Newport Water and Stone Bridge Fire District Source Water Assessment

Top: St. Mary's Pond.
Lower: Constructed wetland in the Bailey Brook Watershed helps treat runoff from roads and parking lots.
Right: Maidford River, Middletown.

Rhode Island Department of HEALTH

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University of Rhode Island Cooperative Extension in cooperation with RI Health Source Water Assessment Program

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Acknowledgements

This assessment was conducted in partnership with the Newport Water Division, Stone Bridge Fire District, municipal officials representing watershed communities, staff of RI HEALTH and the RI Department of Environmental Management, the Eastern RI Conservation District, other nonprofit organizations promoting conservation and environmental stewardship of watershed resources, and many other citizen volunteers. These volunteers made significant contributions to the mapping and assessment work. They reviewed draft maps, commented on preliminary assessment results, offered valuable insights on local water quality concerns, and offered practical suggestions to better protect source waters. While we have tried to incorporate local comments to the extent possible, any errors or omissions are the sole responsibility of the authors. The findings and recommendations were developed based on discussions with the assessment volunteers but represent the best professional judgment of the authors based on available data, modeled assessment results and supporting scientific literature, and do not necessarily reflect municipal, URI or RI HEALTH policies..

As the State SWAP Program Coordinator and project manager, Clay Commons provided essential support throughout this project, which included assistance in developing risk analysis procedures, making RI HEALTH technical reports available, organizing public outreach, and participating in the assessment process. Debra LaFleur made public well monitoring data readily available and helped us interpret this rich database. June Swallow, Chief Office of Drinking Water Quality and EPA Region 1 project officer, Buddy Souza, provided support and direction throughout the project.

Dr. Arthur Gold, Professor in the Natural Resources Science Department and Extension Water Quality Program served as scientific advisor on this project. Dr. Gold oversaw development of the assessment approach and provided guidance in evaluating pollution risks and interpreting modeled results. Other key URI staff who contributed to the assessments include Dorothy Q. Kellogg, who provided support in modifying the MANAGE nutrient loading spreadsheet for SWAP assessments. Holly Burdett and Alyson McCann assisted in public outreach and trained volunteers to update land use maps used in the assessment. Kaytee Manchester, URI Coastal Fellowship Program intern, assisted in GIS mapping and well data analysis. Emmanuel Falck also assisted in final well data analysis and report editing. The URI Environmental Data Center provided direct access to the RIGIS database and the Center's knowledgeable staff generously provided technical support in GIS database development and mapping.

Newport Water and Stone Bridge Fire District Source Water Assessment

April 2003

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This report and a fact sheet summarizing results are available to view or download at the URI Cooperative Extension website and RI HEALTH websites. Large format maps of the water supply areas developed to inventory natural features and map potential pollution sources are available for review at municipal offices.

For more information about the RI Source Water Assessment Program or this report contact:

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Funding for this report was provided by the RI HEALTH Office of Drinking Water Quality through a grant from the U.S. Environmental Protection Agency under the Source Water Assessment Program, established by the 1996 amendments to the federal Safe Drinking Water Act.

This is Technical Report #03-02, Contribution 3987 of the University of Rhode Island College of Environment and Life Sciences and Rhode Island Cooperative Extension. URI Cooperative Extension provides equal program opportunities without regard to race, age, sex or preference, creed or disability...

Newport Water and Stone Bridge Fire District Source Water Assessment

Table of Contents

LIST OF APPENDICES

LIST OF FIGURES

LIST OF MAPS

LIST OF TABLES

Newport Water and Stone Bridge Fire District Source Water Assessment

1. INTRODUCTION

This report summarizes the results of the Rhode Island Source Water Assessment Program for both Newport Water and Stone Bridge Fire District drinking water supply areas. The study area includes the watersheds for 10 public drinking water reservoirs located in the towns of Newport, Middletown, Portsmouth, Little Compton and Tiverton.

The goal of Rhode Island's Source Water Assessment Program is to better protect drinking water supplies at their source by evaluating threats to future water quality and making this information available to water suppliers, town officials, and landowners. Because the vast majority of land in reservoir watersheds and groundwater recharge areas is privately owned, the assessment is designed to generate information municipal officials can use to support local planning and regulation of land use in drinking water supply watersheds and aquifers. The assessment provides a consistent framework for identifying and ranking threats to all Rhode Island public water supplies following three basic steps:

- Inventory and map potential sources of pollution within wellhead .protection areas or reservoir watersheds;
- Assess the risk associated with these potential sources of contamination and rank the susceptibility of the water supply;
- Identify practical steps town officials and residents can take to reduce pollution risks and make results available.

This assessment was conducted by the University of Rhode Island Cooperative Extension in cooperation with the Rhode Island Department of Health and numerous water suppliers, municipal officials and local volunteers dedicated to protecting local drinking water supplies. Participants in the mapping and assessment phases of the program attended a series of workshops to help identify potential sources of contamination within the study areas. Assessment volunteers reviewed draft products and helped to identify alternative management options for better protection of local drinking water supplies.

What is Source Water?

Source water is untreated water from streams, lakes, and interconnected underground aquifers that recharge public and private wells and replenish drinking water supply reservoirs.

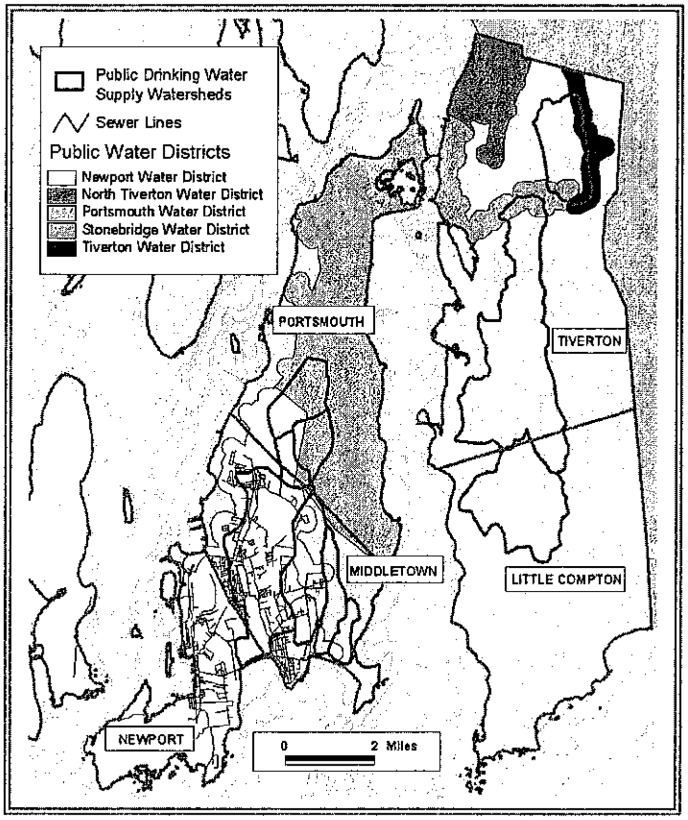
While some treatment is usually necessary for public drinking water supplies, preventing drinking water contamination at the source makes good sense. Keeping headwater streams and groundwater recharge areas free of pollution:

- *Safeguards public health,*
- *Reduces treatment costs, and*
- *Protects environmental quality.*

U.S. Environmental Protection Agency Source Water Protection Program

The Newport Water and the Stone Bridge Fire District Source Water Assessment

Map 1: Public Water and Sewer Utilities



The City of Newport Water Division owns nine surface water reservoirs located within five Rhode Island municipalities. Newport Water provides water services to residents and business in the three communities on Aquidneck Island: the district provides public drinking water to 100 percent of residents and businesses in Newport, 75 percent in the town of Middletown, and 3 percent in the town of Portsmouth. In addition, Newport Water provides Portsmouth Water and Fire District with 60 percent of that district's supply, serving the majority of residents and businesses in Portsmouth. In total, Newport Water supplies public drinking water to over 16,000 customers. The net available supply from its nine reservoirs is 11 million gallons a day (mgd).

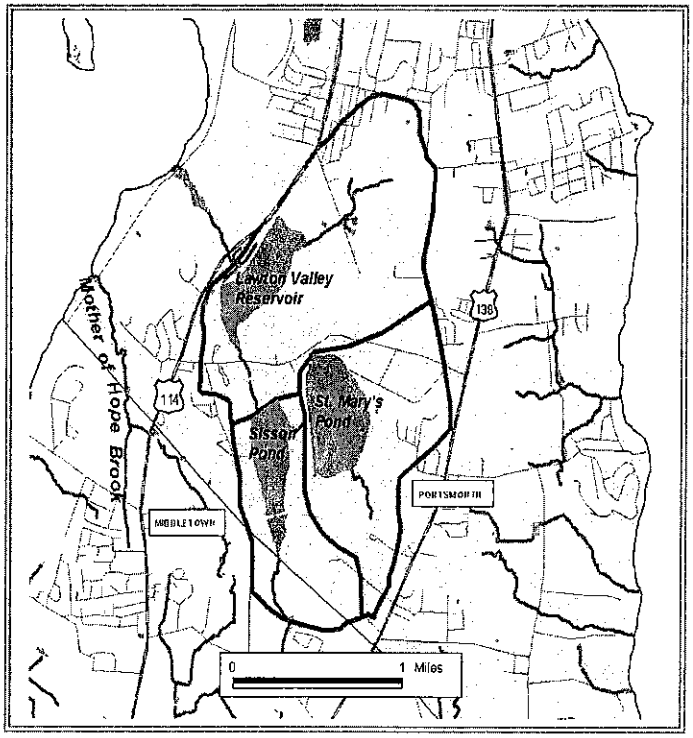
The Newport Water study area includes the watersheds for its 9 reservoirs: Lawton Valley Reservoir, St. Mary's Pond, Sisson Pond, Easton Reservoir (North & South Ponds), Gardiner Pond, Nelson Pond, Nonquit Pond and Watson Pond. Newport Water relies on a state-of-the art treatment plant to treat water contaminated with polluted runoff, algae and sediment. All of the public drinking water supplies on Aquidneck Island have been placed on the state's 303(d) List of Impaired Waterbodies for biodiversity impacts.

Newport Water's distribution system is comprised of two interconnected systems. The Station 1 system draws source water from North and South Easton ponds, which are fed by Bailey Brook. Station 1 is also supplemented seasonally by Nelson Pond and Gardiner Pond. Station 1 distributes water to the City of Newport, Middletown and the U.S. Navy Base. The Lawton Valley-Portsmouth system draws from Lawton Valley Reservoir, St. Mary's Pond and Sisson Pond. The system is supplemented seasonally by Watson Pond in Little Compton and Nonquit Pond in Tiverton. This distribution system services Middletown, the U.S. Navy Base and the Portsmouth Water and Fire District. Sewer services are provided in three of the nine drinking water supply watersheds: Easton Pond, Nelson Pond and Gardiner Pond watersheds. Sewer services are also provided in the

Maidford River watershed. Water from the Maidford River is diverted into Gardiner Pond.

The Stone Bridge Fire District provides public drinking water to 8,000 customers in the town of Tiverton, including 3,400 residential connections. The district withdraws 750,000 gallons of water a day from Stafford Pond during peak demand. The district also sells treated water to the Town of Portsmouth. Stafford Pond, besides being a source of raw water for a *Large Community Water Supplier*, is a popular fishing and recreation area. The pond supports one the state's few remaining populations of small mouth bass, and RIDEM, Fish and Wildlife Division stocks the pond with trout. Boating activity on the pond is high. Although the treated water withdrawn from Stafford Pond meets all state and federal drinking water standards, the pond has been placed on the state's 303(d) List of Impaired Waterbodies. A TMDL study has been conducted in the watershed to determine the cause of excessive algal growth and nutrients in the pond. There are no public sewer services in the Stafford Pond Watershed.

Map 2: Aquidneck Island Drinking Water Supply



1.1 Assessment Study Areas

Newport Water, Lawton Valley Reservoir Watershed

The 829-acre watershed for the Lawton Valley Reservoir lies between Routes 114 and 138 in the town of Portsmouth. Newport Water owns a buffer strip of land around the entire perimeter of the reservoir. Land use activity in the watershed is primarily agricultural and medium density residential development. Based on current zoning, approximately half of the existing cropland and pastureland (100 acres) will be converted to residential development in coming years. The area is presently unsewered.

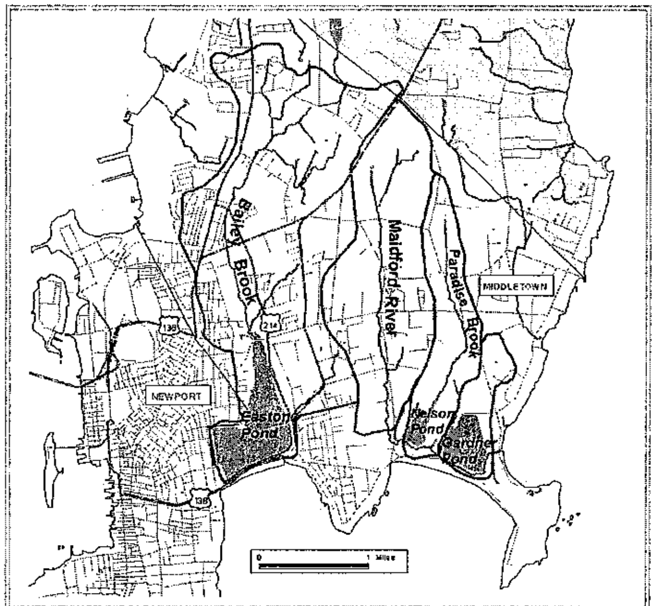
Newport Water, Saint Mary's Pond Watershed

Saint Mary's Pond lies between Routes 114 and 138 in the Town of Portsmouth. Water from the pond is discharged to a pipeline connected to the Lawton Valley Reservoir as well as to a pipeline leading to the headwaters of Bailey Brook, where it continues to North Easton Pond. The watershed for the pond encompasses approximately 515 acres. Newport Water owns a buffer strip of land around 40 percent of the pond. Land use activity in the watershed is primarily agricultural (168 acres) and medium density residential development (94 acres). Approximately 60 acres of agricultural land may be converted to residential development in coming years. The area is presently unsewered.

Newport Water, Sisson Pond Watershed

The 330-acre Sisson Pond watershed lies adjacent to the Lawton Valley Reservoir watershed and St. Mary's Pond watershed, and extends into the Town of Middletown. Water from the pond flows through a discharge pipe into a stream connected to Lawton Valley Reservoir; it also overflows to the south into Bailey Brook. Newport Water owns a buffer strip around 60 percent of the pond. Land development in the watershed is over 70 percent agricultural (140 acres); medium density residential development accounts for an additional 15 percent of land use in the watershed. Approximately 70 acres of agricultural land may be converted to medium density residential development based on current zoning. The area is presently unsewered.

Map 3: Aquidneck Island Drinking Water Supply Watersheds



Newport Water, Bailey Brook Watershed

The Bailey Brook watershed encompasses 2,874 acres in the towns of Middletown and Newport. The brook and its watershed drain to the Easton Pond reservoir complex, the primary water supply for Newport Water's Station 1 distribution system. North Easton and South Easton ponds are separated by an earthen embankment and are connected by a pipeline. South Easton Pond is better protected than North Easton Pond and has higher water quality.

The Bailey Brook watershed is highly developed. Sewer services are provided throughout most of the watershed. Approximately 50 percent of land use in the area is higher density residential development. Commercial and industrial development account for an additional 20 percent of land use activity. Most of the remaining undeveloped land in the watershed is used for agricultural purposes.

Newport Water, Nelson Pond Watershed

Nelson Pond is located in the town of Middletown and is connected by pipeline to Gardiner Pond. The two ponds are operated as a single reservoir. The ponds receive water from their own watersheds as well as receiving flow from both the Maidford River and Paradise Brook. The watershed for Nelson Pond is 600-acres in area and fully encompasses Paradise Brook. This is one of the least developed of the public water supply watersheds on Aquidneck Island; over 20 percent of the watershed remains forested. Newport Water owns a buffer strip around 60 percent of the pond. Land use activity is primarily agricultural and medium density residential development. Much of the remaining agricultural land (115 acres) could be converted to medium or low-density residential development in coming years.

Newport Water, Gardiner Pond Watershed

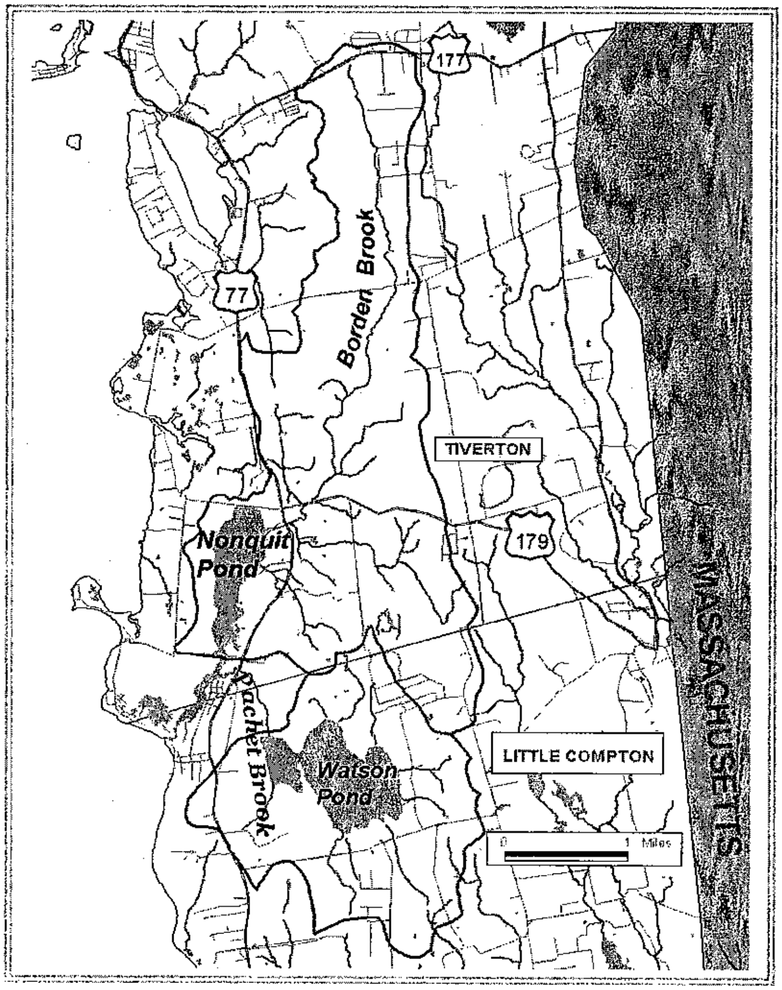
The 292-acre watershed for Gardiner Pond is almost entirely undeveloped. Newport Water owns a buffer strip around the entire perimeter of the pond. Residential and commercial development account for less than 10 percent of land use activity in the area. However, over 25 percent of the watershed is in some form of agricultural development (90 acres). Approximately half of this agricultural land could be converted to medium-density residential development in coming years.

Newport Water, Maidford River Watershed

The Maidford River, with a watershed of approximately 1,335 acres in area, flows through a diversion into Gardiner Pond. Land use activity in the watershed is a mix of medium density residential and commercial development and extensive agricultural activities. The developed area of the watershed is sewered.

Newport Water, Nonquit Pond Watershed

Map 4: *Nonquit Pond and Watson Pond Drinking Water Watersheds*



The Nonquit Pond watershed is located primarily in the town of Tiverton, with a small area of the watershed located in the town of Little Compton. The total area of the watershed is approximately 4,408 acres. Over 60 percent of the watershed is either forested upland or wetlands. Newport Water uses Nonquit Pond as a back-up supply for its Lawton Valley-Portsmouth distribution system. There is no publicly owned buffer strip around the pond.

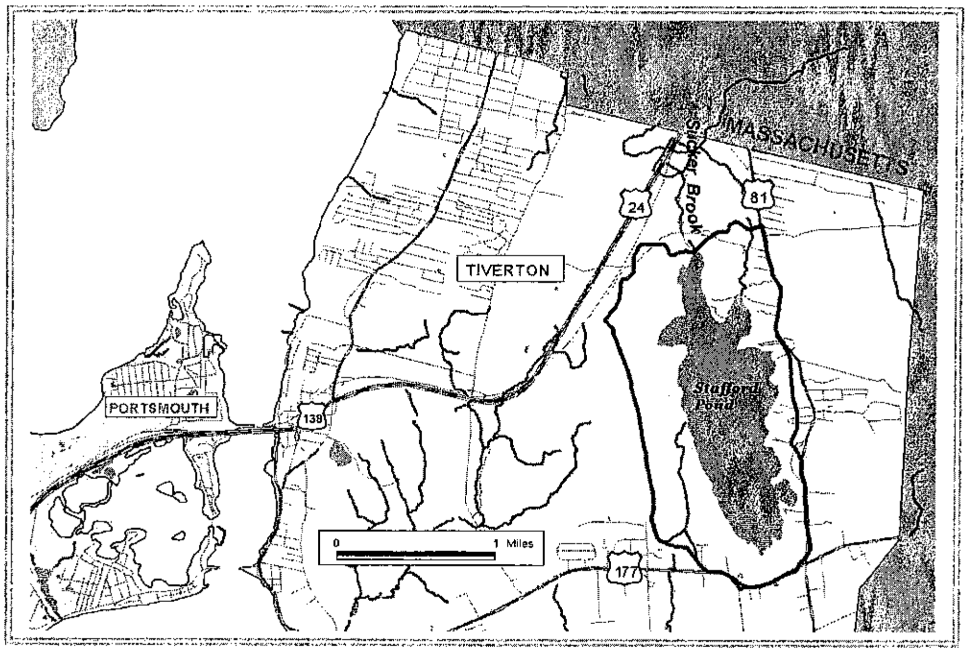
Land use activity in the watershed is a mix of residential and commercial development and farming. Based on current zoning, roughly 1,000 acres of remaining forestland could be lost or seriously fragmented with conversion to low-density residential development.

Newport Water, Watson Pond Watershed

The 2,295-acre watershed for Watson Pond lies almost entirely in the town of Little Compton. A large portion of the watershed remains forested upland or wetland. Newport Water uses Watson Pond as a back-up supply for its Lawton Valley-Portsmouth distribution system. There is no publicly owned buffer strip around the pond.

Land use activity in the watershed is primarily agricultural, with a mix of some residential and commercial development. Remaining undeveloped land in the watershed is zoned primarily for low-density residential development (450 acres).

Map 5: Stafford Pond Public Drinking Water Supply Watershed



Stone Bridge Fire District, Stafford Pond Watershed

The 947-acre watershed for Stafford Pond is located in the town of Tiverton. Stafford Pond is the primary drinking water supply for the Stone Bridge Fire District. The pond itself is 487 acres in area. The west side of the watershed is largely undeveloped. However, the eastern shore of the pond is almost entirely developed with higher density residential development. There are no sewer services in the watershed, and many of the septic systems pre-date 1970 statewide standards for Onsite Waste Water Disposal systems. Water quality monitoring in the pond has documented declines in water quality over the years. In 1996, RIDEM initiated a study to identify and evaluate pollution sources affecting the pond. Farms, highways, boats, and failing septic systems were identified as principal sources of pollution entering the pond.

In 1986, the Town of Tiverton adopted the *Stafford Pond Watershed Protection Overlay District* to restrict hazardous land use practices in the watershed. Most of the remaining developable land in the watershed is zoned for medium-low density residential development (200 acres) and open space. However, the town has zoned 65 acres in the northwest corner of the watershed for new industrial development.

1.2 Summary of Existing Conditions

As a first step in evaluating potential pollution risks in the assessment study areas, this section summarizes existing, readily available information on water quality concerns, pollution sources, and existing management practices (See Appendix D for further information). This overview has several purposes:

- To insure that the assessments build on existing information;
- To highlight the most valuable or vulnerable water resources;
- To provide a basis for refining water supply system management plans, wellhead protection plans and town water resource protection goals and priorities;
- To provide a baseline for reviewing progress in water resource protection efforts and for establishing new
- watershed management strategies.

This summary is drawn from information sources such as water supply system management plans, municipal plans and ordinances, water quality monitoring data, and input from state and municipal officials, water suppliers, and other participants in these assessments. Key features of this water quality status check are summarized below.

Water Quality Goals and Water Resource Protection Strategies

The City of Newport Water Division has a Water Quality Protection Plan as part of its mandated Water Supply System Management Plan. The plan clearly sets forth an analysis of potential sources of contamination within the nine drinking water supply watersheds, and provides detailed recommendations for enhanced protection of its drinking water supplies. Newport Water currently owns and protects perimeter buffers around most of the reservoirs. Continued acquistion of land for conservation and protection purposes is listed as a top priority in the Water Quality Protection Plan.

The protection of drinking water supplies is addressed in each of the five town comprehensive plans. On Aquidneck Island, Middletown is the only town that has adopted a watershed protection overlay district to protect drinking water resources. The ordinance does not, however, restrict the use of underground storage tanks in the watersheds, hence limiting the protection it affords. In 1999, the Aquidneck Island Partnership, representing each of the three municipalities on the Island, conducted a series of workshops entitled *"A Safe, Sustainable Drinking Water Supply"* to promote regional cooperation in the protection of the Island's drinking water resources. The Town of Portsmouth has adopted a 500 foot no-build setback from Lawton Valley Reservoir, St. Mary's Pond and Sisson Pond. Better stormwater management is a concern for all three towns on the Island.

Monitoring Requirements for Public Drinking Water Supplies

Rhode Island Department of Health Testing

Parameter	Testing Requirement
Asbestos	Once every ninth year.
Nitrates	Quarterly for 1 year; reduce to annually.
Nitrites	One sample.
Pesticides/Synthetic Organic Compounds (SOCs)	Quarterly every 3 years; reduced to twice every third year.
Selected Inorganics	Annually.
Unregulated Organics	Quarterly every 3 years.
Volatile Organic Compounds (VOCs)	Quarterly for 1 year; then annually; then reduced to every 3 years.

The Town of Tiverton has adopted a watershed protection overlay district for both Stafford Pond and Nonquit Pond. Tiverton has also recently adopted a wastewater management district in the Stafford Pond watershed, and has bought the 500-acre Weetamoo Woods property in the Nonquit Pond watershed. The Stone Bridge Fire District along with town residents and officials, URI Cooperative Extension, RI DEM and RI Bass Federation created a *Public Education Committee for Stafford Pond.* The group wrote and published *Your Guide to Protecting Stafford Pond* as part of its educational outreach strategy.

2. ASSESSMENT METHOD

This assessment uses a screening-level approach to evaluate pollution risks in water supply watersheds and recharge areas. The focus is on identifying land use and natural features where pollutants are most likely to be generated and move to drinking water supplies. This approach takes advantage of existing information sources, including the extensive computer-mapping database readily available to water supply managers and municipalities through the Rhode Island Geographic Information System (RIGIS). Computer mapping provides the chief tool to identify, analyze, and display potential pollution threats. Assessment results are intended to generate information water suppliers and local officials can use to make land use decisions that reduce pollution risks to water supplies.

This chapter briefly summarizes our approach in assessing the susceptibility of water supply source areas to contamination.. It includes:

- A brief overview of the two-level assessment approach used in RI for small and major supplies,
- Background on the challenges of evaluating water quality impacts from land use in source water areas;
- Description of the assessment approach using watershed features to evaluate pollution risk, with outline of data source,
- Methods and assumptions in creating the land use database for current conditions and future projections; and
- Steps in conducting the assessment, and use of assessment products.

This section is designed to provide an overview of assessment issues and our approach. Complete documention of assumptions and methods are provided in the Appendix to this report.

__MANAGE__ is the __M__ethod for __A__ssessment, __N__utrient-loading, and __G__eographic __E__valuation of watersheds and groundwater recharge areas. This screening-level pollution risk assessment method uses computerized maps known as Geographic Information Systems (GIS) to compile, analyze, and display watershed and recharge area information.

The assessment incorporates a suite of pollution risk factors including:

- *Map analysis locating likely pollution "hot spots."*
- *Land use and landscape features summarized as watershed health "indicators".*
- *Nutrient loading estimates comparing potential pollution sources associated with different land uses.*

This method incorporates a simple mass balance hydrologic spreadsheet but is a collection of assessment techniques rather than a packaged model. MANAGE was developed and is applied by URI Cooperative Extension as a watershed education and decision support tool for use with Rhode Island communities.

For more information go to: http://www.uri.edu/ce/wq/mtp/html/manage.html.

2.1 Two Levels of Assessment

The RI Source Water Assessment program uses a two-tiered assessment strategy developed by RI HEALTH and URI Cooperative Extension in partnership with an advisory Technical Committee. This provides a consistent review process for all water supplies while ensuring a more thorough assessment of the largest and most productive community supplies.

Basic assessment and ranking - all water supplies

All water supplies were assessed and ranked according to their susceptibility to contamination. The assessment considers potential sources of pollution and natural features that promote movement of pollutants, to include, for example: high intensity land use, number of mapped potential pollution sources such as underground storage tanks, location of potential sources by soil type and proximity to the supply, and existing water quality. A simple scoring system assigns a

"Rhode Island's groundwater resources are extremely vulnerable to contamination because of the generally shallow depth to groundwater, aquifer permeability, and the absence of any confining layers. Preventing groundwater pollution must be a priority if the long-term quality of the state's groundwater resources is to be protected.

The focus of state water pollution concerns has shifted from specific discharges or 'point' sources.... Maintaining or restoring state waters requires that non-point sources of pollution be addressed."
RIDEM 2002

numerical value, which categorizes the water supply's overall risk of pollution from low to high. Results of this basic ranking for the source water areas are included in the appendix of this report.

Comprehensive assessment - major community supplies

In addition to the basic mapping and ranking of pollution sources, major community water systems supplying more than 50 million gallons per day also receive a more in-depth assessment using the URI Cooperative Extension MANAGE pollution risk assessment method. This makes more extensive use of computer map databases, in order to evaluate land development patterns and landscape features posing the greatest risk to local water resources. The additional analyses may include any or all of the following:

- Calculation of percent impervious area, percent forest and wetland, land use characteristics in shoreline buffers, and other factors.
- Development of a hydrologic and nutrient loading budget estimating average annual nitrogen inputs to surface runoff and groundwater leaching; phosphorus to surface runoff.
- Forecast of potential threats using a "build out" analysis to evaluate future growth based on zoning.
- Comparison of the relative effectiveness of alternative pollution controls in reducing pollutant inputs using nutrient loading estimates.
- Public involvement in the assessment by field checking and updating land use maps; and reviewing and commenting on draft results.

Both the basic and comprehensive assessment are fully consistent with each other as the basic ranking was developed using elements of the MANAGE method. This technical report includes the combined results of both the basic and in-depth assessment.

2.2 Background on assessing water quality impacts

Pollutants most likely to contaminate drinking water

According to the RI Department of Environmental Management's report to congress on the state's water quality, pollution from routine land use activities is the greatest threat to water quality outside of urban areas (RIDEM 2002). Stormwater runoff, septic systems and erosion are the number one threat to the State's drinking water supplies and other high quality fishable and swimmable waters. Bacteria, nutrients and sediment associated with these sources have adversely affected drinking water reservoirs, inland lakes and ponds, and coastal shell fishing waters. In fact, pollutants from land use activities are the main cause of new shellfish closures (RIDEM 2002).

Land use activities are also the primary threat to groundwater. The most frequently detected contaminants in RI public wells, excluding naturally occurring compounds, are MTBE, a highly soluble gasoline additive, and the widely used chemical solvents such as trichloroethene and tetrachloroethane. According to RIDEM's 2002 report on the state's waters, between 15 and 30 percent of all RI public wells have been found to contain low levels of these volatile organic solvents (VOCs). Petroleum products from leaking underground storage tanks are the leading cause of new groundwater contaminant incidents. Nitrate is also a concern as it is often detected at concentrations far above natural background levels. Annually, almost 90 percent of wells have nitrate concentrations less than 3 mg/l, with only five wells slightly exceeding the 10 mg/l nitrate standard. Because even 3 mg/l is more than 10 times the naturally occurring level, this is a serious concern in coastal areas where shellfishing habitat can be impaired at total nitrogen levels as low as 0.35 mg/l (Howes et.al.1999). This low level is near the natural background concentration of groundwater in undeveloped areas of Rhode Island.

Because most land in a reservoir watershed or overlying a well head protection area is often privately owned and not controlled by the water supplier, source water areas are just as susceptible to land use pollutants unless local watershed protection regulations are adopted and enforced. With Rhode Island's population moving out of urban centers to new homes in outlying suburbs and rural source water areas, the potential for water quality impacts to drinking water supplies is greater than ever.

Challenges of measuring 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. Field monitoring data provides the most solid information to assess water quality conditions and identify pollution sources. However, field studies of even small watersheds is complex and time consuming, especially when compared to traditional sampling of discharge pipes. Pollutants from multiple sources such as over fertilized lawns, storm drains, and septic systems enter streams and groundwater at many locations scattered throughout a watershed, making it difficult to accurately evaluate impacts. In addition, any one sample represents only a snap shot in time. Regular sampling is needed to separate variations due to weather or season and to establish trends.

To complicate matters, mounting evidence points to basic changes in hydrology brought about by development as a root cause of water quality problems. Increased runoff with construction – almost impossible to avoid unless strictly controlled, prevents rainwater from naturally infiltrating into the ground. Water running off the ground surface escapes treatment that would have occurred through slow movement through soil. The combined result is reduced groundwater

Threats to lakes and ponds

22% of RI lakes and ponds are not clean enough for healthy aquatic life or swimming due to bacteria, nutrients, low oxygen or metals. The major sources are:

- *Runoff*
- *Septic systems*
- *Agricultural fertilizers*
- *Water withdrawals and other changes in flow.*

RIDEM's assessment of lakes and ponds includes 42 drinking water supply reservoirs. Of these reservoirs, 99 percent are meeting drinking water standards. In most areas, however, this assessment does not include information on upstream tributaries due to lack of data.

RIDEM 2002

"It is generally recognized that protecting the quality of drinking water is cheaper than treating water after it has been contaminated, and more certain than seeking new sources."

RI HEALTH Source Water Assessment Plan, 1999.

recharge and degraded surface water quality. Monitoring is a challenge given the wide range of physical, chemical and biological impacts that are possible. Finally, even where significant resources are devoted to field studies, results are often inconclusive. For example, DEM scientists have conducted extensive field studies of impaired surface waters only to conclude that "in the majority of cases there is not enough data to link the causes of non-support to actual sources of pollution" (RIDEM 2002).

Watershed scale models provide an alternative or supplement to field sampling. Modeling uses information regarding specific features of a study area, such as soil types and water flow patterns, with research data about pollutant interactions. It then makes simplifying assumptions to apply these facts to the whole study area, creating a picture of how a study area functions. Modeling is frequently used to estimate sources of pollutants, especially when sparse or inconclusive field data indicates the amount of pollutant present without leading to a verified source. Modeling is used to extrapolate from known data points to make assumptions about the larger study area, thus gaining a "big picture" perspective needed to evaluate cumulative impacts. And modeling is a valuable tool in testing.

It is important to remember that all models generate results that are only as good as the input values. Results of both simple and sophisticated models are estimates. Complex models may not generate more useful data for management, especially when comparing relative differences is adequate for choosing pollution controls (Center for Watershed Protection 1998). For both simple and complex models alike, great uncertainty surrounds the fate and transport of pollutants in the environment. Because of these data gaps, quantifying a direct response between pollution sources and resulting water quality in a down gradient well or surface reservoir is extremely complex and filled with uncertainty. In the Waquoit Bay watershed in Cape Cod, Massachusetts, for example, researchers modeling watershed nutrient dynamics concluded that even in heavily studied watersheds with an extensive field monitoring database, the relationship between pollution sources and resulting water quality was the most difficult to estimate (Weiskel, 2001). These unknowns currently preclude researchers from setting up a direct relationship between pollution sources in a watershed and resulting impact of those pollutants in receiving waters.

2.3 Approach: Linking landscape features to pollution risks

Given the difficulties in assessing land use impacts through field monitoring and conventional water quality models, the RI Source Water Assessment Program relies on accepted pollution risk factors established by the U.S Environmental Protection Agency (EPA) and other scientific organizations to identify and rate pollution threats (EPA, 1996; Chesapeake Bay Foundation, 2001; Maryland Department of Environmental Protection, 2002; Nolan et.al 1997). Given that water quality is a reflection of the land use activities and physical features of a watershed or recharge area, this approach relates the characteristics of the watershed to potential sources of pollution that may lead to impaired water quality through "cumulative" effects of increased pollutant inputs and hydrologic stresses with increased impervious and surface water runoff. These indices couple high quality spatial data on a suite of landscape features with our current understanding of land use impacts to evaluate and compare risks to water supplies. Our focus is on identification of high risk situations that could lead to impaired water quality and identification of appropriate management options to prevent degradation.

The relationship between watershed characteristics and water quality is grounded on basic, widely accepted concepts about movement of water and pollutants applicable to both surface stormwater flow and leaching to groundwater (Dunne and Leopold, 1978; National Academy of Sciences, 1993). These principles include:

- Most water pollution comes from the way we use and develop land.
- Intensive land use activities are known to generate pollutants through for example, accidental leaks and spills, septic system discharges, fertilizer leaching, or runoff from impervious areas.
- Forest, wetlands, and naturally vegetated shoreline buffers have documented ability to retain, transform, or treat pollutants.
- Natural landscape features such as soil types and shoreline buffers determine water flow and pollutant pathways to surface waters and groundwater.

Land use pollutants are therefore not completely diffuse across a landscape but are associated with recognizable patterns of intense land use in combination with hydrologically active sites, such as areas of high water table and excessively permeable soils, where pollutant movement is more likely given soil type and proximity to receiving waters. Recent findings by the U.S. Geological Survey document the validity of using this approach to assess pollution risk. In an extensive national review comparing water quality of streams and aquifers with watershed characteristics, USGS researchers (Nolan et.al. 1997) concluded that water quality is the result of multiple variables, not pollutant inputs alone. This study demonstrated that a combination of land use and landscape characteristics were highly reliable in identifying settings at greatest risk of contamination.

Using these accepted concepts, areas of high pollution risk can be mapped to provide a rapid, first-cut assessment to screen pollution

Threats to Groundwater

Ninety percent of Rhode Island groundwater is suitable for drinking but low-level organic contaminants have been found in 15 – 30% of wells tested. The most common contaminants are petroleum products, organic solvents, nitrates and pesticides.

The major sources are:

- *Underground storage tanks*
- *Hazardous and industrial disposal sites*
- *Spills*
- *Landfills*
- *Septic systems*
- *Road salt*
- *Fertilizers and pesticides*

RIDEM 2002

risks and set a direction for additional analysis or management. The indicators used in this source water assessment are standard measures commonly used in similar watershed analyses to evaluate a waterbody's susceptibility to degradation. These indicators include for example, the factors listed below.

Type of Pollution Risk	Indicators
The presence of likely pollution sources and stressors.	▪ Percent high intensity land use ▪ Percent impervious cover ▪ Estimated average annual runoff and nutrient loading
Landscape features promoting pollutant movement to surface or ground waters.	▪ Location and extent of highly permeable soils ▪ Location and extent of shallow water table networks. ▪ Developed shoreline buffers
Waterbody features that amplify vulnerability to contaminants.	▪ Aquifer type ▪ Reservoir depth and flushing rate ▪ Existing water quality condition.

More detailed information about pollution risk indicators and mass balance modeling methods used in this assessment are provided in the results section of this report, with more extensive information also provided in the appendix.

Data Sources and Outputs

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

- Review of existing water supply management plans, municipal plans and ordinances, state reports, Rhode Island Department of Health water quality monitoring data.
- Local input from municipal officials, water supply representatives and assessment volunteers for important information on existing conditions and concerns.
- Map analysis of land use, soils, known pollution sources and other watershed features to systematically locate probable pollution "hotspots" using the RI Geographic Information System (RIGIS) database. Data derived from the RIGIS database is intended for planning-level analysis only.
- Land use and soils acreages extracted from the RIGIS map database, compiled using a separate spreadsheet and summarized as averages for each study area.
- Modeled estimates of average annual runoff, groundwater recharge, and nutrient loading as measures of cumulative pollution risk. This is a standard mass balance method similar to those widely used in comparable applications elsewhere including Cape Cod and the New Jersey Pine Barrens.

2.4 Database Development

Land use derived from the RIGIS database provides the main source of data for land use. Complete documentation of methods used to create a land use database, and detailed results for each study area, is included in the Appendices. This includes a land use breakdown by soil type for each study area, land use characteristics of shoreline zones, and estimated future land use based on buildout projections.

Land Use Inventory

The land use data for this analysis was derived from the 1995 RIGIS coverage, using twenty-one land use categories consolidated from 32 mapped categories based on similar use, intensity, and pollution risk. Land use maps were updated with major changes and corrections identified by assessment mapping volunteers based on their know-ledge of the area and windshield surveys. The number of dwelling units was estimated from the RIGIS residential land use categories. Population was based on 2.4 persons per dwelling unit, unless otherwise determined. The town sewer service district was updated when possible using sewer line information provided by the towns. Without parcel level data on the number of homes actually connected to the sewer line, we assumed homes within 500 feet are reasonably likely to take advantage of public sewers. Based on the land area outside the sewer district, we estimated the number of houses with septic systems per acre based on RIGIS residential land use categories.

Build-out Methods and Assumptions

To estimate future development potential we conducted a build-out analysis for each study area individually. Using town zoning maps as the future land use scenario, we assumed all privately owned and unprotected land would be eventually developed based on the underlying zoning district. We did not estimate a time frame for this growth. In calculating the potential change in future land use acreages we made the following assumptions:

- All permanently protected open space will not be built upon.
- New development density will adhere to current zoning.
- Most privately held open space (Scout Camps, golf courses, rod & gun clubs) will not be developed further.
- Areas with wetlands, bedrock on surface, and very high water table soils (>1.5') will not be built upon.
- Surface waters and their tributaries will retain undisturbed buffers of 200 feet.

2.5 Assessment Steps

The following steps briefly outline the process used to involve the public and conduct the assessment.

1. ***Organize an assessment group.*** In each study area, RI Health and URI Cooperative Extension worked with the water supplier and municipal officials to coordinate and schedule the assessment, identify key organizations to be involved, and recruit local volunteers to participate in the assessment. *Mapping volunteers* were trained to field check land use maps and inventory potential sources of pollution. A small group of *Assessment volunteers* – primarily town staff and board members –reviewed draft results, provided input on local resource issues, and made suggestions for management controls.

2. ***Create land use and natural resource inventory maps for display and analysis.*** The study area boundaries were selected in cooperation with the water suppler and/or town officials. At a minimum this included the water supply watershed or wellhead protection area but in some cases was expanded to include other areas for future planning purposes. In cooperation with local volunteers, RIGIS land use maps were updated with major land use changes and known or suspected pollution sources. A future land use/zoning map was created using town coverages or digitized from zoning boundaries provided by the town. The basic coverages used in the assessment include land use, soils, sewer lines (buffered to create an area coverage) and surface water buffers (200 feet).

3. ***Briefly summarize existing conditions.*** This is a brief overview, based on available plans, monitoring data, and water quality issues identified by water suppliers, municipal officials and assessment volunteers. In addition, the RI HEALTH public well database was analyzed and results for the past five years were summarized and ranked using the RI Source Water Assessment ranking.

4. ***Identify and rank pollution risks based on current land use.*** Using land use, soils, and other mapped data, the MANAGE model uses 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. Basic land use characteristics, number of potential pollution sources, and monitored data are factored into a pollution risk rating for each source water area.

5. ***Map high-risk pollution "hot-spots" for the whole wellhead protection area or reservoir watershed.*** 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.

6. ***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 municipal zoning and future land use maps created in step 2.

7. ***Forecast future land use impacts to water resources using the "build-out" analysis.*** Pollution risk indicators and a hydrologic budget/ nutrient loading for future land use are estimated by re-running the spreadsheet analysis (Step 4) using the future land use map.

8. ***Summarize and rank pollution risks.*** The RI Source Water Assessment Ranking was used to summarize and rate pollution risks for each water source, with results averaged as one ranking for suppliers having more than one source of supply. This basic rating is used for all public water supplies in Rhode Island. For major community supplies additional risk factors, such as impervious estimates, nutrient loading and build out results, were also identified and rated.

9. ***Evaluate effectiveness of management options to reduce pollution risk.*** Using the MANAGE spreadsheet, we estimated the relative change in runoff and nutrient loading that could be expected under different pollution control practices. Because this analysis is limited to change in nutrient loading only, a wide range of management options were identified based on accepted current best pollution prevention practices.

10. ***Make results available to water suppliers, local decision makers and the public.*** Final results are summarized as a technical report and a 4-page full color fact sheet. These are available through the RI HEALTH and URI Cooperative Extension web sites. Fact sheets are suitable for direct mail to watershed residents by water suppliers or municipalities. Although it is beyond the scope of the source water assessment program to develop detailed action plans, reports include recommendations focusing on pollution prevention. Map analyses are made available as large-format maps. In cooperation with RI HEALTH, final summary results will be presented to town officials, with presentations scheduled at the convenience of town councils and planning/zoning boards.

Source Water Protection Savings

Rhode Island public water suppliers are estimated to have saved **$2,755,180** in a three-year period through "monitoring waivers" granted by US EPA based on source water protection plans.

Where a supplier has a source water protection plan in place, where certain pesticides and organic chemicals are not used in a source area or state, and where sampling data also confirms the supply is not vulnerable, water suppliers may reduce monitoring. This means money saved can be better spent protecting against actual threats.

Source: Technical and Economic Capacity of States and Public Water Systems to Implement Drinking Water Regulations, Report to Congress, September 1993, as reported by New England Interstate Water Pollution Control Commission, 1996.

Applying Results

In addition to meeting EPA requirements, source water assessments have many practical applications. One key benefit for water suppliers is to support monitoring flexibility. Based assessment results, RI HEALTH may grant monitoring waivers to a supplier for specific contaminants that are not found within the source area. This can amount to savings of several hundred dollars per year for each system that receives waivers. The actual amount depends on the specific testing requirements that may be waived. The state can also use assessment results to require additional monitoring for supplies at risk or to earmark grant money for pollution prevention programs for the systems at highest risk (RI Health 1999).

Assessment results can also provide a basis for future watershed assessment. The GIS map inventory of land use risk factors and mapped pollution sources establish a database that can be used to update watershed protection plans. In source water areas where field monitoring data is limited, assessment results may be used to locate high risk areas for additional field monitoring, to support design of expanded field monitoring, or identify areas where specialized field studies or modeling is warranted.

Because the assessment focuses on potential land use impacts, assessment results have been used to strengthen local land use planning and regulation. The following are, for instance, a few ways RI communities have used assessment results:

- Update town water quality goals and priorities for action. Towns have incorporated assessment findings and recommendations into town comprehensive plans, water supply or wastewater management plans, and other watershed plans.
- Support adoption of wastewater inspection and upgrade ordinances, and develop standards for performance of onsite systems through zoning overlay districts. Information generated on pollution risks and suitability for onsite wastewater treatment has been used to build support for better wastewater management and to determine level of improvement needed.
- Create and distribute public information materials, incorporating assessment results and maps, targeting high risk areas.
- Use map products generated in routine town planning and project review.

Assessment recommendations incorporate current accepted management practices focusing on pollution prevention. Although these were developed with local input, recommendations in this report are not truly town priorities unless incorporated into town plans, capitol improvement budgets, and ordinances. The next step is for local officials to review assessment results in light of current policies and management practices, and develop their own list of protection priorities with implementation plan.

3. POLLUTION RISK RESULTS

This chapter summarizes the primary results of the assessment using land use and landscape characteristics of each study area and modeled estimates of nutrient sources based on these local features. Summary statistics generated are used as "indicators" of watershed health and potential risk to water quality. Findings are organized as follows:

- Background on the relationship between watershed characteristics and water quality explains our assumptions about indicators, their appropriate use, and how to interpret results.
- Each indicator is briefly described and results for the study areas presented in chart form with brief narrative. Although each study area is assessed separately, results are reported for the study areas as one group, using a summary chart and brief narrative. A ranking is assigned to frame results in terms of low to high risk.
- Runoff and nutrient loading estimates, which are additional indicators modeled using a simple mass balance approach, are described and results summarized in a similar way.

Results are typically presented for both current and future conditions, with projections based on land use data extracted from the build out analysis. In some cases the potential effect of alternative management practices may be tested by adjusting input values to represent various pollution control practices, such as reduced fertilizer application or use of nitrogen-reducing on-site wastewater treatment systems. Alternative management scenarios are generally explored using nutrient loading estimates but other indicators may be used as well depending on the type of change expected.

Results presented in this chapter are key findings from a relatively small number of indicators most appropriate for the local study areas. These were selected considering the particular pollutants and stresses of concern to local water resources, current land use risks, and type of growth expected. Complete summary statistics for each study area and in some cases, results of additional analyses not shown here, are included in the appendix to this report. Supporting documentation on selection, use and ranking of indicators is also included in appendices.

3.1 Linking Land Use to Water Quality

The quality of ground and surface water is the product of multiple variables. Although land use is an extremely useful gauge of pollutant inputs, other factors, such as depth to water table, forested buffers, and characteristics of a reservoir or aquifer, also influence contaminant movement at different scales. Extensive comparison of watershed and aquifer features with monitored water quality show that the combination of natural features and human influences are the most reliable predictors of impaired water quality (Nolan et.al.,1997).

Rhode Island's Drinking Water

Public Water Suppliers
have at least 15 service connections, or serve at least 25 people per day for at least 60 days of the year. Rhode Island has about 477 public water suppliers serving more than 1,055,000 people. These fall into four categories:

Types of water supplies
17 *Large community water suppliers* pump at least 50 million gallons per year.

About 70 *Small community water suppliers* serve residential customers such as clusters of homes, trailer parks and nursing homes, but pump less than 50 million gallons per year.

74 *Non-transient non-community suppliers* serve at least 25 of the same people for at least 60 days a year, such as schools or businesses.

330 *Transient non-community suppliers* serve at least 25 different people at least 60 days of the year. These include for example, hotels, campgrounds and restaurants

Surface or Groundwater
74% of Rhode Islander's drink water from surface water supplies – the Scituate Reservoir alone provides water for 60% of the state's population.

The 22 largest water companies use surface water.
The other 455 water systems use groundwater.

26% of Rhode Islanders rely on groundwater for water supply, about 100,000 of these have private wells.

Vulnerability of Public Wells

In a recent U.S. Geological Survey study conducted in Rhode Island, researchers verified that public groundwater supplies are more likely to show elevated levels of toxic contaminants and nitrogen when high intensity uses are located within the wellhead protection areas.

Solvents and other toxics were clearly associated with industrial land uses. 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 schools.

(DeSimone and Ostiguy, 1999).

Taking advantage of these established relationships, this assessment uses selected characteristics of the study areas as watershed "health" indicators. These indicators are ranked to evaluate the degree to which water resources in each study area are susceptible to pollution. Results reported in this section highlight situations where pollutants are more likely to be generated and transported to surface or groundwater. The potential for pollutant movement considers the most likely immediate water flow pathway, based on soils and proximity to receiving waters to evaluate whether surface or ground waters are more susceptible to contamination.

Indicators used in this assessment provide estimates of potential threats to water quality based on established but generalized relationships between landscape features and water quality. It is important to emphasize that results indicate potential, not verified pollution problem areas. These estimates may not hold true in every case due to wide variation and inherent unpredictability of natural systems. Given this uncertainty, risk factors provide useful information to identify key threats most likely to affect drinking water quality and to rank those threats based on trends observed in other water bodies. Results are designed to direct pollution prevention actions to high-risk locations threatening high value resources.

Understanding and Interpreting Results

Assessment results are best used to compare relative differences in risk among study areas or between different land use scenarios. Subwatersheds or recharge areas representing a range of land use types and densities provide the most useful comparative results. Undeveloped study areas with extensive forest and undisturbed shorelines are particularly valuable as "reference" sites representing natural, low-risk conditions. At the other end of the spectrum, densely developed or disturbed study areas, where water quality is highly susceptible to impact, represent "high risk" circumstances. In each case reference watersheds provide more realistic benchmarks when monitored water quality data corresponds to estimated risk levels based on mapped features or modeled nutrient loading estimates.

Future pollution risk estimates developed from the build out analysis are approximate projections intended to highlight potential future pollution risks and should not be viewed as absolute values. Because current and future values were created using consistent methods, both can be compared directly. This generates useful information in determining whether water resources are at greater risk from current activities or future development. Perhaps most importantly, results can support selection of appropriate management actions to address areas of greatest risk, focusing for instance on mitigating existing threats, con-trolling impacts of new development or avoiding future impacts by modifying town land use goals and zoning standards. In some cases the potential effects of improved pollution control practices may be tested by adjusting input values to represent various pollution control options, such as reduced fertilizer application or use of nitrogen - reducing on-site wastewater treatment systems.

In evaluating assessment results it bears repeating that this is a screening level analysis generating approximate values. At the same time, these estimates are based on current, high-resolution data that is adjusted for the study areas. Input values for basic indicators, such as high intensity land use, were calculated directly from updated local land use maps in combination with other reliable data sources, such as population and housing occupancy derived from U.S. Census data and town records. Nutrient loading inputs to groundwater are based on research conducted in Rhode Island on typical local land uses; values for lawn area and fertilizers rates may also be modified based on local recommendations. Consequently, results are designed to reflect site-specific conditions to the maximum extent possible while still relying on mapped coverages and other readily available data sources. As a follow-up to this assessment, we recommend that results, especially mapped locations of potential high-risk pollution sources, be verified based on local knowledge and field investigations.

Ranking Pollution Risks

To make the assessment more useful for management decisions, indicator results are generally ranked along a scale from low to high or extreme risk. These thresholds are general guidelines serving as a frame of reference in interpreting results. They should be considered points along a continuum, not rigid categories with distinct boundaries. In setting pollution ratings for the various watershed indicators, risk thresholds are generally set low as an early warning of potentially hazardous conditions before adverse impacts occur. For example, in drinking water supply watersheds the presence of any high intensity land use within 200 feet of surface waters automatically rates a moderate risk to water quality. This is based on the assumption that *any* high-risk land use within this critical buffer zone is a possible threat and should be investigated. Low risk thresholds are designed to help prevent degradation of high quality waters, including drinking water supplies that may be un-treated, coastal waters that are sensitive to low level increases in nitrogen, and unique natural habitats that may also be sensitive to small fluctuations in sediment levels, temperature or phosphorus. Identifying risks in early stages also provides an opportunity to take pollution prevention actions as the most cost effective approach to protecting local water quality rather than relying on clean up actions after degradation occurs. In general, restoring a polluted water body is much more costly and technically challenging than pollution prevention.

Interpreting results of indicators

Establishes relationship between watershed condition and potential water quality condition based on trends observed in other water bodies.

Estimates derived from GIS databases should be verified using local maps or field data. Actual water quality condition should be verified through field measurements.

Estimates are best used to compare relative differences among study areas or between different land use / pollution management scenarios.

Ranking thresholds are not sharp breakpoints but points along a continuum.

Results are intended to identify key threats most likely to affect drinking water quality, and to direct pollution prevention actions to high risk locations threatening high value resources.

While ranking systems are useful in organizing and distilling results it is important to recognize that any ranking system can easily mask or over-simplify results. For instance, when indicator risk levels are near the edge of one risk category, a change in only a few points causing a shift to the next risk level may represent only a minor increase in actual threats. At the same time, greater increases occurring within a category may represent real threats that go unnoticed. Likewise, low summary rankings created by averaging results of several variables can easily obscure localized but extreme risks, giving a false sense of confidence in existing protection measures. Because all watershed indicators represent averages for a study area or shoreline zone, we recommend careful review of land use and hot spot maps to identify site-specific locations for pollutant movement. When interpreting indicator results we have tried to emphasize areas of greatest risk, major differences among different study areas or development scenarios, and general trends. We have chosen not to evaluate results using statistical measures, partly because doing so may imply results are solid data points rather than estimates of potential risk. Rather than focusing on exact values generated, we believe results are best used to compare actual conditions and trends, to stimulate discussion of acceptable risks, and to support selection of appropriate management practices.

3.2 Land Use / Landscape Risk Indicators

HIGH INTENSITY LAND USE

High intensity land use activities use, store or generate pollutants that have the potential to contaminate nearby water resources. Both sewered and unsewered areas are included in this indicator based on evidence that densely developed areas generate high levels of pollutants regardless of the presence of public sewers. The water quality risks associated with intense land use activities cover a broad range of pollutants and hydrologic stresses, generated from a wide variety of sources. These include for example:

- Fuel products from leaking underground storage tanks.
- Solvents and other toxic materials from accidental spills or improper disposal, especially at industrial sites.
- Hydrologic impacts and polluted runoff from roads, parking lots and other impervious surfaces.
- Nutrient, bacteria and increased runoff from subsurface drains used to intercept groundwater on house lots and in agricultural fields.
- Nutrients and pesticides applied to tilled cropland, home lawns, parks and golf courses; also bacteria and nutrients from animal waste storage sites and where livestock have access to water.
- Nutrient and bacteria from leaking sewer lines or malfunctioning pump stations, and from septic systems in dense unsewered areas (Pitt et al. 1994).

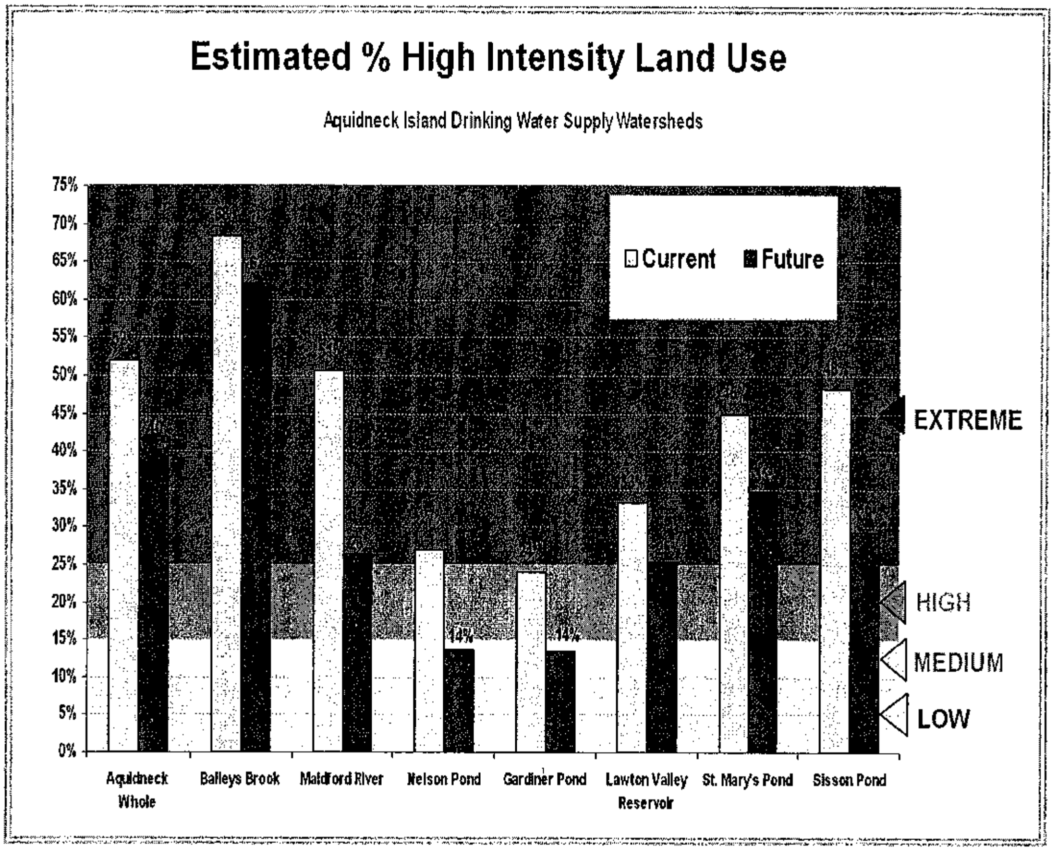
At the site level, ranking the intensity of development or its potential to pollute surface and groundwater resources must also take into consideration the suitability of the land to accommodate development as well as the proximity of the development to shoreline zones. For ex-ample, although medium density residential development on one acre size lots is not considered a high intensity land use, it could have a potentially serious impact on water resources depending on soil conditions, slope or hydrology of the land. Other indicators designed to evaluate these site features include: percent high intensity land use within shoreline zones, on high water table, and on excessively permeable soils. Results are presented in this chapter and/or in the appendices to this report. In addition, co-occurrence of high intensity land use with problem soils and shoreline areas was mapped to identify potential high-risk pollution "hot spots".

We identify six high intensity land use categories. A complete list is included in the Manage Technical Documentation, an appendix to this report. The ranking system used assigns a low risk to watershed areas having 10 percent or less land in high intensity uses. Water quality is considered to be at extreme risk in study areas with greater than 40 percent high intensity land use.

High Intensity Land Uses

- *Commercial and industrial uses.*
- *Highways, railroads and airports.*
- *Junk yards.*
- *High and Medium-high density residential >4 units / acre.*
- *Schools, hospitals and other institutional uses.*
- *Tilled cropland such as corn, potatoes, and nursery crops.*

Figure 1a. Estimated High Intensity Land Use



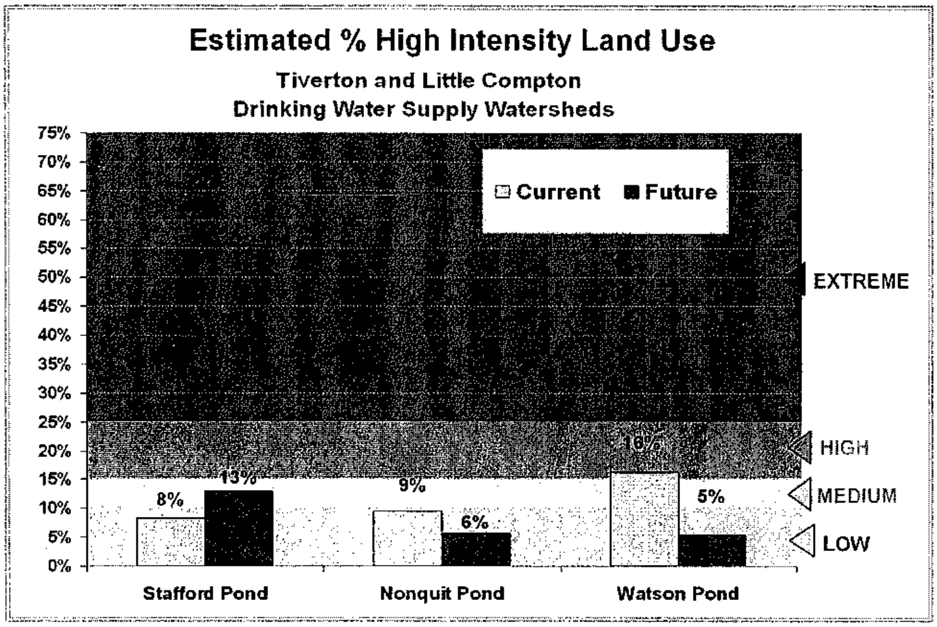
Results: High Intensity Land Use

- As is evident in Figure 1a, the Bailey Brook watershed has the highest proportion of high intensity land use (68%). All seven public drinking water supply watersheds on the Island are either in the extreme or high risk category for this indicator.

- Declines in the percent of high intensity land use are due to the expected conversion of cropland to lower density residential development.

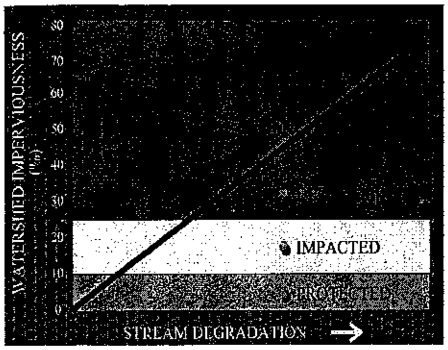
- Based on the land use build-out analysis conducted for this study, only Nelson Pond and Gardiner Pond watersheds are expected to fall into the medium risk category if cropland is converted to residential development. Under current agricultural land use, pollution risks are primarily related to use of fertilizers and pesticides and erosion from tilled land, all of which can be minimized through use of good farmland management practices.

Figure 1b. Estimated High Intensity Land Use



- In the Tiverton and Little Compton public drinking water supply watersheds, only Watson Pond watershed has reached the high risk category for this indicator. Currently, both Stafford Pond and Nonquit Pond watersheds are in the low risk category.

- Conversion of cropland to low-density residential will reduce levels of high intensity land use in both the Nonquit Pond and Watson Pond watershed in coming years. In the Stafford Pond watershed, on the other hand, new industrial development would send this area into the medium risk category.



Increasing impervious cover results in declining stream health.
Adapted from Schueler, et. al. 1992

The Relationship Between Percent Impervious Cover and Water Quality

The connection between impervious cover and water quality applies to wetlands, streams and small rivers (1st, 2nd and 3rd order) and has not been validated for other waters such as lakes, reservoirs and aquifers (Center for Watershed Protection, 2002; Hicks, 1997). Increasing impervious cover with urbanization has been shown to lower groundwater tables, however, the thresholds where the extent of impervious surfaces begin to affect groundwater quality or quantity has not been established.

Recent findings suggest that the relationship between impervious cover and stream quality is weakest for streams in less developed watersheds in the 0-10 percent impervious range. These were found to be most susceptible to other influences such as percent forest cover, continuity of vegetated shoreline buffers, soils, agriculture, historical discharges, and other stressors. As a result, more careful review of forest cover, other factors and field measurements become more important in watersheds with less than 10 percent imperviousness. (Center for Watershed Protection 2002)

IMPERVIOUS COVER

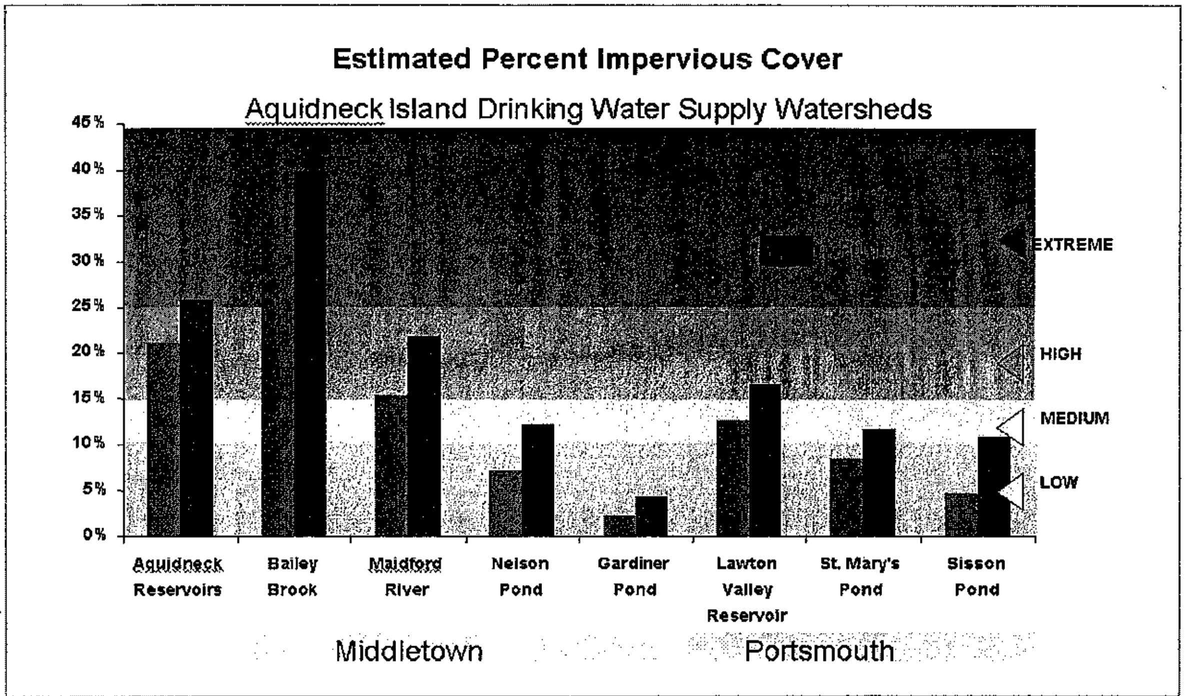
Impervious cover is a catchall term for pavement, rooftops, and other impermeable material that prevent rainwater from seeping into the ground. Impervious surfaces affect water quality by increasing polluted runoff. Paved areas provide a surface for accumulation of pollutants and create an express route for delivery of pollutants to waterways. Just as importantly, impervious cover alters the natural hydrologic function of the landscape by dramatically increasing the rate and volume of runoff and reducing groundwater recharge.

High levels of impervious surfaces within a watershed lead to "flashier" streams with widely fluctuating water levels, diminished stream flow during critical summer low-flow periods, higher stream temperatures, and increased sedimentation in streambeds, which decreases the capacity of streams to accommodate floods. In streams and wetlands these changes result in loss of habitat, reduced biodiversity, and chemical changes in water quality. Without subsurface water infiltration, natural pollutant removal by filtering and soil microbes is bypassed, compounding pollutant delivery. In groundwater recharge areas, impervious cover reduces recharge to deep groundwater supplies.

Numerous studies have linked the extent of impervious surfaces to declining aquatic habitat quality in streams and wetlands (Schueler 1995; Arnold and Gibbons, 1996; Prince George's County, 2000). According to these reports, stream and wetland habitat quality is often impaired as watershed impervious levels exceed 10 percent, with as little as 4 to 8 percent affecting sensitive wetlands and trout waters (CWP 2002, Azous and Horner 1997, Hicks 2002). At greater than 25-30 percent imperviousness, the extent of flooding and stream water quality impacts can become severe. Under these conditions, flooding may be controlled but stormwater treatment systems designed to improve the quality of runoff have much lower success rates.

We use standard methods to calculate impervious cover for RIGIS land use categories (USDA 1986). These represent averages for each land use type including local roads. Impervious cover on individual lots is likely to be lower. Assumptions are listed in the Manage Tech-nical Documentation (appendix). Although RIGIS photo-interpreted land use is considered a highly reliable data source for estimating impervious cover, researchers at the University of Connecticut have found that impervious levels for similar land use types can vary considerably by community (Prisloe et.al., 2001). Our estimates are therefore best used to compare relative differences between current and future levels and among watersheds. For greater accuracy, impervious estimates could be refined by either direct measurement of aerial photographs and subdivision plans or by local knowledge of typical house, driveway, road, and parking areas for local neighborhoods.

Figure 2a. Estimated Impervious Surface Area



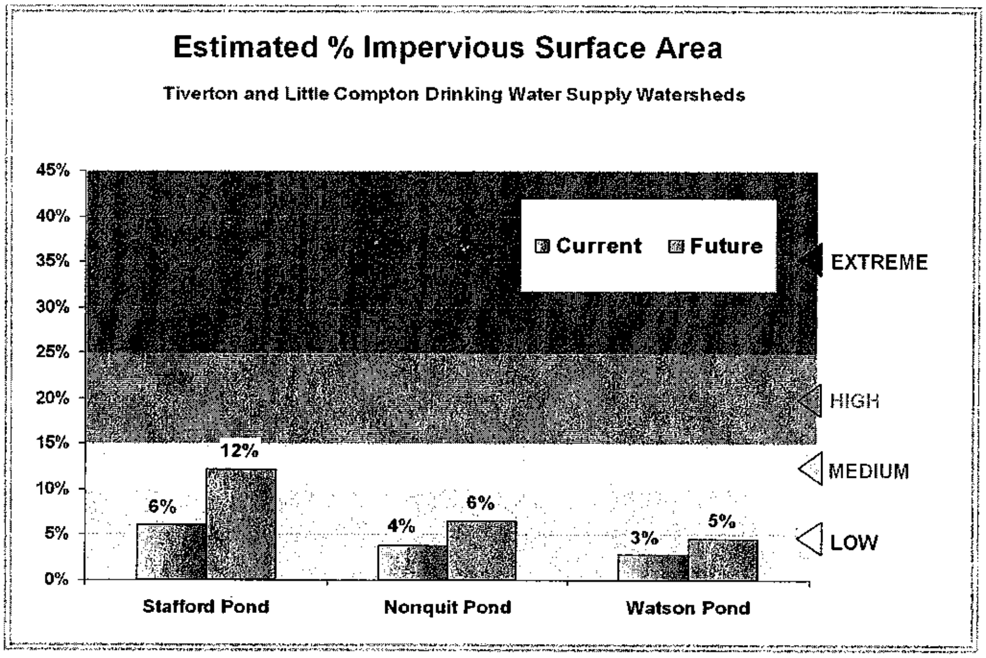
Results: Impervious Cover

- The Bailey Brook watershed is in the extreme risk category for this indicator, with impervious surfaces covering 35 percent of the watershed. High levels of impervious surface area are a serious concern given potential impacts to aquatic life in streams and wetlands, and because of the difficulty of improving stormwater runoff *quality* once levels have exceeded 25 percent.

- In the Lawton Valley Reservoir and Maidford River watersheds, minimizing current impacts of impervious area (ranked as medium and high risk, respectively) and preventing projected increases to the next risk level are priorities.

- Aquidneck Island towns have a real opportunity to maintain low levels of impervious surface area in the Nelson Pond, Gardiner Pond, St. Mary's Pond, and Sisson Pond watersheds. To do so, municipal regulations can require reduced levels of impervious surface area for all new developments in public drinking water supply watersheds, including reductions in road width, shorter driveways and reduced lot coverage.

Figure 2b. Estimated Impervious Surface Area



Note: *Percent impervious area is presented as an average for each study area. Within each area small lots and high water table soils are likely to generate a higher proportion of runoff given limited space for infiltration and the fact that runoff occurs primarily on high water table sites.*

- Based on the assumptions used in this study, the percent of impervious surface area in the Nonquit Pond and Watson Pond watersheds are expect to remain in the low risk category.
- Impervious surface area is expected to rise into the medium risk category in the Stafford Pond watershed due to the high proportion of impervious surface area associated with industrial development (72% of lot coverage).

FOREST AND WETLAND

Experts agree that forest and wetlands are directly linked to the health of watershed streams and coastal waters (EPA 1999, CWP 2002). Forest and wetlands serve as ecosystem treatment systems, helping to preserve and maintain watershed health. Unlike the other risk factors presented in this study, there is an *inverse* relationship between the amount of these undeveloped lands and risk to water quality. Although some indices assign separate ratings to forest and wetlands area, we combine them based on the simple observation that in Rhode Island, healthy watersheds often consist of one or the other.

Together, both forest and wetlands help to offset the negative hydrologic impacts of development and corresponding pollution inputs to surface and groundwater. In this assessment we consider wellhead protection areas or watersheds that have a combined forest and wetlands cover of 80 percent or more to be at low risk of pollution. Conversely, study areas with less than 20 percent forest and wetlands cover are considered to have little ability to function as treatment areas, and are ranked as having an extreme risk of pollution.

Forests are highly productive, living filters in the natural hydrologic cycle on which we all depend for clean and plentiful source water. Forested watersheds have the capacity to intercept, store, and infiltrate precipitation, thereby recharging groundwater aquifers and maintaining natural stream flows. Undisturbed forest soils tend to store organic matter and nutrients, including atmospheric pollutants associated with acid rain. Forested wetlands and stream buffers also provide shade to surface waters, stabilize stream banks, and filter sediment. In calculating the percent of forest cover in a wellhead protect-ion area or watershed, we also include brush and unfertilized pasture, which provide similar ecological functions in the hydrologic cycle.

Wetlands are a vital link between land and water. Wetland ecosystems function in significant ways to improve water quality and control flooding. At a watershed scale, the extent of wetlands is a mea-sure of the potential for sediment trapping, stormwater storage, and nutrient transformation. Individual wetland functions are highly variable, however, depending on factors such as seasonal changes, location in the larger watershed, storage capacity and ecological condition with respect to pollutant inputs. Despite this variability, the extent of wetlands within a watershed is strongly correlated with healthy eco-systems (Hicks 1997, Amman and Stone 1991, Azous and Horner 1997). Watersheds with a small amount of wetland area have potentially less opportunity for pollutant treatment, less storage capacity to moderate changes in hydrology brought on by urbanization, and a higher potential for direct pollutant delivery to surface waters.

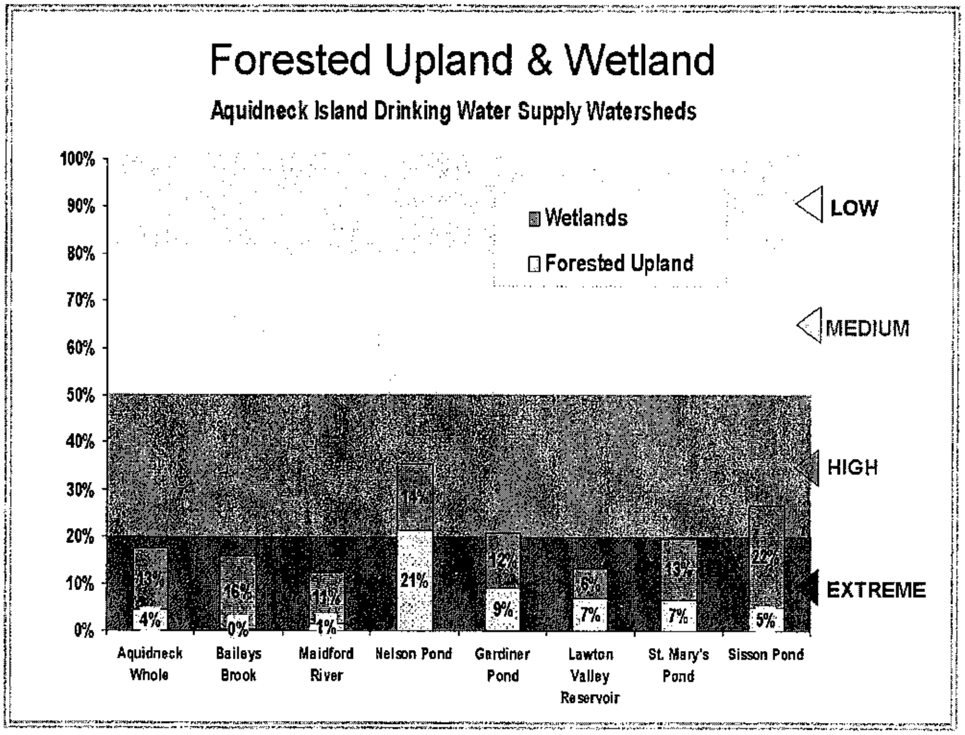
Forests: Watershed Treatment Zones

In New England, field measurements show that rain and snow contain and deposit 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 nearby surface water. However, when this nitrogen-rich rain falls on forested land, the organic matter in soil absorbs and stores the rainwater, and converts atmospheric nitrogen into nutrients for plants and microbes.

In areas rich in forests and meadows, about 95 percent of rainfall infiltrates the soil. It is estimated that of the eight pounds of nitrogen deposited from rain and snow, six pounds are naturally recycled back into soil as nutrients, and only about two pounds per acre are lost to runoff.

Source: Ollinger et.al. 1993 & Yang et.al. 1996.

Figure 3a. Estimated Forest and Wetlands Cover



Wetland value vs. function

Percent wetland area gauges the generalized water quality benefit of wetlands within a watershed. However, wetlands themselves are subject to degradation through habitat disruption. Increased sedimentation, nutrients, and water level fluctuations can disrupt habitat and impair water quality treatment function. Wetlands therefore 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 may be used to estimate potential impacts to wetlands from watershed activities.

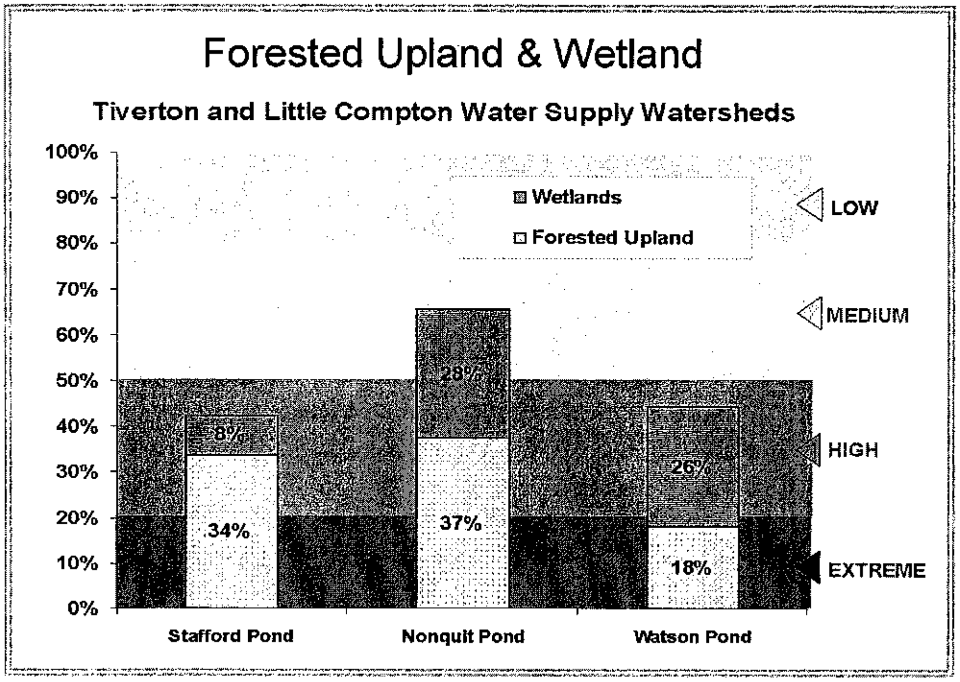
Results: Forest and Wetlands

- None of the Aquidneck Island study areas contain optimal expanses of forest and wetlands for ensuring high water quality. Based on Figure 3a, most of the public drinking water supply watersheds on Aquidneck Island fall into the extreme risk category for this indicator.

- The Gardiner Pond and Sisson Pond watersheds are approaching the extreme risk category.

- In coming years, all of the areas will lose additional forest cover due to suburban growth. The loss of forested land as a natural treatment system for atmospheric and land-based pollutants pose significant risks to the long-term health of public drinking water supplies in these areas.

Figure 3b. Estimated Forest and Wetlands Cover



- The public drinking water supply watersheds in the towns of Tiverton and Little Compton are either in the high or medium risk category for this indicator.

- Both Stafford Pond and Nonquit Pond watersheds may loss over half of their remaining forestland, given current zoning regulations. The loss of 1,000 acres of forestland in the Nonquit Pond watershed would move it into the high risk category in coming years. With the potential loss of 250 acres of forestland, the Stafford Pond watershed would rise into the extreme risk category.

- Protecting forestland in the Stafford Pond watershed should be a priority given current water quality impairments in the pond.

Water Quality Benefits of Shoreline Buffers

Vegetated buffers perform the following important functions

- *Filter sediment, phosphorus and other pollutants in runoff.*
- *Allow stormwater to infiltrate, promoting natural pollutant removal processes in the soil.*
- *Store floodwaters to reduce flooding and habitat scouring.*
- *Stabilize stream banks, 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 – especially important on smaller streams < 100' wide.*
- *Remove nitrogen, potentially transforming up to 80 percent of nitrogen into harmless nitrogen gas through microbial activity (Addy, K. et al. 1999).*
- *Other benefits include scenic views and open space, recreation, and wildlife habitat.*

SHORELINE LAND USE

High intensity, Impervious, and Forest and Wetland

Riparian simply refers to the shoreline zone, especially where surface and groundwater interact at the margin between land and water. To identify the most serious pollution threats to surface water, this assessment includes a separate analysis of land use and soils within 200 feet of surface waters. The shoreline area is calculated for all ponds, perennial streams, rivers and coastal waters that are large enough to be shown on a 1:24,000 scale USGS topographic map.

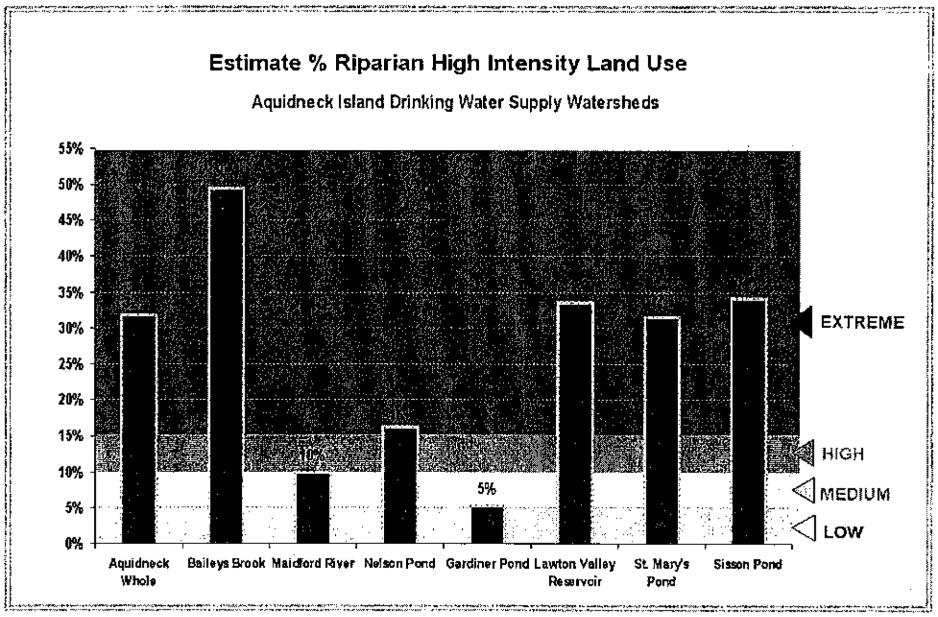
The riparian land use indicator actually incorporates a number of analyses, including the percent high intensity land use and percent impervious cover within the total shoreline zone of each study area. The proportion of undisturbed forest and wetland within the riparian area – and its inverse, disturbed forest and wetland – may also be used as a measure of watershed health in sensitive watersheds where any loss of protective buffers is a concern. Riparian characteristics are most useful in evaluating threats to surface waters, but may also indicate risks to wells hydrologically connected to nearby rivers and streams. Key findings are reported in this section with full results provided in the appendix.

Riparian functions

From a water quality perspective, riparian areas have the opportunity to function in two very different ways: 1) Vegetated shorelines 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. Consequently, developed shorelines have diminished capacity to filter pollutants, and may also contain impervious surfaces that can easily deliver pollutants directly to surface waters. Because of the potential for direct contamination of surface waters in the riparian zone, we assign a very low pollution tolerance to shoreline development. For analysis of drinking water supplies, the presence of any high intensity uses within the shoreline zone is considered a risk, with more than 15 percent is ranked as an extreme threat.

- It is important to note that in this assessment, the 200 ft. shoreline area is purely for analysis of immediate threats and not a recommended regulatory setback. State agencies or municipalities may require more or less than the 200 feet setback from surface waters. Because our goal is to identify the most direct threats to surface waters, our analysis does not include wetland buffers even though these are critical for wetland and water quality protection.

Figure 4a. Estimated High Intensity Land Use in Riparian Buffer



Map scale and accuracy errors *are most pronounced when dealing with small slivers such as buffer zones, especially when overlaying data layers produced from various sources at different scales. All map analysis, and particularly shoreline data, is suitable for planning level analysis only. Field inventory is needed to verify boundaries and pollution risk.*

Results: Shoreline Land Use Features

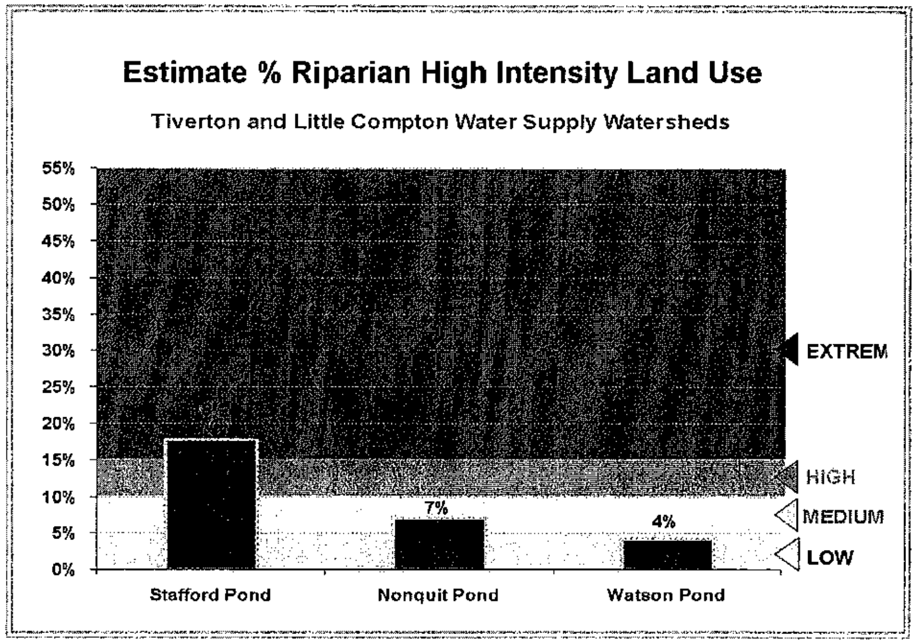
- Roughly 32 percent of shoreline buffers (200') to streams, ponds and reservoirs on Aquidneck Island are developed with high-intensity land uses. This creates an extreme risk of direct pollutant inputs to surface waters and limits the potential for buffers to function as treatment zones.
- The Bailey Brook watershed has the most extreme risk of pollutant inputs from streamside development, with high intensity urban land uses covering 50 percent of the 200-foot buffer zone.
- Other watersheds with extreme pollution risk from developed buffers on Aquidneck Island include the Lawton Valley Reservoir, Sisson Pond, and St. Mary's Pond watersheds, where 32 to 34 percent of shoreline buffers are developed in high intensity land uses. The Nelson Pond watershed is also in the extreme category, with 16 percent developed shoreline buffers.
- The Maidford River watershed is considered at high risk with 10 percent developed buffers.
- In each of the Aquidneck Island watersheds, agricultural lands account for at least a portion of the high risk land use within buffer zones.

Shoreline and wetland buffer protection strategies

Most wetland loss occurs through gradual encroachment of backyard wetlands (RIDEM 2002).
Local strategies for strengthening wetlands protection include:

- *Careful siting to avoid wetlands, with use of zoning variances from other less critical setbacks where necessary.*
- *Subtracting wetlands from calculations of maximum impervious area.*
- *Set limits of clearing and disturbance during construction; fence -off protected areas in the field.*
- *Set upland boundary for re-vegetation of buffers using native plants and shrubs; re-quire permanent fencing or other boundary marker to be installed at upland edge.*

Figure 4b. Estimated High Intensity Land Use in Riparian Buffer



- In Tiverton, the Stafford Pond watershed is in the extreme risk category due to the presence of higher density residential development along the northeastern shore of the pond.
- The Nonquit Pond and Watson Pond watersheds are in the medium and low risk categories, respectively.

SOILS

The ability of pollutants to move through various soil types is a critical factor in determining the inherent vulnerability of a water supply. Highly permeable soils will allow water and soluble contaminants to move quickly toward a working well, while impermeable or shallow soils will promote runoff to nearby surface waters. Locating potential pollution sources that lie on highly permeable soils in groundwater re-charge areas, or on impermeable or shallow soils near surface water supplies is an important component of this source water assessment. The assessment uses RIGIS data from the Rhode Island Soil Survey to map soils by four standard categories known as hydrologic soil groups. These soil "hydrogroups" describe capability of soils to accept and infiltrate water. Other features evaluated include: seasonal high water table depth; presence of restrictive "hardpan" layers where downward infiltration is extremely slow; and erosion potential, based on slope and 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. For example, in areas with sandy soils and a deep water table, pollutants can easily infiltrate and percolate to underlying groundwater reservoirs. Alternatively, soils with slow permeability have lower infiltration rates and tend to have a higher water table. In New England wet soils are almost always connected to wetlands, intermittent drainage ways and small streams, forming an extended drainage network where pollutants can easily flow from wet soils to surface waters.

Limitations of soil types

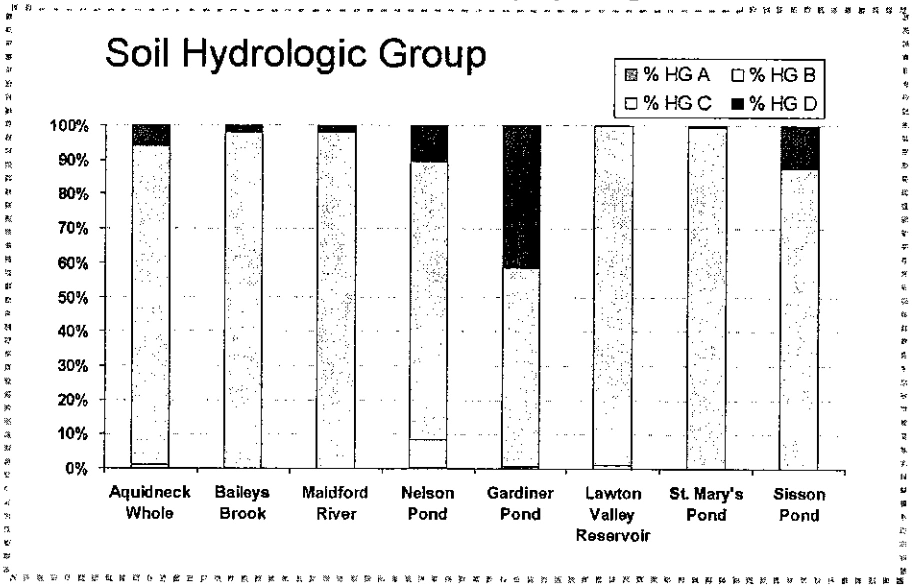
Knowing the proportion and location of soil constraints is a critical variable in predicting pollution risks and in selecting pollution controls. However, soil types are less useful indicators of water flow and pollutant movement where artificial drainage systems are used. Urban storm drains, channelized streams, building sites with subsurface drains, and artificially drained fields all bypass natural rainfall storage and infiltration processes and quickly divert runoff to downstream discharge points. These artificial improvements are not identified and must be field-inventoried. Under the RIDEM Phase II stormwater regulations, municipalities with urban areas will be required to inventory these stormwater systems.

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.

Soils in shoreline buffers
Using 100 randomly selected locations within a 100 foot stream shoreline zone, URI researchers recently compared field-verified soils with RI Soil Survey maps. These researchers found that soil maps were highly accurate, correctly identifying the presence or absence of wetland soils in 75 of 100 randomly selected locations within the shoreline zone. This study also found that map accuracy in narrow shoreline zones was also greater than would be expected, with the survey accurately identifying narrow bands of different soils types as small as 22 feet wide, even though national accuracy standards would allow up to 40 feet of deviation between the mapped and actual boundary. (Rosenblatt 1999).

Figure 5a. Estimated Percent of Soil by Hydrologic



Results: Soils

- Figures 5a and 5b represent the percentage breakdown of soils by hydrologic group in the study areas. In this assessment, we are most concerned with identifying the location of high runoff, hydrologic group "C" and "D" soils. These soils allow water to infiltrate slowly and commonly have seasonal high water tables. As a result, they tend to generate runoff. Managing stormwater runoff is difficult on these sites and they also pose a higher risk for septic system failure if developed.
- Hydrologic group "D"soils are primarily wetlands, which can temporarily store floodwaters and retain or recycle nutrients and other pollutants. However, sediment and increased stormwater runoff from development adjacent to these areas can overload this treatment function and promote rapid movement of pollutants to surface waterbodies. Gardiner Pond watershed has the highest percentage of these wetland soils (close to 50 percent). Given the extent of agricultural land uses, protection of wetland buffers is a concern in this watershed. In other more urban areas protection and restoration of natural drainage areas is a priority.
- All of the public drinking water supply watersheds on Aquidneck Island are characterized by hydrologic group "C" soils. Most of these slowly permeable soils have a restrictive "hardpan" soil layer that further restricts downward water infiltration. Seasonal high water tables of at least 3.5 feet from the ground surface are also common in these soils.

Hydrologic Soil Groups

In this assessment soils are grouped by water table depth and hydrologic soil group, which indicates the potential for rainfall to either infiltrate or runoff the ground surface.

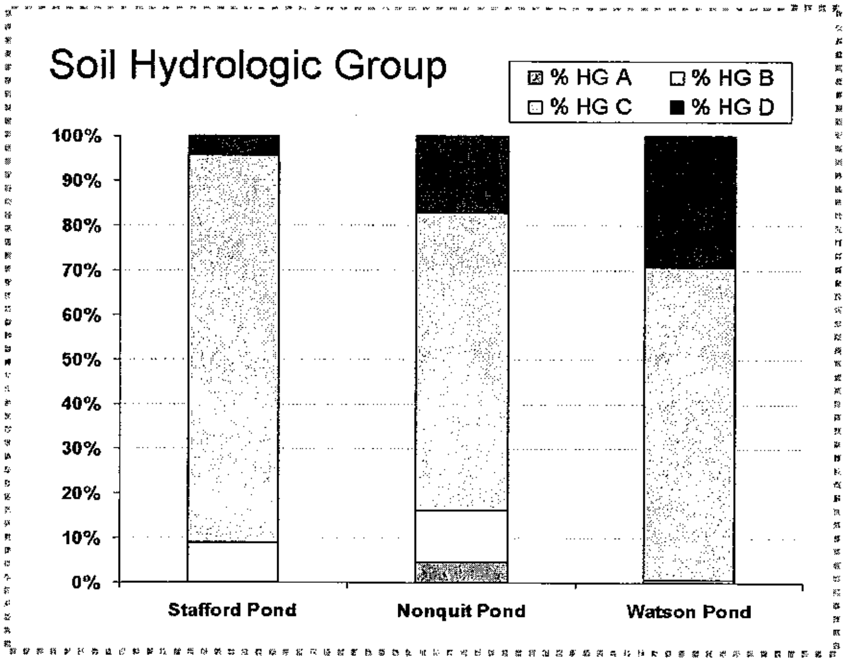
A – Excessively rapid drainage;
Water table > 6 ft.
High recharge, low runoff.

B – Moderate to rapid drainage;
Water table mostly > 6 ft.
High recharge, low-mod. runoff

C – Slow to restrictive drainage;
Water table mostly < 3.5 ft.
Low recharge, high runoff

D – Very slow drainage, mostly wetland, water table < 1.5 ft.
Low recharge, high runoff when wetland storage is full.

Figure 5b. Estimated Percent of Soil by Hydrologic Group



- In Tiverton and Little Compton, all three of the watersheds under study have a high proportion of "C" soils. In each of the watersheds, over 50 percent of soils have a restrictive hardpan soil layer.
- In the Watson Pond watershed, close to 60 percent of soils have a seasonal high water table less than 3.5 feet from the surface of the ground, roughly 30 percent of which are hydrologic group "D" soils.

High Water Table Soils

Recent studies have found that in marginal soils with water tables less than 3.5 feet, groundwater is likely to rise higher than expected following rainstorms and stay elevated for long periods (Morgan and Stolt 2002). Development of these soils therefore requires careful planning to identify suitable areas for temporary storage and infiltration of stormwater, as well as septic system siting to avoid compromising wastewater treatment function.

3.3 Runoff and Nutrient Loading Estimates

The runoff and nutrient loading estimates presented in this section are predictions developed using a standard "mass balance" approach to generate a simple average annual water budget and estimated nutrient sources to runoff and groundwater. These provide additional information on pollution sources and relative contribution from various sources. Phosphorus is used as an indicator of sediment-bound pollutants in runoff. Nitrogen is used as an indicator of other dissolved pollutants in surface runoff and in recharge entering groundwater.

Methods

Calculations are made using an Excel spreadsheet, which also generates statistics on the other watershed indicators described in the previous section. The input data sources are extracted from the RIGIS map database to include site-specific soils, land use types updated by trained volunteers, population estimates, and the estimated number of septic systems in each area studied. The analysis is run first for existing conditions using current land use map data. To evaluate future impacts the analysis is repeated using town zoning maps as the future land use scenario. As noted in the land use summary, this "build out" scenario assumes full development of all unprotected land other than wetlands and surface water buffers (200'). No timetable is estimated for this development to occur.

The model used an average annual precipitation of 42 inches per year, with 21 inches per year lost to evaporation and plant use (U.S. Geological Survey, 1961). The proportion of remaining "available" precipitation (21 inches) that is converted to runoff is estimated 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 NRCS, 1986). The remainder is assumed to seep into the ground to recharge either shallow or deep groundwater. Recharge to groundwater from septic systems is calculated separately based on average per capita water use and discharge to onsite systems of 50 gallons per person per year.

Nitrogen and phosphorus inputs to surface water from storm water runoff are estimated using generalized pollutant coefficients based on published literature values for 21 different land uses and direct atmospheric deposition on surface waters. Nitrate-nitrogen inputs to groundwater recharge are calculated separately, using results of URI field research on nitrogen losses to groundwater from specific sources, including septic systems, lawns, farmland and forest. Complete hydrologic and nutrient loading assumptions are provided in Appendix K, *Technical Documentation, MANAGE GIS-Based*

Mass balance hydrologic models

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).

Pollution Risk Assessment Method, Database Development, Hydrologic Budget and Nutrient Loading. Additional information about the MANAGE assessment method is available at http://www.edc.uri.edu/cewq/manage.html

Note on 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. In order to assemble a reasonable picture of watershed or aquifer conditions, water quality models use available information about pollutant interactions and apply it to a particular study area. Modeling is frequently used to estimate the source of pollutants to supplement 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 a valuable tool in testing relative effects of different land use options or pollution management decisions because even simple models can be used to explore what might happen if land in developed in a different way.

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. In this assessment we use a simple "mass balance" method similar to those widely used in comparable applications elsewhere, including Cape Cod and the New Jersey Pine Barrens. These methods calculate an annual 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.

Typically, results of most mass balance models are generated as average annual estimates of runoff, infiltration, and nutrient loading (loading, or total amount is expressed here as lbs/ acre/year) for each study area. These estimates are useful in comparing relative differences in pollution risk among various land use scenarios or among sub-watersheds. The concentration of nitrogen (mg/l) entering groundwater can also be estimated based on dilution of inputs with infiltrating rainwater. However, concentration estimates may not necessarily represent the concentration at a well because it is difficult to account for nitrogen loss in wetlands or uneven mixing in deeper groundwater. There are times when a more sophisticated modeling approach is needed. Some examples include: situations when estimates must 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 however, complex models usually require extensive field monitoring information as necessary data inputs.

Selecting simple vs. sophisticated models

When choosing a model it is important to be aware of limitations of both simple and complex models. For example:

- 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.
- The cost of complex modeling with field data collection is typically orders of magnitude greater than screening level modeling and assessment approaches.

The decision on whether to use a simple vs. complex model should consider the costs and benefits of additional study vs. implementing pollution controls. Management decisions need to be based on good science with sound findings of fact.

SURFACE RUNOFF

Runoff is not a common natural occurrence. In forested watersheds with sandy soils, up to 97 percent of precipitation can be expected to seep into the ground (Simmons, D. and R. Reynolds 1982). In well-drained upland areas, this infiltrating water recharges deeper groundwater supplies. In areas where the groundwater table is near the surface, water seeping into the soil enters shallow groundwater and flows to nearby wetlands and streams. In critical periods without rain, groundwater discharges to streams as "base flow" - the primary source of water in streams.

Runoff is associated with declining water quality because it disrupts the natural cycle of infiltration and gradual discharge to streams. Land development compacts the soil and adds acres of pavement, dramatically increasing the rate and total volume of storm water runoff. The result is increased flooding, stream scouring with loss of aquatic habitat, and reduced groundwater recharge. In addition to these hydrologic impacts, storm water 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 storm drains, or leaking sewers.

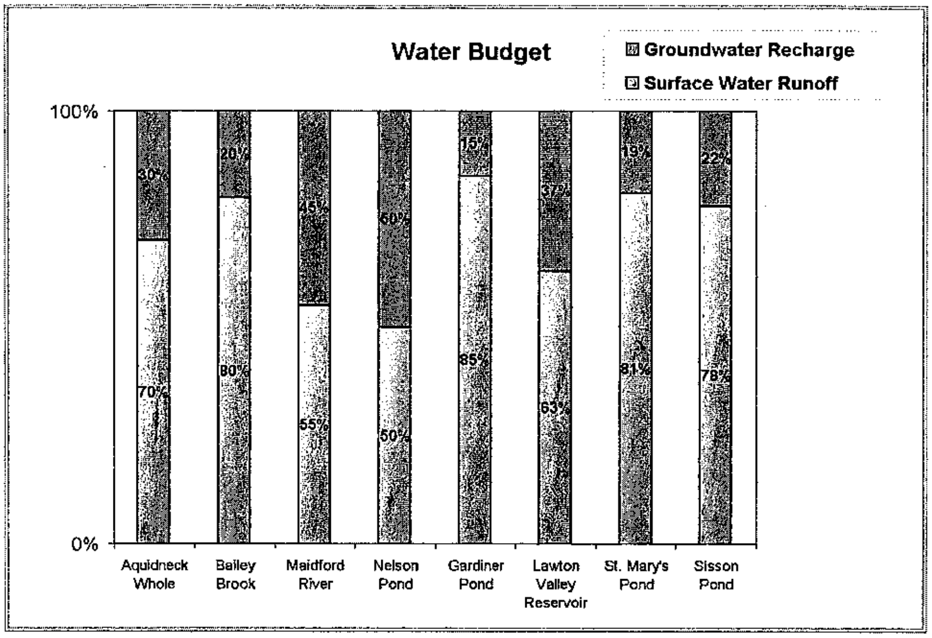
As a watershed health indicator, surface runoff levels signal potential pollution risks by identifying:

- High runoff zones where hydrologic impacts and runoff pollutants are likely to be greatest;
- Relative change in runoff between current and future conditions, and with use of storm water controls; and
- Water flow and pollutant movement pathways to support selection of management practices.

Interpreting runoff estimates

Runoff calculations estimate the proportion of rainfall that is likely to runoff rather than infiltrate the ground surface. This runoff estimate includes rainfall running directly off the surface and shallow subsurface flow that may reach surface waters during or shortly after rain events. However, runoff estimates do not take into account temporary storage and infiltration that will affect the amount of runoff actually reaching a surface water body. Moreover, the effect of closed drainage systems with the potential to rapidly convey runoff to a surface water discharge point is not considered separately from a higher runoff coefficient for more urban impervious land.

Figure 6a. Estimates of Groundwater Recharge and Surface Water Runoff



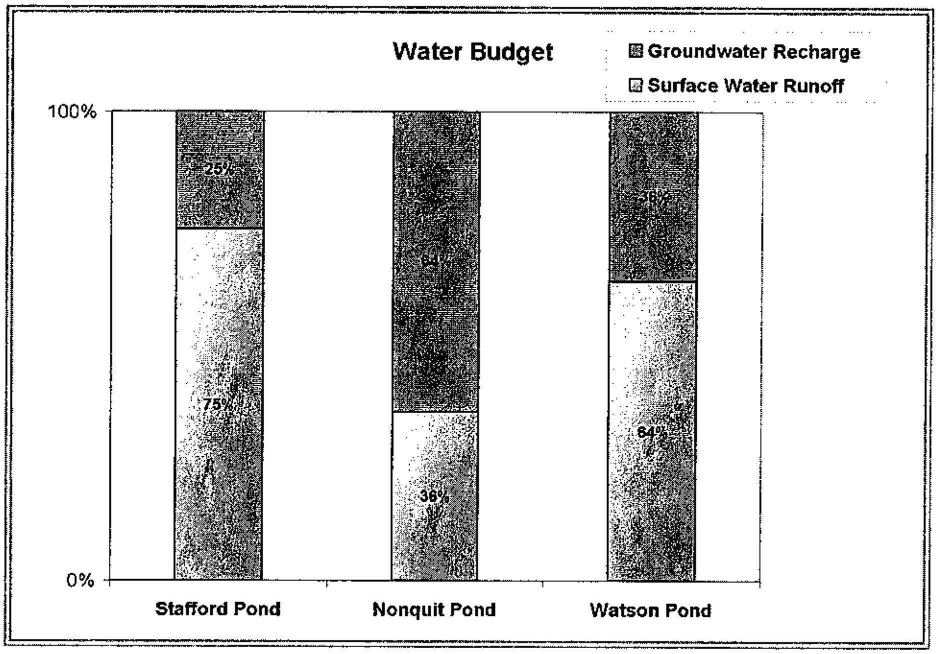
Results: Surface Runoff

- The primary pathway for water flow on Aquidneck Island is surface water runoff, with about 70 percent of available precipitation estimated to runoff the landscape into nearby waterbodies, and 30 percent estimated to infiltrate as groundwater recharge. If the Island were left undeveloped, up to 80 percent of available precipitation would recharge to groundwater, based on local soil characteristics.

- The Gardiner Pond watershed has the highest rate of runoff at 85 percent. This is largely due to the high proportion (42 percent) of wet soils in the watershed, which naturally collect and generate runoff.

- The Bailey Brook, St. Mary's Pond, and Sisson Pond watersheds all generate relatively high runoff, more than the Island average of 70 percent.

Figure 6b. Estimates of Groundwater Recharge and Surface Water



- Commercial and industrial land use activities contribute to a much higher rate of runoff, given their extensive use of impervious surface area. For example, in the Bailey Brook watershed, commercial and industrial land uses account for 18 percent of the area, but contribute an estimated 30 percent of runoff.

- Conditions in the Tiverton and Little Compton watersheds are very similar to those on Aquidneck Island, given similar soil conditions. Runoff in the Stafford Pond watershed is very high due to the size of the pond.

NUTRIENT LOADING

Nitrogen as a pollution indicator

The total amount, or "load," of nutrients generated in the wellhead protection area or watershed is a widely used measure of pollution risk. Nitrogen loading estimates are most critical when assessing potential pollutant inputs to groundwater and coastal waters. Nitrogen is commonly used as an indicator of pollution from human activities 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; the drinking water action level of 5 mg/l triggers increased monitoring. Some municipalities in Rhode Island are currently using 5 mg/l as regulatory limit.
- Nitrogen is associated with human inputs such as fertilizers and septic systems when groundwater nitrogen levels exceed 1 mg/l. The natural background level in Rhode Island groundwater is very low at 0.2 mg/l or less.
- Nitrogen moves easily in surface and groundwater, and can indicate the presence of other dissolved pollutants such as bacteria and viruses, road salt, and some toxic chemicals.
- Nitrogen over fertilizes coastal waters, leading to excessive growth of nuisance seaweed and algae, low dissolved oxygen events, loss of eelgrass, and declines of shellfish beds. Healthy coastal waters generally have extremely low nitrogen concentrations, so even relatively small inputs above naturally occurring background levels can cause a problem.

	Nitrogen Concentrations
0.2 mg/l	Natural background level in Rhode Island groundwater
1 mg/l	A sign of human activities influencing groundwater.
5 mg/l	Planning action standard, indicator of degraded water quality
10 mg/l	Federal drinking water standard or Maximum Contaminant Level (MCL)
	Wastewater Effluent
40-60 mg/l	Effluent from standard septic system.
< 20 mg/l	Treated effluent from nitrogen-reducing septic system.

* In this report, monitored Nitrate-Nitrogen concentrations and estimated loading rates are referred to as nitrate concentrations.

Note on Nutrient Loading Estimates:

The nutrient loading estimates used in this assessment assumes the use of reasonable management practices. However, inputs may be much higher where lawns are over fertilized and over watered or where fertilizers are spilled or otherwise wash into storm drains. In addition, nutrients and bacteria inputs are likely to be comparative-ly higher where pet waste on curbs and sidewalks wash directly into storm drains and where bird and wildlife waste flow directly from roads, storm drains, and under bridges into surface waters. Commercial and Industrial activities vary widely in both the amount of effluent generated and its strength. For a more accurate estimate, these should be calculated individually to determine average flows, flow variability, and concentration of wastewater inputs.

Input values designed to match the local study area

Nutrient loading predictions in this report are modeled estimates based on site-specific land use and soil conditions in each study. This uses accepted values for nutrient inputs from various land uses based on: 1) field research on nitrogen losses to groundwater from septic systems, lawns, turf and corn fields, and forests conducted in southern Rhode Island by URI scientists; and 2) current published literature values for surface runoff. Because groundwater inputs are based on extensive and reliable local data, nitrogen-leaching estimates to groundwater are more accurate than nitrogen inputs to surface runoff.

Nutrient source estimates are derived from the number of homes and businesses in the study area and the total acreage of different land use types. For example the number of septic systems, an important input variable for groundwater nitrogen loading, is estimated from the number of homes and businesses in unsewered portions of each study area based on five residential land use categories, four nonresidential

ASSUMPTIONS

Nitrogen loading to groundwater recharge

Septic systems
2.41 persons/dwelling unit
50 gal/person/day wastewater
2.3 lbs P/person/yr (15.1 mg/l)
7.0 lbs N/person/yr (46 mg/l)
90% leaching to groundwater

Commercial, Industrial and Institutional assumed equivalent to one dwelling unit /acre. Recreational land use assumed same but in use for 6 months annually.

Agricultural Fertilizers
Active cropland and orchard
64.5 lbs N leached to groundwater based on 215 lbs N applied /acre/yr, 30% leaching.

Lawn Fertilizers
25 –50% residential area is lawn.
75% of landowners fertilize.
10.5 lbs N leached to groundwater based on 175 lbs (4 lbs N /1000 sq.ft.) N applied /acre/yr, 6% leaching.

Pets
0.41 lb N/person/yr. Leaches to groundwater from pet waste.

Background
1.2 lbs/acre/yr leaches from unfertilized lawns, pastures, forests and brush areas.

As a result of uncertainties inherent in this mass balance approach, modeled nutrient estimates are most useful in comparing relative differences among land use types, among sub-watersheds, between current an future land use, and in comparing potential reductions in nutrient inputs with use of management practices.

mapped land use types, and mapped sewer districts. To refine our estimate, we updated the RIGIS 1995 land use using corrections mapped by trained local volunteers and adjusted the residential units to reflect the town parcel database. U.S. Census data was used to estimate occupancy per dwelling unit. Nutrient loading assumptions were also reviewed by local assessment volunteers and revised as needed.

Types of Outputs

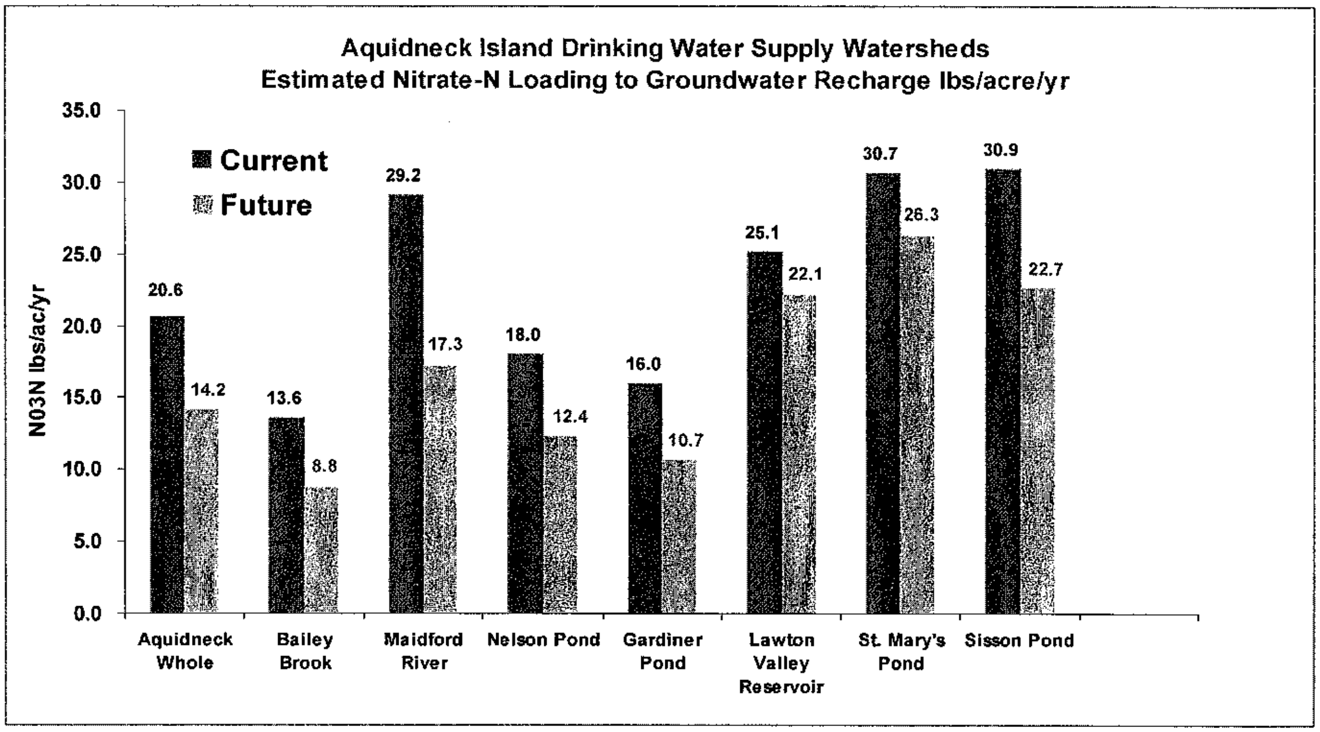
Nutrient inputs are estimated as the total average annual amount, or loading (pounds/acre/ year) of nitrogen and phosphorus entering surface water runoff, and the total amount of nitrate-nitrogen entering groundwater recharge annually. These estimates represent nutrient sources at the point of origin, not the amount that might ultimately reach a groundwater aquifer, pumping well, wetland, or other surface water body. 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 the groundwater with precipitation and septic system effluent. Nitrate loading to groundwater recharge is also estimated as a concentration by diluting the total load with the volume of infiltrating rainwater and septic system effluent. Due to uneven mixing in groundwater we don't assume this concentration will be the same at a pumping well.

Uncertainties in Mass Balance Models

Since model estimates represent sources potentially generated, the actual amount that might ultimately reach a well or surface water body is likely to be less. 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 protection areas where nitrogen enters groundwater as recharge to a pumping well without treatment in wetlands. In these wellhead protection areas we assume that over time the quality of the underlying groundwater will begin to reflect the quality of recharge water entering the wellhead.

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. In addition, wastewater flow from nonresidential land uses are highly variable in both effluent strength and volume and should be calculated individually if a more accurate estimate is needed.

Figure 7a. Estimated Nitrogen Loading to Groundwater



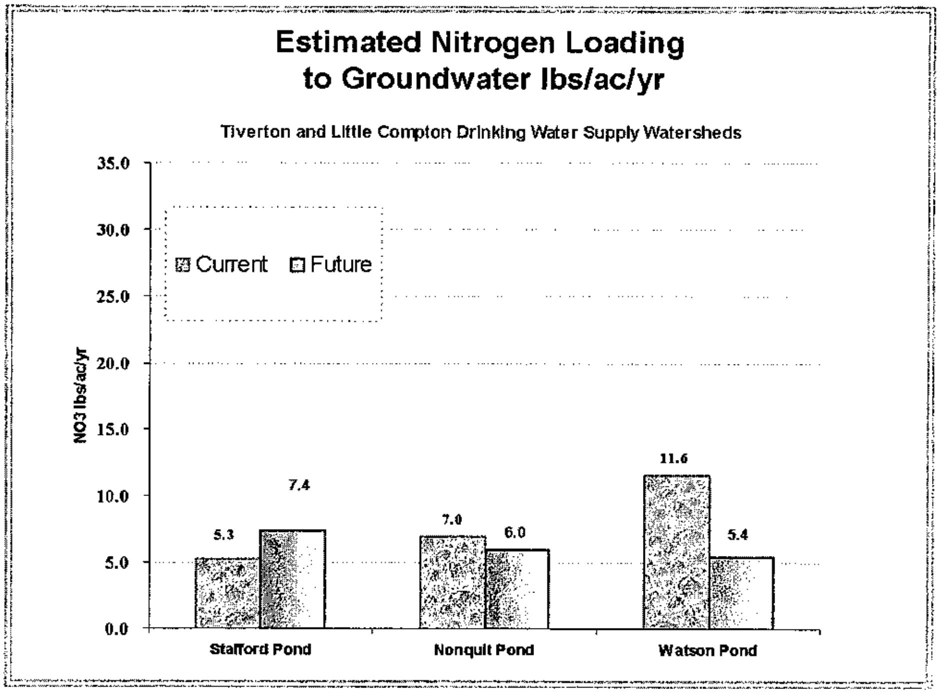
Results: Nitrogen Loading

- Estimated nitrogen loading to groundwater is highest in the watersheds with large tracts of agricultural land.
- In St. Mary's Pond watershed, agricultural fertilizer accounts for 70 percent of nitrogen entering groundwater, while septic systems account for 25 percent of loadings.
- In the Lawton Valley Reservoir watershed, agricultural fertilizer accounts for 54 percent of nitrogen enter groundwater, while septic systems account for 37 percent of loadings.
- In the Sisson Pond watershed, agricultural fertilizer accounts for over 80 percent of nitrogen entering both groundwater and surface water runoff.
- In the Maidford River watershed, agricultural fertilizers account for 78 percent of nitrogen loading to groundwater and 40 percent of nitrogen in surface water runoff.

Nutrient Loading from Farmland
Our nutrient loading estimates assume use of standard fertilizer application rates of 4.9 lbs/ 1000 sq.ft./yr for tilled crops such as corn, potatoes and nursery plants, with 30 percent leaching of nitrogen to groundwater. Areas mapped as pasture are assumed to be unfertilized. Actual nutrient losses to groundwater and surface water runoff can likely vary greatly depending on the type of crop and management practices used.

It is important to note that although agricultural activities have the potential to generate nutrients and sediment, farmland retains the high permeability found in natural landscapes, without contributing to increased runoff and loss of groundwater recharge that degrades water quality in developed areas. In addition, agricultural impacts can be effectively managed by controlling irrigation and fertilizer use, by protecting shoreline buffers, and use of other conservation practices.

Figure 7b. Estimated Nitrogen Loading to Groundwater



- Reductions in future projections for nitrogen loading are due to the conversion of agriculture to medium or low density residential development.
- In the Watson Pond watershed, agricultural fertilizer accounts for 85 percent of nitrogen loading to groundwater.
- In the Stafford Pond watershed, septic systems are the primary source of nitrogen entering groundwater (75 percent).

Phosphorus as a pollution indicator

Phosphorus is the key nutrient responsible for over fertilizing freshwater lakes, ponds, and streams. Although phosphorus is essential for algal and aquatic plant productivity, even minute increases in the amount of phosphorus can trigger tremendous increases in growth. For example, the natural background concentration of phosphorus in Rhode Island waters is only 5 to 10 *parts per billion*, which is equivalent to .005 to .010 parts per million or mg/l. The RIDEM maximum average total phosphorus standard for freshwater lakes and reservoirs is 25 parts per billion.

The degree of nutrient enrichment or "eutrophication" in a lake or pond is measured by the abundance of aquatic plants and algae, and phosphorus. Although eutrophication is a natural process whereby nutrients, sedimentation, and aquatic plant productivity increase as a lake or pond ages, phosphorus inputs from human activities can greatly accelerate this process. Managing phosphorus inputs to surface drinking water supplies is particularly important for man-made reservoirs as they tend to become eutrophic more rapidly than naturally formed lakes. There is a tendency for these reservoirs to revert back to their original state, usually a stream system or marsh (Addy and Green, 1996).

In drinking water reservoirs, nutrient enrichment is a problem because algae and accumulating sediment from runoff and decaying aquatic plants increases organic matter and suspended solids. These affect the taste and odor of drinking water. And while organic matter is not necessarily a health hazard, it reacts with chlorine in the disinfection process to create trihalomethanes. These byproducts are considered a health hazard and EPA has recently reduced that maximum allowable level from 100 to 80 ppb. One way to reduce disinfection byproducts is to reduce excessive organic matter in drinking water supplies by controlling nutrient inputs. Phosphorus's tendency to attach to sediment makes controlling erosion and sedimentation from farming and construction sites, controlling runoff from highways and other sources, and protecting shoreline buffers effective control measures.

We use phosphorus loading estimates as a pollution indicator for the following reasons:

- Land use activities have significant, measurable impacts on phosphorus levels in surface water bodies.
- High phosphorus levels in freshwater bodies are associated with stormwater runoff containing sediment from construction sites and other disturbed land, lawn and garden fertilizers, improperly sited and maintained septic systems, leaking sewers, agricultural drainage, and pet waste.
- Phosphorus tends to be associated with sediment and is a good indicator of other runoff-borne pollutants such as metals and bacteria

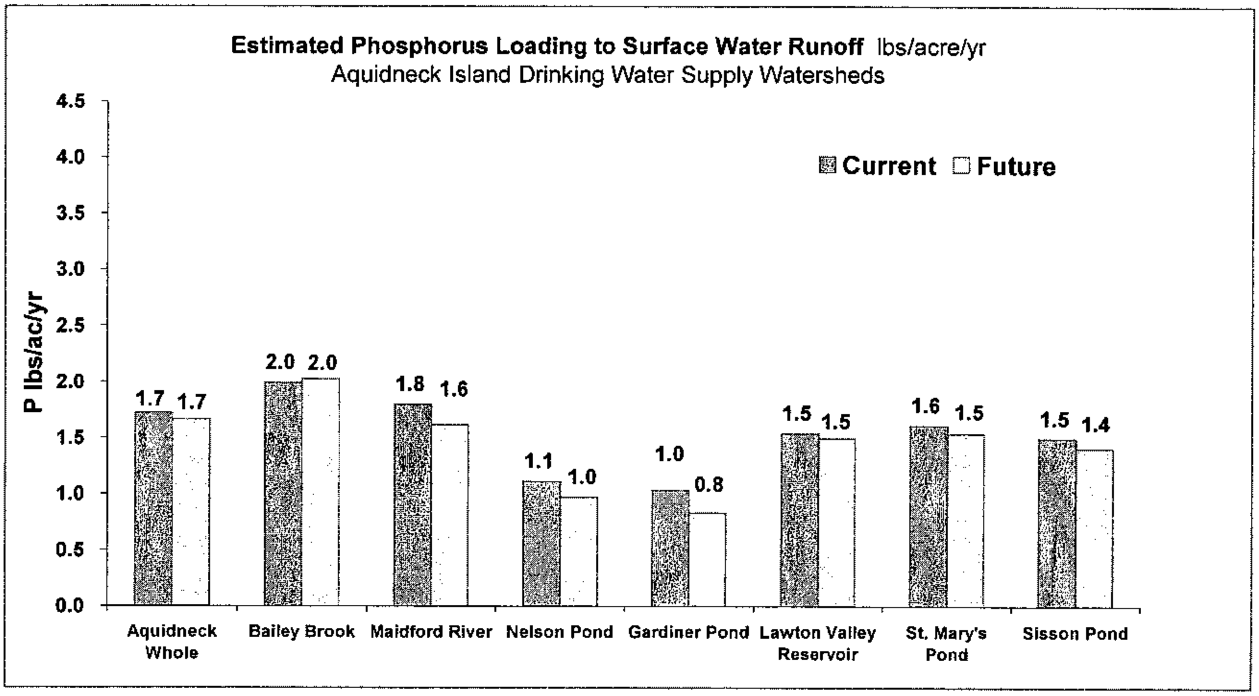
Trihalomethanes *(THM) are a group of four chemicals — chloroform, bromodichloromethane, dibromochloromethane, and bromoform — that are formed when chlorine or other disinfectants used to control microbial contaminants in drinking water react with naturally occurring organic and inorganic matter in water.*

Individual TTHMs have been classified as being potentially hazardous to human health. To reduce this health risk, EPA published the Stage 1 Disinfectants/Disinfection Byproducts Rule in December 1998. This requires water systems to use treatment methods to reduce the formation of disinfection byproducts and meet stricter regulatory standards.

This rule reduced the federal standard for Total Trihalomethanes (TTHM) from the 100 parts per billion maximum allowable annual average level to 80 parts per billion for all public supply systems beginning in December 2003.

For more information go to EPA's website: www.epa.gov/enviro/html/icr/dbp.html#regulatory

Figure 8a. Estimated Phosphorous Loading to Surface Water Runoff



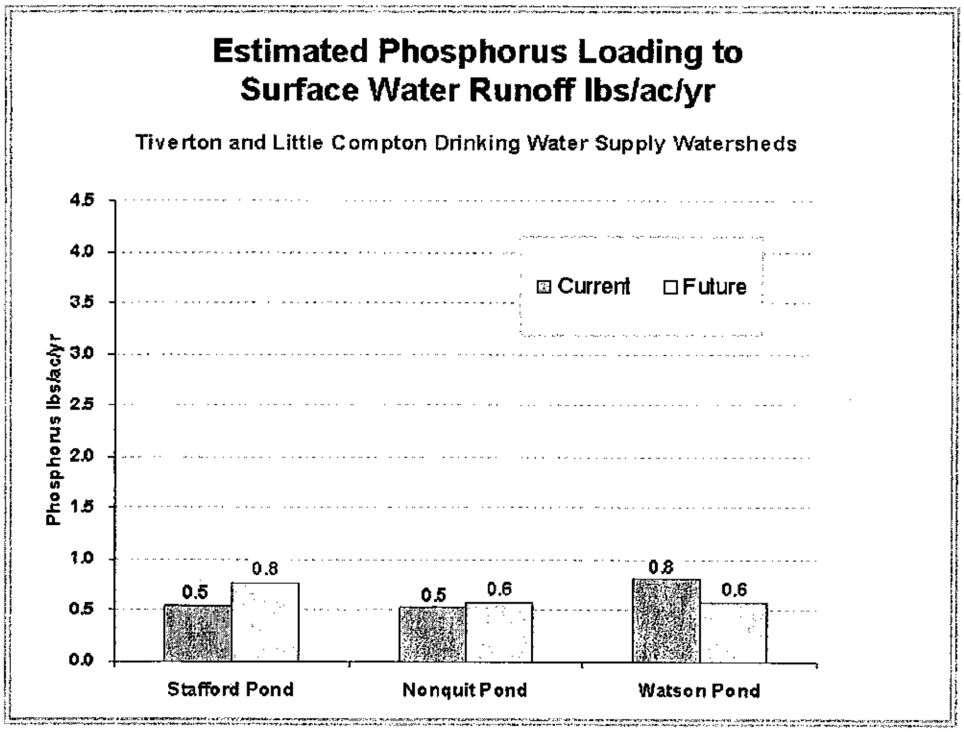
Ranking Phosphorus inputs

Based on modeled runoff and phosphorus inputs from drinking water supplies throughout Rhode Island, phosphorus levels of one lb/acre/yr are considered a high risk to water quality. Estimated phosphorus loading rates higher than 1.5 lbs./acre/year are ranked as an extreme risk to downstream reservoirs.

Results: Phosphorus Loading

- Surface water runoff contributes an estimated 70 percent of the water flow on Aquidneck Island. Estimated phosphorus inputs, which are partially derived from runoff values, average 2.4 pounds per acre each year on the Island.
- The major sources of phosphorus on Aquidneck Island are general runoff pollutants such as sediment from construction sites and agricultural land, lawn and agricultural fertilizers, pet wastes, and improperly treated effluent from septic systems. Of the general runoff pollutants, we estimate the land use sources to be residential runoff (37 percent); agriculture (24 percent), commercial and industrial land use (7 percent), direct atmospheric deposition on surface waters (less than 1 percent), other sources (8 percent). See Figures 9a & 9b for percent contributions from different land uses for each study areas.
- All areas have estimated phosphorus levels at or above 1 lb/acre/yr., which is considered a high risk to downstream reservoirs. Several areas, including Bailey Brook, Lawton Valley, Maidford, St. Mary's and Sisson reservoirs, are above 1.5 lbs./acre/year, which is considered an extreme risk to water quality. The primary concerns are the potential for excessive growth of algae, which can affect taste and odor of drinking water, are formation of undesirable by products with chlorination.

Figure 8b. Estimated Phosphorous Loading to Surface Water Runoff



- Phosphorus loadings in the Tiverton and Little Compton watersheds are much lower than on Aquidneck Island, and below the high risk level of 1 lb/acre/year.
- Phosphorus levels are not expected to change dramatically in coming years. In the Watson Pond watershed, loadings may decline slightly as from 0.8 to 0.6 lbs/ac/year. In the Stafford Pond area even a slight increase from 0.5 to 0.8 lbs/ acre/year is a concern given present levels of nutrient enrichment.
- With future development, the contribution of phosphorus from various sources can be expected to shift from agriculture to residential sources. This change underscores the need to control erosion and sedimentation with new construction and to manage stormwater discharges, ideally by controlling both the rate and volume of runoff.

Figure 9a. Phosphorus Contributions from Different Land Uses

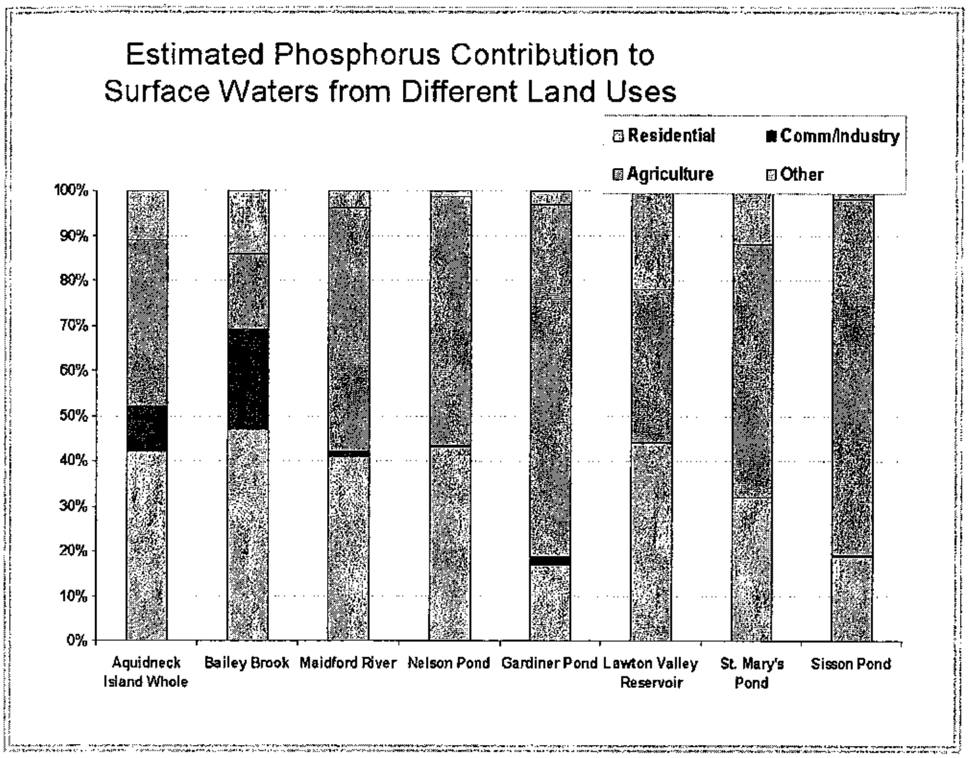
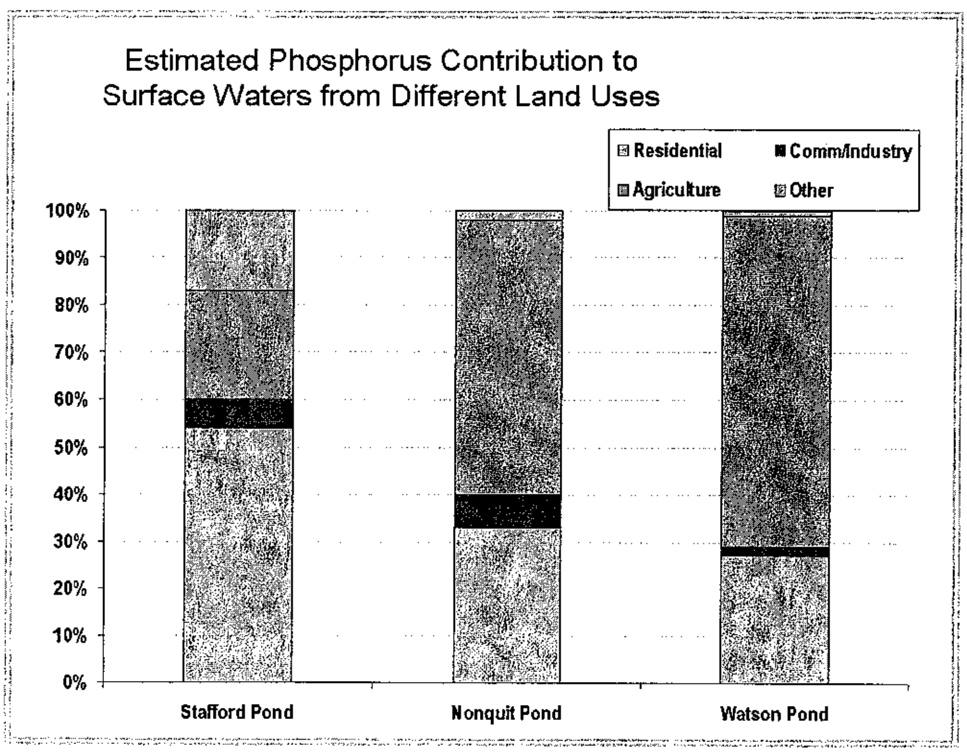


Figure 9b. Phosphorus Contributions from Different Land Uses



- Figures 9a & 9b provide a proportional breakdown of phosphorus contributions to surface waterbodies by land use activity.
- Contributions from agriculture are high in most of the study areas, particularly in the Gardiner Pond and Sisson Pond watersheds (close to 80 percent in both areas).
- Contributions of phosphorus from commercial and industrial development are an issue mostly for the Island as a whole and the urbanized Bailey Brook watershed.
- Contributions from residential development are significant in all of the watersheds.
- In the Tiverton and Little Compton watersheds, contributions from agriculture are highest in the Watson Pond and Nonquit Pond watersheds at 70 percent and 58 percent, respectively.
- Contributions from residential land use are highest in the Stafford Pond watershed at 54 percent.
- The *Other* category in Figures 9a & 9b reflect contributions from land uses such as institutional and recreational development.

3.4 Mapping Pollution Risks

Map analysis of land use activities 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 vegetated shorelines. Mapping supplements the information on pollution risk indicators summarized above, which are calculated as averages for different land use types, or for the study area as whole, not by geographic location. In this section we briefly summarize the two types of map analyses conducted: pollution source "hot spot mapping" and an inventory of potential sources of contamination. Results are incorporated into the basic source water assessment ranking and provided to the town as large-format maps that are not easily reproduced here. A full list of the natural features inventory maps, pollution "hotspot" maps, and other map analyses are provided in the appendix to this report.

Limitations of "Hotspot" Mapping

It is important to emphasize that this assessment and "hotspot" mapping is a rapid, screening level analysis. The soils and land use information are planning level and 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. Also, estimates of high runoff areas are overshadowed by man-made drainage alterations. Follow-up field investigations are necessary to verify land use, soil conditions, and presence of potential pollution sources.

POLLUTION SOURCE HOTSPOTS

Contrary to popular belief, pollutants from land use activities – referred to as non-point pollution sources – are not diffusely spread throughout the landscape in random or unpredictable patterns. In fact, much of this "non-point" source pollution can be traced to: 1) high intensity land use activities that generate known pollutants; and 2) specific landscape characteristics such as soil types and shoreline buffers that promote pollutant movement, either to surface waters via stormwater runoff or to groundwater with infiltration. Fortunately, most municipalities in Rhode Island have easy access to mapped data of both land use activities and important landscape features.

When this data is in electronic form, it is relatively easy to overlay known high intensity land uses with problem soils to rapidly pinpoint pollution "hot-spots" – high-risk areas for movement of pollutants to either groundwater or surface waters. These hotspots generally comprise a relatively small land area, but may contribute the largest percent of pollutants to the environment. Directing management actions to the most serious problem sites can be a cost-effective way to prevent or remediate local pollution problems.

Results: Pollution Source Hotspots

The pollution source "hotspot analysis" completed for the Newport Water and the Stone Bridge Fire District Source Water Assessment focused on identifying high risk areas for pollutant movement to surface water. The study used updated RIGIS land use data and soils data to map high intensity land use overlying high water table soils (> 1.5 ft). Hard copy maps of this analysis will be made available to town planning departments. All of the studies areas on Aquidneck Island, with the exception of the Lawton Valley watershed are in the high to extreme risk category for this indicator. The Nonquit Pond watershed and Stafford Pond watershed are both in the medium risk

NOTE: It is important to emphasize this is a rapid, screening-level analysis. The soils and land use information used are planning level and 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. Also, estimates of high runoff areas are overshadowed by man-made drainage alterations. Follow-up field investigations are necessary to verify land use, soil conditions, and presence of potential pollution sources.

category. The Watson Pond watershed is in the high risk category for this indicator. Detailed ratings for each study area are located in Appendix B of this report.

All high intensity land use activities located in source water areas should be considered potential sources of contamination. It is also important to identify the specific type, location and extent of high risk land uses in relationship to each reservoir or tributary. These mapped locations should be investigated to determine the actual land use at the site and potential for pollutant movement.

Because RIGIS coverages are generally most suitable for planning-level analysis, it is important to understand limitations of the database. In particular, mapping potential "hotspots" based on water flow pathways is less useful where extensive drainage alterations have been made. In this analysis we did not specifically identify and map stormwater discharge locations. A comprehensive source water protection strategy should include field inspections and mapping of these potential problem areas, in coordination with storm drainage system mapping required under EPA Phase II stormwater management planning. Areas of concern include the following:

- Urban stormwater drainage systems short circuit natural water flow and pollutant removal processes. Direct tie-in of sanitary wastes to storm drains, known as illicit discharges, can be an associated contamination source, especially in older settlements.
- 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.
- Water withdrawal resulting in low stream flow during summer periods is a growing concern in areas where various uses compete for limited water supplies or where direct runoff to streams results in loss of groundwater recharge. Similarly, loss of recharge through out-of-basin water supply lines or sewer service can be an additional source of stress.

MAPPED POTENTIAL SOURCES OF CONTAMINATION

The primary goal of the Source Water Assessment is to encourage more comprehensive protection of drinking water sources by providing a consistent framework for identifying and evaluating potential contamination risks. For this purpose, a susceptibility ranking system was developed by RI HEALTH and URI Cooperative

Extension that incorporates information on both the vulnerability and sensitivity of each water source. Mapping the location and number of potential sources of contamination is a key component of this ranking system.

Volunteer-identified potential sources of contamination

Mapping volunteers involved in the source water assessment were asked to identify specific high-risk land uses within the individual wellhead protection areas. A master list of these land uses was developed by Rhode Island Department of Health based on the contaminants normally associated with each type of land use, to include:

- **Agricultural** operations were identified based on the likely presence of pesticides, organic compounds, bacteria from animal waste, and nutrients.
- **Automotive** businesses were identified based on the likely presence of solvents and other organic compounds and underground storage tanks.
- **Medical Facilities** were identified based on the likely presence of organic compounds, microbes and nutrients.
- **Other Commercial** including beauty salons, dry cleaners, paint shops, printing or photographic processing and golf courses were identified based on the likely presence of solvents and other organic compounds.
- **Industrial/Manufacturing** businesses were identified based on the likely presence of solvents and other organic compounds.

RIGIS-mapped sources of contamination

Known point sources of pollution included under the RIGIS database were also mapped. These were identified using three RIGIS hazardous material coverages:

- **CERCLA** (Superfund) sites—point locations of hazardous material sites designated by the U.S. EPA and RIDEM.
- **Rhode Island Point Discharge Elimination System** (RIPDES)—point locations for all sanitary waste sites where permits have been issued by RIDEM.
- **Leaking Underground Storage Tank** sites (LUSTS)—point locations for storage tanks and associated piping used in petroleum and certain hazardous substances that have experienced leaks as determined by RIDEM.

Incorporating mapped data into the basic SWAP ranking

The basic Source Water Assessment Program ranking incorporates the results of the hot spot mapping analysis and the number of identified potential sources of contamination as key elements of the ranking. A numeric rating was given to each study area based on the number of mapped pollution sites located in the study area and also the number of sites within the 400-foot inner protective radius of each wellhead or within the shoreline area of a surface reservoir.

The ranking method considers four types of pollution risks, three of which are obtained by RIGIS map analysis:

- The extent and location of high intensity land use in the source area – including mapped "hot spots" such as high intensity land use within a shoreline area or overlying slowly permeable soil;
- Number of potential sources of contamination such as underground storage tanks and dry cleaners;
- Aquifer type, with stratified drift aquifers considered more vulnerable than bedrock aquifers.
- Monitoring record, including history of contaminant detects and nitrate levels in groundwater. This is based on a review of RIHEALTH sampling data for a five-year period and is the only ranking value not obtained by RIGIS.

The SWAP ranking methodology and results for the study area(s) are included in the appendix to this report.

3.5 Summary Results

Fact Sheet

Results of the Source Water Assessment are summarized in a number of ways. To make results easily accessible to local officials and the general public, key findings were summarized in fact sheet format. This color, 4-page summary is available to view or download from the University of Rhode Island website at www.uri.edu/ce/wq and at www.HEALTH.ri.gov/environment/dwg/Home.htm, the RI HEALTH website. Paper copies are also available from RI HEALTH and the water supplier.

Basic Source Water Assessment Ranking

The basic assessment and ranking used for all public water supplies in Rhode Island synthesizes a range of risk factors potentially affecting drinking water quality. These factors include: the intensity of development, number of sites where hazardous materials are used, and location of development is soils where contaminants may move easily to surface waters, and existing water quality based on RIDEM records and the sampling history of the water supply. The SWAP ranking results are included in Appendix B of this report.

The results of this ranking show that the Newport and Stone Bridge water supplies have a **MODERATE** susceptibility to contamination. According to RI HEALTH a moderate rating means that the water could become contaminated one day. Protection efforts are important to assure continued water quality.

It is important to note this is an average ranking for the supply as a whole. Individual areas may be more susceptible to contamination due to site-specific conditions and land use activities. When study areas are ranked individually most are also in the moderate risk range except for the Bailey Brook and Nelson Pond watersheds, which are rated as having a high risk, and the Nonquit Pond watershed, which is rated as having low susceptibility to contamination. It is important to note this ranking is based on current land use only, without considering future threats with continued development.

Summary of Land Use Risks

The risk factors described in this chapter, such as percent impervious cover and estimated nutrient inputs, provide additional information on potential threats from land use features beyond the basic Source Water Assessment ranking. Table 1 summarizes results of several key indicators collectively to highlight areas that may be at risk from multiple factors. This "at a glance" overview highlights relative differences in potential pollution risks among study areas. Where a build out analysis was conducted, it also indicates the expected trend between current and future land use.

The first part of Table 1 shows results obtained directly from map analysis or modeled estimates. The cell for each input value is color coded to show the pollution risk rank for current and future values. The second half of the table further synthesizes results by "adding" together results of difference indicators. This is accomplished by converting low to extreme ratings to a simple numerical ranking from 0 to 3. These values are then added up for each study area to create on average value for current and future land use. Final values are then grouped into categories from low to extreme risk, and a final rating from low to extreme assigned based on total scores from less than 1 to 3, as shown below.

The more urban watersheds on Aquidneck Island are generally rated as having a high risk rating based on land use characteristics, with the Bailey Brook, Lawton Valley and Aquidneck Reservoirs as a whole, approaching the extreme risk level. Future risks are not expected to increase substantially, however this assumes use of good management practices with future development and land use based on current zoning, not taking into account any zoning changes or variances and special exceptions from permitted uses and protection measures.

The water supplies in Tiverton and Little Compton are generally at lower risk, however, the projected increase from low to moderate risk in the Stafford Pond watershed is a concern given existing nutrient enrichment of this reservoir.

This overview is intended to help summarize data to compare study areas and evaluate differences between current and future conditions.

Since any method used to summarize and rank results can easily mask important data, even "low risk" areas may be subject to contamination. Site-specific mapping and field data should be used to guide selection of management practices.

Table 1

Current Land Use and Risks - Aquidneck Island Drinking Water Supply

		Aquidneck Whole	Maidford River	Nelson Pond	Gardiner Pond	Lawton Valley Reservoir	St. Mary's Pond	Sisson Pond	Bailey Brook
Septics /acre	Current	0.29	0.30	0.31	0.05	0.60	0.52	0.26	0.20
	Future	0.37	0.46	0.46	0.11	0.73	0.63	0.46	0.23
Intensive Land Use	Current	52%	51%	27%	24%	33%	45%	48%	68%
	Future	40%	26%	14%	14%	25%	35%	29%	62%
Impervious	Current	21%	15%	7%	2%	13%	8%	5%	35%
	Future	25%	22%	12%	4%	17%	12%	11%	40%
Riparian Impervious	Current	15%	9%	6%	1%	11%	1%	0%	28%
	Future	15%	9%	6%	1%	11%	1%	0%	28%
Riparian forest & wetland	Current	42%	32%	59%	56%	45%	66%	66%	32%
	Future	42%	32%	59%	56%	45%	66%	66%	32%
Nitrate to recharge lbs/ac/yr	Current	20.6	23.2	18.0	16.0	25.1	30.7	30.9	13.6
	Future	14.2	17.3	12.4	10.7	22.1	26.3	22.7	8.8
Phos to SW (lbs/ac/yr)	Current	1.72	1.79	1.11	1.03	1.54	1.61	1.49	1.99
	Future	1.66	1.61	0.97	0.83	1.49	1.54	1.41	2.02

		Aquidneck Whole	Maidford River	Nelson Pond	Gardiner Pond	Lawton Valley Reservoir	St. Mary's Pond	Sisson Pond	Bailey Brook
Septics /acre	Current	2	2	2	0	3	3	2	1
	Future	2	2	2	1	3	3	2	1
Intensive Land Use	Current	3	3	3	2	3	3	3	3
	Future	3	3	1	1	3	3	3	3
Impervious	Current	2	2	0	0	1	0	0	3
	Future	3	2	2	0	2	1	1	3
Riparian Impervious	Current	3	1	1	0	2	0	0	3
	Future	3	1	1	0	2	0	0	3
Riparian forest & wetland	Current	3	3	3	3	3	2	2	3
	Future	3	3	3	3	3	2	2	3
Nitrate to recharge lbs/ac/yr	Current	3	3	3	2	3	3	3	2
	Future	2	3	2	2	3	3	3	2
Phos to SW (lbs/ac/yr)	Current	3	3	3	3	3	3	3	3
	Future	3	3	3	3	3	3	3	3
Final Summary	Current	2.7	2.4	2.1	1.4	2.6	2.0	1.9	2.6
	Future	2.7	2.4	2.0	1.4	2.7	2.1	2.0	2.6

Pollution Risk Rating

Low	Moderate	High	Extreme
<1	1 -1.9	2 - 2.9	> 3

Current Land Use and Risks - Stonebridge Water District Drinking Water Supply

		Stafford Pond	Nonquit Pond	Watson Pond
Septics /acre	Current	0.25	0.10	0.08
	Future	0.38	0.17	0.12
Intensive Land Use	Current	8.3%	9.4%	16.2%
	Future	12.9%	5.6%	5.4%
Impervious	Current	6.0%	3.9%	2.9%
	Future	12.2%	6.5%	4.5%
Riparian Impervious	Current	3.6%	2.1%	1.0%
	Future	4.4%	2.6%	0.7%
Riparian forest & wetland	Current	67%	80%	82%
	Future	[illegible]	74%	84%
Nitrate to recharge lbs/ac/yr	Current	5.3	7.0	10.6
	Future	7.4	6.0	5.4
Phos to SW (lbs/ac/yr)	Current	0.54	0.53	0.81
	Future	0.77	0.58	0.58

		Stafford Pond	Nonquit Pond	Watson Pond
Septics /acre	Current	2	1	0
	Future	2	1	1
Intensive Land Use	Current	0	0	2
	Future	1	0	0
Impervious	Current	0	0	0
	Future	1	0	0
Riparian Impervious	Current	0	0	0
	Future	0	0	0
Riparian forest & wetland	Current	2	1	1
	Future	[illegible]	2	1
Nitrate to recharge lbs/ac/yr	Current	0	1	2
	Future	1	1	1
Phos to SW (lbs/ac/yr)	Current	1	1	2
	Future	2	1	1
Final Summary	Current	0.7	0.6	1.0
	Future	1.4	0.7	0.6

Pollution Risk Rating

Low	Moderate	High	Extreme
<1	1 -1.9	2 - 2.9	> 3

4. Source Water Protection Tools

The long-term quality of drinking water depends on the combined actions of state and local government officials, water suppliers, and all others who live or work in source water areas. This chapter offers recommendations on some of the most important steps each group can take to protect valuable drinking water resources. Because municipal decision makers have primary authority over land use, and the responsibility to control associated impacts, recommendations focus on protection measures that can be implemented through local plans, ordinances and development standards. These measures consist of current, standard best management practices for managing land use impacts that are generally applicable to all source water areas. Water system security, distribution, or treatment issues that may affect drinking water quality are not part of the source water assessment but would be included in water supply management plans.

Because the focus of the Source Water Assessment Program is on identifying and ranking pollution risks, it was beyond the scope of this assessment to develop a detailed action plan for each study area. Major community water suppliers in Rhode Island are required to prepare a Water Supply System Management Plan that must describe specific measures needed to protect each reservoir or well field from sources of contamination. In addition, town comprehensive plans must include a water supply management component with a detailed implementation plan for drinking water protection.

Given this planning framework, the recommendations in this chapter are designed to complement existing efforts by providing a checklist of protection tools against which town officials can compare current practices, identify successful programs to be maintained and gaps to be filled. Because the effectiveness of any protection measure lies in the details, an audit of current plans, land use ordinances, and actions already taken to prevent pollution is need to determine their actual effectiveness. For example, the value of a groundwater zoning overlay district would depend on the area covered, the permitted uses and performance standards, the standards for review and approval of variances and special exceptions, and enforcement procedures. Municipal staff and boards who work with these programs on a regular basis are best qualified to conduct this review and make practical recommendations. Priority actions can then be incorporated into municipal plans, capitol improvement budgets, and ordinances to strengthen protection of valuable groundwater resources.

Water Supply System Management Plans

All large community water suppliers in the State are required by Rhode Island law to submit a water supply system management plan to the RI Water Resources Board.

The "water quality protection" component of the plan specifically requires large suppliers to identify "measures needed to protect each reservoir or well field from sources of contamination, including acquisition of buffer zones, diversion of storm water or spills, and desirable land use control regulations," and to prepare "a priority list of actions for implementing these protection measures."

www.wrb.state.ri.us/index.html

Unique Features of Source Water Assessments

SWAP assessments provide a screening level analysis and are not a substitute for a thorough Watershed Management or Groundwater Protection Plan. Yet assessments do have unique and useful features:

- Applied to all RI supplies, large and small,
- Consistent methods used for all supplies,
- All supplies rated for susceptibility to contamination.
- Future impacts evaluated through "build-out" analysis site specific to each wellhead and subwatershed of each major supplies.
- Cumulative effects of land evaluated using nutrient loading, percent impervious cover, other "indicators" and map analysis.
- Geographic information systems used for mapping and analysis provides basis for future planning.
- Results are made available to suppliers, local officials and others for use in developing priority protection actions.

4.1 Factors to Consider in Selecting Management Practices

The risk ratings used in this assessment are intended to help guide selection of management practices and direct efforts to the most serious threats. Given that all public water suppliers already have safeguards in place, it can be difficult to assess when existing efforts are sufficient and when more stringent controls are needed. RI HEALTH makes is clear that no source is free of contamination risk, and that without sufficient protection, any water supply can become contaminated. Even where there is general agreement on the need for stronger drinking water protection, there are no simple formulas for selecting the best mix of controls to achieve the desired degree of protection. This section outlines some of the factors to consider in making management decisions. However, making decisions about drinking water protection depends on town goals and policies that go beyond technical assessment results, as described below.

Municipal support for protecting drinking water and degree of protection desired

Comprehensive community plans establish goals for drinking water protection that identify critical resource areas and the degree of protection desired. These goals are implemented through zoning, land development regulations and budgeting for capital projects. The actual priority given to maintaining water quality is relative to competing goals such as minimizing local land use restrictions and promoting economic development. Some of the factors that influence the degree of protection needed and community willingness to adopt additional protection measures include, for example, the following:

- Co-occurrence of other sensitive resources within or downstream of the source water area. Sensitive aquatic habitat may actually require more pristine water quality than drinking water supplies. Two examples are cold-water trout streams, which are highly sensitive to sediment and increased temperature; and poorly flushed coastal waters, which are sensitive to nitrogen at levels far below 1 mg/l while the drinking water action level is 5 mg/l.
- Availability of multiple supplies, auxiliary supplies or alternative water sources within a system to provide emergency backup or replacement if one source is contaminated. Situations where no options are available call for a greater degree of protection. On the other hand where drinking water taste and odor is already impaired, local officials may feel that restoration is not cost effective and that funds are better spend seeking new sources.
- Willingness to rely on remediation and additional treatment in the case of contamination. Chlorination of groundwater supplies or use of more advanced treatment technologies may be viewed as a viable option to a high level of protection. However, the cost of treatment and changes in taste and odor should be evaluated. Formation of chlorination by-products known as total trihalomethanes may be

difficult to control with nutrient-enriched surface waters even with a high level of water treatment. Contamination by MTBE, fuel or solvents is much more costly and difficult to treat.

- Public perception of the potential for the supply to be compromised and willingness to accept this risk. For example, in developed watersheds where high-risk land uses have co-existed in within a watershed or wellhead without serious impact to water quality, local officials may reason that contamination is unlikely and that current protection practices are adequate.
- Confidence in existing protection measures. The municipality may already have adopted protection measures that may be viewed as sufficient for the time being, especially if additional protection measures are costly or unpopular.

Need for local action: State vs. municipal roles

A common misconception is that state agencies such as the RI Department of Environmental Management are responsible for protecting environmental quality and local controls are unwarranted or even beyond local authority. In reality, state agencies establish statewide, minimum standards for resource protection. Even where more stringent water quality criteria or development standards exist for drinking water supplies, these may not be sufficient to protect sensitive resources or to control cumulative impacts for the following reasons:

- State regulations are directed to avoiding impacts from individual projects on a case-by-case basis and do not specifically address the combined effects of multiple projects. As a result, state regulations may not be sufficient to protect sensitive water resources depending on the intensity of development and it's location in sensitive areas.
- At the State level, permit review is often compartmentalized based on resource type or pollution source. For example, applications for design of septic systems are reviewed based on the potential for a system to function properly on a particular site. Other impacts to wetlands or stormwater runoff must be evaluated separately.
- State agencies may grant variances from minimum standards on a case-by-case basis through established permit review procedures. For example, land that may have been considered unbuildable or uses considered too intense for a site may be approved by variance from individual sewage disposal system regulations or freshwater wetlands alteration permit.
- State agencies may lack site-specific data to identify sensitive resources requiring more stringent control to either prevent degradation of high quality waters or reduce impacts to water bodies showing signs of stress.
- State agencies have limited staff and are under pressure to review and approve permits in a timely fashion. Staff resources for follow-up field inspections and enforcement is often inadequate.

Given the need for resource protection at both the state and local level, the RI Zoning Enabling Legislation specifically authorizes RI cities and towns to designate critical resources and establish more stringent standards that take into account the sensitivity and vulnerability of local resources.

Selection of management practices based on sound planning

Although this chapter takes of broad view of "best management practices" to include planning and zoning strategies, discussion of pollution controls frequently centers on pollution control technologies, such as the type of stormwater treatment system used. Selecting performance standards and accompanying treatment systems is actually the last step in protecting water resources and not a substitute for sound planning and careful site design. Standard resource-based planning practice is based on a hierarchy of these three basic principles.

1) Wise land use planning and zoning. The type and intensity of land use should be appropriate for the resource. Low density, low impact uses, in combination with purchase of land or development rights for the most critical areas and unique resources, offers the surest protection for drinking water supply watersheds and recharge areas. These low-risk uses correspond to source areas with an average of less than 10 percent impervious, well-forested source areas, and undisturbed, forested shoreline zones.

2) Good site design. Careful site analysis based on natural resource mapping and field investigations, use of creative design to preserve the most sensitive and valuable site features, and use of building envelopes to limit clearing and grading within suitable areas are all low-cost, low-maintenance methods for minimizing project impacts.

3) Appropriate "best management practices" are used where impacts can't be avoided or minimized through planning or site design alone. These include, for example, techniques for hazardous materials storage, stormwater treatment systems and wastewater treatment technologies. To provide flexibility to address site-specific constraints performance standards can be set specifying the level of treatment to be provided by stormwater and wastewater systems, with the selection of the actual methods and technologies left to the designer.

When properly designed, operated and maintained, engineered management practices can effectively offset impacts of more intense development, but usually with much higher maintenance demands. High-maintenance technologies also require greater local oversight to ensure maintenance is carried out properly and that safety precautions are used over the long term. As a result, more complex pollution control systems require the greatest local investment of resources over the long run. In undeveloped areas where options are still available, relying on low density land uses is generally the least costly since simple, nonstructural controls such as grassed swales, protected wetland buffers and conventional septic systems are the least costly to maintain over the long run. In communities with limited staff to oversee or assume responsibility for maintenance, prohibiting high risk uses and relying on simple, nonstructural controls may be more practical over the long run. As one town highway supervisor put it when referring to the type of stormwater controls allowed in his rural community – "if it can't be maintained with a backhoe, it doesn't get built".

Use of current management practices

Ongoing research on pollutant movement and effectiveness of various control strategies means that methods for controlling water quality impacts are constantly evolving. What may have been state-of-the-art even a few years ago may now be recognized as inadequate, especially for more sensitive resources. New, updated pollution control methods may also be simpler, with lower maintenance needs, as in the case of "low impact" stormwater controls. The current 5-year review cycle for updating municipal plans and supporting zoning ordinances and land development standards provides a good opportunity to bring performance standards for drinking water supply areas in line with current practices. Because the wheels of state government often move slowly, updating municipal land development standards may require use of new approaches that go beyond State minimum standards.

Level of management appropriate for the type of resource

In general, the more stringent practices are appropriate for more sensitive, high value, or high-risk areas where the goal is to protect very high water quality or restore impaired waters. In these situations, state minimum standards may not be adequate to address cumulative effects of land use activities within a watershed or recharge area using minimum standards. On the other hand, adoption of more stringent performance standards must be grounded in sound science, with required controls based on the pollutants of concern in a particular source area, existing water quality conditions and reasonable expectations for maintaining or restoring water quality.

Focus on pollution prevention

The management practices in this chapter emphasize pollution prevention techniques as the simplest and most cost effective approach to protecting water supplies, as opposed to pollution remediation or additional water treatment. A compelling justification for pollution prevention is that even low-level contaminants can affect taste and odor of drinking water standards at concentrations far below maximum health standards.

Threats to Coastal Waters

30% of RI coastal waters are closed to swimming, shell fishing or unsafe for aquatic life due to bacteria, nutrients or low oxygen.
The major sources are:

- *Runoff*
- *Septic systems*
- *Natural sources*
- *Combined sewers in urban areas.*

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Cost effectiveness and multiple benefits

Water quality benefits of pollution controls may be difficult to measure. For the most part we recommend management practices with documented pollution removal efficiency. Practices with uncertain water quality benefit may also be included where implementation costs are low and where multiple benefits can be achieved. For example, use of conservation development designs are recommended as a useful technique for reducing site disturbance and preserving undisturbed forest and wetland buffers. Water quality benefits are difficult to measure and may vary project by project. However, because cost is the same or lower than with standard development and wee designed projects usually offer multiple aesthetic and open space benefits, conservation development design is included as a primary protection strategy for developing watersheds.

4.2 Management Actions for Municipal Government

The following management practices are loosely organized according to the eight watershed protection tools outlined by the Center for Watershed Protection in the Rapid Watershed Planning Handbook and other publications (Center for Watershed Protection, 1998; 2000; and http://www.cwp.org/tools_protection.htm). These tools correspond to the stages of the development cycle, from initial land use planning, site design, construction, and land ownership. This is a logical progression and integrates a range of pollution controls. Additional information about these practices and guidance on selecting the appropriate level of control based on watershed vulnerability is also available through the Center for Watershed Protection and other sources.

1. Planning and zoning

Review assessment results and incorporate recommendations into town plans

Designate a committee to review assessment results with the following responsibilities: compare general assessment findings with watershed features and actual water quality conditions to validate results with review of technical assumptions as needed; evaluate effectiveness of current water supply protection measures to address identified risks, select priority actions, and report back to council with recommendations.

- Work with neighboring communities sharing water supply sources or service areas.
- Coordinate drinking water protection with stormwater planning under the RIDEM Phase II stormwater program.
- Provide continued support and resources to implement key recommendations, including updating town plans and ordinances.

Update water resource protection goals in comprehensive community plans

Are groundwater recharge areas and watersheds of drinking water supplies and other sensitive water resources clearly identified in town plans as protection priorities? Source water areas and other sensitive water resources should be clearly set apart as resources requiring the highest level of protection.

Establish specific water quality goals for critical areas, specifying the level of water quality and associated sensitive uses to be met. Typical goals include for example: maintaining existing high level of water quality to avoid the need for additional treatment, protection of co-occurring sensitive resources such as cold water fisheries or unique aquatic habitat, and ensuring maximum quantity of groundwater supply by maintaining pre-development infiltration rates.

Update town plans to incorporate source water protection goals and recommended actions at the 5-year Comprehensive Plan revision and associated visioning sessions.

Set aside an annual council work session with staff to review progress on meeting plan goals. Invite representatives of Planning and Zoning Boards, Conservation Commission, water suppliers, groundwater committee an others. Set annual action items.

Evaluate current and potential future impacts of zoning

In areas where current land use activities already present a high risk, are zoning standards and land development regulations adequate to minimize existing threats? A detailed review of current practices in comparison to recommendations of this assessment, water supply management plans, and other existing plans is needed to

Compare the change in risk from current to future land use for the study areas using bar charts for individual indicators in the "pollution risk results" chapter of this report. In a few cases where a build out analysis was not conducted, town future land use or zoning maps should be consulted to identify areas where commercial, industrial or high intensity development are planned.

Where future risks are noticeably higher than current conditions, are permitted uses consistent with town goals for the area? If not, is it possible to revise permitted uses in keeping with water quality goals?

Is there an opportunity to re-zone to lower intensity activities? If not, have standards for site design and best management practices been established to minimize risks?

Threats to rivers and streams
35% of RI rivers and streams do not meet fishable or swim quality due to bacteria, nutrients or metals. Major sources are:

- Runoff
- Septic systems
- Waterfowl and wildlife
- Direct discharges in urban areas

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Set goals for average watershed impervious cover

Use estimated impervious levels to set maximum levels based on current and future estimates. Wherever possible set average impervious goals below 10 percent for undeveloped watersheds (or less than eight percent in watersheds with sensitive aquatic habitat). Where watershed restoration is a priority, set average impervious goal at less than 25 percent. These are average levels for the watershed or recharge area as a whole; low-density residential areas may be 8-10 percent, while commercial areas may be set at 25 percent. In all cases target levels should be realistic based on estimated current levels and build out projections.

Incorporate impervious cover limits into zoning ordinances and land development regulations. Define maximum lot coverage to include all improvements such as buildings, driveways and parking areas, accessory structures with a foundation, impermeable patios, pools and similar surfaces.

Specialized plans

Groundwater / watershed protection plan. Has a municipal groundwater protection plan or watershed protection plan been adopted? If so, compare current practices with plan recommendations. Evaluate need to update plan or accelerate progress in implementing recommendations.

Water Supply Management Plan. Have town boards and commissions been involved in development of water supply management plans? Development and implementation of these plans should be closely coordinated with municipal planning and zoning activities.

Wastewater Management Plan. Municipalities are responsible for ensuring onsite wastewater treatment systems are properly maintained. Adopting a wastewater management plan is the first step in this process. This plan describes the existing status of onsite systems, including areas in need of remediation. It identifies future treatment needs and potential problem areas, evaluates septage handling capacity, sets town policies for promoting proper system maintenance, repair and upgrading, and describes proposed actions such as proposed inspection ordinances and educational strategies. An approved plan qualifies town residents to access low interest loans for septic system repair using the state revolving loan fund.

Update Water and Sewer facility plans with service boundaries

Have water and sewer utility districts been established, setting limits for future sewer and water extension into source water areas? How are applications handled for changes to established utility districts? Major changes to sewer districts require revision of sewer facility plans, which must be approved by RIDEM. However, small changes that may be inconsistent with town plans and utility plans may be approved more easily. Urban growth boundaries may also be set, consistent with utility service districts, to clearly demarcate village and urban areas where infill is encouraged, sensitive source water areas where sewered development is contained, and outlying areas where low density is maintained without utilities.

Consistency with State Plans

Town plans must be reviewed by the Rhode Island Statewide Planning Program and other state agencies and approved for consistency with the State Guide Plan and programs administered by various state agencies. Situations remain, however, where drinking water source areas are zoned for high-risk activities such as industrial, commercial or high density uses after town plans are approved. State planners should consider establishing standards for review of town plans and ordinances to ensure that minimum protection measures are in place. Where more intensive land use is allowed through zoning, land development standards should be strengthened accordingly to minimize impact of high-risk activities.

Update zoning ordinances and land development standards consistent with adopted plans

Zoning standards and land development regulations are the mechanism used to implement land use goals. As noted above, the actual effectiveness of land use standards lies in the detailed provisions and their implementation. Specific strategies for controlling land development impacts are described in other section of this chapter.

Groundwater / watershed overlay zoning

Special protection measures are often adopted as part of an overlay zone where more stringent provisions apply to the source water area in general or to particularly sensitive areas such as shoreline zones and areas with high water table or other siting limitations. Factors to consider in evaluating effectiveness of the overlay zone include the following:

- Does the district cover all important recharge areas such as the aquifer recharge area, not only deeper reservoirs or wellhead protection areas?
- Are general protection measures in place for areas served by private wells outside of the key recharge areas?
- Are high-risk activities that use, generate or store hazardous materials prohibited? (Note: RIDEM regulates hazardous waste, not storage of hazardous products before waste is generated.)
- If commercial or industrial zones exist within the protection area are these activities consistent with town plans? If not, is a zoning change possible? If so, are site design, performance standards and

RIDEM's Wellhead Protection Program and Requirements

Since 1997, RIDEM has required under its "Rules and Regulations for Groundwater Quality," that municipal governments and all large water suppliers submit detailed wellhead protection plans.

The Wellhead Protection Program applies to all 671 public wells in the State.

Required plan elements include:

1) An evaluation of the groundwater quality within the wellhead protection area

2) A description of past and present efforts to protect groundwater quality

3) Identification of the protection strategies determined to be most appropriate for protecting groundwater quality

4) Recommend or draft a five-year implementation plan.

RIDEM. Wellhead Protection Plan Guidance, September 1996 town oversight and enforcement procedures strict enough to minimize impact?

- In areas that are already intensively developed, do land development standards include provisions to minimize impact with infill and redevelopment? For example, redevelopment of urbanized areas often provide an opportunity to retrofit drainage system for improved stormwater treatment, reduced impervious area through good design or use of permeable materials, restoration of wetland buffers, and improved wastewater treatment.
- Are new underground fuel storage tanks prohibited? Does this apply to all tanks, including new home heating fuel tanks? Are owners of existing home heating tanks required to remove tanks at the time of house sale or are incentives offered to encourage tank removal? For example, the town of New Shoreham offers a $300 rebate for each tank removed.

Other provisions for control of stormwater and wastewater discharges that may be included in overlay zoning are described in other parts of this chapter.

2. Land Conservation

Open Space Planning

Most water supply lands are designated for protection of the water supply and are not open for public recreation for security reasons. Municipalities should consider working with water suppliers and nonprofit organizations and neighboring communities to develop a regional open space plan for recreation and conservation, with linkages to existing open space. Low intensity recreation, preservation of unique habitat, and protection of unfragmented forest for habitat or woodland management, are all uses that are compatible with watershed and recharge area protection.

Use new subdivisions as opportunities to implement open space plans

Land protection priorities set out in town or regional open space plans can then be used to guide selection of common open space in new subdivisions. With each subdivision, protected open space can be pieced together into greenways, habitat corridors, expanded wetland buffers and protected unfragmented forest. The same might be accomplished with traditional cluster subdivisions but often inflexible design standards, with rigid lot frontage widths and building setbacks limit the designer's ability to adjust placement of roads and buildings to achieve the same level of protection. Conservation development design technique are effective in any area but large-lot residential zoning offer the greatest opportunity to preserve the largest acreages, especially if 50 percent or more of each parcel is preserved.

Continue to acquire land or development rights for water supply protection.
Priorities areas for water quality protection include:

- Reservoir intake and shoreline areas, stream shoreline areas throughout the watershed, and marginal lands that if development, present a higher risk of impact.
- Inner well protection areas and areas of deep, well-drained soil serving as deep groundwater recharge areas.
- Open space protection priorities identified through open space planning.

3. Shoreline buffers to Wetlands and Surface Waters

Maintain forested buffers to wetlands and surface waters.
Protecting or restoring forested shoreline buffers to wetlands, streams and other surface waters is one of the most effective methods for protecting surface drinking water supplies. In groundwater recharge areas, shoreline buffers have less direct benefit but help to maintain the overall health of water resources.

Establish or update setbacks from surface waters and wetlands in drinking water supply areas. Within the buffer zone, prohibit or regulate high-impact activities such as onsite wastewater treatment systems, new building construction, and land alterations such as clearing, filling and grading.

Where activities in buffers are allowed by special use permit or variance, evaluate whether standards for permit approval provide specific guidelines to minimize disturbance and reduce potential impacts to the maximum extent possible.

Include identification and protection of vernal pools in wetland protection provisions, to include a buffer surrounding the pool and travel corridors to surrounding upland or wetland habitat.

Consider establishing standards for wetland and surface water buffers to include:

- Maximum protection of forest and other natural vegetation with the shoreline zone, with the goal or maintaining or restoring a contiguous forested buffer.
- Revegetation of disturbed buffers following construction using native trees and shrubs.
- Restoration of developed buffers as existing uses in shoreline area are re-developed or expanded.
- Maximum protection of wetland buffers having high potential for nitrogen removal where source waters are located in coastal watersheds.

Small streams, big benefits

Small headwater streams (first and second order) are the workhorses in protecting good water quality despite their small size. These small tributaries, which typically comprise 60-80% of stream miles in less developed watersheds, are considered to have much greater ability to remove pollutants because of their extensive shoreline contact. (Alexander et al. 2000). In larger streams, the proportion of stream flow interacting with bottom sediments is considered too small to have notable effects on nitrogen dynamics.

Small streams are however, more susceptible to disturbance because they are abundant in the landscape and may be perceived to be less important. Because of their small size they are more likely to be impaired through direct disturbance during subdivision construction, secondary backyard "improvements", and by related changes in flow and sedimentation. To protect these valuable small streams, maximum buffer distances are often recommended for third order streams and smaller. (Center for Watershed Protection, 2000b; Alexander et.al. 2000)

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

Consider implementing a shoreline buffer mitigation program where all onsite protection standards can't be met and after all possible efforts have been made to minimize onsite impacts to the extent possible. Applicants unable to meet all buffer requirements due to lot size, other site features or intense use for the parcel, would be required to provide compensation toward restoration of disturbed shorelines or permanent protection of shoreline areas on other properties.

In surface water supply watersheds, identify and prioritize shoreline areas in need of restoration. Target these for restoration with applications for redevelopment or expansion. Seek funding for restoration through RIDEM and the Natural Resources Conservation Service.

Educating residents about maintenance or restoration of shoreline zones is most critical in neighborhoods where wetlands and streams flow through backyards, and in waterfront developments. Topics include avoiding dumping yard wastes shoreline zones, maintaining or restoring naturally vegetated shorelines, discouraging waterfowl, avoiding shoreline alterations and bulkheads, and limiting disturbance for shoreline access.

Shoreline buffer widths

The optimum width for an effective buffer varies depending on the type of pollutant to be removed, the percent removal needed to protect sensitive waters, and site conditions. In their widely accepted buffer guidance document, the USDA Forest Service (Welsh 1991) recommends a minimum shoreline buffer distance of 95 feet, and up to 185 feet in areas of high water tables and steep slopes. These guidelines are specifically designed to maintain pollutant removal effectiveness of shoreline buffers in forested, farmland, and suburban /rural areas.

In their review of effectiveness of riparian buffers, Desbonnet and others (1994) concluded that a buffer between 200 and 250 feet wide is needed to reduce phosphorus and other pollutants by 80 percent. However, effectiveness of buffers for removal of nitrogen is less dependent on buffer width alone. Instead nitrogen removal by microbial denitrification requires shallow groundwater flow through wetland sediments, which varies, based on site conditions (Addy et.al.1999). Rosenblatt (REF) found that wetlands and associated buffers located on gently sloping outwash soils were more likely to provide proper conditions for denitrification.

The preceding recommendations focus on buffers in rural and agricultural area where, according to analysis by the Center for Watershed Protection, pollutant removal "appears to be due to relatively slow transport of pollutants across the buffer in sheet flow or under it in shallow groundwater. In both cases, this relatively slow movement promotes greater removal by soils, roots, and microbes." These findings stress the importance of infiltrating runoff for maximum water quality benefit. However, the Center for Watershed Protection qualifies this by noting, "Ideal buffer conditions are rarely encountered in urban watersheds. In urban watersheds, rainfall is rapidly converted into concentrated flow. Once flow concentrates, it forms a channel that effectively short-circuits a buffer" (Center for Watershed Protection 2000b). The management implications are that buffers need to be carefully designed to promote infiltration, avoid channelized flow, and in high-use areas, provide additional stormwater treatment and avoid over-reliance on natural buffer functions.

Summary guidelines for multiple use vegetated buffers

The approaches to establishing a buffer distance vary from standard, one-size fits all approach to more complex formulas based on site-specific conditions. For the sake of simplicity most RI municipalities adopt a standard buffer setback, then review and approve special use permits or variances on a case-by-case basis. Where buffer standards have been established, standards for approval of special use permits and variances should be evaluated to determine their adequacy in avoiding and mitigating impacts, while maintaining the water quality function of the buffer. Factors to consider include:

- Sensitivity of the nearby resource.
- Characteristics of the buffer itself, such as erodible soil types, steep slopes, high water table or floodplain, and poor vegetation. Many rating systems recommend greater buffer distances to compensate when any of these conditions are present within the buffer.
- Use of the parcel and potential for the buffer to be disturbance, with high-intensity activities requiring greater buffer distances.
- Management practices to maintain buffer function over the long term and prevent encroachment.

Table 3
Summary of standard buffer widths for water quality protection*

Buffer distance (ft)	Type of buffer	Pollutant removal / special conditions
150	Multiple use standard buffer	75% removal of sediment and nutrients
250	Protection of sensitive areas	80% removal of sediment and nutrients
100	Minimum buffer for water quality protection for low-intensity uses.	60- 70% removal for phosphorus, nitrogen and total suspended solids or less. Assumes good site conditions and runoff managed through sheet flow or infiltration through buffer.
360	Viral inactivation	Based on rapid ground-water flow rate of three feet/day; also temperature dependant.
35 – 50	Restoration of urban buffers	50 – 60% removal of sediment and nutrients possible; poor wildlife habitat.

Increased buffer distance is generally recommended where buffers include steep slopes, high water tables and sensitive habitat. Wildlife habitat values not included above.

Sources: Addy et.al. 1999; CWP 2000b; Desbonnet et.al.1994; Herson-Jones et.al. 1995; Horsely & Witten, Inc. 1997; Welsh 1991.

Buffers for new land development projects

Shoreline buffers located on private property are most susceptible to gradual alteration by landowners – activities that are very difficult to monitor and enforce. Reduce potential for gradual wetland loss by delineating parcel boundaries within suitable building areas and including wetlands and associated buffers within designating open space

Review of variances or special exceptions from buffer standards on existing lots of record

- Consider buffer characteristics in establishing buffer widths and uses – are there limiting conditions such as high water table or erodible soils that would reduce effectiveness of the buffer?

- Minimize extent of disturbance to the maximum degree possible, moving construction and clearing out of the buffer wherever possible.
- Require the applicant to seek variances from side, front, and other setbacks before seeking reduction in buffer distance.
- Reduce size of project to minimize impact, with smaller building footprint and reduced wastewater flow from septic systems.
- Establish performance standards for control of stormwater and wastewater discharges. Limit impervious cover and require use of low impact stormwater controls to maintain pre-development runoff volume. Require advanced wastewater treatment systems in sensitive areas and problem soils.
- Establish limits of disturbance on plans and fence off in field to avoid unnecessary construction damage.

Protect the buffer from alteration after construction

- Mark the upland boundaries with permanent fencing and signs that describe allowable uses.
- Require revegetation after construction using native shrubs and trees.
- Educate buffer owners about the purpose, limits, benefits and allowable uses of the buffer. Also educate residents about the operation and maintenance of stormwater drainage systems located on individual lots, such as drainage swales and rain gardens that homeowners may need to maintain or avoid altering.
- Use pamphlets, neighborhood association meetings, demonstration sites and stream walks to educate homeowners.

4. Land Development standards: Site Design, Erosion and Sediment Control, and Stormwater Management

At the project level, managing development impacts begins with careful site design to direct development to suitable areas, limit site disturbance and impervious area, and incorporate nonstructural stormwater controls into project design from the earliest stages. Good land development practices are needed even where pollution risks are estimated to be low because this rating is an estimate for the study area as a whole. In practice, impacts are likely to occur in site-specific locations, affecting water quality of stream segments and surface waters locally. In addition, our estimates assume use of good management practices to avoid steep slopes and high water table, keep wetland buffers intact, implement effective erosion controls, and keep septic systems functioning properly with good maintenance. Actual impacts may be much greater depending on the site conditions, the location of development and intensity of use. Establishment of mini farms with horses or other animals would also result in much higher pollutant inputs than predicted, especially if animal wastes are not properly managed. Because of the potential for site-specific

Changes in hydrology = water quality impacts

Urban runoff alters basic water flow and pollutant pathways in a way that robs watershed ecosystems of natural pollutant removal functions.

- *Water running off, rather than infiltrating the ground bypasses natural pollutant removal pathways in soil.*
- *Stormwater flowing to wetlands and surface waters is often channelized in pipes, swales, or other drainage ways, bypassing most of the riparian buffer area and escaping treatment in shoreline buffers.*
- *Reduced recharge as a result of high runoff is known to lower water tables. As a result, groundwater discharging to streams may flow below, rather than through shallow wetland sediments, bypassing potential groundwater nitrogen treatment zones of high microbial activity.*

impacts, use of good land development practices remains important when watershed risks are low, and becomes critical where marginal sites are subject to development.

Guidelines for land development

The following practices represent current management practices for new land development as well as re-development and expansion of existing uses. These are not intended to be comprehensive. Implementing these may require amendment to zoning ordinances and land development regulations. In each case, education, field inspection and enforcement would also be needed.

Project planning and review

Soil mapping provides critical information such as soil permeability and water table depths needed to locate sites for buildings, onsite wastewater treatment systems, and both structural and non-structural stormwater facilities. RI Soil Survey maps are useful for general planning purposes but are not accurate at the parcel level. Site-specific soils mapping by a professional soil scientist should be required for all land development projects to accurately identify soil conditions as early as possible in the site planning process, ideally, when wetland boundaries are first delineated. Accurate soil mapping results can then be used to identify sites for more costly site investigations such as installation of water table monitoring wells and soil evaluation pits excavated using heavy equipment.

Use conservation design principles to preserve forest cover and protect wetland buffers from backyard encroachment. Relatively undeveloped areas with large lot zoning stand to gain the greatest acreage of open space with this technique, especially if at least 50 percent of the parcel is reserved as open space. The principles are equally appropriate for more dense development, including commercial and village areas where effective use of even small open space areas can have substantial benefits.

Use site analysis to identify permeable soils suitable for stormwater infiltration. Integrate planning for nonstructural stormwater drainage systems with site layout, to include rooftop runoff diverted to vegetated areas, use of small landscaped stormwater storage and infiltration areas known as "rain gardens" and use of roadside swales rather than traditional curb and catch basin.

Limit impervious cover with narrower roads and modified cul-de-sacs. Consider use of permeable pavements in sensitive areas and where necessary to achieve impervious target levels.

Review parking requirements and set maximum parking requirements for commercial and industrial developments. Use permeable materials for overflow parking.

Establish limits of disturbance for new road construction, with individual building envelopes for buildings and driveways. Mark disturbance limits on plans and fence off in the field. Where septic systems are used, fence off the proposed leach field to protect against compaction by heavy equipment during construction. Earmark individual trees or groups of trees to be protected and fence off at the dripline or other root protection zones identified by qualified arborists. With new septic system construction, fence off the leach field during construction to protect against compaction by heavy equipment. This is essential to ensure long-term function of the leach field.

Clearly identify all material storage areas, stockpiles and stump dumps (if on-site disposal is allowed) on plans. Keep within specified limits of disturbance or store at another location.

Prohibit disposal of "clean fill" in source water areas, which, by definition, may contain construction debris such as asphalt.

Prohibit use of subdrains to lower high water tables for development sites. Prohibit use of subdrains to intercept high water table for individual building sites and septic systems unless the discharge can be accommodated on site without contributing to offsite runoff. In environmentally sensitive areas, or where lot sizes are small, prohibit construction of basements in high water tables, which require either extensive filling or use of subdrains.

Establish standards for control of runoff volume, keeping the amount of runoff at pre-development levels in sensitive areas.

Identify highly erodible areas during project review and take additional erosion and sediment control precautions in these areas. Where town staff is limited, establish permit review fees to cover cost of hiring outside consultant to review erosion control and stormwater management plans, and most importantly, conduct field inspections during construction.

Require plans for erosion and sediment control and for stormwater management for all land development projects, including minor subdivisions. Require approval of maintenance plans for stormwater systems, with responsible parties identified and enforceable provisions for ensuring routine maintenance.

Develop and distribute educational materials to homeowners on importance of nonstructural stormwater controls, maintenance requirements for facilities located on private lots, and penalties for altering drainage systems. Follow up with field inspections and enforcement.

Resources for site design and low impact development

Excellent resources for controlling environmental impacts through site design and innovative stormwater control are available for in-depth guidance. The following are particularly useful and all but one are designed for Rhode Island communities.

- The *Conservation Design Manual* describes the step-by-step process for evaluating a site, identifying open space for preservation, and selecting suitable areas for development. Produced by Dodson Associates for RIDEM. Available to view or download at the www.state.ri.us/dem/programs/bpoladm/suswshed/ConDev.htm , the RIDEM website.

- The two-volume set: *Low –Impact Development Design Strategies: An Integrated Design Approach*, and *Low-Impact Hydrologic Analysis*, describes the current approach to stormwater management emphasizing control of runoff volume using nonstructural controls. The manual stresses site design and micro-management of runoff to keep stormwater on site and mimic pre-development hydrology. Produced by Prince George's County with EPA support and available to view or download at http://www.epa.gov/nps/lid/ . Hard copies may be ordered through the EPA National Service Center for Environmental Publications on line at www.epa.gov/ncepihom/ordering.htm , or by phone at 1-800-490-9198.

South County Technical Planning Assistance Project. Prepared by Dodson Associates for RIDEM. Includes several resources for land use planning and design to protect open space, all available to at www.state.ri.us/dem/programs/bpoladm/suswshed/sctpap.htm, including:

- Model ordinances for conservation development and other land use strategies;
- South County Design Manual, which uses actual sites in southern Rhode Island to illustrate future development scenarios using conventional development vs. more compact designs with conservation development techniques.
- Rapid Site Assessment Guide – Produced by URI Cooperative Extension for RIDEM. Offers guidance on use of Geographic Information Systems to conduct a planning level site analysis using simple static maps available on the web and RIGIS coverages for those with access to ArcView GIS software.

Scituate Reservoir Watershed Zoning Project – Parts 1 and 2. 1998. Two-volume set prepared by Newport Collaborative Architects for RIDEM. Describes design strategies to preserve rural character while protecting local water quality. Includes model development standards. Additional information at the RIDEM website at www.state.ri.us/dem/programs/bpoladm/suswshed/Scituate.htm . Available only in paper copies through RIDEM. Contact Scott Millar at 401-222-3434.

5. Wastewater Management

When properly sited, operated and maintained, onsite systems provide a safe, cost-effective and environmental sound treatment option for low-density areas. The RIDEM Individual Sewage Disposal System (ISDS) program establishes minimum standards for siting, design and installation of onsite wastewater treatment systems. Once installed, however, Rhode Island municipalities are responsible for making sure septic systems are properly maintained. To keep these systems functioning over the long term, and to protect public health and local water quality, many Rhode Island communities are establishing onsite wastewater management programs with support and funding by the RIDEM. Use of advanced onsite wastewater treatment systems is becoming commonplace, however, these systems are bound to fail unless properly maintained. Town oversight is needed to ensure all advanced wastewater treatment systems, including existing systems, have maintenance contracts in place that are renewed annually.

Management of centralized wastewater systems - Sewers

Make sewer leak detection and repair a priority in source water areas. Watertight lines and pump stations prevent wastewater leakage, loss of groundwater recharge, and overloading of wastewater treatment facilities with infiltrating groundwater.

Establish sewer and water district boundaries to avoid sewer expansion into source water areas unless necessary to accommodate existing high density and high risk land uses, and where all other onsite options have been evaluated, such as improved wastewater management and use of advanced onsite wastewater treatment systems. Where sewers already exist or are planned for source water areas, existing zoning and land development standards should be carefully evaluated to determine if current standards are adequate to control high risk land uses, limit development of marginal sites, and mitigate potential impacts of more intense development supported by sewers. Control of hazardous materials, stormwater treatment and recharge, and protection or restoration of wetland buffers are particularly critical in more intense development is permitted.

Local management of septic systems - decentralized onsite wastewater treatment systems

Develop a local wastewater management program. Most communities begin with development of a wastewater management plan. A RIDEM-approved plan qualifies town residents for low-interest loans for septic system repair under the RI State Revolving Loan Fund. Implementation of the plan includes public education and in many cases, development of a wastewater management ordinance that requires regular system inspection with pumping as needed, repair or replacement of failing systems. Some communities require gradual phase-out of cesspools over time. When hiring staff to manage the program, consider joining with neighboring communities to share personnel and equipment.

Consider establishing treatment standards specifying use of advanced treatment systems in critical areas. Examples of existing programs: Block Island has set treatment standards townwide, with advanced treatment required in the town's primary drinking water supply wellhead, and based on soil type in other wellhead protection areas. Little Compton requires alternative systems as a condition of approval for construction in wetland buffers. Jamestown requires advanced treatment in densely developed areas served by private wells with high water table.

Prohibit use of deep leaching chambers (4'x4' galleys) due to lack of treatment potential with deep discharge.

Require alternative treatment systems for large flow and high strength systems within source water areas; and also for smaller systems located in critical areas, including shoreline buffers and inner protected well radius, and in areas with poor soils where horizontal and vertical setbacks can't be met.

Where development is clustered on small lots and high water table, require use of advanced treatment systems rather than raised fill systems to avoid increased runoff and nuisance flooding to neighboring properties.

Where monitored nitrate levels are elevated (>2 mg/l) and where septic systems are estimated to be the dominant source and where projections show nitrogen sources from onsite systems increasing with future development, require use of advanced treatment systems for new or replacement systems for high intensity development. The need for advanced treatment is especially critical where monitored nitrate concentrations are near the 5 mg/l level, especially where projections indicate increased future inputs.

Prohibit new development on marginal sites (less than 2 ft. water table depth) in source water areas due to risk of treatment failure where water tables are likely to rise to the surface during wet periods.

Where advanced treatment systems are already being used, establish maintenance fees to cover cost of town oversight in tracking annual renewal of maintenance contracts and ensuring that maintenance is properly conducted.

Establishment of a mandatory inspection program will identify failing systems and illicit discharges, as required under the RIDEM Phase 2 stormwater program. Wastewater and stormwater management planning should be closely coordinated.

Establish a computerized database for tracking septic system inspection results and maintenance schedules. Several programs are available, including low-cost, web-based reporting systems with minimal staff requirements. Begin by putting town-owned onsite wastewater treatment systems on inspection and maintenance schedules. Budget for upgrading of large institutional systems to advanced treatment in critical areas. Technical assistance in selecting appropriate technologies is available through the URI Onsite Wastewater Training Center. For more information about conventional and alternative systems, go to the URI Cooperative Extension site: www.uri.edu/ce/wq/owtc/html/owtc.html .

6. Use and Storage of Hazardous Materials

Background

Underground fuel storage tanks are the major source of new groundwater contamination incidents in Rhode Island (RIDEM 2002).
Prohibiting siting of new underground storage tanks in source water areas is the most effective way to prevent increased risk of contamination.

The technology does not exist to ensure underground storage tanks and components will be 100% leak proof and only small quantities can contaminate water supplies.
Even with a major overhaul of state regulations for UST in the last few decades, with new standards for tanks, a DEM review of its waste management program has found that leaks and spills from underground storage tanks are almost impossible to prevent entirely (RIDEM 2001). Improved double wall and fiberglass tanks are now much less prone to leaks but leaks from fuel lines and pumps are common and unpredictable, and no method exists to test. Leak detection methods are imprecise. Leaks may go unnoticed for a long

period and even relatively small quantities can have disastrous effects. Tank pressure testing is not 100 percent accurate, and even small leaks can be a major source of contamination. There is no convenient way to test pumps and lines for leaks.

Not all underground tanks are regulated.

RIDEM regulates all commercial tanks but does not regulate underground tanks storing heating fuel consumed on-site at homes or businesses. RIDEM underground storage tank (UST) regulations prohibits new underground storage tanks in community wellhead protection areas only; new tanks are allowed in all other areas, including, non-community wellhead protection areas, aquifer recharge areas, and surface water supply watersheds.

RIDEM has limited staff to inspect these facilities and even more limited resources to effectively enforce violations.

In 2001, the RIDEM Office of Waste Management carried out 47 compliance monitoring inspections of UST facility operations. The purpose was to determine compliance with continuous monitoring systems or corrosion protection systems to ensure that tanks are not leaking and releasing gasoline or other hazardous materials such as MBTE into the environment. Results: DEM inspections found noncompliance at just about every facility inspected (RIDEM 2001)

Enforcement is difficult and time consuming. In 2001 RIDEM notified 59 UST facilities of non-compliance, but only 27 were brought into compliance. Municipal staff lack the training, time or jurisdiction to inspect these facilities on their own (RIDEM 2001).

Recommended local actions

New underground storage tanks

Prohibit installation of new underground storage tanks, in town-identified critical areas through groundwater protection overlay zone or site review standards. Include both commercial tanks and heating oil tanks for onsite use.

Existing underground storage tanks

Make formal inquiry to DEM to identify existing state-regulated underground storage tanks and other facilities generating or storing hazardous waste within town critical areas. Determine type of facility and compliance record. Identify additional improvements that can be made beyond minimum standards. Invite representatives of Planning Board, Conservation Commission, water suppliers, groundwater committee to participate in review. Set annual action items.

Establish standards for existing facilities triggered by renovation, expansion, or sale of existing uses. Required improvements should be based on RIDEM recommendations to include for example: replacement of underground storage tank with above ground unit; improved monitoring and reporting requirements, including use of downgradient wells and sampling; and employee training.

Require removal of existing heating fuel tanks for homes and businesses at the time of property sale, building improvement or expansion. Establish sunset clause for removal of tanks in high risk areas; offer rebates for voluntary removal in less critical areas. For example, the New Shoreham offers a $300 rebate for each underground tank removed.

Promote private well water testing of all wells located within 1000 feet (or greater for larger wells) of underground storage tanks for fuel components and MTBA

Commercial and industrial facilities using or storing hazardous materials

RIDEM regulates storage and transport of hazardous waste but does not have jurisdiction over facilities that use hazardous materials, even though the hazardous product and the waste may be the same material.

Review and update groundwater /watershed zoning to prohibit siting of new facilities that use, store, or generate hazardous materials and wastes. Regulate storage of hazardous materials in the same way that hazardous waste is regulated. A useful guide to best management practices is the RIDEM Hazardous Waste Compliance Workbook for RI Generators, available through the Office of Waste Management at www.state.ri.us/dem/programs/benviron/waste/index.htm .

Identify areas where new lower-risk commercial /industrial facilities may be permitted by right or by special exception in less critical portions of the groundwater recharge area. Establish local performance standards for design, siting and monitoring.

Update standards for stormwater management, wastewater treatment and wetland buffer protection for businesses in aquifer recharge areas. For example, gas stations and convenience stores are known to generate more heavily contaminated runoff and require special stormwater runoff controls. Oil and water separators typically used may not be appropriate; other treatment units are now available that may have better pollutant treatment performance. All such units require routine care and maintenance contracts should be in place.

Update standards for review and approval of special use permits or variances to bring businesses in closer conformance with current performance standards. These requirements may include for example, shoreline buffer restoration, stormwater system retrofitting, or site design and landscaping improvements.

Town owned facilities

Identify town-owned facilities using or storing hazardous materials. Evaluate management practices at these locations and in routine operations such as road maintenance and landscape care in town parks. Install model practices at town facilities. Coordinate these activities with required improvements under RIDEM Phase 2 stormwater planning.

7. Monitoring, Education and Stewardship

Investigate results of hotspot mapping

Identify appropriate methods to investigate sites to determine if mapped site is actually a potential source of pollution, determine if action is necessary. Consider different strategies for residential, business and agricultural properties. For example, to investigate potential hotspots in agricultural areas: work with local farmers, the Natural Resource Conservation Service, and the RIDEM Division of Agriculture to determine if mapping represents actual field conditions, current conservation practices, and need for additional management to minimize impacts. Use RIDEM Division of Agriculture mapping to review current type of crop, location and number of large animals, and animal waste storage sites. Cooperate with these groups to conduct field investigations and contact landowners to discuss assessment results and management options.

Municipal Lawn and landscape Care

Provide training for municipal staff in lawn and landscape care. Low-impact landscape care, using current fertilizer and irrigation practices, and use of low-maintenance sustainable plants, can improve local parks and lawns while reducing landscaping costs over the long run. Contact the URI GreenShare program at www.healthylandscapes.org/

Hydrologic modifications

The RI Water Resources Board is currently working with governmental officials and water suppliers to identify water use needs and establish policies for allocating water among different users, including protection of downstream water flow for habitat. All interested parties are welcome to participate in this process. For more information go to www.wrb.state.ri.us/ .

Compliance and enforcement

In many cases plans and regulations are comprehensive but staff is lacking to monitor and enforce current activities. Municipalities and water suppliers should discuss opportunities to coordinate in improving enforcement of local regulations, including hiring an environmental enforcement officer to work with town staff such as the building inspector, wastewater management coordinator and others conduct field inspections, educate landowners and developers, and pursue enforcement actions where needed.

Community pollution prevention education

As a joint effort between water suppliers and local officials, expand public education to promote awareness of local water resources and the need for protection. Use educational campaigns to encourage individual adoption of good management practices and also to build public support for local source water protection ordinances.

- Start by mailing the assessment summary fact sheet to watershed residents and water users.
- Join forces with existing organizations promoting conservation and education. Work with nonprofit organizations to implement watershed education programs in schools.
- Support private well water protection education and facilitate private well water sampling; actions taken to protect private wells will also protect public supplies.
- Aim to establish a continuous educational program targeting different audiences through a variety of methods. Occasional educational efforts are less effective. The most successful communities have appointed a committee with citizen volunteers to spearhead efforts, such as the North Kingstown Groundwater Committee, which works closely with the town water supply department, the planning department, and other town officials.
- Target residents and businesses in critical areas for education on issues of concern in their neighborhood such as shoreline development in waterfront areas, lawn care in areas with large lots and high-maintenance lawns, and areas in need of septic system repair and upgrading.
- Work with business groups to promote good "housekeeping" practices among commercial and industrial property owners.

Consumer Confidence Reports

The 1996 Amendments to the Safe Drinking Water Act (SDWA) require public water supply systems that serve residential customers to prepare and distribute annual consumer confidence reports. These reports are intend to help educate public water supply consumers and to promote a dialogue between water suppliers and their customers on the importance of source water protection.

4.3 Management Actions for Water Suppliers

Implementing municipal management actions listed above would require coordination with water suppliers and their active support. In many cases water suppliers already are leading non-regulatory efforts, such as educational outreach and monitoring. Additional actions water suppliers can take to protect drinking water supplies follow. In many cases, water suppliers already have active watershed management programs that incorporate many of these elements.

- Implement all recommendations of the latest water supply systems management plan.
- Continue to prioritize and acquire land for protection.
- Identify priorities for restoration, including potential sites for stormwater drainage system improvements and shoreline revegetation. In cooperation with government agencies and nonprofit organizations pursue funding to implement projects through capital budgets and competitive grants.
- Post signs alerting the public to location of Wellhead or Watershed Protection Area.
- Cooperate with local officials to update local plans and ordinances to implement land use protection measures.
- Inspect water supply and protection area regularly for potential pollution sources.
- Provide assistance to communities in review of development proposals to evaluate potential impacts and identify alternative designs and management practices to minimize impact.
- Expand monitoring where needed to evaluate stream water quality through simultaneous monitoring of stream quality and flow. In surface reservoirs track nutrient enrichment status through standard benchmarks such as Carlson's Trophic State Index.
- In groundwater aquifers promote private well water protection education and encourage private well water sampling. Actions taken to protect private wells will also protect public supplies.
- Cooperate with local officials and nonprofit organizations to develop and carry out watershed/groundwater education programs for those who live and work in source water areas.

4.4 What Residents, Landowners and Businesses Can Do

Drinking water protection eventually comes down to the individual actions of those who live and work in water supply areas. The following are basic actions each person can take to protect public supplies and the health of their own home and yard.

Residents

Vehicle and Engine Maintenance

- Recycle used motor oil. Never pour waste oil on the ground or down storm drains.
- Local sanitation departments or service stations can often accept used motor oil.
- Keep up with car maintenance and the maintenance of other motorized equipment such as lawn mowers and snowmobiles, to reduce leaking of oil, antifreeze, and other hazardous fluids.

Heating fuel

Replace underground home heating fuel tanks with properly-contained above ground tanks.

Household Hazardous Products

- Follow the product label directions for use and storage very carefully.
- Keep products in their original, labeled containers and out of the reach of children.
- Buy only as much as you will need. Give surplus products to friends, neighbors and groups who can use them.
- Consider using nontoxic, nonhazardous alternative products.
- Do not pour paints, used oil, cleaning solvents, polishes, pool chemicals, insecticides, and other hazardous household chemicals down the drain, in the yard, or on the street.
- Dispose of household hazardous waste properly and recycle wastes where possible.

Septic system care

- All septic systems need regular care to function properly and avoid costly repairs. Inspect septic systems annually and pump when needed, usually every 3 – 7 years.
- Comply with local wastewater management requirements.
- Repair or replace failing septic systems. If you have a cesspool plan to replace it.
- Avoid using septic system additives.
- Place only toilet paper in the toilet.
- Don't pour grease or hazardous household products down the drain.
- Compost kitchen wastes rather than using a garbage disposal.
- Conserve household water to reduce the amount of wastewater generated.

Yard and garden care

- Maintain wooded buffers or restore natural vegetation along wetlands or watercourses than run through your property.
- Avoid dumping leaves and brush in shoreline areas.
- Use native, low-maintenance plants that require less fertilizer and water.
- Reduce fertilizer and pesticide use. When using these, follow product labels carefully.
- Use organic fertilizers or compost instead of chemical fertilizers.
- Limit outdoor water use. Summer water demand typically doubles or triples due to outdoor watering.
- Reduce stormwater runoff by limiting paved surfaces. Direct runoff to well-vegetated areas or gravel rather than pavement leading to storm drains.
- If you have a private well have it tested annually.

Pets and livestock

- If you have horses or other livestock, provide proper animal waste collection and storage. Keep animals out of streams and waterways.
- Pick up after your pets.

Contacts:

Healthy yard and garden care:
URI Cooperative Extension Master Gardener Hotline
URI GreenShare Program http://www.healthylandscapes.org/
Septic systems
URI Onsite Wastewater Training Center www.uri.edu/ce/wq and Master Gardener Hotline 1-800-448-1011, M-Th. 9am –2pm.
Private well protection:
URI Home*A*Syst, 401-874-5398,
Animal waste management:
USDA Natural Resources Conservation Service 401-828-1300, www.ri.nrcs.usda.gov .
Hazardous waste recycling and disposal:
RI Resource Recovery Corporation, Eco-Depot 401-942-1430.

Farmers and Landowners

Work with the USDA Natural Resource Conservation Service to develop a conservation plan that addresses proper nutrient, manure, pest, and irrigation water management.
Consider use of conservation tillage to minimize erosion.
Maintain and restore naturally vegetated buffers to surface waters. This is especially critical in watersheds of drinking water supply reservoirs.
Contact them at (401) 828-1300, www.ri.nrcs.usda.gov

Businesses

- Adhere to all laws, regulations, and recommended practices for hazardous waste management, above and underground storage tanks, floor drains and wastewater discharges.
- Clearly post signs to show proper hazardous material handling and storage practices
- Provide regular training for employees in management of fuel tanks, monitoring equipment, and safety practices.
- Contact RIDEM Pollution Prevention Program for assistance in reducing use of hazardous materials and in voluntary good "housekeeping" inspections.

Check local regulations with city/town hall and state regulations with the RI DEM Office of Water Resources (401) 222-4700, www.state.ri.us/DEM/program/benviron/water/index.htm .

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APPENDICES

A. **RI Source Water Assessment Program, Methods and Assumptions in ranking public water supply susceptibility** *Summary of the RISWAP assessment method used to evaluate susceptibility to contamination; describes basic susceptibility ranking applied to all supplies and more in-depth assessment conducted for major community supplies.*

B. **Susceptibility Ranking Worksheet** Assessment results using basic RI SWAP ranking applied to all RI public water supplies.

C. **Sampling Data Analysis and Rating** *Summarizes review of water supplier monitoring data for the past five years and assigns rating for risk of contamination; results provide input to the basic SWAP Susceptibility Ranking.*

D. **Public Participation in the Assessment Process** *Sample public notice of assessment developed for each study area; provides overview of assessment approach, volunteer roles in mapping and assessment, list of meetings and typical agendas.*

E. **Existing Condition of Surface and Ground Water Resources** *Table used to organize data collection and public input during the assessment process; this is not a complete summary.*

F. **Current and Future Land Use Estimates** *Summary results of GIS land use analysis with current land use, future build out acreage and percent change.*

G. **Characteristics of Rhode Island Soils** *Itemizes soil features incorporated into assessment; useful reference.*

H. **RIGIS Coverages used in the MANAGE Assessment of Major Community Supplies**

I. **MANAGE Summary Results** *Summary output from MANAGE spreadsheets with land use features, soil characteristics, hydrologic budget and nutrient loading for each study area. Results reported for current land use and other scenarios such as future build out and use of alternative management practices.*

J. **MANAGE GIS-Based Pollution Risk Assessment Method, Watershed / Aquifer Pollution Risk Indicators.** *List and rating key for land use, landscape features and modeled nutrient loading estimates used to evaluate pollution risk. Includes background information on interpreting results.*

K. **Hydrologic and Nutrient Loading Assumptions** *Summary of MANAGE input values and assumptions using average annual values. Includes surface runoff coefficients for nitrogen and phosphorus, nitrogen inputs to groundwater from specific sources, housing occupancy, and other assumptions. Complete technical documentation, MANAGE GIS-Based Pollution Risk Assessment Method - Database Development, Hydrologic Budget and Nutrient Loading, available at* http://www.edc.uri.edu/cewq/manage.html.

APPENDIX A

RI Source Water Assessment Program
Methods and Assumptions in ranking public water supply susceptibility

Prepared by URI Cooperative Extension and RI HEALTH
April 2003

The Rhode Island Source Water Assessment Program assigns a susceptibility rating to each public water supply. The ranking considers potential sources of pollution from land use and identified facilities, as well as the water supply's vulnerability to contaminants based on geology, well type and sampling history. This summary outlines the methods and assumptions made in assigning ranking scores, including evaluating public water supply sampling history using the RI HEALTH public water supply database.

The Rating System

Surface water supplies and groundwater supplies use a slightly different ranking system that accounts for unique features of each resource. In each case, the full watershed or wellhead protection area was evaluated.

The ranking system assigns a rank from low to extreme for each factor. A numeric score from 5 to 25 is also assigned to each rank. Totaling scores for all factors results in a maximum score of 200 for surface water supplies and 210 for groundwater supplies. The final susceptibility rank is assigned as follows: Low 0-49, Medium 50-100, and High > 100.

IIn general, low threshold limits were set to identify potential threats as an early warning to provide ample opportunities to implement pollution prevention measures as a cost effective way to protect future water quality. Setting low threshold also allows a water supplier to track changes over time as source areas become developed and begin monitoring trends that would otherwise go unnoticed at higher detection levels. For example, review of sampling data for groundwater supplies includes monitoring increases in nitrogen above background levels to detect trends in drinking water supplies and also in nitrogen-sensitive coastal areas that are subject to nutrient enrichment at very low levels far below drinking water standards.

Each groundwater supply and surface waters supply watershed wellhead protection was ranked separately. Large surface water supply watersheds were divided into subwatersheds ranging generally from 500 to 5,000 acres. Each subwatershed was evaluated individually for land use factors but where water from different subwatersheds or even geographically separate watersheds was treated at one location, the same sampling data was used for each.

Where several wells are located within one wellhead area, the same input data for wellhead land use was used for each well. However, sampling data specific to each well was used except where wells within one wellhead area were owned by one water supplier or located so close to one another that all would be susceptible to any contaminate present in one. In this case well sampling data as analyzed as one group to identify maximum levels.

Although each water supply source was ranked separately, where one water supplier managed more than one well or surface water reservoir results were averaged to create an average susceptibility rank for the supplier.

Assessment Factors

Watershed Land use, landscape features, and potential sources of pollution
Information on land use characteristics, soils and identified facilities are derived from the RIGIS database. For major community supplies, 1995 land use maps were reviewed and updated by local volunteers to correct for major changes. Volunteers were also trained to conduct windshield surveys to update locations of potential sources of pollution such as gas stations and manure storage areas.

Aquifer, watershed and reservoir characteristics
For groundwater supplies, well construction was used as one factor in evaluating vulnerability to contamination, with unconfined sand and gravel wells considered at higher risk than bedrock wells. Well construction was identified based on RI HEALTH records.

For surface reservoirs, vulnerability to contamination was based on estimated nutrient enrichment levels using readily available reports, input at local assessment group meetings, and RI Department of Environmental Management data including 305 (b) reports. Where no data on nutrient enrichment level was available, a moderate level was assigned. Factors considered in assigning a high or extreme level in the absence of monitored chlorophyll, clarity or phosphorus levels included: local reports of frequent or severe algal blooms, DEM applications for herbicide application, high (> ½ MCL) levels of disinfection byproducts such as total trihalomethanes, and impaired status for biodiversity.

Determination of compliance with water quality standards was based on the RIDEM 303 (d) impaired waters listing and supporting data.

All determinations of nutrient enrichment status and compliance with water quality standards were made in cooperation with RI DEM Office of Water Resources.

Outflow / Well Water Quality
The RI HEALTH public water supply database was used to evaluate sampling history over the past five years.

The method for evaluating and ranking sampling results is different for surface waters and groundwater to account for unique features of each resource, as follows:

Samples for both reservoir outflows and wellwater were analyzed for history of contaminant detects based on Maximum Contaminant Levels for public health.

Groundwater supplies were also evaluated specifically for bacteria detects. Since most surface water supplies are disinfected, this analysis was not considered necessary for surface waters.

In addition, groundwater supplies were evaluated using nitrogen concentrations as an indicator of wastewater and fertilizer inputs from human activities. In this case low ranking thresholds were set to identify levels above background concentrations rather than identifying contaminant detects based on the Maximum Contaminant Levels for public health. Relatively low concentrations were used to identify trends and areas at higher risk to coastal waters in addition to public health risks.

Data was collected at the source, before treatment; except that distribution samples after treatment were used to evaluate the level of disinfection by products such as total trihalomethanes. Where distribution samples were not available, the available consumer confidence reports were used to determine the maximum level.

For more information contact:
RI HEALTH, Office of Drinking Water Quality 401-222-6867
URI Cooperative Extension, Nonpoint Education for Municipal Officials 401-874-2138

APPENDIX B Susceptibility Ranking

Susceptibility Ranking for Surface Water Reservoirs WORKSHEET - Stonebridge Water District

#	RISK INDICATOR	RATING					Rating Method	RESULTS	
	Note: Input data are preliminary, based on RIGIS data and limited assessment information. Final input data and ratings will be assigned in cooperation with the water supplier. Where no data are available, a medium rating will be assigned.							**Stafford Pond**	
		LOW	MEDIUM	HIGH	EXTREME	Max. Rating		**Current land use**	
		0	5	10	25			Input data	**Rating**
	Watershed Land use and landscape features								
1	High intensity land use (%) throughout the watershed	<10%	≥10-15%	≥15-25%	≥25%	25	1. list	8.0%	**0**
2	High intensity land use (%) located on highly impermeable soils throughout the watershed	none	≤5%	≥5-15%	≥15%	25	2. list	2.0%	**5**
3	High intensity land use (percent) located within 200' buffer of reservoir and tributaries.	none	≤5%	≥5-15%	≥15%	25	3. List	18.0%	**25**
4	**Watershed Land Use Risk**					75	4. sum of 1, 2, & 3.		**30**
5	Mapped point sources within 200' buffer to reservoir and tributaries	none			Presence of one or more sources	25	5. List	0	**0**
6	Mapped point sources (per 10 acres) throughout watersheds including within 200' buffer to reservoir and tributaries	<0.1/10 acres	<0.5/10 acres	<1/10 acres	>1/10 acres	25	6. List	0.000	**0**
7	**Known Pollution Souce Risk**					50	7. Sum of 5 and 6.		**0**
8	**WATERSHED LAND USE AND LANDSCAPE FEATURES RISK RATING**					125	**8. Sum of 4 and 7**		**30**
	Watershed and Reservoir Characteristics								
9	Trophic status (clarity, phosphorus, dissolved oxygen) (A measure of the amount of treatment needed)*	oligotrophic (O)	mesotrophic (M)	meso / eutrophic (M/E)	eutrophic (E)	25	9. List	E	**25**
10	Compliance with water quality standards, based on RIDEM 303 (d) List March 2003.*	Fully supporting (all standards)	Waterbody and/or tributary impaired (minor, not affecting supply)	Waterbody and/or tributary impaired (potential to affect supply)	Not fully supporting for drinking water.	25	10. list	Waterbody and/or tributary impaired (potential to affect supply)	**10**
11	**WATERSHED AND RESERVOIR CHARACTERISTICS RISK RATING**					50	**11. Sum of 9 & 10.**		**35**
	Outflow water quality								
12	History of contaminant detects (organics, HC, pesticides, metals, etc.) within 5 yrs.	trace	≤1/2 MCL	>1/2 MCL	violation	25	12. List	trace	**0**
13	**OUTFLOW QUALITY RISK RATING**					25	**13. Sum of 11 & 14.**		**0**
14	**SUMMARY RATING for Reservoir Watersheds**					200	**14. Sum of 8, 11 & 13.**		**65**
									Moderate

Notes:

N and S Easton ponds rated as eutrophic based on input from local advisory committee on occurrence of algal blooms

Trophic state and compliance with water quality standards based on personal communication with Connie Carey, RIDEM Division of Water Resources.

Susceptibility Ranking for Surface Water Reservoirs WORKSHEET - Newport Water District

#	RISK INDICATOR	RATING: LOW	MEDIUM	HIGH	EXTREME	Max. Rating	Rating Method
	Note: Input data are preliminary, based on RIGIS data and limited assessment information. Final input data and ratings will be assigned in cooperation with the water supplier. Where no data are available, a medium rating will be assigned.	0	5	10	25		
	Watershed Land use and landscape features						
1	High intensity land use (%) throughout the watershed	<10%	≥10-15%	≥15-25%	≥25%	25	1. list
2	High intensity land use (%) located on highly impermeable soils throughout the watershed	none	≤5%	≥5-15%	≥15%	25	2. list
3	High intensity land use (percent) located within 200' buffer of reservoir and tributaries.	none	≤5%	≥5-15%	≥15%	25	3. List
4	**Watershed Land Use Risk**					75	4. sum of 1, 2, & 3.
5	Mapped point sources within 200' buffer to reservoir and tributaries	none			Presence of one or more sources	25	5. List
6	Mapped point sources (per 10 acres) throughout watersheds including within 200' buffer to reservoir and tributaries	<0.1/10 acres	<0.5/10 acres	<1/10 acres	>1/10 acres	25	6. List
7	**Known Pollution Souce Risk**					50	7. Sum of 5 and 6.
8	**WATERSHED LAND USE AND LANDSCAPE FEATURES RISK RATING**					125	8. Sum of 4 and 7.
	Watershed and Reservoir Characteristics						
9	Trophic status (clarity, phosphorus, dissolved oxygen) (A measure of the amount of treatment needed)*	oligotrophic (O)	mesotrophic (M)	meso / eutrophic (M/E)	eutrophic (E)	25	9. List
10	Compliance with water quality standards, based on RIDEM 303 (d) List March 2003.*	Fully supporting (all standards)	Waterbody and/or tributary impaired (minor, not affecting supply)	Waterbody and/or tributary impaired (potential to affect supply)	Not fully supporting for drinking water.	25	10. list
11	**WATERSHED AND RESERVOIR CHARACTERISTICS RISK RATING**					50	11. Sum of 9 & 10.
	Outflow water quality						
12	History of contaminant detects (organics, HC, pesticides, metals, etc.) within 5 yrs.	trace	≤1/2 MCL	>1/2 MCL	violation	25	12. List
13	**OUTFLOW QUALITY RISK RATING**					25	13. Sum of 11 & 14.
14	**SUMMARY RATING for Reservoir Watersheds**					200	14. Sum of 8, 11 & 13.

RESULTS (Current land use)

#	Bailey Brook and North & South Easton Ponds: Input data	Rating	Maidford River: Input data	Rating	Nelson Pond: Input data	Rating	Gardiner Pond: Input data	Rating
1	68.0%	25	50.0%	25	27.0%	25	24.0%	10
2	34%	25	44%	25	25%	25	20%	25
3	31.6%	25	9.6%	10	16.3%	25	5.3%	10
4		75		60		75		45
5	10	25	0	0	1	25	0	0
6	0.2	5	0.020	0	0.060	0	0.000	0
7		30		0		25		0
8		105		60		100		45
9	E	25	M/E	10	M	5	M	5
10	Waterbody and/or tributary impaired (potential to affect supply)	10	Waterbody and/or tributary impaired (potential to affect supply)	10	Fully supporting (all standards)	0	Fully supporting (all standards)	0
11		35		20		5		5
12	≤1/2 MCL	5	≤1/2 MCL	5	≤1/2 MCL	5	trace	0
13		5		5		5		0
14		145		85		110		50
	High		Moderate		High		Moderate	

#	Lawton Valley Reservoir: Input data	Rating	St. Mary's Pond: Input data	Rating	Sisson Pond: Input data	Rating	Nonquit Pond: Input data	Rating	Watson Pond: Input data	Rating
1	33.0%	25	34.8%	25	29.3%	25	9.0%	0	16.0%	10
2	2%	5	9%	10	16%	25	2.0%	5	5.0%	10
3	33.6%	25	31.6%	25	34.1%	25	7.1%	10	4.3%	5
4		55		60		75		15		25
5	1	25	0	0	0	0	5	25	1	25
6	0.030	0	0.000	0	0.000	0	0.030	0	0.004	0
7		25		0		0		25		25
8		80		60		75		40		50
9	M	5	M	5	M	5	M	5	M	5
10	Fully supporting (all standards)	0	Fully supporting (all standards)	0	Fully supporting (all standards)	0	Fully supporting (all standards)	0	Fully supporting (all standards)	0
11		5		5		5		5		5
12	≤1/2 MCL	5	≤1/2 MCL	0	≤1/2 MCL	5	trace	0	≤1/2 MCL	5
13		5		5		5		0		5
14		95		70		85		45		60
	Moderate		Moderate		Moderate		Low		Moderate	

Low	Moderate	High
0 - 49	50 - 100	>100

Newport Supplier Average: 83 — Moderate

Notes:

N and S Easton ponds rated as eutrophic based on input from local advisory committee on occurrence of algal blooms

*Trophic state and compliance with water quality standards based on personal communication with Connie Carey, RIDEM Division of Water Resources.

APPENDIX C: Sampling Data Analysis and Rating - *Summarizes review of water supplier monitoring data for the past five years and assigns rating for risk of contamination; results provide input to the basic SWAP Susceptibility Ranking.*

NEWPORT WATER (Station 1 System):

Bailey Brook Watershed (North and South Ponds)

PWSID#	Contaminant	MCL	Units	Max	Rank	Rating
1592010	Nitrate As N	10	ppm	1.6	medium	5
1592010	Chromium	0.1	ppm	0.009	low	0
1592010	Gross Alpha	15	pCi/l	0	low	0
1592010	Gross Beta	50	pCi/l	3.65	low	0
1592010	Benzo[B]Fluoranthene	\	ppm	0.00023	*	*
1592010	Benzo[A]Pyrene	0.0002	ppm	0.00025	*	*
1592010	Di(2-Ethylhexyl)Phthalate	0.006	ppm	0.0021	*	*
1592010	Diethylphthalate	\	ppm	0.0002	*	*
1592010	Lindane	0.0002	ppm	0.00001	*	*
1592010	Methylene Chloride	0.005	ppm	0.0022	*	*
1592010	Pyrene			0.12	*	*

* Detects occurred only once in a five-year period and are excluded the well ranking.

Overall Rate of SWA		
Contaminants	medium	5

> No violations of the standards for regulated contaminants (excluding bacteria and nitrates) have been identified. However, there have been detections below levels considered acceptable by US EPA. This indicates the need for continued monitoring.

H.E. Watson Reservoir

PWSID#	Contaminant	MCL	Units	Max	Rank	Rating
1592010	Nitrate As N	10	ppm	1.2	medium	5
1592010	Gross Beta	50	pCi/l	2.4	Low	0
1592010	Chromium	0.1	ppm	0.007	*	*
1592010	Diethylphthalate	\	ppm	0.00035	*	*
1592010	Gross Alpha	15	pCi/l	0	*	*
1592010	Isophorone	\	ppm	0.00023	*	*

* Detects occurred only once in a five-year period and are excluded the well ranking.

Overall Rate of SWA		
Contaminants	medium	5

> No violations of the standards for regulated contaminants (excluding bacteria and nitrates) have been identified. However, there have been detections below levels considered acceptable by US EPA. This indicates the need for continued monitoring.

Lawton Valley Reservoir

PWSID#	CHEMICAL	MCL	Units	Max	Rank	Rating
1592010	Nitrate As N	10	ppm	2.3	medium	5
1592010	Gross Beta	50	pCi/l	3.42	low	0
1592010	Nitrite	1	ppm	0.02	low	0
1592010	Anthracene	/	ppm	0.0001	*	*
1592010	Benzo[B]Fluoranthene	/	ppm	0.0001	*	*
1592010	Benzo[G,H,I]Perylene	/	ppm	0.0003	*	*
1592010	Chloromethane	/	ppm	0.0019	*	*
1592010	Chromium	0.1	ppm	0.007	*	*
1592010	Diethylphthalate	/	ppm	0.00018	*	*
1592010	Gross Alpha	15	pCi/l	0	*	*
1592010	Indeno[1,2,3,C,D]Pyrene	/	ppm	0.0002	*	*
1592010	Methylene Chloride	/	ppm	0.0026	*	*
1592010	Phenanthrene	/	ppm	0.0001	*	*
1592010	Xylene (Total)	10	ppm	0.011	*	*

* Detects occurred only once in a five-year period and are excluded the well ranking.

Overall Rate of SWA		
Contaminants	medium	5

> No violations of the standards for regulated contaminants (excluding bacteria and nitrates) have been identified. However, there have been detections below levels considered acceptable by US EPA. This indicates the need for continued monitoring.

Nonquit Pond

PWSID#	Contaminant	MCL	Units	MAX	Rank	Rating
1592010	Gross Beta	50	pCi/l	3.69	low	0
1592010	Nitrate As N	10	ppm	0.6	low	0
1592010	Chromium	0.1	ppm	0.006	low	0
1592010	Diethylphthalate	/	ppm	0.0002	low	0
1592010	Di-N-Butylphthalate	/	ppm	0.002	low	0
1592010	Gross Alpha	15	pCi/l	0	low	0

* Detects occurred only once in a five-year period and are excluded the surface water ranking.

Overall Rate of SWA		
Contaminants	low	0

> There has been no detection of regulated contaminants (excluding bacteria and nitrates).

St. Mary's Watershed

PWSID#	CHEMICAL	MCL	Units	Result	Rank	Rating
1592010	Nitrate As N	10	ppm	1.3	medium	5
1592010	Chromium	0.1	ppm	0.008	low	0
1592010	Gross Beta	50	pCi/l	2.7	low	0
1592010	Chloroform	/	ppm	0.0001	*	*
1592010	Diethylphthalate	/	ppm	0.00032	*	*
1592010	Gross Alpha	15	pCi/l	0	*	*
1592010	Isophorone	/	ppm	0.00024	*	*
1592010	Methylene Chloride	0.005	ppm	0.0014	*	*

* Detects occurred only once in a five-year period and are excluded the surface water ranking.

Overall Rate of SWA		
Contaminants	medium	5

> No violations of the standards for regulated contaminants (excluding bacteria and nitrates) have been identified. However, there have been detections below levels considered acceptable by US EPA. This indicates the need for continued monitoring.

Gardiner Pond

PWSID#	CHEMICAL	MCL	Units	MAX	Rank	Rating
1592010	Nitrate As N	10	ppm	0.9	low	0
1592010	Chromium	0.1	ppm	0.009	low	0
1592010	Gross Alpha	15	pCi/l	0	low	0
1592010	Gross Beta	50	pCi/l	4.74	low	0
1592010	Cadmium	0.005	ppm	0.0017	*	*
1592010	Diethylphthalate	\	ppm	0.0002	*	*
1592010	Metolachlor	\	ppm	0.00009	*	*

* Detects occurred only once in a five-year period and are excluded the surface water ranking.

Overall Rate of SWA		
Contaminants	low	0

> There has been no detection of regulated contaminants (excluding bacteria and nitrates).

Paradise Pond

PWSID#	Contaminant	MCL	Units	Max	Rank	Rating
1592010	Nitrate As N	10	ppm	1.6	medium	5
1592010	Atrazine	0.003	ppm	0.00048	low	0
1592010	Gross Beta	50	pCi/l	3.15	low	0
1592010	Simazine	0.004	ppm	0.00041	low	0
1592010	Di-N-Butylphthalate	\	ppm	0.0025	*	*
1592010	Isophorone	\	ppm	0.00006	*	*
1592010	Diethylphthalate	\	ppm	0.00019	*	*
1592010	Gross Alpha	15	pCi/l	0.85	*	*

* Detects occurred only once in a five-year period and are excluded the surface water ranking.

Overall Rate of SWA		
Contaminants	medium	5

> No violations of the standards for regulated contaminants (excluding bacteria and nitrates) have been identified. However, there have been detections below levels considered acceptable by US EPA. This indicates the need for continued monitoring.

STONEBRIDGE: Stafford Pond

Stafford Pond

PWSID#	Contaminant	MCL	Units	Max	Rank	Rating
1615619	Gross Beta	50	pCi/l	3.4	low	0
1615619	Nitrate As N	10	ppm	0.5	low	0
1615619	Chromium	0.1	ppm	0.011	*	*

* Detects occurred only once in a five-year period and are excluded the surface water ranking.

Overall Rate of SWA		
Contaminants	low	0

> There has been no detection of regulated contaminants (excluding bacteria).

APPENDIX D: Public Participation in the Assessment Process- *Sample public notice of assessment developed for each study area; provides overview of assessment approach, volunteer roles in mapping and assessment, list of meetings and typical agendas.*

Public Participation in the Assessment Process

The RI Source Water Assessment Program was designed to actively involve local officials, water suppliers, and the general public in the assessment process. The attached sample workshop notice outlines this public participation effort. It provides an overview of the assessment approach, describes roles of mapping and assessment volunteers and lists training sessions and meetings, with summary agendas.

Complete documentation of the public participation process is provided at the URI Cooperative Extension web site. This includes a list of workshops held in each study area and complete guide to working with volunteers in source water assessments organized as a how-to manual for others interested in working with volunteers to update pollution source maps.

For more information go to: www.uri.edu/ce/wq/program/html/SWAP2.htm.

SAMPLE
Public notice and public participation process

Rhode Island Department of HEALTH

UNIVERSITY OF RHODE ISLAND

Evaluating pollution risks to Public drinking water supplies

North Kingstown • Exeter • Kent County

RI HEALTH and University of Rhode Island Cooperative Extension in partnership with municipalities and water suppliers

PROJECT DESCRIPTION

RI HEALTH and the University of Rhode Island Cooperative Extension are assessing pollution threats to all public drinking water supplies throughout the State. The focus is on public drinking water supply "source" areas – the wellhead protection area that recharges a well or the watershed that drains to a surface water reservoir. Under the *Source Water Assessment Program* (SWAP) all states are required to conduct these assessments. Rhode Island has adopted a unique approach that involves the active participation of local water suppliers, town officials, and interested citizens.

SCHEDULE

Assessments will be conducted for public water supplies in North Kingstown, Exeter, Jamestown, and Kent County in 2001, beginning in March. Public wells throughout Kent County and southern Rhode Island will also be assessed in 2001.

GOAL

To ensure that public water systems have the ability to provide safe drinking water, now and into the future, the assessments will identify and rank each drinking water source according to its likelihood of becoming contaminated. A more extensive assessment of major water supplies will:

- Identify pollution risks under current land use and predict future threats.
- Evaluate the effectiveness of management options.
- Identify practical steps town officials and residents can take to reduce pollution risks.

Groundwater

Whether pumped from a shallow backyard well or piped from a high-yield public supply, groundwater is a major source of drinking water for many Rhode Islanders.

For residents of North Kingstown and Exeter, groundwater is the *only* source of drinking water.

A recent URI survey found that protecting this vulnerable and precious resource is the number one land use concern of local officials in southern Rhode Island.

APPROACH

Our assessment method is based on the following:

- Most pollution comes from the way we use and develop land.
- Most land overlying a wellhead recharge area or within a reservoir watershed is privately owned, not protected by a water supplier.
- Rhode Island cities and towns have primary authority to manage land use and minimize associated impacts.
- Effective protection of local water supplies requires local action.

LOCAL ROLE

The assessment is carried out in partnership with water suppliers, town officials, and other local volunteers such as business interests, environmental organizations and interested citizens. Volunteers may choose one or both of the following "jobs". The focus is on the major drinking water supplies but inventory volunteers may choose to work in smaller supply areas.

➢ Inventory volunteers

Update and verify land use within the wellhead protection areas and reservoir watersheds through a windshield survey, using simple maps. All materials and training are provided. This updated information provides a more accurate picture of potential risks to water supplies as a basis for the assessment.

Study area: Volunteer may choose a particular wellhead or watershed area but focus is on the major water supplies.

Time Commitment: 7-10 hours total. This includes one, 2-hour training session, conducting the windshield inventory of assigned areas on your own time (alone or with partner), and one, 1-hour session to report results.

➢ Assessment volunteers

Work closely with URI and HEALTH staff to guide the assessment process.

- Review and provide input on draft products,
- Identify local water quality goals, protection priorities, and land use issues,
- Assist in selecting management options for analysis,
- Develop recommendations for future action.

Study area: In-depth analysis focuses on the major water supplies, with opportunity for review and comment on basic assessments carried out for the smaller supplies throughout each town.

Time Commitment: Three work sessions over a 4-5 month period, scheduled at the convenience of local volunteers.

ASSESSMENT METHOD

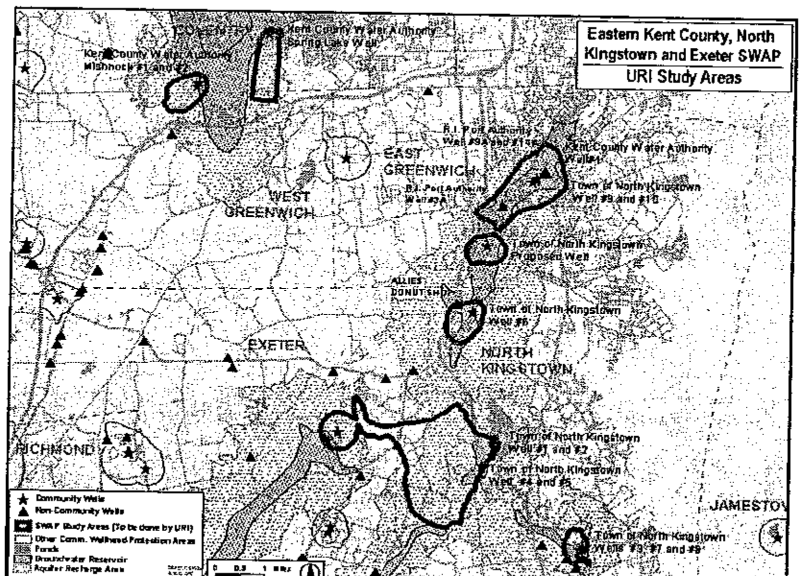
Our approach relies on computer-generated maps known as Geographic Information Systems (GIS) to identify, evaluate, and display pollution risks. This is a screening-level analysis using readily available sources of information, including wellhead protection inventories, watershed protection plans, and other local data. Using land use and soil information extracted from the GIS database, the method identifies and ranks pollution threats based on:

- Proportion of high intensity land uses where pollutants are most likely to be generated.
- Number of mapped pollution sources, both known and potential sources.
- Soil features and buffers where pollutants are most likely to reach a well or surface waters.

In addition, map analysis of each wellhead and watershed area is used to locate high-risk pollution sources on problem soils. The pollution potential in each wellhead /watershed is then ranked so town officials can compare risks among different areas and direct management actions.

Attention to Major Supplies

For the major community water supplies, URI Cooperative Extension will conduct a more in-depth analysis using the MANAGE risk assessment method. In addition to the assessment information developed for all smaller supplies, this will include:



- Multiple "watershed health indicators" such as percent impervious cover and percent forest,
- Modeled estimates of average annual runoff, groundwater recharge, and nutrient loading as an additional indicator of cumulative impact. We use a standard mass balance method similar to those widely used in comparable applications elsewhere including Cape Cod, Massachusetts and the New Jersey Pine Barrens,
- Future land use impacts envisioned through a "build-out" analysis,
- Comparison of the relative effectiveness of stormwater controls, wastewater management, and reduced fertilizer use in reducing nutrient sources.
- Work with the local volunteer group in developing water supply protection recommendations.

FINAL PRODUCTS

- Updated land use and pollution source mapping in source water areas.
- Pollution source "hot spot" mapping identifying high risk land uses where pollutants are most likely to move into groundwater or surface waters.
- Assessment of cumulative land use impacts using multiple risk factors.
- Future land use "build-out" analysis with population, building units, and septic systems estimates for each major water supply source area.
- Estimated water budget with runoff and nutrient loading (nitrogen and phosphorus) estimates for each major source water area, with relative comparison of current land use, future growth, and management options.
- Summary of assessment results and public presentation to town officials and general public.

BENEFITS

- Focus on source water protection to reduce or avoid treatment costs and improve taste/odor.
- Obtain monitoring waivers for low-susceptibility contaminants.
- Use map products in town planning and routine land development review.
- Incorporate results in water supply management plans, town plans, and wastewater management programs.
- Prioritize water supply protection needs and management actions.
- Direct education, monitoring, inspection, and enforcement to identified problem areas.
- Incorporate findings as technical basis for improved stormwater or wastewater pollution controls.
- Adopt protection measures with support from local officials and citizens involved in the assessment process.
- Receive priority for RIDEM nonpoint /groundwater grants to address identified threats.
- Follow-up assistance from RIDEM in pollution prevention at public facilities and businesses.

CONTACTS

Source Water Assessment Program	***Assessment of Major Supplies***	***To Volunteer***
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Project funded by RI HEALTH

Rhode Island Department of HEALTH

UNIVERSITY OF RHODE ISLAND

Evaluating pollution risks to public drinking water supplies

North Kingstown • Exeter • Jamestown • Kent County

Work Sessions with Assessment Volunteers

MEETING 1 **Land Use Issues and Assessment Goals**
April 11, 2001 4-6 PM North Kingstown Library, Wickford, RI

- Introduction to the Source Water Assessment Program.
- Risk assessment approach using MANAGE: overview of data sources, type of analyses, results generated, and final products.
- Role of advisory committee – input needed and expectations for next two sessions.
- Discussion of local water quality goals, water supply management priorities, and information sources for existing conditions.
- Review of land use maps and selection of study area boundaries; directions to update land use and ID pollution problems (where inventory help not available).

MEETING 2 **Pollution Risks - existing and future land use**
May 30, 2001 4-6 PM North Kingstown Library, Wickford, RI

- Review summary of existing conditions and management goals.
- Presentation of preliminary results:
  - Method and assumptions,
  - Land use updates and results of build-out analysis,
  - Watershed indicators for current and future land use,
  - Pollution source "hot spot" mapping,
  - Summary of analysis and discussion.
- Discuss Management practices:
  - Limitations in modeling,
  - Select best management practices to model.

MEETING 3 **Management alternatives and future direction**
June 27, 2001 4-6 PM North Kingstown Library, Wickford, RI

- Brief review of findings for current and future land use.
- Present results of nutrient loading change with management practices.
- Discuss management options and form recommendations.
- Determine next outreach steps: fact sheet format and distribution, presentation of results to public and decision makers, action steps for advisory committee.

Volunteers Conducting the Land Use Inventory

Training Workshop

April 2, 2001 7-9 PM Rocky Hill Grange, East Greenwich, RI

- Introduction to the Source Water Assessment Program.
- Basics about groundwater and wellhead protection areas, watersheds and the hydrologic cycle.
- Review Training Packets to learn how to:
  - Read and work with maps
  - Identify land use changes
  - Identify high risk activities
  - Conduct a "windshield survey"

Conduct Land Use Inventory over One-Month Period

In pairs or teams on own time

- Contact CE staff for assistance or answers to questions at any time.
- Follow-up calls are made by CE staff two weeks after the training workshop to status progress.

Meeting to Collect Land Use Inventory Results

April 30, 2001 6 –7 PM Rocky Hill Grange, East Greenwich, RI

- Briefly review land use inventory maps and data with CE staff.
- Clarify final questions or discrepancies.
- Complete a volunteer evaluation of land use inventory process.

CONTACTS

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Cooperative Extension provides equal program opportunities without regard to race, age, sex or preference, creed, or disability

Project funded by RI HEALTH

Characteristics of Rhode Island Soils

SOIL NAME	MAP SYMBOL	Hydrologic Soil Group	Restrictive Soils[1]	Flooding Duration & Depth	Water Table Depth(ft)	High Water Table Duration & Type[2]	Parent Material	Highly Erodible	Hydric/ Drain Class	Groundwater N Removal Potential[5]
Adrian	Aa	A/D**	-------	Long; Nov-May	0 - 1.0[4]	Nov-May, A	Organic	No	VP	High
Agawam	AfA, AfB	B[3]	-------	-------	> 6.0	-------	Outwash	No		
Birchwood	Bc	C	Restrictive	-------	1.5 - 3.5	Nov-April, P	Lodgement Till	No		
Bridgehampton	BhA, BhB, BmA, BmB	B[3]	-------	-------	> 6.0	-------	Outwash	No		
Bridgehampton	BmA, BmB	B	-------	-------	> 6.0	-------	Ablation Till	No		
Bridgehampton/Charlton	BnB*, BnC*, BoC*	B	-------	-------	> 6.1	-------	Ablation Till	No		
Broadbrook	BrA, BrB, BsB	C	Restrictive	-------	> 6.0	-------	Lodge. Till, EM	No		
Canton Charlton	CaC*, CaD*, CB*, CC*, CdA*, CdB*, CdC*, CeC*, ChB*, ChC*, ChD*, CkC*	B	-------	-------	> 6.0	-------	Ablation Till	Yes		
Carlisle	Co	A/D**	-------	Long; Nov-May	0 - 1.0[4]	Sep-Jun, A	Organic	No	VP	High
Deerfield	Dc	B[3]	-------	-------	1.0 - 3.0	Dec-Apr, A	Outwash	No		
Enfield	EfA, EfB	B[3]	-------	-------	> 6.0	-------	Outwash, E.M.	No		
Gloucester	GBC*, GBD*, GhC*, GhD*	(A/B)[3]	-------	-------	> 6.0	-------	Ablation Till	Yes		
Hinckley	HkA, HkC, HkD, HnC*	A[3]	-------	-------	> 6.0	-------	Outwash	Yes		
Ipswich	Ip	D	-------	Very brief; Jan-Dec	1 - 0.0[4]	Jan-Dec, A	Organic	No	VP	High
Lippitt	LgC	C[3]	BEDROCK	-------	> 6.0	-------	Ablation Till	No		
Mansfield	Ma, Mc	D	Restrictive	-------	0 - 0.5	Nov-Jul, A	Lodgement Till	No	VP	
Matunuck	Mk	D	-------	Very brief; Jan-Dec	1 - 0.0[4]	Jan-Dec, A	Organic	No	P, VP	High
Merrimac	MmA, MmB, MU	A[3]	-------	-------	> 6.0	-------	Outwash	No		
Narragansett	NaA, NaB, NbB, NbC, NcC	B	-------	-------	> 6.0	-------	Ablation Till	No		
Newport	NeA, NeB, NeC, NfB, NoC	C	Restrictive	-------	> 6.0	-------	Lodgement Till	Yes		
Newport (Urban Land)	NP	C	Restrictive	-------	>6.0	-------	-------	No		
Ninigret	Nt	B[3]	-------	-------	1.5 - 3.5	Nov-April, A	Outwash	No		
Paxton	PaA, PaB, PbB, PbC, PcC	C	Restrictive	-------	> 6.0	-------	Lodgement Till	No		

Paxton (Urban Land)	PD	C	Restrictive	-------	> 6.0	-------	-------	No		
Pittstown	PmA, PmB, PnB	C	Restrictive	-------	1.5 - 3.0	Nov-April, P	Lodgement Till	No		
Podunk	Pp	B	-------	Brief, Nov - May	1.5 - 3.0	Nov-May, A	Alluvial	No		
Poquonock	PsA, PsB	C	Restrictive	-------	> 6.0	-------	Lodge. Till, S.M	No		
Quonset	QoA, QoC	A[3]	-------	-------	> 6.0	-------	Outwash	No		
Rainbow	RaA, RaB, RbB	C	Restrictive	-------	1.5 - 3.5	Nov-April, P	Lodge. Till, EM	No		
Raypol	Rc	C[3]	-------	-------	0 - 1.0[4]	Nov-May, A	Outwash, E.M.	No	SP, P	High
Ridgebury	Re, Rf*	C	Restrictive	-------	0 - 1.5[4]	Nov-May, P	Lodgement Till	No	SP, P	
Rumney	Ru	C	-------	Brief, Oct - May	0.0 - 1.5	Nov-June, A	Alluvial	No	P	High
Scarboro	Sb	D[3]	-------	-------	0 - 1.0[4]	Nov-Jul, A	Outwash	No	VP	High
Scio	ScA, SdB	B	-------	-------	1.5 - 3.0	Nov-May, A	Ablation Till, E.M.	No		
Stissing	Se, Sf	C	Restrictive	-------	0 - 1.5[4]	Nov-May, P	Lodgement Till	No	SP, P	
Sudbury	Ss	B	-------	-------	1.0 - 3.0	Nov-April, A	Outwash	No		
Sutton	StA, StB, SuB, SvB	B	-------	-------	1.5 - 3.5	Nov-April, A	Ablation Till	No		
Tisbury	Tb	B[3]	-------	-------	1.5 - 3.5	Nov-April, A	Outwash	No		
Walpole	Wa	C	-------	-------	0 - 1.0[4]	Nov-April, A	Outwash	No	SP, P	High
Wapping	WbA, WbB, WcB, WdB	B	-------	-------	1.5 - 3.5	Nov-April, A	Ablation Till, E.M.	No		
Windsor	WgA, WgB	A[3]	-------	-------	> 6.0	-------	Outwash	No		
Woodbridge	WhA, WhB, WoB, WrB	C	Restrictive	-------	1.5 - 3.0	Nov-April, P	Lodgement Till	No		

[1] Restrictive soils have a permeability of <0.2 in/hr at a depth of about 20 to 60 inches.

[2] A=Apparent, P=Perched

[3] Excessive permeabilit in the subsoil may cause ground water pollution from septic system effluent, Permeability rates range from 6-20 in/hr or greater. From Soil Survey of RI Table 19; for septic tank absorption fields.

[4] Designated as Hydric Soils.

[5] Nitrogen removal potential based on URI research indicating high N removal in hydric soils with organic, alluvial, and outwash parent material (Rosenblatt 1999).

*See description of map unit from the Soil Survey of Rhode Island, 1981; for composition and behavior characteristics of the map unit.

** Designated as D for MANAGE

Source: *Soil Survey of Rhode Island, Dean R. Rector, Soil Conservation Service, 1981.*

Hydric Soil Drainage Classes
V-Poorly Drained
SP-Somewhat Poorly Drained
VP-Very Poorly Drained

Compiled by Adam Rosenblatt, URI
Amended by Jim Lucht 10/00

Soil Hydro-Group	Basic Description	Typical Depth to Seasonal High Water Table From ground surface	Water Quality Risks with Developed Land Use	Management implications
A	Sandy, deep water table, high infiltration, low runoff	Greater than 6 feet	• Highest pollutant movement to *groundwater* from septic systems and fertilizers, • Largest increase in runoff with impervious cover, • Greatest loss of groundwater recharge with impervious cover.	• Preserve as recharge areas. • Direct stormwater runoff to these areas to promote infiltration after pretreating to remove sediment and other pollutants. • Consider prohibiting deep wastewater seepage pits (galleys); evaluate need for advanced onsite treatment systems.
B	Most are well-drained, moderate runoff, moderate infiltration	Greater than 6 feet or 1½ to 3½ feet	• High potential for pollutant movement to *groundwater* from septic systems in sandy subsoils, • Moderate increase in runoff and loss of recharge with impervious cover. • May include prime farmland soils.	• Prime soils for building and agriculture. Consider best use to meet town goals and strategies to preserve prime farmland. • Consider prohibiting deep wastewater seepage pits (galleys); evaluate need for advanced onsite treatment systems.
C	Slowly permeable, collection areas for surface water, typically high water table, high runoff	1½ to 3½ feet or 0 to 1½ feet	• High pollutant movement to *surface waters* from septic systems, fertilizers, and land disturbance. • High potential for *hydraulic failure* of septic systems, with surfacing or lateral movement of effluent. • High potential for wet basements, temporary flooding.	• Septic systems may require use of filled leachfields to achieve minimum separation distance to groundwater; consider aesthetic impact of fill and need for advanced treatment. • Stormwater treatment ponds not suitable where water table is less than 2 feet from the ground surface. • Limit filling and regrading required to raise elevation of homes with full basements; consider prohibiting basements in wet soils. • Maintain undisturbed wetland buffers and drainageways. • Prohibit use of subdrains to lower water table; regulate location of subdrains adjacent to isds and their discharge, • Divert runoff from wells and septic systems.
D	Very high water table, often classified as wetlands based on wet (hydric) soils	0 to 11/2 feet	• Highest pollutant movement to surface waters • Loss of pollution treatment potential with disturbance of wetland buffers. • Wetland habitat encroachment.	• Avoid impacts to small streams, wetlands and wetland buffers with development. • Treat runoff before discharge to wetlands. • Identify wetland buffers for restoration. • Prohibit use of advanced wastewater treatment systems on less than 2 ft. water table for new construction.

APPENDIX H: RIGIS Coverages used in the MANAGE Assessment of Major Community Supplies

RIGIS coverages used in the MANAGE Assessment of Major Community Supplies
RI Source Water Assessment Program

Original analysis maps are generally produced at the watershed level. In order to create a more useful product, some basic inventory maps were redone at the town level. All maps have major and minor roads differentiated, with annotation on numbered routes- annotation from RIGIS Roads or USGS Topographic Overlay.

GIS Coverages

1. STUDY AREA BOUNDARY OUTLINE (Watershed, subwatershed, wellhead protection area, or aquifer recharge area)

Data Layers	*Description*	*Use*
Watershed boundaries	Surface water drainage basins and sub-basins in RI. For metadata go to: http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hdb90.html	Study Area boundary outline
Community Wellhead Protection Areas	Areas around public community wells considered critical for the protection of their source water supplies. For metadata go to: http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hwa97.html	
Non-Community Well Head Protection Areas	Areas around public non-community wells considered critical for the protection of their source water supplies. For metadata go to: http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hwb97.html	
Aquifer recharge areas	Critical portions of recharge areas for major RI groundwater aquifers suitable as sources for untreated drinking water. For metadata go to: http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hgg94.html	

2. Land Use

Data Layers	*Description*	*Use*
1995 RIGIS Land Use	1995 Land use / land cover updated using 1988 land use as a base. Coded to Anderson modified level 3 with one half acre minimum polygon resolution. For metadata go to: http://www.edc.uri.edu/rigis-spf/Metadata/Landuse/s44llu95.html	Note: Light colored forest to allow writing on map- also emphasizes developed areas. Local volunteers assist with land use updates for each study area

3. Soils

Data Layer	*Description*	*Use*
Soils	1996 USDA/NRCS SSURGO soils delineated with name, type	See below for uses.

	and feature attributes. Replaces 1990 RIGIS soils dataset. For metadata go to: http://www.edc.uri.edu/spfdata/rigisup2002/Soil/risoi96.met	

4. Sewers

Data Layer	*Description*	*Use*
Sewer Lines	Sewer mains and interceptors for public sewer systems - Generally shows only pipes with a diameter of 10 inches or greater. For metadata go to: http://www.edc.uri.edu/rigis-spf/Metadata/Utilities/s44usl96.html	Buffered to 750' to estimate service area

5. Community Water Supply Wells

Data Layer	*Description*	*Use*
Community Wells	Public wells serving at least 25 residents or 15 service connections year round. For metadata go to: http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hwc97.html	Existing water quality impacts
Non-Community Wells	Public wells serving at least 25 persons at least 60 days of the year. For metadata go to: http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hwn97.html	

6. Public Water Systems

Data Layer	*Description*	*Use*
Water Supply Lines	Water lines for public water systems. For metadata go to: http://www.edc.uri.edu/rigis-spf/Metadata/Utilities/s44uwl95.html	Existing water quality impacts

7. Political Boundaries

Data Layer	*Description*	*Use*
Municipalities	RI state and municipal boundaries with city and town attribute codes and annotation. For metadata go to: http://www.edc.uri.edu/rigis-spf/Metadata/Boundary/s44btp88.html	Basemap and reference
State of RI	RI state line boundary including coastline. For metadata go to: http://www.edc.uri.edu/rigis-spf/Metadata/Boundary/s44bri89.html	

8. Roads

Data Layer	*Description*	*Use*
Roads	All roads in RI including paved , unpaved and track/trail with name attributes and annotation. For metadata go to: http://www.edc.uri.edu/rigis-spf/Metadata/Transportation/s44trd98.html	Basemap and reference

9. Water Resources

Data Layers	*Description*	*Use*
Hydro lines	Centerlines for all fresh water rivers and streams including some seasonal streams in RI. For metadata go to: http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hhl98.html	Location of critical resource areas and existing water quality impacts.

Major Surface Water Bodies	Major freshwater rivers and lakes as polygon features with name annotation and RIDEM water quality attribute designation. For metadata go to: http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hhm99.html	
Reservoirs	Surface reservoirs used as sources for public drinking water supplies. For metadata go to: http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hpr94.html	
Narragansett Bay Water Classification	Water zone classifications in Narragansett Bay by the RI CRMC and RIDEM. For metadata go to: http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hbc94.html	
Shellfishing Closure Areas	Rhode island coastal waters & Narragansett Bay shellfish closure areas. For metadata go to: http://www.edc.uri.edu/rigis-spf/Metadata/Nature/s44nsc00.html	
Coastal Water Classification	Near shore water classifications by the RI Coastal Resources Management Council (CRMC) for the south coastal regions of Rhode Island and Block Island Sound. For metadata go to: http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hcc94.html	
Groundwater Classification	Groundwater quality classifications for major aquifers, public well head areas and other subsurface resources. For metadata go to: http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hgc93.html	

10. Open Space and Protected Areas

Data Layer	*Description*	*Use*
Audubon Lands	Protected open space lands owned and managed by the Audubon Society of Rhode Island. For metadata go to: http://www.edc.uri.edu/rigis-spf/Metadata/Openspace/s44oal95.html	Facilitates comparison of hot spots to resource areas. Shows potential for greenway linkages. Open space was updated with town data in each watershed.
State Conservation and Recreational Openspace 1990	State Conservation, Open Space, and Recreational Program lands as of 1990. For metadata go to: http://www.edc.uri.edu/spfdata/rigisup2002/OpenSpace/scorp90.htm	
Protected Public Lands	Protected open space lands managed by or acquisition supported through the Rhode Island Department of Environmental Management. For metadata go to: http://www.edc.uri.edu/spfdata/rigisup2002/OpenSpace/demopen.htm	
Private Land Trust Holdings	Land owned by The Nature Conservancy or Municipal Land Trusts. For metadata go to: http://www.edc.uri.edu/rigis-spf/Metadata/Openspace/s44onc98.html	
Protected Open Space	Protected open space land, the majority of which is not fully developed. Owned or maintained by Rhode Island cities, towns, and non-for-profit conservation groups. For metadata go to: http://www.edc.uri.edu/spfdata/rigisup2002/OpenSpace/protopen.htm	
Rare Species	Estimated habitat and range of rare species and noteworthy natural communities. For metadata go to: http://www.edc.uri.edu/rigis-spf/Metadata/Nature/s44nrs97.html	

11. Topography

Data Layer	*Description*	*Use*
USGS 7.5 Minute Topo	TIF image files of USGS 7.5 minute topoquads that	Used as base map for

Maps	encompass RI. Distributed on USGS Quad basis.	most maps in Wickford Harbor Assessment. Provides topography, annotation, and local landmarks.

12. Point Sources of Pollution

Data Layer	*Description*	*Use*
CERCLIS	Point locations of hazardous material sites designated by the U.S. EPA and RIDEM. For metadata go to: http://www.edc.uri.edu/rigis-spf/Metadata/Hazmat/s44xcc97.html	Determining exact locations of known pollution sources and the proximity to water resources. Additions and revisions made by town and state officials, and volunteers.
RIPDES	Rhode Island point discharge elimination system point locations for all sanitary waste sites where permits have been issued by RIDEM. For metadata go to: http://www.edc.uri.edu/rigis-spf/Metadata/Hazmat/s44xsp99.html	
LUSTs	Storage tanks and associated piping used for petroleum and certain hazardous substances that have experianced leaks as determined by RIDEM. For metadata go to: http://www.edc.uri.edu/rigis-spf/Metadata/Hazmat/s44xlt99.html	

13. Zoning

Data Layer	*Description*	*Use*
Town Level Zoning	Town blue-print for future development patterns	Buildout analysis

MANAGE – Modified coverages

Surface Water Hot Spots

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

Groundwater Hot Spots

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

Buildout Analysis

Data Layer	*Use*
MANAGE modified land use/zoning	Shows patterns of future development coded to the current land use legend for comparison.

STUDY AREA STATISTICS Aquideck Island

STANDARD - NO BMPS

Study Area	Scenario	Study Area Land Use Indicators: Acres	% Sewer	% High Intensity Land Use	% Im-pervious	% Forest	% Wetland	Riparian Indicators: % Forest & wetland	RIP % HILU	RIP%Im-pervious	RIP % Forest	RIP % Wetland	RIP % Forest and Wetland	Estimated Nutrient Loading: NO3N in GW Recharge mg/l	NO3N to GW recharge lbs/ac/yr	N SW runoff lbs/ac/yr	Total N to study area lbs/ac/yr	% N in SW runoff from Atm.	P to SW lbs/ac/yr
Aquidneck Whole	Current Land Use	6708	49%	52%	21%	4%	13%	18%	32%	15%	8%	34%	41%	18.6	20.6	11.8	32.4	4.5%	1.7
Bailey Brook	Current Land Use	2811	79%	68%	35%	0%	16%	16%	50%	28%	1%	30%	30%	24.0	13.6	10.4	24.0	0.9%	2.0
Gardiner Pond	Current Land Use	292	15%	24%	2%	9%	12%	21%	5%	1%	10%	46%	56%	85.5	16.0	11.7	27.8	22.5%	1.0
Lawton Valley Reservoir	Current Land Use	827	0%	33%	13%	7%	6%	13%	34%	11%	21%	24%	45%	16.0	25.1	11.0	36.1	7.5%	1.5
Maidford River	Current Land Use	1336	49%	51%	15%	1%	11%	12%	10%	9%	0%	32%	32%	14.9	29.2	14.0	43.2	0.1%	1.8
Nelson Pond	Current Land Use	604	11%	27%	7%	21%	14%	36%	16%	6%	21%	38%	59%	8.2	18.0	9.3	27.4	7.0%	1.1
St. Mary's Pond	Current Land Use	508	0%	45%	8%	7%	13%	20%	32%	1%	17%	49%	66%	54.7	30.7	14.9	45.6	12.0%	1.6
Sisson Pond	Current Land Use	330	3%	48%	5%	5%	22%	27%	34%	0%	7%	59%	66%	35.1	30.9	16.0	47.0	10.1%	1.5

Note: Runoff and nutrient loading estimates based on local RIGS land use and soils data, local research on nitrogen leaching, and assumptions from literature review.
Nutrient loading estimates represent potential sources entering runoff or groundwater recharge.
Nutrient removal in surface or groundwater is not quantified but depends on multiple factors such as extent and location of developed land, extent of wetlands and forest, soil types, and undeveloped shoreline buffers .

STUDY AREA STATIST

STANDARD - NO BMPS

Estimated Nitrate-N sources to grw **SOILS** hyrdrologic groups **SWAP**

Study Area	Scenario	Septic Systems	Lawn Fert.	Agri. Fert	Pet Waste	Other	% A	% B	% C	% D	%SHWT <1.5-3.5'	%SHWT 1.5'-3.5'	%Restr. C,.2"/hr	% Erode	HILU on A soil	HILU on HWT <3.5'
Aquidneck Whole	Current Land Use	21%	6%	67%	5%	1%	0%	1%	93%	6%	55.8%	40%	69%	22%	0%	28%
Bailey Brook	Current Land Use	23%	10%	56%	11%	1%	0%	0%	98%	2%	52.0%	40%	60%	14%	0%	34%
Gardiner Pond	Current Land Use	4%	2%	92%	0%	2%	0%	0%	58%	42%	59.4%	38%	58%	6%	0%	20%
Lawton Valley Reservoir	Current Land Use	36%	7%	54%	2%	1%	0%	1%	99%	0%	26.1%	15%	83%	54%	0%	2%
Maidford River	Current Land Use	16%	4%	76%	3%	1%	0%	0%	98%	2%	90.9%	69%	83%	8%	0%	44%
Nelson Pond	Current Land Use	26%	3%	66%	2%	3%	0%	8%	81%	11%	67.2%	44%	60%	19%	0%	25%
St. Mary's Pond	Current Land Use	25%	3%	70%	2%	0%	0%	0%	99%	1%	28.3%	18%	65%	51%	0%	9%
Sisson Pond	Current Land Use	13%	1%	85%	1%	0%	0%	0%	88%	12%	39.9%	18%	57%	39%	0%	16%

Note: Runoff and nutrient loading
Nutrient loading estimates represe
Nutrient removal in surface or grou

STUDY AREA STATIST

STANDARD - NO BMPS

Estimated Water Budget / Runoff / Recharge

Study Area	Scenario	# ISDS	ISDS /Acre	Precip Inches	ET Inches	Avail. Precip Inches	SW runoff Inches	Net recharge Precip. Inches	ISDS recharge Inches	SW runoff % avail.	GW recharge % avail	Precip Mgal/yr	ET Mgal/yr	Avail. Precip Mgal/yr	surface runoff Mgal/yr	Avg.net recharge precip. Mgal/yr	ISDS recharge Mgal/yr	If 100% forested surface runoff Mgal/yr	Lost recharge from 100% forested Mgal/yr
Aquidneck Whole	Current Land Use	1,950	0.29	42	21	21	16.6	4.4	0.5	79%	21%	7650	3825	3825	3,018	807	85	991	2,027
Bailey Brook	Current Land Use	570	0.20	42	21	21	18.8	2.2	0.3	90%	10%	3205	1603	1603	1,437	166	25	252	1,185
Gardiner Pond	Current Land Use	14	0.05	42	21	21	20.2	0.8	0.1	96%	4%	333	167	167	161	6	1	126	35
Lawton Valley Reservoir	Current Land Use	500	0.60	42	21	21	15.0	6.0	1.0	72%	28%	943	472	472	337	134	22	153	184
Maidford River	Current Land Use	400	0.30	42	21	21	12.8	8.2	0.5	61%	39%	1523	762	762	465	296	18	104	361
Nelson Pond	Current Land Use	190	0.31	42	21	21	11.8	9.2	0.5	56%	44%	688	344	344	193	151	8	98	96
St. Mary's Pond	Current Land Use	262	0.52	42	21	21	19.4	1.6	0.8	92%	8%	580	290	290	267	23	11	160	107
Sisson Pond	Current Land Use	85	0.26	42	21	21	17.5	3.5	0.4	83%	17%	376	188	188	157	31	4	97	59

Note: Runoff and nutrient loading
Nutrient loading estimates represe
Nutrient removal in surface or gro

STUDY AREA STATISTICS Aquideck Island

STANDARD - NO BMPS

Future		Acres	% Sewer	% High Intensity Land Use	% Im-pervious	% Forest	% Wetland	% Forest & wetland	RIP % HILU	RIP%Im-pervious	RIP % Forest	RIP % Wetland	RIP % Forest and Wetland	NO3N in GW Recharge mg/l	NO3N to GW recharge lbs/ac/yr	N SW runoff lbs/ac/yr	Total N to study area lbs/ac/yr	% N in SW runoff from Atm.	P to SW lbs/ac/yr
			Study Area Land Use Indicators						Riparian Indicators					Estimated Nutrient Loading					
			Study Area Land Use Indicators						Riparian Indicators					Estimated Nutrient Loading					
Aquidneck Whole	Future Land Use	6682	49%	40%	26%	4%	13%	17%	31%	16%	8%	35%	42%	13.9	14.2	8.7	22.9	6.2%	1.7
Bailey Brook	Future Land Use	2785	79%	62%	40%	0%	16%	16%	51%	29%	1%	31%	32%	26.2	8.8	8.8	17.5	1.1%	2.0
Gardiner Pond	Future Land Use	292	15%	14%	4%	9%	12%	21%	5%	1%	10%	46%	56%	29.2	10.7	8.5	19.2	31.1%	0.8
Lawton Valley Reservoir	Future Land Use	827	0%	25%	17%	7%	6%	13%	31%	13%	20%	24%	45%	14.4	22.1	8.8	31.0	9.3%	1.5
Maidford River	Future Land Use	1336	49%	26%	22%	1%	11%	12%	6%	10%	0%	32%	32%	8.7	17.3	7.9	25.2	0.1%	1.6
Nelson Pond	Future Land Use	604	11%	14%	12%	19%	14%	33%	15%	6%	21%	38%	59%	5.4	12.4	5.4	17.8	12.0%	1.0
St. Mary's Pond	Future Land Use	508	0%	35%	12%	6%	13%	19%	32%	1%	17%	49%	66%	46.5	26.3	12.3	38.6	14.6%	1.5
Sisson Pond	Future Land Use	330	3%	29%	11%	4%	22%	25%	34%	0%	7%	59%	66%	27.3	22.7	11.5	34.2	14.1%	1.4

STUDY AREA STATIST

STANDARD - NO BMPS

Estimated Nitrate-N sources to grw SOILS hydrologic groups SWAP
Estimated Nitrate-N sources to grw SOILS hydrologic groups SWAP

Future		Septic Systems	Lawn Fert.	Agri. Fert	Pet Waste	Other	*% A*	*% B*	*% C*	*% D*	%SHWT <1.5-3.5'	%SHWT 1.5'-3.5'	%Restr. C,.2"/hr	% Erode	HILU on A soil	HILU on HWT <3.5'
Aquidneck Whole	Future Land Use	40%	13%	39%	7%	1%	0%	1%	93%	6%	56.0%	41%	69%	22%	0%	20%
Bailey Brook	Future Land Use	40%	20%	21%	18%	1%	0%	0%	98%	2%	52.3%	40%	60%	14%	0%	30%
Gardiner Pond	Future Land Use	16%	6%	75%	1%	3%	0%	0%	58%	42%	59.4%	38%	58%	6%	0%	12%
Lawton Valley Reservoir	Future Land Use	50%	10%	36%	3%	1%	0%	1%	99%	0%	26.1%	15%	83%	54%	0%	2%
Maidford River	Future Land Use	40%	14%	39%	6%	1%	0%	0%	98%	2%	90.9%	69%	83%	8%	0%	23%
Nelson Pond	Future Land Use	56%	11%	25%	4%	3%	0%	8%	81%	11%	67.2%	44%	60%	19%	0%	13%
St. Mary's Pond	Future Land Use	36%	5%	56%	2%	0%	0%	0%	99%	1%	28.3%	18%	65%	51%	0%	8%
Sisson Pond	Future Land Use	30%	5%	62%	2%	0%	0%	0%	88%	12%	39.9%	18%	57%	39%	0%	11%

Estimated Water Budget / Runoff / Recharge

Estimated Water Budget / Runoff / Recharge

Future		# ISDS	ISDS /Acre	Precip Inches	ET Inches	Avail. Precip Inches	SW runoff Inches	Net recharge Precip. Inches	ISDS recharge Inches	SW runoff % avail.	GW recharge % avail	Precip Mgal/yr	ET Mgal/yr	Avail. Precip Mgal/yr	surface runoff Mgal/yr	Avg.net recharge precip. Mgal/yr	ISDS recharge Mgal/yr	If 100% forested surface runoff Mgal/yr	Lost recharge from 100% forested Mgal/yr
Aquidneck Whole	Future Land Use	2,484	0.37	42	21	21	17.1	3.9	0.6	81%	19%	7620	3810	3810	3,097	713	109	988	2,109
Bailey Brook	Future Land Use	645	0.23	42	21	21	19.9	1.1	0.4	95%	5%	3175	1588	1588	1,504	83	28	249	1,255
Gardiner Pond	Future Land Use	33	0.11	42	21	21	19.6	1.4	0.2	93%	7%	333	167	167	155	11	1	126	29
Lawton Valley Reservoir	Future Land Use	603	0.73	42	21	21	15.4	5.6	1.2	73%	27%	943	472	472	346	126	26	153	192
Maidford River	Future Land Use	610	0.46	42	21	21	12.9	8.1	0.7	62%	38%	1523	762	762	469	292	27	104	365
Nelson Pond	Future Land Use	277	0.46	42	21	21	11.7	9.3	0.7	56%	44%	688	344	344	191	153	12	98	94
St. Mary's Pond	Future Land Use	319	0.63	42	21	21	19.5	1.5	1.0	93%	7%	580	290	290	269	21	14	160	109
Sisson Pond	Future Land Use	151	0.46	42	21	21	18.1	2.9	0.7	86%	14%	376	188	188	162	26	7	97	64

STANDARD - NO BMPS Tiverton/Little Compton

			Study Area Land Use Indicators						Riparian Indicators					Estimated Nutrier	
Study Area	Scenario	Acres	% Sewer	% High Intensity Land Use	% Im-pervious	% Forest	% Wetland	% Forest & wetland	RIP % HILU	RIP%Im-pervious	RIP % Forest	RIP % Wetland	RIP % Forest and Wetland	NO3N in GW Recharge mg/l	NO3N to GW recharge lbs/ac/yr
Nonquit Pond	Current Land Use	4392	0%	9%	4%	37%	28%	66%	7%	2%	17%	62%	80%	2.3	7.0
Stafford Pond	Current Land Use	1296	0%	8%	6%	34%	8%	42%	18%	4%	42%	25%	67%	4.1	5.3
Watson Pond	Current Land Use	2290	0%	16%	3%	18%	26%	44%	4%	1%	30%	52%	82%	6.6	11.6

STANDARD - NO BMPS

			Study Area Land Use Indicators						Riparian Indicators					Estimated Nutrier	
Study Area	Scenario	Acres	% Sewer	% High Intensity Land Use	% Im-pervious	% Forest	% Wetland	% Forest & wetland	RIP % HILU	RIP%Im-pervious	RIP % Forest	RIP % Wetland	RIP % Forest and Wetland	NO3N in GW Recharge mg/l	NO3N to GW recharge lbs/ac/yr
Nonquit Pond	Future Land Use	4395	0%	6%	6%	15%	28%	43%	7%	3%	14%	61%	74%	2.0	6.0
Stafford Pond	Future Land Use	1297	0%	13%	12%	14%	8%	23%	18%	4%	25%	25%	50%	8.6	7.4
Watson Pond	Future Land Use	2290	0%	5%	5%	15%	26%	41%	4%	1%	29%	55%	84%	2.7	5.4

STANDARD - NO BN

ıt Loading — Estimated Nitrate-N sources to grw recharge — **SOILS** hyrdrologic groups

Study Area	**Scenario**	N SW runoff lbs/ac/yr	Total N to study area lbs/ac/yr	% N in SW runoff from Atm.	P to SW lbs/ac/yr	Septic Systems	Lawn Fert.	Agri. Fert	Pet Waste	Other	***% A***	***% B***	***% C***	***% D***	%SHWT <1.5-3.5'
Nonquit Pond	Current Land Use	4.6	11.6	8.4%	0.5	22%	5%	63%	1%	8%	5%	12%	67%	17%	42.0%
Stafford Pond	Current Land Use	5.2	10.5	58.0%	0.5	73%	9%	5%	4%	9%	0%	9%	87%	4%	17.9%
Watson Pond	Current Land Use	8.2	19.8	16.4%	0.8	8%	3%	85%	0%	3%	0%	1%	70%	29%	50.9%

STANDARD - NO BN

ıt Loading — Estimated Nitrate-N sources to grw recharge — **SOILS** hyrdrologic groups

Study Area	**Scenario**	N SW runoff lbs/ac/yr	Total N to study area lbs/ac/yr	% N in SW runoff from Atm.	P to SW lbs/ac/yr	Septic Systems	Lawn Fert.	Agri. Fert	Pet Waste	Other	***% A***	***% B***	***% C***	***% D***	%SHWT <1.5-3.5'
Nonquit Pond	Future Land Use	3.4	9.4	11.3%	0.6	44%	16%	33%	3%	5%	5%	12%	67%	17%	42.0%
Stafford Pond	Future Land Use	5.6	13.0	54.0%	0.8	80%	13%	0%	4%	3%	0%	9%	87%	4%	17.9%
Watson Pond	Future Land Use	4.7	10.1	28.9%	0.6	26%	14%	54%	2%	5%	0%	1%	70%	29%	50.9%

STANDARD - NO BM

SWAP **Estimated Water Budget / Runoff / Recharge**

Study Area	Scenario	%SHWT 1.5'-3.5'	%Restr.C, .2"/hr	% Erode	HILU on A soil	HILU on HWT <3.5'	# ISDS	ISDS /Acre	Precip Inches	ET Inches	Avail. Precip Inches	SW runoff Inches	Net recharge Precip. Inches	ISDS recharge Inches	SW runoff % avail.
Nonquit Pond	Current Land Use	11%	53%	45%	0%	2%	438	0.10	42	21	21	7.6	13.4	0.2	36%
Stafford Pond	Current Land Use	9%	46%	24%	0%	2%	320	0.25	42	21	21	15.7	5.3	0.4	75%
Watson Pond	Current Land Use	12%	56%	32%	0%	5%	189	0.08	42	21	21	13.4	7.6	0.1	64%

STANDARD - NO BM

SWAP **Estimated Water Budget / Runoff / Recharge**

Study Area	Scenario	%SHWT 1.5'-3.5'	%Restr.C, .2"/hr	% Erode	HILU on A soil	HILU on HWT <3.5'	# ISDS	ISDS /Acre	Precip Inches	ET Inches	Avail. Precip Inches	SW runoff Inches	Net recharge Precip. Inches	ISDS recharge Inches	SW runoff % avail.
Nonquit Pond	Future Land Use	11%	53%	45%	0%	2%	729	0.17	42	21	21	7.9	13.1	0.3	38%
Stafford Pond	Future Land Use	9%	47%	24%	0%	3%	490	0.38	42	21	21	17.8	3.2	0.6	85%
Watson Pond	Future Land Use	12%	56%	32%	0%	2%	282	0.12	42	21	21	12.3	8.7	0.1	59%

STANDARD - NO BM

Study Area	Scenario	GW recharge % avail	Precip Mgal/yr	ET Mgal/yr	Avail. Precip Mgal/yr	surface runoff Mgal/yr	Avg.net recharge precip. Mgal/yr	ISDS recharge Mgal/yr	If 100% forested surface runoff Mgal/yr	Lost recharge from 100% forested Mgal/yr
Nonquit Pond	Current Land Use	64%	5009	2505	2505	904	1,600	20	561	344
Stafford Pond	Current Land Use	25%	1477	739	739	552	186	15	617	(65)
Watson Pond	Current Land Use	36%	2612	1306	1306	831	475	6	604	228

STANDARD - NO BM

Study Area	Scenario	GW recharge % avail	Precip Mgal/yr	ET Mgal/yr	Avail. Precip Mgal/yr	surface runoff Mgal/yr	Avg.net recharge precip. Mgal/yr	ISDS recharge Mgal/yr	If 100% forested surface runoff Mgal/yr	Lost recharge from 100% forested Mgal/yr
Nonquit Pond	Future Land Use	62%	5012	2506	2506	946	1,560	33	561	385
Stafford Pond	Future Land Use	15%	1479	739	739	627	112	22	618	10
Watson Pond	Future Land Use	41%	2612	1306	1306	766	540	9	604	163

APPENDIX J

University of Rhode Island

University of Rhode Island NEMO

MANAGE GIS-Based Pollution Risk Assessment Method
Watershed / Aquifer Pollution Risk Indicators

List of Indicators and Rating Key

The following indicators are commonly used in the MANAGE watershed assessment, although not all may be used in each assessment, depending on the characteristics of the study area and type of analysis. Mapping the site-specific location of these features, including overlay mapping to identify potential pollution source "hotspots" is an important aspect of the assessment conducted separately identified characteristics is The mapping analysis, including "hot spot" mapping is conducted separately.

WATERSHED / AQUIFER INDICATOR	Relative Pollution Risk Rating			
	Low	Medium	High	Extreme
1. LAND USE [1] **Watershed-wide**				
High intensity land use	< 10 %	10 – 14 %	15 – 25%	> 25 %
Impervious surface area	< 10 %	10 – 14%	15 – 25%	> 25 %
Forest and Wetland	> 80 %	50 – 80%	20 – 49%	< 20%
Septic systems per acre [4]	< .10	.10 – .23	.24 – .49	.50 – 1.15
Percent sewered land use	Not rated [3]			
Riparian (shoreline)				
Riparian High intensity land use	< 5 %	5 – 9 %	10 – 15 %	> 15 %
Riparian Impervious surface area	< 5 %	5 – 9 %	10 – 15 %	> 15 %
Riparian Forest and Wetland	> 95 %	80 – 95 %	60 – 79 %	< 60 %
Disturbed Riparian Area (inverse of Riparian Forest and Wetland)	< 5 %	5 – 19 %	20 – 40 %	> 40 %
Existing or potential pollution sources				
Mapped pollution sources within study area, within 200' buffer to surface waters and tributaries, or within public well inner protected radius (200' bedrock; 400' gravel well).	Mapped and used in basic SWAP ranking			

2. NATURAL FEATURES [2]	Low	Med – High	Extreme
SOILS- Risk to groundwater			
Very sandy, rapidly permeable	< 10 %	10 – 60 %	> 60 %

SOILS - Risk to surface water and/or shallow groundwater				
Slowly permeable soils			Not rated [3]	
Presence of restrictive layers	< 2%		2 – 10 %	> 10 %
High water table	< 5 %		2 – 20 %	> 20 %
Erosion potential	< 5 %		2 – 20 %	> 20 %
Wetlands with high potential for nitrogen removal (organic sediments in outwash parent material).			Mapped	

3. COMBINED LAND USE/ NATURAL FEATURES	Mapped and also used in basic SWAP rating			
High intensity land use on highly permeable soils	< 5 %	≥ 5 – 15	≥ 15 – 30	≥ 30
High intensity land use on highly permeable soils	none	≥ 5	≥ 5 – 15	≥ 15
High intensity land use within shoreline zone.	NONE	≥ 5	≥ 5 – 15	≥ 15
Erodible soils in vacant, unprotected areas			Mapped	

4. HYDROLOGIC BUDGET and NUTRIENT LOADING ESTIMATES				
Phosphorus to surface runoff [4] (lbs / acre/ year)	< .46	.47 – .68	.69 – .93	> .93
Nitrogen loading to groundwater recharge (lbs / acre/ year) [4]	< 5.4	5.4 – 8	8.1 – 16	> 16
Nitrate-N concentration to groundwater recharge (mg/l) [4]	< 2	2 – 4.9	5 – 7.9	8 –10
Nitrogen to surface runoff (lbs / acre/ year)			Not rated [3]	
Surface water runoff (inches /year)			Not rated [3]	
Infiltration and recharge from rainfall and septic systems (inches /year)			Not rated [3]	

5. OTHER POLLUTION SOURCES and HYDROLOGIC MODIFICATIONS — Not rated, may be mapped. Field inspection needed

"Point sources" - discharges to surface or groundwater, salt storage, underground storage tanks, hazardous waste sites, contaminated sediments, composting sites.

Boat and marina discharges; fuel from 2-stroke engines, wastes from recreational vehicles.

Livestock, manure storage, kennels, large assemblages of birds

Well pumping, water withdrawal from or into a basin; dams

Closed stormwater systems; stream channelization; subsurface drainage of fields, subdivisions, and individual home sites.

6. RECEIVING WATER CHARACTERISTICS

	Existing Condition			
History of contaminant detects	Trace	< ½ MCL	> ½ MCL	Violation
Existing Condition - Groundwater				
Monitored concentration of nitrate (mg/l)	< .5	.5 – 2	> 2 – 5	> 5
Existing Condition – Surface waters				
Nutrient enrichment level (based on trophic state index, phosphorus concentration, clarity, frequency and severity of algal blooms; also dissolved oxygen and other factors.				
History of contaminant detects				
Visual and physical condition (odors, trash)				
Invasive vegetation, use of herbicides				
Compliance with water quality goal				
Eelgrass health extent and condition (coastal waters)				
Sensitivity to impact				
Flushing time, depth, shoreline configuration (D_L)				
Aquifer type- bedrock (low risk) vs. sand and gravel (high risk) (RIDOH, 1999); USGS vulnerability rating (USGS, 1999); potential for lateral flow				

Rating Pollution Risks

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

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

3 Not rated – Results are used to compare relative differences among study areas, between different land use / pollution control scenarios; or compared with forested reference conditions.

4. Rating developed based on percentile ranking (25^{th} = low, 50^{th} moderate, 75^{th} = high, 95^{th} = extreme) of all ranked results of analyses conducted for all major drinking water supplies.

Measuring Indicators

Unless otherwise noted, indicators are calculated as a percent of the study area, using either the full watershed /aquifer study area or just the shoreline area within this zone. The following ratios apply:

$$\text{Study area risks} = \frac{\text{Sum of indicator land use area (acres)}}{\text{Total study area (acres)}}$$

$$\text{Shoreline Risks} = \frac{\text{Sum of indicator land use within 200 ft. of surface waters (acres)}}{\text{Total area of the 200 ft. shoreline buffer (acres)}}$$

For example:

$$\text{High intensity land use} = \frac{\text{Sum of all high intensity land use in the study area (acres)}}{\text{Total study area (acres)}}$$

Understanding Watershed / Aquifer Pollution Risk Indicators

Using multiple indicators to evaluate pollution risk

The MANAGE pollution risk assessment method uses selected characteristics of a watershed or groundwater recharge area to evaluate the degree to which water resources in each study area are susceptible to pollution. Watershed land use and natural features used as "indicators" of watershed health were chosen based on their documented relationship to water quality conditions. Practical considerations factored into the selection, such as availability of data using high-resolution GIS coverages and ease in deriving summary statistics about the indicator from the RIGIS database. The indicators used are best suited to identifying pollution risks in rural and suburban communities characterized by a mix of forest and agriculture, limited village and urban development that may be sewered, and unsewered residential development where groundwater is the primary pathway for water flow and pollutant movement. Given this focus on suburbanizing landscapes the indicators used are well suited to Rhode Island drinking water supply watersheds and aquifers, most of which are subject to intense development pressure. Because of similar soils and land use characteristics the indicators used are generally suitable for the southern New England area provided corresponding GIS coverages are available. The assessment approach is less useful in highly urban areas where surface water flow is controlled more by engineered stormwater drainage systems than soils. In these urban areas more site-specific information on the particular type of high risk uses, stormwater discharge locations and treatment systems, good housekeeping practices at industries and businesses, and age and maintenance of sewer lines all become important variables that are not directly addressed in this screening level assessment.

Although many watershed assessment methods rely heavily on one or two indicators – most commonly percent impervious cover and nutrient loading, the MANAGE approach incorporates a number of watershed characteristics focusing on both land use and natural features. The additional factors used, such as forest cover and riparian buffer continuity, are widely used measures of potential water quality impacts at the watershed scale, and have long been used in evaluating water quality function of both individual wetlands and collective wetland resources within a drainage area (Center for Watershed Protection 2002; Ammann, A. and A. Stone, 1991). As with any watershed assessment method, the effort required to calculate additional indicators must be weighed against the value of the information generated. Where high quality GIS databases for soils and land use are available, such as the RIGIS system, a wide range of indicators may also be readily available for direct use with minimal database development.

Clearly one of the primary advantages of using a variety of different watershed indicators is that the range of data generated can shed light on the type of pollutant or stress most likely to influence water quality. This is especially useful where the link between one watershed characteristic and associated water quality condition is weak. For example, more recent research on the effect of watershed impervious suggests that in relatively undeveloped watersheds with average impervious cover less than 10%, other factors such as forest cover, contiguous shoreline buffers, soils, agriculture, historical land use and a "host of other stressors" can greatly influence water quality in sensitive areas. Consequently watershed managers "should evaluate a range of supplemental watershed variables to measure or predict actual stream quality within these lightly developed watersheds" (Center for Watershed Protection, 2002). Because drinking water supply watersheds often fall under the 10% impervious level, multiple indicators are especially valuable in evaluating these sensitive watersheds.

Using a range of indicators avoids over-reliance on one or two factors, especially where input values and results may be uncertain. Minor map errors and inaccuracies are common to all map databases, but in general the simplest watershed indicators obtained directly from high quality maps – such as percent high intensity land use and percent forest– are the most reliable. Some indicators, such as percent impervious cover, the estimated number of septic systems within a study area, and all future projections, are created by overlaying map coverages in combination with population and housing data, and use of simplifying assumptions. Any of these operations can amplify map errors and introduce uncertainty associated with input values and assumptions. These uncertainties are inherent in any type of modeling and as long as assumptions remain consistent among study areas, the comparative value of the results is unaffected. Using a range of indicators, including reliable land use factors, can help reduce reliance on any one factor while providing a range of supporting data.

When a variety of watershed features are available, key indicators can be selected to focus on pollutants of concern to particular receiving waters. For example, primary factors for evaluating impacts to groundwater aquifers include: nitrogen loading to groundwater– where nitrogen is a both drinking water contaminant and indicator of other dissolved pollutants; and percent high intensity land use in general, and especially commercial and industrial land use where hazardous materials may be used. In contrast, key indicators for fresh surface waters would include impervious cover, percent watershed forest, estimated phosphorus inputs and land use within shoreline buffers.

A brief look at the indicators used clearly show that many of the factors measure similar features. For example, high intensity land use, impervious cover, runoff and nutrient loading all tend to increase as development increases. Results are best used to compare general trends and to focus on few primary pollutants or stressors of concern for particular receiving waters rather than trying to "add up" total risks from a large number of different factors. Where indicators appear to be very similar, basic differences factor into interpreting results and selecting management practices. For example, high intensity land uses encompass both urban land and tilled agriculture while impervious cover measures only urban roads, rooftops and parking. As a result, riparian buffers having both high intensity land use and high impervious cover are likely to be more urbanized and difficult to restore; those with high intensity land use and low impervious are likely to be in agricultural use or in backyards of moderate to large lot house lots where reclaiming natural buffers may be more feasible. For sensitive cold water trout streams, any areas where naturally vegetated shoreline buffers have been lost would provide useful information on extent of impact and potential restoration sites.

Interpreting Results

Assessment results are best used to compare relative differences in risk among study areas or between different land use scenarios. When comparing results for a number of subwatersheds or recharge areas it is useful, but not always possible, to select study areas representing a range of different land use types and densities. Undeveloped study areas with unfragmented forest and naturally vegetated shorelines are particularly valuable as "reference" sites representing natural background conditions. Even lightly developed study areas with good water quality, though not pristine, provide a useful benchmark of low-risk conditions. At the other end of the spectrum, densely developed or disturbed study areas, whose water quality is highly susceptible to impact, represent "high risk" circumstances. In each case reference watersheds provide more realistic benchmarks when monitored water quality data corresponds to estimated risk levels based on mapped features or modeled nutrient loading estimates.

Watershed indicators are useful in evaluating sensitivity of a watershed or aquifer recharge area to changing land use and to different pollution control practices. Typical analyses include the following:

- Comparing differences between current and future land use, where a future "build-out" map is used to calculate indicators representing future land use;

- Evaluating the range of results possible using low and high input values for factors that are difficult to estimate precisely, such as impervious cover or nutrient loading; and
Comparing the relative change in risk among alternative management scenarios. Typical pollution control strategies that can be modeled include: reduced fertilizer application, use of nitrogen-reducing septic systems, and use of stormwater treatment systems designed to remove nitrogen or phosphorus. Alternative land development options and pollution control practices can be modeled for the entire study area, for particular land use types, or for any combination of land use by soil type or location in shoreline buffers.

Ranking Pollution Risks

To make the assessment more useful for management decisions, indicator results are generally ranked along a scale from low to high or extreme risk. These thresholds are general guidelines designed to serve as a frame of reference in interpreting results. They should be considered points along a continuum, not rigid categories with distinct boundaries. These threshold levels are set based on the following factors, as described below.

- Ranking based on literature values. Each indicator is a standard, widely accepted measure of watershed health. In some cases extensive research results are available to document a solid relationship between the presence or extent of watershed features and associated water quality condition. The relationship between percent impervious cover and stream habitat is probably the most well documented, where average watershed impervious levels above 10% are associated with declining stream quality. For other indicators, supporting data linking the extent of the water features to water quality conditions is more limited. Where minimal literature data is available to rank pollution potential, best professional judgment was used to select risk thresholds based on known water quality conditions compared to watershed risk indicators.

- Relative comparison of results using a selected range of study areas. To establish a representative range of values for watershed indicators, assessments were first conducted for a small number of study areas representing extremes in soil types and development levels. Study areas included pristine forests to highly urban watersheds with known water quality impairment. For example, indicator results for pristine areas were set as low risk, while results for the most highly developed watersheds with known water quality impairment were ranked as having an extreme risk of contamination., with a moderate risk ranking assigned to study areas with intermediate indicator levels. Where research data was available to support selection of risk rankings, we used the literature values but adjusted them where necessary to correspond to known low or high risk situations based on actual water quality.

- Percentile ranking of assessment results. When a large, representative database is available, risk thresholds may be set using statistical breakpoints to rank assessment results. Assessment results for 74 major community water supplies and other Rhode Island watersheds and aquifers were compiled using current land use conditions. We ranked results various mapped indicators, including: percentage of forest and wetland in shoreline areas, number of septic systems per acre, nitrogen loading to groundwater, and phosphorus loading to surface runoff. Each indicator was examined individually using results from all 74 study areas. Results were ranked and percentiles (25^{th}, 50^{th}, 75^{th} and 95^{th}) were calculated for each indicator, and a corresponding rank of low, moderate, high and extreme risk was assigned respectively. This method provided an objective ranking based purely on comparative results where literature values on risk thresholds were very weak or unavailable. For example, the risk levels for the number of septic systems per acre and phosphorus loading to surface waters were established this way. Although this method generates an objective ranking, it does not necessarily provide a better relationship to actual water quality unless indicator levels are also correlated with monitored data. Although the assessment areas covered a wide range of rural and urban watersheds, most of the study areas are not highly developed, resulting in more conservative ranking than if the range of rural, suburban and urban watershed were equally distributed.

Setting risk levels

In setting pollution risk levels for the various watershed indicators, risk thresholds are generally set low as an early warning for potentially hazardous conditions before adverse impacts occur. For example, in drinking water supply watersheds the presence of any high intensity land use within 200 feet of surface waters automatically rates a moderate risk to water quality. This is based on the assumption that *any* high-risk land use within this critical buffer zone is a potential threat and should be investigated. This approach is designed to provide early warning of potential threats to high quality waters, including drinking water supplies that may be untreated, coastal waters that are sensitive to low level increases in nitrogen, and unique natural habitats that may also be sensitive to minute increases in sediment, temperature or phosphorus. Identifying risks in early stages also provides time to take pollution prevention actions as the most cost effective approach to protecting local water quality rather than relying on clean up actions after degradation occurs. In general, restoring a polluted water body is much more costly and technically challenging than pollution prevention.

Indicators have also been selected to focus on situations of highest pollution risk and may not detect circumstances where a variety of factors combine to magnify pollution potential. For example, we do not include medium density residential development (1 to 3.9 dwellings per acre) as a high-intensity land use. But development at this density could easily affect water quality depending on site specific features such as soil suitability, proximity to surface waters, level of septic system maintenance, and landscape care practices. Likewise, we assume a high level of protection to wetlands, which may underestimate risks where wetlands are disturbed through DEM approval, by zoning variance, or unpermitted encroachment. For example, only buffers to surface waters and tributaries are evaluated when considering shoreline pollution risks. Wetland buffers are not considered because wetlands themselves provide an extra measure of protection, potentially capturing or transforming pollutants before they reach downstream surface waters. Wetland buffers are often less suitable for development due to high water table and usually don't attract waterfront development pressure. Given these conservative assumptions, any development in wetland buffer zones would obviously result in greater pollution risk beyond our estimates.

When interpreting indicator results we have tried to emphasize major differences while minimizing minor variations that are not likely to represent real differences. Recognizing major differences is equally important where a rating system is used since rating and ranking systems can easily mask or oversimplify results. For instance, when indicator risk levels are near the edge of one risk category, a change in only a few points can shift the rating to the next risk level while greater increases may occur within a category. We have chosen not to evaluate results using statistical measures, partly because doing so may suggest results are actual data points rather than estimates of potential risk. Instead we have relied on professional judgment in making interpretations and hope results stimulate discussion of what is an acceptable level of risk and management actions.

Limitations of GIS-based screening level analysis

The quality of any screening level assessment relying on map databases is only as good as the resolution and accuracy of the coverages available. No amount of sophisticated overlays or data analysis will compensate for map data generated at too small a scale to distinguish between significantly different features. Even up-to-date GIS coverages are primarily screening level, suitable for planning purposes but not site-specific analysis. It is important to keep data limitations in mind when combining planning scale data – for example parcel ownership boundaries can easily be laid over soils types but results are best used to evaluate the area as a whole rather than examining soil features individually on lots, especially when working with lots as small as 5,000 sq. ft. in area. There is also a point when information needed simply may not be obtainable by maps. For example, unless locations where livestock are pastured and fed are mapped and frequently updated, even one or two large animals such as horses and cows could be a pollution risk if they are allowed access to surface waters or wastes are improperly stored. Although fields and pastures adjacent to surface waters or overlying high water table soils can be mapped, local knowledge and field inspection is needed to identify these areas.

APPENDIX K

Newport Water and Stone Bridge Source Water Assessment Hydrologic and Nutrient Loading Assumptions

HYDROLOGIC BUDGET:

Average Annual Precipitation	*42.0*	inches
Average Annual Evapotranspiration	*21.0*	inches

Surface Runoff Nutrient Loading Factors

Surface Runoff Coefficients			**Phosphorus** lb P/acre/year		**Nitrogen** lb N/acre/year		
LAND USE	Low	High	Low	High	Low	High	
[1] HD Res.(>8 /ac)	*0.64*	*0.77*	*3.4*	*4.1*	*11.1*	*13.4*	
[2] MHD Res.(4-7.9/ac)	*0.39*	*0.64*	*2.1*	*3.4*	*6.8*	*11.1*	
[3] MD Res.(1-3.9/ac)	*0.23*	*0.39*	*1.2*	*2.1*	*4.0*	*6.8*	
[4] MLD Res.(0.5-0.9/a	*0.16*	*0.23*	*0.8*	*1.2*	*2.8*	*4.0*	
[5] LD Res.(<0.5/ac)	*0.10*	*0.16*	*0.5*	*0.8*	*1.7*	*2.8*	
[6] Commercial	*0.50*	*0.85*	*1.0*	*2.5*	*2.0*	*20.0*	
[7] Industrial	*0.50*	*0.85*	*1.0*	*3.5*	*2.0*	*15.0*	
[8] Roads	*0.70*	*0.82*	*1.0*	*3.5*	*2.0*	*20.0*	
[9] Airports	*0.70*	*0.82*	*1.0*	*3.5*	*2.0*	*20.0*	
[10] Railroads	*0.70*	*0.82*	*1.0*	*3.5*	*2.0*	*20.0*	
[11] Junkyards	*0.70*	*0.82*	*1.0*	*3.5*	*2.0*	*20.0*	
[12] Recreation	*0.10*	*0.30*	*0.5*	*1.5*	*1.5*	*4.0*	
[13] Institution	*0.39*	*0.64*	*2.1*	*3.4*	*6.8*	*11.1*	
[14] Pasture	*0.05*	*0.25*	*0.3*	*1.0*	*2.0*	*5.5*	
[15] Cropland	*0.15*	*0.50*	*0.5*	*4.5*	*4.0*	*50.0*	
[16] Orchards	*0.05*	*0.25*	*0.4*	*2.0*	*4.0*	*35.0*	
[17] Brush	-	*0.10*	*0.1*	*0.2*	*0.9*	*2.9*	
[18] Forest	-	*0.10*	*0.1*	*0.2*	*0.9*	*2.9*	
[19] Barren	*0.05*	*0.80*	*0.1*	*0.2*	*0.9*	*2.9*	
[20] Wetland	-	*0.10*	*0.0*	*0.0*	*0.0*	*0.0*	Water N =
[21] Water	*1.00*	*1.00*	*0.3*	*0.3*	*8.0*	*8.0*	atmospheric deposition

Calculating the most likely runoff and nutrient loading coefficients

C = LC + (HC - LC)*X
C= most likely export coefficient
LC = low export coefficient for a land use
HC = high export coefficient for a land use
X = 0 for soil type A;
1/3 for soil type B;
2/3 for soil type C;
1 for soil type D.
Calculation of UC and LC for residential uses is based on Schueler's (1987) Simple Method:
C=0.05+0.9I where I = percent impervious.

Percent impervious from USDA TR55 (1975)

Land Use	% Impervious
RESIDENTIAL	
1/8 acre	65
1/4 acre	38
1/3 acre	30
1/2 acre	25
1 acre	20
2 acre	12
COMMERCIAL	85
INDUSTRIAL	72

Note: *Some of the loading factors are calculated using precipitation and surface runoff coefficients.*

GROUNDWATER NUTRIENT LOADING ASSUMPTIONS:

Septic Systems:

Factors determining septic tank effluent characteristics

	2.4	people/dwelling unit	*Derived from town and/or U.S.census data*
	50	gallons H2O /person/day	
	2.3	lb P/person/year	
	7.0	lb N/person/year	
Concentration of P	15.1	mg/l	
Concentration of N	46.0	mg/l	

90% of the N in the septic effluent leaches to the groundwater

Estimated Septic System Density in Unsewered Areas

LAND USE	Number of Dwelling Units/Acre	= *number of septic systems/acre*
[1] HD Res.(>8 /ac)	***8.00***	*Low end in each residential category is closest to actual*
[2] MHD Res.(4-7.9/ac)	***3.60***	*count based on comparison with census and/or parcel data*
[3] MD Res.(1-3.9/ac)	***1.00***	*in many study areas. Where a more accurate count is*
[4] MLD Res.(0.5-0.9/ac)	***0.50***	*available the final number of septic systems is adjusted in*
[5] LD Res.(<0.5/ac)	***0.20***	*the main spreadsheet.*
[6] Commercial**	***1.00***	
[7] Industrial**	***1.00***	*** Commercial, Industrial, Institution, and Recreation are*
[12] Recreation **	***0.50***	*assumed to contribute at the same level as MD Res. except*
[13] Institution**	***1.00***	*Recreation is assumed to be in use for 6 months each year.*

Fertilizers:

Lawn Fertilizers

Estimated Lawn Area by Land Use

LAND USE	Fraction of area which is lawn
[1] HD Res.(>8 /ac)	***0.25***
[2] MHD Res.(4-7.9/ac)	***0.35***
[3] MD Res.(1-3.9/ac)	***0.50***
[4] MLD Res.(0.5-0.9/a	***0.35***
[5] LD Res.(<0.5/ac)	***0.25***
[6] Commercial	***0.05***
[7] Industrial	***0.10***
[12] Recreation	***0.70***
[13] Institution	***0.25***

75% of residents and businesses apply fertilizer
at a rate of ***175*** lb N/ac/yr
or 4.0 lb N/1000 sq. ft./yr
6% of the N applied leaches
to the groundwater

Agricultural Fertilizers

Agricultural fertilizer applied at a rate of ***215*** lb N/ac/yr
or 4.9 lb N/1000 sq. ft./yr.

30% of the nitrogen applied leaches to the groundwater.

Other:

Pets in Residential Areas

0.41 lb N/person/yr leaches to the groundwater from pet waste.

Unfertilized Pervious Areas

1.2 lb/acre/yr leaches to the groundwater from unfertilized
lawns, pastures, forests, and brush areas (background level).

BEST MANAGEMENT PRACTICES (BMP'S)

1. Agricultural Management

Reduces surface runoff volume and nutrient loading to both
surface and ground water by ***20%***

2. Lawn Management

Assume that ***35%*** of residents who are currently applying fertilizer will adopt improved lawn care recommendations with education. Improvements will include a reduction in the amount of fertilizer applied t ***87.5*** lb N/acre/year
which is equivalent to 2.0 lb N/1000 sq. ft./year
and a reduction in the amount of nitrogen leached to groundwater to ***3%***

3. Stormwater Management

Nutrient loads to surface waters will be reduced by:

45% WITH a maintenance program, and
10% WITHOUT a maintenance program.

4. Reducing Imperviousness Through Creative Design

Imperviousness is reduced by ***20%***
reducing runoff coefficients and nutrient loads accordingly. Otherwise impervious areas are converted to unfertilized pervious areas (e.g., forest, brush or unfertilized lawn).

5. Septic System Alternatives

Denitrification or Advanced Treatment Systems

The fraction of N leached to groundwater
from advanced treatment systems is rec ***50%***

Improved Septic System Maintenance

Nitrogen and phosphorus delivery to surface waters from malfunctioning systems, primarily from hydraulic failure, is eliminated.

Sewering

Nitrogen and phosphorus delivery to surface water from malfunctioning septic systems is eliminated, and nitrogen delivery to groundwater from all septic systems is eliminated. NOTE: Leakage from sewer lines does occur, and will contribute pollutants to groundwater. These estimates do not account for this leakage. Other factors, such as water diversion outside the watershed, are not considered here, but are important when looking at the overall effects of sewering.

NOTE: The nutrient loading estimates do not consider: Animals other than dogs and cats, wildlife, polluted runoff that may infiltrate groundwater with concentrations higher than natural forested conditions, direct discharges, landfills, and other mapped sources. Consult maps to locate these sites.