Coastal Watershed Nutrient Loading and Assessing Groundwater Quality Risk from Onsite Wastewater Treatment Systems (OWTS) in a SNEP Pilot Watershed

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Town of Charlestown

Town of Charlestown, R.I. On-Site Wastewater Management Program

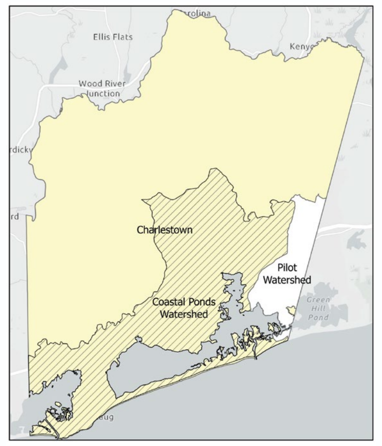
Water Resource and Environmental Protection

1. Introduction

In Charlestown, RI, onsite wastewater treatment systems (OWTS) are the only option for managing domestic wastewater, while groundwater serves as the Town's only potable water source. Charlestown is a coastal community situated on three salt ponds along the south shore of RI. High OWTS densities, exceeding 10 per acre, are clustered near these ponds. The Town's economy is based around its coastal zone, supporting tourism, recreation, and coastal businesses.

OWTS can be an effective method of managing wastewater in the absence of a sewer system by treating and recycling wastewater onsite. Yet, even in the best circumstances, not all pollutants are removed during wastewater treatment.

Conventional septic systems are typically effective at removing bacteria and pathogens; however, the pollutant nitrogen (N) remains at elevated concentrations in septic effluent plumes in older conventional and substandard systems and is problematic for both human health and surface water resources.



2. Problem

With densely developed areas adjacent to sensitive salt ponds and a lack of centralized sewer and potable water infrastructure, our coastal watersheds are at risk of elevated levels of nitrogen (N) pollution in groundwater and coastal salt ponds.

We have recently correlated this risk by identifying a statistically significant positive relationship between OWTS density and groundwater N concentrations sampled from well water. Over 70% of OWTS in the area employ outdated substandard and conventional systems, which typically contribute 2/3 more nutrient loading than modern N reducing technologies. Sewering has been determined to be fiscally infeasible.

These findings reinforce the need for OWTS infrastructure modernization. The **EPA SNEP funded Greater Allen's Cove/Eastern Ninigret Pond Pilot Watershed Initiative** has provided funding to develop a OWTS modernization program in the Pilot Watershed shown to the right.

A method to identify outdated OWTS most at risk for impacting water resources was required.

Substandard and older conventional OWTS in areas with the highest development densities within the closest proximity to the salt ponds are highlighted to the right. Risk to water resources is exacerbated in areas with high N mass loading, high impervious cover, shallow water tables and in proximity to coastal resources.

Here we have developed a method to quantify risk to water resources from OWTS and identify individual OWTS best suited for upgrading to modern N reducing technology.

3. Modeling Methods for Groundwater Nitrate (NO3-N)

To develop the method, each OWTS was assigned a "per system nitrogen loading value" calculating the estimated maximum output of N per year in kg/yr. This model of current groundwater NO3-N concentration is based on the OWTS density methods of Dowling et al. (2024) and was applied to the Pilot Watershed for enhanced N loading analysis based on the equation (right).

Nitrogen Loading Calculation

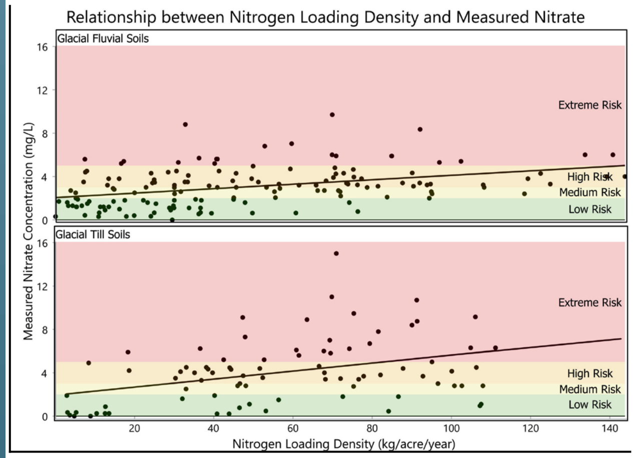
$$N = \left(\left((B \times 435.3) \times C \times 365\right) \times 1{,}000{,}000\right) \times S$$

Nitrogen Loading (N) Calculated Using Bedroom Count (B), OWTS System Type (as Discharge Concentration (C)), and Seasonality (S)

N loading assumptions were made based on the following:

Conventional and substandard OWTS effluent N concentrations were assumed to be 65 mg/L and modern advanced/nitrogen reducing OWTS were assumed to be 19 mg/L. Volume was based on the maximum design daily flow of 115 gallons (435.3 Liters) per day.

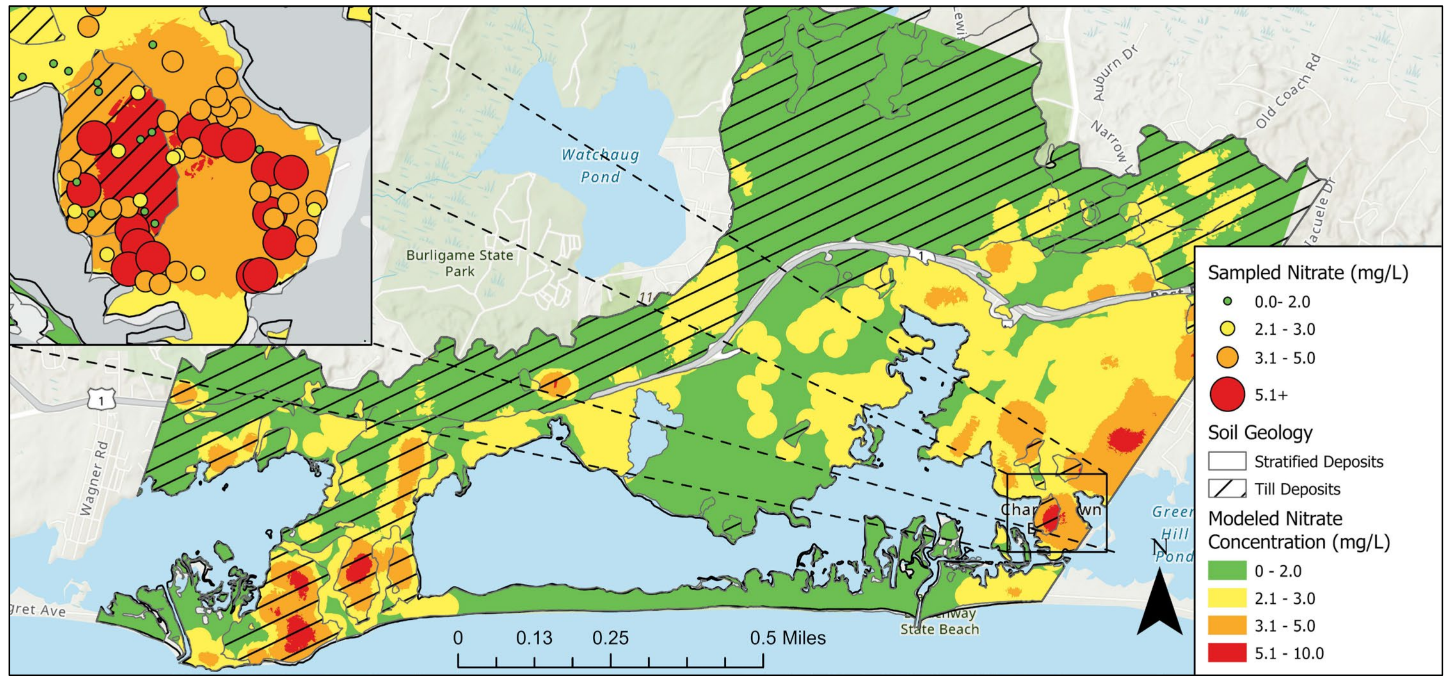
The N loading values (kg-N/yr) were then joined with a 400-foot buffer around each building point (assumed OWTS point) to calculate the total nitrogen (TN) output within a theoretical individual OWTS effluent plume. The resultant value was converted to mass as kg/acre and applied to a point density analysis to formulate a weighted density.

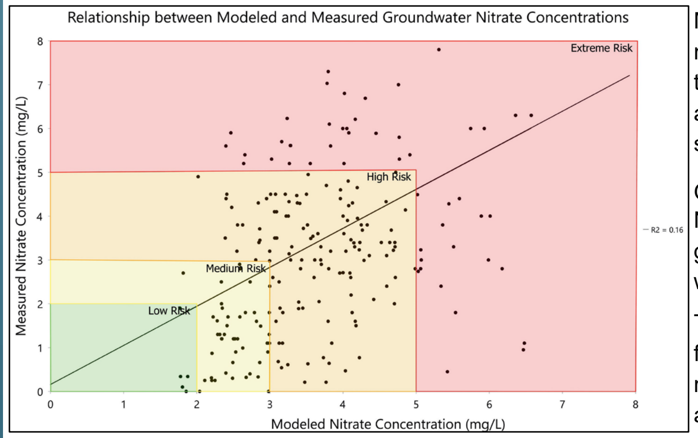


This point density results were clipped using the outlines for the aquifer soil groups and extracted to the sites of existing potable well N samples (n=165 Pilot Watershed) where they were assessed for the relationship between the N loading and the measured groundwater N concentrations.

Linear regression was used as the best fit model and calculated into the analysis to generate a model for estimated groundwater N concentrations for two generalized aquifer types in the Pilot Watershed, glacial fluvial and till independently (Left).

4. Groundwater Nitrate Model Results



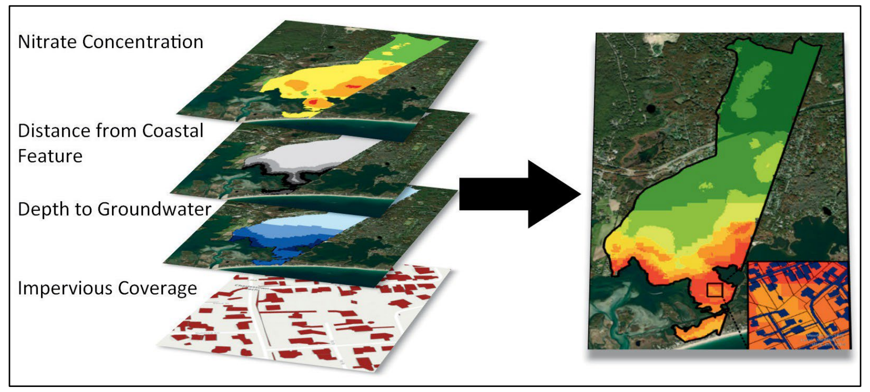


Modeling was conducted in ArcGIS Pro and displayed as a N loading map. The predictive model within the Pilot Watershed estimates that the maximum groundwater NO3-N concentration is 6.32 mg/L with an average NO3-N concentration of 2.6 mg/L. Although several sampling sites identified actual concentrations over 10 mg/L.

Only 8% of the total area of the pilot watershed has groundwater NO3-N under 2 mg/L. Five individual areas of the pilot watershed have groundwater concentrations NO3-N above 5 mg/L, three of which are within 300 meters of one or more coastal features.

This modeled relationship operates within a 95% confidence interval for data relatedness and an R-squared value of 0.16 (left) for the relationship between modeled groundwater NO3-N concentrations and measured well samples in the coastal watershed.

5. Development and Use of OWTS Risk Assessment



OWTS Risk Map Development

OWTS riskmapping was defined using the following criteria with a point based ranking.

- Modeled groundwater concentration from the loading analysis
- Distance to a coastal feature
- Modeled depth to water table
- Impervious coverage (as a stand in for in specific groundwater recharge capacity)

These values were utilized to assess the current OWTS impact to water resources on an individual OWTS basis.

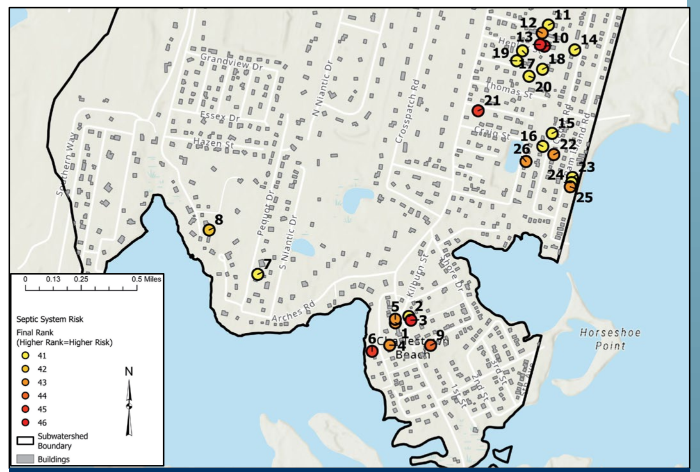
Selection of OWTS for Grant Funded Replacement

Additional criteria were considered for the final risk based OWTS selection and included OWTS age, type, and the residential occupancy. These are used in consideration of additional prioritization of at-risk, high-impact systems.

Life Expectancy
The US EPA estimates that the average life expectancy of a septic system is approximately 40 years. Further, older OWTS often do not conform with modern system component requirements (i.e. tank and drainfield sizing) and are more likely to allow for partially and undertreated wastewater effluent to be discharged into the subsurface.

System Type
OWTS types provide varying levels of risk with cesspools and substandard at more risk than older conventional systems. Since modern N reducing OWTS already are effective in nitrogen reduction those sites were removed from the site selection analysis.

Seasonal Residency
Approximately 2/3 of the dwelling units in the coastal zone of Charlestown are seasonally utilized. Full time occupancy allows for approximately 2/3 more annual flow of wastewater (i.e. pollutant loading) into the watershed, thus OWTS used for full time occupancy are ranked higher.



6. Results

The final risk ranking was used to identify 26 individual OWTS most at risk for impacting coastal water resources (highest ranked values) shown above and listed in the table below. This assessment was conducted as part of the SNEP Pilot Watershed Initiative to identify sites for implementing OWTS upgrade funding.

7. Next Steps

Final OWTS Risk Ranking Table

Site ID	GW Score	Nitrogen Score	OWTS Age Score	Occupancy Score	OWTS Type Score	Impervious % Score	Final Rank
1	10	7	10	5	5	6	43
2	10	10	10	0	5	6	41
3	10	10	10	0	10	6	46
4	7	10	10	5	5	6	43
5	10	7	10	5	5	6	43
6	7	7	10	5	10	6	45
7	10	7	10	5	5	4	41
8	10	3	10	5	10	4	42
9	10	10	10	5	5	4	44
10	7	10	10	5	10	4	46
11	7	10	10	0	10	4	41
12	7	10	10	5	5	6	43
13	7	10	10	5	10	4	46
14	7	10	10	5	5	4	41
15	10	7	10	0	10	4	41
16	10	7	10	0	10	4	41
17	7	10	10	0	10	4	41
18	7	10	10	5	5	4	41
19	7	10	10	5	5	4	41
20	7	10	10	5	5	4	41
21	7	7	10	5	10	6	45
22	10	7	10	0	10	6	43
23	10	7	10	0	10	4	41
24	10	7	10	0	10	4	41
25	10	7	10	0	10	6	43
26	7	7	10	5	10	4	43

Site Ranking will be used to complete the 15 OWTS upgrades as part of the SNEP PIlot Watershed.

The methods described here have recently been instrumental in the Town's successful acquisition of over $600,000 in additional OWTS infrastructure modernization funding from Senator Whitehouse Congressionally Directed Spending for Fiscal Year 2024.

SNEP continues to facilitate important resource protection and management projects that are transferable and serve as tools for implementation of additional water resource mitigation projects in the region.

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Project partners: New England Onsite Wastewater Training Resource Center, New England Onsite Wastewater Training Program, University of Rhode Island Laboratory of Soil Ecology and Microbiology, Salt Ponds Coalition, and Save The Bay

Citations:
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United States Environmental Protection Agency

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