Application of the Watershed Treatment Model to the City Of Newport's Drinking Water Supply Reservoirs

Summary Report

Rhode Island Department of Environmental Management

Office of Water Resources

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Overview

The Rhode Island Department of Environmental Management (RIDEM), has initiated a Total Maximum Daily Load (TMDL) study to address drinking water and aquatic life use impairments on all nine Newport Water Supply Reservoirs. All nine reservoirs exhibit degraded water quality, showing moderate to severe nutrient enriched conditions that include elevated levels of both total phosphorus and total nitrogen, total organic carbon (TOC), chlorophyll-*a*, low water clarity, frequent algal and cyanobacteria blooms, and low levels of dissolved oxygen. As part of TMDL development, RIDEM will establish total phosphorus targets that will apply to all reservoirs. These targets will then be used to establish allowable loadings of phosphorus to each water supply reservoir.

The TMDLs include calculations of annual nutrient (both P and N) loads to each reservoir from both the watershed (external loading) and from within the waterbody itself (internal loading). This document summarizes results from the application of the Watershed Treatment Model to the nine reservoirs and the Maidford River to estimate external watershed loadings of total phosphorus and total nitrogen to each waterbody. Internal cycling of phosphorus from reservoir sediments may make up a part of the total phosphorus load to various reservoirs, particularly those deeper reservoirs having a small contributing drainage area and periods of anoxia in the hypolimnion. Estimation of internal loads were made by RIDEM and are addressed in a separate report.

Outline of Watershed Treatment Model and Intended Application

The Watershed Treatment Model (WTM) 2013, developed by the Center for Watershed Protection (http://www.cwp.org/pollution-calculators/), is a spreadsheet-based model used to calculate annual pollutant loads (total phosphorus, total nitrogen, total suspended sediment, and fecal coliform) and runoff volumes as well as estimate benefits from a wide range of stormwater runoff and pollutant removal practices. Recent watershed restoration projects undertaken by the Town of Middletown and City of Newport (add references to the documents) have included application of the WTM to the Maidford River, Paradise Brook, St. Marys Pond, and Watson Reservoir. To be consistent with these studies, RIDEM has chosen to also use the WTM as its watershed modeling tool. It has been re-applied to St. Marys Pond, Watson Reservoir, the Maidford River, and Paradise Brook and newly applied to Nonquit Pond, Lawton Valley Reservoir, Sisson Pond, North and South Easton Ponds, and Gardiner and Paradise Ponds.

RIDEM's primary purpose for applying the WTM is to evaluate sources/source categories of nutrients generated from various land uses within each watershed and acquire information as to the relative importance (i.e. magnitude) of each source. The WTM results may be used to help apportion the allowable annual nutrient loads to various source categories (i.e. urban runoff, onsite wastewater treatment systems (OWTS), agricultural, etc.) within each reservoir's catchment. Application of the WTM model has an additional purpose in providing a secondary estimate of the annual total phosphorus and total nitrogen load to each reservoir (corroborating estimates based on reservoir volumes and ambient water quality results). The TMDL will set allowable loads for total phosphorus only. Total suspended sediment (TSS) and fecal coliform loads to the reservoirs were not modeled.

Two versions of the WTM are available for download. The "Off the Shelf" version incorporates a user interface, and is more user-friendly because many of the calculations are hidden and the interface allows the user to hide all but the necessary input sections. In the "Custom" version, equations are more visible to the user and includes a companion "Users Guide" document. RIDEM applied the "Custom" version of the WTM to the Newport reservoirs and the Maidford River.

For the WTM application to the Newport reservoirs, three workbooks were populated with information- the Primary Source workbook, Secondary Source workbook, and to the extent information was available, the Existing Management Practices Workbook. The primary source workbook evaluates nutrient sources from land use categories within the watershed using a combination of event mean concentrations and annual loading rates. The secondary source workbook evaluates sources of nutrients from onsite sewage disposal systems, stream erosion, sanitary and combined sewer overflows, illicit connections, livestock, road sanding, and other non-point related sources. The existing management workbook estimates nutrient loads from existing turf management (i.e. fertilizer application on both residential and commercial-industrial land uses), pet waste, street sweeping and catch basin cleanouts, and existing BMPs).

Model Sources of Data and Quality Assurance

All sources of data and assumptions regarding information used in the WTM applications to the Newport reservoir watersheds are presented in Appendix A and B of this report. A reference list documenting literature-derived sources of information that were utilized in the model applications is located at the end of this report. In general, event mean concentration and annual loading rate information was gleaned from sources of data restricted to the Northeast. Other information, primarily required for the secondary source and existing conditions workbooks, were derived from a variety of sources including municipal MS4 annual reports, statewide documentation, communication with municipal officials, and BPJ of RIDEM staff. Where possible, local Information and or studies/research were used to evaluate nutrient loadings from both septic systems and residential fertilizer applications. At present, existing BMP's in the watershed were not thought to be of sufficient quantity or size to reduce the surface loadings of phosphorus and nitrogen to the reservoirs and were therefore not included in this analysis.

The following steps were taken to ensure that quality data was used to populate the WTM:

1. All land use-related information was acquired from RIDEM's Supervising GIS Specialist.

2. The Event Mean Concentration and Annual Loading Rate values chosen were taken from multiple sources and from as many local (Northeast) studies as possible.

3. Field visits and aerial photo analysis was used to further delineate/refine agricultural land uses in each reservoirs watershed.

4. Model cells entered/changed by RIDEM staff have been colored light red.

5. Separate DEM staff reviewed model input data for any inconsistencies, input errors, etc.

Model Setup and Input Files

Primary Source Workbook

Pollutant loads from both urbanized and rural land uses are calculated in the 'Primary Source Workbook' of the WTM. The WTM uses the Simple Method (Schueler 1987) to calculate loads from urban stormwater runoff and area loading factors (i.e. annual loading rates) to calculate loads from rural land uses. All Primary Source Workbook model inputs for each watershed are presented in Appendix A of this report. The majority of information needed for this workbook includes but is not limited to: land use category area and percent impervious cover for each land use category, event mean concentration data (for urban land uses), annual pollutant loading rates (for rural land uses), total watershed area, stream length, average depth to groundwater, soils information, land use specific runoff coefficients, and mean annual rainfall.

Land use categories in all modeled watersheds were initially determined from the RIGIS database and agricultural land uses were further refined based on extensive fieldwork and site investigation by RIDEM staff. The following land use categories were modeled in the Newport reservoirs: low, medium-low, medium-high, and high density residential, commercial, institutional, transportation (all roadways), waste disposal, forest, wetland, brushland, meadow, hay, nursery, orchard, vineyard, tree farm, pasture, quarry, row crop, managed grass/turf, transitional, open water. Open water is generally the surface area of open water, inclusive of the primary reservoir, in the watershed and is used to determine atmospheric deposition of nitrogen and phosphorus. Percent impervious cover for each land use was determined from the RIGIS database.

For the impoundments located on Aquidneck Island, the NWS Newport airport station provided rainfall data. Annual average rainfall based on the period of record is 46.33 inches and the annual rainfall reported in 2015 was 39.75 inches. For Watson Reservoir and Nonquit Pond, the NWS Tiverton station provided rainfall data. Annual average rainfall based on the period of record is 48.54 inches and the annual rainfall reported in 2015 was 48.09 inches. Annual rainfall for the period of record is what is reported in Tables 1-9 (i.e. the WTM was run using annual average precipitation for the period of record).

All primary source workbook input data for each watershed are displayed in Tables 1-9. As stated earlier, the source of information (i.e. values used for event mean concentration values and annual loading rate values) are presented in Appendix A of this report.

Table 1. Watershed Treatment Model Primary Source Worksheet Input-Nonquit Pond.

WTM Land Use Category	Acres	Percent Impervious Cover	Percent Turf Cover	Total Phosphorus EMC Concentration (mg/l)	Total Nitrogen EMC Concentration (mg/l)	Total Phosphorus Annual Loading Rate (lbs/acre)	Total Nitrogen Annual Loading Rate (lbs/acre)
Low Density Residential	2.3	12	71	0.36	2.25		
Medium Low Density Residential	17.6	35	52	0.41			
Medium Density Residential	271.6	22	62	0.41	3.92		
Medium High Density Residential	19.9	25	60	0.41			
High Density Residential	3.1	42	46	0.43	3.41		
Commercial	31.4	61	31	0.28	2.49		
Institutional	5.7	51	40	0.28	2.49		
Transportation	55	76	0	0.35	2.8		
Waste Disposal	52	25	0	0.34	1.74		
Forest	2766.8	0	0			0.2	2.5
Wetland	52.4	0	0			0.03	0.4
Brushland	189.3	2	0			0.63	5.1
Hay	179.5	1	0			0.63	5.1
Meadow	70	1	0			0.63	5.1
Nursery	0		0			0.94	15.1
Orchard/Vineyard/ Tree Farm	21.6	6	0			0.63	5.1
Pasture	125.4	4	0			0.63	5.1
Quarry	17.6	0	0			0.63	5.1
Row Crop	138.8	0	0			0.94	15.1
Managed Grass	15	6	0			0.63	5.1
Transitional	3.6	2	0			0.63	5.1
Open Water	200					0.142	8.0

Partitioning Coefficients for Rural and Forest Land	**Pollutant**	Total Nitrogen	Total Phosphorus
	Fraction as Storm Load	50 %	70%
Watershed Data			
Annual Rainfall (inches)	**49 inches**		
Watershed Area (acres)	**4238 acres**		
Total Stream Length in Watershed (miles)	**16 miles**		
Average Depth to Groundwater (ft)	**< 3 ft**		

Soils Information	**Runoff Coefficient**			
Hydrologic Soil Group (Fraction as a %)	Impervious	Turf	Forest	Rural
A (1%)	0.96	0.22	0.11	0.26
B (12%)	0.96	0.25	0.14	0.28
C (64%)	0.96	0.51	0.16	0.32
D (23%)	0.96	0.65	0.20	0.35

Land Use Specific Runoff Coefficients

Soil Group	Meadow	Hay	Transitional	Orchard/ Vineyard/ Tree Farm	Pasture	Row Crop	Managed Grass
A	0.22	0.27	0.22	**0.27**	0.25	0.27	0.45
B	0.28	0.43	0.28	**0.43**	0.34	0.43	0.45
C	0.35	0.61	0.35	**0.61**	0.42	0.61	0.63
D	0.40	0.67	0.40	**0.67**	0.50	0.67	0.74

Table 2. Watershed Treatment Model Primary Source Worksheet Input-Watson Reservoir.

WTM Land Use Category	Acres	Percent Impervious Cover	Percent Turf Cover	Total Phosphorus EMC Concentration (mg/l)	Total Nitrogen EMC Concentration (mg/l)	Total Phosphorus Annual Loading Rate (lbs/acre)	Total Nitrogen Annual Loading Rate (lbs/acre)
Low Density Residential	104.5	15	68	0.36	2.29		
Medium Low Density Residential	92.8	13	70	0.41	3.92		
Medium Density Residential	112.5	18	66	0.41	3.92		
Commercial		66	27	0.28	2.50		
Institutional		0		0.28	2.50		
Transportation	31.8	66	0	0.35	2.8		
Forest	969	0	0			0.2	2.5
Wetland	37.8	0	0			0.03	0.4
Brushland	27.8	4	0			0.63	5.1
Hay	122.4	1	0			0.63	5.1
Meadow	106.3	1	0			0.63	5.1
Nursery	12.1	7	0			0.94	15.1
Orchard/Vineyard/ Tree Farm	90.6	4	0			0.63	5.1
Pasture	22.3	2	0			0.63	5.1
Row Crop	173.5	3	0			0.94	15.1
Managed Grass	0.7	1	0			0.63	5.1
Open Water	382.5					0.142	8.0

Partitioning Coefficients for Rural and Forest Land	**Pollutant**	Total Nitrogen	Total Phosphorus
	Fraction as Storm Load	50 %	70%

Watershed Data	**Value**
Annual Rainfall (inches)	49 inches
Watershed Area (acres)	2293 acres
Total Stream Length in Watershed (miles)	6.0 miles
Average Depth to Groundwater (ft)	< 3 ft

Soils Information	**Runoff Coefficient**			
Hydrologic Soil Group (Fraction as a %)	Impervious	Turf	Forest	Rural
A (0%)	0.96	0.22	0.11	0.26
B (1%)	0.96	0.25	0.14	0.28
C (79%)	0.96	0.51	0.16	0.32
D (20%)	0.96	0.65	0.20	0.35

Land Use Specific Runoff Coefficients

Soil Group	Meadow	Hay	Nursery	Orchard/ Vineyard/ Tree Farm	Pasture	Row Crop	Managed Grass
A	0.22	0.27	0.22	**0.27**	0.25	0.27	0.45
B	0.28	0.43	0.28	**0.43**	0.34	0.43	0.45
C	0.35	0.61	0.35	**0.61**	0.42	0.61	0.63
D	0.40	0.67	0.40	**0.67**	0.50	0.67	0.74

Table 3. Watershed Treatment Model Primary Source Worksheet Input-Lawton Valley Reservoir.

WTM Land Use Category	Acres	Percent Impervious Cover	Percent Turf Cover	Total Phosphorus EMC Concentration (mg/l)	Total Nitrogen EMC Concentration (mg/l)	Total Phosphorus Annual Loading Rate (lbs/acre)	Total Nitrogen Annual Loading Rate (lbs/acre)
Low Density Residential	2.3	12	70	0.36	2.25		
Medium Low Density Residential	17.6	35	52	0.41	3.92		
Medium Density Residential	71.7	19	65	0.41	3.92		
Medium High Density Residential	139.3	29	56	0.41	3.92		
Commercial	4.3	67	27	0.28	2.49		
Transportation	22.7	82	0	0.35	2.84		
Forest	155.3		0			0.20	2.5
Wetland	7.2		0			0.03	0.4
Brushland	22		0			0.63	5.1
Meadow	7.3	2	0			0.63	5.1
Hay	10.2	1	0			0.63	5.1
Nursery	10	19	0			0.94	15.1
Golf Course	80.3	3	0			0.63	5.1
Pasture	9.3	7	0			0.63	5.1
Row Crop	87.9	10	0			0.94	15.1
Transitional	10.1	3	0			0.63	5.1
Institutional	3.5	38	0			0.63	5.1
Open Water	81.2					0.142	7.5

Partitioning Coefficients for Rural and Forest Land	**Pollutant**	Total Nitrogen	Total Phosphorus
	Fraction as Storm Load	50 %	70%

Watershed Data	**Value**
Annual Rainfall (inches)	46 inches
Watershed Area (acres)	742 acres
Total Stream Length in Watershed (miles)	1 mile
Average Depth to Groundwater (ft)	< 3 ft

Soils Information	**Runoff Coefficient**			
Hydrologic Soil Group (Fraction as a %)	Impervious	Turf	Forest	Rural
A (0%)	0.96	0.22	0.11	0.26
B (0%)	0.96	0.25	0.14	0.28
C (98%)	0.96	0.51	0.16	0.32
D (2%)	0.96	0.65	0.20	0.35

Land Use Specific Runoff Coefficients

Soil Group	Brushland/ Meadow	Hay	Nursery	Golf Course	Pasture	Row Crop	Institutional/ Transitional
A	0.22	0.27	0.27	0.45	0.25	0.27	0.45
B	0.28	0.43	0.43	0.45	0.34	0.43	0.45
C	0.35	0.61	0.61	0.63	0.42	0.61	0.63
D	0.40	0.67	0.67	0.74	0.50	0.67	0.74

Table 4. Watershed Treatment Model Primary Source Worksheet Input-Sisson Pond.

WTM Land Use Category	Acres	Percent Impervious Cover	Percent Turf Cover	Total Phosphorus EMC Concentration (mg/l)	Total Nitrogen EMC Concentration (mg/l)	Total Phosphorus Annual Loading Rate (lbs/acre)	Total Nitrogen Annual Loading Rate (lbs/acre)
Low Density Residential	1.8	24	61	0.36	2.25		
Medium Density Residential	24	13	70	0.41	3.92		
Medium High Density Residential	15.2	24	61	0.41	3.92		
Commercial	5.6	31	55	0.27	2.1		
Transportation	2.5	80	0				
Forest	14.4	2	0			0.2	2.5
Wetland	63.4	0	0			0.03	0.4
Brushland	4.1	1	0			0.63	5.1
Hay	6.7	2	0			0.63	5.1
Meadow	20.1	1	0			0.63	5.1
Nursery	88.3	1	0			0.94	15.1
Pasture	33.7	1	0			0.63	5.1
Row Crop	55.5	2	0			0.94	15.1
Open Water	66.9					0.142	7.5

Partitioning Coefficients for Rural and Forest Land	Pollutant	Total Nitrogen	Total Phosphorus
	Fraction as Storm Load	50 %	70%

Watershed Data	Value
Annual Rainfall (inches)	46 inches
Watershed Area (acres)	402 acres
Total Stream Length in Watershed (miles)	0 miles
Average Depth to Groundwater (ft)	< 3 ft

Soils Information	Runoff Coefficient			
Hydrologic Soil Group (Fraction as a %)	Impervious	Turf	Forest	Rural
A (0%)	0.96	0.22	0.11	0.26
B (0%)	0.96	0.25	0.14	0.28
C (85%)	0.96	0.51	0.16	0.32
D (15%)	0.96	0.65	0.20	0.35

Land Use Specific Runoff Coefficients

Soil Group	Brushland	Hay	Nursery		Pasture	Row Crop	Meadow
A	0.22	0.27	0.27		0.25	0.27	0.45
B	0.28	0.43	0.43		0.34	0.43	0.45
C	0.35	0.61	0.61		0.42	0.61	0.63
D	0.40	0.67	0.67		0.50	0.67	0.74

Table 5. Watershed Treatment Model Primary Source Worksheet Input-St. Marys Pond.

WTM Land Use Category	Acres	Percent Impervious Cover	Percent Turf Cover	Total Phosphorus EMC Concentration (mg/l)	Total Nitrogen EMC Concentration (mg/l)	Total Phosphorus Annual Loading Rate (lbs/acre)	Total Nitrogen Annual Loading Rate (lbs/acre)
Low Density Residential	1.8	41	48	0.36	2.29		
Medium Low Density Residential	3.4	29	57	0.41	3.92		
Medium Density Residential	57.8	20	64	0.41	3.92		
Medium High Density Residential	5.4	31	55	0.41	3.92		
High Density Residential	47.8	40	48	0.43	3.41		
Commercial	4	51	39	0.28	2.10		
Transportation	13.7	78	0	0.35	2.30		
Forest	85.1	1	0			0.2	2.5
Wetland	2.3	0	0			0.03	0.4
Brushland	5.7	1	0			0.63	5.1
Meadow	6.3	2	0			0.63	5.1
Hay	18.3	0	0			0.63	5.1
Nursery	20	0	0			0.94	15.1
Golf Course	38.6	5	0			0.63	5.1
Pasture	6.0	1	0			0.63	5.1
Row Crop	114.2	1	0			0.94	15.1
Open Water	112					0.142	7.5

Partitioning Coefficients for Rural and Forest Land	**Pollutant**	Total Nitrogen	Total Phosphorus
	Fraction as Storm Load	50 %	70%

Watershed Data	**Value**
Annual Rainfall (inches)	46 inches
Watershed Area (acres)	546 acres
Total Stream Length in Watershed (miles)	0.35 miles
Average Depth to Groundwater (ft)	< 3 feet

Soils Information	**Runoff Coefficient**			
Hydrologic Soil Group (Fraction as a %)	Impervious	Turf	Forest	Rural
A ()	0.96	0.22	0.11	0.26
B ()	0.96	0.25	0.14	0.28
C (100%)	0.96	0.51	0.16	0.32
D ()	0.96	0.65	0.20	0.35

Land Use Specific Runoff Coefficients

Soil Group	Brushland	Hay	Nursery	Golf Course	Pasture	Row Crop	Meadow
A	0.22	0.27	0.27	0.25	0.25	0.27	0.45
B	0.28	0.43	0.43	0.25	0.34	0.43	0.45
C	0.35	0.61	0.61	0.51	0.42	0.61	0.63
D	0.40	0.67	0.67	0.65	0.50	0.67	0.74

Table 6. Watershed Treatment Model Primary Source Worksheet Input-North and South Easton Ponds.

WTM Land Use Category	Acres	Percent Impervious Cover	Percent Turf Cover	Total Phosphorus EMC Concentration (mg/l)	Total Nitrogen EMC Concentration (mg/l)	Total Phosphorus Annual Loading Rate (lbs/acre)	Total Nitrogen Annual Loading Rate (lbs/acre)
Low Density Residential	7.5	15	68	0.43	3.41		
Medium Low Density Residential	6.1	16	68	0.41	3.92		
Medium Density Residential	180.6	17	66	0.41	3.92		
Medium High Density Residential	560.1	34	53	0.41	3.92		
High Density Residential	142.4	41	47	0.36	2.29		
Commercial	547.7	66	28	0.28	2.10		
Institutional	69.2	41	47				
Transportation	143	85	0	0.35	2.30		
Forest	109.6	1	0			0.2	2.5
Wetland	54.3	2	0			0.03	0.4
Brushland	204.3	2	0			0.63	5.1
Meadow	54	3	0			0.63	5.1
Hay	111.8	2	0			0.63	5.1
Nursery	69	20	0			0.94	15.1
Managed Grass/Turf	40.8	11	0			0.63	5.1
Pasture	13.7	1	0			0.63	5.1
Row Crop	56.7	6	0			0.94	15.1
Transitional	7.4	0					
Open Water	257.7					0.142	7.5

Partitioning Coefficients for Rural and Forest Land	**Pollutant**	Total Nitrogen	Total Phosphorus
	Fraction as Storm Load	50 %	70%

Watershed Data	**Value**
Annual Rainfall (inches)	46 inches
Watershed Area (acres)	2636 acres
Total Stream Length in Watershed (miles)	9 miles
Average Depth to Groundwater (ft)	< 3 feet

Soils Information	**Runoff Coefficient**			
Hydrologic Soil Group (Fraction as a %)	Impervious	Turf	Forest	Rural
A (0%)	0.96	0.22	0.11	0.26
B (0%)	0.96	0.25	0.14	0.28
C (83%)	0.96	0.51	0.16	0.32
D (17%)	0.96	0.65	0.20	0.35

Land Use Specific Runoff Coefficients

Soil Group	Brushland	Hay	Nursery	Managed Grass/Turf	Pasture	Row Crop	Meadow
A	0.22	0.27	0.27	0.25	0.25	0.27	0.45
B	0.28	0.43	0.43	0.25	0.34	0.43	0.45
C	0.35	0.61	0.61	0.51	0.42	0.61	0.63
D	0.40	0.67	0.67	0.65	0.50	0.67	0.74

Table 7. Watershed Treatment Model Primary Source Worksheet Input-Gardiner Pond.

WTM Land Use Category	Acres	Percent Impervious Cover	Percent Turf Cover	Total Phosphorus EMC Concentration (mg/l)	Total Nitrogen EMC Concentration (mg/l)	Total Phosphorus Annual Loading Rate (lbs/acre)	Total Nitrogen Annual Loading Rate (lbs/acre)
Low Density Residential	2.4	5	76	0.36	2.29		
Medium Density Residential	0.1	14	69	0.41	3.92		
Commercial	1.3	41	47	0.27	2.33		
Transportation	0.9	77	0	0.35	2.89		
Wetland	3.6	0	0			0.03	0.4
Brushland	20.0	0	0			0.63	5.1
Meadow	5.8	0	0			0.63	5.1
Hay	8.3	0	0			0.63	5.1
Row Crop	5.7	0	0			0.94	15.1
Open Water	98.1					0.142	7.5

Partitioning Coefficients for Rural and Forest Land	**Pollutant**	Total Nitrogen	Total Phosphorus
	Fraction as Storm Load	50 %	70%

Watershed Data	**Value**
Annual Rainfall (inches)	46 inches
Watershed Area (acres)	146 acres
Total Stream Length in Watershed (miles)	0 miles
Average Depth to Groundwater (ft)	< 3 feet

Soils Information	**Runoff Coefficient**			
Hydrologic Soil Group (Fraction as a %)	Impervious	Turf	Forest	Rural
A (0%)	0.96	0.22	0.11	0.26
B (0%)	0.96	0.25	0.14	0.28
C (93%)	0.96	0.51	0.16	0.32
D (7%)	0.96	0.65	0.20	0.35

Land Use Specific Runoff Coefficients

Soil Group	Brushland	Hay	Row Crop	Meadow			
A	0.22	0.27	0.27	0.45			
B	0.28	0.43	0.43	0.45			
C	0.35	0.61	0.61	0.63			
D	0.40	0.67	0.67	0.74			

Table 8. Watershed Treatment Model Primary Source Worksheet Input-Paradise Pond.

WTM Land Use Category	Acres	Percent Impervious Cover	Percent Turf Cover	Total Phosphorus EMC Concentration (mg/l)	Total Nitrogen EMC Concentration (mg/l)	Total Phosphorus Annual Loading Rate (lbs/acre)	Total Nitrogen Annual Loading Rate (lbs/acre)
Low Density Residential	26.7	15	68	0.36	2.29		
Medium Low Density Residential	30	19	65	0.36	2.29		
Medium Density Residential	59.6	20	64	0.41	3.92		
Medium High Density Residential	16.7	25	60	0.41	3.92		
Commercial	2.3	72	22	0.27	2.33		
Institutional	7.1	41	47	0.27	2.30		
Transportation	11.6	69	0	0.35	2.89		
Forest	112.3	0	0			0.20	2.5
Wetland	5.4	0	0			0.03	0.4
Brushland	50.1	1	0			0.63	5.1
Hay	17	1	0			0.63	5.1
Meadow	73.1	0	0			0.63	5.1
Nursery	5.8	2	0			0.94	15.1
Orchard/Vineyard/ Tree Farm	5.8	2	0			0.63	5.1
Pasture	54	0	0			0.63	5.1
Quarry	7.6	4	0			0.63	5.1
Row Crop	31.9	5	0			0.94	15.1
Open Water	31.0					0.142	7.5

Partitioning Coefficients for Rural and Forest Land	**Pollutant**	Total Nitrogen	Total Phosphorus
	Fraction as Storm Load	50 %	70%

Watershed Data	**Value**
Annual Rainfall (inches)	46 inches
Watershed Area (acres)	548 acres
Total Stream Length in Watershed (miles)	3 miles
Average Depth to Groundwater (ft)	< 3 feet

Soils Information	**Runoff Coefficient**			
Hydrologic Soil Group (Fraction as a %)	Impervious	Turf	Forest	Rural
A (0%)	0.96	0.22	0.11	0.26
B (9%)	0.96	0.25	0.14	0.28
C (83%)	0.96	0.51	0.16	0.32
D (8%)	0.96	0.65	0.20	0.35

Land Use Specific Runoff Coefficients

Soil Group	Brushland	Hay	Row Crop	Meadow	Orchard	Pasture	Row Crop
A	0.22	0.27	0.27	0.45	0.27	0.25	0.27
B	0.28	0.43	0.43	0.45	0.43	0.34	0.43
C	0.35	0.61	0.61	0.63	0.61	0.42	0.61
D	0.40	0.67	0.67	0.74	0.67	0.50	0.67

Table 9. Watershed Treatment Model Primary Source Worksheet Input-Maidford River.

WTM Land Use Category	Acres	Percent Impervious Cover	Percent Turf Cover	Total Phosphorus EMC Concentration (mg/l)	Total Nitrogen EMC Concentration (mg/l)	Total Phosphorus Annual Loading Rate (lbs/acre)	Total Nitrogen Annual Loading Rate (lbs/acre)
Low Density Residential	41.9	14	69	0.36	2.29		
Medium Low Density Residential	26.1	17	66				
Medium Density Residential	309.6	22	62	0.39	3.92		
Medium High Density Residential	85	25	60				
High Density Residential	47	14	69	0.43	3.41		
Commercial	30.2	45	44	0.27	2.33		
Transportation	53.6	81	0	0.27	2.33		
Institutional	13.3	37	51	0.35	2.89		
Forest	61.5	1	0			0.2	2.5
Wetland	49.4	0	0			0.03	0.4
Brushland	141.7	1	0			0.63	5.1
Hay	151.4	1	0			0.63	5.1
Meadow	91	1	0			0.63	5.1
Nursery	84.4	17	0			0.94	15.1
Orchard/Vineyard/ Tree Farm	97.1	1	0			0.63	5.1
Pasture	14.4	1	0			0.63	5.1
Quarry	3.3	10	0			0.63	5.1
Row Crop	148.2	17	0			0.94	15.1
Managed Grass	50.9	7	0			0.63	5.1
Open Water	1.6					0.142	7.5

Partitioning Coefficients for Rural and Forest Land	**Pollutant**	Total Nitrogen	Total Phosphorus
	Fraction as Storm Load	50 %	70%

Watershed Data	**Value**
Annual Rainfall (inches)	46 inches
Watershed Area (acres)	1502 acres
Total Stream Length in Watershed (miles)	4.0 miles
Average Depth to Groundwater (ft)	< 3 feet

Soils Information	**Runoff Coefficient**			
Hydrologic Soil Group (Fraction as a %)	Impervious	Turf	Forest	Rural
A ()	0.96	0.22	0.11	0.26
B (1%)	0.96	0.25	0.14	0.28
C (96%)	0.96	0.51	0.16	0.32
D (3%)	0.96	0.65	0.20	0.35

Land Use Specific Runoff Coefficients

Soil Group	Brushland/ Meadow	Hay	Nursery	Orchard/ Vineyard/ Tree Farm	Pasture	Row Crop	Quarry Managed Grass
A	0.22	0.27	0.22	**0.27**	0.25	0.27	0.45
B	0.28	0.43	0.28	**0.43**	0.34	0.43	0.45
C	0.35	0.61	0.35	**0.61**	0.42	0.61	0.63
D	0.40	0.67	0.40	**0.67**	0.50	0.67	0.74

Secondary Source and Existing Conditions Workbooks

As stated earlier, the secondary source workbook of the WTM evaluates nutrient loads from various sources including onsite wastewater disposal systems (both surface and groundwater loads), sanitary sewer overflows (SSO's), combined sewer overflows (CSO's), illicit connections, channel erosion, livestock (hobby farms), road sanding, and other user-identified non-point sources of pollution. SSO, CSO, and illicit connections are not applicable to the Newport reservoir applications of the WTM. Channel erosion was not modeled, and no specific non-point sources of pollution were noted in any of the watersheds. The existing management practices workbook evaluates nutrient loads from existing turf (lawn) conditions and management practices (namely-fertilizer application) on residential and commercial and industrial properties, pet waste education, street sweeping, catch basin cleanouts, etc.

All secondary source and existing conditions workbook input data for each watershed are displayed in Tables 10-18. Appendix B provides additional information regarding assumptions made with respect to OWTS loadings and turf management.

Table 10. Watershed Treatment Model Secondary Source and Existing Conditions Worksheet Input-Nonquit Pond.

SECONDARY SOURCES			
General Sewage Use Data			
# Dwelling Units of (Type)	***Individuals/Dwelling Unit***	***Water Use (gpcd)***	***Wastewater Characteristics***
Single family- 448	2.2	57.5	**TN- 60 mg/l**
Multi-family- 7	6.6	57.5	**TP- 11 mg/l**
Commercial- 32	6	10	
Public- 5	35	10	
Onsite Sewage Disposal Systems			
Unsewered Dwelling Units (% of total)- 100%			
Percent of Septic Systems <100 feet to waterway- 2%			
Failure Rates- 3.3%			
Soils- Clay/Mixed Soils			
System Type	***% of Systems***	***TN Removal Efficiency (%)***	***TP Removal Efficiency (%)***
Conventional	92.5%	25%	25%
Intermittent Sand Filter	3.75%	55%	36%
Advantex	3.75%	55%	36%
Current Septic System Management- Medium (Inspection at installation and education to encourage ongoing maintenance)			
Typical separation from groundwater- < 3 feet			
Density (#/acre)- < 1/acre			
SSOs- none			
CSOs- none			
Illicit Connections- none			
Urban Channel Erosion- only applies to stream reaches in urbanized portions of the watershed			
Livestock- 25 horses, assumed 25% exposed to erosion. TN (102 lbs/animal/yr) TP (42 lbs/animal/yr)			
Marinas- none			
Road Sanding- 3795 lbs/yr and 56% fraction of roads open section			
Non-Stormwater Point Sources- none in watershed			
EXISTING MANAGEMENT PRACTICES- Residential Turf Area- 102 acres-assume just over 50% fertilize			
Turf Condition and Management Practices-Residential			
Percent of lawns bare/compacted- 5%, 4 applications per year at 91 lbs N/acre			
Percent of homes < 10 years old- 10%			
Percent of lawn area highly managed- 10%			
95% Slow release, 5% P free			
Pet Waste Education Program in Place- YES			
Number of Dwelling Units- 492			
Awareness of Message (Fraction of population)- 8% (Brochure- assumed mailing from Town)			
Street Sweeping			
Sweeper Type- mechanical			
Acres Swept- 55acres			
Frequency- monthly (only option is monthly or weekly)			
Technique- 0.5 (no parking restrictions or operator training)			
STRUCTURAL STORMWATER MANAGEMENT PRACTICES			
Type	**Total Drainage Area**	**Impervious Area**	
Catch Basin Clean-outs			
Impervious Area Captured-55 acres			
Clean-out Frequency- semi-annual (options are semi-annual or monthly)			
Disposal Technique-0.5 (Landfill disposal)			

Table 11. Watershed Treatment Model Secondary Source and Existing Conditions Worksheet Input- Watson Reservoir.

SECONDARY SOURCES			
General Sewage Use Data			
# Dwelling Units of (Type)	***Individuals/Dwelling Unit***	***Water Use (gpcd)***	***Wastewater Characteristics***
Single family- 204	2.2	57.5	**TN- 60 mg/l**
Multi-family-			**TP- 11 mg/l**
Commercial- 7	3	10	
Public-			
Onsite Sewage Disposal Systems			
Unsewered Dwelling Units (% of total)- 100%			
Percent of Septic Systems <100 feet to waterway- 2%			
Failure Rates-3.3%			
Soils- Clay/Mixed Soils			
System Type	***% of Systems***	***TN Removal Efficiency (%)***	***TP Removal Efficiency (%)***
Conventional	92.5%	25%	25%
Intermittent Sand Filter	3.75%	55%	36%
Advantex	3.75%	55%	36%
Current Septic System Management- Medium (Inspection at installation and education to encourage ongoing maintenance			
Typical separation from groundwater- < 3feet			
Density (#/acre)- <1/acre			
SSOs- none			
CSOs- none			
Illicit Connections-none			
Urban Channel Erosion- applies only to stream reaches in urban portions of the watershed			
Livestock-none			
Marinas- not applicable			
Road Sanding- 2190 lbs applied. 50% roads are open section			
Non-Stormwater Point Sources- not applicable			
EXISTING MANAGEMENT PRACTICES			
Turf Condition and Management Practices-Residential- residential turf area- 111.10 acres, assume just over 50% fertilize			
Percent of lawns bare/compacted- 5%, 4 applications per year,			
Percent of homes < 10 years old- 20%			
Percent of lawn area highly managed- 10%			
Estimated average fertilizer application rate is 91 lbs N/acre			
Pet Waste Education Program in Place- NO- Little Compton			
Awareness of Message (Fraction of population)			
Street Sweeping			
Sweeper Type- Mechanical			
Acres Swept- 32			
Frequency- monthly			
Technique- 0.5 (no parking restrictions and no operator training)			
STRUCTURAL STORMWATER MANAGEMENT PRACTICES			
Type	**Total Drainage Area**	**Impervious Area**	
Catch Basin Clean-outs			
Impervious Area Captured- 32 acres			
Clean-out Frequency- monthly (annual not an option)			
Disposal Technique- 1.0 No prohibitions			

Table 12. Watershed Treatment Model Secondary Source and Existing Conditions Worksheet Input- Lawton Valley Reservoir.

SECONDARY SOURCES			
General Sewage Use Data			
# Dwelling Units of (Type)	***Individuals/Dwelling Unit***	***Water Use (gpcd)***	***Wastewater Characteristics***
Single family- 333	2.4	57.5	**TN- 60 mg/l**
Multi-family-			**TP- 11 mg/l**
Commercial- 4	9	10	
Public-			
Onsite Sewage Disposal Systems			
Unsewered Dwelling Units (% of total)- 100%			
Percent of Septic Systems <100 feet to waterway- 1%			
Failure Rates- 3.3%			
Soils- Clay/Mixed Soils			
System Type	***% of Systems***	***TN Removal Efficiency (%)***	***TP Removal Efficiency (%)***
Conventional	92.5%	25%	25%
Intermittent Sand Filter	3.75%	55%	36%
Advantex	3.75%	55%	36%
Current Septic System Management- Medium (Inspection at installation and education to encourage ongoing maintenance			
Typical separation from groundwater- < 3 feet			
Density (#/acre) < 1/acre			
SSOs-none			
CSOs- none			
Illicit Connections- none			
Urban Channel Erosion- None- applies to stream reaches in urban portions of the watershed			
Livestock- none			
Marinas- not applicable			
Road Sanding- 1585 lbs/yr (1/3% of roads open section)			
Non-Stormwater Point Sources- none			
EXISTING MANAGEMENT PRACTICES			
Turf Condition and Management Practices-Residential- Residential turf area- 68.05, assume just over 50% fertilize			
Percent of lawns bare/compacted- 5%			
Percent of homes < 10 years old- 20%			
Percent of lawn area highly managed- 10%			
Average fertilizer rate- 91 lbs N/yr, 95% slow release, 5% P-free			
Pet Waste Education Program in Place- None			
Number of Dwelling Units			
Awareness of Message (Fraction of population)			
Street Sweeping- None Identified			
Sweeper Type-			
Acres Swept			
Frequency			
Technique			
STRUCTURAL STORMWATER MANAGEMENT PRACTICES			
Type	**Total Drainage Area**	**Impervious Area**	
Catch Basin Clean-outs			
Impervious Area Captured- 23.1 acres			
Clean-out Frequency- semi-annual			
Disposal Technique- 1.0 (No Prohibitions)			

Table 13. Watershed Treatment Model Secondary Source and Existing Conditions Worksheet Input- Sisson Pond.

SECONDARY SOURCES			
General Sewage Use Data			
# Dwelling Units of (Type)	***Individuals/Dwelling Unit***	***Water Use (gpcd)***	***Wastewater Characteristics***
Single family- 5	2.4	57.5	**TN- 60 mg/l**
Multi-family-			**TP- 11 mg/l**
Commercial- 2	7.2	10	
Public-			
Onsite Sewage Disposal Systems			
Unsewered Dwelling Units (% of total)- 100%			
Percent of Septic Systems <100 feet to waterway- 0%			
Failure Rates- 3.3%			
Soils- Clay/Mixed Soils			
System Type	***% of Systems***	***TN Removal Efficiency (%)***	***TP Removal Efficiency (%)***
Conventional	92.5%	25%	25%
Intermittent Sand Filter	3.75%	55%	36%
Advantex	3.75%	55%	36%
Current Septic System Management- Medium (Inspection at installation and education to encourage ongoing maintenance)			
Typical separation from groundwater- < 3 feet			
Density (#/acre)- <1/acre			
SSOs-none			
CSOs- none			
Illicit Connections- not applicable			
Urban Channel Erosion- none (applies only to stream reaches in urban portions of the watershed)			
Livestock- none			
Marinas- not applicable			
Road Sanding- 178 lbs/year (50% of roads open section)			
Non-Stormwater Point Sources- none			
EXISTING MANAGEMENT PRACTICES			
Turf Condition and Management Practices-Residential- 14.35 acres residential turf area- assume just over 50% fertilie			
Percent of lawns bare/compacted- 5%			
Percent of homes < 10 years old- 20%			
Percent of lawn area highly managed- 10%			
Estimated average fertilizer application is 91 lbs N/acre, 95% slow release, 5% P-free			
Pet Waste Education Program in Place- None			
Number of Dwelling Units			
Awareness of Message (Fraction of population)			
Street Sweeping- None			
Sweeper Type			
Acres Swept			
Frequency			
Technique			
STRUCTURAL STORMWATER MANAGEMENT PRACTICES			
Type	**Total Drainage Area**	**Impervious Area**	
Catch Basin Clean-outs- None			
Impervious Area Captured			
Clean-out Frequency			
Disposal Technique			

Table 14. Watershed Treatment Model Secondary Source and Existing Conditions Worksheet Input-St. Marys Pond.

SECONDARY SOURCES			
General Sewage Use Data			
# Dwelling Units of (Type)	***Individuals/Dwelling Unit***	***Water Use (gpcd)***	***Wastewater Characteristics***
Single family- 96	2.7	70	**TN- 45 mg/l**
Multi-family- 89	8.1	70	**TP- 11 mg/l**
Commercial- 2	5.8	10	
Public-			
Onsite Sewage Disposal Systems			
Unsewered Dwelling Units (% of total)- 100%			
Percent of Septic Systems <100 feet to waterway- 0%			
Failure Rates- 3.3%			
Soils- Clay/Mixed Soils			
System Type	***% of Systems***	***TN Removal Efficiency (%)***	***TP Removal Efficiency (%)***
Conventional	92.5%	25%	25%
Intermittent Sand Filter	3.75%	55%	36%
Advantex	3.75%	55%	36%
Current Septic System Management- Medium (Inspection at installation and education to encourage ongoing maintenance			
Typical separation from groundwater- < 3 feet			
Density (#/acre)- < 1/acre			
SSOs- none			
CSOs- none			
Illicit Connections- not applicable			
Urban Channel Erosion- Not applicable (applies to stream reaches in urban parts of the watershed)			
Livestock- none			
Marinas- not applicable			
Road Sanding- 958 lbs/yr (0% roads are open section)			
Non-Stormwater Point Sources- none			
EXISTING MANAGEMENT PRACTICES			
Turf Condition and Management Practices-Residential- 34.77 acres of residential turf area- assume just over 50% fertilize			
Percent of lawns bare/compacted- 5%			
Percent of homes < 10 years old- 20%			
Percent of lawn area highly managed- 10%			
Average Fertilizer Application rate -91 lbs N/acre, 95% slow release, 5% P-free			
Pet Waste Education Program in Place- None			
Number of Dwelling Units			
Awareness of Message (Fraction of population)			
Street Sweeping			
Sweeper Type- Mechanical			
Acres Swept- 13.7 acres			
Frequency- monthly (no annual or semi-annual option)			
Technique- 0.5 (No parking restrictions or operator training)			
STRUCTURAL STORMWATER MANAGEMENT PRACTICES			
Type	**Total Drainage Area**	**Impervious Area**	
Catch Basin Clean-outs- None			
Impervious Area Captured			
Clean-out Frequency			
Disposal Technique			

Table 15. Watershed Treatment Model Secondary Source and Existing Conditions Worksheet Input- North and South Easton Ponds.

SECONDARY SOURCES			
General Sewage Use Data			
# Dwelling Units of (Type)	***Individuals/Dwelling Unit***	***Water Use (gpcd)***	***Wastewater Characteristics***
Single family- 36	2.4	57.5	**TN- 60 mg/l**
Multi-family- 92	7.2	57.5	**TP- 11 mg/l**
Commercial- 9	14	10	
Public-			
Onsite Sewage Disposal Systems			
Unsewered Dwelling Units (% of total)- 100%			
Percent of Septic Systems <100 feet to waterway- 2%			
Failure Rates- 3.3%			
Soils- Clay/Mixed Soils			
System Type	***% of Systems***	***TN Removal Efficiency (%)***	***TP Removal Efficiency (%)***
Conventional	92.5%	25%	25%
Intermittent Sand Filter	3.75%	55%	36%
Advantex	3.75%	55%	36%
Current Septic System Management- Medium (Inspection at installation and education to encourage ongoing maintenance)			
Typical separation from groundwater- < 3 feet			
Density (#/acre)- < 1/acre			
SSOs- none			
CSOs- none			
Illicit Connections- none			
Urban Channel Erosion			
Livestock- none			
Marinas- not applicable			
Road Sanding- 29,531 lbs/yr			
Non-Stormwater Point Sources- none			
EXISTING MANAGEMENT PRACTICES			
Turf Condition and Management Practices-Residential- 260.6 residential turf area, assume just over 50% fertilize			
Percent of lawns bare/compacted- 5%			
Percent of homes < 10 years old- 20%			
Percent of lawn area highly managed- 10%			
Est. average fertilizer application rate is 91 lbs N/acre with 95% slow release and 5% P-free			
Pet Waste Education Program in Place- YES			
Number of Dwelling Units- 128			
Awareness of Message (Fraction of population)- 40%			
Street Sweeping- YES			
Sweeper Type- Mechanical			
Acres Swept- 146 acres			
Frequency- monthly (annual or semi-annual not an option)			
Technique- 1.0 (Parking restrictions and operator training)			
STRUCTURAL STORMWATER MANAGEMENT PRACTICES			
Type	**Total Drainage Area**	**Impervious Area**	
Catch Basin Clean-outs- YES			
Impervious Area Captured- 14.6 acres (10% annually of 146 acres total)			
Clean-out Frequency- (choose semi-annual, annual not an option)			
Disposal Technique- 1.0 (No prohibitions)			

Table 16. Watershed Treatment Model Secondary Source and Existing Conditions Worksheet Input-Gardiner Pond.

SECONDARY SOURCES			
General Sewage Use Data			
# Dwelling Units of (Type)	***Individuals/Dwelling Unit***	***Water Use (gpcd)***	***Wastewater Characteristics***
Single family- 1	2.4	57.5	**TN- 60 mg/l**
Multi-family-			**TP- 11 mg/l**
Commercial-			
Public- 1	48	10	
Onsite Sewage Disposal Systems			
Unsewered Dwelling Units (% of total)- 100%			
Percent of Septic Systems <100 feet to waterway- 0%			
Failure Rates- 3.3%			
Soils- Clay/Mixed Soils			
System Type	***% of Systems***	***TN Removal Efficiency (%)***	***TP Removal Efficiency (%)***
Conventional	92.5%	25%	25%
Intermittent Sand Filter	3.75%	55%	36%
Advantex	3.75%	55%	36%
Current Septic System Management- Medium (Inspection at installation and education to encourage ongoing maintenance)			
Typical separation from groundwater- < 3 feet			
Density (#/acre)- <1/acre			
SSOs- None			
CSOs- None			
Illicit Connections- Not applicable			
Urban Channel Erosion- Not applicable (no tributary inflow)			
Livestock- None			
Marinas- Not applicable			
Road Sanding- 600 lbs/yr (50% open section roads)			
Non-Stormwater Point Sources- None			
EXISTING MANAGEMENT PRACTICES			
Turf Condition and Management Practices-Residential- 1 acre residential turf area-assume over half fertilize			
Percent of lawns bare/compacted- 5%			
Percent of homes < 10 years old- 20%			
Percent of lawn area highly managed- 10%			
Fertilizer application rate is 91 lbs N/acre with 95% slow release and 5% P-free			
Pet Waste Education Program in Place- YES			
Number of Dwelling Units- 2			
Awareness of Message (Fraction of population)- 40%			
Street Sweeping- Yes			
Sweeper Type- Mechanical			
Acres Swept- 0.9 acres			
Frequency- Monthly			
Technique- 1.0 (Parking restrictions and operator training)			
STRUCTURAL STORMWATER MANAGEMENT PRACTICES			
Type	**Total Drainage Area**	**Impervious Area**	
Catch Basin Clean-outs- YES			
Impervious Area Captured- 0.9 acres			
Clean-out Frequency- Semi-annual			
Disposal Technique- 1.0 (No prohibitions)			

Table 17. Watershed Treatment Model Secondary Source and Existing Conditions Worksheet Input-Paradise Pond.

SECONDARY SOURCES			
General Sewage Use Data			
# Dwelling Units of (Type)	***Individuals/Dwelling Unit***	***Water Use (gpcd)***	***Wastewater Characteristics***
Single family- 117	2.4	57.5	**TN- 60mg/l**
Multi-family- 4	7.2	57.5	**TP- 11 mg/l**
Commercial- 5	14	10	
Public-			
Onsite Sewage Disposal Systems			
Unsewered Dwelling Units (% of total)- 100%			
Percent of Septic Systems <100 feet to waterway- 5%			
Failure Rates- 3.3%			
Soils- Sandy			
System Type	***% of Systems***	***TN Removal Efficiency (%)***	***TP Removal Efficiency (%)***
Conventional	92.5%	25%	25%
Intermittent Sand Filter	3.75%	55%	36%
Advantex	3.75%	55%	36%
Current Septic System Management- Medium (Inspection at installation and education to encourage ongoing maintenance			
Typical separation from groundwater- < 3 feet			
Density (#/acre)- < 1/acre			
SSOs- None			
CSOs- None			
Illicit Connections- None			
Urban Channel Erosion- None (applies only to stream reaches in urban portions of the watershed)			
Livestock- Estimate 12 horses in watershed (25% Exposed to runoff, 102 lbs N per animal/yr, 43 lbs TP per animal/yr)			
Marinas- Not applicable			
Road Sanding- 7222 lbs/yr (50% of roads open section)			
Non-Stormwater Point Sources- None			
EXISTING MANAGEMENT PRACTICES			
Turf Condition and Management Practices-Residential- 45.50 acres of residential turf area, assume just over 50% fertilize			
Percent of lawns bare/compacted- 5%			
Percent of homes < 10 years old- 20%			
Percent of lawn area highly managed- 10%			
91 lbs N/acre- fertilizer application rate with 95% slow release and 5% P-free			
Pet Waste Education Program in Place-YES			
Number of Dwelling Units- 121			
Awareness of Message (Fraction of population)- 40%			
Street Sweeping			
Sweeper Type- Mechanical			
Acres Swept- 11.6 acres			
Frequency- monthly (annual or semi-annual not an option)			
Technique- 1.0 (Parking restrictions and operator training)			
STRUCTURAL STORMWATER MANAGEMENT PRACTICES			
Type	**Total Drainage Area**	**Impervious Area**	
Catch Basin Clean-outs			
Impervious Area Captured- 11.6 acres			
Clean-out Frequency- Semi-annual			
Disposal Technique (1.0- No restrictions)			

Table 18. Watershed Treatment Model Secondary Source and Existing Conditions Worksheet Input- Maidford River.

SECONDARY SOURCES			
General Sewage Use Data			
# Dwelling Units of (Type)	***Individuals/Dwelling Unit***	***Water Use (gpcd)***	***Wastewater Characteristics***
Single family- 38	2.4	57.5	**TN- 60 mg/l**
Multi-family- 2	7.2	57.5	**TP- 11 mg/l**
Commercial- 4	14	10	
Public- 1	48	10	
Onsite Sewage Disposal Systems			
Unsewered Dwelling Units (% of total)			
Percent of Septic Systems <100 feet to waterway			
Failure Rates- 3.3%			
Soils- Clay/Mixed Soil			
System Type	% of Systems	TN Removal Efficiency (%)	TP Removal Efficiency (%)
Conventional	92.5%	25%	25%
Intermittent Sand Filter	3.75%	55%	36%
Advantex	3.75%	55%	36%
Current Septic System Management- Medium (Inspection at installation and education to encourage ongoing maintenance			
Typical separation from groundwater- < 3 feet			
Density (#/acre)- < 1/acre			
SSOs- None			
CSOs- None			
Illicit Connections- None			
Urban Channel Erosion- None (applies only to stream reaches in urban portions of the watershed)			
Livestock- None			
Marinas- Not applicable			
Road Sanding- 10929 lbs/yr (50% of roads open section)			
Non-Stormwater Point Sources- None			
EXISTING MANAGEMENT PRACTICES			
Turf Condition and Management Practices-Residential- 171 acres of residential turf area, assume just over 50% fertilize			
Percent of lawns bare/compacted- 5%			
Percent of homes < 10 years old- 20%			
Percent of lawn area highly managed- 10%			
91 lbs N/acre- fertilizer application rate with 95% slow release and 5% P-free			
Pet Waste Education Program in Place- YES			
Number of Dwelling Units- 40			
Awareness of Message (Fraction of population)			
Street Sweeping- YES			
Sweeper Type- Mechanical			
Acres Swept- 53			
Frequency- monthly			
Technique-1			
STRUCTURAL STORMWATER MANAGEMENT PRACTICES			
Type	**Total Drainage Area**	**Impervious Area**	
Catch Basin Clean-outs			
Impervious Area Captured- 5.3 acres			
Clean-out Frequency- semi-annual			
Disposal Technique- 1			

Watershed Treatment Model Results

Evaluation and Interpretation of Results

Like all desktop watershed models, there is a certain amount of uncertainty associated with the WTM and its nutrient loading results. The main reasons for this uncertainty include: 1) lack of comprehensive nutrient loading data, for calibration purposes; 2) limitations in the understanding of the environmental processes (i.e. event mean concentration data, nutrient loading rates, nutrient load attenuation factors) affecting nutrient loadings to the waterbodies; 3) limitations of the modeling approach in representing the environmental processes accurately, and 4) limitations on incorporations of existing management practices (i.e. BMP's) in the watersheds. It is difficult to precisely quantify the amount of uncertainty related to the latter three items. With respect to the first item, three years (2015-2017) of streamflow and nutrient concentration data exist in Bailey Brook and the Maidford River. These data were used to calculate average annual phosphorus loads and will be compared to the loads generated by the WTM (there are additional uncertainties as described below). As stated earlier, the WTM was run using annual average precipitation values from appropriate National Weather Service (NWS) station data.

The quality of water in each of Newport Water Department's (NWD) nine reservoirs can vary widely, particularly during late spring through early fall when environmental conditions favor peak phytoplankton growth. The reservoirs are interconnected through a complex network of piping, tributaries, and pumping stations. Sources of inflow and outflow for each reservoir are described in Table 20. The interconnections provide the means for the NWD to bring in the highest quality source water for treatment at Station 1 and Lawton Valley Water Treatment Plant. Oftentimes this necessitates the mixing or 'blending' of water from various reservoirs. Blending occurs as necessary and can occur in various combinations on time scales ranging from daily to monthly. Because the transfer of water from one reservoir also includes the transfer of its various chemical constituents (i.e. a mass), including nutrients, these transfers constitute a 'nutrient load' export from the source reservoir and import to the receiving waterbody. At present, these nutrient loads are unquantifiable and depending on environmental and operational factors can vary widely on both a seasonal and annual basis.

In addition to the aforementioned issues, several other factors will affect both the interpretation of the WTM results, as well as their comparability to phosphorus loading estimates derived from other approaches (i.e. FLUX software applications, various empirical loading methodologies, loading estimates derived using URI tributary flow and water chemistry data for Maidford River and Baileys Brook). These factors, applicable in various modeled watersheds, are described below.

1. **Bailey Brook (North and South Easton Ponds) WTM application**- Bailey Brook is the main tributary to North and South Eason Ponds. Review of historical aerial photography revealed the existence of what was a pond, located just upstream of the confluence of Baileys Brook with North Easton Pond, on the north side of Green End Avenue in Middletown. This (~2.4 acre) pond was observed on the 1950 aerial photos and remained static in size until 1972. Aerial imagery from 1981 to 1997 shows the pond decreasing in size and becoming filled in with vegetation. After 1997 it does not appear to exist and instead appears as a wetland. This indicates that this pond has acted and likely continues to act as a (potentially effective) settling basin for sediment and nutrients (namely phosphorus). This is not accounted for in the WTM and therefore the actual annual phosphorus loads to North and South Easton Ponds are likely much lower than the model predicts.

2. **Watson Reservoir WTM application-** The tributaries to Watson Reservoir are fairly short in length and originate in wetlands surrounding the reservoir. These tributaries are ephemeral and oftentimes dry from late spring to early fall. This has been documented by RIDEM staff on numerous occasions. The WTM does not take this into account and actual annual phosphorus loads may be less than what the WTM predicts.

3. **Paradise Pond and Gardiner Pond applications-** Both Paradise Brook and Gardiner Pond receive flow from the Maidford River. A diversion structure is located up-gradient of both ponds and flow from the river can be diverted into either pond or bypass the diversion entirely and flow directly out to Third Beach in the Sakonnet River. When both ponds are at full capacity, no additional flow gets diverted to them and all flow goes to Third Beach. In addition, under wet weather events much of the flow goes to Third Beach. This cannot be accounted for in the WTM.

   In addition, there is a piped connection between Paradise and Gardiner Ponds that is controlled seasonally by valves- it is closed in the winter and open in the summer. These factors cannot be accounted for in the WTM.

4. The various transfers and interconnections described below in Table 19 cannot be accounted for with the WTM.

Despite the complexities of applying the Watershed Treatment Model to the Newport reservoirs, it provides a useful tool to understand the relative importance of the various sources of nutrients generated in all nine watersheds. There are a fixed number of sources of nutrients to the Newport reservoirs and the WTM accounts for all of them, except those derived from internal cycling (although the original source of the phosphorus and nitrogen in the sediments is from the watershed). With respect to water transfers between reservoirs, the ultimate source(s) of both phosphorus and nitrogen are watershed derived, and as such is still accounted for in the WTM applications.

The TMDLs for the Newport reservoirs are based on monitoring data and a total phosphorus target of 18 ppb. Two empirical lake/reservoir loading models (Dillon and Rigler 1974, Canefield and Bachman 1981) were used to estimate the total current phosphorus loads. Internal load estimates for each reservoir may or may not be added (depending on accuracy of prediction) to the total external load. The required nutrient load reductions are based on the difference between the current and target loads established as the TMDL. The WTM is used to apportion this total load to various point and non-point sources in the watershed. It is also used to estimate a 'natural background' nutrient load from forest, wetlands, and atmospheric inputs.

Table 19. Newport Water Supply Reservoirs and Interconnections.

Reservoir	Source of Inflow	Outflow Transfer Method	Destination of Outflow
Nonquit Pond	Watershed Drainage	Sakonnet Pumping Station and Pipeline	St. Marys Pond Lawton Valley WTP North Easton Pond via Bailey Brook
Watson Reservoir	Watershed Drainage	Sakonnet Pumping Station and Pipeline	St. Marys Pond Lawton Valley WTP North Easton Pond via Bailey Brook
Lawton Valley Reservoir	Watershed Drainage Sisson Pond via Lawton Valley Brook Watson Reservoir	Pumping Station and Pipeline	Lawton Valley WTP
Sisson Pond	Watershed Drainage St. Marys Pond	Lawton Valley Brook	Lawton Valley Reservoir
St. Marys Pond	Watershed Drainage Watson Reservoir Nonquit Pond	St. Marys Pumping Station and Pipelines Reservoir spillage to Sisson Pond	Lawton Valley WTP North Easton Pond via Bailey Brook
North Easton Pond	Watershed Drainage (Bailey Brook) St. Marys Pond Paradise Pond Gardiner Pond Sisson Pond via Bailey Brook	Pumping Station and Pipeline South Easton Pond	Station 1 WTP (at North Easton Pond
South Easton Pond	Watershed Drainage North Easton Pond Paradise Pond Gardiner Pond	Pumping Station and Pipeline	Station 1 WTP (at North Easton Pond)
Paradise Pond	Watershed Drainage (Paradise Brook) Maidford River Diversion	Paradise Pump Station and Pipeline	Station 1 WTP Gardiner Pond North Easton Pond
Gardiner Pond	Watershed Drainage Maidford River Diversion Paradise Pond	Paradise Pump Station and Pipeline	Station 1 WTP Paradise Pond North Easton Pond

WTP- Water Treatment Plant

Model results for each reservoir are presented in Tables 20-28. *Results are presented by land use category and represent estimated loads from each reservoirs' immediate watershed only.* It does not account for loadings from inter-reservoir transfers of water. The results presented in Tables 20-28 provide additional information on pollution sources, or 'source categories' and the relative contribution from each source. Total phosphorus is used as an indicator of sediment bound pollutants in runoff and groundwater phosphorus loads are not considered to be significant. Total nitrogen is used as an indicator of dissolved pollutants in surface runoff as well as in recharge entering groundwater.

Table 20. WTM Results Nonquit Pond.

Source Category	Annual TP Load (lbs)	% of Total Annual Load		Annual TN Load (lbs)	% of Total Annual Load
Urban Land Uses (load to surface water)	752	38.1		6,400	18.6
Tiverton Landfill	64	3.2		326	0.9
Agricultural Land Uses	541	27.4		5,285	15.3
OWTS failure to surface water	36	1.8		194	0.6
OWTS to groundwater	-	-		8,100	23.5
Urban Land Uses (load to groundwater)	-	-		5,610	16.3
Forest and Atmospheric	583	29.5		8,538	24.8
Total Annual Load	**1,976**			**34,452**	

Table 21. Watson Reservoir WTM results.

Source Category	Annual TP Load (lbs)	% of Total Annual Load		Annual TN Load (lbs)	% of Total Annual Load
Urban Land Uses (load to surface water)	718	51.7		5,300	21.7
Agricultural Land Uses	408	29.3		4,690	19.2
OWTS failure to surface water	15	1.1		80	0.3
OWTS to groundwater	-	-		3,345	13.7
Urban Land Uses (load to groundwater)	-	-		5,563	22.7
Forest and Atmospheric	249	17.9		5,498	22.5
Total Annual Load	**1,390**			**24,476**	

Table 22. Lawton Valley Reservoir WTM results.

Source Category	Annual TP Load (lbs)	% of Total Annual Load		Annual TN Load (lbs)	% of Total Annual Load
Urban Land Uses (load to surface water)	582	69.9		4,946	28.1
Agricultural Land Uses	182	21.8		2,206	12.5
OWTS failure to surface water	26	3.1		41	0.2
OWTS to groundwater	-	-		5,955	33.9
Urban Land Uses (load to groundwater)	-	-		3,432	19.5
Forest and Atmospheric	43	5.2		1,000	5.7
Total Annual Load	**833**			**17,580**	

Table 23. Sisson Pond WTM results.

Source Category	Annual TP Load (lbs)	% of Total Annual Load		Annual TN Load (lbs)	% of Total Annual Load
Urban Land Uses (load to surface water)	99	34.1		791	16.1
Agricultural Land Uses	176	60.7		2,501	51.0
OWTS failure to surface water	1	0.3		5	0.1
OWTS to groundwater	-	-		195	4.0
Urban Land Uses (load to groundwater)	-	-		853	17.4
Forest and Atmospheric	14	4.8		563	11.5
Total Annual Load	**290**			**4,908**	

Table 24. St. Marys Pond Pond WTM results.

Source Category	Annual TP Load (lbs)	% of Total Annual Load		Annual TN Load (lbs)	% of Total Annual Load
Urban Land Uses (load to surface water)	311	56.9		2,255	15.9
Agricultural Land Uses	176	32.2		2,428	17.2
OWTS failure to surface water	28	5.1		152	1.1
OWTS to groundwater	-	-		6,464	45.7
Urban Land Uses (load to groundwater)	-	-		1,797	12.7
Forest and Atmospheric	32	5.8		1,056	7.5
Total Annual Load	**547**			**14,152**	

Table 25. North and South Easton Ponds (Baileys Brook) WTM results.

Source Category	Annual TP Load (lbs)	% of Total Annual Load		Annual TN Load (lbs)	% of Total Annual Load
Urban Land Uses (load to surface water)	3,404	87.7		27,920	45.6
Agricultural Land Uses	390	10.1		4,101	6.7
OWTS failure to surface water	25	0.6		136	0.2
OWTS to groundwater	-	-		5,698	9.3
Urban Land Uses (load to groundwater)	-	-		21,205	34.6
Forest and Atmospheric	61	1.6		2,229	3.6
Total Annual Load	**3,880**			**61,288**	

Table 26. Gardiner Pond WTM results.

Source Category	Annual TP Load (lbs)	% of Total Annual Load		Annual TN Load (lbs)	% of Total Annual Load
Urban Land Uses (load to surface water)	5	11.1		27	2.3
Agricultural Land Uses	2	58.5		260	22.2
OWTS failure to surface water	0	0		2	0.2
OWTS to groundwater	-	-		80	6.8
Urban Land Uses (load to groundwater)	-	-		68	5.8
Forest and Atmospheric	14	30.4		737	62.8
Total Annual Load	**46**				

Table 27. Paradise Pond WTM results.

Source Category	Annual TP Load (lbs)	% of Total Annual Load		Annual TN Load (lbs)	% of Total Annual Load
Urban Land Uses (load to surface water)	106	32.7		807	10.3
Agricultural Land Uses	179	55.3		1,674	21.3
OWTS failure to surface water	11	3.4		59	0.7
OWTS to groundwater	-	-		2,370	30.1
Urban Land Uses (load to groundwater)	-	-		2,434	30.9
Forest and Atmospheric	28	8.6		527	6.7
Total Annual Load	**324**			**7,871**	

Table 28. Maidford River WTM results.

Source Category	Annual TP Load (lbs)	% of Total Annual Load		Annual TN Load (lbs)	% of Total Annual Load
Urban Land Uses (load to surface water)	1,180	66.9		9,648	36.3
Agricultural Land Uses	565	32.0		6,316	23.8
OWTS failure to surface water	4	0.2		22	0.1
OWTS to groundwater	-	-		914	3.4
Urban Land Uses (load to groundwater)	-	-		9,507	35.8
Forest and Atmospheric	14	0.8		186	0.7
Total Annual Load	**1,763**			**26,593**	

APPENDIX A. WTM DOCUMENTATION

	Parameter	Source(s)	Model Assumptions and Notes
Primary Sources	Watershed Boundary	Watershed boundaries were delineated by RIDEM	
	Land Cover and Land Use	RIGIS/RIDEM. Field reconnaissance was conducted in all watersheds to further refine agricultural land use categories	Land use verified using aerial photos and field reconnaissance
	Percent Impervious Cover	Statewide dataset representing impervious surfaces in Rhode Island in 2011.	The number of polygons for a particular land use/land cover were determined and minimum, maximum, and average % impervious was calculated. This 'average' value was used in the WTM
	Event Mean Concentration Data for TN and TP	Event Mean Concentration Data were compiled from 10 sources. See appendix X for references. Mean values for TN and TP were used for various land uses.	Final EMC values used in the WTM were obtained by calculating a mean value from the 10 sources. Because of source overlap, the mean value was calculated from those sources which differed.
	Rainfall	NOAA Climate Data Online	NOAA website: http://climod2.nrcc.cornell.edu/ Used Newport Airport site and Tiverton site.
	Stream Length	RIDEM/RIGIS	
	Hydrologic Soil Groups	RIDEM/RIGIS Soils information 2016	Subaqueous soil percentage was subtracted from the watershed soil acreage and % of A, B, C, and D soils were recalculated for use in WTM. Variable Soil percentages were added to D soils
	Runoff Coefficients	Knox County (TN) Stormwater Management Manual (2008) NJDEP Technical Manual for Land Use Regulation Program (1985)	Atmospheric coefficients Appendix B
	Depth to Groundwater	RIDEM OWTS Program Staff	
	Partitioning Coefficients	WTM Default (See WTM Documentation Table 3.7)	
	Annual Loading Rate	Use values selected for previous applications of the WTM to St. Marys and Watson Reservoir.	Previous applications of WTM for St. Marys and Watson utilized 4 sources and WTM default values. For RI defined agricultural land uses (brushland, hay, managed grass, meadow, orchard/vineyard/tree farm) used annual loading rates of 'Pasture/Orchard' from previous applications. Nursery land use had annual loading rate of 'cropland' applied. Transitional land use had annual loading rate of brushland applied.

Secondary Sources	Number of Buildings	RIGIS (2016) Planning and Management RIDEM Office of Operations & Maintenance Consultants, Ltd., 1995. (non-residential water usage data)	Data on unsewered dwellings (RIGIS)
	Individuals Per Single Family Dwelling	Middletown and Portsmouth (2.4) and Tiverton (2.2) U.S. Census Quick Facts 2017 (No data for Little Compton)	2.4 applied to Aquidneck Island watersheds 2.2 Applied to Mainland East Bay watersheds
	Individuals Per Multi Family Dwelling	Best Professional Judgement	Assumes 3 family units per building
	Individuals Per Commercial and Public Buildings	Rhode Island Department of Labor & Training Quarterly Census of Employment & Wages City & Town Report - First Quarter 2016	Commercial occupancy estimated as total number of private employees divided by number of private business units in the town Public occupancy estimated as total number of government employees divided by number of government buildings in the town
	Water Use-Single and Multi-Family Dwellings	RIDEM Onsite Wastewater System Regulations	57.5 gpcd based on RIDEM Onsite Wastewater System Regulations (112 gallons/bedroom/day assuming double occupancy.
	Water Use-Single Commercial and Public	RIDEM Office of Operations & Maintenance Consultants, Ltd., 1995. (non-residential water usage data)	
	Wastewater Characteristics-TN (mg/l)	Recommendations of the On-Site Wastewater Treatment Systems Nitrogen Reduction Technology Expert Review Panel FINAL REPORT, Wastewater Treatment Workgroup Chesapeake Bay Partnership, 2014; WERF (2007) Influent Constituent Characteristics of the Modern Waste Stream from Single Sources: Literature Review	
	Wastewater Characteristics-TP (mg/l)	WERF (2007) Influent Constituent Characteristics of the Modern Waste Stream from Single Sources: Literature Review; University of West Virginia; Pipeline; Phosphorus and Onsite Wastewater Systems, Vol. 24, No. 1; 2013	
	Failure rates	RIDEM Staff	3% based on 30-year life expectancy of system
	% of Septic Systems < 100 ft to Waterway	RIGIS (2016)	
	Soils	RIDEM OWTS Staff	
	Delivery Ratios	Used Default WTM value	
	% Conventional and Advanced Systems	RIDEM OWTS Staff	
	Conventional TN Efficiency	Recommendations of the On-Site Wastewater Treatment Systems Nitrogen Reduction Technology Expert Review Panel	

		FINAL REPORT, Wastewater Treatment Workgroup Chesapeake Bay Partnership, 2014; Massachusetts Alternative Septic System Test Center; Technology Fact Sheet - Interim Findings; 2001	
	Conventional TP Efficiency	WERF FINAL Factors affecting the performance of primary Treatment in Decentralized Wastewater Systems, 2008	
	Advanced TN Efficiency	Recommendations of the On-Site Wastewater Treatment Systems Nitrogen Reduction Technology Expert Review Panel FINAL REPORT, Wastewater Treatment Workgroup Chesapeake Bay Partnership, 2014	
	Advanced TP Efficiency	Phosphorus Reduction in Sand Filters for On-Site Wastewater Treatment ; Journal of Water Processing Engineering, Vol. 22, pg. 210-217; 2018	
	Typical Separation of Groundwater	RIDEM OWTS Staff	
	Nutrient Concentration in Stream Channels		
	Removal by Soil Below the Leach Field (TN)	RIDEM Staff	
	Removal by Soil Below the Leach Field (TP)	RIDEM Staff; Septic Systems Contribution to Phosphorus in Shallow Groundwater: Field-Scale Studies Using Conventional Drainfield Designs.; Mechtensimer and Toor, 2017	
	SSO, CSO, and Illicit Connection Information	RIDEM Office of Operations & Maintenance Consultants, Ltd., 1995.	Used hard data rather than model algorithm. Used 5 years of SSO data for mean annual value for Bailey Brook watershed only (no recorded SSOs in any other watersheds.)
	Urban Channel Erosion		
	Livestock	Virginia Cooperative Extension (406-208) (nutrient export factors)	Number of horses estimated by length of barn, multiplied by two (assuming a row of stalls along each wall), and a mean stall width of 12 feet). Assumed horses were outside 6 hours per day. Assumed same bacteria loading rate as cattle.
	Road Sanding	Town Public Works Directors RIGIS	Mean town-wide annual roadway sand load, total roadway miles, and sand/salt ratio (Public Works).

			Roadway miles within the watershed (RIGIS). Relative proportion of closed roadway (serviced by a storm drain system) was estimated by the Public Works directors or inspection of street view application of google maps (for presence of catch basins).
Existing Management Practices			
	Turf Condition and Management Practices- Residential	Newport Water Division Source Water Phosphorus Reduction Feasibility Plan- WTM Application to St. Marys Pond and Watson Reservoir. Maidford River Watershed Assessment and BMP Design-WTM Applications to Maidford River and Paradise Brook	Assume 5% of lawns in each watershed were bare/compacted, 20% of homes were less than 10 yrs old, and 10% of lawn area was highly managed.
	Turf Condition and Management Practices- Other	Newport Water Division Source Water Phosphorus Reduction Feasibility Plan- WTM Application to St. Marys Pond and Watson Reservoir. Maidford River Watershed Assessment and BMP Design-WTM Applications to Maidford River and Paradise Brook.	Commercial, Roadway, and industrial land use categories were assumed management/nutrient management than residential turf.
	Pet Waste Education	Information gleaned from Municipal MS4 annual reports	A pet waste program was considered 'in place' if educational materials were (reported to be) distributed on an annual basis. Awareness of Message was derived from information in the MS4 annual report.
	Erosion and Sediment Control	No Information	No information
	Street Sweeping	Information regarding street sweeping was generally found in municipal MS4 annual reports.	If 100% of streets swept on annual basis, then applied existing acreage of roadway as acres swept. Sweeping frequency chosen was monthly. 'Annual' not an option. Technique discount-generally chose 1.0- parking restrictions and operator training assumed.
	Structural Stormwater Management Practices	Newport Water Division Source Water Phosphorus Reduction Feasibility Plan- WTM Application to St. Marys Pond and Watson Reservoir. Maidford River Watershed Assessment and BMP Design-WTM Applications to Maidford River and Paradise Brook.	Per other applications, assumed that there are currently no structural BMPs
	Riparian Buffers		
	Catch basin Cleanouts	Information gleaned from Municipal MS4 annual reports	Information from MS4 reports included # of catch basins cleaned and % of total. Applied % of total to total acreage of roadways. Chose semi-annual cleaning over monthly. No disposal discount

	EMC SOURCE- Total Phosphorus										
Land Use Classification	EMC1	EMC2	EMC3	EMC4	EMC5	EMC6	EMC7	EMC8	EMC9	EMC10	Average EMC value
RESIDENTIAL											
Low Density Res (> 2 acre)							0.5		0.2	0.27	**0.36**
Medium Low Density Res (1-2 acres)							0.3	0.52	0.32	0.41	**0.41**
Medium Density Res (1-1/4 acres)		0.52	0.3	0.3		0.59	0.3	0.52	0.32	0.41	**0.41**
Medium High Density Res (1/4 - 1/8 acres)							0.3	0.52	0.32	0.41	**0.41**
High Density Residential (< 1/8 acre)							0.4		0.355	0.64	**0.43**
COMMERCIAL											
Commercial-Industrial	0.41	0.33	0.24	0.22			0.25	0.33	0.32	0.13	**0.27**
Golf Course	0.6				1.07	1.07			1.07		**0.84**
Institutional	0.3										**0.3**
Waste Disposal	0.34									0.11	**0.225**
ROADWAY											
Transportation	0.34	0.32	0.26	0.25	0.35		0.4	0.43	0.4	0.43	**0.35**
FOREST											
Forest	0.15	0.11			0.15	0.35		0.11	0.13	0.11	**0.19**
Wetland	0.19	0.08						0.08		0.08	**0.11**
RURAL			0.31	0.11							
Brushland	0.13										**0.13**
Hay											**0.13**
Managed Grass											**0.13**
Meadow					0.19						**0.19**
Nursery	0.4										**0.4**
Orchard/Vineyard/Tree Farm	0.4										**0.4**
Pasture		0.37				2.14		0.37		0.37	**1.26**
Row Crop	0.6										**0.6**
Transitional	0.15										**0.15**
Quarry											
WATER											
* all EMC units in mg/l											
EMC1	Lake County Stormwater Management Commission. 2014										
EMC2	New Hampshire Stormwater Manual. 2008. New Hampshire Department of Environmental Services										
EMC3	Maestre and Pitt. 2005. National Stormwater Quality Database v 1.1.										
EMC4	Rhode Island Stormwater Design and Installation Standards Manual. 2015										
EMC5	Pennsylvania Stormwater Best Management Practices Manual. 2008										
EMC6	Lin, J. Review of Published Export Coefficient and EMC data (2004)										
EMC7	Minnesota Pollution Control Agency Stormv										
EMC8	Watershed Management Model- Merrimack River Watershed Assessment Study 2004										
EMC9	DDOE Consolidated TMDL Implementation Plan Appendix D "Selection of Event Mean Concentrations"										
EMC10	QAPP- Development of a Watershed Based Plan for Massachusetts- MADEP 2006										

	EMC SOURCE- Total Nitrogen										
Land Use Classification	EMC 1	EMC 2	EMC 3	EMC 4	EMC 5	EMC 6	EMC 7	EMC 8	EMC9	EMC10	Average EMC value
RESIDENTIAL											
Low Density Res (> 2 acre)			1.90	2.1		2.1			1.98	3.18	**2.29**
Medium Low Density Res (1-2 acres)		5.15						5.15	3.1	3.5	**3.92**
Medium Density Res (1-1/4 acres)		5.15						5.15	3.1	3.5	**3.92**
Medium High Density Res (1/4 - 1/8 acres)		5.15						5.15	3.1	3.5	**3.92**
High Density Residential (< 1/8 acre)									3	3.81	**3.41**
COMMERCIAL											
Commercial-Industrial		3.47	1.7	2.1		1.5		3.47	2.25	2.93	**2.33**
Golf Course											
Institutional											
Waste Disposal										1.74	**1.74**
ROADWAY											
Transportation			3.6	2.3				2.65	3	2.65	**2.89**
FOREST											
Forest		1.78						1.74	1.7	1.74	**1.74**
Wetland											
RURAL				1.74							**1.74**
Brushland											
Hay											
Managed Grass											
Meadow											
Nursery											
Orchard/Vineyard/Tree Farm											
Pasture		5.98						5.98		5.98	**5.98**
Row Crop											
Transitional											
Quarry											
WATER											
* all EMC units in mg/l											
EMC1	Lake County Stormwater Management Commission. 2014. Mill Creek Watershed and Flood Mitigation Plan.										
EMC2	New Hampshire Stormwater M										
EMC3	Maestre and Pitt. 2005. National Stormwater Quality Database v 1.1.										
EMC4	Rhode Island Stormwater Design and Installation Standards Manual. 2015										
EMC5	Pennsylvania Stormwater Best Management Practices Manual. 2008										
EMC6	Lin, J. Review of Published Export Coefficient and EMC data (2004)										
EMC7	Minnesota Pollution Control Agency Stormwater Manual										
EMC8	Watershed Management Model- Merrimack River Watershed Assessment Study 2004										
EMC9	DDOE Consolidated TMDL Implementation Plan Appendix D "Selection of Event Mean Concentrations"										
EMC10	QAPP- Development of a Watershed Based Plan for Massachusetts- MADEP 2006										

Atmospheric N Loading Calculations

Waterbody	WB size (acres)	Avg Annual Precip (inches)	Conc N in rainfall in mg/l	precip ft	WB size ft^2	vol ft^3	liters	lbs	lbs/acre
Nonquit Pond	196	49	0.7205	4.083	8,537,760	34,862,520	711275258	1568	8.0
Watson Reservoir	371	49	0.7205	4.083	16,160,760	65,989,770	1346342453	2968	8.0
Lawton Valley Reservoir	81	46	0.7205	3.833	3,528,360	13,525,380	275948731	608	7.5
Sisson Pond	69	46	0.7205	3.833	3,005,640	11,521,620	235067437	518	7.5
St. Marys Pond	112	46	0.7205	3.833	4,878,720	18,701,760	381558739	841	7.5
North Easton Pond	113	46	0.7205	3.833	4,922,280	18,868,740	384965513	849	7.5
South Easton Pond	219	46	0.7205	3.833	9,539,640	36,568,620	746083606	1645	7.5
Gardiner Pond	92	46	0.7205	3.833	4,007,520	15,362,160	313423250	691	7.5
Paradise Pond	29	46	0.7205	3.833	1,263,240	4,842,420	98796459	218	7.5
******	N input from direct atmospheric deposition on open water was calculated independently from the WTM model								
	assuming NH4 and NO3 (TN) concentration of 0.72 mg/l from National Atmospheric Deposition Program database								
	for Abington, CT (data from 2010-2017). Also used NOAA derived average annual precipitation value (49 inches) and direct waterbody area								
	http://nadp.slh.wisc.edu/data/sites/siteDetails.aspx?net=NTN&id=CT15								

APPENDIX B. DOCUMENTATION OF OWTS and TURF MANAGEMENT ASSUMPTIONS

Below is a summary of the Oct 30, 2018 meeting between RIDEM staff regarding the Watershed Treatment Model applications to the City of Newport drinking water reservoirs- specifically relative to the assumptions related to calculations of N loadings from:

1. **Nutrient Loadings from Fertilizer**
2. **Nutrient Loadings from OWTS**

Consensus at the meeting was that various assumptions relating to estimation of nitrogen loadings from residential fertilizer application and OWTS can be better refined to reflect updated and or more local information/studies. Specifically-

Nutrient Loadings from Lawn Fertilizer

The total fertilizer application rate in the WTM is calculated as the product of the residential turf area in the watershed (in acres) and the estimated average fertilizer application (lbs of N/acre).

Residential turf cover, expressed as a percent, was calculated from % impervious cover. A mean % impervious cover was calculated for each residential land use category (as well as commercial and industrial land uses) and the following equation, as a default in the WTM, calculates corresponding % turf cover as:

$$\% \text{ turf cover} = 80\% (100 - \% \text{ impervious cover})$$

Given the inherent difficulties (as specified by Paul Jordan) in estimating % turf cover directly, it was agreed at the meeting that the above equation was acceptable for calculating the percent turf cover for residential land uses in each reservoirs watershed.

In the WTM, the fertilizer application rate for residential lawns has two components: (1) how much N is applied to a lawn in a year and (2) what percent of lawns are fertilized. The average fertilizer application initially used in the WTM was 171 lbs/acre and was taken from MANAGE model assumptions. The MANAGE model, developed by URI, was previously applied to the nine water supply reservoirs in 2003 as part of the Source Water Assessments for all drinking water supplies in the state.

In 2007, as part of a Final Watershed Management Plan, the MANAGE model was used to evaluate nitrogen loads to Green Hill and Ninigret Ponds. The same fertilizer application rate of 171 lbs/acre was used in this application. Following up on this work, the Town of South Kingstown hired a consultant to re-evaluate nitrogen loads to Green Hill and Ninigret Ponds using the Soil and Water Assessment Tool (SWAT model). To be consistent with the previous MANAGE model runs the fertilizer application rate in the SWAT model was initially kept at 171 lbs N/acre. The lawn fertilizer scenario was revised after input at several public meetings. After input, the application rate, percentage of lawns treated, and timing

were modified. The application rate of 131 lbs N/acre (~ 3.0 lbs/1000 ft^2) was adopted from recently published literature from the University of Rhode Island (White 2003), URI Landscape Horticulture Program factsheet, 2007).

Additional review included additional localized information-in particular- Latimer and Charpentier (2010) used a rate of 2.1 lbs N/1000 ft^2 for the Nitrogen Loading Model in southern New England. In a study of suburban watersheds in Maryland, Law et al. (2004) found that the average application rate was 2.2 lb N/1000 ft^2 for homeowners who maintain their own lawn and 2.1 to 3.3 lb N/1000 ft^2 for lawn care companies. Osmond and Hardy (2004) reported average application rates of 0.5 to 3.1 lb N/1000 ft^2 for watersheds in North Carolina. The Great Bay (Piscataqua Region Watershed) nitrogen study used a value of 2.0 lbs/1000 ft^2. Based on these studies- and in particular, that of Latimer and Charpentier (2010) an average fertilizer application rate of 2.1 lbs/1000ft^2 was chosen as input into the Watershed Treatment Model for the Newport reservoir applications. **This equates to approximately 91 lbs/acre.**

There is no option in the WTM to input the percentage of lawns that are fertilized in a given year. A recent social science survey of residents in the Piscataqua Region found that 40% reported using fertilizer on lawns, either themselves or through a contractor (Rogers and Farrell, 2014). This value is consistent with the percentage used by Latimer and Charpentier (2010) for their application of the Nitrogen Loading Model for watersheds in southern New England (34%). However, multiple other studies from around the country have reported higher rates of fertilizer use. For example, a survey of homeowner behaviors in the Chesapeake Bay watershed found that 50% of lawns were regularly fertilized (CWP, 1999). This report also included a summary of eight other homeowner surveys across the country which showed that an average of 78% of lawns were fertilized yearly. More recent studies in Maryland, Florida, Georgia, and North Carolina reported average participation rates for fertilizing lawns of 62, 84, 76, and 70%, respectively (Law et al., 2004; Florida DEP, 2009; Varlamoff et al., 2001; Osmond and Hardy, 2004). Based on sales data, Scotts MiracleGro estimates that approximately 50% of homeowners in the United States fertilize their lawns (Augustin, 2007). A survey of residents in the Lamprey River watershed in New Hampshire conducted in 2007 reported that 36.4% of residents never fertilized their lawns (i.e. 64% fertilized; Robertson, 2010). The results of these homeowner studies across the country consistently indicate greater than 50% fertilizer use by homeowners.

More recent, and local, investigations on Aquidneck Island by Bristol et al. (2017) are summarized below:

Descriptive Data from 2017 Lawncare Survey

Authors: Miao, Haoran (URI); Michael Price (U of Alabama); Simona Trandafir (URI); Emi Uchida (URI) November 1, 2018

Table 1: Proportion of sample fertilizing their lawn

			By primary management			
			Professionals		Self-management	
Location	**Fertilizing**	**N**	**Fertilizing**	**N**	**Fertilizing**	**N**
RI	56.56%	1220	69.23%	169	54.52%	1051
RI-Aquidneck Island/Portsmouth	*52.63%*	38	*83.33%*	*6*	*46.88%*	*32*
MA	54.34%	265	60.98%	41	53.13%	224
CT	51.52%	231	70.73%	41	47.37%	190
Total	55.54%	1716	68.13%	251	53.38%	1465

Although the sample size for the Aquidneck Island is small (n=38) and the difference in the percent fertilizing between professionals and self-management is larger than in the other locations, the weighted average of 52.63% is similar to those from other locations. **Based on this it is suggested that a value of 53% could be used. The proposed approach for incorporating this into the WTM involves overriding the cell containing the residential turf area-essentially multiplying the existing value times 0.53 and re-entering this value.**

Nutrient Loadings from OWTS

At the meeting, Scott went over how the WTM evaluates nutrient (primarily nitrogen) loads from OWTS. There was general agreement over most of the assumptions in the WTM (individuals/dwelling unit, water use, soils, % of systems in place, typical separation from groundwater, etc). Proposed refinements include refinement of wastewater characteristics (N) and removal efficiencies (primarily for N).

Based on RIDEMs research-specifically with respect to implementation activities from the Chesapeake Bay TMDL, the following values were proposed for wastewater characteristics (N) and removal efficiencies:

Raw sewage 60 mg/l

TN Recommendations of the On-Site Wastewater Treatment Systems Nitrogen:
Reduction Technology Expert Review Panel
FINAL REPORT, Wastewater Treatment Workgroup
Chesapeake Bay Partnership, 2014;

WERF (2007) Influent Constituent Characteristics of the Modern Waste Stream from Single Sources: Literature Review

Total Conventional system efficiency 25% removal TN (includes tank pump out)

Recommendations of the On-Site Wastewater Treatment Systems Nitrogen Reduction Technology Expert Review Panel
FINAL REPORT, Wastewater Treatment Workgroup
Chesapeake Bay Partnership, 2014;
Massachusetts Alternative Septic System Test Center; Technology Fact Sheet - Interim Findings; 2001

Total Denit System efficiency 55% removal TN (includes tank pump out)

Recommendations of the On-Site Wastewater Treatment Systems Nitrogen Reduction Technology Expert Review Panel
FINAL REPORT, Wastewater Treatment Workgroup
Chesapeake Bay Partnership, 2014

Note about Advantex from URI Study

Median effluent value 17.4 mg/l TN which is a 71% reduction.

EVALUATION OF NITROGEN REMOVAL IN ADVANCED ONSITE WASTEWATER TREATMENT SYSTEMS WITHIN THE GREATER NARRAGANSETT BAY WATERSHED. Lancellotti et al, 2017

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