

SUBTERRANEAN RESILIENCY:

Predicting, Assessing and Mitigating Saltwater Intrusion

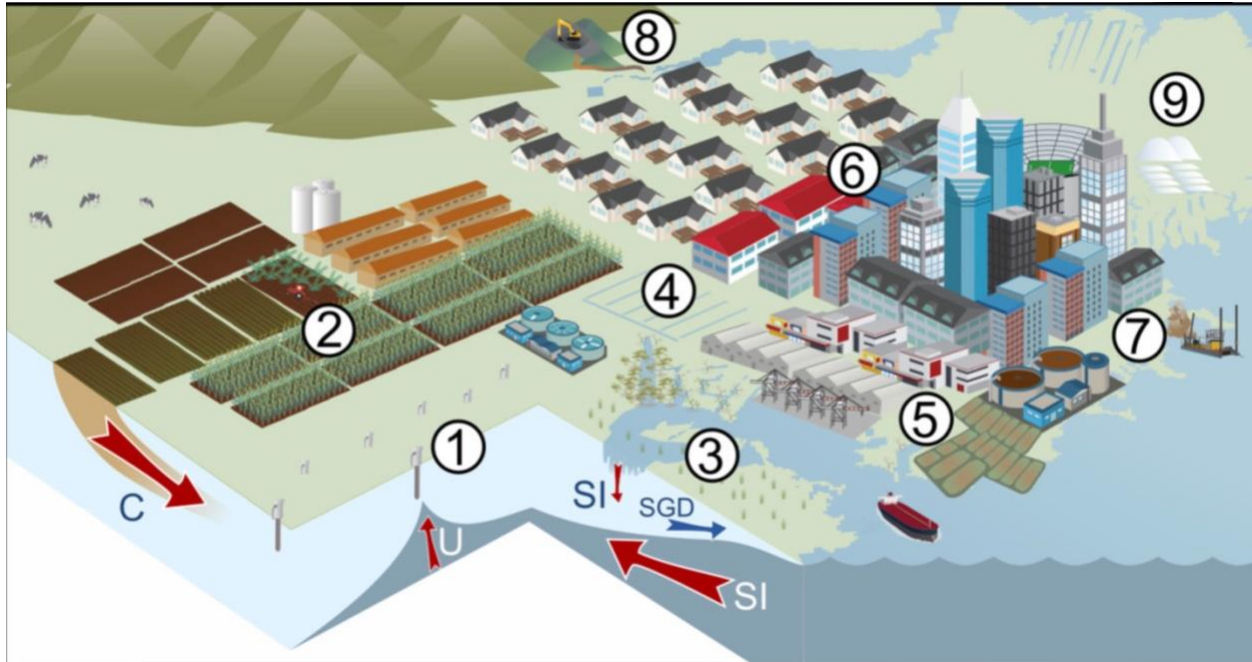


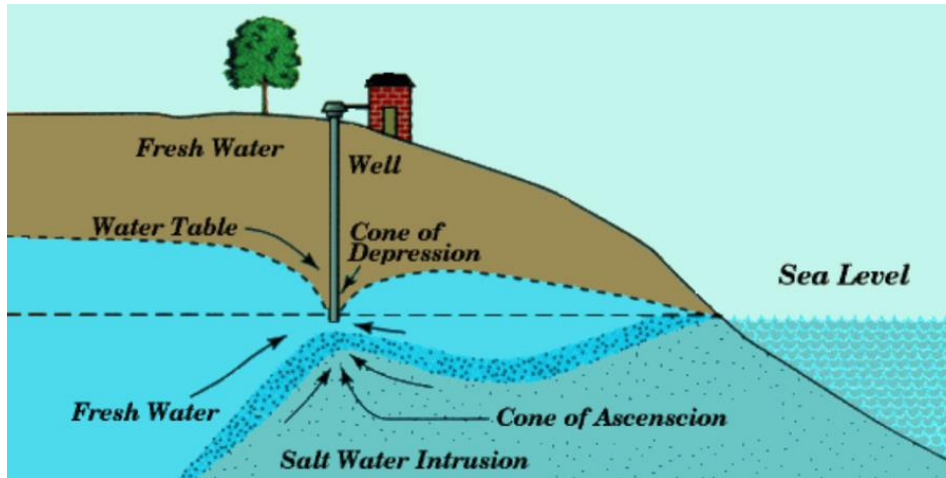
Figure 1 Courtesy Holly Michaels, PhD., from "Science, Society and the Coastal Groundwater Squeeze."

(1) Groundwater over-pumping for agricultural and domestic water use causes saltwater upconing (U) and seawater intrusion (SI), as well as a reduction of submarine groundwater discharge to ecosystems; (2) contamination (C) by the use of fertilizer, pesticides and antibiotics for intensive agriculture; (3) vertical seawater intrusion caused by flooding of low-lying areas by seawater; (4) land subsidence caused by drainage for urban development; (5) nutrient and antibiotics use in aquaculture; (6) urban expansion causing increased water demand and pollution; (7) dredging for land reclamation and navigation; (8) mining-induced water table drawdown and pollution; (9) local salt storage causing salinization. Symbols courtesy of the Integration and Application Network, University of Maryland Center for Environmental Science

A vital and vulnerable resource:

The Town of Plymouth is situated above the second largest sole-source aquifer in the Commonwealth: the only source of drinking water for our 63,000 residents, and a key component of the vitality of a unique, biodiverse ecoregion that includes, in Plymouth alone, over 400 ponds and 75 state-listed species.

In the last several decades the town has invested millions in protecting this aquifer, harvesting its bounty and establishing an efficient distribution system. At the same time commercial and residential development has continued at a rapid pace, with thousands of new residential units' wells drawing from the same source.



A simple pictorial explanation of how excessive groundwater pumping can pull ('upconing') saltwater into wells. Diminished recharge through destruction of woods and wetlands, climate change (less rain) and other factors can also contribute.

Currently, the town is developing a water masterplan to ensure the quality and quantity of our water in the future. In 2019 the town participated in the MVP Planning process where our vulnerability to saltwater intrusion (SWI) was publicly acknowledged for the first time. The town also recently established a citizen-led Water Conservation Committee, passed zoning for aquifer protection areas, and pro-

actively worked to preserve woods, wildlands and restore wetlands in part to ensure that the natural recharge of the aquifer occurs without unnecessary impediments.

In partnership with the University of Massachusetts-Amherst and close coordination with 12 community non-profits this project will build on that previous work and follow directly on priorities determined through the MVP planning process to help ensure both a sustainable, resilient public water supply and healthy natural environment, all of which are threatened by climate change - in particular, the insidious effects of saltwater intrusion.

While researchers work to develop a new tool that allows for the accurate prediction of our most vulnerable sites, now and as climate predictions come to fruition, our 12 partners will launch an aquifer protection outreach campaign within the community.

The town expects the overall project will result in a variety of practical recommendations, including nature-based solutions to the specific threat of SWI that may be implemented locally, and that the capacity developed through the community engagement component of the project will have an ongoing and lasting legacy in the community.

What is saltwater intrusion, and why does it have to be dealt with today?

We are inclined to think of the ocean and groundwater as existing in separate spheres, when in fact there is a constant push and pull between the two and in coastal areas saltwater and freshwater are often only separated by a narrow mixing zone.

Unchallenged, fluctuations in that mixing zone, intensified by climate change, sea-level rise, increasing demands for potable water and other factors can lead to the failure of septic systems, corrosion of underground wires and piping, can threaten the ecological viability of rare coastal plain ponds and their associated species, create critical shortages of drinking water and endanger the health of consumers.

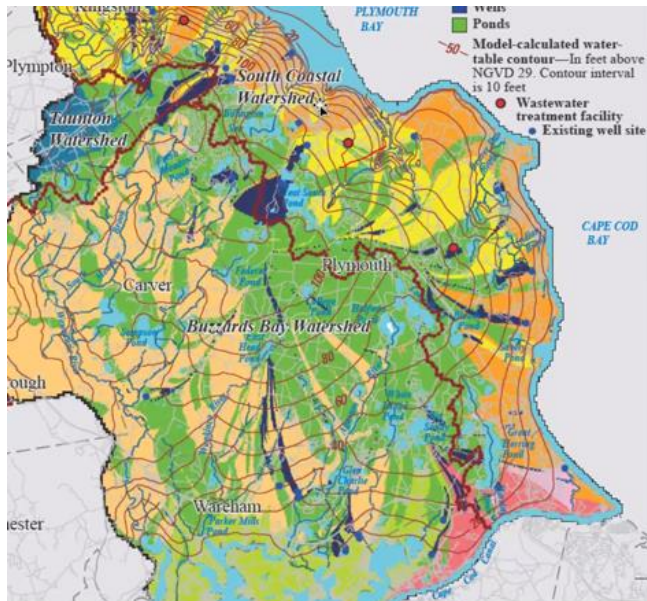
Vulnerable? ResilientMA.org map shows a community literally covered by its sole-source aquifer: a source of pride, and grave concern in the face of sea-level rise, climate change and the increased likelihood of saltwater intrusion.

Once SWI has a foothold the economic costs of mitigation are often prohibitive.

Since 1997 the South Florida Water Management District has distributed \$1.4 billion dollars for adaptations to existing water infrastructure because of SWI.

Health studies have shown a strong association between elevated drinking water salinity and increased frequencies of hospital visits,¹ a special concern for Plymouth with its higher percentage of older citizens who are less adaptable to climate-related conditions.²

The fragility of our local systems and the danger to our aquifer is already on display.



A once pristine coastal plain pond within the climate justice community of White Horse Beach has seen its water quality deteriorate, cyanobacteria blooms appear, resulting in beach closures and a quarter of a million dollar expenditure simply to try and identify the causes.³

Several of the town's groundwater pressure zones are presently operating at a deficit (more water out, than in), restricting development and putting pressure on the town to develop additional municipal wells even as concerns for the effect of those withdrawals on freshwater ponds increase.

In the past events of this kind have been viewed as isolated incidents, but with 100% of the towns's 63,000 residents relying on the Plymouth-Carver sole source aquifer for potable water and 80% actually living within designated aquifer protection districts, we can't continue to think parochially.

The 'Plymouth-Carver' sole-source aquifer encompasses several drainage basins, a half-dozen municipalities, over 500 ponds and nearly 40 miles of coastline.

We do not have to look far to find communities that are suffering from a slow response to the causes and effects of SWI.

- More than 40 states in this country are fighting the SWI battle.⁴
- In Hawaii SWI has jeopardized a sacred indigenous site, its saltwater pond and associated rare plant species.⁵
- In coastal areas of Washington State private wells are now regularly tested for SWI and where intrusion is documented owners are required to perform additional annual testing and future development may be restricted.⁶

1

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6801928/#:~:text=Drinking%20water%20salinity%20has%20been,coastal%20sub%2Ddistricts%20of%20Bangladesh.>

² Mass State Hazard Mitigation and Climate Adaptation Plan: Table 2-5: Vulnerable Populations by County.

³ https://www.plymouth-ma.gov/sites/g/files/vyhlf3691f/uploads/draft_bartlett_pond_diagnostic_report_and_management_plan_rev022620.pdf

⁴ <https://www.nature.com/articles/s41467-020-17038-2>

⁵ https://www.nps.gov/kaho/upload/KAHO_NPS_WMA-petition_2013_September-13_With-photos.pdf

⁶ <https://www.co.jefferson.wa.us/666/Seawater-Intrusion-Policy>

- In California innovative airborne electromagnetic methods (AEM) paint a clear and disturbing picture in a famous farming community along the Pacific Ocean.⁷

Existing resiliency models in Massachusetts outline a variety of threats for Plymouth including intrusion due to sea level rise and hurricane surge. All of these threats are consequential and will need to be addressed. But a ‘top-down’ resiliency approach does not acknowledge the full subterranean threat of SWI.

Even when seas are calm and shore roads dry the process of seawater intrusion may be underway.

Where to begin

Largely through the work of the US Geological Survey (USGS Masterson Model) there is already a great deal known about the basic hydrogeology of the Plymouth area, and of adjacent coastal communities in Southeastern Massachusetts and on Cape Cod. But while existing models provide a tool to predict hydrogeological changes associated with land use and groundwater withdrawals, they do not fully extend to predicting SWI or identifying where we should focus our concerns.

To do so, with accuracy, requires a further refinement of existing hydrogeological models and a more complete delineation of the conditions indicative of SWI potential (e.g. sampling groundwater across varying topographies and drainage basins, measuring groundwater and pond-level elevations relative to sea level).

The creation of such a refined model will lead directly to the development of a new predictive and planning tool that, integrated with established resiliency models, will be used to intelligently guide a variety of nature-based solutions that produce true “subterranean resiliency.”

As we develop this new level of resiliency we will also undertake a 2-year, town-wide, education and outreach program that will utilize this community’s wealth of non-profit conservation groups to create a coordinated plan for instilling a broad awareness of the true value of our aquifer and the efforts needed to protect it.

That outreach effort will provide the practical knowledge necessary for home conservation, the training and tools required to monitor private wells and ponds, hold forums and webinars and take other actions that explain and educate on saltwater intrusion and its connection to climate change while providing an alternative indigenous perspective on environmental science.

One especially noteworthy deliverable of our outreach program will be the establishment of a new resource tentatively named, *The Community Water Sampling Center*. The overall undertaking proposed will require specific tools and supplies to

⁷ <https://earth.stanford.edu/news/understanding-saltwater-intrusion-through-remote-sensing#gs.z1a1gl>

HOW CHLORIDE AFFECTS THE QUALITY OF THE WATER?

According to the U.S. Environmental Protection Agency (EPA), water with high chloride content may, among other things, cause high blood pressure; taste salty; corrode pipes, fixtures, and appliances; and blacken and pit stainless steel. The EPA has set a Secondary Maximum Contaminant Level (SMCL) of 250 mg/L for chlorides. An SMCL is the concentration limit for a nuisance contaminant that could affect the aesthetic quality of water by causing taste, odor, or staining problems (U.S. Environmental Protection Agency, 1996).

sample wells and ponds to, first, provide important data necessary for the refinement of the groundwater model. Those tools will be the basis for a community resource that will continue operating after the project is concluded, a facility dedicated to providing residents the means to monitor groundwater in ponds, streams, vernal pools and the like, thereby engaging the entire Plymouth community in the protection of our aquifer.

This community will not need to be convinced of the need for action on climate change.

Each of this projects' 12 full partners - all Plymouth-based and representing thousands of members - have their own unique commitment to environmental and cultural resiliency.

- Plymouth's coastal setting and unique ecological attributes have already inspired a series of municipality-led innovative, award-winning efforts to remove dams, restore cranberry bogs, re-establish herring runs and increase the resiliency of ponds, rivers, estuaries and beaches.
- The Living Observatory is a collaborative of scientists, artists, engineers and restoration practitioners that was founded with the belief that resiliency of farmland can be achieved through restoration. The organization was a partner in the nationally-acclaimed Tidmarsh Cranberry Bog restoration and has remained committed to making natural restorative processes visible to the layperson.
- The Southeastern Massachusetts Pine Barrens Alliance has established working relationships with most of the leading environmental nonprofits in Massachusetts in the cause of preserving the area's globally-rare ecoregion, has received nationally competitive grants, and recently established an environmental discovery center on Cape Cod Bay that will serve as conference center and citizen-science laboratory for this project.
- Mass Audubon is both our partner, a partner of the Massachusetts' Municipal Vulnerability Preparedness (MVP) Program itself, and a leading advocate for climate action in the Commonwealth, striving to achieve "net zero emissions by 2050 in Massachusetts while maintaining a livable landscape for people and wildlife."
- The Plymouth Area League of Women Voters has an established reputation as a proponent of civic engagement, has demonstrated a commitment to social and environmental justice and represents a national organization with a deep commitment to climate issues..
- Created by the town's Select Board in October 2020 to assist in developing conservation programs to reduce current and future water consumption the citizen-staffed Plymouth Water Conservation Committee's objectives include recommending water conservation measures to be integrated into the town's Water Master Plan, insuring compliance with the Town's Water Management Act permit, minimizing withdrawals from the Plymouth-Carver sole source aquifer and educating all Plymouth residents on the importance of sustainable water practices.
- The Native and non-Native educators and scholars who comprise the Indigenous Resources Collaborative (IRC) are

dedicated to creating and curating educational materials focused on Southern New England Indigenous voices, cultures, history, and Traditional Environmental Knowledge (TEK). Based at Center Hill Preserve, Plymouth, on traditional Herring Pond Wampanoag land, the IRC is also committed to the preservation of the area's globally-rare ecoregion and to promote environmental sustainability and the stewardship of Mother Earth.

- The Herring Pond Wampanoag Tribe have been stewards of 'Patuxet/Plymouth' for thousands of years and understand that land, water, and wildlife are our relatives, to whom we have a responsibility. "Most importantly," Tribal Chairlady Melissa Ferretti notes, "we know that we have a primary responsibility to our tribal youth to ensure that they, and their children, inherit a planet that has been nurtured by us and to promote an understanding of and appreciation for alternative conservation methods."
- The Plymouth Open Space Committee has created a first-of-its-kind climate change addendum to its state-certified Open Space & Recreation Plan.
- Founded in 1973, Wildlands Trust is one of the largest and oldest regional land trusts in Massachusetts and has helped to ensure the protection of 8,500 acres of natural and agricultural lands.

All of our partners have committed to providing substantial, relevant, in-kind support to this proposal, including the creation of webinars, film series, narrative walks, environmental education, water conservation tips, brochures, banners and more. All acknowledge that they are working and living within an historic landscape and guided by an indigenous philosophical foundation that is nearly as old as our globally-rare ecoregion.

For the Wampanoag people the lands on which they live and the natural resources on which they depend are inseparably linked to their identities, cultures and livelihoods: who better to lay the foundation of our outreach and education efforts than this community's original inhabitants.

Using rigorous science, citizen-led sampling, and the support of a chorus of community-based conservationists this project promises a wealth of practical, short and long-term deliverables including:

- **Identification of key points of SWI vulnerability.**
- **Guidelines for the design and location of future municipal wells.**
- **Protection of valuable freshwater ecological attributes.**
- **A sentinel system to sound the SWI alarm if and when.**
- **Identification of cost-effective nature-based solutions.**
- **Increased resiliency of established groundwater sources.**
- **A new community conservation resource: The Community Water Monitoring Center**

We believe that the new resiliency tool that our combined efforts will produce will prove invaluable, both to the town, the variety of environmentally and socio-economically distinct communities it is comprised of, and to many other Massachusetts coastal communities. While we will first look closely at conditions within Plymouth, the transferability of our data, processes and tools to the entire Massachusetts coastal community will also be a project priority.

Thank you for the opportunity to bring this important issue forward.

For the Plymouth SWI Task Force,



Lee Hartmann, Director of Planning, Town of Plymouth

The Town of Plymouth
Living Observatory
Southeastern Massachusetts Pine Barrens Alliance
Mass Audubon
Plymouth Area League of Women Voters
Indigenous Resource Collaborative
Herring Pond Wampanoag Tribe
Wildlands Trust
Plymouth Open Space Committee
Plymouth Water Conservation Committee
Savery Pond Conservancy
Six Ponds Improvement Association