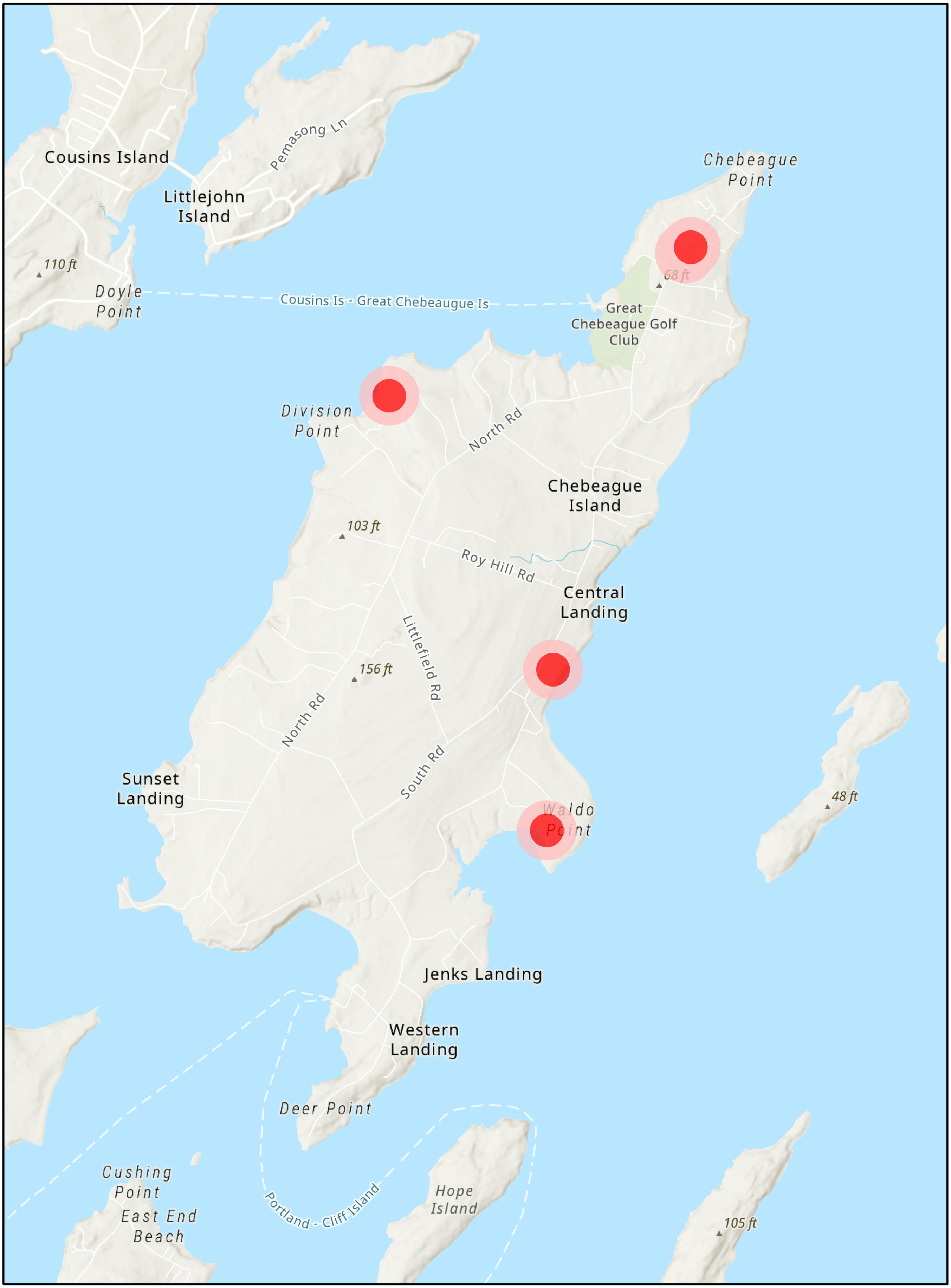
Map 6
Groundwater Recharge
Chebeague Island, Maine



Map 7
Water Supply Wells
Chēbeague Island, Maine
August 2024

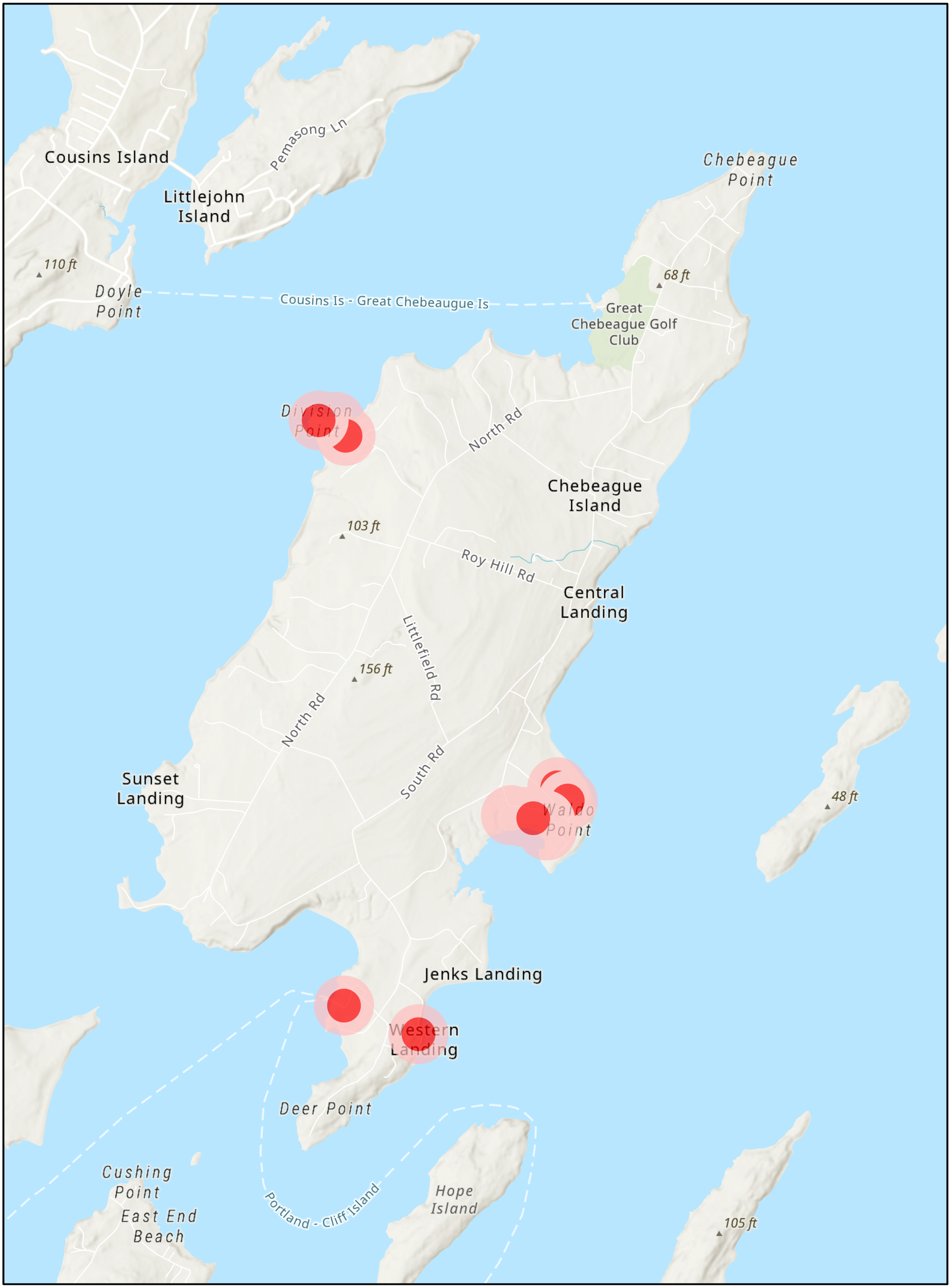


Map 8
2023 Bacteria Test Results
Chebeague Island, Maine
August 2024



Elevated Chloride >100 mg/L

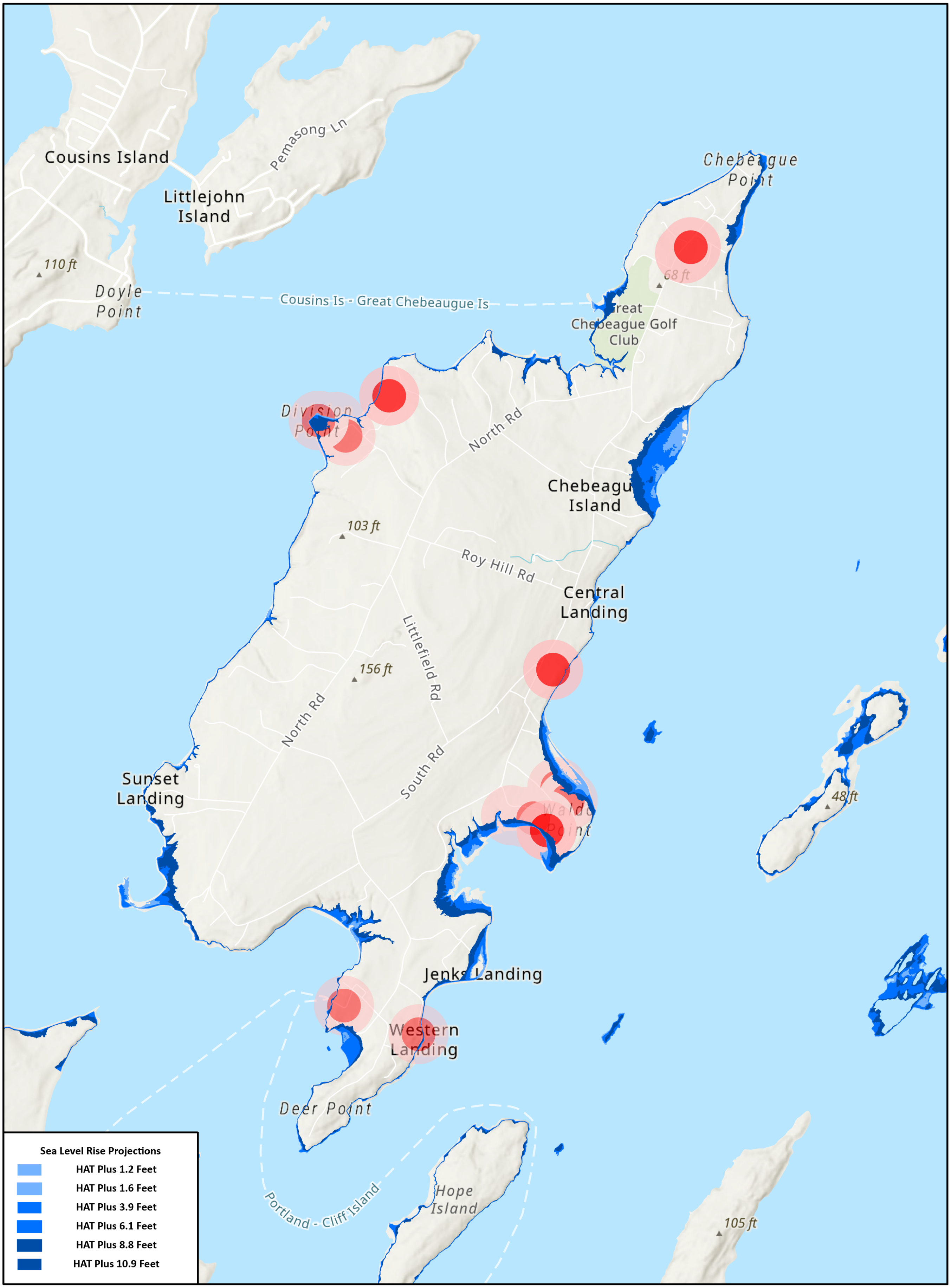
Map 9
2023 Sampling Program Elevated Chloride
Chebeague Island, Maine
August 2024



Elevated Chloride >100 mg/L

Map 10
2001 & 2005 Sampling Programs Elevated Chloride
Chebeague Island, Maine
August 2024

Map 11
Sea Level Rise Impacts on Existing Wells
Chebeague Island, Maine
August 2024



Map 12
Sea Level Rise Impacts and Saltwater Intrusion
Chebeague Island, Maine
August 2024