Appendix A:
Assumptions for current and future ISDS's in study areas (Exeter, RI)

Appendix A: Estimated Nitrogen Load for Study Areas (Exeter, RI)

The MANAGE model calculates the number of ISDS in an area based on assumptions regarding land use. Each land use type is assigned a number of ISDS units per acre and this value is multiplied by the acreage of each land use type to determine the total number of ISDS. This value was utilized in the MANAGE models in this study for current medium density, medium low density and low density residential and recreational land uses. The number of ISDS associated with other types of development as calculated by MANAGE were removed and an estimate based on actual numbers of persons utilizing the commercial and industrial land uses were input into the model. MANAGE assumes that all ISDS are the same size, treat the same volume of wastewater and export the same amount of nutrients. The model assumes a greater density of ISDS per commercial and industrial land uses to average in the affect of a greater loading from commercial and industrial sites then a residential ISDS. A more accurate method for determining the loading from large scale ISDS systems (shown below) was used to determine loading of current commercial structures and projected future development in the model. Estimates of the number of persons utilizing the structure, water use (GPD) and effluent concentration were used to determine the system nutrient load. This nutrient load was then divided by the loading expected from the standard MANAGE ISDS to determine the equivalent number of "MANAGE ISDS" units per structure. These values were then input into the MANAGE model.

ASSUMPTIONS and REFERENCE VALUES

365	day/yr
3.79	L/gal
0.001	g/mg
0.0022	lb/g
2.4	persons/ISDS (This assumption is from MANAGE for single family residential areas)
7	lb N/person year contributed to a septic system from a singe family residential area (MANAGE assumption)
16.8	lb N/year per ISDS (This assumption is from MANAGE and is calculated as follows: number of persons/ISDS x lb N/person year)

LADD SCHOOL

	Persons	GPD per Person	Effluent (mg/L)	System GPD	Number of ISDS	N Load Traditional System (lb N/year)	Number of Denitrification Systems[2]	N Load Denitrifying System (lb N/year)	Number of MANAGE equilavent ISDS
CURRENT									
Existing Institutional Land Use									
Marathon House	95	80	65	7600		1507	0	1507	90
Job Corp	300	80	65	24000		4758	283	2379	283
Fire Fighters	15	30	65	450		89	0	89	5
Remainder of Existing Land Use in WHPA									
MD Residential[1]					36.1	606	0	606	36.1
MLD Residential[1]					3.6	60	0	60	3.6
LD Residential[1]					0.8	13	0	13	0.8
Recreation[1]					0.8	13	0	13	0.8
Total				32050		7047	283	4668	419
FUTURE									
Expanded Commercial Development in WHPA									
Office Building	3000	15	65	45000		8920	531	4460	531
Existing Land Use in WHPA									
Current				32050		7047	283	4668	419
Total (current + future)				77050		15968	814	9129	950

VILLAGE AREA

	Persons	GPD per Person	Effluent (mg/L)	System GPD	Number of ISDS	N Load Traditional System (lb N/year)	Number of Denitrification Systems[2]	N Load Denitrifying System (lb N/year)	Number of MANAGE equilavent ISDS
CURRENT									
Existing Commercial Land Use									
Pizza Restaurant	50	35	65	1750		347	0	347	21
Convenience Store	5	15	65	75		15	0	15	1
Post Office	10	15	65	150		30	0	30	2
Remainder of Existing Land Use in WHPA									
MD Residential[1]					3.9	66	0	66	3.9
MLD Residential[1]					0.7	12	0	12	0.7
LD Residential[1]					0.4	7	0	7	0.4
Recreation[1]					4.3	72	0	72	4.3
Total				1975		548		548	33
FUTURE - LOW									
Expanded Commerical Land Use Within WHPA									
Multi-family homes	300	75	65	22500		4460	265	2230	265
Beauty Salon/Day Spa	10	200	65	2000		396	24	198	24
Office Retail	50	15	65	750		149	9	74	9
Restaurant 40 seat	40	70	65	2800		555	33	278	33
Restaurant single serve	57	35	65	1995		395	24	198	24
Existing Land Use in WHPA									
Current				1975		548	0	548	33
Total (current + future-low)				32020		6504	355	3526	387
FUTURE - HIGH									
Expanded Commercial Development Outside WHPA									
Multi-family	376	75	65	28200		5590	333	2795	333
Beauty Salon/Day Spa	10	200	65	2000		396	24	198	24
Office Retail	500	15	65	7500		1487	88	743	88
Restaurant 80 seat	80	70	65	5600		1110	66	555	66
Restaurant single serve	48	35	65	1680		333	20	167	20
Existing Land Use in WHPA and Expanded Commercial Land Use Within WHPA									
Future-low (plus current)				32020		6504	355	3526	387
Total (current + future-low + future-high)				77000		15420	886	7984	918

CALCULATIONS

System GPD =	GPD per person x persons
Number of MANAGE equilavent ISDS =	(N Load Traditional System lb N/year) / (MANAGE ISDS System lb N/year)
System lb N/year =	persons x GPD per person x effluent (mg/L) x 365 day/yr x 3.79 L/gallon x 0.001 g/mg x .0022 lb/g
or	
System lb N/year =	16.8 lb N/year per ISDS x Number of ISDS

Notes:

[1] The values reported for "Number of ISDS" are obtained using the default MANAGE approach. The default approach for determining the number of ISDS in a system is to assign an average number of ISDS per acre for each RIGIS land use category. The average number of ISDS per acre assigned is as follows: MD Residential = 1.0 / acre, MLD Residential = 0.5 / acre, LD Residential = 0.2 / acre, recreation = 0.5/acre.

[2] It is assumed that denitrification systems reduce the nitrogen in septic tank effluent by 50%.

Appendix B:
MANAGE Model Results and Summary

MANAGE SUMMARY RESULTS Exeter, RI May 2005

Study Area & Scenario		Acres	% Sewer	% High Intensity Land Use	% Im-pervious	% Forest	% Wetland	% Forest & wetland	RIP % HILU	RIP%Im-pervious	RIP % Forest	RIP % Wetland
				Study Area Land Use Indicators					**Riparian Indicators**			
Queen River	Current Land Use -Agri Fert.215 lbs/ac, 30% leaching	23380	0%	10%	2%	59%	15%	75%	4%	1%	37%	50%
Ladd 1 Current	Ladd School - Current with existing I/A ISDS systems	522	0%	14%	5%	48%	20%	68%	3%		45%	50%
Ladd 2 Future	Ladd School - Future All institutional land was converted to commercial land (54.1 acres). Includes current I/A ISDS systems and assumes all future systems will be I/A	522	0%	14%	9%	48%	20%	68%	3%		45%	50%
Ladd 3 Future - Reduced Runoff Coef, 40% Imperv.	Ladd School - Future Same as the Ladd 2 Future with: commerical development reduced to 40% impervious surface (from 72%) and the runoff coefficient was reduced from commerical to high density residential to enhance stormwater infiltration.	522	0%	14%	6%	48%	20%	68%	3%		45%	50%
Queen River	Current Land Use- Low Agri Fert. 175 lbs/acre, 20% leaching	23380	0%	10%	2%	59%	15%	75%	4%	1%	37%	50%
Chipuxet River Watershed	Current Land Use	16452	2%	16%	5%	38%	22%	60%	4%	3%	31%	56%
Village 1 Current	Village - Current	220	0%	25%	3%	18%	18%	36%	6%	3%	29%	39%
Village 2 Future Low	Village - Future Low Development (50 acres of agricultural land (cropland, pasture, brush) was converted to commercial. Assumes all new ISDS would use I/A design.	220	0%	26%	20%	18%	18%	36%	6%		29%	39%
Village 3 Future High	Village - Future High Development (100 acres of agricultural land (cropland, pasture, brush) was converted to commercial. Assumes that all new ISDS would utilize I/A design.	220	0%	49%	36%	18%	18%	36%	6%		29%	39%
Village 4 Future High - Reduced Runoff Coef, 40% Imperv.	Village - Future High Development. Same as Village 4 with: commerical development was reduced to 40% impervious surface (from 72%) and the runoff coefficient was reduced from commerical to high density residential to enhance stormwater infiltration.	220	0%	49%	20%	18%	18%	36%	6%		29%	39%
Village 5 Future High - Reduced Runoff Coef, 25% Imperv.	Village - Future High Development. Same as the Village 3 with: commerical development reduced to 25% impervious surface (from 72%) and the runoff coefficient and surface nutrient loading coefficients were reduced from commerical to brush. This represent	220	0%	49%	13%	18%	18%	36%	6%		29%	39%

Estimated Nutrient Loading						Estimated Nitrate-N sources to grw. recharg					SOILS hydrologic groups			
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	Septic Systems	Lawn Fert.	Agri. Fert	Pet Waste	Other	*% A*	*% B*	*% C*	*% D*
1.6	8.3	3.0	11.3	2.2%	0.3	20%	5%	64%	1%	9%	10%	63%	20%	6%
1.8	9.9	2.4	12.3	0.9%	0.4	74%	6%	13%	1%	7%	21%	47%	26%	7%
3.3	18.3	2.7	21.0	0.8%	0.4	87%	2%	7%	0%	4%	21%	47%	26%	7%
3.2	18.3	2.7	21.0	0.8%	0.4	87%	2%	7%	0%	4%	21%	47%	26%	7%
1.0	5.4	3.2	8.6	2.0%	0.4	23%	8%	54%	1%	14%	10%	63%	20%	6%
2.8	11.4	4.4	15.8	15.8%	0.5	25%	4%	65%	2%	5%	15%	54%	11%	21%
2.4	11.6	5.5	17.1	0.4%	0.6	14%	3%	77%	0%	5%	11%	72%	6%	10%
3.6	16.2	3.3	19.5	0.6%	0.6	94%	3%	0%	0%	4%	11%	72%	6%	10%
8.6	36.3	4.5	40.8	0.5%	0.8	98%	1%	0%	0%	1%	11%	72%	6%	10%
7.1	36.3	4.5	40.8	0.5%	0.8	98%	1%	0%	0%	1%	11%	72%	6%	10%
5.1	36.3	1.4	37.7	1.5%	0.1	98%	1%	0%	0%	1%	11%	72%	6%	10%

Study Area & Scenario	%SHWT <1.5-3.5'	%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.	GW recharge % avail	Precip Mgal/yr
Queen R	33.0%	14%	12%	35%	0%	0%	2,607	0.11	45	18	27	3.9	23.1	0.2	14%	86%	28567
Ladd 1 Current	35.5%	19%	18%	15%	1%	1%	419	0.80	45	18	27	4.5	22.5	1.3	17%	83%	638
Ladd 2 Future	35.5%	19%	18%	15%	1%	1%	950	1.82	45	18	27	5.8	21.2	2.9	21%	79%	638
Ladd 3 Future - Reduced Runoff Coef, 40% Imperv.	35.5%	19%	18%	15%	1%	1%	950	1.82	45	18	27	4.9	22.1	2.9	18%	82%	638
Queen Low Ag	33.0%	14%	12%	35%	1%	2%	1,891	0.08	45	18	27	4.4	22.6	0.1	16%	84%	28567
Chipuxet River Watershed	32.7%	8%	3%	26%	2%	1%	2,675	0.16	48	21	27	9.5	17.5	0.3	35%	65%	21442
Village 1 Current	16.3%	0%	0%	9%	1%	0%	33	0.15	45	18	27	6.0	21.0	0.2	22%	78%	268
Village 2 Future Low	16.3%	0%	0%	9%	1%	0%	387	1.76	45	18	27	9.7	17.3	2.8	36%	64%	268
Village 3 Future High	16.3%	0%	0%	9%	1%	0%	918	4.18	45	18	27	15.1	11.9	6.7	56%	44%	268
Village 4 Future High - Reduced Runoff Coef, 40% Imperv.	16.3%	0%	0%	9%	1%	0%	918	4.18	45	18	27	11.0	16.0	6.7	41%	59%	268
Village 5 Future High - Reduced Runoff Coef, 25% Imperv.	16.3%	0%	0%	9%	1%	0%	918	4.18	45	18	27	2.2	24.8	6.7	8%	92%	268

Study Area & Scenario	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
Queen R	11427	17140	2,466	14,675	114	1,396	1,070
Ladd 1 (Current)	255	383	64	318	18	27	37
Ladd 2 (Future)	255	383	82	301	42	27	55
Ladd 3 (Future - Reduced Runoff Coef. (40% Imperv.))	255	383	70	313	42	27	43
Queen Low Ag	11427	17140	2,779	14,361	83	1,396	1,383
Chipuxet River Current	9381	12061	4,238	7,823	137	2,723	1,514
Village 1 (Current)	107	161	36	125	1	11	25
Village 2 (Future Low)	107	161	58	103	17	11	47
Village 3 (Future High)	107	161	90	71	40	11	79
Village 4 (Future High - Reduced Runoff Coef. (40% Imperv.))	107	161	66	95	40	11	55
Village 6 (Future High - Reduced Runoff Coef. (25% Imperv.))	107	161	13	148	40	11	2

Appendix C:
MANAGE Technical Documentation

Database Development, Hydrologic Budget and Nutrient Loading Assumptions for the "Method for Assessment, Nutrient-loading, And Geographic Evaluation of Nonpoint Pollution" (MANAGE) Including the GIS-Based Pollution Risk Assessment Method

Original documentation 1996, Updated: October 2000
Current update: 2005

Dorothy Kellogg, Marie Evans Esten, Lorraine Joubert, and Dr. Arthur Gold
University of Rhode Island, Department of Natural Resources Science
Cooperative Extension, Nonpoint Education for Municipal Officials
Coastal Institute in Kingston, 1 Greenhouse Rd, Kingston RI 02881
Tel: 401-874-2138 Fax: 401-874-4561
Mevans@mail.uri.edu, Ljoubert@uri.edu, Agold@uri.edu

Outline of the functions of the MANAGE AML

The AML automates the data collection process for the MANAGE Excel Model. Data exported by the AML may be directly imported into the MANAGE Model.

Input coverages utilized by the MANAGE AML:

WATERSHED BOUNDARY COVERAGE – study area boundary outline (watershed, subwatershed, wellhead protection area, or aquifer recharge area).
LAND USE COVERAGE
SOILS COVERAGE
SEWER LINE COVERAGE
HYDRO_LINE COVERAGE (streams and small rivers)
HYDRO_POLY COVERAGE (lakes and large rivers)

Coverages produced and used by the MANAGE AML:

LU = Land use coverage
SLS = Soils coverage
SEW = Sewer line coverage
BASIN = Watershed boundary coverage
HP = Hydro_poly coverage
HL = Hydro_line coverage
SHEDLU = Land use clipped by watershed/study area boundary.
SHEDSLS = Soils clipped by watershed/study area boundary.
LUSL = Land use and soils intersected.
SHEDHL = Hydrolines (rivers and streams) clipped by watershed/study area boundary.
SHEDHP = Hydropolys (pond and large rivers) clipped by watershed/ study area boundary.
SHEDHYDRO = Data from hydrolines and hydropolys joined (appended) together to create a coverage of all surface water features.
SHEDSEW = Sewer Lines (if specified) clipped by watershed/study area boundary.
SHEDSEW_AREA = Buffered sewer lines.
SHED_UNSEW = Land use and soils in watershed/study area that is unsewered.
SHEDRA1 = Buffer of shedhydro coverage (all surface waters). The value used to buffer the coverage (in feet) is provided by the user.

Coverages produced and used by the MANAGE AML (continued):

SHEDRA_LUSL = Land use and soils in riparian areas.
SHEDRA_UNSEW = Land use and soils in riparian areas that are unsewered.

Files created by the MANAGE AML that are utilized by the MANAGE excel spreadsheet:

SW_ALL.CSV = Land use and soils data for watershed/study area
SW_UNSEW.CSV = Land use and soils for the unsewered portion of the watershed/study area
SWRA_ALL.CSV = Land use and soils in riparian areas
SWRA_UNS.CSV = Land use and soils in riparian areas in the unsewered portion of the watershed/study area.

Steps completed by the MANAGE AML:

1. User enters the location of the LAND USE COVERAGE and the file is re-named LU.
2. User enters the location of the SOILS COVERAGE and the file is re-named SLS.
3. User enters the location of the SEWER LINE COVERAGE (if there is one) and the file is re-named SEW.
4. User enters the SEWER LINE BUFFER WIDTH (default value = 500 ft).
5. User enters the location of the WATERSHED BOUNDARY COVERAGE and the file is re-named BASIN.
6. User enters the location of the HYDRO-POLY COVERAGE and the file is re-named HP.
7. User enters the location of the HYDRO-LINE COVERAGE and the file is re-named HL.
8. User enters the WIDTH OF THE RIPARIAN AREA (default value = 200 feet)
9. The coverages listed below are clipped with the BASIN coverage.
    a. LU clipped and new coverage is named: SHEDLU.
    b. SLS clipped and new coverage is named: SHEDSLS.
    c. SEW clipped and new coverage is named: SHEDSEW.
    d. HL clipped and new coverage is named: SHEDHL.
    e. HP clipped and new coverage is named SHEDHP.
10. SHEDLU and SHEDSLS are intersected to create a new coverage: LUSL.
11. The following fields are added to LUSL:
    i. "ACRES" – Area of polygon in acres
    ii. "CE-ID" – Cooperative Extension Land Use Codes used in MANAGE (see Appendix A).
    iii. "IMPERV" – % Impervious surface based on CE-ID field (See Appendix H)
    iv. "CE_SHWT" – Seasonal High Water Table (SHWT) code based on soil type (see Appendix A).
    v. "ERODIBLE" – Erosion potential of soil based on soil type (see Appendix A).
    vi. "EXCESS_PERM" – Excessively permeable soils are identified based on soil type (see Appendix A)
    vii. "PARENT_MATERIAL" – Parent material of the soils are identified based on soil type (organic, outwash, ablation till, etc.) (refer to Appendix A).
    viii. "RESTLAY" – Identify restrictive layers based on soil type (refer to Appendix G).
12. Calculates ACRES of each polygon in LUSL.
13. Selects LULS and loads data into fields just added:
    i. Field CE-SHWT = "U"
    ii. Field ERODIBLE = "N"
    iii. Field EXCESS_PERM = 'N"
    iv. Field PARENT_MATERIAL = "other"
    v. Field RESTLAY = "N"
    vi. Field IMPERV = 0

14. Aggregates land use codes (CODE95) into CE-ID categories. This reduces the number of land use categories (see Appendix A for the aggregate categories).
15. Selects the field SOIL-NAME and adds the appropriate information to the following fields based on soil type: CE_SHWT, EXCESS_PERM, PARENT_MATERIAL, RESTLAY, ERODIBLE (see Appendix A). This action modifies the data input under step 13 for the given fields. Any soils within the soils coverage that are not listed in Appendix A retain the value loaded under step 13.
16. Loads values into field IMPERV based on CE-ID (see Appendix H).
17. Appends HYDROPOLY and HYDROLINES into one coverage (SHEDHYDRO).
18. SHEDHYDRO is buffered by the value input by the user and the buffer saved to file SHEDRA1
19. Adds the field "RADONUT" to SHEDRA1.
20. Removes the areas of surface waters found in SHEDHP from the buffer file SHEDRA1 creating a new file SHEDRA.
21. Deletes SHEDRA1.
22. Selects SHEDRA and adds the field "RADONUT" and makes it equal to "inside".
23. Intersects SHEDRA and LUSL to create the file SHEDRA_LUSL.
24. If there isn't a sewer coverage: Then
    i. Copies LUSL to SHED_UNSEW.
    ii. Copies SHEDRA_LUSL to SHEDRA_UNSEW.
    iii. Adds the field "SEWDONUT" to SHED_UNSEW.
    iv. Adds the field "SEWDONUT" to SHEDRA_UNSEW.
    v. Selects SHED_UNSEW and sets "SEWDONUT" equal to 1.
    vi. Selects SHEDRA_UNSEW and sets "SEWDONUT "equal to 1.
25. If there is a sewer coverage then:
    i. Buffers the sewer coverage by the user specified value creating the file SHEDSEW_AREA.
    ii. Adds a field to SHEDSEW_AREA called "SEWDONUT".
    iii. Sets the field "SEWDONUT" equal to "inside"
26. Intersects (identity) SHEDRA_LUSL and SHEDSEW_AREA to create SHEDRA_UNSEW
27. Intersects LUSL and SHEDSEW_AREA to create SHED_UNSEW
28. Recalculates polygon areas in acres for SHED_UNSEW, SHEDRA_UNSEW and SHEDRA_LUSL.
29. The data is then run through the frequency command to compile the data according to land use/soils and then converted into a .csv format

Documentation of MANAGE Excel Model

The MANAGE Excel Model is organized into five sections:

1) Data Input. The model requires the data listed below. Data may be input from the MANAGE AML export files or from another database.
    a. Land use and soils data for watershed/study area
    b. Land use and soils for the unsewered portion of the watershed/study area
    c. Land use and soils in riparian areas
    d. Land use and soils in riparian areas in the unsewered portion of the watershed/study area.
2) Best Management Practices (BMP's). This section allows the user to specify various existing or proposed BMP's. Possible BMP's include stormwater management options, alternatives to standard septic systems, reduced imperviousness through creative design and methods to improve lawn and agricultural management.
3) Data Processing and Refinement. These sections process the input data and allows the user to add site-specific information, if it is available. Also in this section, model assumptions are stated (such as runoff coefficient values) and the user is given the opportunity to change them. Care should be taken when modifying assumptions to be sure that the selected values are realistic.
4) Calculations. Runoff, nutrient loading, and recharge calculations are completed in this section.
5) Summary. Results are summarized and graphs are generated.

Basic Calculations Completed by MANAGE Excel Model:

1. Calculate runoff from study area based on the lumped sum method

   Volume of runoff from study area to surface receiving water = Total volume
   Total Volume = Σ Runoff from all soil and land use types = (Precipitation) X (Area of Soil/Land use Combination) X (Runoff coefficient for soil/Land use combination) X (Conversion factor)

   BMPs are applied where appropriate

2. Calculate infiltration to groundwater

   V(infil) = V(PPT) - V(surface RO) - V(ET)

   V(infil) = Volume of infiltration
   V (PPT) = Volume of precipitation
   V (surface RO) = Volume of surface runoff
   V(ET) = Volume of evapotranspiration (defined previously)

3. Calculate the Phosphorus and Nitrogen Loading to surface water using the lumped sum method

   Total P load from watershed = Σ over all soil and Land Use combinations =
   = (Area of each soil/land use combination) X ((Loading factor for each soil/land use combination)

   BMPs are applied where appropriate as well as contributions from malfunctioning septic systems via overland flow, with a higher loading from those within riparian areas and point sources.

4. Calculate Nitrogen loading to groundwater reservoir by taking the sum of nitrogen sources listed below:

   a. Approximate number of unsewered dwellings in watershed.
   b. Approximate number of occupants/dwelling, adjusted for seasonal occupancy. (Weiskel and Howes (1991) found water use records better reflected occupancy than did assuming an average number of people/dwelling unit. However, summer water use can go up as a result of several factors, not just population increase. These include filling swimming pools and watering lawns. Garbage collection might be a better indicator. Currently 1990 RI Census data (see Appendix F) and input from local government officials is used to estimate occupancy rates.
   c. Approximate contribution from all septic systems.
   d. Approximate total fertilized lawn area and fertilized agricultural areas in watershed.
   e. Approximate contribution from pets in residential areas.
   f. Approximate contribution from stormwater runoff infiltration from unfertilized pervious areas.
   g. Applying BMPs where appropriate.

5. Review results.

   Generally, after completing the model for current conditions in a study are the inputs are modified to reflect several future build-out scenarios chosen by the community, based on such factors as zoning. This may include BMP's, as well as projected point sources.

APPENDIX A: LAND USE AND SOILS DESIGNATIONS

TABLE A1: RIGIS code and corresponding MANAGE Nutrient Loading Model Land Use Designations

RIGIS Code	RIGIS Category	Explanation	MANAGE Category
111	High Density Residential	> 8 dwelling units/acre (1/8 acre lot)	HDR
112	Medium High Density Residential	4 to 7.9 units/acre (1/4 acre lot)	MHDR
113	Medium Density Residential	1 to 3.9 units/acre (1 acre lot)	MDR
114	Medium Low Density Residential	0.5 to 0.9 units/acre (2 acre lot)	MLDR
115	Low Density Residential	< 0.5 units/acre (> 2 acre lot)	LDR
120	Commercial & Services	Sale of products and services	COMMERCIAL
130	Industrial	Manufacturing, design and assembly, finishing, etc. industrial parks	INDUSTRIAL
141	Roads	Divided Highways	ROADS
142	Airports	Runways, terminals, parking	AIRPORTS
143	Railroads	Terminals, parking repair areas	RAILROADS
144	Water and Sewage Treatment Facilities	Land and associated buildings	INSTITUTION
145	Waste Disposal Areas	Active landfills and junkyards	JUNKYARDS
146	Power Lines	Rights-of-way of 100 feet or more	PASTURE
147	Other	Water-based transportation facilities, commercial docks	COMMERCIAL
150	Mixed Urban	Light industrial/commercial uses that cannot be separated	COMMERCIAL
161	Developed Recreation	Urban parks, zoos, stadiums, golf courses, playfields, marinas	RECREATION
162	Urban Open Space	Vacant land	RECREATION
163	Cemeteries		RECREATION
170	Institutional	Educational, health, correctional, religious, military, etc.	INSTITUTION
210	Pasture	Hay fields, land not suitable for tillage	PASTURE
220	Cropland	Intensively farmed and tillable lands	CROPLAND
230	Orchards, Groves, Nurseries		ORCHARDS
240	Confined Feeding Operations	Animal raising in confined areas	CROPLAND
250	Idle Agriculture	Abandoned fields and orchards, etc.	BRUSH
310	Deciduous Forest	80% or greater deciduous species	FOREST

RIGIS Code	RIGIS Category	Explanation	MANAGE Category
320	Evergreen Forest	80% or greater evergreen species	FOREST
330	Mixed-Deciduous	50-80% deciduous dominant	FOREST
340	Mixed-Evergreen	50-80% evergreen dominant	FOREST
400	Brushland	Shrub and brush areas, cut over areas undergoing reforestation	BRUSH
500	Water	Reservoirs, lakes, ponds	WATER
600	Wetland	Forested and non-forested areas	WETLAND
710	Beaches		BARREN
720	Sandy Areas other than Beaches		BARREN
730	Rock Outcrop		BARREN
740	Strip Mines, Quarries, Gravel Pits		BARREN
750	Transitional Areas		Assigned to MD Res. Unless otherwise specified
760	Mixed Barren		BARREN

TABLE A2: MANAGE Land Use Aggregations based on RIGIS Codes

MANAGE Code	MANAGE Category	RIGIS Category and Code
1	HDR	High Density Residential (111)
2	MHDR	Medium High Density Residential (112)
3	MDR	Medium Density Residential (113)
4	MLDR	Medium Low Density Residential (114)
5	LDR	Low Density Residential (115)
6	COMMERCIAL	Commercial & Services (120)
		Other (147)
		Mixed Urban (150)
7	INDUSTRIAL	Industrial (130)
8	ROADS	Roads (141)
9	AIRPORTS	Airports (142)
10	RAILROADS	Railroads (143)
11	JUNKYARDS	Waste Disposal Areas (145)
12	RECREATION	Developed Recreation (161)
		Urban Open Space (162)
		Cemeteries (163)
13	INSTITUTION	Water and Sewage Treatment Facilities (144)
		Institutional (170)
14	PASTURE	Power Lines (146)
		Pasture (210)
15	CROPLAND	Cropland (220)
		Confined Feeding Operations (240)
16	ORCHARDS	Orchards, Groves, Nurseries (230)
17	BRUSH	Idle Agriculture (250)
		Brushland (400)
18	FOREST	Deciduous Forest (310)
		Evergreen Forest (320)
		Mixed-Deciduous (330)
		Mixed-Evergreen (340)

MANAGE Code	MANAGE Category	RIGIS Category and Code
19	BARREN	Beaches (710)
		Sandy Areas other than Beaches (720)
		Rock Outcrop (730)
		Strip Mines, Quarries, Gravel Pits (740)
		Mixed Barren (760)
20	WETLAND	Wetland (600)
21	WATER	Water (500)
22	Assigned to MD Res. Unless otherwise specified	Transitional Areas (750)

TABLE A3: Hydrologic Soil Groups of Rhode Island Soils Used in MANAGE
(Source: MANAGE AML and RIGIS Attribute Tables)

Abbreviation	Soil Name	Parent Material	SHWT	Excessive Permeable	Restrictive Layer	Erodible	RIGIS – Soil Hydro Group
Aa	Adrian	Organic	S				D
Af	Agawam	Outwash	D	Y			B
Bc	Birchwood	Lodgement Till	M		Y		C
Bh	Bridgehampton	Outwash	D	Y			B
Bm, Bn, Bo	Bridgehampton-Charlton Complex	Ablation Till	D				B
Br, Bs	Broadbrook	Lodgement Till with Eolian Mantle	D		Y		C
CB, CC, Ca	Canton and Canton-Charlton Complex	Ablation Till	D			Y	B
Cd, Ce, Ch, Ck	Canton-Charlton Complex	Ablation Till	D			Y	B
Co	Carlisle	Organic	S				D
Dc	Deerfield	Outwash	M	Y			B
Ef	Enfield	Outwash with an Eolian Mantle	D	Y			B
GB, Gh	Gloucester Complexes	Ablation Till	D	Y		Y	GB =A Gh = A
Hk, Hn	Hinckley & Hinckley Enfield Complex	Outwash	D	Y		Y	Hk =A Hn = B
Ip	Ipswich	Organic	S				D
Lg	Lippitt	Ablation Till	D	Y	Y		C
Ma, Mc	Mansfield	Lodgement Till	S		Y		D
Mk	Matunuck	Organic	S				D
Mm, MU	Merrimac	Outwash	D	Y			A
Na, Nb, Nc	Narragansett	Ablation Till	D				B
Ne, Nf, No	Newport	Lodgement Till	D		Y	Y	C
NP	Newport		D		Y		C
Nt	Ninigret	Outwash	M	Y			B
Pa, Pb, Pc	Paxton	Lodgement Till	D		Y		C
PD	Paxton		D		Y		C
Pm, Pn	Pittstown	Lodgement Till	M		Y		C
Pp	Pootatuck	Alluvial	M				B
Ps	Poquonock	Lodgement till with Sandy mantle	D		Y		C
Qo	Quonset	Outwash	D	Y			A
Ra, Rb	Rainbow	Lodgement till with eolian mantle	M		Y		C

Abbreviation	Soil Name	Parent Material	SHWT	Excessive Permeable	Restrictive Layer	Erodible	RIGIS – Soil Hydro Group
Rc	Raypol	Outwash with Eolian Mantle	S	Y			C
Re, Rf	Ridgebury	Lodgement Till	S		Y		C
Ru	Rippowam	Alluvial	S				C
	Rumney						C
Sb	Scarboro	Outwash	S	Y			D
Sc, Sd	Scio	Ablation Till with Eolian Mantle	M				B
Se, Sf	Stissing	Lodgement Till	S		Y		C
Ss	Sudbury	Outwash	M				B
St, Su, Sv	Sutton	Ablation Till	M				B
Tb	Tisbury	Outwash	M	Y			B
Wa	Walpole	Outwash	S				C
Wb, Wc, Wd	Wapping	Ablation Till with Eolian Mantle	M				B
Wg	Windsor	Outwash	D	Y			A
Wh, Wo, Wr	Woodbridge	Lodgement Till	M		Y		C

Notes:

1. If a soil type is present but not listed in this table then MANAGE assigns the following values to the soil: SHWT = U, Erodible = N, Excessively Permeable = N, Parent Material = Other and Restrictive Layer = N

2. All soils data is coded into the MANAGE AML, except for Hydro-Group. Hydro-group is defined in the imported RIGIS data.

3. Seasonal High Water Table (SHWT) Terms Definition

SHWT	Explanation	
S	Shallow	0-1.5 ft.
M	Moderate	1.5 – 3.5 ft.
D	Deep	> 6 ft.
U	Unknown	

4. Often in the MANAGE analysis soil hydrogroup is combined with SHWT to produce graphics depicting areas with poor drainage and high water table. This graphic is created by combining soil hydro-group and SHWT and then using the table and legend pallet below. A complete description of the procedure to produce these graphics is provided below:

1. In the soils data attribute table check to see if there is a field called: Hydro_group. RIGIS soils data contains this field. If this field is not in the attribute table then add a field for hydro-group and enter hydro-group information for each soil type using information contained in Table A3 (Hydrologic soil groups of Rhode Island soils used in MANAGE).

2. In the soils data attribute table check to see if there is a field called: CE_SHWT. This field is added to the attribute table when the MANAGE aml is run. If this field is not present in the attribute table then add a

field and name it CE_SHWT. Populate the field with CE_SHWT data located in Table A3 (Hydrologic soil groups of Rhode Island soils used in MANAGE).

3. Add a field into the soils data attribute table. The added field should be designated for text. Using the "calculate values" function (right click on the new field) add Hydro_group to CE_SHWT. The resulting values should look like: AD, DS, etc.
4. In the attribute table properties under symbology click on "unique value" then group each of the Hydro_group + CE_SHWT combinations as shown in the table below:

Hydro_group + CE_SHWT	Category/Description
AD, AU	Very rapid, >6 ft.
BD	Moderate, > 6 ft.
BM	Moderate, 1.5-3.5 ft.
CD	Slow, > 6 ft.
CM	Slow, 1.5-3.5 ft.
CS, DS	Slow/Wetland, 0-1.5 ft.
OU, CU, DU, VariableU	Variable/No Data

5. The soil drainage and depth to watertable groups are displayed using the legend as shown below. The colors are available in an ArcView Layer file (ArcView 9.0 will read AVL files but will not allow creation of new AVL files. Legend information may be saved in the layer format).

Legend

Soil drainage class & depth to watertable

- Very Rapid, > 6 ft.
- Moderate, > 6 ft.
- Moderate, 1.5 - 3.5 ft.
- Slow, > 6 ft.
- Slow, 1.5 - 3.5 ft.
- Slow/Wetland, 0 - 1.5 ft.
- Variable/No Data

APPENDIX B: SURFACE RUNOFF COEFFICIENTS

The runoff coefficient for each Soil/Land use combination is estimated using the formula presented by Adamus and Bergman (1993). This calculation is presented below.

$$C = LLC + (ULC - LLC) * X$$

C = runoff coefficient
LLC = lower limit runoff coefficient for a particular land use
ULC = upper limit runoff coefficient for a particular 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.

TABLE B1: Upper and Lower Limit Runoff Coefficients for each Soil/Land use combination

	Reference Values		Calculated Runoff Coefficient (C) Based on Soil Hydrogroup			
Land Use	**LLC**	**ULC**	**A**	**B**	**C**	**D**
HDR[a]	0.37	0.55	0.37	0.43	0.49	0.55
MHDR[a]	0.18	0.37	0.18	0.24	0.31	0.37
MDR[a]	0.15	0.18	0.15	0.16	0.17	0.18
MLDR[a]	0.12	0.15	0.12	0.13	0.14	0.15
LDR[a]	0.11	0.12	0.11	0.11	0.12	0.12
COMMERCIAL[b]	0.5	0.85	0.50	0.62	0.73	0.85
INDUSTRIAL[b]	0.5	0.85	0.50	0.62	0.73	0.85
ROADS[a]	0.7	0.82	0.70	0.74	0.78	0.82
AIRPORTS[a]	0.7	0.82	0.70	0.74	0.78	0.82
RAILROADS[a]	0.7	0.82	0.70	0.74	0.78	0.82
JUNKYARDS[a]	0.7	0.82	0.70	0.74	0.78	0.82
RECREATION[b]	0.1	0.3	0.10	0.17	0.23	0.30
INSTITUTION[c]	0.33	0.39	0.33	0.35	0.37	0.39
PASTURE[d]	0.05	0.25	0.05	0.12	0.18	0.25
CROPLAND[d]	0.15	0.5	0.15	0.27	0.38	0.50
ORCHARDS[d]	0.05	0.25	0.05	0.12	0.18	0.25
BRUSH[b]	0	0.1	0.00	0.03	0.07	0.10
FOREST[d]	0	0.1	0.00	0.03	0.07	0.10
BARREN[b]	0.05	0.8	0.05	0.30	0.55	0.80
WETLAND[c]	0	0.1	0.00	0.03	0.07	0.10
WATER	1	1	1.00	1.00	1.00	1.00

Notes:

[a] Calculation of ULC and LLC for Residential is based on Schueler's (1987) Simple Method:
$C = 0.05 + 0.9 I$
I = fraction of site imperviousness (e.g. 30% impervious would have I = 0.3)

The percentage of site imperviousness for each land use is provided in Appendix H. The fraction of site imperviousness (I) for the calculation of residential ULC and LLC was set at the updated MANAGE values (2003) for site impervious surface. The ULC for each residential land use was set as the residential LLC of the more intense residential development (ie: the ULC for MHDR is set as the LLC for HDR). The fraction of impervious surface for roads, airports, railroads and junkyards was set at theTR55 value for industrial to determine the ULC and commercial to determine the LLC.

[b] Based on data presented by Novotny and Olem (1994), p. 146.

[c] Assuming INSTITUTION is hydrologically similar to MHDR, unless otherwise specified by the user.

[d] Based on best professional judgement, using Curve Number Method as a guide.

[e] Generally WETLANDS will occur on D soils. It is assumed that wetlands are similar to forests on D soils, and for this reason wetlands are set using the same coefficients as the FOREST category.

[f] It is assumed that Evapotranspiration and surface runoff will vary through the year.

APPENDIX C: TOTAL PHOSPHORUS EXPORT COEFFICIENTS TO SURFACE WATER

Because phosphorus tends to adsorb to soil particles, little phosphorus reaches surface waters via groundwater seepage. Instead, the majority of phosphorus is transported to a receiving water body by runoff from rainfall events (some adsorbed to eroding soil, some in dissolved form). Additional phosphorus reaches surface water through overland flow of septic system effluent from malfunctioning septic systems throughout the watershed. The load from those malfunctioning septic systems located immediately adjacent (the riparian areas, assumed to be within 200 feet in this model or a user specified value) to the receiving water body is assumed to be higher than from those located farther away from surface waters. The relatively short distance and travel time from the riparian area septic systems to the surface water provides little or no opportunity for infiltration and adsorption of phosphorus to occur. Phosphorus loading from malfunctioning septic systems is calculated separately (Appendix G). The phosphorus loading factors listed below include contributions from diverse sources such as atmospheric deposition, fertilizers, and small animal waste. The loading factors on surface water reflect direct atmospheric deposition only.

Using a similar formula to that used to calculate the runoff coefficient, a "most likely" phosphorus export coefficient for a particular land use is calculated for each SOIL/LAND USE combination as:

$$PC = LPC + (HPC - LPC)*X$$

PC = "most likely" phosphorus export coefficient
LPC = low phosphorus export coefficient for a particular land use
HPC = high phosphorus export coefficient for a particular 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.

TABLE C1: Total Phosphorus Export Loading Coefficients (lb/acre/yr) for Each Soil/Land use Combination

	Reference Values		Calculated Runoff Coefficient (C) Based on Soil Hydro Group			
LAND USE CATEGORY	**LPC[a]**	**HPC[a]**	**A**	**B**	**C**	**D**
HDR[b]	2.1	3.1	2.1	2.4	2.8	3.1
MHDR[b]	1.0	2.1	1.0	1.4	1.7	2.1
MDR[b]	0.8	1.0	0.8	0.9	0.9	1.0
MLDR[b]	0.7	0.8	0.7	0.7	0.8	0.8
LDR[b]	0.6	0.7	0.6	0.6	0.7	0.7
COMMERCIAL	1	2.5	1.0	1.5	2.0	2.5
INDUSTRIAL	1	3.5	1.0	1.8	2.7	3.5
ROADS[c]	1	3.5	1.0	1.8	2.7	3.5
AIRPORTS[c]	1	3.5	1.0	1.8	2.7	3.5
RAILROADS[c]	1	3.5	1.0	1.8	2.7	3.5
JUNKYARDS[c]	1	3.5	1.0	1.8	2.7	3.5
RECREATION	0.5	1.5	0.5	0.8	1.2	1.5
INSTITUTION[d]	1.0	2.1	1.0	1.4	1.7	2.1
PASTURE[e]	0.3	1	0.3	0.5	0.8	1.0
CROPLAND[f]	0.5	4.5	0.5	1.8	3.2	4.5

	Reference Values		Calculated Runoff Coefficient (C) Based on Soil Hydro Group			
LAND USE CATEGORY	**LPC[a]**	**HPC[a]**	**A**	**B**	**C**	**D**
ORCHARDS	0.4	2	0.4	0.9	1.5	2.0
BRUSH	0.1	0.2	0.1	0.1	0.2	0.2
FOREST	0.1	0.2	0.1	0.1	0.2	0.2
BARREN	0.1	0.2	0.1	0.1	0.2	0.2
WETLAND	0	0	0.0	0.0	0.0	0.0
WATER[g]	0.3	0.3	0.3	0.3	0.3	0.3

[a] These phosphorus export coefficients were selected based on literature reviews by Rast and Lee (1983), Frink (1991), and Budd and Meals (1994), and by considering values given by RIDEM(1993b), Novotny and Olem (1994), and Stigall and others (1993), followed by discussions with Arthur J. Gold at the University of Rhode Island and with Kris Stewart at the Natural Resources Conservation Service of the United States Department of Agriculture

[b] Based on RIDEM (1993b) and assuming 45 inches of precipitation annually (Allen and others, 1966).

[c] Assuming these land uses are similar to INDUSTRIAL land use.

[d] Assuming INSTITUTION is similar to MHDR land use, unless otherwise specified by the user.

[e] If pasture is grazed, or if manure is applied, values will be higher (Reckhow and others (1980) show rotational grazing 0.9 lb/ac/yr; continuous grazing or forage fertilized 3.5 lb/ac/yr (p. 60, 97))

[f] Assuming no conservation tillage or terracing. If BMP's are in place, they will be applied.

[g] Atmospheric deposition only. Some authors (e.g., Reckhow and others (1980) and Horsley & Witten (1994)) suggest 3 different loading rates to the surface of a water body, depending upon the dominant land use in the watershed: forest, agricultural/rural, urban.

Loading from malfunctioning residential septic systems in the unsewered portion of the watershed is calculated as follows:

Septic systems within the 200 ft riparian buffer:

See Appendix G for the proportion of total number of septic systems which malfunction. The total phosphorus loading from malfunctioning riparian septic systems (within 200 ft of surface water) is set at 2.3 lb/cap/yr (15 mg/l and 50 gpd). If it assumed that there is 2.4 cap/residential septic system (1990 RI Census) then there is 5.5 lb P/malfunctioning residential septic system within the 200 ft. buffer.

Septic systems outside the riparian areas:

See Appendix G for proportion of total number of septic systems which malfunction. The total phosphorus loading from malfunctioning septic systems outside the riparian area is set at 1.15 lb/cap/yr. If it is assumed that there is a 2.4 cap/residential septic system (1990 RI Census), this comes to 2.8 lb P/malfunctioning residential septic system outside the 200 ft. buffer.

Note: Background concentration of P in RI Surface Water (no human influence) is ~ 5-10 ppb per Linda Green, URI Watershed Watch.

APPENDIX D: TOTAL NITROGEN EXPORT COEFFICIENTS TO SURFACE WATER

Although nitrogen is generally not considered to be the limiting nutrient in fresh water systems, it has been found to be the nutrient promoting growth of algae and aquatic plants in coastal waters. In order to estimate the total load of nitrogen reaching a coastal embayment, both contributions from surface runoff, as well as from groundwater seepage must be estimated. The surface runoff contribution of nitrogen can be calculated the same way as the phosphorus contribution (Appendix C). Like phosphorus, nitrogen can be transported from malfunctioning septic systems via overland flow to the receiving surface water. Estimation of the nitrogen load from malfunctioning septic systems is done in the same way as estimation of the phosphorus load, using soil properties and increasing the nitrogen loading for systems located within the riparian areas. The nitrogen loading factors listed below include contributions from diverse sources such as atmospheric deposition, fertilizers, and small animal waste. The loading factors on surface water reflect direct atmospheric deposition only. Using a similar formula to that used to calculate the runoff coefficient, a "most likely" nitrogen export coefficient for a particular land use is calculated for each SOIL/LAND USE combination as:

$$NC = LNC + (HNC - LNC) * X$$

NC = "most likely" nitrogen export coefficient
LNC = low nitrogen export coefficient for a particular land use
HNC = high nitrogen export coefficient for a particular 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.

TABLE D1: Total Nitrogen Export Loading Coefficients (lb/acre/yr) for each Soil/Land use Combination

	Reference Values		Calculated Runoff Coefficient (C) Based on Soil Hydro Group			
LAND USE CATEGORY	**LNC[a]**	**HNC[a]**	**A**	**B**	**C**	**D**
HDR[b]	7	10.2	7.0	8.1	9.1	10.2
MHDR[b]	3.3	7	3.3	4.5	5.8	7.0
MDR[b]	2.8	3.3	2.8	3.0	3.1	3.3
MLDR[b]	2.3	2.8	2.3	2.5	2.6	2.8
LDR[b]	2.1	2.3	2.1	2.2	2.2	2.3
COMMERCIAL	2	20	2.0	8.0	14.0	20.0
INDUSTRIAL	2	15	2.0	6.3	10.7	15.0
ROADS[c]	2	20	2.0	8.0	14.0	20.0
AIRPORTS[c]	2	20	2.0	8.0	14.0	20.0
RAILROADS[c]	2	20	2.0	8.0	14.0	20.0
JUNKYARDS[c]	2	20	2.0	8.0	14.0	20.0
RECREATION	1.5	4	1.5	2.3	3.2	4.0
INSTITUTION[d]	3.3	7	3.3	4.5	5.8	7.0
PASTURE[e]	2	5.5	2.0	3.2	4.3	5.5
CROPLAND[f]	4	50	4.0	19.3	34.7	50.0
ORCHARDS	4	35	4.0	14.3	24.7	35.0

LAND USE CATEGORY	Reference Values LNC[a]	HNC[a]	Calculated Runoff Coefficient (C) Based on Soil Hydro Group A	B	C	D
BRUSH	0.9	2.9	0.9	1.6	2.2	2.9
FOREST	0.9	2.9	0.9	1.6	2.2	2.9
BARREN	0.9	2.9	0.9	1.6	2.2	2.9
WETLAND	0	0	0.0	0.0	0.0	0.0
WATER[g]	8	8	8.0	8.0	8.0	8.0

[a] These nitrogen export coefficients were selected based on literature reviews by Rast and Lee (1983), Frink (1991), and Budd and Meals (1994), and by considering values given by RIDEM(1993b), Novotny and Olem (1994), and Stigall and others (1993), followed by discussions with Arthur J. Gold at the University of Rhode Island

[b] Based on RIDEM (1993b) and assuming 45 inches of precipitation annually (Allen and others, 1966).

[c] Assuming these land uses are similar to COMMERCIAL land uses.

[d] Assuming INSTITUTION is similar to MHDR land use, unless otherwise specified by the user.

[e] If pasture is grazed, or if manure is applied, values will be higher (Reckhow and others (1980) show rotational grazing 7.0 lb/ac/yr; continuous grazing or forage fertilized 27.0 lb/ac/yr (p. 60, 97))

[f] Assuming no conservation tillage or terracing. If BMP's are in place, they will be applied.

[g] Atmospheric deposition only based on northeastern U.S. (Ollinger et al. 1993 and Yang 1996). Some authors (e.g., Reckhow and others (1980) and Horsley & Witten (1994)) suggest 3 different loading rates to the surface of a water body, depending upon the dominant land use in the watershed: forest, agricultural/rural, urban.

Loading from malfunctioning residential septic systems in the unsewered portion of the watershed is calculated as follows:

Septic systems within the 200 ft riparian buffer:

See Appendix G for the proportion of total number of septic systems which malfunction. The total nitrogen loading from malfunctioning riparian septic systems (within 200 ft of surface water) is set at 7.0 lb/cap/yr. If it assumed that there is 2.4 cap/residential septic system (1990 RI Census) then there is 16.8 lb N/malfunctioning residential septic system within the 200 ft. buffer.

Septic systems outside the riparian areas:

See Appendix G for proportion of total number of septic systems which malfunction. The total nitrogen loading from malfunctioning septic systems outside the riparian area is set at 5.6 lb/cap/yr. If it is assumed that there is a 2.4 cap/residential septic system (1990 RI Census), this comes to 13.4 lb N/malfunctioning residential septic system outside the 200 ft. buffer.

Note:
Background concentration of N in RI Surface Water (no human influence) is ~ 0.25 ppm based on sampling from ponds whose watersheds are subject to little human influence (data from Watershed Watch 1994, Linda Green). [Art Gold suggests 0.2 to 0.35 mg/l].

APPENDIX E: NITRATE-NITROGEN LOADING TO GROUNDWATER

The long-term water quality of an aquifer can be inferred from the quality of the recharge water (Hantzsche and Finnemore, 1992). Using a mass-balance approach, the average concentration of nitrate found in the infiltrating recharge water can be estimated by dividing the total N loading from various and diverse land use above the aquifer by the recharge volume from precipitation and such artificial sources as septic systems (similar to Frimpter and others (1990); Horsley & Witten (1994); and several other models). There are many complex mechanisms in the nitrogen cycle which are not directly accounted for. However, because nitrate-nitrogen generally behaves conservatively once it reaches the water table, some simplifying assumptions can be made.

$$\text{Average N concentration} = \frac{\text{Annual N load from diverse land uses}}{\text{Annual recharge (natural + septic systems)}}$$

Sources of nitrogen to groundwater include:

i. Septic systems
ii. Lawn fertilizers
iii. Agricultural fertilizers
iv. Large animals (cows, horses)
v. Pet waste
vi. Stormwater infiltration

Sources of recharge include:

i. Precipitation
ii. Septic systems

A) LOAD

Calculate total annual nitrogen load to groundwater, based on land use:

1. Septic systems:

Estimate the total number of residential septic systems in unsewered areas based on housing density. Commercial, Industrial, and Institution areas are all treated as MDR.

Assumptions: 2.4 cap/dwelling unit (Appendix F).
7 lb N/person/yr leaves the septic tank.
50 gal/person/day.
90% of N leaches to the groundwater (Siegrist and Jenssen, 1989).

In Rhode Island where conventional ISDS are typically buried deeper, and gravel fill is brought in, 90% may be a more accurate estimate. This is supported by Lamb and others, 1988).

If only RIGIS land use data is available, estimate the number of homes based on the residential land use category, excluding areas served by sewer systems (see table below). MANAGE assumes a 100% occupancy rate, to determine the worst potential impact (this may not be appropriate for all watersheds).

Table E1: Estimation of the Number of Septic Systems per Acre Based on Land Use

Land Use	Mean Dwelling Unit Density (unit/acre) (Number of Septic Systems/acre)	Assumptions
HDR	8.00	
MHDR	3.60	
MDR	1.00	
MLDR	0.50	
LDR	0.20	
Other:		
COMMERCIAL	1.00	Assume these are similar to MD Residential. Also, we
INDUSTRIAL	1.00	Assume that septic system use in recreational areas is
RECREATION	0.50	Seasonal (6 months out of the year).
INSTITUTION	1.00	

2. Lawns

Estimate lawn area in watershed:

Table E2: Estimation of the Fraction of Lawn Area Associated with Each Land use

Land Use	Fraction of Land Use Attributed to Lawn Area
HDR	0.25
MHDR	0.35
MDR	0.50
MLDR	0.35
LDR	0.25
COMMERICAL	0.05
INDUSTRIAL	0.10
RECREATION	0.70
	(golf courses to be estimated separately)
INSTITUTION	0.25

Assumptions: 75% of residents apply lawn fertilizer.
Fertilizer is applied at a rate of 175 lb N/ac/yr (4 lb/1000 sq. ft./yr)
Leaching rate is 6%, yielding a load of 10.5 lb N/ac/yr leached to the groundwater.
(most models use significantly higher leaching rates (30 to 60 %); a lower estimate is used here due to low leaching rates found by Gold and others (1990), and Morton and

others (1988) in Rhode Island outwash soils, and assuming some mismanagement, such as over-watering, bare spots, compacted soil, and improper fertilizer application.

3. Agriculture (CROPLAND and ORCHAR land use)

Assume a fertilizer application rate of 215 lb N/ac/yr, 30% of which leaches to the groundwater.

4. Pet Waste in Residential Areas

0.41 lb N/person/yr is assumed to leach to the groundwater from pet waste. (Koppleman, 1978)

5. Forests and Unfertilized Lawns

Gold and others (1990) show a loading of 1.2 lb/ac/yr from forest (FOREST, PASTURE and BRUSH land use) and unfertilized lawn (unfertilized lawn area = 25% of total lawn area).

B) RECHARGE

Calculate total annual groundwater recharge, based on land use:

1) Natural recharge:

Average annual infiltration = Annual precipitation - Annual ET - Annual RO

I. Average annual precipitation = 45 inches (Allen and others, 1966)
II. Average annual evapotranspiration (ET) = 18 inches (Johnston and Dickerman, 1985)
III. Average annual run off (RO) is calculated from runoff coefficients for each land use category.
Annual RO = (Annual PPT)*(RO coefficient (C))

Wetlands represent a complex system of interaction between surface and groundwater. It is assumed that there is no runoff from a wetland area. The equation above then implies that wetlands recharge 27 inches to groundwater, which is almost never the case. It is assumed that groundwater generally flows into wetlands, rather than water from wetlands percolating to groundwater. If this assumption is made the total area of wetlands in the watershed X 27 inches must be subtracted from the total volume of average annual recharge to groundwater.

2) Recharge from septic systems

Recharge from septic systems = (total # of septic systems) (2.4 cap/dwelling) (50 gal/cap/day) (365 days/yr)

APPENDIX F: 1990 RI CENSUS FIGURES

	Number persons/dwelling unit[a]	Vacancy Rate[b]
State of RI	2.6	8.8%
Bristol County	2.6	5.4%
Kent County	2.6	5.2%
Newport County	2.5	12.8%
Providence County	2.5	6.9%
Washington County	2.6	21.2%

[a] Based on number of occupied (vs. vacant) dwelling units. Does not include seasonally occupied dwelling units.
[b] Vacancy rate includes seasonally occupied dwelling units.
Source: 1990 Census Data from RI Department of Administration, One Capitol Hill, Providence, RI 02908.
Note: We will use 2.6 persons/dwelling unit. The two counties, Newport and Providence, with an average of 2.5 persons/dwelling unit (reflecting a higher number of apartments, which tend to have fewer occupants) are heavily sewered. Occupancy rates may be further refined using US Census block data and building permits.
[c] Values for occupancy rate are often adjusted in the MANAGE model based on the input of local officials and the census figures.

APPENDIX G: CALCULATION OF POTENTIAL SEPTIC SYSTEM MALFUNCTION

The number of septic systems estimated to malfunction throughout the unsewered portion of the watershed will be based on the soil on which they are sited. A malfunctioning system is defined as a system that produces surface ponding, leakage of septic effluent or improper treatment with lack of separation distance to groundwater. Malfunction of conventional septic systems is likely if they are sited in soils with a permeability of < 0.2 in/hr at a depth of about 20 to 60 inches, these soils are termed restrictive. Restrictive Rhode Island soils include:

Birchwood	Poquonock
Broadbrook	Rainbow
Lippitt	Ridgebury
Mansfield	Newport
Stissing	Paxton
Woodbridge	Pittstown

Of the restrictive soils, seven have a high water table (depth to groundwater of 3.5 feet or less) and six of those with high water table have a perched water table. Eleven of the twelve soils are in hydrologic soil group C and one is in hydrologic soil group D (Mansfield).

Table G1: SUMMARY OF PROPERTIES OF "RESTRICTIVE" SOILS (Source: Tables 25 and 26 from Rector, 1981)

Soil Name (Hydro Group)	Depth (inches) at which Permeability < 0.2 in/hr	High Water Table Depth (ft)	Water Table Type	Months with High Water Table
Birchwood (C)	24-60	1.5-3.5	Perched	Nov-Apr
Broadbrook (C)	36-60	>6		
Lippitt (C)	20-40 (BEDROCK)	>6		
Mansfield (D)	15-60	0.0-0.5	Apparent	Nov-Jul
Newport (C)	24-60	>6		
Paxton (C)	23-60	>6		
Pittstown (C)	28-60	1.5-3.0	Perched	Nov-Apr
Poquonock (C)	28-60	>6		
Rainbow (C)	23-60	1.5-3.5	Perched	Nov-Apr
Ridgebury (C)	20-60	0.0-1.5	Perched	Nov-May
Stissing (C)	15-60	0.0-1.5	Perched	Oct-May
Woodbridge (C)	32-60	1.5-3.0	Perched	Nov-Apr

Because of the limitations just described, the proportion of septic systems sited in these soils which are assumed to malfunction will be set at 65%. For septic systems sited in all other soils, the failure rate will be assigned by hydrologic soil group:

Table G2: Septic System Malfunction Rate for Non-restrictive Soils

Soil Hydro Group	Malfunction Rate
A & B	10%
C	30%
D	50%

The user can change these failure rates if necessary. These percentages are based on Nizeyimana and others (1996).

Due to uncertainties in this function it is rarely utilized in MANAGE analysis, mapping is often used instead of this function to determine areas at risk for septic system failure.

The proportion of nutrients present in the septic tank effluent that eventually reach the receiving water body depends upon whether the malfunctioning system is within the 200 ft. riparian area. Within the riparian area, we will assume that 100% of the phosphorus and nitrogen leaving the malfunctioning septic system will reach the receiving water. Outside the buffer, 50% of the phosphorus and 80% of the nitrogen is assumed to reach the surface water. The likelihood of some treatment occurring during percolation after leaving the malfunctioning septic system increases with distance from the surface water. The higher loading rate of 80% for nitrogen is used because the typical nitrogen removal rate for a functioning conventional septic system is 20% (Siegrist and Jenssen, 1989), so this is the best that could realistically be expected from a malfunctioning system.

Table G3: Amount of Nitrogen and Phosphorus Estimated to Reach a Receiving Water Body Based on Location

Nutrient Load Leaving Septic Tank	Nutrient Load Reaching Surface Water Body	
	For Systems in the 200 ft riparian buffer	For Systems outside the 200 ft riparian buffer
7.0 lb N/cap/yr	7.0 lb N/cap/yr (100%)	5.6 lb N/cap/yr (80%)
2.3 lb P/cap/yr	2.3 lb P/cap/yr (100%)	1.15 lb P/cap/yr (50%)

(See Appendix I for a summary of values and their sources on which these numbers are based)

APPENDIX H: IMPERVIOUSNESS OF DEVELOPED LAND

Table H1: Estimated Percent Impervious Surface for Land Use Used in SWAP Report (Original MANAGE Impervious Values)

Land Use	Low	High	Original Values used in MANAGE (and SWAP reports)
	Estimated % Impervious		
HDR[a]	65	80	72
MHDR[a]	38	65	50
MDR[a]	20	38	30
MLDR[a]	12	20	16
LDR[a]	5	12	8
COMMERCIAL[b]	50	94	72
INDUSTRIAL[b]	50	94	72
ROADS[c]	72	85	72
AIRPORTS[c]	72	85	72
RAILROADS[c]	72	85	72
JUNKYARDS[c]	72	85	72
RECREATION	5	28	10
INSTITUTION[d]	38	65	50

Notes:
[a] Based on estimate of impervious fraction used in TR55 (1975).
[b] Calculated from low and high runoff coefficients estimated from Novotny and Olem (1994), p. 146.
[c] Based on TR55. Low is that of Industrial and high is commercial.
[d] Assuming INSTITUTION is hydrologically similar to MHD residential, unless otherwise specified by the user.

Table H2: Updated Estimated Percent Impervious Surface for Land Use Used in MANAGE

Land Use Category	TR 55 USDA	New Jersey DEP[a]	Center for Watershed Protection[b]	Value Used in MANAGE[c] (updated 2003)
	Estimated Site Impervious (%)			
HDR (1/8 acre lot)	65	59	33	55
MHDR (1/4 acre lot)	38	39	28	36
1/3 acre lot	30	34		
1/2 acre lot	25	27	21	
MDR (1 acre lot)	20	18	14	14
MLDR (2 acre lot)	12	12	11	11
LDR (> 2 acre lot)		9.6		9
AGRICULTURE			2	
OPEN URBAN			9	
TOWN HOUSE			41	
MULTIFAMILY			44	
COMMERCIAL	85		72	72
INDUSTRIAL	72		53	54
ROADS			80	72
AIRPORTS				72
RAILROADS				72
JUNKYARDS				72
RECREATION				10
INSTITUTION			34	34

[a] New Jersey DEP
[b] CWP 2002. The Watershed Treatment Model. Ellicott City MD. www.stormwatercenter.net
[c] Values for impervious surface are in the MANAGE code.

APPENDIX I: SEPTIC SYSTEM PARAMETERS

		SOURCE
Residential Wastewater Flow	66 gal/cap/day	Brown and Assoc. (1980)
	45 gal/cap/day	USEPA (1980)
	45 gal/cap/day	Canter and Knox (1985)
	65 gal/cap/day	Frimpter and others (1990)
	33.8 gal/cap/day (=128 liters)	Gold and others (1990)
	45 gal/cap/day (=170 liters)	Postma and others (1992)
	55 gal/cap/day	Horsley & Witten (1994)
	45 - 60 gal/cap/day	RIDEM (Galen Howard, 1995)
Number of people/dwelling	3.5 cap/dwelling	Brown and Assoc. (1980)
	2.7 cap/dwelling	Valiela and Costa (1988)
	3.0 cap/dwelling	Buzzards Bay Project (1990)
	2.7 cap/dwelling	Frimpter and others (1990) (as cited in Weiskel and Howes (1991)
	3.0 cap/dwelling	Horsley & Witten (1994)
Phosphorus in effluent	16.4 mg/l (mean from lit review) (3.3 lb/cap/yr @ 66 gcd)	Brown and Assoc. (1980)
	3 - 5 g/cap/day (in wastewater)	USEPA (1980)
	18 - 29 mg/l (in wastewater)	USEPA (1980)
	15 mg/l (2 lb/cap/yr @ 45 gcd)	Canter and Knox (1985)
	1.4 kg/cap/yr (3.1 lb/cap/yr)	Valiela and Costa (1988)
	1.45 kg/cap/yr (3.2 lb/cap/yr)	Olem and Flock (1990)
	13 mg/l (1.8 lb/cap/yr @ 45 gcd)	Postma and others (1992)
	0.5 - 1.5 kg/system/yr (1.1 - 3.3 lb/system/yr)	Budd and Meals (1994)
	7 - 40 mg/l	Budd and Meals (1994)
	3.2 lb/cap/yr	Horsley & Witten (1994)
Nitrogen in effluent	44.6 mg/l (mean from lit review)	Brown and Assoc. (1980)
	11.2 g/cap/day (9 lb/cap/yr)	Brown and Assoc. (1980)
	6 - 17 g/cap/day (in wastewater)	USEPA (1980)
	35 - 100 mg/l (in wastewater)	USEPA (1980)
	[USEPA assumes 10% removal in septic tank; Gold and others (1990) found up to 21% removal]	
	40 mg/l (5.5 lb/cap/yr @ 45 gcd)	Canter and Knox (1985)
	3.8 kg/cap/yr (8.4 lb/cap/yr)	Valiela and Costa (1988)
	6.72 lb/cap/yr	Buzzards Bay Project (1990)
	40 mg/l (Nitrate-N) (includes 5 mg/l background concentration)	Frimpter and others (1990)
	5 lb/cap/yr	Frimpter and others (1990)
	3.1 kg/cap/yr (7 lb/cap/yr)	Gold and others (1990)
	30 - 60 mg/l	Budd and Meals (1994)
	33.9 mg/l (WHPA)	Horsley & Witten (1994)

	(5.7 lb/cap/yr @ 55 gcd)	
	40 mg/l	(Buttermilk Bay)
	(6.7 lb/cap/yr @ 55gcd)	
	30 - 80 mg/l	RIDEM (Galen Howard, 1995)
	5 - 10 lb/cap/yr	RIDEM (Galen Howard, 1995)
	59.3 mg/l	Gold (unpublished?)
	(8 lb/cap/yr @ 45 gcd)	
Conversion to Nitrate during infiltration		
	50%	RIDEM
	100%	Frimpter and others (1990)

OTHER sources of effluent (e.g. Commercial, Institution, etc.) are described in Tables 4-6 to 4-8 in USEPA (1980)

APPENDIX J: BEST MANAGEMENT PRACTICES (BMP'S)

The MANAGE model assumes that no BMP's are applied unless they are specified by the user. There are many and varied methods which are used to reduce pollutant loadings to water resources. Five general categories of BMP's are available in MANAGE:

1) Agricultural Management: conservation techniques such as cover crops, terracing, reduced tillage, improved nutrient (fertilizer) management.

2) Lawn Management: improved lawn maintenance, including improved fertilizer management, as well as avoiding overwatering, and reducing bare spots and compaction.

3) Stormwater Management: Water quality enhancement basins, which follow Rhode Island Dept. of Environmental Management design guidelines. Basins which were designed only for flood control generally do not meet this specification.

4) Imperviousness Reduction through Creative Design: Landscape design using cluster developments, shared parking, etc.

5) Septic System (On-Site Sewage Disposal System, or OSDS) Alternatives:
   a) On-site denitrification systems (alternative to the conventional OSDS)
   b) Improved maintenance (frequent pumping), regular inspection to reduce failure
   c) Sewering

Agricultural Management

Table J1: Reductions in Surface Runoff, Phosphorus and Nitrogen by Agricultural BMPs

BMPs	Reduction to Surface Water (%)	Reduction to Groundwater (%)	Literature Source
Cover crops Reduced tillage Diversions and swales Terraces Filter strips Nutrient management[a]	20% Surface Runoff 20% TP 20% TN	20% TN	Representative value based on data presented in Pennsylvania State University, 1992, and on estimates from USDA, NRCS and URICE.

There is a wide variation in the possible nutrient loading reductions due to varying methods, as well as soil type, topography, etc.

[a]The amount of fertilizer applied to agricultural areas may be reduced in Section 3 of the MANAGE model (Data Processing and Refinement), but doing so will give reductions only in nitrogen leaching to groundwater and will apply to all cropland and orchards. Applying agricultural BMP's and reducing the fertilizer applied in Section 3 is invalid, because reductions will be taken in two places for only one BMP.

Lawns

Table J2: Reductions in Surface Runoff, Phosphorus and Nitrogen by Lawn Care BMPs

BMPs	Reduction to Surface Water (%)	Reduction to Groundwater (%)	Literature Source
Reduced fertilizer applications Reduced occurrence of overwatering Mower height at 2-3" Use of slow release fertilizers Leave clippings on the lawn	Unknown	80% TN	Morton and others (1988)

Stormwater Management

Table J3: Reduction in Surface Runoff, Phosphorus and Nitrogen by Stormwater Management BMPs

BMPs	Reduction to Surface Water (%)	Reduction to Groundwater (%)	Literature Source
	With maintenance		
Wet Basins Extended Detention Ponds Infiltration Practices Basins, trenches, dry wells Vegetated Filter Strips Grassed Swales	80% TSS 45% TP 45% TN	Increased risk of TN leaching to groundwater, depending upon type of management	Representative values based on data presented in USEPA, 1993
	Without maintenance		
	Unknown TSS 10% TP 10% TN		

Note:
Any chosen method must comply with RIDEM guidelines for water quality enhancement basin design.

Creative Land Development Design

Table J4: Reduction in Surface Runoff, Phosphorus and Nitrogen by Creative Land Development Design

BMPs		Literature Source
Creative Landscaping to reduce imperviousness, e.g. shared parking, use of geotextiles, cluster developments	20% reduction in impervious areas (therefore reduction in surface runoff and nutrient loading)	City of Olympia, 1996

Septic Systems

Table J5: Reduction in Surface Runoff, Phosphorus and Nitrogen by Alternative/Innovative Septic Systems

BMPs		Literature Source
Denitrification Systems	50% TN reduction to groundwater	Siegrist and Jenssen, 1989
Improved Maintenance	Eliminate failures	
Sewering	Eliminate leakage failures	

REFERENCES

Adamus, C. and M. Bergman. 1993. *Development of a nonpoint source pollution load screening model.* Technical Memorandum No. 1. Department of Surface Water Programs, St. Johns River Water Management District, Palatka, FL. 39 pp.

Allen, W. B., G. W. Hahn, and R. A. Brackley. 1966. *Availability of Ground Water Upper Pawcatuck River Basin Rhode Island.* U. S. Geological Survey Water-Supply Paper 1821. Washington, DC. 66 pp.

Brown, K. W., and Associates. 1980. *An Assessment of the Impact of Septic Leach Fields, Home Lawn Fertilization and Agricultural Activities on Groundwater Quality.* New Jersey Pinelands Commission. 104 pp.

Budd, L. F. and D. W. Meals. 1994. *Lake Champlain Nonpoint Source Pollution Assessment.* Lake Champlain Basin Program Technical Report Nos. 6A and 6B. Burlington, VT.

Buzzards Bay Project. 1990. *Buzzards Bay Comprehensive Conservation and Management Plan.* USEPA and Massachusetts Office of Environmental Affairs, Marion, MA. 215 pp.

Canter, L. W. and R. C. Knox. 1985. *Septic Tank System Effects on Ground Water Quality.* Lewis Publishers, Chelsea, MI. 336 pp.

Chow, V. T. 1964. *Handbook of Applied Hydrology.* McGraw-Hill, New York, NY.

City of Olympia. 1996. Impervious Surface Reduction Study, Executive Summary. Olympia Public Works Department, Olympia, WA. 30 pp.

Frimpter, M. H., J. J. Donohue IV, and H. V. Rapacz. 1990. *A Mass-Balance Model for Predicting Nitrate in Ground Water.* Journal of New England Water Works Association 104 (4): 214-231.

Gold, A. J., W. R. DeRagon, W. M. Sullivan, and J. L. Lemunyon. 1990. *Nitrate-nitrogen losses to groundwater from rural and suburban land uses.* J. of Soil and Water Conservation 45: 305-310.

Hantzsche, N. N. and E. J. Finnemore. 1992. *Predicting Ground-Water Nitrate-Nitrogen Impacts.* Groundwater 30(4): 490-499.

Horsley & Witten, Inc. 1994. *Coastal Protection Program: Workshops in Innovative Management Techniques for Estuaries, Wetlands, and Near Coastal Waters.* Office of Wetlands, Oceans and Watersheds, U. S. Environmental Protection Agency, Washington, DC.

Johnston, H. E. and D. C. Dickerman. 1985. *Hydrology, Water Quality, and Ground-Water-Development Alternatives in the Chipuxet Ground-Water Reservoir, Rhode Island.* U. S. Geological Survey Water-Resources Investigations Report 84-4254. Providence, RI. 100 pp.

Koppleman, L. 1978. *The Long Island comprehensive waste treatment management plan. Vol. I and II.* Nassau-Suffolk Regional Planning Board, Hauppauge, NY. 206 pp.

Lamb, B., A. J. Gold, G. Loomis, and C. McKiel. 1988. Evaluation of Nitrogen Removal Systems for On-Site Sewage Disposal. On-Site Wastewater Treatment Vol. 5. **In** *Proceedings of the Fifth National Symposium on Individual and Small Community Sewage Systems.* American Society of Agricultural Engineers, Chicago, IL, December 14-15, 1987, pp. 151-160. ASAE Publication No. 10-87.

Morton, T. G., A. J. Gold, and W. M. Sullivan. 1988. *Influence of Overwatering and Fertilization on Nitrogen Losses from Home Lawns*. J. of Environmental Quality 17(1): 124-130.

Nizeyimana, E., G. W. Petersen, M. C. Anderson, B. M. Evans, J. M. Hamlett, and G. M. Baumer. 1996. *Statewide GIS/Census Data Assessment of Nitrogen Loading from Septic Systems in Pennsylvania.* J. of Environmental Quality 25:346-354.

Novotny, V. and H. Olem. 1994. *Water quality: prevention, identification, and management of diffuse pollution.* Van Nostrand Reinhold, New York, NY. 1054 pp.

Olem, H. and G. Flock, eds. 1990. *Lake and Reservoir Restoration Guidance Manual.* 2nd edition. EPA 440/4-90-006. Prep. by N. Am. Lake Management Soc. for U. S. Environmental Protection Agency, Washington, DC.

Ollinger, S.V., J. Aber, G. Lovett, S. Millham, R. Lathrop and J. Ellis. 1993. *A Spatial Model of Atmospheric Deposition for the Northeastern U.S.* Ecological Applications 3 (3): 459-472.

Pennsylvania State University. 1992. *Nonpoint Source Database*. Pennsylvania State University, Department of Agricultural and Biological Engineering, University Park, PA. Reported in USEPA. 1993. *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters.* 840-B-92-002, USEPA Office of Water, Washington, DC. 836 pp.

Postma, F. B., A. J. Gold, and G. W. Loomis. 1992. *Nutrient and Microbial Movement from Seasonally-Used Septic Systems.* J. of Environmental Health 55 (2): 5-10.

Rast, W. and G. F. Lee. 1983. *Nutrient Loading Estimates for Lakes*. J. of Environmental Engineering 109 (2): 502-517.

Reckhow, K. H., M. N. Beaulac, and J. T. Simpson. 1980. *Modeling Phosphorus Loading and Lake Response Under Uncertainty: A Manual and Compilation of Export Coefficients*. U. S. Environmental Protection Agency, EPA 440/5-80-011. 214 pp.

Rector, D. D. 1981. *Soil Survey of Rhode Island*. USDA Soil Conservation Service in cooperation with Rhode Island Agricultural Experiment Station. 200 pp.

Richardson, C. J. 1985. *Mechanisms controlling phosphorus retention capacity in wetlands*. Science 228:1424 - 1427.

RIDEM. 1993a. *Nonpoint Source Pollution Management Plan for the Pawtucket Water Supply Watersheds*. Rhode Island Department of Environmental Management, Office of Environmental Coordination. Providence, RI. 50 pp.

RIDEM. 1993b. *Stormwater Design and Installation Standards Manual*. Rhode Island Department of Environmental Management and Rhode Island Coastal Resources Management Council. Providence, RI. 92 pp.

Schueler, T. R. 1987. *The Simple Method in controlling urban runoff: a practical manual for planning and designing urban BMP's*. Metropolitan Washington Council of Governments, Water Resources Planning Board, Washington, DC. 275 pp.

Siegrist, R. L. and P. D. Jenssen. 1989. *Nitrogen removal during wastewater infiltration as affected by design and environment factors*. Proceedings of 6th Northwest On-Site Wastewater Treatment Short Course, September 18-19, 1989, University of Washington, Seattle, Washington. p. 304 - 318.

Stigall, E., L. C. Linker, and A. S. Donigian. 1993. *Application of the Hydrologic Simulation Program-Fortran (HSPF) Model to the Potomac River Basin* **in** Proceedings Watershed '93, A National Conference on Watershed Management, March 21-24. Alexandria, VA, p.767-775.

U. S. Environmental Protection Agency. 1980. *Onsite Wastewater Treatment and Disposal Systems.* EPA 625/1-80-012. USEPA Office of Water Program Operations, Washington, DC. 391 pp.

U. S. Environmental Protection Agency. 1993. *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters.* 840-B-92-002, USEPA Office of Water, Washington, DC. 836 pp.

U. S. Soil Conservation Service, 1975. Urban Hydrology for Small Watersheds. USDA Soil Conservation Service, Technical Release No. 55, Washington, DC.

Valiela, I. and J. E. Costa. 1988. *Eutrophication of Buttermilk Bay, a Cape Cod Coastal Embayment: Concentrations of Nutrients and Watershed Nutrient Budgets.* Environmental Management 12 (4): 539-553.

Weiskel, P. K. and B. L. Howes. 1991. *The Use of Loading Models to Predict Nitrogen Inputs to Coastal Waters.* NWWA Eastern Focus Conference, Oct 29-31, 1991.

Weiskel, P. K. and B. L. Howes. 1992. *Differential transport of sewage-derived nitrogen and phosphorus through a coastal watershed.* Environmental Science Technology 26 (2): 352-360.

Yang, X., D.R. Miller, S. X. Xu, L.H. Yang, H. Chen, and H. Nikolaidis. 1996. *Spatial and Temporal Variations of Atmospheric Deposition in Interior and Coastal Connecticut.* Atmospheric Environment 30 (22): 3801-3810.

Appendix D:
MANAGE Pollution Risk Indicator

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 analy-sis. 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	**1.1.1** *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]	
	Low	Med – High	Extreme
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				
	Low	Med	High	Extreme
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			
	Low	Med	High	Extreme
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				

1.2 *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 (25th = low, 50th moderate, 75th = high, 95th = 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:

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

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

For example:

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

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 (25th, 50th, 75th and 95th) 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.