Wickford Harbor Watershed Assessment

Prepared by URI Cooperative Extension in partnership with the Town of North Kingstown and Save the Bay

November 2000

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Acknowledgements

This watershed assessment was conducted by URI Cooperative Extension in partnership with Save the Bay and the Town of North Kingstown, under the oversight of a local advisory group consisting of the Conservation Commission and town planning staff. Members of the Harbor Commission, Groundwater Committee, Wastewater Management Commission, and other interested citizens also participated in this group. Town planners Rebecca Cipriani and Pat Nickles provided local review, responded promptly to requests for information, and coordinated the local advisory group.

These staff members and volunteers devoted their time to participate in the assessment by sharing their considerable knowledge of the watershed and its resources and by guiding the assessment to ensure results address practical local concerns. Through a series of six meetings the group identified local land use issues and resource protection priorities, participated in updating and verifying accuracy of maps used; reviewed draft products; recommended realistic management options for analysis; and identified initial steps for future action. We gratefully recognize their contribution to this report and accept full responsibility for any errors or shortcomings.

Members of the Conservation Commission leading the local advisory group included:

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Jack Green
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This assessment was conducted in support of the larger Wickford Harbor Watershed Restoration Project. Led by Save the Bay and the Town of North Kingstown, the goal of this project is to restore once-extensive eelgrass habitat to Wickford Harbor. By identifying potential sources of pollution this assessment is designed to identify management practices that can reduce threats to eelgrass habitat while enabling the Town to meet broader water quality goals for this important resource. We gratefully acknowledge Save the Bay and the Town of North Kingstown for funding URI Cooperative Extension's participation in this project. Additional support to URI was provided under the Cooperative State Research Education and Extension Service, Project #97-EWQI-1-0098.

This Report represents Technical Report #00-03, Contribution #3847 of the College of Environment and Life Sciences and Rhode Island Cooperative Extension, University of Rhode Island. Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Patrick Logan, Director, Cooperative Extension Service, University of Rhode Island. Cooperative Extension provides equal program opportunities without regard to race, age, sex or preference, creed, or disability.

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Wickford Harbor Watershed Assessment

I. INTRODUCTION

Evaluating pollution risks in the Wickford Harbor Watershed

This report summarizes the results of a screening-level watershed assessment of the Wickford Harbor watershed. This assessment was conducted by the University of Rhode Island Cooperative Extension in cooperation with Save the Bay and a local advisory group led by the North Kingstown Conservation Commission. The purpose of this study is to support Town watershed management decisions by identifying local actions that can effectively reduce pollutant inputs to Wickford Harbor and its tributaries.

Our study objectives were to:

- Identify pollution sources in the Wickford Harbor watershed using existing sources of data;
- Evaluate pollution risks under existing and future land use;
- Identify local management options.

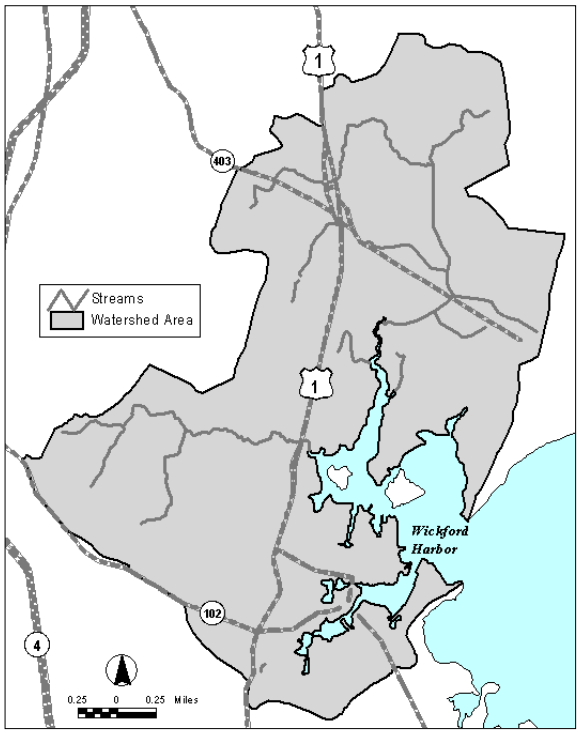


Figure 1: Wickford Harbor Watershed
Wickford Harbor is a 400 acre sheltered cove of Narragansett Bay. The area of land that drains to Wickford Harbor – its watershed, is more than ten times larger, covering about 4500 acres. The watershed collects precipitation and pollutants from the land and carries them to the Harbor via streams and groundwater flow. The quality of the water in Wickford Harbor is directly related to land use activities throughout the watershed.

Wickford Harbor – a valuable but threatened resource

Wickford Harbor is a 400 acre sheltered cove of Narragansett Bay in North Kingstown, RI. A working port since Roger Williams founded the State's first waterfront trading post here, the Harbor is now a marina for recreational boats and commercial fishing support businesses. Centrally located along the Town's 31-mile coastline, the Harbor and surrounding Wickford Village are at the economic and social heart of the Town. With its historic homes and waterfront shops lining the cove, Wickford Village is a thriving business district serving local residents and tourists. The Harbor complex itself is equally valuable as a natural resource, supporting quahogs, oysters and finfish nurseries. Harbor waters continue to support highly sensitive activities such as shellfishing, swimming, kayaking and youth sailing. Together, these features make Wickford Harbor an important economic, recreational, and historic resource supporting a high quality of life in North Kingstown.

One of Wickford Harbor's most significant natural resources is also one of its least well known: Eelgrass. This underwater seagrass is a critical link in coastal food webs. It provides habitat for fish and

shellfish and filters nutrients to maintain good water quality. Because it is sensitive to pollution, it also serves as a vital indicator of coastal water quality.

Historical records and monitoring show that once extensive eelgrass beds are now limited to small areas of the Cove (Kopp et al. 1995). The reasons for this decline are uncertain. But poor water clarity – the result of over-abundant nutrients combined with restricted flushing, is considered a major factor (Dennison et al. 1993, Valiela 1992). Other identified water quality threats (North Kingstown 1996) that reduce sunlight penetration include heavy boating use, polluted runoff, and septic system effluent from high-intensity land use in the watershed and clustered along the Harbor shoreline.

Eelgrass: Hidden *Underwater* Gardens

Eelgrass (*Zostera marina*) is an underwater seagrass, or submerged aquatic vegetation growing in shallow coastal waters. This inconspicuous grass with long thin blades grows as a single plant or spreads by roots to form underwater meadows. Underwater grasses provide food for waterfowl and habitat for fish, shellfish, and lobster. By baffling wave energy and slowing currents, eelgrass reduces bottom scouring and suspended sediment. They cycle nutrients out of the water column and add oxygen to the water.

Scientists believe that eelgrass beds were once widespread in shallow coves throughout Narragansett Bay, even in the Providence River. However, increasing amounts of nutrients and sediment in water have contributed to declines in eelgrass acreage. Too much nitrogen stimulates the growth of nuisance seaweeds and algae – microscopic aquatic plants. The algae collect on the eelgrass blades and cloud the water column, interfering with the plants' ability to receive light for photosynthesis. Nuisance seaweeds, such as sea lettuce, can smother the underwater eelgrass beds. As eelgrass became scarce in the Bay, some of the fish and shellfish that depend on this plant – like bay scallops, declined as well.

Photo: Perry Gayaldo, U. of Washington

Today, eelgrass beds cover fewer than 100 of the 96,000 acres that make up Narragansett Bay (Kopp et al. 1995, RI CRMC 1998). Once plentiful in Wickford Harbor, only two small eelgrass beds remain. *This is one of the few remaining eelgrass meadows in the West Passage of Narragansett Bay. And it is the only eelgrass still found in a shallow, poorly flushed cove within the Bay.* Protecting these beds is important to maintaining a healthy shellfishery. Because eelgrass is so dependent on good quality waters where light penetration is good, eelgrass is also an important barometer of the health of the Harbor.

II. METHOD

Risk Assessment Approach – a watershed *health check-up*.

We used a screening-level assessment method known as MANAGE to evaluate pollution risks throughout the Wickford Harbor watershed. Our approach identifies pollution risks and management options focusing on the most serious threats given the Town's local water quality goals. This is a planning assessment designed to be conducted with a small investment of local resources. Our goal is to provide useful information for decision making given practical constraints of limited data and limited budgets for additional studies. Given the gaps in our understanding of pollutant interactions, results are described in terms of *potential* pollution sources and *risks* to water quality rather than certain sources having known impacts. Assessment results can support concrete actions such as: targeted monitoring to fill data gaps, specialized investigations to verify and remediate suspected problems, adoption of watershed-specific land development standards, focused public education, and implementation of stormwater or wastewater pollution controls.

Our approach relies on computer-generated maps and other existing, readily available local sources of information to locate land development patterns and landscape features most likely to affect local water resources. These maps enable us to make full use of data that is specific to North Kingstown and to the Wickford Harbor watershed such as up-to-date land use, soils, and watershed characteristics. This first-cut assessment is a type of watershed "health checkup." Similar to a health physical, the assessment describes current conditions, points out problems, and identifies changes that can reduce health risk.

MANAGE is the **M**ethod for **A**ssessment, **N**utrient-loading, and **G**eographic **E**valuation of watersheds and aquifers. This screening-level pollution risk assessment method uses computerized maps known as Geographic Information Systems (GIS) to compile, analyze, and display watershed and aquifer information. The assessment incorporates a suite of pollution risk factors to include: 1) map analysis locating likely pollution hotspots; 2) land use and landscape features summarized as watershed indicators such as percent impervious cover and shoreline buffer characteristics; and 3) nutrient loading estimates as an additional indicator. MANAGE was developed by URI Cooperative Extension for use with Rhode Island communities as a tool for nonpoint pollution education and local management of water resources. For more information see www.edc.uri.edu/cewq/manage.html.

NOTE: This section presents an overview of the assessment approach. Additional information on methodology is integrated in Results, Section IV. In addition, detailed documentation is provided in attached appendices.

Linking watershed features with water quality conditions

We rely on accepted pollution risk factors, or health "indicators" used by EPA and others to rate pollution risks. Indicators are simple measurements that integrate the impact of various stresses in a qualitative way. Indicators used include, for example: 1) pollution *sources* such as percent high intensity land use and *stressors* such as percent impervious cover and runoff area that bring about fundamental changes in water flow patterns; 2) indicators of pollutant *movement* to ground or surface waters, such as percent highly permeable soils; and 3) the potential *impact* of pollutants considering factors such as local water quality goals, its existing condition such as the level of nutrient enrichment, and vulnerabilty as indicated by flushing.

All indicators are most useful in comparing *relative* differences in pollution potential and are used as follows:

- To identify land use types or subwatershed areas where pollution risks are concentrated or contributing a disproportionate "share".
- To rank pollution risks using generalized ratings, from low to extreme risk. We assign a rating when supporting documentation is available.
- To track trends with changing land use or management practices. We use hypothetical but realistic "what if" scenarios to compare differences in estimated nutrient inputs between current and future land use, or with use of pollution controls for stormwater treatment or septic system management.

Pollution source "hotspot" mapping carries this analysis further to locate site specific high-risk areas. This analysis maps high intensity land uses that are known pollution sources and overlays them with soil features where contaminant movement is most likely. A complete list of risk indicators and map analyses used is included in Appendix A.4. *Maps produced for the Wickford Harbor MANAGE assessment*, and Appendix A.9. *MANAGE List of watershed indicators and rating key*. Key watershed indicators specifically for the study area are reported in Appendix A.2. *Wickford Harbor Watershed Summary Results*, with a more complete list in Appendix A.3. *Wickford Harbor Watershed summary of selected watershed indicators*.

Data Sources and Outputs

The assessment results are based on four types of information either used or generated in the risk analysis.

- Review of existing Town plans, reports, water quality data including monitoring data collected by Save the Bay and RIDEM. The North Kingstown Conservation Commission supplemented existing map data with updated land use and water features and current knowledge of additional potential sources. Results are reported in Section III and Appendix A.1.

- Key land use and soils information summarized as watershed health indicators extracted from the RIGIS map database and compiled using a separate spreadsheet. Results are presented in Section IV (A & B) and Appendices A.2. and A.3.

- Modeled estimates of average annual runoff, groundwater recharge, and nutrient loading as measures of cumulative pollution risk. We use a standard watershed-scale mass balance method similar to those widely used in comparable applications elsewhere including Cape Cod and the New Jersey Pine Barrens. Results are provided in Section IV (C) and Appendix B.

NOTE: The mass balance concept uses a simplified water and nutrient "budget" to establish a quantitative relationship between pollutant inputs and outputs to a system. The nutrient loading component of MANAGE estimates pollutant outputs as nutrients (nitrogen and phosphorus) entering surface water runoff or infiltrating as recharge to groundwater. This standard mass balance method is similar to those widely used in comparable watershed assessment applications elsewhere. *(Adamus, C. and M. Bergman 1993, Brown, K.W. and Associates 1980, Budd, L.F. and D.W. Meals 1994, Frimpter, M.H. et al. 1990, Fulton III, R.S. 1994, Nelson, K.L. et al. 1988, Reckhow, K.H. and S.C. Chapra 1983, Schuler, R.R. 1987, Weiskel, P.K. and B.L. Howes 1991, EPA, 1990).*

- Map analysis of land use, soils, and other watershed features to systematically locate probable pollution "hotspots" using the RI Geographic Information System (RIGIS) database. All watershed land use, soils, and other natural features derived from the RI Geographic Information System are intended for planning-level analysis only. The results are provided to the Town as large format maps. These are not easily reproduced in this report but the analysis is briefly described in Section IV (D) with additional documentation in Appendix A.4.

Final Products

Results of the assessment are presented in the following format:

- Map inventory of study area land use and natural features, including pollution source hotspot maps and detailed property boundary (parcel) maps for central Wickford Village, provided in large-format paper and digital forms.

- "Build-out" analysis specific to each subwatershed with population, building units, and septic system estimates.

- Watershed health "indicators" summarizing key information about land use and soil characteristics under current and future land use scenarios.

- Hydrologic budget and nutrient loading to groundwater recharge and to surface runoff as an additional pollution risk indicator for each land use scenario and pollution control option evaluated.

- Summary report focusing on pollution risks and management options with supporting technical appendices.

- Presentation to town officials and the public on final results.

Evaluating water quality impacts of land use:
Water quality standards vs. watershed risks

When most industries and municipal treatment plants discharge treated wastewater to a river or bay, the type and amount of pollutants is regulated and downstream waters are monitored to ensure pollutant limits are not exceeded. Since 1970, EPA and RIDEM have been very successful in controlling these direct, or "point" discharges this way. Now we know more pollution comes from many small sources such as lawns, stormdrains, and septic systems where pollutants enter streams and groundwater at many places throughout a watershed.

These so-called "non-point" pollution sources are not easy to control by traditional pollutant limits and compliance monitoring. Some of the reasons are:

- Evaluating water quality impacts of land use activities has proven to be a challenge given the number of possible sources and the wide range of physical, chemical, and biological impacts possible.
- Everyday activities that generate nonpoint source pollutants are unregulated; where regulations do exist such as erosion controls and hazardous material disposal rules, inspection and enforcement is often inadequate among numerous small residential, commercial, and boating entities. The result is poor awareness and financial responsibility for environmental impacts.
- Pollutant limits are not always adequate to protect sensitive waters, partly because the amount each waterbody can assimilate is uncertain and varies based on its specific characteristics.
- Field monitoring provides the most solid information on water quality conditions but thorough investigations can be expensive and time consuming.
- Long term data is needed to distinguish between natural effects due to weather and seasonal variation.
- Monitoring results are often inconclusive in verifying the source of nonpoint pollutants.

Because scientists have found it difficult to assess land use impacts in conventional ways, there is growing reliance on use of watershed characteristics as watershed health "indicators". Instead of measuring pollution effects directly, these indicators establish a relationship between pollutant sources and their resulting impact on water quality. Rather than comparing sampling results to an established standard, these indicators gauge the *risk* that pollutant inputs and physical stresses will lead to poor water quality conditions.

As a screening-level assessment, this risk-based approach offers the following advantages:

- Relatively rapid and low cost review reserves limited resources for implementing pollution controls;
- Targets the most serious problems for monitoring, more sophisticated analysis, or management actions;
- Generates a map database and other products useful for town planning and project review;
- Provides supporting data that can be incorporated into town plans or zoning performance standards documenting the need for improved pollution protection measures;
- Provides early warning of high pollution inputs to support pollution prevention rather than more costly cleanup efforts.

Assessment Steps

The assessment was carried out in cooperation with a local advisory group coordinated by the Town Planning Department and headed by the Town Conservation Commission.

1. **Create land use and natural resource inventory maps to display and analyze watershed conditions.** This included mapping six subwatershed boundaries, updating land use, mapping known or suspected pollution sources, and creating a future land use/zoning map.

2. **Predict future land use and population change through a "build-out" analysis for each study area.** This map-based analysis projects the type and location of growth assuming all unprotected land is eventually developed based on the Town's zoning and future land use map.

3. **Briefly summarize existing conditions based on available plans, monitoring data, and water quality issues identified by the local group.** We also provided assistance to Save the Bay in designing a tributary monitoring program and in evaluating monitoring results.

4. **Identify and rate pollution risks of current land use.** Using land use, soils, and other mapped data, we used a spreadsheet to generate summary statistics, or "indicators" such as percent impervious area. The same spreadsheet calculates a hydrologic budget and nutrient loading estimate as an additional indicator of pollution risk. This analysis was conducted for the full Wickford Harbor watershed and run separately for each of six subwatersheds delineated for this project, as shown in **Figure 2**.

5. **Envision future impacts through "build-out" analysis.** Pollution risk indicators and a hydrologic budget/ nutrient loading for future land use were estimated by re-running the spreadsheet analysis (Step 4) using the future land use ("build-out") map.

6. **Map high risk pollution "hot-spots" for the whole watershed area.** Mapped hot spots help to target the location of potential pollution sources by combining high intensity land uses that are known pollution *sources* with soil features where pollution *movement* is most likely. More detailed analysis of septic system failure risk was conducted using the Wickford Village parcel database.

7. **Evaluate effectiveness of management options to reduce pollution risk.** Using the spreadsheet, we estimated the relative change in runoff and nutrient loading that could be expected under different pollution control practices. Management options were also evaluated using other available information.

8. **Summarize findings in a format useful for decision making.** Final results take into account all available information collected and data generated. Recommendations focus on taking action to protect existing water quality rather than waiting for further signs of impairment given that pollution prevention is generally considered much more cost effective than restoring degraded waters. Map analyses are made available as large-format maps and in digital form.

Figure 2. Wickford Harbor Study Areas. The Wickford Harbor watershed was divided into six smaller subwatersheds for this assessment. Mill Creek and Cocumcussoc Brook, the two major tributaries, drain the largest subwatersheds; the Mill Cove North, Fishing Cove, Wickford Cove and Mill Cove South subwatersheds drain directly to the Harbor. The Wickford Cove and Mill Cove South subwatersheds roughly correspond to the center of Wickford Village.

III. SUMMARY OF EXISTING CONDITIONS

As a first step in evaluating pollution sources within the watershed we briefly summarized existing, information on water quality concerns, pollution sources – both documented or perceived, and management actions already recommended within Town plans and other sources. This overview is based on data compiled and documented, in Appendix A.1. *Existing Condition of Wickford Harbor and Watershed Resources.* As a foundation for the assessment, this summary serves several purposes:

- Documents baseline conditions *prior to the assessment* which the assessment builds upon;
- Identifies data gaps, especially in monitoring data;
- Highlights the Town's most valuable or vulnerable water resources, especially where continued public enjoyment of those uses may be threatened by pollution sources;
- Provides a basis for refining Town water resource protection goals and protection priorities; and
- Provides a checkpoint for reviewing progress in implementing recommended actions and baseline for new watershed management decisions.

This summary is drawn from readily available information sources such as Town plans and monitored data. We also summarize water quality concerns and potential threats raised by Conservation Commission members, other local board members, staff, and others participating in this assessment. It is not intended to be a comprehensive synthesis and it may not include all available data. Key features of this water quality status check are summarized below.

Town Water Quality Goals

While the Town is committed to restoring aquatic habitat in Wickford Harbor – with eelgrass as a barometer of healthy conditions – discussions with the Conservation Commission and review of Town plans show that the community goals for this important resource are much broader. Shellfishing, swimming, and other contact recreation such as canoeing, kayaking, and youth dinghy sailing are locally important uses of the Harbor. These are sensitive uses subject to degradation from nonpoint sources of bacteria. For shellfishing and swimming the State maximum allowable limits for bacteria (fecal coliform) are typically the most difficult to achieve. Town water quality goals include the following:

- Providing for full enjoyment of contact recreation such as kayaking, canoeing, and sailing;
- Maintaining safe shellfishing and swimming in existing areas;
- Protecting aquatic habitat throughout the Harbor and tributary waters; and
- Safeguarding groundwater supplies underlying the watershed.

In addition, the Conservation Commission suggested the following specific goals for the Harbor:

- Document continuous improvement in Wickford Harbor water quality into the future.
- Allocate and spend available funds in the most cost-effective manner to achieve continuous harbor water quality improvement.
- Continue to identify and publicize industrial, commercial, municipal, agricultural, and residential practices that might contribute to poor harbor water quality.
- Continue to monitor and identify polluted areas within the watershed and harbor.
- Maintain a balance of uses within the harbor and watershed to maximize economic, aesthetic and environmental value for the greatest number of Town residents and visitors.
- Maintain at least the year 2000 level and quality of fishing, swimming and aesthetics in and surrounding Wickford Harbor forever.
- Where monitoring data indicates impaired water quality, re-establish safe water quality levels for swimming and shellfishing.

What do we know about water quality?

The Harbor is considered safe for shellfishing and swimming in designated areas based on *only one bacteria monitoring station.* Because this site is located in the open Harbor, additional bacteria monitoring data is needed to assess risk to swimming and other primary contact recreation outside of the most well flushed waters. These areas might include the Wilson Park boat ramp area, the Wickford Yacht Club, the Town docks on Brown Street and Main Street, all Town and marina slip and mooring areas in the Harbor, the Hussey Bridge and the Kayak Centre.

Habitat quality is considered threatened based on infrequently documented low dissolved oxygen events. Low oxygen levels, eelgrass decline, algal blooms, and poor water clarity are all symptoms of "overfertilization" caused by excessive nutrient inputs.

There is a great deal of uncertainty about how much nitrogen the Harbor can assimilate without adverse environmental consequences. The amount of nitrogen reduction needed to bring about a noticeable

improvement in water clarity is also unknown. Flushing studies that measure how long water stays in the Harbor before flowing out to the Bay can help determine how sensitive the Harbor is to nitrogen. But depending on the method used these investigations can be costly and results inconclusive. However, water quality conditions currently do support eelgrass populations in better-flushed areas of Wickford Harbor. This makes Wickford Harbor a good candidate for habitat restoration because it is easier to restore adjacent areas where it currently exists (Kopp et al. 1995).

Town-Identified Pollution Sources, Threats, and Issues

- Polluted runoff, failing septic systems, marina use, and past effects of waste disposal at the Quonset Point /Davisville navy base are well recognized but unquantified threats.
- Visitors to Wilson Park, occasionally observed to swim and take shellfish, need to be alerted to water quality conditions and directed to safe shellfishing and swimming areas. Improved signage clearly identifying safe areas is needed, along with water quality monitoring to assess conditions at the Park.
- Public health is a concern with increasing use of the Harbor by kayakers, youth dinghy sailors, and other low-intensity recreational boaters, particularly in poorly flushed areas of the Harbor.
- Safe and sanitary disposal of wastewater to accommodate downtown businesses and homeowners is a longstanding concern. The Town has found that Sewer extension to Wickford does not appear to be an appropriate or desirable option at this time for the following reasons: high cost; lack of agreement on access to the State's Quonset/Davisville wastewater treatment facility; the difficulty of establishing an equitable means of allocating costs to all residents who might benefit; and perhaps most importantly, the potential for uncontrollable growth. This last concern, well documented by other communities, is that unrestricted wastewater disposal capacity would allow intensive waterfront development that is inconsistent with the scale and character of Historic Wickford Village, even under present zoning. In addition, sewer extension is likely to invite zoning changes leading to further new construction and redevelopment, thereby affecting environmental quality and general quality of life for residents.
- Effects of stormwater runoff from roadways and heavily developed areas is a concern voiced by Town staff and others. Areas of greatest concern include: existing runoff from Rt. 1, Main Street, Dana Road, and the Quonset /Davisville Industrial Park, and also increased future runoff, especially with roadway improvements and redevelopment in the Industrial Park.

IV. RESULTS: WATERSHED POLLUTION RISKS

A. Land Use

The quality of groundwater and surface waters in the Wickford Harbor watershed is a direct reflection of land use in the watershed. Land use activities generate pollutants and bring about fundamental changes in watershed hydrology as drainage alterations and impermeable residential and commercial surfaces such as roads, parking lots, roofs, and sidewalks reduce infiltration into soils and increase storm runoff. Even in developed land areas that remain permeable, increased lawn fertilizers, septic system, commercial and industrial discharges generate additional pollutant inputs to the watershed. Consequently, land use is one of the most important factors in evaluating pollution risks and forms the basis for other health indicators such as nutrient loading. Land use risk factors used in this assessment include the following:

LAND USE RISK FACTORS	
Watershed-wide risks	**Riparian (shoreline) buffer risks**
• High intensity land use	• Riparian high intensity land use
• Impervious surface area	• Riparian impervious surface area
• Wetland and forest cover	• Riparian wetland and forest cover

All indicators above are measured as percent of land use. The following ratios are used:

- Watershed wide risks = indicator land use area /total study area.
- Shoreline buffer risks = indicator land use area within 150 feet of surface waters / the total area of the 150 foot shoreline buffer.

The shoreline, or riparian area where the land meets water is especially important as a zone for either pollution removal (with forested shoreline buffers) or for pollutant delivery to surface waters (with developed shorelines). The full subwatershed study area and the shoreline buffer zone are evaluated separately (**Figure 3**). In the Wickford Harbor watershed the shoreline buffer includes all land within 150 feet of the Harbor shore, perennial streams, and other lakes and ponds shown on a USGS topographic map.

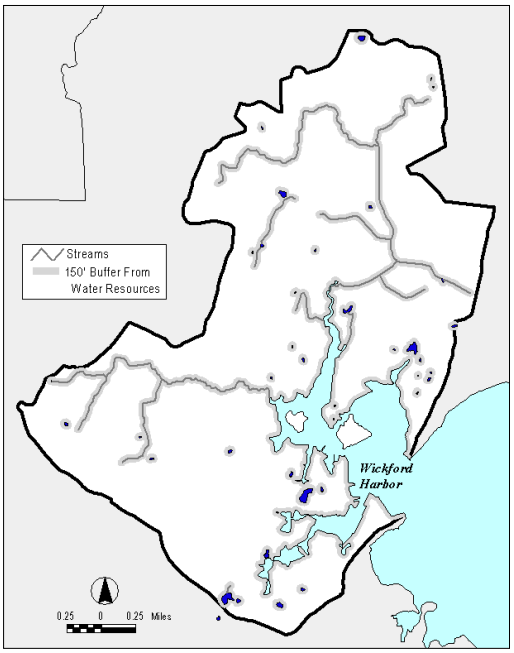


Figure 3: Harbor, Ponds, and Streams with 150' Shoreline Buffer

What is a Riparian Area?
The riparian area is the shoreline zone. In undisturbed shorelines, the riparian area is a vegetated ecosystem along a waterbody through which energy, materials, and water pass. Riparian areas characteristically have a high water table and are subject to periodic flooding and influence from the adjacent waterbody. These systems encompass wetlands, uplands, or some combination of these two land forms. They will not in all cases have all of the characteristics necessary for them to be classified as wetlands. (EPA 1993).

WICKFORD HARBOR WATERSHED LAND USE OVERVIEW

Current Land Use

Land use characteristics of the Wickford Harbor watershed and its six subwatersheds are itemized in Appendix B, using 21 land use categories. This is based on 1995 RIGIS land use maps updated to reflect 1999 conditions with input by the Conservation Commission. The number of dwelling units and occupancy rates were estimated based on the mapped RIGIS residential density categories. Using 1990 U.S. Census block-level data to "fine-tune" (Appendix A.5) our mapped estimates, we calculate the number of dwelling units in the watershed is approximately 3,430 dwelling units with 2.4 persons per dwelling unit. Of these, we estimate approximately 3,000 dwelling units rely on septic systems for wastewater disposal within the watershed. Estimates for each subwatershed are included in Appendix B for current and future land use.

Historical land use

The Wickford Harbor watershed has been extensively altered. With construction of Quonset Point Naval Base in 1939, about one half of the 650 acres comprising the Base is built on dredge spoils or filled coastal waters or wetland (Olsen et al. 1980).

Future land use

To predict growth potential and future sources of pollution we conducted a "build-out" analysis to show the location and type of expected land use changes assuming full development of all privately owned and unprotected land. According to our future growth estimates for full "build-out", the watershed is already largely developed. But about 500 acres of forest land could potentially shift to other uses, primarily medium density residential with slight increases also expected in commercial and industrial land use.

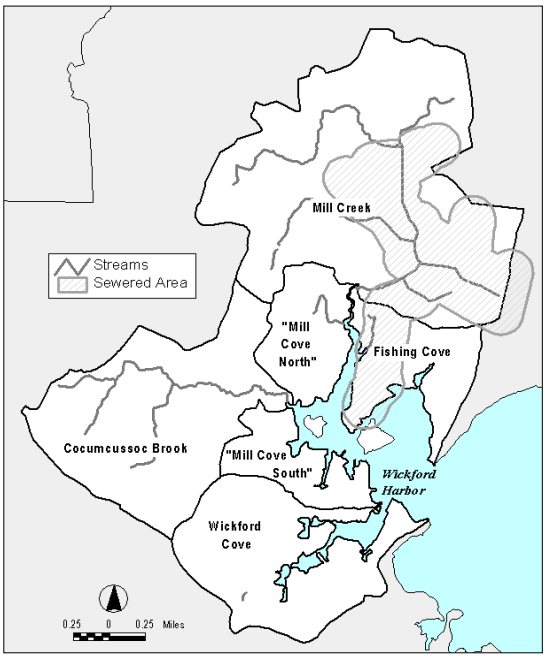


Figure 4: Sewer Service Areas
Because septic systems are a major source of nitrogen and a contributor to groundwater recharge, the number of homes and businesses in the watershed outside of public sewer service areas is an important factor in the assessment. This information is used to estimate the number of septic systems in each subwatershed, the recharge and nutrient output from those systems, and to develop nutrient loading estimates.

To approximate the number of homes connected to a public sewer, we mapped the major RIGIS sewer lines, then buffered this line by 750 feet on each side for a total of 1,500 feet. This distance was selected as a realistic sewer tie-in zone based on input from municipal planners. We then assumed that all buildings within the buffered sewer service area are connected to the sewer. This estimated sewer service area is shown above. The results show that only the Fishing Cove and Mill Creek subwatersheds have sewer lines (41% and 36% of these areas, respectively). Most of this serves the Quonset /Davisville industrial park. Approximately eighteen percent of the total Wickford Harbor Watershed is sewered.

1. RISK FACTOR: HIGH INTENSITY LAND USE

High intensity land use activities use, store or generate pollutants that can move offsite to cause contamination. Both sewered and unsewered areas are included in this indicator based on evidence that densely developed areas contribute watershed pollutants regardless of the presence of public sewers. Some of the risks associated with intense land use activities include for example: residential, park, and gold course fertilizers, inadequate or poorly maintained septic systems, marina runoff, leaking underground storage tanks, a variety of pollutants deposited or spilled on pavement and transported in runoff, and leaking sewer lines or malfunctioning pump stations (Pitt et al. 1994). In a recent RI study comparing land use with drinking water contaminants, U.S. Geological Survey researchers (DeSimone and Ostiguy 1999) verified that groundwater underlying industrial land use is more likely to contain toxic contaminants. They also found that elevated nitrogen (>1 mg/l nitrate-N) in groundwater was associated with urban land uses whether or not the area was sewered, due to leaking sewers and fertilizers from home lawns, parks, golf courses, and institutional lands. We consider less than 10 % high intensity land use a low risk to water quality, with greater than 25 % of these intense land uses rated as an extreme risk.

We identify and map the following high intensity land uses listed below. Some high risk areas are too small to map reliably and must be field checked. For example, livestock areas and manure storage areas have the potential to generate wastes that are very high in nutrients and pathogens. These may be found in pasture, cropland, or residential uses and are therefore best mapped through local knowledge taking advantage of the hotspot maps as a start.

HIGH INTENSITY LAND USES	
Very High Risk	**High Risk**
• Commercial and industrial	• High and Medium-high density residential (>4 units/acre)
• Highways, railroads & airports	• Schools, hospitals and other institutional uses
• Junk yards	• Actively tilled cropland such as corn or potatoes

RESULTS: HIGH INTENSITY LAND USE

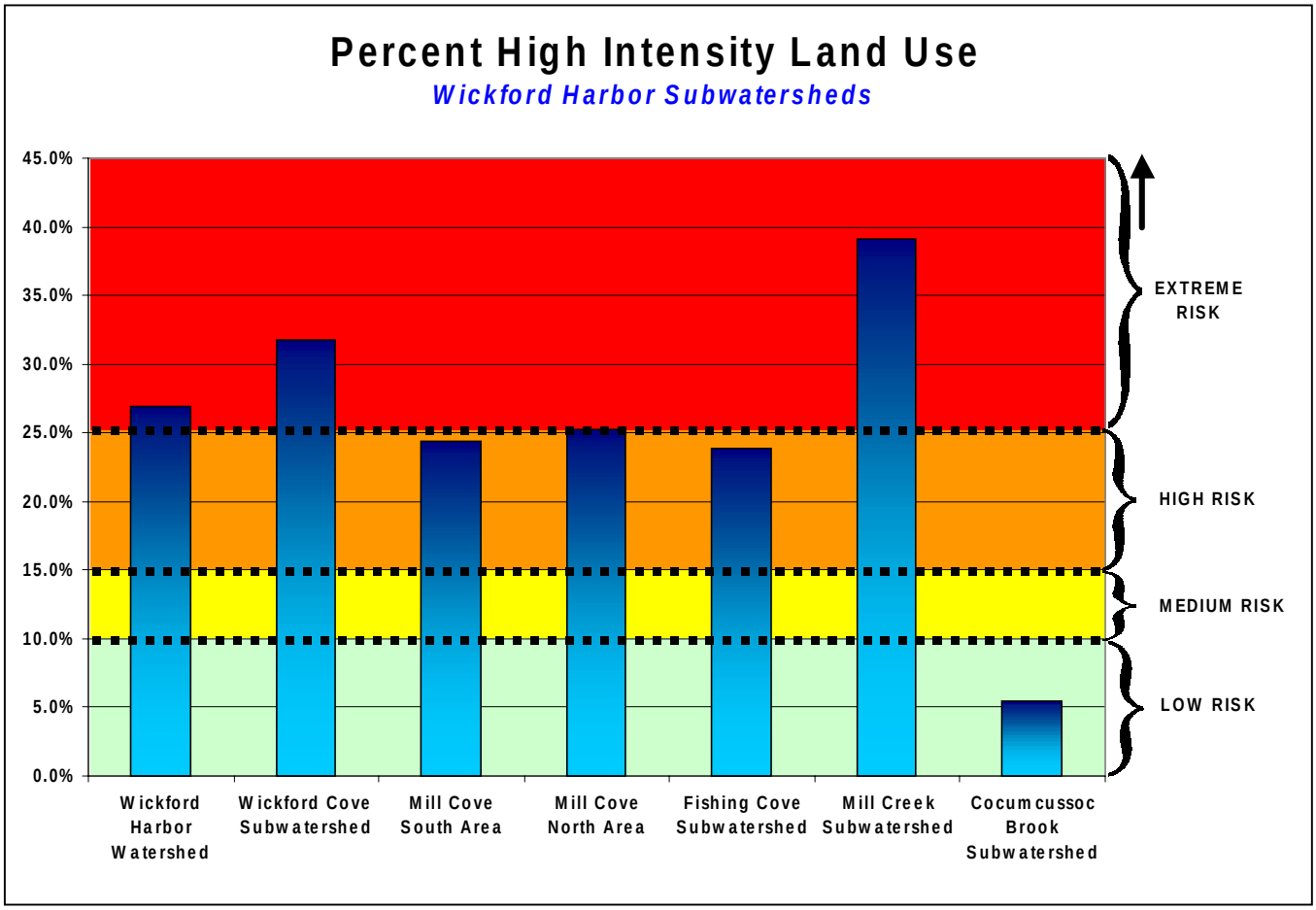
- The average percent high intensity land use in the Wickford Harbor watershed is 27%, representing an extreme risk to water quality from pollutants likely to be generated by these uses.

- All subwatersheds, except for the relatively undeveloped Cocumcussoc Brook Watershed, have 24% or more high intensity land use, putting these watersheds into the high to

extreme risk category for generating pollutants associated with dense development.

- The Wickford Cove and Mill Creek subwatersheds have the highest proportion of high intensity land use with 32% and 39% respectively. The percent high intensity land use for the Wickford Harbor Watershed and its six subwatersheds are shown in **Figure 5.**

Figure 5: High Intensity Land Use



2. RISK FACTOR: IMPERVIOUS COVER

Impervious cover is a catch-all term for pavement, rooftops, and other impermeable material that prevent rainwater from seeping into the ground. Numerous studies have linked the extent of impervious surfaces to declining aquatic habitat quality in streams and wetlands (Schueler 1995, Arnold, C. L. and C. J. Gibbons 1996, Prince George's County 2000) due to a variety of stresses. Increased imperviousness alters watershed hydrology by dramatically increasing the rate and volume of runoff and reducing groundwater recharge. This leads to "flashier" streams with fluctuating water levels, diminished streamflow during critical summer low-flow periods, sedimentation with decreased capacity of streams to accommodate floods, and higher stream temperatures. In streams and wetlands these changes result in loss of habitat, reduced biodiversity, and chemical and physical changes in water quality and quantity. In aquifers, impervious cover reduces recharge to deep groundwater supplies. We use standard methods to calculate impervious cover for 13 different land use types (Appendix D and USDA 1986).

According to recent studies, stream and wetland habitat quality is often impaired as watershed impervious levels exceed 10 percent, with as little as 4 – 8 percent affecting sensitive wetlands and trout waters (The Center for Watershed Protection 2000; Azous, A. and R. Horner 1997). At greater than 25 – 30 percent imperviousness, stream water quality impacts can be expected to become severe. At these higher levels, it may be possible to control flooding through use of stormwater detention basins but improving runoff quality, even with use of retention ponds, constructed wetlands, and other stormwater treatment systems, becomes much more challenging.

RESULTS: IMPERVIOUS COVER

- The average pavement area in the Wickford Harbor watershed is estimated to be 23 percent under current land use, increasing to 27 percent with full development as zoned. This is well above the 10 percent threshold level for maintaining good stream habitat quality and near the 25 percent level where potential impact to streams and wetland habitat is considered extreme.

- Subwatersheds with extreme or high impervious levels greater than the watershed average include Mill Brook, Wickford Cove, and Fishing Cove.

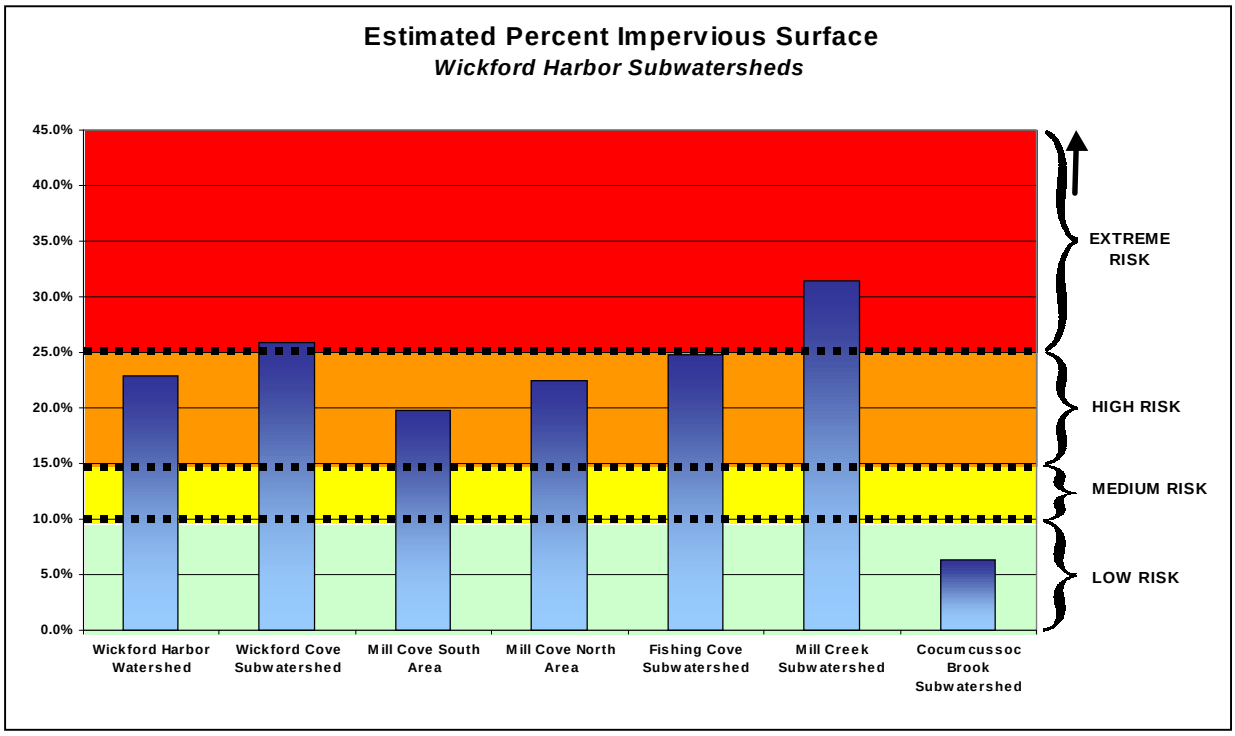
- The Mill Brook subwatershed, with extensive highway commercial development along Rt. 1, and industrial land in Quonset/Davisville has the highest estimated percent impervious

cover at 31percent under present land use, potentially increasing to 36 percent with full development. These levels are cause for concern because of the potential impacts to aquatic life in streams and wetlands and because of the difficulty of improving stormwater runoff *quality* above the 25 – 30 percent impervious level. These estimates are based on 72 percent average impervious cover for industrial land; the exact amount may be higher or lower depending on site-specific conditions.

- The largely undeveloped Cocumcussoc Brook watershed has very little impervious cover at six percent, increasing potentially to nine percent with future development. These low levels suggest minimal future impact with development with use of erosion controls and stormwater management practices. Because we assumed that State-owned Cocumcussoc Brook management area would remain undeveloped this growth will be concentrated in developable areas where stormwater control will still be necessary to limit localized impacts.

The percent impervious cover for the Wickford Harbor Watershed and its six subwatersheds are shown in **Figure 6.**

Figure 6: Estimated Impervious Surface



3. RISK FACTOR: FOREST AND WETLAND

Experts agree that forests and wetlands are directly linked to the health of watershed streams and coastal waters (EPA 1999). Forests and wetlands serve as ecosystem treatment systems, helping to preserve and maintain watershed health. Unlike the other risk factors, this is an *inverse* relationship, with more than 80 percent forest and wetland area translating to a *low* risk to water quality; and less than 20 percent of these undeveloped lands considered a high risk to water quality. Although some indices assign separate ratings to forest and wetland area, we combine them based on the simple observation that in RI, healthy watersheds often consist of one or the other (RIGIS 1995). Together both wetlands and forest help offset hydrologic impacts and pollution inputs to maintain health of aquatic systems. We rate watersheds having a combined forest and wetland cover of 80 percent or more as having a low risk to water quality by treating or moderating effects of land uses impacts; watersheds with less than 20 percent forest and wetland cover have little ability to function as treatment areas and are rated at extreme risk of pollution.

Forests act as living filters to intercept, temporarily store, and infiltrate rainfall, reduce stormwater runoff, maintain stream flow, reduce erosion and cycle nutrients. A high percent of forest land in a watershed correlates with healthy aquatic ecosystems. Forested watersheds have the capacity to intercept, store, and infiltrate precipitation, thereby maintaining natural streamflows. Forested wetland and stream buffers shade surface waters, stabilize streambanks and filter sediment. Undisturbed forest soils tend to store organic matter and nutrients, including atmospheric pollutants associated with acid rain. In calculating percent forest cover we also include brush and unfertilized pasture, which also have very low rates of nitrogen leaching to groundwater.

Wetlands are a vital link between land and water, helping to maintain water quality and control flooding while also providing important habitat for aquatic life. The extent of wetlands is a measure of the potential for sediment trapping, pollutant storage, and nutrient transformation by natural processes in wetlands themselves and in their adjacent buffers. The efficiency of wetlands in retaining sediment and nutrients is highly variable and depends on seasonal changes, rainfall, and very site specific features such as the wetland location in the watershed and its storage capacity. Despite this variability, the extent of wetlands within a watershed is strongly correlated with healthy ecosystems (Hicks 1997, Amman and Stone 1991, Azous and Horner 1997). Watersheds with small wetland area

Forests: watershed treatment zones for acid rain

In New England, where incoming winds carry automobile exhaust and industrial emissions, field measurements show that rain and snow also bring nitrogen - about eight pounds per acre each year.

When this rain lands on pavement most, if not all of the nitrogen can be expected to run off to the nearest culvert and then directly into the Harbor, flushing in additional pollutants along the way. But when this nitrogen-rich rain falls on forested land, the soil organic matter layer absorbs and stores the rainwater, while plants and microbes serve as a nitrogen sink. As a result, about 95% of available rainfall is estimated to infiltrate forest and meadow lands rather than runoff.

Only about two pounds of nitrogen per acre is expected to be lost to groundwater and surface runoff in forest lands, compared to the eight pounds of nitrogen deposited on pavement and directly to surface waters.

Unfortunately, the ability of forests to absorb nitrogen is not limitless. Some northern New England forests are showing signs of stress from too much atmospheric nitrogen, which also causes vital minerals to leach from soil and acidifies soil and downstream waters. Under these conditions forest health is in serious decline.

have potentially less opportunity for pollutant treatment, less storage capacity to moderate changes in hydrology with urbanization, and a higher potential for direct pollutant delivery to surface waters. The percent wetland area measures this potential treatment capacity and tracks changes in wetland area over time. A very low percent wetland area can be the natural result of sandy soils or an indication of historical wetland loss.

RESULTS: FORESTS AND WETLANDS

- The largely undeveloped Cocumcussoc Brook subwatershed is the only study area with more than 80% forest and wetland, resulting in a low risk of impact due to the positive benefits of these land uses.

- The average percent forest and wetland for all subwatersheds other than Cocumcussoc is less than 50%, putting these areas at high pollution risk based on lack of natural capacity to moderate land development impacts.

- Subwatersheds at greatest risk include the Wickford Cove area, with a total of only 36% wetlands and forest cover. With build-out we optimistically assume that the wetland acreage will remain the same given their protected status under State regulations. With conversion of privately owned forested lots to other uses, the percent forest land could drop to as low as 8-9% in the Wickford Cove and Mill Creek watersheds. With full buildout we estimate that the projected average percent of *both* wetland and forested land could drop to 22% in the Wickford Cove subwatershed and to about 30% in the other developed subwatersheds.

- The Cocumcussoc Brook watershed could experience a drop to about 66% forest and wetland land cover with future buildout, shifting this subwatershed from the low to the medium risk category.

NOTE: Percent wetlands area gauges the generalized water quality benefit of wetlands within a watershed. Wetlands are subject to degradation with increasing sediment, nutrients, and water level fluctuations and cannot be expected to serve as the primary line of defense against unmanaged discharges. Other indicators, such as the percent impervious cover and percent high-risk land use are used to estimate potential impacts to wetland habitat from watershed activities.

4. RISK FACTORS: RIPARIAN LAND USE - HIGH INTENSITY, IMPERVIOUS, AND FOREST AND WETLAND

The riparian (shoreline) buffer zone

We selected a 150' riparian buffer to all surface waters in the watershed as a critical buffer zone for analysis of shoreline features. Riparian simply refers to the shoreline zone, especially where surface and groundwaters may interact. This buffer includes all surface water streams, ponds and coastal waters large enough to be shown on a 1:24,000 scale USGS topographic map. It is important to note that in this study, the buffer is purely for analysis and not a recommended regulatory setback. State agencies or the Town may require more than 150 feet from surface waters and also wetlands. A 150 foot buffer is also a reasonable and defensible *minimum* distance for preventing major water quality impacts from small scale development (Welsch, D. 1991; Desbonnet et al. 1994; and Herson-Jones, L., M. Heraty, and B. Jordan. 1995).

Riparian buffer functions

From a water quality perspective, shoreline buffers to the Harbor, its tributary streams, and also wetlands have the potential to function in two ways: 1) Vegetated buffers can serve as water quality *treatment zones*, maintaining ecosystem health by filtering polluted runoff and removing groundwater nitrogen through biochemical processes; or 2) Disturbed buffers may become high risk *pollutant delivery zones*, especially when intensely developed.

Vegetated shoreline buffers are the last lines of defense for pollutants reaching surface waters. These buffers, especially when *forested*, protect the health of surface waters in the following ways:

- Filter sediment and other runoff-borne pollutants including phosphorus.
- Store floodwaters and infiltrate runoff, particularly with porous *forest* soils.
- Stabilize streambanks, especially with undisturbed *forest* soils and deep rooted trees.
- Remove or recycle nutrients through plant uptake, especially with deep-rooted *trees* and shrubs.
- Maintain cooler temperatures and high dissolved oxygen levels for sensitive aquatic life such as native trout with *tree* canopy cover - a critical function on smaller streams (less than 100' wide).
- Remove nitrogen, potentially transforming up to 80% of groundwater nitrogen into harmless nitrogen gas through microbial activity (Addy, K. et al. 1999).
- Other benefits include open space, recreation, scenic views, and wildlife habitat and/or travel corridors.

We assign a lower tolerance for pollution risks within buffer zones, with more than 15 percent of these land uses considered a high risk

to water quality. More than 95% riparian forest cover is considered a protected buffer, with pollution risk becoming extreme when riparian forest cover diminishes to 60 percent or less of the buffer zone.

RESULTS: RIPARIAN LAND USE FEATURES

- About 20% of the 150' shoreline buffer to streams, ponds and coastal waters in the Wickford Harbor watershed is developed in high-intensity land uses. This creates an extreme risk of direct pollutant inputs to surface waters and limits the potential for buffers to function as treatment zones.

- In the Wickford Cove subwatershed the proportion of high intensity land use is extremely high, covering **46%** of the 150' buffer zone. This concentration of high-risk land uses in the critical buffer zone greatly diminishes the natural treatment capability of shoreline buffers and presents a very serious risk of direct pollutant delivery to surface waters. In comparison, the 150 foot buffer zone to surface waters in the Pawcatuck River watershed has only 5% high intensity land uses.

- Other subwatersheds with developed buffers and extreme pollution risk include the Mill Creek and Mill Cove South subwatersheds. Mill Cove North and Fishing Cove subwatersheds are generally ranked as having a high, rather than extreme pollution risk based on the proportion of the buffer area in impervious cover, high intensity land use, and forest / wetland.

- As expected, the Cocumcussoc subwatershed has a high level of protection from potential pollution sources with undisturbed buffers that are 98 percent forest and wetland.

- Forest and wetland coverage in shoreline buffers throughout the watershed averages only 60 percent, with only 35 percent in Wickford Cove. This is extremely low in comparison to undeveloped areas such as the Cocumcussoc but also compared to more developed systems such as the Pawcatuck River watershed in southern Rhode Island, where wetland and forest comprise 85 percent of shoreline cover throughout the watershed.

- The Fishing Cove and Mill Cove South subwatersheds have the highest proportion of watershed land in the shoreline buffer zone, at 25 and 22 percent, respectively. Educating residents about streambank and wetland management would be a priority in these areas.

B. Natural Landscape Features

1. RISK FACTOR: SOILS

Soil characteristics are perhaps the single most useful natural feature available to predict water flow and pollutant pathways. Using RIGIS data from the Soil Survey of Rhode Island we mapped soils by four standard categories known as hydrologic soil groups. These groups indicate soil permeability, the potential for rainfall to either seep into or run-off the ground surface. Other useful features evaluated include: seasonal high water table depth, presence of restrictive layers such as "hardpan" where downward infiltration is very slow; and erosion potential (based on slope and soil texture) where stabilizing construction sites and other land disturbance may be difficult.

When mapped together, hydrologic soil groups and water table depth reveal likely pathways for water flow and pollutant movement. Sandy soils with deep water table are zones of groundwater recharge where pollutants can easily infiltrate to deeper groundwaters. Slowly permeable soils on the other hand, have low infiltration rates and tend to have high water table. These areas naturally collect surface water and generate runoff. High water table areas are almost always connected to small streams, wetlands, and intermittent drainageways, forming an extended drainage network. As a result of these connections, pollutants generated in these areas can move rapidly to surface waters or to shallow groundwater with reduced chances for removal through natural processes. Septic systems constructed in these slowly permeable soils are also more likely to fail, especially where a dense compacted "hardpan" soil layer restricts downward flow of water. Characteristics of the four hydrologic soil groups are described in Appendix A.8.

Limitations of soil types
Knowing the proportion and location of soil constraints is valuable in predicting pollution risks and in selecting pollution controls. But the effect of soil type in estimating runoff impacts becomes less important in urban areas with extensive drainage alterations or "improvements". Stormwater drainage systems, channelized streams, and artificially drained fields and building sites all bypass natural rainfall storage and infiltration processes and quickly divert runoff to downstream discharge points. These artificial improvements are not identified in this map-based assessment but could be field-inventoried. However, developed watersheds with highly permeable soils may be better suited for stormwater retrofitting because of their higher capacity for natural infiltration.

The Rhode Island Soil Survey mapped and classified soils into 43 different soil series that are alike based on features such as texture and drainage characteristics. Soil series are commonly named for a place where that soil series was first mapped, such as Narragansett silt loam. The Soil Series are further broken down by slope, stoniness, and other features. For example, NaA is Narragansett silt loam where the "A" suffix denotes 0-3 percent slope.

It is important to note the RI Soil Survey is designed as a planning tool and is not intended for parcel-level analysis. A site-specific soil survey would be needed to determine actual soil conditions on a particular site.

RESULTS: SOILS

- Sandy soils found throughout about 50% of the watershed increase the potential that polluted runoff and septic system effluent will rapidly seep into the ground without adequate treatment. Once in the groundwater, dissolved pollutants such as nitrogen, some solvents, and viruses can move relatively unimpeded via groundwater flow paths and discharge into Wickford Harbor.

- The Wickford Cove and Fishing Cove subwatersheds are at greatest risk of pollutant movement to groundwater from sandy soils, with 70% of these study areas classified as excessively permeable. Because these areas are highly developed, storm drainage systems are probably in place and short-circuiting infiltration.

- The Cocumcussoc Brook area is much less sandy than the other subwatersheds (35% sandy soils, compared to the watershed average of 50%). With 22% slowly permeable high water table soils, this area is at greater risk from surface water runoff with future development.

- The Cocumcussoc and Mill Cove South areas are at greatest risk from erosion and sedimentation with more than 20% erodible soils. Stabilizing construction sites and other land disturbance is likely to be more difficult here; proper installation and maintenance of erosion controls would be a priority.

How accurate is that soil map?

General

The soil boundaries delineated in the RI Soil Survey were field-mapped at a scale of 1" = 1,320 feet. At this scale the actual soil boundary on-the-ground may vary by up to 40 feet on either side of the line. The smallest mapped unit is ¼ acre.

Shoreline Buffers

Long narrow bands of soil where upland soils transition to wetland soils along stream shoreline buffers are some of the most challenging to map. All wetlands are valuable but research shows that even narrow bands of hydric (associated with wetlands) soils in stream corridors can function as nitrogen removal zones.

To compare the difference between the mapped vs. actual hydric soil boundaries URI researchers randomly selected 100 stream sites in southern RI and ground-truthed soils within a 30 meter (96 ft.) shoreline stream buffer at each site (Rosenblatt et al. 1999). Results showed that the RI Soil Survey accurately characterized the occurrence or absence of poorly and very poorly drained hydric soils in approximately 75 percent of stream shoreline buffer sites. Even though map accuracy standards recognize the soil boundary may vary up to 40 feet, the band of hydric soils on all sites averaged only 38 feet wide, and less than 22 feet wide in steeper (> 3% slope) buffers.

These findings show that the RI Soil Survey identifies hydric soils in shoreline buffers despite the difficulty in mapping these linear, narrow features. In general, the soil maps are reliable in planning-level analysis, and provides valuable information beyond what might be expected based on map scale in buffer zones.

2. RISK FACTOR: HEADWATER STREAMS

Watershed tributaries are often classified based on their relative position, or stream order. The smallest mapped streams located in uppermost reaches of a watershed are known as first order streams. When two first order streams join together, a second order stream results. The joining of two second order streams forms a third order tributary, and so on. The small first and second order streams, known as headwater streams, generally comprise 70% or more of the stream miles in a healthy watershed. These headwater streams are extremely important in maintaining water quality because they form an extensive *interface between* wetland and upland. Here pollutant removal interactions can occur as surface runoff and groundwater flows to these streams and associated wetlands. This stream network also provides an extensive shoreline buffer zone where there is the opportunity to intercept pollutants from adjacent developable uplands. But because of their small size and abundance in the landscape, these small streams are generally more susceptible to disturbance. They are the first areas to be considered inconsequential. And they are more likely to be impaired through direct disturbance during subdivision construction, secondary backyard "improvements" and by related changes in flow and sedimentation.

RESULTS: HEADWATER STREAMS

In natural resource inventory maps prepared for the Wickford Harbor watershed, USGS-mapped streams are displayed on all watershed maps. The small first and second order headwater streams are easily identifiable on these maps. Protecting these small streams and restoring hydrologic connections where these have been channelized is a priority to maintain the health of Wickford Harbor.

3. RISK FACTOR: POTENTIAL NITROGEN TREATMENT RIPARIAN ZONES

The total proportion of wetlands in a watershed is a generally recognized asset in maintaining healthy aquatic systems. But certain wetlands have the specialized capability to remove nitrogen. Recent studies (Addy, K. et al. 1999). Show that nitrogen in groundwater can be transformed to harmless nitrogen gas when shallow groundwater flows through wetlands and associated buffers where the seasonal water tables is within 24 inches from the ground surface. This interaction can take place as groundwater moves toward and discharges to surface waters provided certain conditions are met. Field studies (Rosenblatt 2000) suggest that wetland

(hydric) soils located in outwash landscapes (glacial sand and gravel deposits), organic material, or floodplains are most effective in performing this function. In these areas groundwater is most likely to move through biologically active zones within about 24 inches of the ground surface. But even in these sites the capacity for nitrogen removal will be limited if deep groundwater flow from the upland moves below the biologically active zone.

RESULTS: POTENTIAL NITROGEN TREATMENT RIPARIAN ZONES

Potential nitrogen-reducing wetlands and associated riparian areas were identified using the RIGIS soils database (hydric soils overlying outwash, organic deposits, or floodplain (alluvium). These areas were displayed using large-format watershed maps. In the

Wickford Harbor watershed, where nitrogen management is important to eelgrass restoration and maintenance of shellfishing habitat, these are critical areas for protection and restoration. Although all wetlands have important water quality functions, these wetlands and associated shoreline buffers have been identified as potentially more effective in nitrogen treatment and are therefore priorities for management as follows:

- Protect riparian zones to maintain potential nitrogen treatment function.
- Restore disturbed wetlands to restore nitrogen treatment potential; establish forested buffers where possible for optimum function.
- Maintain groundwater infiltration to avoid short-circuiting treatment potential with surface runoff.
- Avoid use of subsurface drains to artificially lower water table and bypass shallow groundwater flow.
- Avoid shoreline alterations such as bulkheading.
- Consider pollution source controls (such as nitrogen removal wastewater systems, density restrictions, or nutrient loading limits) in the most high risk areas and where natural removal potential is low.
- Recognize limitations of riparian features – nitrogen removal potential is highly variable and capacity uncertain over time.

C. Runoff and Nutrient Loading Estimates

The runoff and nutrient loading estimates presented in this section are predictions developed using the MANAGE nutrient loading spreadsheet. The spreadsheet uses a standard "mass balance" approach to calculate a simple water budget and estimate nutrient sources to runoff and to groundwater. These analyses are run separately for the full Wickford Harbor watershed and for each of the six subwatersheds evaluated. The input data sources are extracted from the RIGIS map database to include site-specific soils, updated land use, population estimates, and estimated number of septic systems for the Wickford Harbor watershed. The analyses are run first for existing conditions using current land use map data; to evaluate future impacts the analyses are repeated using the future land use map.

We use an average annual precipitation for Rhode Island of 48 inches (NOAA 1999) per year, with 18 inches per year lost to evaporation and plant use. Rainfall data from local long-term weather station records is used to refine statewide estimates wherever possible. The proportion of available precipitation (27 inches) infiltrating or converted to runoff is split using runoff coefficients based on the estimated impervious cover for each land use type and the underlying soil hydrologic group. This is adapted from standard methods (USDA 1986). Recharge to groundwater from septic systems is calculated separately. Nitrogen and phosphorus inputs to surface water are estimated using generalized pollutant coefficients based on current literature values for 21 different land uses and direct atmospheric deposition on surface waters. Nitrate-nitrogen inputs to groundwater recharge are estimated using Rhode Island research data for specific sources, including septic systems, lawns, farmland, pets, and stormwater infiltration in unfertilized areas. The MANAGE hydrologic and nutrient loading assumptions are available at the URI web site http://www.edc.uri.edu/cewq/manage.html (abbreviated version), with full documentation provided in Appendix D, *Technical Documentation, Nutrient-Loading Component of the MANAGE Geographic Information System-Based Risk Assessment Method.*

TECH NOTES: Using models to evaluate land use impacts

Field monitoring and modeling are two basic approaches, often used hand-in-hand to evaluate effects of land use activities on water quality. Water quality models use available information about pollutant interactions and apply it a particular study area to assemble a reasonable picture of watershed or aquifer conditions. Modeling is frequently used to estimate the *source* of pollutants as a supplement to water quality monitoring, especially when field data is sparse or inconclusive. As an alternative to project-by-project impact review, modeling offers a "big-picture" perspective that is needed to evaluate cumulative impacts. Modeling is also a valuable tool in testing relative effects of different land use options or pollution management decisions.

Models can range from the simplest "back of the envelope" calculation, to complex methods that require extensive field data to simulate physical, chemical and biological responses. The nutrient loading component of MANAGE uses a simple "mass balance" method similar to those widely used in comparable applications elsewhere including Cape Cod and the New Jersey Pine Barrens. This method calculates a general water budget based on water inputs (precipitation) and outputs (evaporation and plant use, runoff, and groundwater recharge). Research results of nutrient losses from different land uses are then used to predict nutrient loads from similar land uses mapped in the study area. This incorporates accepted input values from published literature. Our estimates of nitrogen leaching to groundwater are strengthened by use of carefully selected input values derived from local research conducted in sandy soils typical of those of the watershed (supporting literature cited in Appendix D).

Results of MANAGE and many other mass balance models are generated as average annual estimates of runoff, infiltration, and nutrient loading for the study area. These estimates are useful in comparing relative differences in pollution risk among various land use scenarios or among subwatersheds. The nitrogen concentrations entering groundwater can also be estimated based on dilution of inputs with infiltrating rainwater. However, concentration estimates can be misleading because it is difficult to account for nitrogen loss in wetlands or uneven mixing in deeper groundwater.

When basic models generating average annual estimates do not provide the answers needed to evaluate impacts, then a more sophisticated modeling approach is needed. Example applications that call for a more complex model include: generating estimates that can be compared with monitored water quality data; estimating pollutant loads in runoff or flowing waters on a storm event basis; or tracking movement of an effluent plume in groundwater. In order to generate reliable results, complex models typically require extensive field monitoring information as necessary data inputs.

Note on simple vs. sophisticated models

- All models generate results that are only as good as the input values; results of both simple and sophisticated methods are estimates.
- Because output data from sophisticated models can easily appear to be more solid than it actually is, users must be careful to avoid generating false confidence in uncertain results.
- Complex models may not generate more useful data for management, especially when comparing relative differences may be adequate for choosing pollution controls (Center for Watershed Protection 1998).

1. RISK FACTOR: SURFACE RUNOFF

Runoff is not a common natural occurrence. In forested watersheds with sandy soils like the Wickford Harbor watershed, up to 97% of precipitation can be expected to seep into the ground (Simmons and Reynolds 1982). Where the groundwater table is near the surface, water seeping into the soil enters shallow groundwater and flows to nearby wetlands and streams. In well-drained uplands this infiltrating water recharges deeper groundwater supplies which also eventually flow toward streams. In critical periods without rain, groundwater discharge to streams, known as base flow, is the primary source of water to streams.

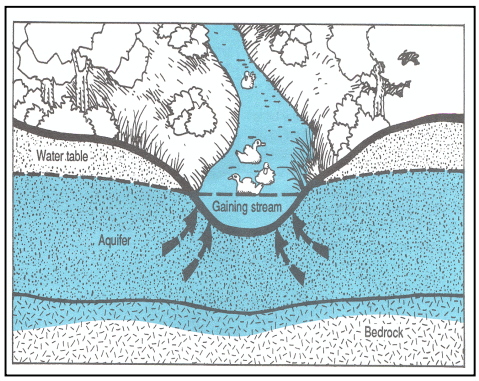


Figure 7. Groundwater and surface waters: one resource.
Within the Wickford Harbor watershed groundwater and surface waters are closely connected. Groundwater within the watershed boundaries generally flow towards and discharge to surface waters, either to tributary streams or directly to the Harbor.

Because ground and surface waters are connected land use activities affect both. Runoff conveys pollutants directly to streams and also drastically reduces groundwater recharge, cutting subsurface water flow to streams and short circuiting natural pollutant removal in soils and wetlands.

Runoff is associated with declining water quality because it disrupts this natural cycle of infiltration with gradual discharge to streams. Land development compacts the soil and adds acres of pavement, dramatically increasing the rate and total volume of stormwater runoff. The result is increased flooding, stream scouring with loss of aquatic habitat, and reduced groundwater recharge. In addition to these hydrologic impacts, stormwater runoff washes off and delivers pollutants directly to the nearest surface waters. Street runoff is contaminated with oil and grease, metals, sediment, nitrogen from atmospheric sources, and other pollutants. Runoff from residential areas carries pesticides, fertilizers, and animal waste. Runoff may also be contaminated with wastewater effluent from failing septic systems, improper connections of sanitary wastes to stormdrains, or leaking sewers.

As a watershed health indicator, surface runoff levels signal potential pollution risks by identifying:

- high runoff zones where hydrologic impacts and runoff pollutants are likely to be greatest;
- relative change in runoff from current conditions, with future development, and with use of stormwater controls; and
- water flow and pollutant movement pathways to support selection of management practices.

RESULTS: SURFACE RUNOFF

- The primary pathway for waterflow in the watershed is groundwater, with about 60% of the available precipitation estimated to infiltrate the ground, and 40% estimated to generate surface runoff.

- The Mill Creek watershed has the lowest estimated rate of groundwater recharge, with about 50% of available precipitation recharging groundwater. The average estimate for the full watershed is 60% infiltration as noted above. In contrast, the full watershed would be expected to infiltrate 95% of available

rainfall if it were fully forested given its soil characteristics.
For comparison: Long term USGS studies in two Long Island watersheds with sandy soils similar to the Wickford Harbor watershed show that groundwater infiltration provided 95-97% of the stream flow when watersheds were undeveloped. As these watersheds became more urban, groundwater infiltration dropped to 87%; after sewering, groundwater recharge, declined more sharply to 40 – 46%, as measured as baseflow to streams. (Simmons and Reynolds 1982)

- The Mill Creek subwatershed which drains a portions of the Rt. 1 commercial strip and the Quonset Point /Davisville Industrial Park generates the most runoff at 13.6 inches /year, compared to the watershed average of 10.4 inches /year. Fishing Cove and Wickford Cove subwatersheds also exceed this average at 11.7 and 11.0 inches/year respectively.

- High intensity land use, which includes dense residential (greater than 4 dwelling units per acre), commercial and industrial, highway, and tilled farmland comprise only 27% of the total land area in the Wickford Harbor watershed but are estimated to contribute 65% of the stormwater runoff in the watershed.

- Commercial and industrial lands contribute more than their "share" of runoff among the high intensity land uses, comprising 15% of the total Wickford Harbor watershed area but contributing 40% of the runoff to the watershed.

NOTE: Based on an annual average precipitation of 48 inches for the Wickford area we estimate that almost half (21 inches) is lost through evaporation and use by plants (transpiration). The remaining 27 inches of rainfall are available to either seep into the ground or runoff the surface. For the full Wickford Harbor watershed we estimate that 10.4 inches of this available water will become surface runoff and 16.6 inches will seep into the ground. Septic system effluent is estimated to contribute an additional 1.1 inches to the full watershed each year. Full hydrologic and nutrient loading results are included as an attachment to this report.

2. RISK FACTOR: NUTRIENT LOADING

Nitrogen as a pollution indicator

The total amount or "load" of nutrients generated in the watershed is used as one measure of pollution risk. Estimates were generated for both nitrogen and phosphorus. We focus on nitrogen for the following reasons:

- Nitrogen contaminates drinking water, interfering with oxygen absorption in infants and causing other health effects. The federal health standard for the nitrate form is 10 mg/l. North Kingstown and other towns use 5 mg/l as a safety margin.
- Nitrogen is associated with human activity such as fertilizers and septic systems at groundwater nitrogen levels over 1 mg/l. The natural background level in RI groundwater is very low at 0.2 mg/l.
- Nitrogen overfertilizes coastal waters, leading to excessive growth of nuisance seaweed and algae, low dissolved oxygen events, loss of eelgrass, and declining shellfish in Wickford Harbor. Healthy coastal waters generally have very low nitrogen, far below drinking water standards, near background levels.
- Nitrogen moves easily in surface and groundwaters, and can indicate the presence of other dissolved pollutants such as bacteria and viruses, road salt, and some toxic chemicals.

TECH NOTE: Interpreting nutrient loading estimates

Nutrient sources to the Wickford Harbor watershed were estimated as a total average annual amount, or loading (pounds per year) generated from the whole watershed and from each of the six subwatersheds. Our predictions are modeled ***estimates*** based on site-specific land use and soil conditions in the Wickford Harbor watershed. We use well accepted values for nutrient inputs from various land uses based on 1) field research on nitrogen losses to groundwater from septic systems, lawns, agriculture, and forests conducted in southern Rhode Island by URI scientists; and 2) current published literature values for surface runoff (Appendix D). Because groundwater inputs are based on extensive and reliable local data, we have more certainty in nitrogen leaching estimates to groundwater than nitrogen inputs to surface runoff.

Nutrient source estimates are sensitive to the number of homes and businesses in the watershed with septic systems, and the acreage of different land use types in the watershed. To refine our estimate, we updated land use using corrections mapped by the Conservation Commission, and incorporated US census data and building permits to refine occupancy estimates per dwelling unit.

These estimates represent ***sources*** of nitrogen at the *point of origin*, not the amount that might ultimately reach a groundwater aquifer, pumping well, a stream, or the Harbor. The nitrogen inputs to surface water represent the amount entering surface runoff at the point where runoff is generated; nitrogen inputs to groundwater represent the amount of nitrogen percolating into groundwater with precipitation and septic system effluent. The actual amount that might ultimately reach a well or the Harbor is likely to be less.

The estimates do not consider a number of factors such as: concentrated plumes of effluent where nitrogen levels may be much higher than average per acre loadings; the effect of storm events; other pollutants such as spills from underground storage tanks; and nitrogen uptake through natural processes.

The opportunity for nitrogen uptake is greater in large watersheds with abundant wetlands, where shoreline buffers have high nitrogen removal potential, and where pollution sources are further removed from sensitive receiving waters. The potential for nitrogen removal is lower in wellhead areas where nitrogen enters groundwater as recharge to a pumping well without treatment in wetlands. In these wellhead areas we assume that over time the quality of the underlying groundwater will begin to reflect the quality of recharge water entering the wellhead.

Modeled nutrient estimates are most useful in comparing relative differences among land use types, among subwatersheds, between current and future land use, and in comparing potential reductions in nutrient inputs with use of management practices.

The concentration of nitrogen in groundwater entering the Harbor may be more representative of past land use rather than current nutrient inputs given the slow travel time for groundwater throughout the watershed to reach the Harbor when groundwater flow is typically measured in inches per day.

RESULTS: NUTRIENT LOADING

- The total amount of nitrogen entering Wickford Harbor from all sources is estimated to be about 73,400 pounds per year, with groundwater recharge contributing the largest proportion at 75 percent. Primary sources of nitrogen are listed below.

Sources of Nitrogen to the Wickford Harbor Watershed	Percent Contribution	Nitrogen (pounds per year)
Groundwater recharge	75 %	56,000
Surface runoff	20%	14,100
Precipitation to Wickford Harbor	5 %	3,300
Total	100 %	73,400

- Septic systems are the major source of nitrogen to groundwater in the Wickford Harbor watershed, contributing an estimated 80% of the nitrogen entering groundwater throughout the watershed.

- Estimated sources of nitrogen to groundwater are listed below. These proportions vary only slightly among watersheds, with septic system contributions ranging from 74% in Cocumcussoc Brook watershed to a high of 85% in Mill Cove South. Lawn fertilizer inputs range from 8-12%, Contributions from pets and agriculture are generally low in all areas.

Sources of nitrogen entering groundwater recharge*	Percent Contribution	Nitrogen (pounds per year)
Septic systems	81 %	45,600
Lawns	10 %	5,600
Agriculture	< 1 %	400
Pets	5 %	2,600
Other	3 %	1,800
Total	100 %	56,000

NOTE: Estimated inputs for septic systems in commercial and industrial areas are comparable to medium density residential uses and may be low based on the type of activity, number of employees, and amount of water used. Other estimates assume reasonable management practices. Inputs may be much higher where lawns are overfertilized, overwatered, where fertilizers are spilled or otherwise wash into stormdrains in addition, nutrients and bacteria inputs arelikely to be comparatively high where pet wastes on curbs and sidewalks wash directly into stormdrains and where bird and wildlife wastes flow directly from

* Because surface water nitrogen sources are calculated using generalized nutrient loading coefficients based on land use type, it is not possible to break down the surface runoff nitrogen inputs by pollution source as calculated here for groundwater recharge inputs.

- The Wickford Village area (Wickford Cove and Mill Cove South subwatersheds) and the Fishing Cove subwatersheds have the highest estimated per acre loading of nitrogen to groundwater. With estimated inputs ranging from 21.2 to 23.7 pounds per acre annually, these inputs to groundwater recharge are generally twice as high as the other developed watersheds and the watershed average. This is not surprising for Wickford village; we attribute high loadings in Fishing Cove to septic systems from dense unsewered residential development. All three of these subwatersheds also have the highest septic system densities per acre, at about 1.2 systems per acre.

- Nitrogen inputs to groundwater from septic systems may be underestimated in areas with extensive commercial and industrial use such as Mill Creek, Mill Cove North, and Wickford Cove subwatersheds. We estimate a wastewater nitrogen concentration in domestic septic system effluent at about 40 mg/l, which is slightly low compared to levels monitored by URI researchers under similar flows. However, recent MA DEP studies have found commercial wastewater nitrogen concentrations can be as high as 100 mg/l. The authors attribute this to use of ammonia-based cleansers (Higgins and Groves 1999) as one likely cause; lack of dilution could be another factor.

- The three subwatersheds with highest nitrogen inputs to groundwater – Wickford Cove, Mill Cove South, and Fishing Cove – also have the highest nitrogen inputs to surface runoff, with Mill Creek a close fourth. Estimated per acre average annual nitrogen inputs to surface runoff in these subwatersheds range from 3.3 pounds per acre annually in Mill Creek to 4.5 pounds per acre annually in the Fishing Cove subwatershed.

- The projected future increase in nutrient loading for the full watershed is relatively low, with nitrogen inputs to groundwater recharge and surface runoff estimated to increase by an average of 11 and 13 percent higher than present levels, respectively. The highest increases are expected in the Mill Cove North subwatershed, where groundwater nitrogen concentrations are estimated to increase 32% to 14 pounds per acre annually. These levels are still well below the estimated inputs in the highest-contributing subwatersheds where inputs exceed 21 pounds per acre.

- Although the potential increase in nutrient loading is relatively low, any increase is a concern for the following reasons:

1) Present estimated nutrient inputs are extremely high;

2) Harbor waters are already showing signs of stress from existing pollution inputs; and

3) The full effect of present inputs has most likely not been seen given the lag time involved with the slow movement of groundwater flow to the Harbor-for example, new pollution sources infiltrating groundwater today may eventually discharge to the Harbor several years in the future.

The relatively high proportion of nutrient inputs from current land uses underscores the need to manage existing sources while also taking advantage of every opportunity to control future inputs with new development or redevelopment.

D. Map Analyses of Pollution Risks

Map analysis of land use and landscape features helps target the site-specific location of pollution sources and other features that can increase or minimize pollution risk, such as the presence of riparian shoreline treatment zones. This map analysis supplements the information on pollution risk indicators summarized above, which are calculated as averages for different land use types, or study areas, not by geographic location. In this section we briefly summarize the type of analyses conducted. Results are provided to the town as large-format maps that are not easily reproduced here. A full list of natural feature inventory maps, pollution "hotspot" maps, and other map analyses are provided in Appendix A.4.

NOTE: It is important to emphasize this is a rapid, screening-level analysis. The soils and land use information used are suitable for planning level analysis only and are less accurate for small areas and at boundaries of mapped data layers created at different scales, such as the overlay of soil types, wetlands included under the land use coverage, and stream boundaries. In addition, mapped high runoff areas are overshadowed by man-made drainage alterations. Follow-up field investigations would be needed to verify land use, soil conditions, and presence of potential pollution sources.

1. MAPPED RISK FACTOR: POLLUTION SOURCE HOTSPOTS

Contrary to popular belief, pollutants from land use activities – so called 'nonpoint source pollution" are not diffusely spread throughout the landscape in random or unpredictable patterns. In fact, much of this "nonpoint" pollution can be traced to: 1) intense land use activities that generate the most pollutants; and 2) natural features such as soil types and shoreline buffers that promote pollutant movement, either to surface waters via stormwater runoff or to groundwater with infiltration. Both these land use and natural features are generally well mapped, at least at a planning scale.

Using these known patterns, we can overlay high intensity land use and problem soils to rapidly pinpoint pollution "hot-spots" – high-risk areas for movement of pollutants to either groundwater or surface waters. These hot spots generally comprise a relatively small land area but contribute the large majority of pollutants. Directing management actions to the most serious problem sites, can be a cost-effective way to prevent or remediate pollution problems.

RESULTS: POLLUTION SOURCE HOTSPOTS

The Pollution source hotspots analyses completed for the Wickford Harbor watershed included the analyses listed below.

	Type of map analysis	Information generated
Groundwater hotspots	High intensity land use overlying rapidly permeable soil	Identifies higher risk areas for pollutant movement to groundwater.
Surface water hotspots	High intensity land use overlying high water table soils (0 –3.5 feet from ground surface)	Identifies higher risk areas for pollutant movement to surface waters or shallow groundwater.
Shoreline buffer hotspots	Unvegetated shoreline buffers (150 feet) to surface waters.	Identified higher risk areas for direct pollutant movement to surface waters

2. MAPPED RISK FACTORS: BUILDING AGE AND SEPTIC SYSTEM REPAIRS

A parcel-level analysis of septic system risks was conducted in the central Wickford Village area. This area, which corresponds to the Wickford Harbor and Mill Cove South subwatersheds, is the most densely developed and is also situated immediately adjacent to poorly flushed areas of the Harbor. Eight CAD-based North Kingstown Plat maps were converted to GIS format and linked to assessor's data. This analysis examined built and vacant parcels and building age. DEM septic system repair records were also address-matched townwide. Full results, including analyses of population density and septic system counts for the study area are included in the Appendix A.5.

RESULTS: BUILDING AGE AND SEPTIC SYSTEM REPAIRS

Village parcel data

- Approximately 926 developed plats are located in Wickford Village. An additional 212 parcels were coded as vacant and may be developable; no coding was assigned to 111 other lots. Since this analysis, the town has identified merged lots and wetland areas that are undevelopable.

- Of the 926 developed parcels, 78% (722 parcels) were developed before 1970. These predate adoption of DEM minimum standards for onsite wastewater disposal and are more likely to be cesspools or other substandard systems *without taking into account repairs.*

Septic system repairs / substandard systems

- Using DEM repair permit records since 1980, we successfully matched addresses and mapped approximate locations of 820 permits for septic system repairs townwide. Of these, 244 are in the Wickford Harbor watershed and about 70 are in the Wickford Village area.

- If we assume all septic system repairs in Wickford Village were conducted on lots built before 1970, then approximately 650 substandard septic systems would remain. This is a conservative estimate since the repairs are not necessarily only on pre-1970 systems, suggesting that the number of substandard systems might be higher.

- The estimated proportion of substandard systems in the Wickford Village area – at 70%, is extremely high. The average for the town is likely to be much lower. The dense development, in combination with the potential number of substandard systems presents a very high risk of contamination from untreated effluent. Because much of the watershed has sandy soils, septic systems may be failing by discharging untreated effluent to groundwater without obvious signs of failure, such as slow drains and surfacing of effluent in drainfields.

E. Other risk factors – Pollution sources, hydrologic modifications, and natural vulnerability.

1. MISCELLANEOUS POLLUTION SOURCES

A variety of contaminant sources may exist in the watershed that are not specifically addressed in this assessment. A number of these are mapped and can be located through map inspection. But whether or not they are specifically identified, impacts are typically difficult to assess. A list of these potential pollution sources, hydrologic modifications that can degrade aquatic habitat, and other potential stressors are provided here as a checklist for consideration. Potential impacts must be determined on a case-by-case basis.

- Livestock waste storage and spreading – horse farms, dairy cows, kennels, and other concentrations of animals can be a significant source of nutrients and bacteria when animals have access to surface waters and wetlands or when animal wastes are not properly stored. Based on past experience, we include pasture as a high intensity land use in pollution hotspot mapping. Even though unfertilized pasture is likely to have nutrient inputs as low as forest, we include these areas as a reminder to consider whether large animals may be present.

- Unusual concentrations of waterfowl have been considered a source of bacteria in some waterbodies.

- Marinas and moorings. No-discharge regulations now apply throughout in-shore Rhode Island waters but even a small percentage of violators can increase bacteria counts. Boat maintenance activities and refueling are also potential sources.

- Boating. Marine two stroke engines power the majority of outboards and jet skis. These motors discharge 20-30% of their fuel straight into the water, unburned. (NEIWPCC 1999)

- Point sources such as hazardous waste sites, underground storage tanks, contaminated sediments, abandoned landfills, and many others have been mapped using RIGIS data as either known or potential pollution sources. Impacts of these are highly site-specific and related to management practices used to prevent or remediate pollution.

2. HYDROLOGIC MODIFICATIONS AND OTHER STRESSORS

Changes in natural water flow patterns, such as increased runoff, act as water quality "stressors" by physically impairing stream habitat. Although not actually a source of contaminants, hydrologic changes can result in higher pollutant inputs by altering natural pollutant treatment pathways. In this analysis we did not specifically identify and map these stressors. Further map/ field inspection by individuals with local knowledge of the area, would be needed to identify potential problem areas.

- Urban stormwater drainage systems short circuit natural water flow and pollutant removal processes. Direct tie-in of sanitary wastes to stormdrains can be an associated contamination source, especially in older settlements such as Wickford Village. Illicit connections have been documented in Wickford Village (personal communication, George Loomis, URI Onsite Wastewater Training Center).

- Subsurface drains installed in farmland and building lots to lower water tables can serve as a conduit for untreated runoff, carrying fertilizers and untreated effluent to downstream discharge points, especially in high water table areas where the practice may be widespread. These areas should be identified and impacts evaluated at least through observation.

- Dams may obstruct fish passage and alter habitat both upstream and below. Slower flows behind dams allow contaminated or nutrient-rich sediments to accumulate behind the impoundment, increase water temperature, and promote growth of nuisance algae and aquatic plants.

- Water withdrawal with associated low stream flow during summer periods is a growing concern in some rapidly growing areas where various uses compete for limited water supplies. Similarly, loss of recharge through out-of-basin water supply lines or sewer service can be an additional source of stress.

- Invasive species, such as the wetland plant purple loosestrife and some submerged aquatic plants, can outcompete native species and impair aquatic habitat. The invasion of Common Reed *(Phragmites australis)* into coastal areas can indicate disturbance of hydrologic conditions as well as human induced nitrogen loading. Herbicide applications or raking for weed control can also have detrimental side effects.

3. EXISTING CONDITION AND VULNERABILITY OF A WATERBODY

The existing condition of priority water resources is summarized using available monitoring data, plans, and studies in Part III of this report. Additional map inspection can be useful in identifying other characteristics that can shed light on the existing conditions and natural vulnerability of a waterbody to impact.

Flushing – No studies have been conducted to estimate flushing rates, but portions of the Cove appear to be poorly flushed, allowing nutrients to accumulate in the Harbor before flowing out to more open waters of Narragansett Bay. Factors likely to lengthen flushing time include:

- Manmade flow constrictions such as the old railroad grade upstream of the Hussey (Rt.1) bridge in Wickford and the Loop Drive culverts;

- The constructed breakwater sheltering the Cove that, by local observation, may have changed historical flushing patterns; and

- A highly convoluted shoreline with many shallow inlets in upper reaches of the Cove relatively distant from the ocean outlet. In addition to possibly retarding flushing, this highly irregular shoreline increases the interface between the land and water, increasing opportunity for direct pollutant movement from developed shoreline areas.

V. Analysis of Management Options

1. CHANGE IN RUNOFF AND NUTRIENT LOADING WITH MANAGEMENT PRACTICES

We evaluated the potential change in runoff and nutrient loading expected with use of pollution controls in different parts of the watershed. These scenarios were selected with input from the local committee as hypothetical but reasonable options based on available technology. The management scenarios were tested using the MANAGE nutrient loading spreadsheet, which allows the user to input land use acreage receiving different pollution control treatments. The results compare which management practices are potentially most effective in reducing nutrient inputs. The treatment options evaluated in this assessment are listed below:

Stormwater Management

- Treating polluted runoff to remove 45% of nitrogen through use of stormwater treatment systems such as wet retention basis or created wetlands.
- Reducing runoff and nutrient loading by reducing impervious cover by 20% through use of more creative development designs.

Wastewater Management

- Improved maintenance of conventional systems with reduced risk of direct discharge of untreated effluent to surface waters from failing systems.
- Use of alternative systems reducing nitrogen inputs to groundwater by 50%.
- Central collection with elimination of wastewater nitrogen from the watershed.

Various scenarios were applied throughout the watershed and also for selected subwatersheds with comparatively high inputs, where targeting the most serious pollution sources may be more cost-effective. Changes in management of farmland, lawns, and pet wastes were not evaluated because these inputs were comparatively low. Nitrogen inputs from lawns and pet wastes can also vary widely depending on site-specific practices that are difficult to estimate. It is important to note that our predictions consider only the change in nitrogen, not the many other pollutants generated by land use activities such as pathogens, solvents, hydrocarbons, pesticides, sediment, hydrologic changes, etc.

RESULTS:

1. Maintenance and repair of conventional septic systems:

- Can eliminate direct discharges of untreated effluent to surface waters and groundwater from failing systems.
- Reduces the most serious public health risks from bacteria and viruses.
- Does not reduce estimated nitrogen inputs because properly functioning septic systems are designed to discharge nitrogen to groundwater.
- By infiltrating wastes, may allow limited wastewater treatment through natural processes under favorable site-specific circumstances.
- May be ineffective unless cesspools are also phased out, especially in Wickford Village, where at least 70% of homes were built before adoption of State septic system standards in 1970 and are likely to have a cesspool or other substandard system.

2. Use of advanced wastewater treatment systems:

- The only onsite treatment option that can remove nitrogen to protect the long term health of the Harbor and also assure pathogen treatment without relying on uncertain removal of bacteria and viruses in highly permeable soils characteristic of the watershed.
- May be the only feasible repair option on difficult lots.
- Avoids use of fill with retaining walls, with resulting expense, site disturbance, and visual impact of conventional mounded systems that would otherwise be required on difficult sites.
- Using denitrification systems in the Wickford Cove and Mill Cove South subwatersheds (Wickford Village) could reduce average nitrogen inputs to groundwater from about 22 pounds of nitrogen per acre annually to about 14 pounds of nitrogen per acre each year, a reduction of about 40% in Wickford Village. The watershed-wide benefits if nitrogen removal systems only in Wickford Village would be a decline in average nitrogen inputs to groundwater from 12.5 to 10.7 pounds per acre /year. In practice, it would be more realistic to use advanced treatment systems in the most critical shoreline areas and problem sites in Wickford Village and in other subwatersheds.

3. Onsite versus offsite wastewater treatment

Because septic systems are the major source of nitrogen to Wickford Harbor our review of management options focused on onsite wastewater treatment alternatives. The Town advisory group made it clear to us that sewer extension is neither a realistic nor feasible option for Wickford Harbor. But because the town wastewater management plan includes central collection as one wastewater treatment option for selected areas of the town, we included sewering with offsite wastewater treatment as a strictly hypothetical option to compare the maximum nitrogen reduction potential from out-of-basin wastewater treatment with advanced on-site treatment systems.

Advanced treatment systems can remove **50%** of nitrogen in effluent through treatment, and are the most effective **on-site** method for reducing nitrogen inputs in the watershed. Sewers can transport **100%** of the effluent from the watershed but this is not treated at the wastewater treatment plant as described below, have other associated impacts that offset these benefits. Nutrient loading estimates show that widespread use of advanced treatment systems begins to approach the nitrogen reduction levels possible with sewers, as summarize below.

Because it is not realistic to assume that sewers would be available exclusively for Wickford Village without allowing tie-in businesses and homes along Rt. 1 from the existing line near Quonset, we were unable to compare sewers vs. denitrifying systems directly for the same areas. Similarly, sewer extension throughout the whole

Nitrogen Concentrations

Standards

10 mg/l Drinking water standard

5 mg/l North Kingstown groundwater standard

1 mg/l A sign of human activities influencing groundwater.

Natural levels

0.2 mg/l Natural background level in Rhode Island groundwater.

N in healthy coastal waters – varies but is generally very low, near background levels.

Wastewater effluent

40 –60 mg/l Effluent from standard septic system

< 20 mg/l Treated effluent from nitrogen-reducing septic system.

NO LIMIT for Quonset Point and other Wastewater Treatment Facilities.

NOTE on Concentration vs. Loading: The concentration of nitrogen can be relatively low (for example, the Quonset Point effluent is relatively dilute at under 10 mg/l). In comparison, the nitrogen concentration in septic systems averages about 40 mg/l or higher. But when low concentrations are combined with high flows, the total amount, or loading of nitrogen (concentration x flow = load) can still be high.

To protect nutrient-sensitive waters such as Wickford Harbor, the total **loading** of nitrogen from all sources must be considered, rather than the concentration alone.

watershed would also be unrealistic given the cost in less developed neighborhoods. The following table therefore provides a comparison that is equalized in terms of pounds of nitrogen per acre but for different parts of the watershed.

Wastewater Management Options	Nitrogen loading to groundwater Wickford Harbor Watershed (average pounds per acre per year)
Current Wickford Harbor watershed	12.5
Nitrogen removal systems only in Wickford Village	10.7
Sewering Wickford Village and Route 1	7.7
Nitrogen removal systems throughout the watershed	7.9

Removing wastewater nitrogen from the watershed through sewering or other central collection method can potentially reduce groundwater nitrogen loading to the lowest levels but benefits can be more than offset by other serious environmental consequences:

- Sewering can potentially remove the largest proportion of nitrogen, at least within the service area, but these gains can be offset by more intense development, increased fertilizer inputs, increases in polluted runoff, and changes in stream hydrology with further increases in impervious surfaces.

- Sewering transports wastewater out of the basin for direct discharge to Narragansett Bay, eliminating a valuable source of recharge to groundwater. The resulting loss of recharge reduces stream flow in critical low flow periods and reduces the amount of fresh water available to flush the Harbor. As older sewer lines begin to leak there is the potential for discharge of nitrogen to groundwater, and also increased groundwater export from the basin as groundwater infiltration increases as pipes age.

- Advanced onsite treatment systems remove nitrogen by converting it to harmless N2 gas; sewer options divert wastes directly to Narragansett Bay without removing nitrogen. For example, the Quonset Point wastewater treatment facility currently has no limit on either maximum nitrogen concentrations or total nitrogen loading.

- The Wickford Harbor watershed is much more poorly flushed than the Bay area receiving the Quonset Point treatment plant discharges; however, pollutant inputs from the plant are directly discharged, with 100% delivery to Bay waters. In comparison,

Comparison of nitrogen inputs from septic systems vs. the Quonset Point Wastewater Treatment Facility:

*The total average annual discharge from the **Quonset Point wastewater treatment facility** is approximately 26,800 pounds per year based on a wastewater nitrogen concentration of 9.77 mg/l at an average annual flow of 0.9 MGD (RIDEM 1999). This is about **60%** of the total nitrogen loading from all septic systems throughout the Wickford Harbor. The permitted flow limit is 1.78 MGD – about twice the actual 1999 flow.*

Assuming the concentration of nitrogen remained constant, the potential future nitrogen discharge could double to almost 53,600 pounds of nitrogen per year. This amount is well above the nitrogen contribution from all septic systems in the entire Wickford Harbor watershed; it is equivalent to 96% of estimated nitrogen inputs to groundwater from all sources in the watershed, including fertilizers and pets for example.

These estimates do not take into account polluted runoff, which is proportionately higher in commercial and industrial land uses compared to other areas.

estimated inputs from watershed land use are estimates of pollution sources without considering uptake by natural processes, which, under the right conditions, can be as high as 80%. The effect of nitrogen discharges from the Quonset Point treatment plant on the health of Narragansett Bay or Wickford Harbor is unknown, making nitrogen limits difficult to establish.

4. Stormwater Treatment

Retrofitting existing drainage systems with stormwater treatment systems can potentially remove up to 45% of nitrogen in runoff. The most effective methods for reducing nitrogen concentrations are generally permanent wet basins that allow sediment settling and also provide biological removal of dissolved pollutant such as nitrogen. Infiltration following solids settling provides additional benefits by restoring groundwater recharge and also providing opportunity for nitrogen removal through shallow groundwater flow in wetlands and associated shoreline areas. Our nutrient loading estimates can predict the potential removal in the stormwater basin but not the additional benefits of recharge and wetland treatment, which are potentially greater.

In the Wickford Harbor watershed the average annual nitrogen loading to surface runoff is 4.6 pounds per acre /year. Retrofitting stormwater systems for water quality treatment only in the Mill Creek subwatershed would potentially reduce this average loading to 4.1 pounds per acre/year. Although this is a relatively small amount, the localized benefits just in the Mill Creek watershed would be much greater, and more widespread retrofitting in other watershed locations would also expand benefits. It is important to note that our estimates are unable to calculate benefits of restoring infiltration and subsequent nitrogen removal in wetland treatment areas.

Ensuring high nitrogen removal with new stormwater discharges in combination with retrofitting existing storm drains offers the greatest potential to reduce nitrogen loading in runoff. For example, the projected nitrogen loading to surface runoff in the Mill Cove North subwatershed is 5.1 pounds per acre /year with future development. With stormwater treatment only in new high intensity land use this could potentially be reduced to 4.5 pounds per acre/year. The most significant reduction would occur with both future controls and retrofitting existing stormdrains serving high intensity land use, resulting in a reduction to 3.6 pounds per acre annually.

5. Cost Comparison of Stormwater and Septic System Improvements

Developing cost estimates for upgrading septic systems and for installing stormwater treatment systems is inexact at best given the site-specific factors involved. To compare the cost effectiveness of

both types of controls in reducing nitrogen inputs from the Wickford Village area, we developed very rough estimates for both management options using local construction costs. Using the modeled nutrient loading estimates, we then estimated the cost per pound of nitrogen removed by septic system upgrading vs. stormwater treatment. We chose Wickford Village because the Wickford Cove and Mill Cove South subwatersheds that correspond to the Village center have nitrogen loading rates (per acre) to groundwater recharge and to surface water runoff that are among the highest in the watershed.

Stormwater runoff treatment

Locating stormwater facilities to treat the most highly contaminated runoff from high intensity development is most cost effective since construction costs are based on the drainage area served. Targeting direct stormwater discharges to the Harbor also makes sense, since these have no potential for pollutant removal through natural processes with overland flow or infiltration before entering the Harbor. In the Wickford Village area (about 940 acres) approximately 380 acres are developed in high intensity land use and would, we estimate, need stormwater runoff treatment. Assuming stormwater retention basin construction costs of $3,000 per acre treated, the total construction cost would be $1,140,000. At 45% removal of nitrogen potentially, the cost of removing nitrogen averages about **$53** per pound of nitrogen treated, based on construction costs averaged over 25 years. This estimate does not include land acquisition cost or maintenance; if maintenance is included, the cost may be double.

NOTE: According to leading stormwater managers (Schueler 1999) stormwater ponds, wetlands and filtering systems for treating stormwater runoff are some of the most expensive watershed protection tools. They estimate the basin construction costs at $2,000 to $50,000 per acre. These estimates do not include the cost of land. Maintenance, necessary for optimum water treatment performance and longevity, is roughly equal to the initial construction cost, spread out over a 20-25 year estimated life span.

Advanced wastewater treatment

Upgrading septic systems in the Wickford Village area would require use of advanced treatment systems to remove 50% nitrogen and enhance pathogen treatment. Alternative systems may also be the only feasible repair option on difficult sites with very small lots and site constraints. Assuming 650 systems require upgrading (those predating 1970 standards without DEM repair permit). We estimate an additional cost of about $5,000 for an advanced treatment system compared to a conventional system (actual costs may be higher depending on site conditions; conventional system costs are frequently higher than alternative systems on difficult sites due to fill requirements. Combined with maintenance expenses of $200 per year over 25 years, the final cost would average annual cost of $400 per system. The resulting cost effectiveness is **$40** per pound of nitrogen removed on a per acre basis, which includes annual maintenance.

Based on this simple comparison, reducing nitrogen inputs through wastewater treatment may be more cost effective than stormwater treatment systems; however, all potential management options

should be considered, especially where stormwater improvements can be made cost effectively as part of new construction or redevelopment. The full cost comparison is provided in Appendix A.6.

VI. Summary Findings and Recommendations

A. Water Quality Goals and Concerns

Based on review of town plans, other available studies, and local advisory group input.

Wickford Harbor supports a remarkably wide range of uses, from high-intensity boating to shellfishing and swimming.

State regulations, Town plans and Conservation Commission policies strongly support maintaining water quality for safe boating, existing swimming and shellfishing use, restoring healthy aquatic habitat, and safeguarding groundwater supplies within the watershed.

Intense use of the Harbor and surrounding watershed, both now, in the past and in the future, are recognized but unquantified threats to continued support of existing uses. Specific concerns include:

- Polluted runoff and failing septic systems with industrial, commercial, and intense residential use;
- History of extensive wetland filling and waste disposal at the Quonset Point/Davisville Naval Base whose present day impacts are not fully known; and
- Marina use with potential accidental discharges of fuel, anti-fouling compounds, boat washing, and less than full compliance of the no-discharge regulations.

Public health is a concern with increasing use of the Harbor by kayakers, sailors, fishing, and occasional shellfishing and swimming use by visitors to Wilson Park and near the various docks, bridges and coves throughout Town.

Safe and sanitary disposal of wastewater to accommodate downtown businesses and homeowners is a longstanding concern. A related issue is the need to support continued economic development of the Wickford Village business district while maintaining its historic and scenic character and associated environmental qualities.

B. Summary of Existing Water Quality Conditions

Based on review of town plans, RIDEM reports, analysis of Save the Bay monitoring data, and local advisory group input.

NOTE: Water quality for safe shellfishing and swimming is based primarily on measurements of fecal coliform bacteria – a harmless organism that indicates the presence of disease-causing pathogens.
The general health of a waterbody is often measured by how enriched it is with nutrients and other pollutants. Standard measures of general aquatic health include: dissolved oxygen, clarity, excessive growth of algae, and presence of healthy eelgrass beds.

SAFETY FOR SWIMMING AND SHELLFISHING

The Harbor is considered safe for shellfishing and swimming in designated areas based on *only one bacteria monitoring station* located in a well flushed area near the mouth of the Harbor that does not represent the many poorly flushed Harbor areas. Additional fecal coliform monitoring would be needed to fully address public health concerns with primary contact recreation in coves and near-shore waters. Existing monitoring data for other pollutants, combined with the preponderance of substandard cesspools adjacent to the shore, suggest a likelihood that expanded fecal coliform monitoring would indicate safety and water quality concerns.

GENERAL AQUATIC HABITAT AND NUTRIENT ENRICHMENT

Monitoring and aerial surveys document that eelgrass – a measure of the Cove's health, is in decline. Historically extensive eelgrass beds are now limited to small areas of the Cove. The reasons for this decline are uncertain but are likely the combined result of excessive nutrients to the Harbor and restricted flushing.

Save the Bay monitoring documents that Harbor waters are showing signs of stress. Water quality sampling and observations over the last 6 years document concentrated growth of algae and poor water clarity in some coves, with dissolved oxygen occasionally dipping below safe levels for fish and other aquatic life.

RIDEM considers the habitat quality of Wickford Harbor to be "threatened" based on occasional low dissolved oxygen levels. This occurs in poorly flushed areas as overabundant algae die off, decay, and consume oxygen.

Water clarity and nutrient enrichment

- Water clarity is an indicator of the "health" of a waterbody. Simple measurements of water clarity show that Wickford Cove waters are periodically clouded with excessive growth of algae, microscopic aquatic plants that thrive with overfertilization. More than a purely aesthetic matter, poor water clarity reduces the chance that established eelgrass beds and transplanted seedlings will survive.

- Wickford Cove, Hussey Bridge, and near Rabbit Island are considered to be overfertilized based on a standard index comparing water clarity with nutrient levels. This is cause for concern, especially since nutrients can accumulate in sediments and continue to recycle internally, making water quality improvement difficult to achieve even when nutrient inputs are reduced.

- Nitrogen is the basic nutrient considered responsible for overfertilizing Harbor waters. There is a great deal of uncertainty about how much nitrogen the Harbor can safely assimilate. The amount of nitrogen reduction needed to bring about a noticeable improvement in water clarity is also unknown. Flushing studies that measure how long water stays in the Harbor before flowing out to the Bay can help determine how sensitive the Harbor is to nitrogen. But depending on the method used these investigations can be costly and results inconclusive.

- Probable sources of nitrogen and other pollutants include failing or substandard septic systems and cesspools, lawn fertilizers, live stock and other animal waste runoff to surface waters, and stormwater runoff from commercial and highway sources, as described in Section IV of this report.

STREAM WATER QUALITY

- Streams flowing through developed portions of the watershed carry much higher nitrogen loads into the Cove than Cocumcussoc Brook, which drains an undeveloped watershed.

- Stream monitoring in Mill Brook at Camp Avenue and at the mouth of Cocumcussoc Brook clearly shows the effect of watershed development on stream water quality. In spring wet weather very high stream flows in the undeveloped Cocumcussoc Brook watershed *dilute* pollutants to very low levels. In contrast, high flows in the developed Mill Brook watershed *wash* pollutants into the stream at levels five times higher than in the Cocumcussoc on a per acre basis.

C. Summary of Watershed Pollution Risks

Based on map analysis of current land use and landscape features, "build-out" analysis predicting future growth, watershed features summarized as pollution risk indicators, and modeled estimates of runoff and nutrient loading.

INTERPRETING RESULTS

Results of the watershed assessment are presented in terms of potential pollution sources and risks to water quality rather than certain sources having known impact. These risks describe the potential for cumulative impacts from human activities but can't be used to document a direct cause and effect relationship between pollution sources and resulting conditions in Wickford Harbor.

Results presented here are estimates based on the most current land use maps available, further updated with input from the local advisory group. These maps are useful as a screening level analysis for planning purposes. Field investigations would be needed to verify site-specific land uses and soil characteristics.

1. LAND USE

Historical use

The Wickford Harbor watershed has been extensively altered. With construction of the Quonset Point Naval Base in 1939, about one half of the 650 acres comprising the Quonset Point Naval Base is built on dredge spoils or fill coastal waters or wetland (Olsen et al. 1980). Other historical uses and alterations that may have affected water quality in Wickford Harbor include:

- Installation of the Harbor breakwater decreased flushing of the Harbor and Coves
- Raised railroad beds, land bridges and levees have altered flows and flushing
- Grading and filling for dense residential and commercial development
- Pavement, roads, sidewalks, docks and other impervious areas have increased runoff and associated pollutants
- Dredging and spoil placement associated with piers, slips, docks and marinas

High intensity land use

High intensity land use, such as dense residential (greater than 1 dwelling unit per ¼ acre), commercial and industrial, highway, and actively tilled agriculture are known pollutant sources, contributing polluted runoff to surface waters or leaching pollutants via groundwater recharge.

- High-risk land uses make up 27% of the watershed, representing an extreme risk to water quality from pollutants likely to be generated by these uses.
- The Wickford Cove and Mill Creek subwatersheds have the highest proportion of high intensity land use with 32% and 39% respectively.
- The highest concentrations of dense, unsewered development is clustered around the Harbor in Wickford Village, increasing the

risk of direct pollutant delivery to the Cove from runoff and failing septic systems.

- Existing and proposed development is partially located in high water table, shallow bedrock and groundwater recharge areas. The proportion of development in poorly suited areas is likely to increase as the demand for new construction increases the profitability of building on marginal sites.

Impervious cover

Impervious cover is a catch-all term for paved roads, parking lots, driveway, rooftops, and other impermeable surfaces that prevent rainwater from seeping into the ground. Pavement and other impervious surface cover are accepted indicators of the health of small streams and wetlands, as well as a measure of potential impact from watershed activities.

Numerous studies show that stream and wetland habitat quality often begins to decline when impervious levels approach 10 percent; at 25 percent impervious cover, stream impacts are expected to become severe and difficult to control through stormwater management practices.

- The average impervious cover in the Wickford Harbor watershed is estimated to be 23 percent, potentially increasing to 27 percent with full development as zoned. This is far above the 10 percent threshold level for maintaining good stream habitat quality and near the 25 percent level where potential impact to streams and wetland habitat is considered extreme. Any future development is likely to increase existing risks.

- Subwatersheds with extreme or high impervious levels greater than the watershed average include Mill Brook, Wickford Cove, and Fishing Cove.

- The Mill Brook subwatershed, with extensive highway commercial development along Rt. 1, and industrial land in the Quonset/Davisville area, has the highest estimated percent impervious cover at 31 percent under present land use, potentially increasing to 36 percent with full development. These levels are cause for concern because of the potential impacts to aquatic life in streams and wetlands and because of the difficulty of controlling stormwater runoff impacts above the 25 – 30 percent impervious level.

- The largely undeveloped Cocumcussoc Brook watershed has very little impervious cover at 6 percent, increasing potentially to 9 percent with future development. These low levels suggest minimal future impact with development with use of erosion controls and stormwater management practices. Because we assumed that State-owned Cocumcussoc Brook management area would remain undeveloped this growth will be concentrated

in developable areas where stormwater control will still be necessary to limit localized impacts.

Forest and wetland

Forests and wetlands serve as ecosystem treatment systems, helping to preserve and maintain watershed health. Unlike other risk factors, this is an *inverse* relationship. More than 80 percent forest and wetland area translates to a *low* risk to water quality. Less than 20 percent forest and wetland area translates to a high risk to water quality.

- All subwatersheds except the Cocumcussoc Brook watershed have a high risk of water quality impact from low forest cover.

- The largely undeveloped Cocumcussoc Brook subwatershed could experience a drop from more than 80 percent to about 66% forest and wetland land cover with future buildout, shifting this subwatershed from the low to the medium risk category. Careful site design to avoid unnecessary land disturbance could minimize future development impacts in this watershed.

Riparian land use features

Land use in near-shore areas is one of the most useful predictors of human impact on water resources. Forested buffers have great potential to maintain ecosystem health by filtering polluted runoff, removing groundwater nitrogen through biochemical processes; and stabilizing and shading streams. On the other hand disturbed buffers can very easily function as pollutant delivery zones, especially when intensely developed.

- The Wickford Cove subwatershed has the most extreme risk of pollutant inputs from near shore development, with high intensity land uses covering **46%** of the 150' buffer zone.

- Other subwatersheds with extreme pollution risk from developed buffers include the Mill Creek and Mill Cove South, subwatersheds. Mill Cove North and Fishing Cove subwatersheds are generally ranked as having a high pollution risk based on the proportion of the buffer area in impervious cover, high intensity land use, and forest/ wetland.

- The Fishing Cove and Mill Cove South subwatersheds have the highest proportion of watershed land in the shoreline buffer zone, at 25 and 22 percent, respectively. Educating residents about streambank and wetland management would be a priority in these areas.

2. NATURAL LANDSCAPE FEATURES

Soils

- Sandy soils found throughout about 50% of the watershed increase the potential that polluted runoff and septic system effluent will rapidly seep into the ground without adequate treatment.

- The Wickford Cove and Fishing Cove subwatersheds are at greatest risk of pollutant movement to groundwater from sandy soils, with 70% of these study areas classified as excessively permeable. Because these areas are highly developed, storm drainage systems are probably in place and short-circuiting infiltration.

- The Cocumcussoc Brook area is much less sandy than the other subwatersheds (35% sandy soils, compared to the watershed average of 50%). With 22% slowly permeable high water table soils, this area is at greater risk from surface water runoff with future development.

- The Cocumcussoc and Mill Cove South areas are at greatest risk from erosion and sedimentation with more than 20% erodible soils. Stabilizing construction sites and other land disturbance is likely to be more difficult here; proper installation and maintenance of erosion controls would be a priority.

Surface Runoff

- The primary pathway for waterflow in the watershed is groundwater, with about 60% of the available precipitation estimated to infiltrate the ground, *and 40% estimated to generate surface runoff. In contrast, the full watershed would be expected to infiltrate 95% of available rainfall if it were fully forested given its soil characteristics.* Groundwater is also the main pathway for pollutant movement, with about 75 percent of nitrogen estimated to enter the watershed as groundwater recharge.

- The Mill Creek subwatershed generates the highest estimated runoff on a per acre basis, followed by Fishing Cove and Wickford Cove subwatersheds.

- High intensity land use in the Wickford Harbor watershed are estimated to contribute 65% of the stormwater runoff in the watershed even these land uses comprise only 27 percent of the land area.

- Commercial and industrial lands contribute more than their "share" of runoff among the high intensity land uses, comprising 15% of the total Wickford Harbor watershed area but contributing an estimated 40% of the runoff to the watershed.

Nutrient loading

- Septic systems are estimated to be the major source of nitrogen to groundwater in the Wickford Harbor watershed, contributing an estimated 80% of the nitrogen entering groundwater throughout the watershed.

- The Wickford Village area (Wickford Cove and Mill Cove South subwatersheds) and the Fishing Cove subwatersheds have the highest estimated per acre loading of nitrogen to groundwater. These are generally twice as high as the other developed watersheds due to high septic system densities per acre

- The three subwatersheds with highest nitrogen inputs to groundwater – Wickford Cove, Mill Cove South, and Fishing Cove – also have the highest nitrogen inputs to surface runoff, with Mill Creek a close fourth.

- The total estimated nitrogen sources to runoff and groundwater combined are highest in Mill Cove South, Fishing Cove, and Wickford Cove.

- The potential increase in nutrient loading with future development is relatively low, but any increase would tend to offset benefits of reduced nutrient inputs achieved by the Town's new septic system inspection ordinance and storm water improvements that might be installed.

- The relatively high proportion of nutrient inputs from current land uses underscores the need to manage existing sources while also taking advantage of every opportunity to control future inputs with controls, new development or redevelopment.

- The estimated proportion of substandard systems in the Wickford Village area – at 70%, is extremely high. Dense village development, in combination with the potential number of substandard systems presents a very high risk of contamination from untreated effluent. Because much of the watershed has sandy soils, septic systems may be failing by discharging untreated effluent to groundwater without obvious signs of failure, such as slow drains and surfacing of effluent in drainfields.

- The new septic system inspection ordinance cannot address the 70% of substandard system (cesspool) pollutant impacts. Phase-out of cesspools, implemented over the next five to ten years , could be considered to address this weakness. (The Town could consider fortifying the current ordinance and/or offering one-time property tax incentives for replacing cesspools.)

Management Options

1. Planning and regulation
Use the findings and recommendations of this assessment to outline a management plan for the Wickford Harbor watershed to achieve selected goals.

Establish benchmarks to gauge progress in achieving watershed management goals. These may include for example: maintaining shellfishing status in designated areas; safe fecal coliform levels for swimming and shellfishing (based on expanded regular monitoring); length of shoreline buffer restored to natural vegetation; reduction in impervious cover; growth in size and health of eelgrass beds; increase in clarity based on secchi disc measurements; and number of acres treated with stormwater treatment systems; and number of septic systems repaired or upgraded to advanced treatment.

Other planning issues:

- Establish /update specific goals for Wickford Harbor in comprehensive plan

- Incorporate the recommendations of this Watershed Assessment document into the Town's upcoming five-year Comprehensive Plan Update and associated Visioning Sessions this year.

- Establish performance standards for new development and re-development to include:
  - Limits on impervious cover
  - Limits on forest disturbance in developing areas
  - Stormwater treatment standards to include restoring recharge, preventing increase or reducing stormwater discharge volume, and nitrogen removal through wet ponds or series of treatment systems.
  - Establish treatment standards for onsite wastewater treatment including cesspool phaseout, and specifying areas where advanced nitrogen or bacteria treatment is required.

- Consider fortifying the current septic system inspection ordinance to phase out cesspools over the next five to ten years, and/or offering one-time property tax incentives for replacing cesspools.

- Increase follow-up inspections of residential and commercial development to ensure that stormwater, erosion control and septic commitments and requirements were completed satisfactorily by developers and homeowners.

- Request or require "mitigation" from developers in the early project planning phases and during Conservation Commission and Planning Department project reviews. Mitigation might

include improving ground surface permeability and decreasing runoff in some areas to at least offset any increases in paved, roofed or less permeable areas to be developed. (This would be consistent with "Phase 2" stormwater regulations that would apply to North Kingstown and are being developed by the RI DEM to be promulgated this year).

2. General land development and conservation

The new development expected is in the medium density residential areas, with slight increases in commercial and industrial land use. Focus new development controls in these areas, to include:

- Limits of disturbance, enforced by delineating on plans and in field.
- Minimize loss of forests
- Protect existing vegetated buffers
- Focus on nonstructural stormwater controls through site design

Since the risk of contamination from existing land use is already very high under current land use, controlling pollution inputs from new development will help avoid additional impacts but will do little to control current threats. The only way to substantially reduce pollution risks is by controlling inputs from existing development.

3. Shoreline buffers

Restoring vegetated shoreline buffers is one of the most effective actions to protect the Harbor. Subwatershed priorities include the highly developed shorelines in Wickford Cove, Mill Creek, Mill Cove South, Mill Cove North, and Fishing Cove.

Educating residents about shoreline and wetland management would be most important in areas where backyards include shoreline buffers such as Fishing Cove, Wickford Cove, and Mill Cove South.

The presence of naturally vegetated shoreline buffers to wetlands, streams, and harbor waters can mitigate the impacts on nitrogen inputs under certain conditions. Take advantage of natural capability of wetland riparian areas to remove nitrogen in potential high-nitrogen removal areas. Stormwater management and shoreline protection practices include:

- Protect riparian zones to maintain potential nitrogen treatment function.

- Restore disturbed wetlands to restore nitrogen treatment potential; establish forested buffers where possible for optimum function.

- Maintain groundwater infiltration to avoid short-circuiting treatment potential with surface runoff.

- Avoid use of subsurface drains to artificially lower water table and bypass shallow groundwater flow.

- Avoid shoreline alterations such as bulkheading that circumvent nitrogen removal in riparian areas.

- Consider pollution source controls (such as nitrogen removal wastewater systems, density restrictions, or nutrient loading limits) in the most high-risk areas and where natural removal potential is low.

- Recognize limitations of riparian features – nitrogen removal potential is highly variable and capacity uncertain over time, requiring pollution prevention and treatment before discharge to shoreline areas.

4. Stormwater management

The most significant reductions in stormwater pollutants can potentially be achieved by controlling stormwater discharges from new development and by retrofitting stormdrains serving high intensity land use. Stormwater systems should be designed specifically to remove nitrogen and restore recharge.

- Locating stormwater facilities to treat the most highly contaminated runoff from high intensity development and especially commercial and industrial land uses is most cost effective since construction costs are based on the drainage area served.

- Targeting direct stormwater discharges to the Harbor also makes sense, since these have no potential for pollutant removal through natural processes with overland flow or infiltration before entering the Harbor.

- Focus urban stormwater system improvements in subwatersheds with high impervious cover and high intensity land use such as the Mill Brook, Wickford Cove and Fishing Cove subwatersheds. Because it will be difficult to find suitable land for large basins, in practice, all available land and every redevelopment project should be considered as a retrofit opportunity.

- Explore opportunities to install groundwater infiltration systems in sandy areas such as Wickford Cove.

- Take advantage of busy in-town locations to site stormwater improvements for education and awareness.

- Restoring recharge will maintain natural hydrology and promote groundwater nitrogen removal. Consider infiltration retrofits upgradient of wetlands mapped as having high potential for groundwater nitrogen removal.

- Map major stormdrain discharges and where possible, map drainage network to identify contributing drainage area. Consider involving volunteers, at least in initial stormdrain mapping through shoreline surveys, to build local awareness and interest.

Prevent localized stormwater runoff impacts with new development in the Cocumcussoc Brook watershed and other developing areas through:

- erosion and sediment controls with field inspections,
- incorporate nonstructural stormwater controls in site design to prevent increases in stormwater runoff volume,
- minimize loss of forest cover and protect forested wetland buffers,
- promote groundwater infiltration to maintain recharge and potential for nitrogen removal in shoreline zones,
- limit impervious cover to 8-10 percent in Cocumcussoc; higher limits may be more realistic in other subwatersheds.

5. Wastewater management

Conventional systems

Controlling septic system failure offers a high potential for reducing pathogen inputs to the Harbor.

- Accelerate wastewater inspection and repair program in Wickford Village; require inspection results to be documented and filed versus simply requiring evidence of pump-outs.

- Phase out cesspools and failing systems

Advanced wastewater treatment

Alternative wastewater treatment systems are the most effective option available to remove groundwater nitrogen inputs, reduce the risk of pathogen movement on problem sites, provide a small footprint necessary for substandard lots, and may be the only feasible repair option on difficult sites with very small lots and site constraints.

- Consider performance standards requiring advanced treatment for new and repaired systems in critical areas based on a combination of site constraints and location in watershed.

- Analyze feasibility and cost of retrofitting Wickford area system with combination of individual and shared on-site systems with advanced treatment in the most critical areas.

- Consider and evaluate the feasibility of future advanced treatment systems using pressurized collection "sewer" lines to pump wastewater to central treatment areas in Wilson Park or other areas owned by the Town.

6. Monitoring

Harbor

- Expand fecal coliform monitoring in the Harbor, focusing on actively used coves. In order for the data to be used in the DEM shellfish compliance program, samples must be analyzed using the Most Probable Number (MPN) method. Sampling sites might include the Wilson Park boat ramp area, the Wickford Yacht Club, the Town docks on Brown Street and Main Street, all Town and marina slip and mooring areas in the Harbor, the Hussey Bridge and the Kayak Centre. Post signs if necessary warning against unsafe swimming from probable locations.

- Continue monitoring the Harbor and tributaries. Long term monitoring would be needed to identify normal seasonal variations and weather effects, evaluate water quality, and document trends. As described in Appendix C, URI *Review of Wickford Harbor Watershed 1999 Monitoring Data*. Continue Harbor monitoring of clarity, dissolved oxygen, and visual observations to monitor trends. Evaluate need for nitrogen sampling at all stations; fall and winter nitrogen levels may be most representative of ambient concentrations when algal uptake is low.

- Consider establishing a volunteer monitoring program for the Harbor and tributaries. Citizen volunteers may be organized locally and trained by URI Watershed Watch or other qualified group with approved quality control/quality assurance plans. Involving volunteers expands monitoring capability and can enhance visibility of the program, leading to improved public awareness of Wickford Harbor as an important habitat.

- Consider using quantitative methods to monitor macroalgae extent and abundance, also using volunteers. For example, simply mapping the location and extent of bottom algae can show changes in the type of algae and area covered more objectively than photos. Various methods are also available to measure biomass produced by collecting and weighing random samples of macroalgae.

Tributaries

- Continue stream monitoring program, measuring nutrients and streamflow simultaneously.

- Consider installing stream gages at tributary sampling points. Establish stage-discharge relationships by measuring the height of flow along a staff gage and also measuring flow using a flow meter. After a range of samples are taken under low and high flows, the height of the staff gage alone will indicate flow.

- Delineate subwatershed boundaries for each tributary sampling site and estimate subwatershed area. Using nutrient loading data developed from nitrogen concentrations sampled at known flows, develop estimates of nutrient loading equalized on a per acre basis to allow direct comparison among sampling stations. This type of data is currently available only for the 1999 Mill Creek and Cocumcussoc Brook sampling stations

Watershed

- Submit request to DEM Division of Water Resources to consider ranking Wickford Harbor as a high priority for a Total Maximum Daily Loading (TMDL) to identify causes of low dissolved oxygen that are affecting aquatic habitat.

- Investigate pollution source "hotspots" to verify and where necessary, remediate.

7. Public Education

Summarize monitoring results in a user-friendly format annually and make available for wide distribution to residents, possibly through the town water department newsletter.
Send "Puddle" brochure to additional residents who may not receive public water bills, but who could have impacts to Town water quality. These might include people who live in apartment houses or condo developments that do not pay water bills. (For example, they might reach more people if they were sent with Town automobile property tax bills.)

Publicize value of Wickford Harbor as a scenic, recreational, and natural resource; describe pollution threats from watershed activities; town protection measures in place or planned; and actions individuals can take.

Target homeowners and businesses in critical areas for education on topics of concern in their watershed such as shoreline restoration, lawn care, and ISDS retrofitting.

Expand public education – ISDS function and inspection workshops, management practices around the home and yard, no-discharge awareness and education, large scale display of the village with

findings and actions for individuals and town, continue to report on monitoring and actions taken.

Consider innovative approaches to encourage homeowners and businesses to voluntarily adopt pollution controls. Stimulate voluntary adoption of pollution controls among industry and business by focusing on incentives such as cost savings, improved public image, increased property values and recognition awards.

Marina and Boating use – impact assessment and public education

This assessment did not specifically evaluate pollution threats from boating such as "good housekeeping" with boat maintenance and repair, refueling spills, and compliance with no-discharge regulations. These sources were considered potential threats. The Harbor Commission may already have a long wish list of education priorities. Some options the Harbor and Conservation Commissions may wish to consider include:

- Boater /shoreline landowner surveys to identify attitudes and management practices;
- Boater education, including specific information about the Harbor and any survey results;
- Organizing local businesses to voluntarily support pollution prevention practices;
- Bacteria monitoring and visual observations in marina areas;
- Shoreline surveys to identify physical conditions and potential pollution sources in developed shoreline areas (using pollution source hotspots to identify potential problems).
- Ensure that marina discharges are in compliance with RI Pollutant Discharge Elimination System (RIPDES) regulations for industrial discharges to the Harbor from boat and motor maintenance and cleaning. (There appear to be a number of point sources in Town that probably require RIPDES permits).

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APPENDIX B

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APPENDIX C

Review of Wickford Harbor Watershed 1999 Monitoring Data

APPENDIX D

Technical Documentation. Nutrient Loading Component of the MANAGE Geographic Information System -Based Risk Assessment Method