Appendix C

Technical Memorandum – Pollutant Loading Model
Pomperaug River Watershed Based Plan

FUSS & O'NEILL

MEMORANDUM

TO: Pomperaug River Watershed Coalition (PRWC)

FROM: Erik Mas, P.E, Stefan Bengtson, MSc

DATE: March 5, 2018; Revised September 27, 2018

RE: Pollutant Loading Model
Pomperaug River Watershed Based Plan

This memorandum summarizes the methods and results of a pollutant loading model that was developed for the Pomperaug River Watershed. The model is used to support the development of a watershed-based plan for the Pomperaug River watershed.

1. Introduction

The Watershed Treatment Model (WTM), developed by the Center for Watershed Protection, was used to estimate annual pollutant loads from the following Connecticut Subregional Drainage Basins (also referred to as "subwatersheds" in this document) located within the larger Pomperaug River Regional Basin watershed (Figure 1):

- East Spring Brook
- Hesseky Brook
- Nonnewaug River
- Pomperaug River
- Sprain Brook
- Transylvania Brook
- Weekeepeemee River.

The WTM is a screening-level model that can be used to estimate the loading of pollutants to a waterbody based on land use and other activities within a watershed. Based on user-specified input describing characteristics of the watershed, the WTM estimates pollutant loads from various land uses and activities, as well as load reductions associated with structural and non-structural best management practices. While fecal indicator bacteria impairments are the primary focus of the watershed based plan, the WTM also provides loading estimates for other pollutants including total suspended solids (TSS), total phosphorus (TP), and total nitrogen (TN). BMPs that will be recommended in the watershed based plan will not only help to reduce bacteria but may also help to reduce these other pollutants.

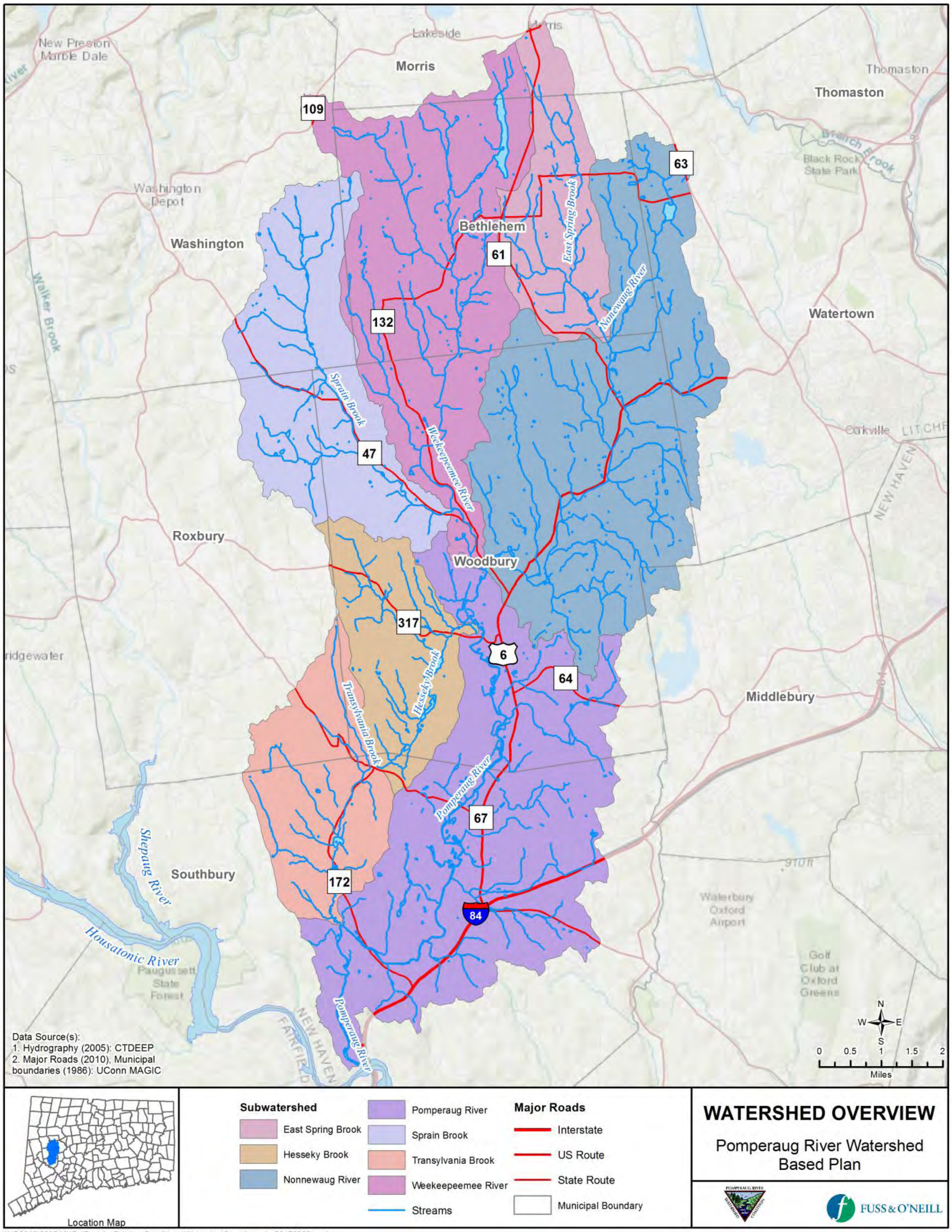

Figure 1: Subregional Drainage Basins in the Pomperaug River Regional Basin Watershed

2. Model Inputs

Primary Sources (Land Use)

Land use is considered a primary source of runoff pollutant loads in the WTM, which uses the Simple Method (Schueler, 1987) to calculate loads from urban land uses, and area loading factors to calculate loads from non-urban land uses. 2016 parcel-based land use data available from the Naugatuck Valley Council of Governments (NVCOG) were adapted for use with the WTM. Impervious area for each land use category was calculated from the National Land Cover Database (NLCD) 2011 impervious cover dataset. Table 1 in *Attachment A* summarizes the modeled land use category and impervious area for each land use classification. Table 2 provides a breakdown of existing modeled land use by subregional drainage basin.

Model inputs were specified for each land use category, including area, impervious cover, runoff coefficient, and runoff pollutant concentrations or export coefficients. Literature-based event mean concentration (EMC) values were used for all developed land use categories, while selected regional export coefficients were used for non-urban land uses. WTM default export coefficients were used for rural, powerline, and open water land use categories. The cropland land use category included both row crops and pasture land. The export coefficients for this land use category were approximated as the area-weighted average of the export coefficients of the two sub-categories. Discussions with the PRWC Land Use Committee revealed that some farmers in the watershed apply manure to their hay fields to increase yields, which was also considered when selecting an appropriate export coefficient for cropland. Tables 3 and 4 in Attachment A summarize the selected EMC and export coefficient values and associated references. Average annual precipitation for the watershed (51.09 inches) was estimated from the average precipitation recorded at the Woodbury station over the period of record (1967-2008) (Northeast Regional Climate Center http://www.nrcc.cornell.edu/).

Secondary Sources

In addition to pollutants generated from land uses, the WTM estimates pollutant loads from other activities or sources (secondary sources) that may be present, but are not necessarily associated with a particular land use. The following secondary sources were included in the WTM for the Pomperaug River watershed:

- Failing or Malfunctioning Septic Systems – Most of the Pomperaug River watershed is served by individual septic systems. A septic system failure rate of 1% was assumed for residential areas throughout the watershed. This rate represents an estimate based on regional failure rates and information provided by Pomperaug and Torrington Health Districts. Based on a review of aerial imagery, tax assessor's database information, and parcel land use mapping, an estimated 3.25% of septic systems in the watershed are within 100 feet of surface water bodies.

- Stream Channel Erosion – Due to the limited data available on stream channel erosion loads in the watershed, a simplified approach was used in which stream channel erosion sediment loads were estimated as a fraction of total watershed sediment load, based on overall stream channel stability. Stream channel erosion sediment loads were assumed to be 50% of the total sediment load for the watershed (reflecting "medium" stream channel degradation and stability), consistent with the model guidance.

- Livestock – This secondary source accounts for pollutant loads from animals that are confined (e.g., feedlots, stables). In the model, pollutant loads associated with pastured animals are simulated as Primary Sources (i.e., cropland land use). Hobby farms with a few horses are common throughout the watershed. Equestrian centers, including stables or boarding, are also prevalent. There are small and large farm operations for cattle, goats, sheep, and alpacas ranging from 10 to more than 300 head. Estimates of head per subregional drainage basin were based on information provided by Sarah Turoczi, a local resident and farmer in the watershed with first-hand knowledge of livestock head counts. Further site-specific information was derived from observations by Fuss & O'Neill personnel during field assessments and from aerial imagery. Tables 7 and 8 in *Attachment A* summarize livestock head counts and other model inputs for the Livestock Secondary Source.

- Road Sanding – Sediment loads from road sanding were calculated based on a 2015 CTDOT report entitled Winter Highway Maintenance Operations. The report includes a survey of 31 municipal public works operations and reveals an average annual application rate of 6.1 tons of sand per lane mile between 2009 and 2014. This was assumed to be uniform over municipally-maintained roads in the watershed. The Connecticut Department of Transportation does not apply sand to state roads, so state-maintained roads were not included in the calculation of lane miles.

- Potential Illicit Connections – In areas served by sanitary sewers, illicit connections were assumed for one in every 1,000 sewered connections and 5% of businesses, consistent with values reported in several national studies, modified to account for local conditions. Model default pollutant concentrations and daily flow values were used.

- Wastewater Treatment Plants – Average daily flow and effluent concentrations reported in Discharge Monitoring Reports obtained from the EPA's Integrated Compliance Information System (ICIS) website were used for estimating pollutant loads from the wastewater treatment plants in the watershed, including Heritage Village, IBM Southbury, and Woodlake Condos.

Refer to Tables 5 and 6 in *Attachment A* for a detailed description of the model inputs and assumptions.

3. Model Results

Existing Pollutant Loads

Annual loads of bacteria, TP, TN, and TSS were estimated for each subregional drainage basin (Figures 2, 3, and 4). Existing modeled pollutant loads are provided in Tables 9.1 – 9.7 in *Attachment A*. The model results indicate that the Pomperaug, Nonnewaug, and Weekeepeemee River subregional drainage basins have the highest annual pollutant loads. This result is not surprising since these are the largest subregional drainage basins by land area. In addition, the primary land uses and activities in these subregional drainage basins have higher EMCs and pollutant loading factors (e.g., residential areas, agriculture, road sanding, and septic systems).

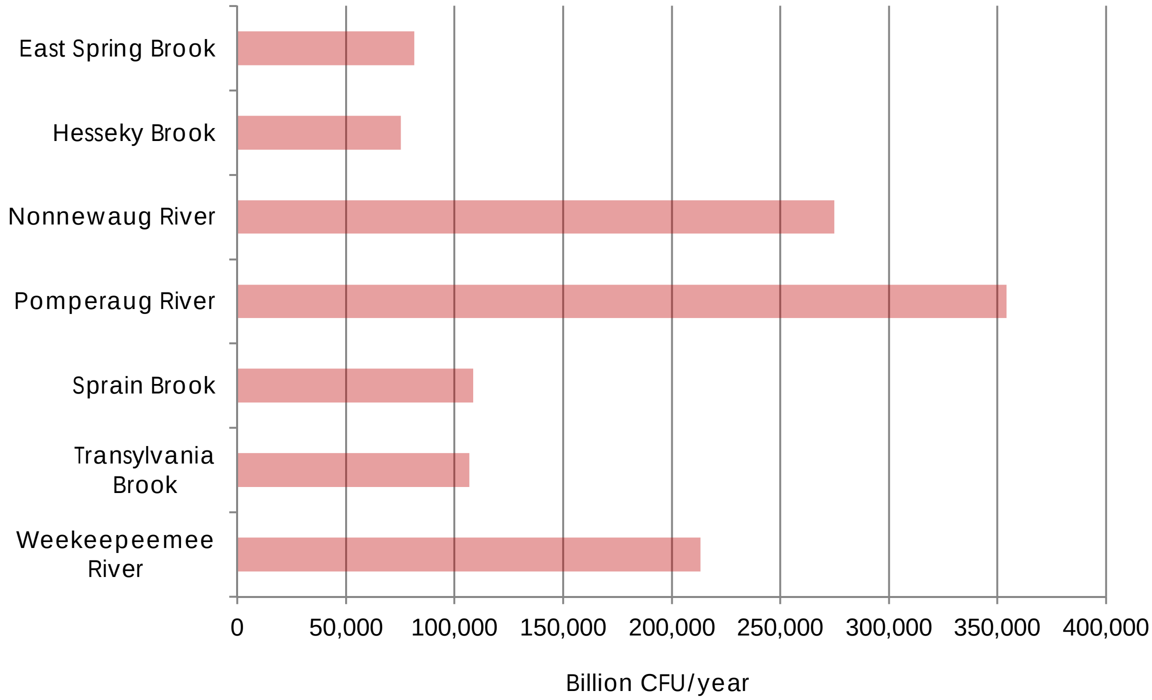

Figure 2: Modeled bacteria loads by subregional drainage basin

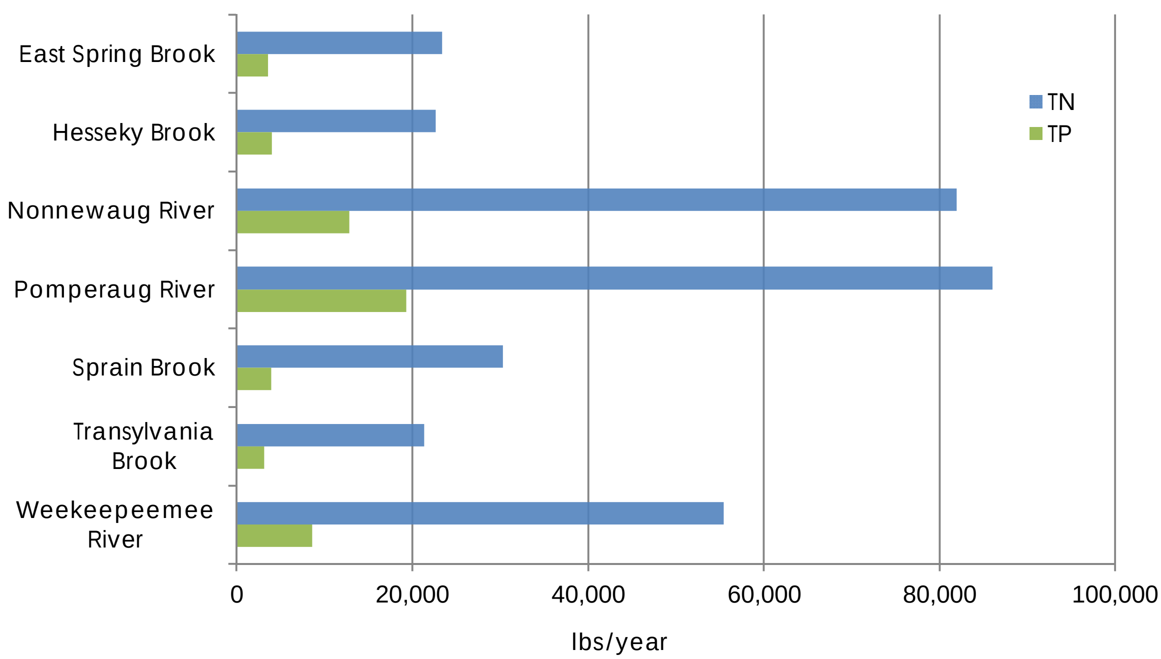

Figure 3: Modeled Total Nitrogen (TN) and Total Phosphorus (TP) loads by subregional drainage basin

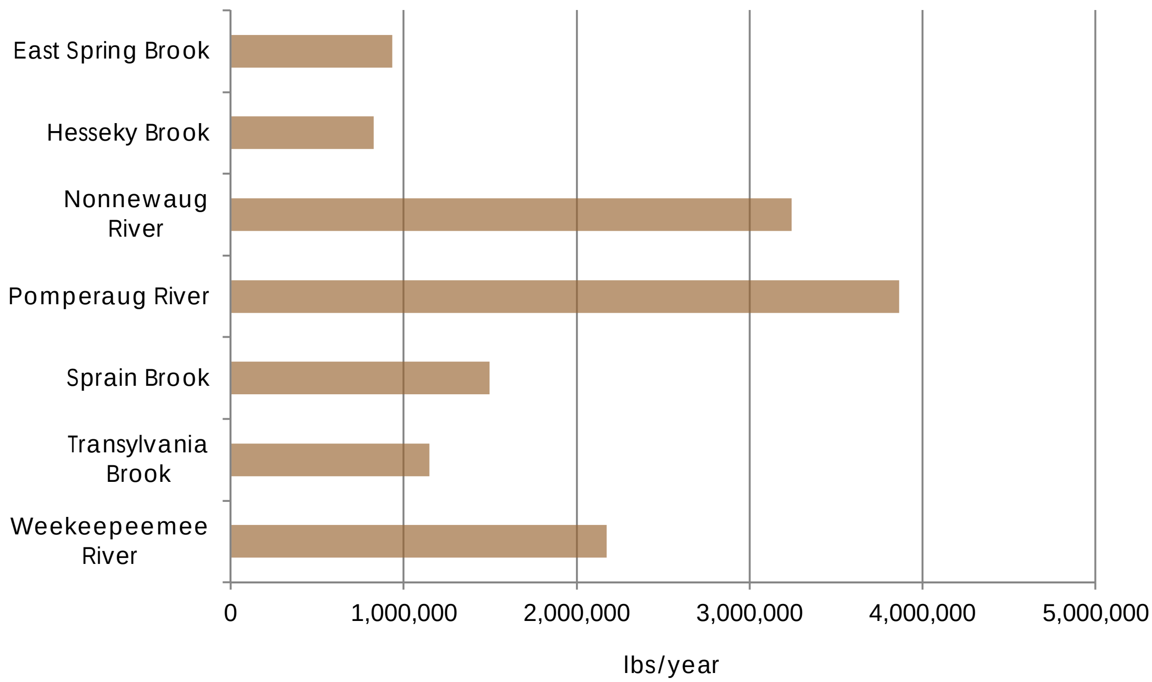

Figure 4: Modeled total suspended solids (TSS) loads by subregional drainage basin

Existing Pollutant Yields

Watersheds differ in area, which directly influences pollutant loads – a larger watershed may have a higher load than a smaller watershed simply because it has a larger area. To remove this effect, pollutant loads were divided by the subwatershed area to derive a per-acre pollutant "yield," which provides a better comparison of pollutant contributions among subwatersheds of varying sizes.

In addition to the highest annual loads, the Pomperaug River subregional drainage basin also has the highest modeled TP, TSS, and bacteria yields and among the highest TN yields (Figures 5, 6, 7). The Pomperaug River subregional drainage basin is characterized by a greater intensity of development and land use activities, namely larger percentages of developed land uses with higher EMCs, larger numbers of septic systems in proximity to mapped streams, greater commercial development with potential for illicit connections, and higher numbers of road lane miles subject to sanding, as well as point source discharges from wastewater treatment facilities. In contrast, the Sprain Brook subregional drainage basin, the fourth largest of the 7 subregional drainage basins considered in this study, has among the lowest annual loads and yields for all pollutants considered. This reflects the predominantly forested nature (approximately 64%) and relatively limited development and agricultural practices within this basin.

In order to assess the reasonableness of the WTM results, the modeled pollutant yields were compared with those of the U.S. Geological Survey (USGS) SPAtially Referenced Regressions On Watershed attributes model (SPARROW) for TN and TP for the overall Pomperaug River watershed. Comparison of the yields in Table 1 shows that there is relatively good agreement between the two models. Notably, WTM results are within the same order-of-magnitude but slightly above the range of SPARROW values.

This result is not very surprising since the SPARROW results are based on data from 1993 and the patterns and intensity of development in the watershed have changed.

Table 1: Comparison of TN and TP estimates

Parameter	TN	TP
WTM (lbs/acre/yr)	4.3 – 6.4	0.6 – 1.4
SPARROW (lbs/acre/yr)	0.9 – 5.9	0.1 – 0.9

Figures 6 and 7 show that most subregional drainage basins have similar modeled nutrient and TSS yields. Despite this similarity, the sources of these pollutants in each subregional drainage basin vary. For example, in the Pomperaug subregional drainage basin, developed land use and residential turf management dominate. In the less developed East Spring Brook subregional drainage basin, agricultural land use more strongly influences pollutant yields. While there are distinct locations in every subregional drainage basin where opportunities for bacteria source reduction could be pursued, the more developed areas and areas with higher concentrations of livestock in the watershed are the dominant sources of existing modeled bacteria loads in the watershed.

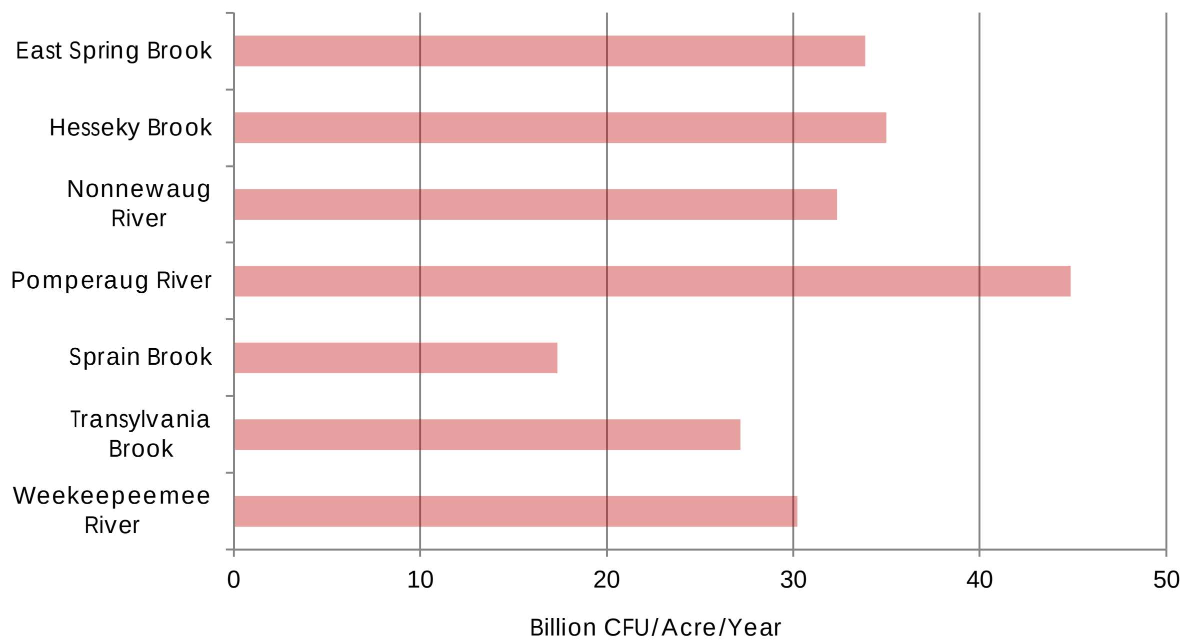

Figure 5: Modeled bacteria yields by subregional drainage basin

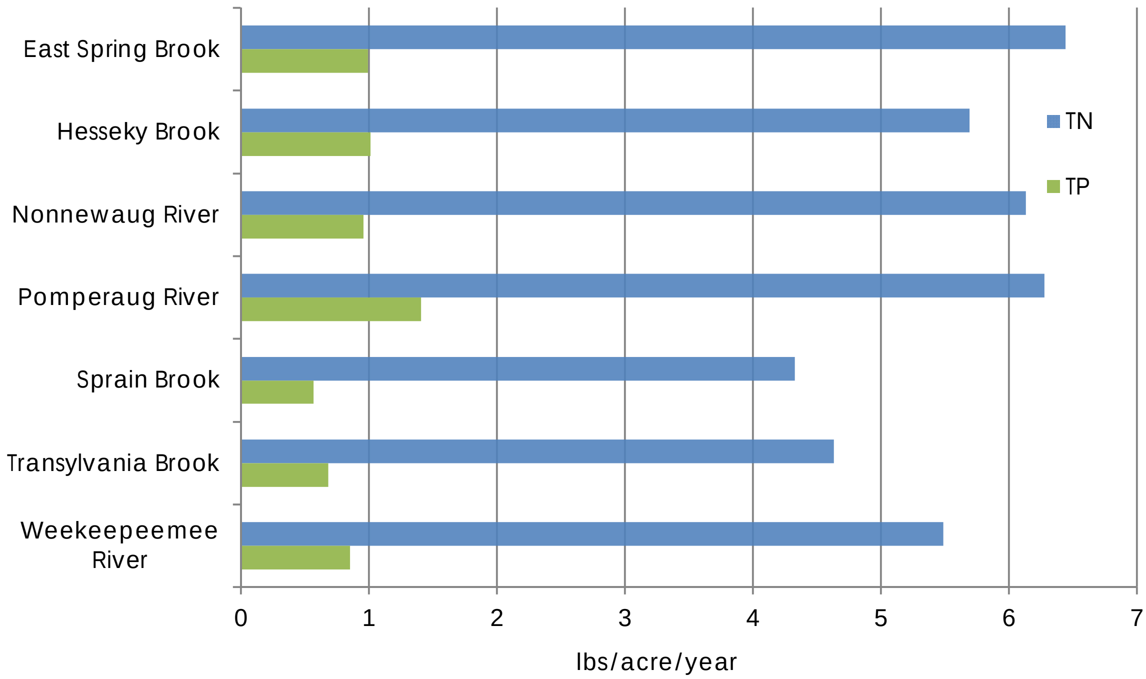

Figure 6: Modeled Total Nitrogen (TN) and Total Phosphorus (TP) yields by subregional drainage basin

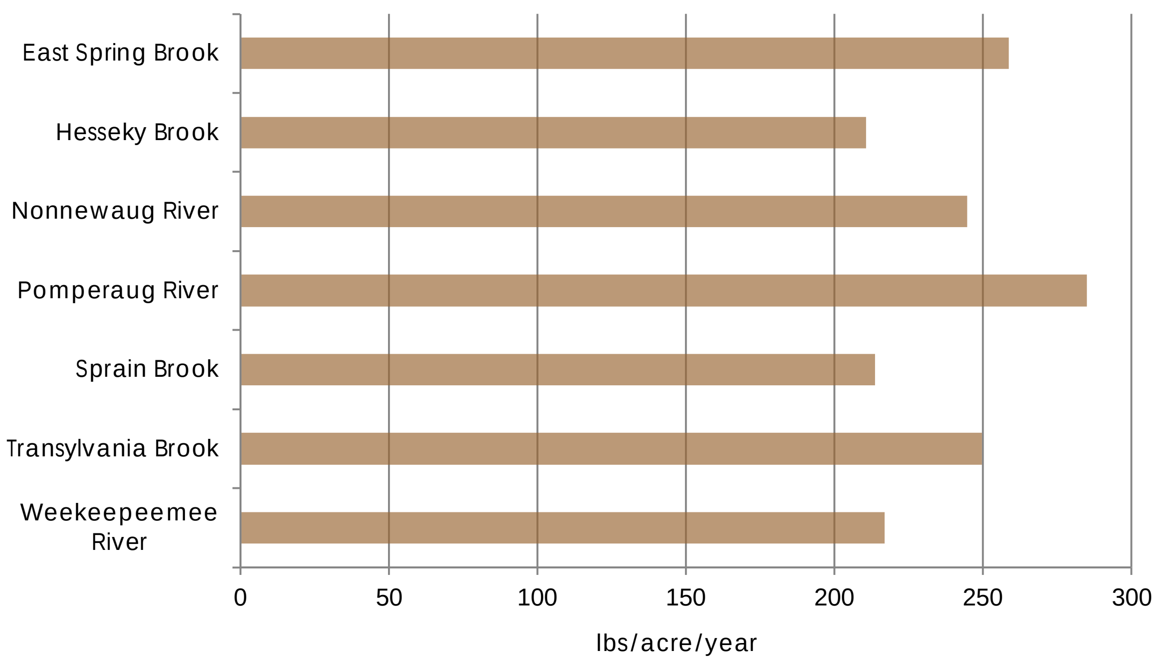

Figure 7: Modeled total suspended solids (TSS) yields by subregional drainage basin

Discussion

Bacteria sources in the watershed reflect both the underlying land use (i.e., agriculture, forest, residential, etc.) and specific activities that can result in bacteria loading to streams (e.g., livestock, septic system failures, illicit discharges). The relative contribution of bacteria from different land uses and activities is well illustrated by a comparison of the modeled loads in the various subregional drainage basins (Figures 8-14). In the more-developed Pomperaug River subregional drainage basin, modeled bacteria loads are dominated by stormwater runoff from urban land use (43%) and potential illicit connections associated with residential and commercial land use (31%), with agricultural sources estimated to contribute approximately 10% of the estimated annual 354,000 billion CFU load (Figure 8). By contrast, in the more rural Weekeepeemee River subregional drainage basin, agricultural land uses (rural land and livestock), contribute an estimated 45% of the annual bacteria load, with stormwater runoff contributing approximately one-quarter of the 213,000 billion CFU annual load (Figure 9).

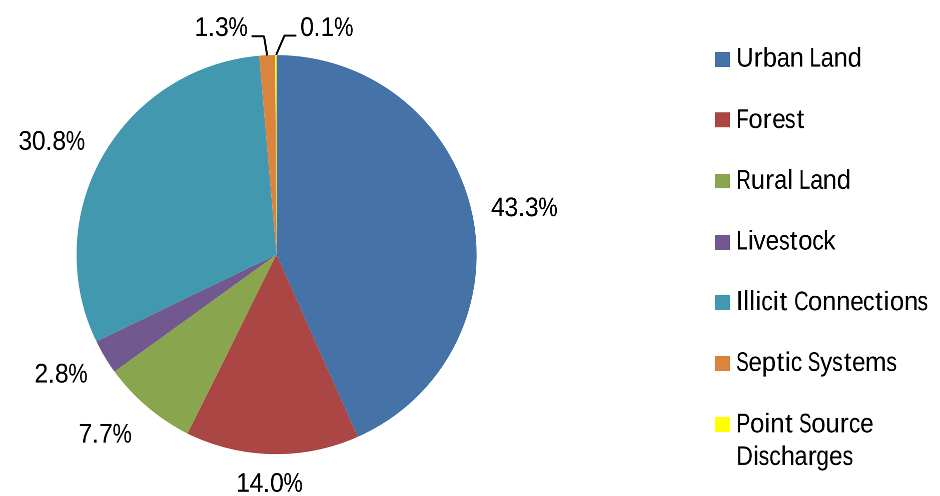

Figure 8: Relative contributions of various bacteria sources in the Pomperaug River subregional drainage basin. Total annual load: 354,000 billion CFU

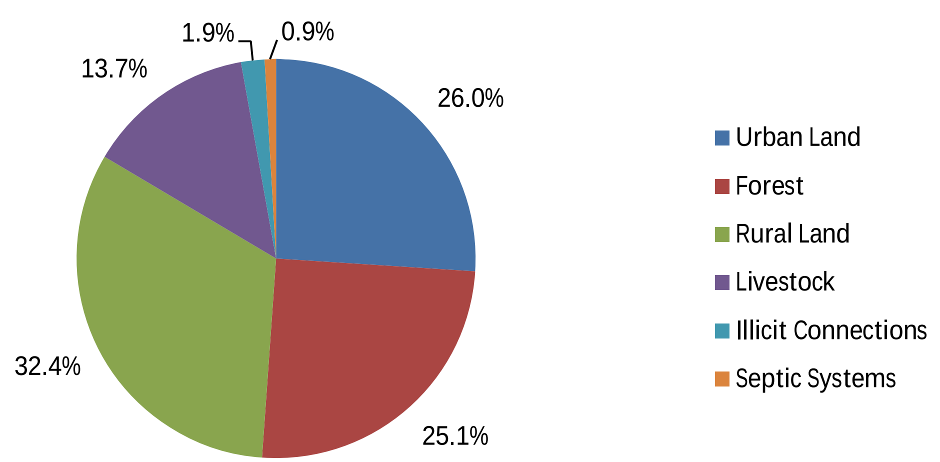

Figure 9: Relative contributions of various bacteria sources in the Weekeepeemee River subregional drainage basin. Total annual load: 213,000 billion CFU

The comparison points out some of the opportunities and challenges in watersheds with mixed land use. The modeled bacteria loads in the Pomperaug River subregional drainage basin illustrate the benefits of management measures that focus on sources of fecal indicator bacteria associated with urban stormwater runoff, including source controls, structural stormwater BMPs, education and outreach, and illicit discharge detection and elimination (IDDE). Even though the estimates of illicit connections are modest (0.1% of the subwatershed population and 5% of the businesses served by sewer), the elimination of these discrete sources of bacteria could substantially reduce bacteria loadings where sanitary-related illicit connections are present (i.e., in areas served by sanitary sewers). Consequently, implementing an IDDE program in the more developed and/or sewered areas of the watershed can be effective at reducing bacteria loads.

In contrast, in the more rural subregional drainage basins, livestock and agricultural practices are key drivers of bacteria loads, though pockets of residential and commercial development in these areas also contribute bacteria loads from urban runoff (Figures 10-14). Agricultural sources of bacteria typically require a combination of structural and non-structural best management practices to reduce loadings, including identification of "hot spot" bacteria sources and site-specific management strategies to achieve load reductions. Livestock in particular represent a considerable bacteria source in the Weekeepeemee River, Nonnewaug River, and Hesseky Brook subregional drainage basins. Where practicable, load reduction in these basins should focus on agricultural best management practices.

The impaired segments of the Pomperaug and Weekeepeemee Rivers are included in the Connecticut Statewide Bacteria TMDL (2012). The TMDL identifies percent reductions (Table 2) in geometric mean and single sample fecal indicator bacteria (*E. coli*) concentrations required to meet recreational water quality criteria. These percentages are for reducing fecal indicator bacteria concentrations at ambient monitoring locations in each river segment, not at the end of stormwater outfalls or other pollutant loads to the river. It is also important to note that these impairments and percent reductions are based on a very limited data set consisting of approximately 10 samples (wet and dry weather) collected at a single station in each river segment in 2010.

Table 2: Bacteria (E. coli) Percent Reductions to Meet TMDL

Impaired River Segment	Geometric Mean	Single Sample
Pomperaug River (CT-6800-00_01)	65%	90%
Pomperaug River (CT6800-00_03)	75%	92%
Weekeepeemee River (CT6804-00_01)	48%[1]	98%[1]

[1]The required percent reductions in *E. coli* concentrations are incorrectly reported (geometric mean and single sample percent reductions are switched) in the Weekeepeemee River Watershed Summary document for the statewide Bacteria TMDL.

Further, the TMDL and modeled load reductions are not directly comparable since the TMDL load reductions targets are daily, seasonal (i.e., worst-case) values, whereas the modeled pollutant loads are annual values. The modeled load reductions are also based on the use of fecal coliform rather than E. coli, the latter being a subset of fecal coliform which is more specific to humans and other warm-blooded animals. E. coli is the indicator bacteria for freshwater monitoring in Connecticut and was used in the TMDL. Additional bacterial monitoring is recommended, as well as further coordination between PRWC and CTDEEP to discuss the watershed based plan findings, recommendations, and modeled potential load reductions relative to the TMDL reduction goals and implications for proposed bacteria monitoring locations.

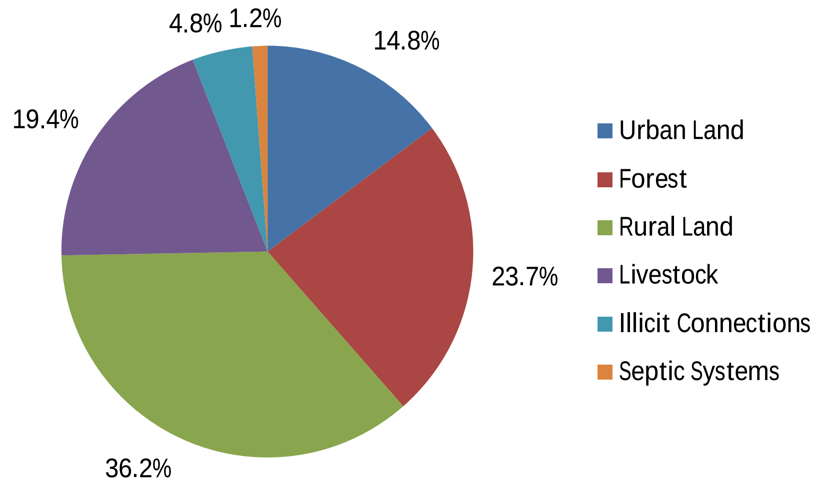

Figure 10: Relative contributions of various bacteria sources in the Nonnewaug River subregional drainage basin. Total annual load: 275,000 billion CFU

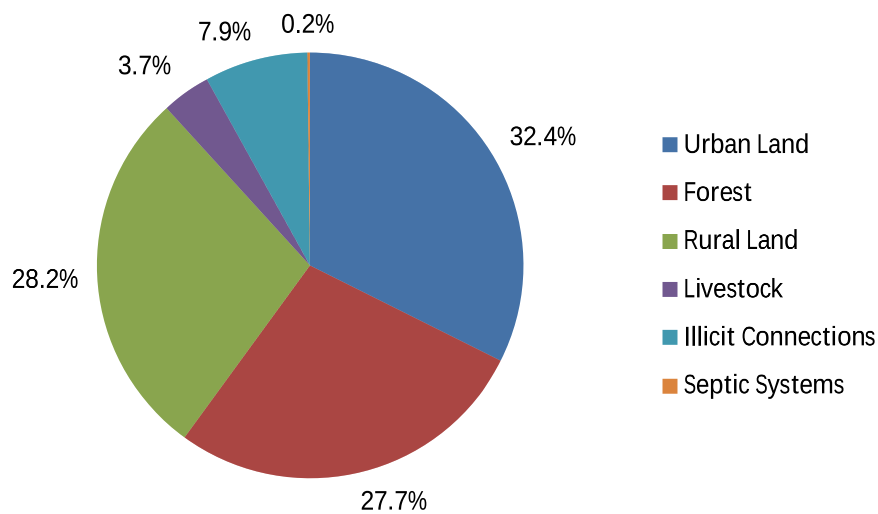

Figure 11: Relative contributions of various bacteria sources in Transylvania Brook subregional drainage basin. Total annual load: 107,000 billion CFU

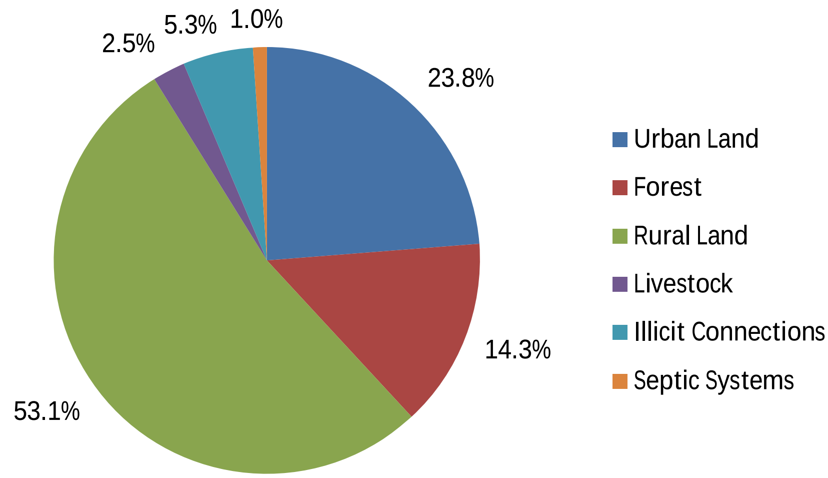

Figure 12: Relative contributions of various bacteria sources in East Spring Brook subregional drainage basin. Total annual load: 81,000 billion CFU

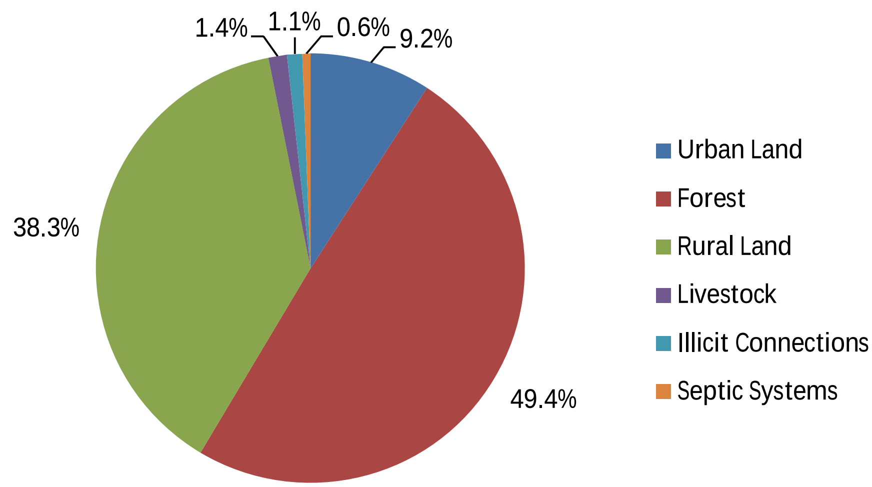

Figure 13: Relative contributions of various bacteria sources in Sprain Brook subregional drainage basin. Total annual load: 109,000 billion CFU

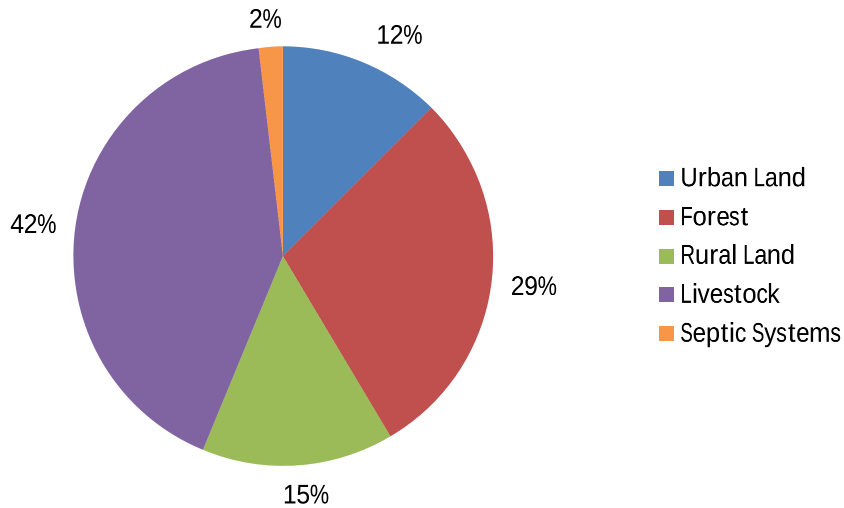

Figure 14: Relative contributions of various bacteria sources in Hesseky Brook subregional drainage basin. Total annual load: 75,000 billion CFU

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Attachment A

Watershed Treatment Model
Model Parameter Values, Input Data, and Model Results

Table 1
Land Use and Impervious Cover in the Pomperaug River Watershed (acres)

	Land Use	Percent Impervious	East Spring Brook	Hesseky Brook	Nonewaug River	Pomperaug River	Sprain Brook	Transylvania Brook	Weekeepeemee River	Watershed Total
Developed	Residential - High Density	13.5	0	0.1	9.6	18.8	0	0	3.2	31.7
	Residential - Medium Density	17.9	16.6	116	126.2	876.6	1.8	78.7	48.9	1,264.90
	Residential - Medium-Low	9.4	37.3	41.9	179.4	381.3	14.9	141.1	65.4	861.5
	Residential - Low Density	2.0	1,383.60	1,561.00	4,082.20	4,664.60	1,217.30	774.9	3,089.40	16,773.00
	Developed Recreation	5.6	0.5	0	206	453.5	30.7	6.1	6.5	703.4
	Commercial	23.1	50.6	0	84.7	659.8	15.5	5	142.7	958.2
	Industrial	7.5	5.8	0	24.8	53.5	0	0	97.4	181.5
	Institutional	15.7	44	2.9	60.2	304.2	0	234.7	206.3	852.3
	Mining	0.1	0	0	87.2	408.4	0	0	0	495.6
	Roadway	17.5	13	153.8	444.8	978.9	140.4	129.7	99.4	1,960.00
	Utilities	3.0	11.5	0	0	0	0	0	0	11.5
Rural	Barren	12.0	0	0	0.2	28.4	21.2	6.5	1.4	57.7
	Cropland	1.0	1,096.20	285.6	2,550.30	699.6	1,066.60	773	1,771.80	8,243.10
	Forest	0.2	971.9	1,823.60	5,432.40	4,123.90	4,472.60	2,462.90	4,455.70	23,743.00
	Water	0.4	0.7	0	72	51.7	13.6	0	111.8	249.9
	Sub-watershed Total		3,631.80	3,985.00	13,360.00	13,703.30	6,994.60	4,612.60	10,099.90	56,387.10

Table 2
Pomperaug Watershed Land Use Map to Modeled Land Uses

	Land Use	Modeled Land Use	Notes
Developed	Residential - High Density	High Density Residential	
	Residential - Medium Density	Medium Density Residential	
	Residential - Medium-Low	N/A	Assigned equally to Medium and Low Density Residential
	Residential - Low Density	Low Density Residential	
	Developed Recreation	Barren	Modeled as barren land use, but with FC value below Low Density Residential
	Commercial	Commercial	
	Industrial	Industrial	
	Institutional	Commercial	Assumed to be same as commercial
	Mining	Mining	
	Roadway	Highway	
	Utilities	Rural	
Rural	Barren	Barren	
	Cropland	Cropland	Combined Pasture, Hay Fields, and Row Crops
	Forest	Forest	
	Water	Open Water	

Table 3
Developed Land Uses - Event Mean Concentrations
(TN, TP, TSS in mg/L and Fecal Coliform in MPN/100ml)

Land Use	WTM Default Values				Regional Values				Selected Values			
	TN	TP	TSS	FC	TN	TP	TSS	FC	TN	TP	TSS	FC
Low Density Residential	2.1	0.31	49	20,000	3.18	0.27	34	2,950	3.18	0.27	34	2,950
Medium Density Residential	2.1	0.31	49	20,000	3.5	0.41	49	12,360	3.5	0.41	49	12,360
High Density Residential	2.1	0.31	49	20,000	3.81	0.64	102	16,901	3.81	0.64	102	16,901
Highway	-	-	-	-	2.65	0.43	141	600	2.65	0.43	141	600
Commercial	2.1	0.22	43	20,000	1.85	0.15	44	9,306	1.85	0.15	44	9,306
Institutional	2.1	0.22	43	20,000	1.85	0.15	44	9,306	1.85	0.15	44	9,306
Industrial	2.2	0.25	81	20,000	4	0.11	42	1,467	4	0.11	42	1,467
Mining	-	-	-	-	1.18	0.15	94	300	1.18	0.15	94	300
Barren	-	-	-	-	1.74	0.11	51	5,000	1.74	0.11	51	300

Notes:
TN = Total Nitrogen; TP = Total Phosphorus; TSS = Total Suspended Solids; FC = Fecal Coliform
Sources:
BETA Group, Inc. (2006). Quality Assurance Project Plan. Development of a Watershed Based Plan for Massachusetts.
Caraco, D. and Center for Watershed Protection, Inc. (2013). Watershed Treatment Model (WTM) 2013 Documentation.

Table 4
Rural Land Uses - Export Coefficients
(TN, TP, and TSS in lb/ac/yr and Fecal Coliform in billion/ac/yr)

Land Use	WTM Default Values				Regional Values				Selected Values				Comments
	TN	TP	TSS	FC	TN	TP	TSS	FC	TN	TP	TSS	FC	
Forest	2.0	0.2	100	12	2.5	0.2	100	12	2.5	0.2	100	12	Selected regional values
Rural	4.6	0.7	100	39	-	-	-	-	4.6	0.7	100	39	Selected WTM Default values
Power Lines	4.6	0.7	100	39	-	-	-	-	4.6	0.7	100	39	Selected WTM Default values
Open Water	12.8	0.5	155	-	0.4 (2)	0.03 (2)	2 (2)	0.4 (2)	0.4	0.03	2	0.4	Selected regional values
Cropland	-	-	-	-	Pasture 1.9 (2) 7.7 (3) 5.6 (4) Row Crops 14.4 (3) 15.7 (4)	Pasture 0.1 (2) 1.3 (3) 0.5 (4) Row Crops 4.0 (3) 0.94 (4)	Pasture 47 (2) 591 (4) Row Crops 1997 (4)	Pasture 7 (2) Row Crops -	10	0.8	300	39	Selected TN, TP, and TSS based on regional sources for pasture and row crops; FC assumed same as Rural land use

Notes:

TN = Total Nitrogen; TP = Total Phosphorus; TSS = Total Suspended Solids; FC = Fecal Coliform

Conversion equation used for Pasture/Orchard

NSQD (2005) and MA DEP QAPP do not provide rural land use data.

Cropland export coefficients are based on regional values. This category includes both pasture and crop land. Pasture land and hay fields are more prevalent in the Pomperaug River Watershed, so the selected coefficients tend towards those values. Information from the Pomperaug River Watershed Coalition Land Use Committee indicates that some farmers apply manure to hay fields, which is reflected in the choice of coefficients.

Sources:

Maestre & Pitt and Center for Watershed Protection (2005). The National Stormwater Quality Database, Version 1.1.

Caraco, D. and Center for Watershed Protection, Inc. (2013). Watershed Treatment Model (WTM) 2013 Documentation.

Regional values identified by number:

1. CDM (2004). Merrimack River Watershed Assessment Study - Screening Level Model.
2. BETA Group, Inc. (2006). Quality Assurance Project Plan. Development of a Watershed Based Plan for Massachusetts. Converted values presented in mg/L into lb/ac/yr assuming 0% impervious area for Forest and 2% impervious area, 46 inches of rain per year, for agricultural land uses.
3. Reckhow et al. (1980): “Modeling Phosphorus Loading and Lake Response under Uncertainty: A Manual and Compilation of Export Coefficients.” From Lin, J. (2005) Review of Published Export Coefficient and Event Mean Concentration (EMC) Data. Converted values from kg/ha/yr to lb/ac/yr.
4. CH2M HILL (2001). PLOAD version 3.0, An ArcView GIS Tool to Calculate Nonpoint Sources of Pollution in Watershed and Stormwater Projects: User’s Manual.

Table 5
Sources and Model Assumptions

Parameter	Sources	Model Assumptions & Notes
Primary Sources		
Watershed Boundary	CTDEEP – Subregional basins	The Watershed Boundary for the subregional basins within the Pomperaug River watershed.
Land Cover and Land Use	NVCOG – Land Use 2016 NLCD 2011 CTECO – 2016 Orthophotography	NVCOG land use classifications were simplified for input into WTM. Acreage for various classifications was determined in ArcGIS by intersecting the land use with the Sub Watersheds. NVCOG land use classifications include Medium-Low Density Residential, which was equally divided and assigned to both Medium Density and Low Density Residential. Because NVCOG does not include Morris, Washington, and Roxbury, their land uses were converted from raster to vector from national land cover data and manually assigned to NVCOG land use categories based on 2016 CT aerial imagery (3-inch resolution).
Pollutant Event Mean Concentrations (EMCs) and Export Coefficients	WTM Default Values, Selected Regional Values used in MA Watershed Based Plan (2006)	Selected regional EMCs used for residential, transitional, commercial, highway, and industrial land use categories. WTM default values used for rural, powerlines, and open water land use categories.
Impervious %	NLCD, 2011	The impervious surface data set available from USGS NLCD as a nationwide dataset representing impervious surfaces in 2011. The percent impervious for land use classes in each subwatershed was determined by intersecting the raster with the 2016 land use data.
Annual Rainfall	Northeast Regional Climate Center	Weather station on Saw Pitt Hill Rd, Woodbury. Period of record 1967-2008.
Stream Length	CTDEEP Hydrography Line	Stream lengths in each subwatershed were calculated based on intersecting the CTDEEP Hydrography Line data layer with the Sub Watershed boundaries.
Soils Information	CTDEEP Soils Data – NRCS SSURGO-Certified Soils 2009	Hydrologic Soils Group data were available from SSURGO and matched to CTDEEP soils data based on the Soil Map Unit Key (MUKey) field An estimate of the depth to groundwater was made by converting USDA drainage classes, which are essentially an estimate of seasonal high water table. Depth to groundwater was estimated at 3-5 ft across the watershed.
Runoff Coefficients	Virginia Erosion & Sediment Control Handbook, 1980.	Runoff coefficients for Rural Land Uses were selected from a range of values listed in the Virginia Erosion & Sediment Control Handbook. Values for Cropland ranged from 0.15 to 0.4 and for Pasture/Orchard, etc. values ranged from 0.12 to 0.35.

Parameter	Sources	Model Assumptions & Notes
Secondary Sources		
General Sewage Data	UConn MAGIC, NVCOG parcel-based land use and WTM defaults	Parcel-based land use in NVCOG area includes dwelling units. The sum of these within the sewered area delineated by UConn MAGIC data was used.
Nutrient Concentration in Stream Channels	Haith et al. 1992	A mid- range value of 0.15 was used for Soil P (%) and Soil TN (%). See figures 4.1 and 4.2 in the WTM 2013 Documentation.
On-Site Sewage Disposal (OSDS)	UConn MAGIC Sewered Areas, NVCOG land use and WTM defaults	All dwelling units assumed to be served by OSDS unless the parcel is within an area served by sanitary sewers. Unsewered areas were set to Clay/Mixed Soils. The default failure rate of 10% was assumed. System type was set to 100% conventional, with medium maintenance. Typical separation from groundwater was assumed to be 3-5 ft. The OSDS density was set at 1-2 per acre based on calculated dwelling unit density in unsewered areas.
SSOs, CSOs,	NA	It was assumed that neither SSOs nor CSOs exist in the study area based on the typical design of sanitary systems in the region.
Illicit Connections	NVCOG Parcel-based land use 2016	In sewered areas, 1/1000 residential connections and 5% of business connections assumed to be illicit. Defaults used for pollutant concentrations and percent wash water.
Stream Channel Erosion	NA to Non-urban watersheds.	Method 1 was selected as the method to estimate channel erosion which is assumed that some fraction of the total watershed load comes from stream channel erosion. A stream degradation value of "medium" (50% of the total sediment load) was applied to each sub watershed.
Livestock	Sarah Turoczi, aerial imagery, Fuss & O'Neill watershed survey	Livestock head counts based on information from Sarah Turoczi, a farmer who has first-hand knowledge of many farm operations in the watershed. Other farms were identified by aerial imagery and head counts inferred based on observations made by Fuss & O'Neill personnel during a watershed assessment. Nutrient loads converted from daily loads in kilograms (Ruddy et al., 2006). E. coli loads converted from daily loads reported by Borel et al. (2015), which are based on those from Wagner and Moench (2009), who incorporated daily fecal production and fecal coliform concentration into their load estimates. These loads are based on the concept of an animal unit (AU), which standardizes animals based on unit forage intake, relative to cows (Scarnecchia 1985).

Parameter	Sources	Model Assumptions & Notes
Road Sanding	Winter Highway Maintenance Operations, 2015 UConn MAGIC – Connecticut Roads (2010)	Based on the CTDOT report, state agencies switched from sand to sodium chloride. An anonymous survey of 31 municipalities in Connecticut showed that 6.143 tons/lane mile of sand was used. This rate was multiplied by the lane miles under municipal jurisdiction to determine the amount of road sand applied per HUC12 Sub Watershed/WTM Area. Road miles were determined by intersection of the Connecticut Roads layer with the shape file containing the respective HUC12 Sub Watershed/WTM Area. Lane miles were double, because all municipal roads are two-lane. The fraction of roads that are open is determined by dividing the amount of roadway that is open by the amount of road that drains to catch basins. Open sections do not have catch basins. Based on the rural/suburban nature of the study area, the length of road within the Municipal Separate Storm Sewer System (MS4) regulated area was used to estimate that 60% of roads were classified as open, on the assumption that urbanized areas are more likely to have closed section roads than more rural areas.
Non-Stormwater Point Sources	EPAs ICIS web data service	Daily discharge values of reported effluent concentrations on the EPA ICIS website were used for evaluating the contributing load from this source. The two treatment facilities with data available through this website were Heritage Village and IBM.

Haith, DA, R Mandel, and RS Wu. 1992. Generalized Watershed Loading Functions, Version 2.0 User's Manual. Department of Agricultural and Biological Engineering, Cornell University, Ithaca, NY.

Northeast Regional Climate Center. 2015. CLIMOD2: Woodbury, CT Precipitation Record 1967 – 2008.

USGS. 2011. National Land Cover Dataset.

Virginia Erosion and Sediment Control Handbook, 1980. Virginia Soil and Water Conservation Committee.

Winter Highway Maintenance Operations, 2015. Connecticut Academy of Science and Engineering report to the Connecticut Department of Transportation.

Table 6
Additional Model Inputs

	East Spring Brook	Hesseky Brook	Nonewaug River	Pomperaug River	Sprain Brook	Transylvania Brook	Weekeepeemee River
Road Sanding (lbs/yr) - Entire Watershed	558,563	614,684	1,861,852	2,778,710	752,034	768,705	1,258,228
% With storm drains	20	20	20	40	20	20	20
% Without storm drains	80	80	80	60	80	80	80
Total length of streams (miles)	16.1	17.0	58.2	46.3	22.2	17.8	38.0
Dwelling units	611	1,050	2,368	5,807	466	761	1,446
Percentage of dwelling units un-sewered	100	100	100	58.3	100	21.7	100
Percentage of dwelling units with onsite septic within 100 ft of surface water[1]	10	10	10	10	10	10	10
Residential Sewered units	0	0	0	2,422	0	596	0
Commercial/Business Sewered units	0	0	0	161	0	2	0
Hydrologic Soil Group (Percent)							
A	2.6	4.3	10.4	10.2	2.8	1.8	4.1
B	23.8	41.2	33.9	51.9	59.7	44.1	52.2
C	57.6	32.6	26.8	14.5	18.3	33.6	25.9
D[2]	16.1	21.9	28.9	23.4	19.3	20.5	17.8

[1]An estimated 10% of dwelling units with septic systems are assumed to be located within 100 feet of a waterbody based on a review of aerial imagery and parcel land use mapping.
[2]Hydrologic soil group designation does not consider surface water. This area has been included under Group D which has the most similar infiltrative properties.

Table 7
Livestock Pollutant Loading Rates/Export Coefficients

Livestock	Nitrogen[1] (lbs/animal/year)	Phosphorus[1] (lbs/animal/year)	E. coli[2] (billion cfu/AU/year)
Bovine	164	26	1,966
Equine	102	18	84
Ovine	18.5	3.2	7,165
Poultry	1.1	0.4	85

[1] Ruddy et al (2006). Loads converted from daily loads in kilograms.

[2] E. coli loads converted from daily loads reported by Borel et al. (2015), which are based on those from Wagner and Moench (2009), who incorporated daily fecal production and fecal coliform concentration into their load estimates. These loads are based on the concept of an animal unit (AU), which standardizes animals based on unit forage intake, relative to cows (Scarnecchia 1985).

Table 8
Estimated Head of Livestock by Subregional Drainage Basin

Livestock	East Spring Brook	Hesseky Brook	Nonnewaug River	Pomperaug River	Sprain Brook	Transylvania Brook	Weekeepeemee River
Bovine	20	175	450	100	15	40	150
Equine	60	40	50	100	15	25	40
Ovine	25	40	25	15	0	0	40
Poultry	30	75	50	50	250	25	50

Notes:

Livestock head counts based on information from Sarah Turoczi, a local resident and farmer who has first-hand knowledge of farming practices in the watershed. Other farms were identified by aerial imagery and head counts inferred based on observations made by Fuss & O'Neill personnel during field assessments.

Table 9.1
Modeled Pollutant Loads in the
East Spring Brook Subregional Basin

Source	Existing Loads to Surface Waters					Percent of total load				
	FC (billion/year)	TN (lb/yr)	TP (lb/yr)	TSS (lb/yr)	Runoff Volume (acre-feet/yr)	FC (%)	TN (%)	TP (%)	TSS (%)	Runoff Volume (%)
Urban Land	19,335	8,125	2,241	78,182	2,146	15.72	34.72	62.31	8.32	61.85
SSOs	-	-	-	-	-	-	-	-	-	-
Channel Erosion	-	5	5	168,847	-	-	0.02	0.14	17.98	-
Road Sanding	-	-	-	256,939	-	-	-	-	27.36	-
Forest	11,663	2,430	194	97,190	140	9.48	10.38	5.40	10.35	4.03
Rural Land	43,200	11,015	885	330,010	1,184	35.12	47.07	24.61	35.14	34.12
Livestock	2,010	630	68	-	-	1.63	2.69	1.90	-	-
Illicit Connections	24,633	39	10	277	-	20.03	0.17	0.27	0.03	-
Point Source Discharges	-	-	-	-	-	-	-	-	-	-
OSDS/Septic	22,151	1,158	193	7,723	-	18.01	4.95	5.37	0.82	-
Open Water	0.28	0.28	0.02	1.40	-	0.00	0.00	0.00	0.00	-
Total Storm Load	76,209	15,482	3,070	888,448	3,470	61.96	66.16	85.36	94.60	100.00
Total Non-Storm Load	46,785	7,920	527	50,720	-	38.04	33.84	14.64	5.40	-
Total Load to Surface Waters	122,993	23,402	3,596	939,168	3,470	100.00	100.00	100.00	100.00	100.00

Table 9.2
Modeled Pollutant Loads in the
Hesseky Brook Subregional Basin

Source	Existing Loads to Surface Waters FC (billion/year)	TN (lb/yr)	TP (lb/yr)	TSS (lb/yr)	Runoff Volume (acre-feet/yr)	Percent of total load FC (%)	TN (%)	TP (%)	TSS (%)	Runoff Volume (%)
Urban Land	9,396	8,734	2,623	128,496	2,624	6.74	38.49	64.97	15.30	82.83
SSOs	-	-	-	-	-	-	-	-	-	-
Channel Erosion	-	4	4	146,900	-	-	0.02	0.11	17.49	-
Road Sanding	-	-	-	282,755	-	-	-	-	33.67	-
Forest	21,883	4,559	365	182,360	253	15.69	20.09	9.03	21.72	7.98
Rural Land	11,138	2,856	228	85,680	291	7.99	12.59	5.66	10.20	9.19
Livestock	31,574	4,508	479	-	-	22.64	19.87	11.86	-	-
Illicit Connections	27,380	36	6	241	-	19.64	0.16	0.15	0.03	-
Point Source Discharges	-	-	-	-	-	-	-	-	-	-
OSDS/Septic	38,067	1,991	332	13,272	-	27.30	8.77	8.22	1.58	-
Open Water	-	-	-	-	-	-	-	-	-	-
Total Storm Load	73,992	16,954	3,521	799,387	3,167	53.06	74.73	87.22	95.20	100.00
Total Non-Storm Load	65,447	5,735	516	40,318	-	46.94	25.27	12.78	4.80	-
Total Load to Surface Waters	139,439	22,689	4,037	839,705	3,167	100.00	100.00	100.00	100.00	100.00

Table 9.3
Modeled Pollutant Loads in the
Nonnewaug River Subregional Basin

Source	Existing Loads to Surface Waters: FC load (billion/year)	TN (lb/yr)	TP (lb/yr)	TSS (lb/yr)	Runoff Volume (acre-feet/yr)	Percent of total: FC (%)	TN (%)	TP (%)	TSS (%)	Runoff Volume (%)
Urban Land	40,606	26,931	7,672	382,699	7,432	9.39	32.87	59.98	11.70	68.19
SSOs	-	-	-	-	-	-	-	-	-	-
Channel Erosion	-	18	18	589,396	-	-	0.02	0.14	18.02	-
Road Sanding	-	-	-	958,854	-	-	-	-	29.32	-
Forest	65,189	13,581	1,086	543,240	770	15.08	16.57	8.49	16.61	7.07
Rural Land	99,462	25,503	2,040	765,090	2,697	23.01	31.12	15.95	23.40	24.75
Livestock	53,224	11,254	1,192	-	-	12.31	13.73	9.32	-	-
Illicit Connections	87,851	136	32	953	-	20.33	0.17	0.25	0.03	-
Point Source Discharges	-	-	-	-	-	-	-	-	-	-
OSDS/Septic	85,849	4,490	748	29,932	-	19.86	5.48	5.85	0.92	-
Open Water	29	29	2	144	-	0.01	0.04	0.02	0.00	-
Total Storm Load	258,510	57,774	11,072	3,108,590	10,899	59.81	70.51	86.56	95.05	100.00
Total Non-Storm Load	173,701	24,167	1,718	161,719	-	40.19	29.49	13.44	4.95	-
Total Load to Surface Waters	432,210	81,941	12,791	3,270,308	10,899	100.00	100.00	100.00	100.00	100.00

Table 9.4
Modeled Pollutant Loads in the
Pomperaug River Subregional Basin

	Existing Loads to Surface Waters					Percent of total load				
Source	FC (billion/year)	TN (lb/yr)	TP (lb/yr)	TSS (lb/yr)	Runoff Volume (acre-feet/yr)	FC (%)	TN (%)	TP (%)	TSS (%)	Runoff Volume (%)
Urban Land	153,444	55,974	15,925	1,056,415	14,799	24.96	65.06	82.45	27.06	92.40
SSOs	-	-	-	-	-	-	-	-	-	-
Channel Erosion	-	18	18	592,836	-	-	0.02	0.09	15.19	-
Road Sanding	-	-	-	1,583,865	-	-	-	-	40.57	-
Forest	49,487	10,310	825	412,390	544	8.05	11.98	4.27	10.56	3.40
Rural Land	27,284	6,996	560	209,880	673	4.44	8.13	2.90	5.38	4.20
Livestock	9,893	2,690	287	-	-	1.61	3.13	1.49	-	-
Illicit Connections	251,484	407	105	2,903	-	40.91	0.47	0.54	0.07	-
Point Source Discharges	352	3,204	524	2,764	-	0.06	3.72	2.71	0.07	-
OSDS/Septic	122,737	6,419	1,070	42,794	-	19.97	7.46	5.54	1.10	-
Open Water	21	21	2	103	-	0.00	0.02	0.01	0.00	-
Total Storm Load	240,129	67,355	17,200	3,793,263	16,016	39.06	78.29	89.06	97.16	100.00
Total Non-Storm Load	374,574	18,682	2,114	110,687	-	60.94	21.71	10.94	2.84	-
Total Load to Surface Waters	614,703	86,038	19,314	3,903,950	16,016	100.00	100.00	100.00	100.00	100.00

Table 9.5
Modeled Pollutant Loads in the Sprain Brook Subregional Basin

	Existing Loads to Surface Waters					Percent of total load				
Source	FC (billion/year)	TN (lb/yr)	TP (lb/yr)	TSS (lb/yr)	Runoff Volume (acre-feet/yr)	FC (%)	TN (%)	TP (%)	TSS (%)	Runoff Volume (%)
Urban Land	9,951	8,003	2,170	99,613	1,976	8.20	26.42	54.59	6.66	54.56
SSOs	-	-	-	-	-	-	-	-	-	-
Channel Erosion	-	8	8	281,857	-	-	0.03	0.21	18.86	-
Road Sanding	-	-	-	345,936	-	-	-	-	23.14	-
Forest	53,671	11,182	895	447,260	605	44.21	36.91	22.51	29.92	16.71
Rural Land	41,597	10,666	853	319,980	1,040	34.26	35.21	21.47	21.41	28.73
Livestock	1,537	405	44	-	-	1.27	1.34	1.10	-	-
Illicit Connections	14,638	21	4	146	-	12.06	0.07	0.11	0.01	-
Point Source Discharges	-	-	-	-	-	-	-	-	-	-
OSDS/Septic	-	-	-	-	-	-	-	-	-	-
Open Water	5	5	0.41	27	-	0.00	0.02	0.01	0.00	-
Total Storm Load	106,762	19,346	3,446	1,417,949	3,621	87.94	63.87	86.70	94.86	100.00
Total Non-Storm Load	14,638	10,945	529	76,870	-	12.06	36.13	13.30	5.14	-
Total Load to Surface Waters	121,400	30,291	3,974	1,494,819	3,621	100.00	100.00	100.00	100.00	100.00

Table 9. 6
Modeled Pollutant Loads in the
Transylvania Brook Subregional Basin

	Existing Loads to Surface Waters					Percent of total load				
Source	FC (billion/year)	TN (lb/yr)	TP (lb/yr)	TSS (lb/yr)	Runoff Volume (acre-feet/yr)	FC (%)	TN (%)	TP (%)	TSS (%)	Runoff Volume (%)
Urban Land	34,588	6,096	1,849	114,373	1,991	27.60	28.52	59.00	9.94	63.23
SSOs	-	-	-	-	-	-	-	-	-	-
Channel Erosion	-	6	6	202,703	-	-	0.03	0.19	17.61	-
Road Sanding	-	-	-	353,604	-	-	-	-	30.72	-
Forest	29,555	6,157	493	246,290	350	23.59	28.81	15.71	21.40	11.13
Rural Land	30,147	7,730	618	231,900	807	24.06	36.17	19.73	20.15	25.64
Livestock	3,948	1,041	111	-	-	3.15	4.87	3.53	-	-
Illicit Connections	21,087	29	5	194	-	16.83	0.13	0.17	0.02	-
Point Source Discharges	-	-	-	-	-	-	-	-	-	-
OSDS/Septic	5,987	313	52	2,087	-	4.78	1.46	1.66	0.18	-
Open Water	-	-	-	-	-	-	-	-	-	-
Total Storm Load	98,237	14,087	2,744	1,101,051	3,148	78.39	65.91	87.53	95.65	100.00
Total Non-Storm Load	27,074	7,286	391	50,101	-	21.61	34.09	12.47	4.35	-
Total Load to Surface Waters	125,311	21,373	3,135	1,151,152	3,148	100.00	100.00	100.00	100.00	100.00

Table 9. 7
Modeled Pollutant Loads in the
Weekeepeemee River Subregional Basin

Source	Existing Loads to Surface Waters FC (billion/year)	TN (lb/yr)	TP (lb/yr)	TSS (lb/yr)	Runoff Volume (acre-feet/yr)	Percent of total load FC (%)	TN (%)	TP (%)	TSS (%)	Runoff Volume (%)
Urban Land	55,460	19,820	5,399	212,994	5,254	18.16	35.75	62.72	9.72	69.36
SSOs	-	-	-	-	-	-	-	-	-	-
Channel Erosion	-	12	12	403,028	-	-	0.02	0.14	18.40	-
Road Sanding	-	-	-	578,785	-	-	-	-	26.42	-
Forest	53,468	11,139	891	445,570	598	17.51	20.09	10.35	20.34	7.89
Rural Land	69,100	17,718	1,417	531,540	1,723	22.63	31.96	16.47	24.26	22.74
Livestock	29,111	3,893	414	-	-	9.53	7.02	4.81	-	-
Illicit Connections	45,786	67	14	459	-	14.99	0.12	0.16	0.02	-
Point Source Discharges	-	-	-	-	-	-	-	-	-	-
OSDS/Septic	52,423	2,742	457	18,278	-	17.17	4.95	5.31	0.83	-
Open Water	45	45	3	224	-	0.01	0.08	0.04	0.01	-
Total Storm Load	207,185	38,198	7,444	2,074,430	7,575	67.84	68.91	86.48	94.68	100.00
Total Non-Storm Load	98,209	17,237	1,164	116,448	-	32.16	31.09	13.52	5.32	-
Total Load to Surface Waters	305,393	55,435	8,608	2,190,878	7,575	100.00	100.00	100.00	100.00	100.00