APPENDIX A

1. Existing condition of Wickford Harbor and watershed resources.

2. Wickford Harbor Watershed Summary Results - Watershed indicators and nutrient loading, Current land use.

3. Wickford Harbor Watershed Summary of Selected Watershed Indicators

4. Maps produced for the Wickford Harbor Watershed Assessment.

5. Wickford septic system repair and parcel building data summary

6. Cost comparison of stormwater retrofit versus alternative septic systems, Wickford Harbor and Mill Cove South Subwatersheds (Wickford Village Area).

7. MANAGE list of watershed indicators and rating key.

8. Soil summary table w/ hydrologic soil group description

General MANAGE information and nutrient loading assumptions (short version; full documentation in Appendix D) available at http://www.edc.uri.edu/cewq/manage.html.

Existing condition of Wickford Harbor and watershed resources

April, 2000

Watershed Resources	Use and significance	Water quality goals	Monitoring data	Assessment of actual condition	Pollution sources, concerns and recommended actions
Wickford Harbor and tributaries,wetlands and groundwater within watershed where data available.	*Describes how these water resources are used and their importance to the town.*	*Town goals and RIDEM and CRMC classifications for use of these waters.*	*How much field data is available?*	*Are water quality goals being met?*	*Includes documented and potential pollution sources, related water quality issues, and Town plan recommendations.*
DRINKING WATER SUPPLIES Groundwater Supplies	900 acres (20%) of the watershed overlies the Town's sole source aquifer. [7] Residents rely on private wells outside village centers.	All groundwater supplies classified as GAA or GA. [7] Protection of groundwater supplies identified as top priority of comp-rehensive plan. [2]	No public wells in watershed[7]; therefore, no monitoring required by RI Health. No other quality data available.[7]	Assumed to be fully supporting. [5] Pollution threats to Wellhead protection areas to be assessed by RI Health under Source Water Assessment Program 2001.	The town has an active public education program promoting drinking water protection through the Groundwater Committee and the Water Department's newsletter *The Puddle.* Pollution threats to NK wellhead protection areas to be assessed by RI HEALTH under the Source Water Assessment Program in 2001. [8]
RECREATIONAL WATERS Shellfishing	Harbor has state-mapped shellfish beds.[11] Public access is available. Oysters and quahogs are harvested for private use.[3] Visitors to the Town park take shellfish from this closed area.[3]	Class SA/B waters partially open to shellfishing, winter only. Includes Harbor west of the breakwater to Cornelius Island, Fishing Cove to the north, and extending south to Big Rock Point. [6] Class SB waters permanently closed in coves and shoreline areas.[6] For shellfishing, the fecal coliform limit is the most difficult criteria to achieve.	1 monitoring location in well flushed portion of Harbor (near Buoy 2, inside breakwater).[5] Fecal coliform monitored 6 x year by RIDEM at this station.	Fully supporting partial SA/B use based on single sampling location. [5]	Members of the Conservation Commission familiar with Harbor shellfish noted that the last good year for scallops occurred in 1948, just before the Wickford Harbor breakwater was built in 1954. With the breakwater in place, flushing rates appeared to change and scallops eventually disappeared.[3] Town Plan cites water quality degredation due to onsite wastewater systems, storm-water runoff, and boating usage. Plan calls for Wickford Harbor wastewater management district that would: a) monitor water quality; b) monitor septic system failures; and c) assist property owners with needed improvements to improve Harbor water quality. The Town's 1999 Wastewater Management Ordinance will begin to address address item (b) by mandating regular inspection and maintenance of onsite wastewater systems.[2] Develop and adopt an ordinance establishing a 150' setback buffer for the entire coastline.

Swimming and low intensity boating and fishing	Public access available and small beaches within the Harbor are used by residents. [3] Visitors to the Wilson Park sometimes swim there. [3]	Class SB designated for swimming and other primary contact. [6] For swimming, the fecal coliform limit is the most difficult criteria to achieve. [5]	One fecal coliform monitoring site, described above. [5]	Fully supporting swimming use and other contact recreation based on single sampling location. [5]	Public health concern with kayaking, other recreational contact; need for improved signage at Wilson Park to discourage swimming and shellfishing in closed areas. [3] Need for monitoring data.[3]
High intensity boating	380 slips and moorings occupied on average summer day; handful only in winter. [3]	Wickford Harbor marina "dual use for recreational boating and support for commercial fishing activities"[2]	Not documented	Not documented	Over-use a concern. [2] Potential for hydrocarbon and MBTE release with 2-stroke engines. [1] Refueling spills and enforcement. Need for boater education 100% compliance with boat pumpouts uncertain; need for water quality monitoring to determine compliance. [3]
AQUATIC HABITAT Fish and shellfish	Wickford Cove- major state-mapped winter flounder spawning area. [11] Coccumcussoc Brook- existing anadromous fish run. [11]	Mill Creek and Wickford Cove are CRMC Type 1 Conservation Waters. [4] . For healthy aquatic habitat, the dissolved oxygen criteria is often the limiting factor determining compliance with the goals.	Nitrogen, dissolved oxygen, transparency and other conventional pollutants monitored by Save the Bay since 1994, at 47 sites, frequency variable but primarily spring and summer.	Assessed as "Fully Supporting But Threatened" for aquatic habitat due to in-house reports of occasional low dissolved oxygen.[5] Tributaries not assessed due to lack of data. High nitrogen in Mill Creek relative to Wickford Harbor stations. [10]	Town plan cites runoff, wastewater, solid waste, and intense boating as threats. [2] Notes need to protect shoreline wetlands by establishing 150' buffer to Harbor coastline. [2] Unknown effects of past waste disposal at Quonset Pt./Davisville . [3]
Nutrient sensitive eelgrass habitat	Two State-mapped eelgrass beds in main harbor. Subject of restoration efforts. [11]	Protection of eelgrass is CRMC and RIDEM priority; also stated goal of NK Comprehensive Plan. [4,2]	Extent and condition of eelgrass bed is field-monitored by Save the Bay. [9]	Historical decline in eelgrass documented. Current bed apparently stable but subject to natural shifts. Attempts to expand by planting have been unsuccessful. [9]	Not documented

High quality waters, wetlands and unique habitat.	Deciduous forested wetland such as red maple swamps are the most common wetland type, comprising about 78% of all wetlands in the watershed. Some of the other types, such as bogs and fens (which make up less than 1% of watershed wetlands), are generally considered more sensitive to hydrologic changes and nutrient inputs. Vernal pools are important habitats which are not often mapped. [7] State-mapped unfragmented forest in Black Swamp area at NW boundary of watershed.[11]	Not documented	Not documented	Tributaries not assessed due to lack of monitoring data.	Not documented
HYDROLOGY AND WATER QUALITY FUNCTIONS	Pollutant removal and groundwater recharge functions of wetlands and shoreline areas are important functions addressed in following sections of this report.	Not documented	Not documented	Not documented	Not documented
OTHER QUALITY OF LIFE FACTORS Scenic/open space	The watershed encompasses a number of publicly-owned lands, including the town-owned Wilson Park, State conservation land at Cocumcussoc Park, a number of small shoreline access points, and scenic viewpoints.	Not documented	Not documented	Not documented	Town plan recommends improved public access to coastal waters by creating a network of linked trails via the Sea View Railroad right-of-way. Access to the east of Brown Street should be clearly signed, and a continuous walkway investigated along the water. [2]
Economic value of water resources	Wickford Harbor is an "integral component of tourism and economic development activities" [2]	Not documented	Not documented	Not documented	Provide for wastewater treatment for continued economic growth of village. [2]

Data Sources

1 New England Interstate Water Pollution Control Commission. 1999. Interstate News. Facts Focus. Issue 23. NEIWPCC. Lowell, MA. (Marine two stroke engines power a majority of outboards and jet skis. These motors discharge 20-30% of their fuel straight into the water, unburned. These spills are estimated to cause more air pollution in seven hours than a 1998 passenger car driven 100,000 miles. The fuel additive MTBE released into lakes and rivers has the potential to contaminate water supplies).

2 North Kingstown. 1996. Comprehensive Plan, Natural and Cultural Resources Plan. North Kingstown, RI.

3 North Kingstown Conservation Commission. 1999. Discussions at Commission meetings and correspondence related to the Wickford Watershed Assessment project. North Kingstown, RI.

4 RI Coastal Resources Management Council. Rhode Island Coastal Resources Management Program. 1977 (revised 1979). Providence, RI.

5 RI Department of Environmental Management. 1998. Report to Congress on the State of the State's Waters (305b), and supporting documentation, per Constance Carey, personal communication, RIDEM Division of Water Resources. Providence, RI.

6 RI Department of Environmental Management. 1997. Water quality regulations. RI DEM Division of Water Resources. Providence, RI.

7 RI Geographic Information System. Department of Administration. Providence, RI.

8 RI Department of Health. 1999. RI Source Water Assessment Plan. Providence, RI.

9 Richardson, Mac. Personal communication. Save the Bay. Providence, RI.

10 Tietjen, C. 1998. A Water Quality Report for Wickford Harbor and Surrounding Coves. Save the Bay Unpublished report. Providence, RI.

11 U.S. Environmental Protection Agency. 1997. The Rhode Island Resources Protection Project Report. EPA Region 1. Boston, MA.

Wickford Harbor Watershed Summary Results - Watershed indicators and nutrient loading, Current land use
August, 2000

	LAND USE								HYDROLOGIC / NUTRIENT LOADING ESTIMATES		
	STUDY AREA					SHORELINE BUFFERS			STUDY AREA		
STUDY AREAS	Acres	% Sewered	% High Intensity Land Use	% Impervious	% Forest & Wetland	Riparian % High Intensity Land Use	Riparian % Impervious	Riparian % Forest & Wetland	Surface Runoff (inch/yr)	Nitrogen to surface runoff (lbs./ac./yr.)	Nitrogen to groundwater recharge (lbs./ac./yr.)
Wickford Harbor Watershed	4495	18	**27**	**23**	**48**	**20**	**16**	**58**	10.4	4.6	12.5
Wickford Cove	690	0	**32**	**26**	**36**	**46**	**31**	**35**	**11.0**	***5.8***	**21.2**
Mill Cove South	253	0	**24**	**20**	**38**	**22**	**16**	**46**	9.0	***5.6***	***23.7***
Mill Cove North	299	0	**25**	**23**	**46**	**11**	**11**	**70**	9.3	3.4	10.7
Fishing Cove	349	41	**24**	**25**	**34**	**16**	**15**	**62**	**11.7**	**8.7**	**21.3**
Mill Creek	1826	36	**39**	**31**	**20**	**20**	**21**	**52**	**13.6**	4.6	10.3
Cocumcussoc	1026	0	*6*	*6*	*82*	*0.6*	*1*	*98*	4.4	2.2	5.4

RELATIVE POLLUTION RISK RATING KEY

Indicator	*Low*	Moderate	**High**	**Extreme**
% High intensity land use	*< 10 %*	10 – 14 %	**15 – 25%**	**> 25%**
% Impervious	*< 10 %*	10 – 14%	**15 – 25%**	**> 25%**
% Forest and Wetland	*> 80 %*	50 – 80%	**20 – 49%**	**< 20%**
Riparian % High intensity land use*	*< 5 %*	5 – 9 %	**10 – 15 %**	**> 15 %**
Riparian % Impervious*	*< 5 %*	5 – 9 %	**10 – 15 %**	**> 15 %**
Riparian % Forest and Wetland	*> 95 %*	80 – 95 %	**60 – 79 %**	**< 60 %**
Hydrologic / nutrient loading estimates	Not Rated / **Higher than watershed average**			

** The rating used for drinking water supplies for percent high intensity land use and percent impervious cover in riparian buffers is: Low = 0; Med = < 5 %; High = 5 – 15 %; Extreme = > 15 %.*

Wickford Harbor Watershed - Summary of Selected Watershed Indicators

Watershed Indicators	Wickford Harbor Watershed	Wickford Cove	Mill Cove South	Mill Cove North	Fishing Cove	Mill Creek	Cocum-cussoc
Watershed land use							
Acres	4495	690	253	299	349	1826	1026
% Sewered	18	0	0	0	41	36	0
Estimated # septic systems	3015	790	337	176	411	1008	269
Estimated # septic systems per acre	0.7	**1.1**	**1.3**	0.6	**1.2**	0.6	0.3
% High intensity land use	27	**32**	24	25	24	**39**	6
% Impervious (current / future)	23 / 27	**26 / 31**	20 / 22	**23 / 33**	**25 / 27**	**31 / 38**	6
% Wetland	20	**13**	**15**	**18**	**14**	**19**	32
% Forest	28	**23**	**23**	28	**20**	**20**	50
% Forest and wetland	**48**	**36**	**38**	**46**	**34**	**39**	**82**
Surface water buffers (150')							
% Land in riparian buffer (150 ft.)	15	13	**22**	15	**25**	13	12%
Riparian % high intensity land use	20	**46**	**22**	11	16	**25**	0.6
Riparian % impervious	**16**	**31**	**16**	**11**	**15**	**21**	**1**
Riparian % forest and wetland	58	**35**	**46**	70	62	**52**	98
Soils							
% Highly permeable soil (HSG A)	54	**71**	51	**67**	**71**	54	35
% High. permeable subsoil (NRCS)	48	**68**	45	**60**	**72**	35	45
% Mod. permeable soil (HSG B)	18	14	32	14	1.1	18	26
% Slowly permeable (HSG C)	15	12	12	7	**16**	12	**22**
% restrictive	8	2	4	4	17	7	12
% erodible	15	9	**28**	**16**	0	14	**22**
Runoff and nutrient loading							
Runoff IF 100% forested (inch/yr)	1.5	1.1	1.1	1.1	1.7	1.6	1.9
Runoff - current land use (inch/yr)	10.4	**11**	9	9.3	**11.7**	**13.6**	4.4
Recharge - precipitation (inch/yr)	16.6	**16**	18	17.7	**15.3**	**13.4**	22.6
Recharge - % avail. precip. (27inch)	61%	59%	67%	66%	57%	50%	84%
Recharge - onsite systems (inch/yr)	1.1	1.8	2.2	1	1.9	0.9	0.4
Total grw.recharge (inch/yr)	17.7	17.8	20.2	18.7	17.2	**14.3**	22.6
Phosphorus to runoff (lbs/yr)	1.2	**1.5**	**1.5**	0.9	**2.2**	**1.3**	0.4
N to runoff NO ISDS failure (lbs/yr)	14,072	2,788	932	713	1,557	6,047	1,720
Nitrate-N to groundwater (lbs/yr)	56,028	14,618	5,984	3,210	7,427	18,786	5,504
Total N to runoff and gr water (lbs/yr.)	70,100	17,406	6,916	3,923	8,984	24,833	7,224
N to runoff with ISDS failure (lbs/ac/yr)	4.6	**5.8**	**5.6**	3.4	**8.7**	4.6	2.2
N to runoff NO ISDS failure (lbs/ac/yr)	3.1	**4**	**3.7**	2.4	**4.5**	**3.3**	1.7
Nitrate-N to grw. recharge (lbs/ac/yr)	12.5	**21.2**	**23.7**	10.7	**21.3**	10.3	5.4
Both N to grw.rech.& runoff (lbs/ac/yr)	15.6	**25.2**	**27.4**	13.1	**25.8**	13.6	7.1
% Nitrogen sources to runoff	20%	16%	13%	18%	17%	24%	24%
% Nitrogen sources to recharge	80%	84%	87%	82%	83%	76%	76%

NOTES:
Subwatershed results in **bold** are higher risk than watershed average. Some results provide additional information but are not rated.

Total estimated nitrogen sources in the watershed = 70,100 lbs/yr; Direct rainfall to Harbor = 3,288 lbs/yr (411 acre x 8 lb. N /yr.)

Maps Produced for the Wickford Harbor MANAGE Assessment

Original analysis maps were produced as watershed close-ups at 1: 8,500. In order to create a more useful product, some basic inventory maps were redone town-wide at 1: 24,000. These are designated **(TW)**.
All maps have major and minor roads differentiated, with annotation on numbered routes- annotation from RIGIS Roads or USGS Topographic Overlay.

Land Use (TW)

Data Layers	*Use*
1995 RIGIS Land Use	Note: Light colored forest to allow writing on map- also emphasizes developed areas

Water Resources (TW)

Data Layers	*Use*
Hydro lines and polys	Location of critical resource areas and existing water quality impacts.
Aquifer recharge areas and reservoirs	
Watershed boundaries	
Wells and protection areas	
CRMC Designations	
Shellfishing Closure Areas	
DEM Water Body Quality Classification	
Monitored water quality information	

Soils- Hydrography (TW)

Data Layer	*Use*
RIGIS (SSURGO) Soil Hydro-group and Water Table Depth	Assess potential water quality threats from current and future development. Identifies constraints for future development.

Soils- Erosion Risk (TW)

Data Layer	*Use*
Soils- NRCS Highly Erodible	Helps identify areas with high erosion potential for new development or redevelopment
1995 Land Use (developed only)	

Open Space and Protected Areas

Data Layer	*Use*
Open Space, Protected Public Lands, Audubon Lands	Facilitates comparison of hot spots to resource areas. Shows potential for greenway linkages.
Land Trust lands	
DEM Wildlife Management Areas	
Rare Species	

Topography

Data Layer	Use
USGS DRG Topographic map	Used as base map for most maps in Wickford Harbor Assessment. Provides topography, annotation, and local landmarks.

High Intensity Land Use

Data Layer	Use
MANAGE modified land use/soil High intensity land use (Pared Land Use)	Identifies land uses that may pose a significant threat to water quality.

Surface Water Hot Spots

Data Layer	Legend Scheme
MANAGE modified land use/soil (high intensity land use on seasonal high water table (0-3.5') soils)	Helps identify areas with higher risk for pollutant movement to surface water.

Groundwater Hot Spots

Data Layer	Use
MANAGE modified land use/soil (high intensity land use on hydro-group A soils)	Helps identify areas with higher risk for pollutant movement to groundwater.

Septic System Risk

Data Layer	Use
Parcel data coded with "year built" Pre- and post 1970 developed, vacant, other (rights of way, docks)	Identifies developed parcels that may have a cesspool or other substandard septic system.
DEM ISDS Repair Address-Matched point coverage	Use to identify all parcels that have had septic system repairs or improvements.

Soils with High Potential for Nitrogen Removal

Data Layer	Use
Hydric soils with organic, outwash, or alluvial parent material.	Identifies areas with higher potential for shallow groundwater flow through wetland riparian soils and opportunity for treatment of groundwater nitrate through microbial denitrification.

Wickford Septic System Repair and Parcel Building Data

ISDS Repairs

Septic system repair data from RI Department of Environmental Management were address-matched for the whole Town of North Kingstown and selected out for the Wickford Harbor watershed and Wickford Cove and Mill Cove South subwatersheds (Wickford Village Area).

Townwide, 820 repairs matched successfully. Of these, 244 are in Wickford Harbor watershed and 70± are in the Wickford Village area.

Plat Maps

As part of the project, eight CAD-based North Kingstown Plat maps were converted to GIS format and assessor's data attached. These plats (90, 91, 92, 93, 116, 117, 118, 119) encompass most of the Wickford Village area. These areas are the most densely developed in Wickford harbor watershed and are adjacent to the least flushed areas of the harbor/cove complex.

RI DEM ISDS regulations were changed in 1969 to require a conventional septic tank and drainfield system. Before this, primitive cesspools were commonly used for on-site sewage disposal. In order to assess risk posed by these substandard systems, parcel data were used to determine all structures built before 1970 (to leave a margin for error).

Of the approximately 926 developed plats, **719 or 78% were developed during or before 1970**. 212 parcels were coded as vacant, and 111 had no coding. Numbers of these vacant and potentially vacant parcels are deceiving, however, as many of the smallest parcels have either been developed as combined large lots or lie in wetland areas and are undevelopable.

When the septic repair and building age data for Wickford Village are combined, it still indicates a substantial number of units (+-650) with substandard septic systems. Additionally, septic repairs are not necessarily only on pre-1970 systems, suggesting that the number of substandard systems might be higher.

Population and Housing Unit Estimates

In order to "tune in" the nutrient loading component of MANAGE, 1990 U.S. Census block-level data were used to determine numbers of dwelling units and population density. These figures are needed to adjust the number of persons per dwelling unit as well as the density assigned to the various RIGIS Land Use categories.

The rough Census block estimate was 3,836 dwelling units. After deducting overlap in blocks that lie only partly in the watershed, the figure is approximately **3,430** units. Considering the Census block estimate of 3836 units and 9,276 persons, we estimated persons per housing unit at **2.4**.

Numbers of units on septic systems were estimated by buffering the RIGIS Sewer Lines coverage (after modification to include Wickford Point development) by 250 meters and using this area to capture land use. For all of Wickford Harbor, MANAGE estimated 2,991 units on septic systems.

Cost Comparison of Stormwater Retrofit versus Alternative Septic Systems
Wickford Harbor and Mill Cove South Subwatersheds (Wickford Village Area)
DRAFT

Stormwater Basins

The stormwater basins we refer to in the MANAGE Assessment are the type specially designed to reduce nutrients and pathogens. They typically have a settling basin leading to a constructed wetland. These structures can remove up to 45% of nutrients and 80% of total suspended solids, but only if properly maintained.

Costs can range widely, from $1,000/ acre to $10,000/ acre depending on area serviced and percent impervious surface (Conversation, Joseph Bachand, Natural Resources Conservation Service 1/17/2000). This is further complicated by availability of land for construction. Larger sites and basins generally cost less per acre served due to economies of scale. Based on estimated impervious surface and density of the study area, we estimated construction cost of $3,000/acre. This is based on actual costs of stormwater facility retrofit projects ranging from $1- $5,000/ acre developed by NRCS.

Maintenance is an additional cost. Basins need to be mowed at least once a year and trash removed. Catch basins leading to the retention system need periodic cleaning. Accumulated sediment needs to be removed at least once every ten years, depending on nearby construction activity (erosion & sedimentation) and weather (winter road sand application). Maintenance cost can vary greatly depending on whether it is done by the Town or by a private contractor. We have no cost estimate for this. In our experience, however, these structures are typically not very well maintained, leading to "treatment failure," and therefore become simple detention basins.

Our analysis estimates that within the Wickford Village area, approximately 380 acres of high intensity development would need treatment.

380 X $3,000 = $1,140,000

To facilitate easy comparison, we estimated a cost *per pound per acre* of Nitrogen removed:

Estimated Cost of Stormwater Retrofit for Wickford Harbor and Mill Cove South Subwatersheds

	Nitrogen lbs/ac/yr	Reduction w' Maint.	Nitrogen Reduction	Construction Cost of Basin per Acre	Payment Period (yrs)	Cost per Year	Cost per Lb N
Wickford Harbor	4.5	*45%*	2.0	$3,000	25	$120	$59
Mill Cove South	5.6	*45%*	2.5	$3,000	25	$120	$47
						Average	**$53**

Note: Nitrogen load estimated with MANAGE nutrient loading model. Removal rate based on research literature- see MANAGE documentation.

Note: Because stormwater system retrofit costs are based on the size of the drainage area treated, areas generating the most concentrated runoff are more cost-effective to treat (on the basis of cost per pound of nitrogen potentially removed). In the estimate above, the higher nitrogen load from Mill Cove south (5.6 lbs./acre/year) has a lower removal cost per pound ($47/lb) nitrogen removed. This example is provided to illustrate cost effectiveness of focusing stormwater improvements where highest loads are expected using runoff estimates, nutrient loading, and Hot Spot mapping to identify these areas. Since our estimates are based on map data actual runoff and estimated nutrient loading should be calculated based on field –verified land use and soil conditions.

Advanced Treatment Septic Systems

We define advanced treatment (AT) septic systems as those systems that use various technologies to remove nutrients, pathogens, or both. The main nutrient of concern in a coastal environment is nitrogen, which is associated with eutrophication and marine habitat degradation. Pathogens include bacteria, viruses, and protozoa, which are associated with human health risk. A standard denitrifying septic system removes about 50% of total nitrogen. Systems geared for maximum pathogen removal do not do a good job at removing nitrogen, and vice-versa.

For houses on small lots closest to the water (such as the one on Loop Drive in N. Kingstown), a pathogen removal system is probably the best management option. For houses further from the water, nitrogen removal would have higher priority, assuming that larger drainfield size and increased travel time will provide adequate pathogen removal.

Conventional septic systems in the Wickford Harbor area cost approximately $8-12,000, given that most sites have some constraints. The cost would be even greater on very difficult sites. Advanced treatment systems cost $13-16,000, a difference of $4-5,000 (Conversation with George Loomis, URI Onsite Wastewater Training Center 1/25/2000).

Advanced treatment systems require regular inspection, maintenance, and pumping at a cost of about $200/year. Installation cost of an advanced treatment system should be considered only as additional cost over that of a conventional system- $5,000 (except when comparing cost of sewering). This takes into account the fact that all (at least all substandard and failing) systems may eventually have to be replaced some time in the future. To compare the nitrogen removal cost per pound per acre, we estimated a cost per household and extrapolated throughout the village area. We also used parcel/assessors data and DEM ISDS repair data to refine the total cost.

Estimated Cost of Advanced Treatment Systems for Wickford Harbor and Mill Cove South Subwatersheds (Wickford Village)

Avg. Conven. System Cost	Avg. AT System Cost	Approx. Difference	Payment Period (yrs)	System Cost/yr	System Maint/yr	Total system Cost/year
$8-12,000	$13-16,000	$5,000	25	$200	$200	$400

Persons per House/ISDS	lbs/ac/yr N per person	lbs Nitrogen Produced	Removal Rate	lbs/ac/yr N Removed	Cost of Removal per pound N per ISDS
2.4	7	16.8	50%	8.4	**$48**

Area of Wickford Village	943 *acres*	Cost of N Removal per ISDS per **Acre**
Houses/ISDS in Village Area	1127	
Average Density	0.8 *units per acre*	**$39.84**

Note: Nitrogen load estimated with MANAGE nutrient loading model. Removal rate based on research literature- see MANAGE documentation.

Using more precise parcel/assessor's data, we were able to come up with a better estimate of how many units will need ISDS repairs or upgrades.

RI DEM ISDS regulations were changed in 1969 to require a conventional septic tank and drainfield system. Before this, primitive cesspools were commonly used for on-site sewage disposal. In order to assess risk posed by these substandard systems, parcel data were used to determine all structures built before 1970 (to leave a margin for error).

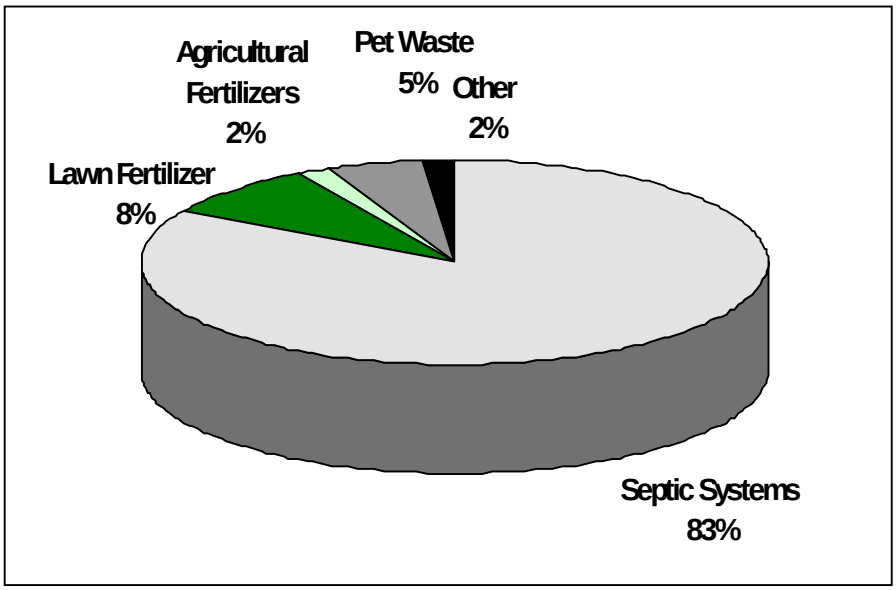
Of the approximately 926 developed plats, **719 or 78% were developed during or before 1970.**
Address-matching of DEM ISDS repair records indicate that 70± of these repairs are in the Wickford Village area.

When the septic repair and building age data for Wickford Village are combined, it still indicates a substantial number of units **(+-650)** with substandard septic systems. Additionally, septic repairs are not necessarily only on pre-1970 systems, suggesting that the number of substandard systems might be higher.
Considering the above estimates:

650 AT Septic Systems X $5,000 *upgrade from conventional system* replacement cost = **$3,250,000**

Again, please note that the above estimate is only for *upgrade* from conventional system replacement cost. Total cost of system replacement would be $8,450,000 to $10,400,000. We have no current estimates on the cost of sewering the Wickford Village area, but any estimates should consider perpetual maintenance.

Figure 1. Estimated Contribution of Nitrate-Nitrogen (NO3) to Groundwater, Wickford Cove and Mill Cove South Subwatersheds



Note: Nitrogen load estimated with MANAGE nutrient loading model. Removal rate based on research literature- see MANAGE documentation.

Figure 1 depicts nitrate-nitrogen contribution estimates from various land uses. Note the proportion of nitrate coming from septic systems (83%) as compared to the other sources (17%). Assuming that most groundwater in the Wickford Harbor watershed eventually moves towards the coast, this loading estimate suggests removing nitrogen from septic system effluent would have the greatest potential benefit to Wickford Cove and Mill Cove in comparison to controlling other sources.

List of Watershed Indicators and Rating Key

The following indicators are commonly used in the MANAGE watershed assessment, although not all may be used in each assessment, depending on the characteristics of the study area and type of analysis. The mapping analysis, including "hot spot" mapping is conducted separately.

WATERSHED INDICATOR (percent area)	RELATIVE POLLUTION RISK RATING			
	Low	Medium	High	Extreme
1. LAND USE *				
Watershed-wide risks				
High intensity land use	< 10 %	10 – 14 %	15 – 25%	> 25 %
Impervious surface area	< 10 %	10 – 14%	15 – 25%	> 25 %
Forest and Wetland	> 80 %	50 – 80%	20 – 49%	< 20%
Riparian (shoreline) buffer risks				
Riparian High intensity land use	< 5 %	5 – 9 %	10 – 15 %	> 15 %
Riparian Impervious surface area	< 5 %	5 – 9 %	10 – 15 %	> 15 %
Riparian Forest and Wetland	> 95 %	80 – 95 %	60 – 79 %	< 60 %
2. NATURAL FEATURES **	Low	Med – High		Extreme
SOILS- Risk to groundwater				
Very sandy, rapidly permeable	< 10 %	10 – 60 %		> 60 %
SOILS - Risk to surface water and/or shallow groundwater				
Slowly permeable soils		Not rated		
Presence of restrictive layers	< 2%	2 – 10 %		> 10 %
High water table.	< 5 %	2 – 20 %		> 20 %
Erosion potential	< 5 %	2 – 20 %		> 20 %
Small streams – 1st and 2nd order		Not rated		
Wetlands with potential nitrogen removal function		Not rated		
3. HYDROLOGIC BUDGET and NUTRIENT LOADING ESTIMATES				
Percent sewered land use	Not rated / compare relative differences			
Septic systems per acre.	Not rated / compare relative differences			
Surface water runoff (inches /year)	Not rated / compare relative differences / compare to forested condition			
Infiltration and recharge from septic systems (inches /year)	Not rated / compare relative differences / compare to forested condition			
Nitrogen to surface runoff (lbs / acre/ year)	Not rated / compare relative differences / compare to forested condition			
Phosphorus to surface runoff (lbs / acre/ year)	Not rated / compare relative differences / compare to forested condition			
Nitrogen to groundwater recharge (lbs / acre/ year)	Not rated / compare relative differences / compare to forested condition			
Nitrogen sources to groundwater recharge (lbs or % contribution)	Not rated			

WATERSHED INDICATOR	RELATIVE POLLUTION RISK RATING (continued)
4. OTHER POLLUTION SOURCES and HYDROLOGIC MODIFICATIONS	Not rated
"Point sources" - discharges to surface or groundwater, salt storage, underground storage tanks, hazardous waste sites, contaminated sediments, composting sites.	
Boat and marina discharges; fuel from 2-stroke engines, wastes from recreational vehicles.	
Livestock, manure storage, kennels, large assemblages of birds	
Well pumping, water withdrawal from or into a basin; dams	
Closed stormwater systems; stream channelization; subsurface drainage of fields, subdivisions, and individual home sites.	
5. RECEIVING WATER CHARACTERISTICS	Not rated
Existing Condition - Groundwater	
Monitored concentration of nitrate	
History of contaminant detects	
Existing Condition – Surface waters	
Nutrient enrichment level (based on trophic state index, phosphorus concentration, clarity, frequency and severity of algal blooms; also dissolved oxygen and other factors.	
Visual and physical condition (odors, trash)	
Invasive vegetation, use of herbicides	
Compliance with water quality goal	
Eelgrass health (coastal waters)	
Sensitivity to impact	
Flushing time, depth, shoreline configuration (D_L)	
Aquifer type- bedrock (low risk) vs. sand and gravel (high risk) (RIDOH, 1999); USGS vulnerability rating (USGS, 1999); potential for lateral flow	

Rating Pollution Risks

*The ratings assigned to the **land use** indicators are approximate thresholds intended to provide a frame of reference for measuring pollution risk. The ratings are based on abundant evidence linking these land use factors to water quality impacts in streams and wetlands (EPA 1996). Documented impacts include changes in stream hydrology, impaired aquatic habitat, and increased pollutant inputs. The relationship between percent impervious cover ratings and resulting impacts to watershed streams is the most well documented. The ratings assigned to the other indicators are loosely based on EPA-recommended indicators, similar research-based ratings used to evaluate habitat impacts to New England wetlands (Ammann, A.P. and A.L. Stone. 1991; Hicks 1997), and best professional judgement. In all cases we assign lower tolerances to risk indicators in shoreline areas, where there is a greater chance for direct pollutant movement into surface waters. Increased travel time from the point where pollutants are generated to discharge to receiving waters generally increases opportunity for pollutant removal through plant uptake, microbial activity, chemical transformations, or physical filtering, even though this may be very limited in sandy soils.

* *Risk ratings for **soil features** are very approximate thresholds indicating increasing risk and need for management practices. They were selected based on best professional judgement considering the range of characteristics typical of Rhode Island soils.

Soil Hydro-Group	**Basic Description**	**Typical Depth to Seasonal High Water Table** From ground surface	**Water Quality Risks with Developed Land Use**	**Management**
A	Sandy, deep water table, high infiltration, low runoff	Greater than 6 feet	• Highest pollutant movement to *groundwater* from septic systems and fertilizers, • Largest increase in runoff with impervious cover, • Greatest loss of groundwater recharge with impervious cover.	• Preserve as recharge areas. • Direct stormwater runoff to these areas to promote infiltration after pretreating to remove sediment and other pollutants. • Consider prohibiting deep wastewater seepage pits (galleys); evaluate need for advanced onsite treatment systems.
B	Most are well-drained, moderate runoff, moderate infiltration	Greater than 6 feet or 1½ to 3½ feet	• High potential for pollutant movement to *groundwater* from septic systems in sandy subsoils, • Moderate increase in runoff and loss of recharge with impervious cover. • May include prime farmland soils.	• Prime soils for building and agriculture. Consider best use to meet town goals and strategies to preserve prime farmland. • Preserve as recharge areas. • Direct stormwater runoff to these areas to promote infiltration after pretreating to remove sediment and other pollutants. • Consider prohibiting deep wastewater seepage pits (galleys); evaluate need for advanced onsite treatment systems.
C	Slowly permeable, collection areas for surface water, typically high water table, high runoff	1½ to 3½ feet or 0 to 1½ feet	• High pollutant movement to *surface waters* from septic systems, fertilizers, and land disturbance. • High potential for *hydraulic failure* of septic systems, with surfacing or lateral movement of effluent. • High potential for wet basements, temporary flooding.	• Septic systems may require use of filled leachfields to achieve minimum separation distance to groundwater; consider aesthetic impact of fill and need for advanced treatment. • Stormwater treatment ponds not suitable where water table is less than 2 feet from the ground surface. • Limit filling and regrading required to raise elevation of homes with full basements; consider prohibiting basements in wet soils. • Maintain undisturbed wetland buffers and drainageways. • Prohibit use of subdrains to lower water table; regulate location of subdrains adjacent to isds and their discharge. • Divert runoff from wells and septic systems.
D	Very high water table, often classified as wetlands based on wet (hydric) soils	0 to 1½ feet	• Highest pollutant movement to *surface waters*. • Loss of pollution treatment potential with disturbance of wetland buffers. • Wetland habitat encroachment.	• Avoid impacts to small streams, wetlands, and wetland buffers with development • Treat runoff before discharge to wetlands. • Identify wetland buffers for restoration. • Prohibit septic systems, including use of advanced treatment systems on shallow water tables (less than two feet from ground surface) for new construction.