

## 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.

In 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 ( $> \frac{1}{2}$  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 Worksheet

Susceptibility Ranking for Surface Water Reservoirs WORKSHEET														
ROW	RISK INDICATOR	RATING				Rating Method	RESULTS		RESULTS		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.														
		LOW	MEDIUM	HIGH	EXTREME	Max. Rating		<b>RESERVOIR #1</b>		<b>RESERVOIR #3</b>		<b>HARRIS POND</b>		
		0	5	10	25			<b>Current land use</b>		<b>Current land use</b>		<b>Current land use</b>		
								Input data	Rating	Input data	Rating	Input data	Rating	
<b>Watershed Land use and landscape features</b>														
1	High intensity land use (%) throughout the watershed.	<10%	>10-15%	>15-25%	>25%	25	1. list	20.0%	10	5%	0	10%	5	
2	High intensity land use (%) located on highly impermeable soils throughout the watershed.	none	<5%	>5-15%	>15%	25	2. list	3%	5	2%	5		0	
3	High intensity land use (percent) located within 200' buffer of reservoir and tributaries.	none	<5%	>5-15%	>15%	25	3. List	15.0%	10	6.0%	10	7.0%	10	
4	<b>Watershed Land Use Risk</b>					75	4. sum of 1, 2, & 3.		25		15		15	
5	Mapped point sources within 200' buffer to reservoir and tributaries	none			Presence of one or more sources	25	5. List	8	25	0	0	5	25	
6	Mapped point sources (per 10 acres) throughout watersheds including within 200' buffer to reservoir and tributaries (psoc/acres*10)	<0.1/10 acres	<0.5/10 acres	<1/10 acres	>1/10 acres	25	6. List	0.07	0	0.000	0	0.010	0	
7	<b>Known Pollution Source Risk</b>					50	7. Sum of 5 and 6.		25		0		25	
8	<b>WATERSHED LAND USE AND LANDSCAPE FEATURES RISK RATING</b>					125	<b>8. Sum of 4 and 7</b>		50		15		40	
<b>Watershed and Reservoir Characteristics</b>														
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	M/E	10	M	5	M	5	
10	Compliance with water quality standards. Based on 303 (d) List March 2003.	Fully supporting (all standards)	Waterbody or tributary impaired (minor, not affecting supply)	Waterbody or tributary impaired (potential to affect supply)	Not fully supporting for drinking water.	25	10. list	Waterbody or tributary impaired (minor, not affecting supply)	5	Waterbody or tributary impaired (minor, not affecting supply)	5	Waterbody or tributary impaired (minor, not affecting supply)	5	
11	<b>WATERSHED AND RESERVOIR CHARACTERISTICS RISK RATING</b>					50	<b>11. Sum of 9 &amp; 10.</b>		15		10		10	
<b>Outflow water quality</b>														
12	History of contaminant defects (organics, HC, pesticides, metals, etc.) within 5 yrs.	trace	<1/2 MCL	>1/2 MCL	violation	25	12. List	>1/2 MCL	10	>1/2 MCL	10	trace	0	
13	<b>OUTFLOW QUALITY RISK RATING</b>					25	<b>13. Sum of 11 &amp; 12.</b>		10		10		0	
14	<b>SUMMARY RATING for Reservoir Watersheds</b>					200	<b>14. Sum of 8, 11 &amp; 13.</b>		75		35		50	
								Moderate		Low		Low		<b>Average Rating</b>
														<b>53</b>
														<b>Moderate</b>
Notes:														
Contaminant detect data for total trihalomethanes from last four quarterly reports of Woonsocket Water Division														

**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.

**WOONSOCKET:  
Mill R/Harris Pond**

PWSID#	Contaminant	MCL	Units	Max	Rank	Rating
1559518	Barium	2	ppm	0.03	low	0
1559518	Gross Beta	50	pCi/l	4	low	0
1559518	Nitrate As N	10	ppm	0.62	low	0

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

Overall Rate of SWA		
Contaminants	low	0

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

**Crook Fall Brook**

PWSID#	Contaminant	MCL	Units	Result	Rank	Rating
1559518	Barium	2	ppm	0.05	low	0
1559518	Gross Beta	50	pCi/l	4.2	low	0
1559518	Nitrate As N	10	ppm	0.2	low	0
1559518	Gross Alpha	15	pCi/l	2	*	*

\* Detects occurred only once in a five-year period and are excluded the well 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](http://www.uri.edu/ce/wq/program/html/SWAP2.htm).

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**SAMPLE**  
**Public notice and**  
**public participation**  
**process**



# 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

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## 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.

## SAMPLE Public notice and public participation process

### 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:

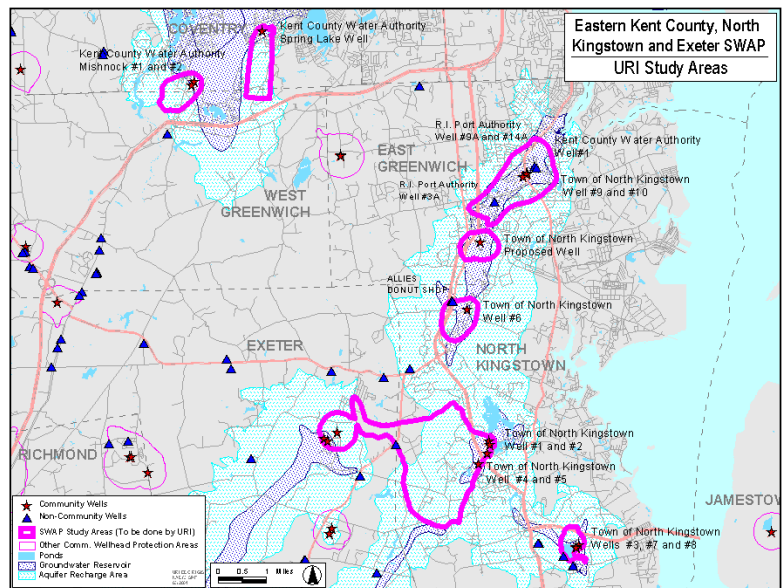
- Proportion of high intensity land uses where pollutants are most likely to be generated.
- Number of mapped pollution sources, both known and potential sources.
- Soil features and buffers where pollutants are most likely to reach a well or surface waters.

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.



## SAMPLE Public notice and public participation process

### 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

<b>Source Water Assessment Program</b>	<b>Assessment of Major Supplies</b>	<b>To Volunteer</b>
Clay Commons	Lorraine Joubert & James Lucht	Alyson McCann & Holly Burdett
SWAP Coordinator	URI Cooperative Extension	URI Cooperative Extension
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*Project funded by RI HEALTH*

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*Evaluating pollution risks to public drinking water supplies*  
North Kingstown • Exeter • Jamestown • Kent County

## **Work Sessions with Assessment Volunteers**

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**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

<b>Source Water Assessment Program</b>	<b>Assessment of Major Supplies</b>	<b>To Volunteer</b>
Clay Commons	Lorraine Joubert & James Lucht	Alyson McCann & Holly Burdett
SWAP Coordinator	URI Cooperative Extension	URI Cooperative Extension
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**APPENDIX 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.**

Existing condition of surface and ground water resources ... <i>What do we already know?</i>			
The City of Woonsocket maintains approximately 47,000 service connections. The district includes all of Woonsocket and parts of North Smithfield, Blackstone (MA) and Bellingham (MA).			
Water resources	Water quantity	Monitoring data & assessment of actual conditions	Pollution sources, concerns and existing protection measures
<i>Source</i>	<i>System capacity-- present and proposed yields; development constraints</i>	<i>Field data available, conditions and trends for source water and associated waterbodies.</i>	<i>Includes documented and potential pollution sources, related water quality issues, and Town plan recommendations.</i>
<b>Woonsocket Reservoir #1 Watershed</b>	Source water from Reservoir #3 is conveyed to Reservoir #1 via Crookfall Brook.	Total Trihalomethanes are half of the MCL.  Sodium Chloride levels are elevated.	<p>Failing ISDS due to severe soil constraints is a concern in the area.</p> <p>The watershed lies within a major transportation corridor. Road salts and other pollutants from highway runoff are a constant concern. Disruptions in watershed hydrology due to the construction of Route 99 is also a concern.</p> <p>Commercial activities using potentially hazardous waste are a concern along with junkyards, the North Central State Airport, and manufacturing activities.</p> <p>There are three potential Superfund sites (CERLIS) located in the watershed. There are also three locations where leaking underground storage tanks have been identified by RIDEM.</p> <p>Over 400 acres in the watershed are zoned for new commercial and industrial development.</p> <p>Woonsocket Water has a land acquisition program; samples raw water weekly; and provides comments on development plans submitted to the towns.</p> <p>Woonsocket Water has recently purchased 100 acres of riparian land along Crookfall Brook in the Reservoir #1 watershed.</p>

Water resources	Water quantity	Monitoring data & assessment of actual conditions	Pollution sources, concerns and existing protection measures
<b>Woonsocket Reservoir #3 Watershed</b>	Reservoir #3 is the main source of water for the distribution system.	The watershed for Reservoir #3 is primarily forested and water quality is high.	<p>Road salts and other highway pollutants pose an ongoing concern due to the close proximity of Route 295 to Reservoir #3.</p> <p>There is an abandoned junkyard and a waste disposal site in the watershed.</p> <p>A livestock farm is located within 2,000 feet of the reservoir in the Town of North Smithfield.</p> <p>Woonsocket Water owns 30% of the watershed; conducts weekly sampling of raw water; and provides comments on development plans submitted to the towns.</p> <p>Both Smithfield and North Smithfield have adopted large lot zoning in the watershed. However, residential development could increase dramatically (over 500 new housing units).</p>
<b>Harris Pond Watershed</b>	Harris Pond is a back-up supply for Woonsocket Water.		<p>The watershed for Harris Pond is approximately 21,260 acres and extends into eight Massachusetts municipalities.</p> <p>Harris Pond is not protected as a Class A, public drinking water reservoir by Massachusetts' law.</p> <p>The banks of the reservoir are heavily developed with higher density residential development. The area is unsewered.</p> <p>There are six Oil and Hazardous Materials Sites (21E) in the watershed, one of which is located in close proximity to the reservoir.</p> <p>There are two Major Hazardous Materials Facilities located at the northern tip of the watershed.</p> <p>Woonsocket Water provides comments and recommendations to the Town of Blackstone, MA on new development proposals for land around Harris Pond.</p>

DATA SOURCES: City of Woonsocket, "2000 Water Quality Report".  
City of Woonsocket, "Water Quality Protection Plan". April 1990.  
MassGIS, 2002.  
Rhode Island Geographic Information System, Department of Administration. Providence, RI.

## APPENDIX F

### Current and Future Land Use Estimates – Woonsocket study areas

Current LAND USE	Reservoir #1		Reservoir #3	
	Acres	% area	Acres	% area
[1] HD Res.(>8 /ac)	9.8	0.3%	0.0	0.0%
[2] MHD Res.(4-7.9/ac)	29.7	0.9%	0.0	0.0%
[3] MD Res.(1-3.9/ac)	204.6	6.5%	60.4	3.3%
[4] MLD Res.(0.5-0.9/ac)	24.1	0.8%	6.2	0.3%
[5] LD Res.(<0.5/ac)	13.3	0.4%	15.9	0.9%
[6] Commercial	169.2	5.4%	5.5	0.3%
[7] Industrial	81.2	2.6%	1.6	0.1%
[8] Roads	168.0	5.4%	25.5	1.4%
[9] Airports	83.2	2.7%	0.0	0.0%
[10] Railroads	0.0	0.0%	0.0	0.0%
[11] Junkyards	31.3	1.0%	19.8	1.1%
[12] Recreation	4.4	0.1%	0.0	0.0%
[13] Institution	12.0	0.4%	1.3	0.1%
[14] Pasture	165.9	5.3%	52.4	2.8%
[15] Cropland	47.3	1.5%	31.2	1.7%
[16] Orchards	4.3	0.1%	0.0	0.0%
[17] Brush	55.8	1.8%	13.8	0.7%
[18] Forest	1,347.1	43.0%	1,089.3	58.6%
[19] Barren	6.4	0.2%	0.0	0.0%
[20] Wetland	660.5	21.1%	280.6	15.1%
[21] Water	13.8	0.4%	254.4	13.7%
<b>Total (acres)</b>	<b>3,132.2</b>	<b>100%</b>	<b>1,858.1</b>	<b>100%</b>

Future LAND USE	Reservoir #1		Reservoir #3	
	Acres	% area	Acres	% area
[1] HD Res.(>8 /ac)	12.6	0.4%	0.0	0.0%
[2] MHD Res.(4-7.9/ac)	29.7	0.9%	0.0	0.0%
[3] MD Res.(1-3.9/ac)	510.2	16.3%	90.5	4.9%
[4] MLD Res.(0.5-0.9/ac)	24.1	0.8%	6.2	0.3%
[5] LD Res.(<0.5/ac)	527.0	16.8%	523.3	28.2%
[6] Commercial	241.6	7.7%	10.6	0.6%
[7] Industrial	200.1	6.4%	1.6	0.1%
[8] Roads	167.6	5.4%	25.5	1.4%
[9] Airports	83.2	2.7%	0.0	0.0%
[10] Railroads	0.0	0.0%	0.0	0.0%
[11] Junkyards	30.9	1.0%	19.8	1.1%
[12] Recreation	4.4	0.1%	0.0	0.0%
[13] Institution	12.0	0.4%	1.2	0.1%
[14] Pasture	129.5	4.1%	47.1	2.5%
[15] Cropland	18.8	0.6%	21.0	1.1%
[16] Orchards	1.3	0.0%	0.0	0.0%
[17] Brush	18.2	0.6%	7.0	0.4%
[18] Forest	441.3	14.1%	562.1	30.3%
[19] Barren	1.9	0.1%	0.0	0.0%
[20] Wetland	653.4	20.9%	276.9	14.9%
[21] Water	24.4	0.8%	265.0	14.3%
<b>Total (acres)</b>	<b>3,132.1</b>	<b>100%</b>	<b>1,857.8</b>	<b>100%</b>

## Change

LAND USE	Reservoir #1		Reservoir #3	
	Acres	% area	Acres	% area
[1] HD Res.(>8 /ac)	2.8	28.7%	0.0 *	
[2] MHD Res.(4-7.9/ac)	0.0	0.0%	0.0 *	
[3] MD Res.(1-3.9/ac)	305.6	149.4%	30.1	49.9%
[4] MLD Res.(0.5-0.9/ac)	(0.0)	0.0%	(0.0)	-0.3%
[5] LD Res.(<0.5/ac)	513.6	3847.6%	507.4	3181.5%
[6] Commercial	72.4	42.8%	5.1	91.3%
[7] Industrial	118.9	146.4%	0.0	0.0%
[8] Roads	(0.4)	-0.3%	0.0	0.1%
[9] Airports	0.0	0.0%	0.0 *	
[10] Railroads	0.0 *		0.0 *	
[11] Junkyards	(0.4)	-1.4%	(0.0)	0.0%
[12] Recreation	0.0	0.0%	0.0 *	
[13] Institution	(0.0)	-0.2%	(0.1)	-10.8%
[14] Pasture	(36.4)	-21.9%	(5.3)	-10.1%
[15] Cropland	(28.5)	-60.2%	(10.1)	-32.6%
[16] Orchards	(3.0)	-70.2%	0.0 *	
[17] Brush	(37.6)	-67.4%	(6.8)	-49.1%
[18] Forest	(905.9)	-67.2%	(527.2)	-48.4%
[19] Barren	(4.6)	-71.3%	0.0 *	
[20] Wetland	(7.0)	-1.1%	(3.8)	-1.3%
[21] Water	10.5	76.3%	10.5	4.2%
Total (acres)				

## APPENDIX G: Characteristics of Rhode Island Soils

### Characteristics of Rhode Island Soils

<u>SOIL NAME</u>	<u>MAP SYMBOL</u>	<u>Hydrologic Soil Group</u>	<u>Restrictive Soils<sup>1</sup></u>	<u>Flooding Duration &amp; Depth</u>	<u>Water Table Depth(ft)</u>	<u>High Water Table Duration &amp; Type<sup>2</sup></u>	<u>Parent Material</u>	<u>Highly Erodible</u>	<u>Hydric/ Drain Class</u>	<u>Groundwater N Removal Potential<sup>5</sup></u>
Adrian	Aa	A/D**	-----	Long; Nov-May	0 - 1.0 <sup>4</sup>	Nov-May, A	Organic	No	VP	High
Agawam	AfA, AfB	B <sup>3</sup>	-----	-----	> 6.0	-----	Outwash	No		
Birchwood	Bc	C	Restrictive	-----	1.5 - 3.5	Nov-April, P	Lodgement Till	No		
Bridgehampton	BhA, BhB, BmA, BmB	B <sup>3</sup>	-----	-----	> 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 <sup>4</sup>	Sep-Jun, A	Organic	No	VP	High
Deerfield	Dc	B <sup>3</sup>	-----	-----	1.0 - 3.0	Dec-Apr, A	Outwash	No		
Enfield	EfA, EfB	B <sup>3</sup>	-----	-----	> 6.0	-----	Outwash, E.M.	No		
Gloucester	GBC*, GBD*, GhC*, GhD*	(A/B) <sup>3</sup>	-----	-----	> 6.0	-----	Ablation Till	Yes		
Hinckley	HkA, HkC, HkD, HnC*	A <sup>3</sup>	-----	-----	> 6.0	-----	Outwash	Yes		
Ipswich	Ip	D	-----	Very brief; Jan-Dec	1 - 0.0 <sup>4</sup>	Jan-Dec, A	Organic	No	VP	High
Lippitt	LgC	C <sup>3</sup>	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 <sup>4</sup>	Jan-Dec, A	Organic	No	P, VP	High
Merrimac	MmA, MmB, MU	A <sup>3</sup>	-----	-----	> 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 <sup>3</sup>	-----	-----	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 <sup>3</sup>	-----	-----	> 6.0	-----	Outwash	No		
Rainbow	RaA, RaB, RbB	C	Restrictive	-----	1.5 - 3.5	Nov-April, P	Lodge. Till, EM	No		
Raypol	Rc	C <sup>3</sup>	-----	-----	0 - 1.0 <sup>4</sup>	Nov-May, A	Outwash, E.M.	No	SP, P	High
Ridgebury	Re, Rf*	C	Restrictive	-----	0 - 1.5 <sup>4</sup>	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 <sup>3</sup>	-----	-----	0 - 1.0 <sup>4</sup>	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 <sup>4</sup>	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 <sup>3</sup>	-----	-----	1.5 - 3.5	Nov-April, A	Outwash	No		
Walpole	Wa	C	-----	-----	0 - 1.0 <sup>4</sup>	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 <sup>3</sup>	-----	-----	> 6.0	-----	Outwash	No		
Woodbridge	WhA, WhB, WoB, WrB	C	Restrictive	-----	1.5 - 3.0	Nov-April, P	Lodgement Till	No		

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

<sup>2</sup> A=Apparent, P=Perched

<sup>3</sup> Excessive permeability 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.

<sup>4</sup> Designated as Hydric Soils.

<sup>5</sup> 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	<ul style="list-style-type: none"> <li>• Highest pollutant movement to <i>groundwater</i> from septic systems and fertilizers,</li> <li>• Largest increase in runoff with impervious cover,</li> <li>• Greatest loss of groundwater recharge with impervious cover.</li> </ul>	<ul style="list-style-type: none"> <li>• Preserve as recharge areas.</li> <li>• Direct stormwater runoff to these areas to promote infiltration after pretreating to remove sediment and other pollutants.</li> <li>• Consider prohibiting deep wastewater seepage pits (galleys); evaluate need for advanced onsite treatment systems.</li> </ul>
B	Most are well-drained, moderate runoff, moderate infiltration	Greater than 6 feet or 1½ to 3½ feet	<ul style="list-style-type: none"> <li>• High potential for pollutant movement to <i>groundwater</i> from septic systems in sandy subsoils,</li> <li>• Moderate increase in runoff and loss of recharge with impervious cover.</li> <li>• May include prime farmland soils.</li> </ul>	<ul style="list-style-type: none"> <li>• Prime soils for building and agriculture. Consider best use to meet town goals and strategies to preserve prime farmland.</li> <li>• Consider prohibiting deep wastewater seepage pits (galleys); evaluate need for advanced onsite treatment systems.</li> </ul>
C	Slowly permeable, collection areas for surface water, typically high water table, high runoff	1½ to 3½ feet or 0 to 1½ feet	<ul style="list-style-type: none"> <li>• High pollutant movement to <i>surface waters</i> from septic systems, fertilizers, and land disturbance.</li> <li>• High potential for <i>hydraulic failure</i> of septic systems, with surfacing or lateral movement of effluent.</li> <li>• High potential for wet basements, temporary flooding.</li> </ul>	<ul style="list-style-type: none"> <li>• 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.</li> <li>• Stormwater treatment ponds not suitable where water table is less than 2 feet from the ground surface.</li> <li>• Limit filling and regrading required to raise elevation of homes with full basements; consider prohibiting basements in wet soils.</li> <li>• Maintain undisturbed wetland buffers and drainageways.</li> <li>• Prohibit use of subdrains to lower water table; regulate location of subdrains adjacent to isds and their discharge,</li> <li>• Divert runoff from wells and septic systems.</li> </ul>
D	Very high water table, often classified as wetlands based on wet (hydric) soils	0 to 1½ feet	<ul style="list-style-type: none"> <li>• Highest pollutant movement to surface waters</li> <li>• Loss of pollution treatment potential with disturbance of wetland buffers.</li> <li>• Wetland habitat encroachment.</li> </ul>	<ul style="list-style-type: none"> <li>• Avoid impacts to small streams, wetlands and wetland buffers with development.</li> <li>• Treat runoff before discharge to wetlands.</li> <li>• Identify wetland buffers for restoration.</li> <li>• Prohibit use of advanced wastewater treatment systems on less than 2 ft. water table for new construction.</li> </ul>

## APPENDIX H

### 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)

<i>Data Layers</i>	<i>Description</i>	<i>Use</i>
Watershed boundaries	Surface water drainage basins and sub-basins in RI. For metadata go to: <a href="http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hdb90.html">http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hdb90.html</a>	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: <a href="http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hwa97.html">http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hwa97.html</a>	
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: <a href="http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hwb97.html">http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hwb97.html</a>	
Aquifer recharge areas	Critical portions of recharge areas for major RI groundwater aquifers suitable as sources for untreated drinking water. For metadata go to: <a href="http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hgg94.html">http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hgg94.html</a>	

#### 2. Land Use

<i>Data Layers</i>	<i>Description</i>	<i>Use</i>
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: <a href="http://www.edc.uri.edu/rigis-spf/Metadata/Landuse/s44llu95.html">http://www.edc.uri.edu/rigis-spf/Metadata/Landuse/s44llu95.html</a>	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

<i>Data Layer</i>	<i>Description</i>	<i>Use</i>
Soils	1996 USDA/NRCS SSURGO soils delineated with name, type and feature attributes. Replaces 1990 RIGIS soils dataset. For metadata go to: <a href="http://www.edc.uri.edu/spfdata/rigisup2002/Soil/risoi96.met">http://www.edc.uri.edu/spfdata/rigisup2002/Soil/risoi96.met</a>	See below for uses.

#### 4. Sewers

<i>Data Layer</i>	<i>Description</i>	<i>Use</i>
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: <a href="http://www.edc.uri.edu/rigis-spf/Metadata/Utilities/s44usl96.html">http://www.edc.uri.edu/rigis-spf/Metadata/Utilities/s44usl96.html</a>	Buffered to 750' to estimate service area

#### 5. Community Water Supply Wells

<i>Data Layer</i>	<i>Description</i>	<i>Use</i>
Community Wells	Public wells serving at least 25 residents or 15 service connections year round. For metadata go to: <a href="http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hwc97.html">http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hwc97.html</a>	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: <a href="http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hwn97.html">http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hwn97.html</a>	

#### 6. Public Water Systems

<i>Data Layer</i>	<i>Description</i>	<i>Use</i>
Water Supply Lines	Water lines for public water systems. For metadata go to: <a href="http://www.edc.uri.edu/rigis-spf/Metadata/Utilities/s44uw195.html">http://www.edc.uri.edu/rigis-spf/Metadata/Utilities/s44uw195.html</a>	Existing water quality impacts

#### 7. Political Boundaries

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

#### 8. Roads

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

#### 9. Water Resources

<i>Data Layers</i>	<i>Description</i>	<i>Use</i>
Hydro lines	Centerlines for all fresh water rivers and streams including some seasonal streams in RI. For metadata go to: <a href="http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hhl98.html">http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hhl98.html</a>	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: <a href="http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hhm99.html">http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hhm99.html</a>	

Reservoirs	Surface reservoirs used as sources for public drinking water supplies. For metadata go to: <a href="http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hpr94.html">http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hpr94.html</a>	
Narragansett Bay Water Classification	Water zone classifications in Narragansett Bay by the RI CRMC and RIDEM. For metadata go to: <a href="http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hbc94.html">http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hbc94.html</a>	
Shellfishing Closure Areas	Rhode island coastal waters & Narragansett Bay shellfish closure areas. For metadata go to: <a href="http://www.edc.uri.edu/rigis-spf/Metadata/Nature/s44nsc00.html">http://www.edc.uri.edu/rigis-spf/Metadata/Nature/s44nsc00.html</a>	
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: <a href="http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hcc94.html">http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hcc94.html</a>	
Groundwater Classification	Groundwater quality classifications for major aquifers, public well head areas and other subsurface resources. For metadata go to: <a href="http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hgc93.html">http://www.edc.uri.edu/rigis-spf/Metadata/Hydro/s44hgc93.html</a>	

## 10. Open Space and Protected Areas

<i>Data Layer</i>	<i>Description</i>	<i>Use</i>
Audubon Lands	Protected open space lands owned and managed by the Audubon Society of Rhode Island. For metadata go to: <a href="http://www.edc.uri.edu/rigis-spf/Metadata/Openspace/s44oal95.html">http://www.edc.uri.edu/rigis-spf/Metadata/Openspace/s44oal95.html</a>	Facilitates comparison of hot spots to resource areas. Shows potential for greenway linkages.
State Conservation and Recreational Openspace 1990	State Conservation, Open Space, and Recreational Program lands as of 1990. For metadata go to: <a href="http://www.edc.uri.edu/spfdata/rigisup2002/OpenSpace/scorp90.htm">http://www.edc.uri.edu/spfdata/rigisup2002/OpenSpace/scorp90.htm</a>	Open space was updated with town data in each watershed.
Protected Public Lands	Protected open space lands managed by or acquisition supported through the Rhode Island Department of Environmental Management. For metadata go to: <a href="http://www.edc.uri.edu/spfdata/rigisup2002/OpenSpace/demopen.htm">http://www.edc.uri.edu/spfdata/rigisup2002/OpenSpace/demopen.htm</a>	
Private Land Trust Holdings	Land owned by The Nature Conservancy or Municipal Land Trusts. For metadata go to: <a href="http://www.edc.uri.edu/rigis-spf/Metadata/Openspace/s44onc98.html">http://www.edc.uri.edu/rigis-spf/Metadata/Openspace/s44onc98.html</a>	
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: <a href="http://www.edc.uri.edu/spfdata/rigisup2002/OpenSpace/protopen.htm">http://www.edc.uri.edu/spfdata/rigisup2002/OpenSpace/protopen.htm</a>	
Rare Species	Estimated habitat and range of rare species and noteworthy natural communities. For metadata go to: <a href="http://www.edc.uri.edu/rigis-spf/Metadata/Nature/s44nrs97.html">http://www.edc.uri.edu/rigis-spf/Metadata/Nature/s44nrs97.html</a>	

## 11. Topography

<i>Data Layer</i>	<i>Description</i>	<i>Use</i>
USGS 7.5 Minute Topo Maps	TIF image files of USGS 7.5 minute topoquads that encompass RI. Distributed on USGS Quad basis.	Used as base map for most maps in Wickford Harbor Assessment. Provides topography, annotation, and local landmarks.

## 12. Point Sources of Pollution

<i>Data Layer</i>	<i>Description</i>	<i>Use</i>
CERCLIS	Point locations of hazardous material sites designated by the U.S. EPA and RIDEM. For metadata go to: <a href="http://www.edc.uri.edu/rigis-spf/Metadata/Hazmat/s44xcc97.html">http://www.edc.uri.edu/rigis-spf/Metadata/Hazmat/s44xcc97.html</a>	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: <a href="http://www.edc.uri.edu/rigis-spf/Metadata/Hazmat/s44xsp99.html">http://www.edc.uri.edu/rigis-spf/Metadata/Hazmat/s44xsp99.html</a>	
LUSTs	Storage tanks and associated piping used for petroleum and certain hazardous substances that have experienced leaks as determined by RIDEM. For metadata go to: <a href="http://www.edc.uri.edu/rigis-spf/Metadata/Hazmat/s44xlt99.html">http://www.edc.uri.edu/rigis-spf/Metadata/Hazmat/s44xlt99.html</a>	

## 13. Zoning

<i>Data Layer</i>	<i>Description</i>	<i>Use</i>
Town Level Zoning	Town blue-print for future development patterns	Buildout analysis

## MANAGE – Modified coverages

### Surface Water Hot Spots

<i>Data Layer</i>	<i>Use</i>
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

<i>Data Layer</i>	<i>Use</i>
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

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

**APPENDIX I: MANAGE Summary Results**

# APPENDIX J



## 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
<b>1. LAND USE <sup>1</sup></b>				
<b>Watershed-wide</b>				
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 <sup>4</sup>	< .10	.10 – .23	.24 – .49	.50 – 1.15
Percent sewered land use	Not rated <sup>3</sup>			
<b>Riparian (shoreline)</b>				
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 %
<b>Existing or potential pollution sources</b>				
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			
<b>2. NATURAL FEATURES <sup>2</sup></b>				
	Low	Med – High		Extreme
<b>SOILS- Risk to groundwater</b>				
Very sandy, rapidly permeable	< 10 %	10 – 60 %		> 60 %
<b>SOILS - Risk to surface water and/or shallow groundwater</b>				

Slowly permeable soils			Not rated <sup>3</sup>
Presence of restrictive layers	< 2%	2 – 10 %	> 10 %
High water table	< 5 %	2 – 20 %	> 20 %
Erosion potential	< 5 %	2 – 20 %	> 20 %
<b>Wetlands</b> 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 <sup>4</sup> (lbs / acre/ year)	< .46	.47 – .68	.69 – .93	> .93
Nitrogen loading to groundwater recharge (lbs / acre/ year) <sup>4</sup>	< 5.4	5.4 – 8	8.1 – 16	> 16
Nitrate-N concentration to groundwater recharge (mg/l) <sup>4</sup>	< 2	2 – 4.9	5 – 7.9	8 – 10
Nitrogen to surface runoff (lbs / acre/ year)				Not rated <sup>3</sup>
Surface water runoff (inches /year)				Not rated <sup>3</sup>
Infiltration and recharge from rainfall and septic systems (inches /year)				Not rated <sup>3</sup>

**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
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**Existing Condition - Groundwater**

Monitored concentration of nitrate (mg/l)	< .5	.5 – 2	> 2 – 5	> 5
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### 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<sub>L</sub>)

Aquifer type- bedrock (low risk) vs. sand and gravel (high risk) (RIDOH, 1999); USGS vulnerability rating (USGS, 1999); potential for lateral flow

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### 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<sup>th</sup> = low, 50<sup>th</sup> moderate, 75<sup>th</sup> = high, 95<sup>th</sup> = 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:

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

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:*

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<sup>th</sup>, 50<sup>th</sup>, 75<sup>th</sup> and 95<sup>th</sup>) 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

### Woonsocket Source Water Assessment Hydrologic and Nutrient Loading Assumptions

#### HYDROLOGIC BUDGET:

Average Annual Precipitation	44.0 inches
Average Annual Evapotranspiration	18.0 inches

#### Surface Runoff Nutrient Loading Factors

Surface Runoff Coefficients	Phosphorus		Nitrogen			
	lb P/acre/year		lb N/acre/year			
LAND USE	Low	High	Low	High	Low	High
[1] HD Res. (>8 /ac)	0.64	0.77	3.6	4.3	11.7	14.0
[2] MHD Res. (4-7.9/ac)	0.39	0.64	2.2	3.6	7.1	11.7
[3] MD Res. (1-3.9/ac)	0.23	0.39	1.3	2.2	4.2	7.1
[4] MLD Res. (0.5-0.9/a)	0.16	0.23	0.9	1.3	2.9	4.2
[5] LD Res. (<0.5/ac)	0.10	0.16	0.6	0.9	1.8	2.9
[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	2.2	3.6	7.1	11.7
[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
[21] Water	1.00	1.00	0.3	0.3	8.0	8.0

Water N = 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

$$X = \begin{cases} 0 & \text{for soil type A;} \\ 1/3 & \text{for soil type B;} \\ 2/3 & \text{for soil type C;} \\ 1 & \text{for soil type D.} \end{cases}$$

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

	<b>2.4</b>	people/dwelling unit	<i>Derived from town and/or U.S.census data</i>
	<b>50</b>	gallons H2O /person/day	
	<b>2.3</b>	lb P/person/year	
	<b>7.0</b>	lb N/person/year	
Concentration of P	15.1	mg/l	
Concentration of N	46.0	mg/l	
	<b>90%</b>	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)	<b>8.00</b>	<i>Low end in each residential category is closest to actual count based on comparison with census and/or parcel data in many study areas. Where a more accurate count is available the final number of septic systems is adjusted in the main spreadsheet.</i>
[2] MHD Res. (4-7.9/ac)	<b>3.60</b>	
[3] MD Res. (1-3.9/ac)	<b>1.00</b>	
[4] MLD Res. (0.5-0.9/ac)	<b>0.50</b>	
[5] LD Res. (<0.5/ac)	<b>0.20</b>	
[6] Commercial**	<b>1.00</b>	
[7] Industrial**	<b>1.00</b>	<i>** Commercial, Industrial, Institution, and Recreation are assumed to contribute at the same level as MD Res. except Recreation is assumed to be in use for 6 months each year.</i>
[12] Recreation **	<b>0.50</b>	
[13] Institution**	<b>1.00</b>	

### Fertilizers:

#### Lawn Fertilizers

Estimated Lawn Area by Land Use

LAND USE	Fraction of area which is lawn	
[1] HD Res. (>8 /ac)	<b>0.25</b>	<b>75%</b> of residents and businesses apply fertilizer at a rate of <b>175</b> lb N/ac/yr or 4.0 lb N/1000 sq. ft./yr
[2] MHD Res. (4-7.9/ac)	<b>0.35</b>	
[3] MD Res. (1-3.9/ac)	<b>0.50</b>	<b>6%</b> of the N applied leaches to the groundwater
[4] MLD Res. (0.5-0.9/a)	<b>0.35</b>	
[5] LD Res. (<0.5/ac)	<b>0.25</b>	
[6] Commercial	<b>0.05</b>	
[7] Industrial	<b>0.10</b>	
[12] Recreation	<b>0.70</b>	
[13] Institution	<b>0.25</b>	

#### 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 to **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 reduced by **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 sewerage.

**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.