5 Management Measures and Pollutant Load Reductions

5.1 Pollutant Loads

The Watershed Treatment Model (WTM), developed by the Center for Watershed Protection, was used to estimate annual pollutant loads from all of the CT DEEP Local Basins in the Farm River watershed, with the exception of the CT DEEP Local Basins that largely consist of undeveloped land owned by the Regional Water Authority in the northern portion of the watershed (Local Basins 5112-04 and 5112-05).

The WTM is a screening-level model that is used to estimate the loading of pollutants to a waterbody based on land use and other activities within a watershed. Based on user-specified inputs 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 management measures. The WTM provides annual loading estimates for fecal indicator bacteria (hereafter referred to as "bacteria"), total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS).

Pollutant Load is the quantity or mass of a pollutant originating from point sources (permitted outfalls) and nonpoint source runoff that is delivered to a surface waterbody, via surface inputs or groundwater, in a specified amount of time. A pollutant loading model was developed for the Farm River watershed to estimate the annual pollutant contribution from various land uses and land use activities in the watershed.

Pollutant Load Reductions are reductions in pollutant loads than can be expected as a result of implementing structural controls and non-structural management practices in a watershed (collectively referred to as Best Management Practices or "BMPs"). The pollutant loading model for the Farm River watershed was used to estimate load reductions associated with many of the management measures recommended in the Farm River Watershed Management Plan.

5.1.1 Model Inputs

Primary Sources

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 based on pollutant Event Mean Concentrations (EMCs) and runoff volumes, and area loading factors to calculate loads from non-urban land uses such as agricultural land use and forested areas. Land use categories simulated in the model include:

- Urban Land Uses – Residential (low, medium, and high density and multi-family), Commercial, Industrial, Roadway
- Non-Urban Land Uses – Forest, Rural, Agricultural (cropland and pasture/hay), Open Water (atmospheric deposition)

Parcel-based land use data available from the South Central Regional Council of Governments (SCRCOG) and land cover data from the National Land Cover Database (NLCD) were adapted for use with the WTM. Default WTM EMCs and area loading factor values were used for most land use categories, with some exceptions where local or regional values were available. The EMCs and loading factor values generally account for atmospheric deposition, which is a significant contributor of TN in surface waters. *Attachment X* summarizes the WTM model inputs for each modeled land use category.

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 Farm River watershed:

- Failing or Malfunctioning Septic Systems – A portion of the Farm River watershed is served by individual septic systems. A septic system failure rate of 1% was assumed for residential areas throughout the watershed. Based on parcel mapping and a 100-foot buffer applied to surface waterbodies, an estimated 15% of septic systems in the watershed are within 100 feet of surface water bodies.

- Livestock – This secondary source accounts for pollutant loads from animals that are primarily confined indoors (e.g., dairy cows). In the model, pollutant loads associated with pastured animals are simulated as Primary Sources (i.e., agricultural land use). There are several dairy farms in the watershed along Totoket Road that were incorporated into the modeling as livestock secondary sources.

- 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 based on visual field assessments.

- 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. Furthermore, Branford is the only major watershed municipality that uses sand in winter road maintenance. Therefore, only subwatersheds partially or fully within Branford had road sanding included as a secondary source.

- 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.

5.1.2 Model Results

Annual loads of bacteria, TP, TN, and TSS were estimated for each of the fourteen local basins (*Figures 5-1, 5-3, 5-5, and 5-7*). Existing modeled pollutant loads are provided in *Attachment X*. The model results indicate that local basin 5112-00 (Farm River mainstem) has, by far, the highest annual pollutant loads for bacteria, TN, TP, and TSS. This result is not surprising since this basin makes up the largest percentage of land area in the Farm River watershed.

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 (*Figure 5-2, 5-4, 5-6, and 5-8*).

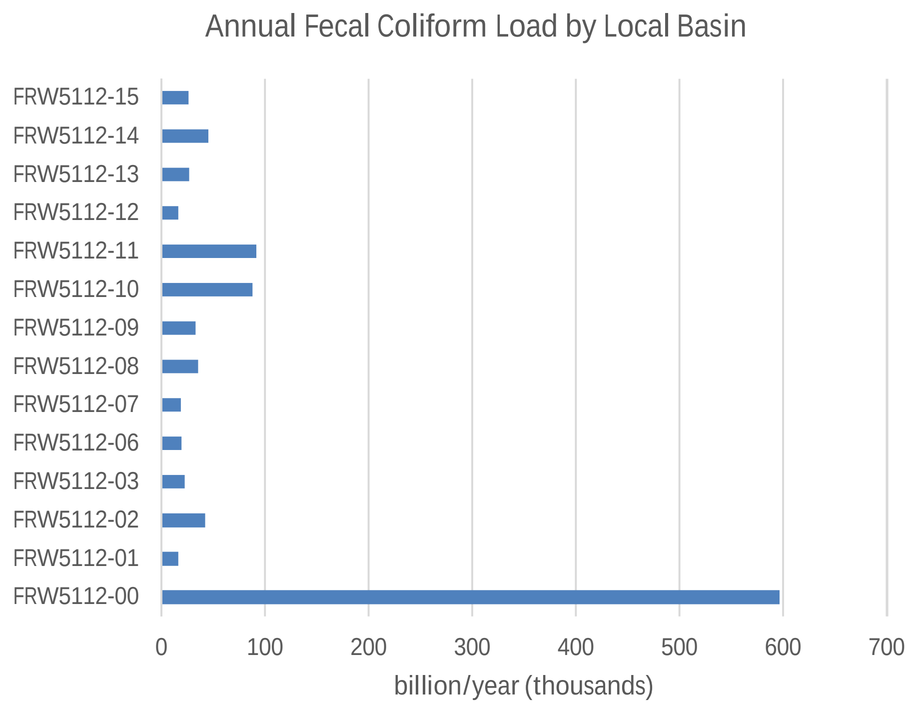


Figure 5-1. Modeled annual fecal coliform bacteria load by local basin in the Farm River watershed

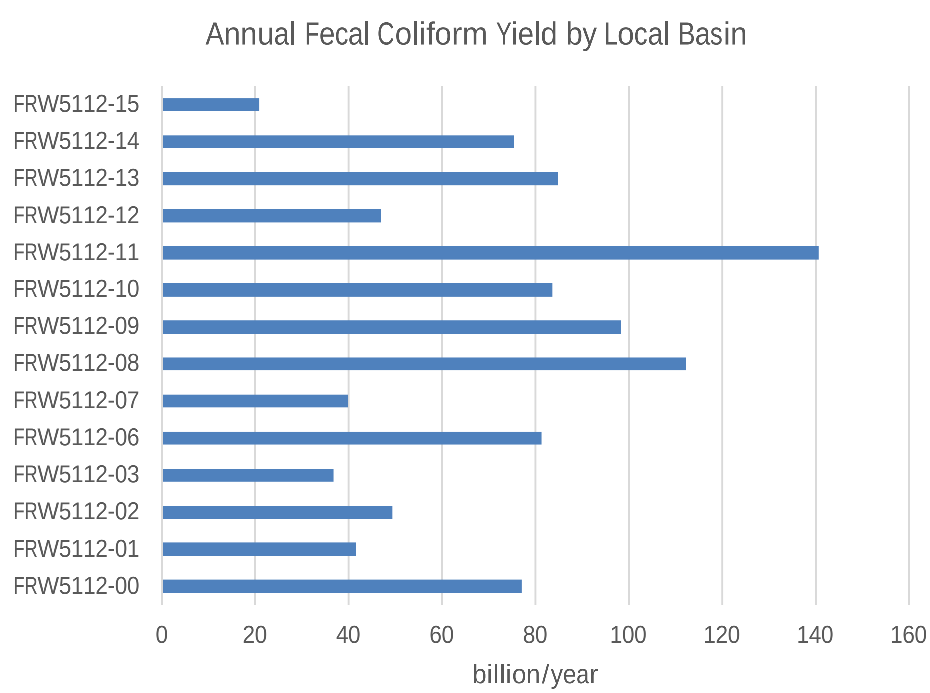


Figure 5-2. Modeled annual fecal coliform bacteria yield by local basin in the Farm River watershed

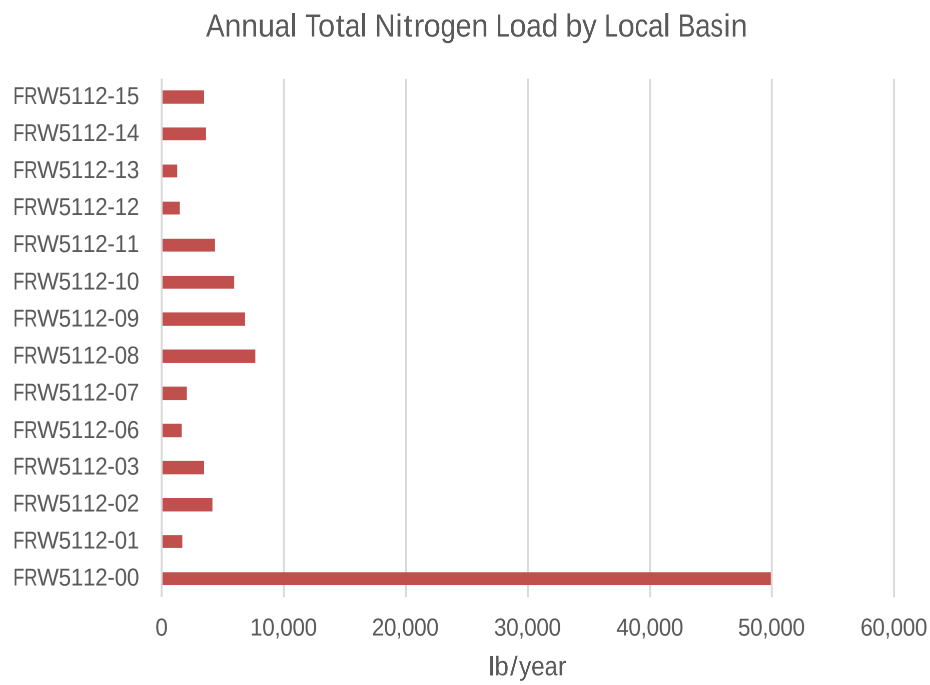


Figure 5-3. Modeled annual total nitrogen (TN) load by local basin in the Farm River watershed

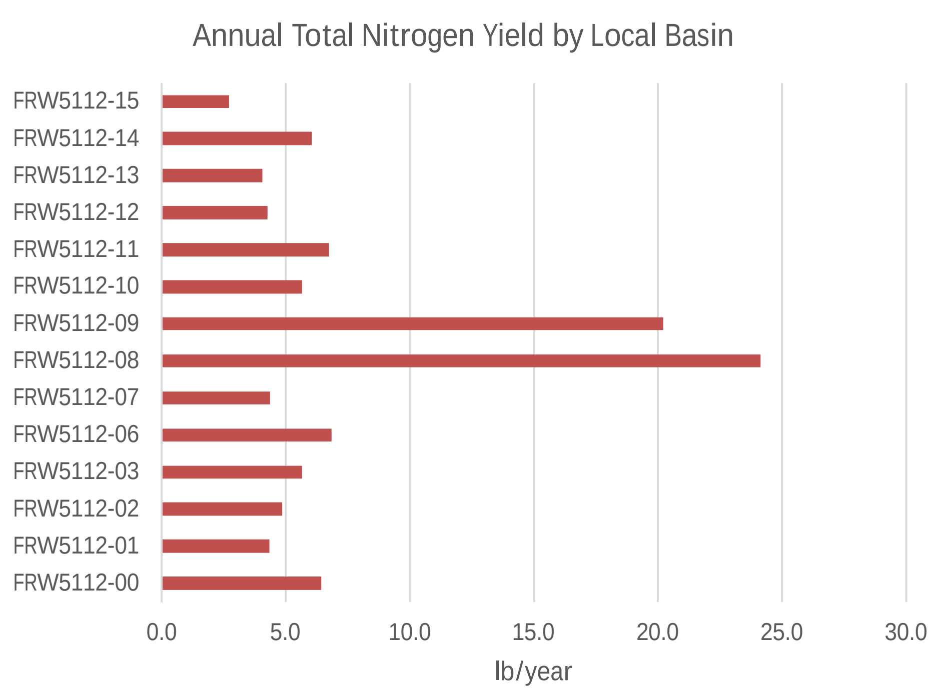


Figure 5-4. Modeled annual total nitrogen (TN) yield by local basin in the Farm River watershed

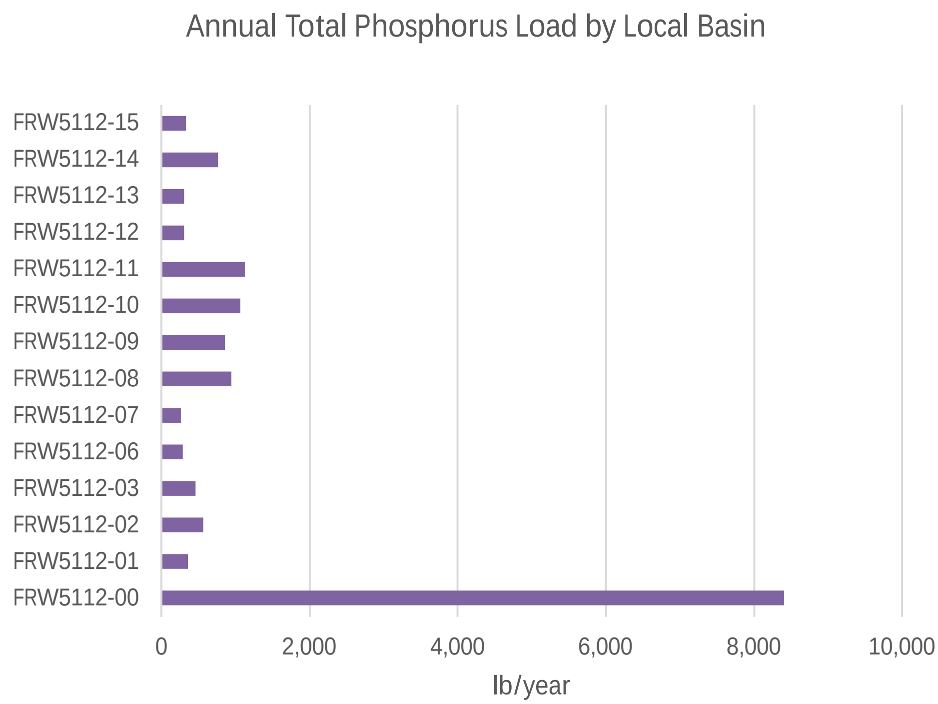


Figure 5-5. Modeled annual total phosphorus (TP) load by local basin in the Farm River watershed

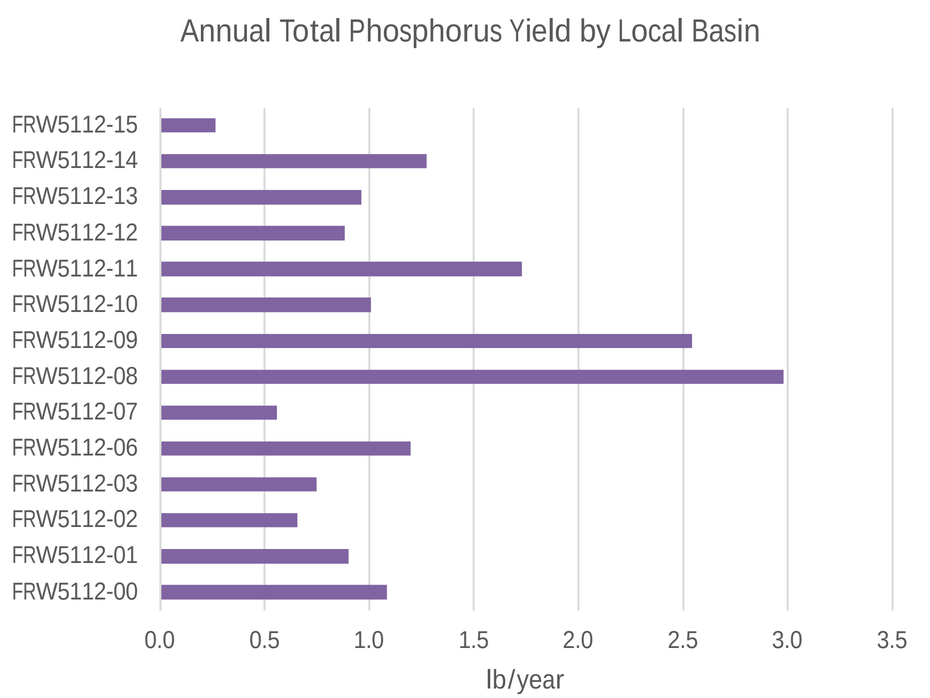


Figure 5-6. Modeled annual total phosphorus (TP) yield by local in the Farm River watershed

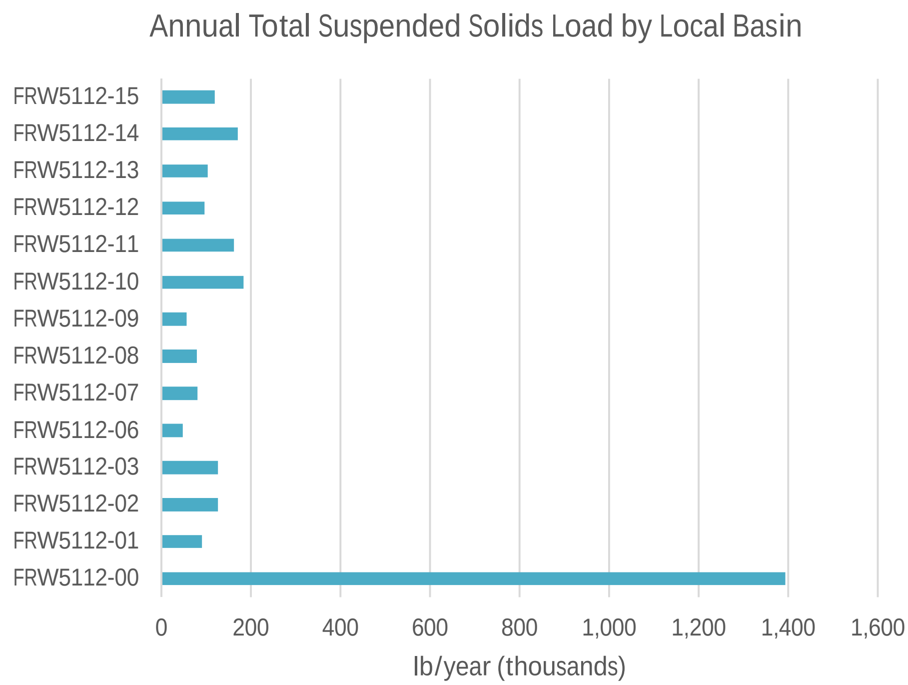


Figure 5-7. Modeled annual total suspended solids (TSS) load by local basin in the Farm River watershed

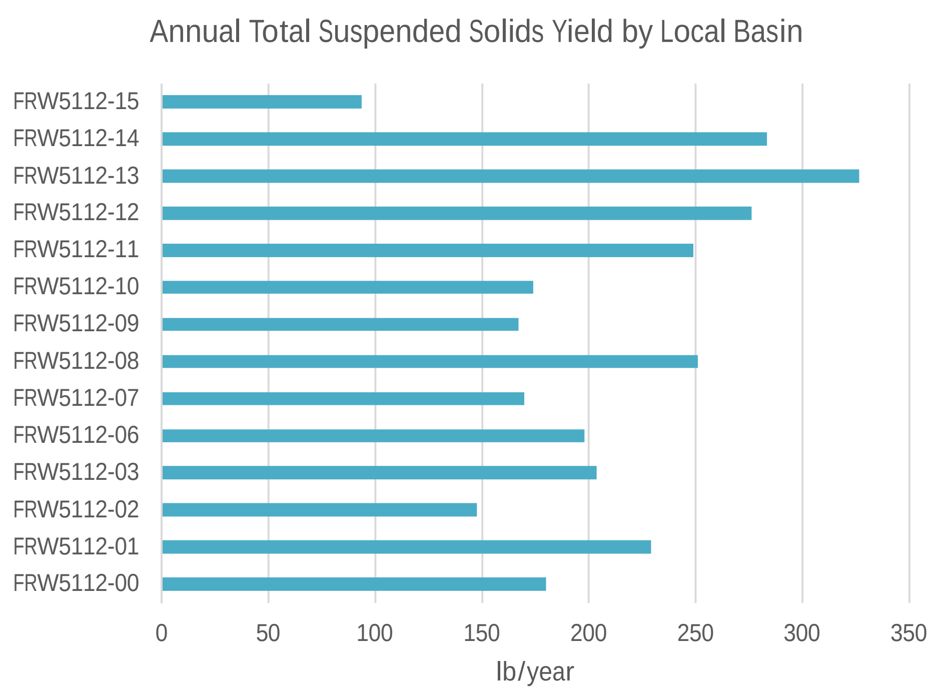


Figure 5-8. Modeled annual total suspended solids (TSS) yield by local basin in the Farm River watershed

Key findings based on the modeled pollutant yields include:

- Bacteria – Local basin 5112-11 (Maloney Brook, East Haven) has the highest modeled bacteria yield, which reflects the high-density residential and commercial development in this subwatershed. This subwatershed also has the highest percentage of impervious cover (26.8%) of the Farm River local basins.
- Nutrients – Local basins 5112-08 (West of Pages Millpond, East Haven and North Branford) and 5112-09 (Northeast of Maloney Brook), which are located on the west-central portion of the watershed, have the highest modeled yields for TN and TP. These results reflect the large percentage of agricultural land use and livestock within these subwatersheds.
- Sediment – Modeled TSS yields are more uniform across the local basins, although local basins partially or wholly within Branford tend to have slightly higher yields due to the use of winter road sand.

Comparison of WTM Results to other Load Estimates

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 Farm River watershed. Comparison of the yields in *Table 5-1* shows that there is relatively good agreement between the two models. Note that the high end of the range of WTM modeled nutrient yields presented in the table reflects the yields for the two local basins with sizeable livestock populations (5112-08 and 5112-09), which have higher yields that are likely not accounted for in the SPARROW estimates.

Table 5-1. Comparison of TN and TP yields in the Farm River watershed derived from WTM and SPARROW model results and USGS water quality monitoring data

Method	TN (lbs/acre/yr)	TP (lbs/acre/yr)
WTM	6.4 (2.7 – 24.1)	1.0 (0.27 – 2.98)
SPARROW	6.2	0.72
USGS Water Quality Monitoring Data	10.25	0.14

The USGS measures flow and collects water quality data at a stream gage on the Farm River near Totoket Road (USGS 01195399). Data collection began in February of 2020 and is ongoing. As of July 2021, approximately monthly water quality monitoring data have been collected for 28 dates, 17 of which include sample results for TN and TP and 13 include *E. coli* data. *Table 5-2* summarizes the water quality monitoring data, including daily loads calculated from TN and TP concentrations measured in the stream and daily streamflow recorded at the gage.

Table 5-2. *E. coli*, TP and TN concentrations and estimated TP and TN daily loads at the USGS gage along the Farm River between February 2020 and June 2021

Date	# Samples Collected	TP (mg/L) T	TN (mg/L)	TP (lbs/day) T	TN (lbs/day)*	*E. coli* (CFU/100 mL)
Feb. 6, 2020	1	0.0172	2.658	2.34	361.77	--
Mar. 2, 2020	1	0.0126	2.642	1.36	284.82	--
Apr. 2020	--	--	--	--	--	--
May 6, 2020	1	0.014	1.898	2.05	277.25	--
June 3, 2020	2 (duplicate)	0.02055 (avg)	2.739 (avg)	1.41	187.50	400.0 460.0+
July 7, 2020	1	0.0332	2.403	0.22	16.02	380.0
Aug. 5, 2020	1	0.0437	2.618	1.59	94.97	400.0
Sept. 1, 2020	1	0.0361	2.237	0.59	36.29	160.0
Oct. 5, 2020 Oct. 30, 2020	2	0.0568 (avg)	1.9075 (avg)	6.81	228.67	74.0 1,413.6+
Nov. 2, 2020	1	0.0572	1.538	5.36	144.25	1,119.9+
Dec. 8, 2020	1	0.0324	2.376	5.31	389.34	767+
Jan. 2021	--	--	--	--	--	--
Feb. 8, 2021 Feb. 27, 2021	2	0.0217 (avg)	2.5105 (avg)	3.42	395.14	81.3 --
Mar. 2, 2021	1	0.0369	2.077	12.77	718.76	187.0
Apr. 8, 2021	1	0.0175	1.986	1.02	115.61	141.2
May 20, 2021	1	0.0248	2.4352	0.24	23.98	--
June 24, 2021	1	--	--	--	--	647.0+
Mean		0.0303	2.2875			
Geomean						302.25

T Unfiltered water results for TP
*Unfiltered water TN results were not available for this station
+ Values in red exceed the single sample threshold for *E. coli* fecal indicator bacteria for freshwater in non-designated swimming areas, as contained in the CT Water Quality Standards (410 CFU/100 mL). The corresponding geometric mean threshold for E. coli is 126 CFU/100 mL

Daily TN and TP loads were aggregated for each month to calculate monthly TP and TN loads, and annual loads were calculated based on average monthly loads over the monitoring period multiplied by 12 months. Annual TN and TP yields (lbs/acre/year) were calculated by dividing the annual loads by the drainage area at the USGS gage (12.9 square miles). *Table 5-1* presents TN and TP yield estimates from the USGS water quality monitoring data. This method resulted in yields of 10.25 lbs/acre/year for TN and 0.14 lbs/acre/year for TP. The estimated TN yield is somewhat higher than the WTM modeled yields; however, the WTM modeled loads and yields don't account for groundwater contribution of TN to surface waters, which may account for some of the difference. The estimated TP yield is somewhat lower than the yields modeled by WTM. This suggests that the amount of phosphorus delivered to the stream is actually lower than the amount of phosphorus generated from various land uses, pointing to physical processes in the landscape (e.g., sedimentation and filtration by wetlands) and in-stream processes that attenuate phosphorus loads, which are not accounted for in the WTM model. The WTM model still provides a reasonable estimate of relative pollutant loads and yields for use in screening-level applications such as this watershed management plan.

Table 5-2 also summarizes the *E. coli* monitoring results relative to the single-sample threshold value (410 CFU/100 mL) and geometric mean threshold value (126 CFU/100 mL) for freshwater in non-designated swimming areas, from the Connecticut Water Quality Standards. Five of the thirteen samples collected for *E. coli* exceeded the single sample threshold value of 410 CFU/100 mL, and the geometric mean of the thirteen *E. coli* sample results (302.25 CFU/100 mL) exceeded the geometric mean threshold value of 126 CFU/100 mL. Most of the single sample exceedances occurred in the summer or fall. Three other samples collected during the summer months had *E. coli* levels just below the single sample threshold. These results underscore the continued recreational impairment along this segment of the Farm River due to elevated *E. coli* levels and the need for load reductions.

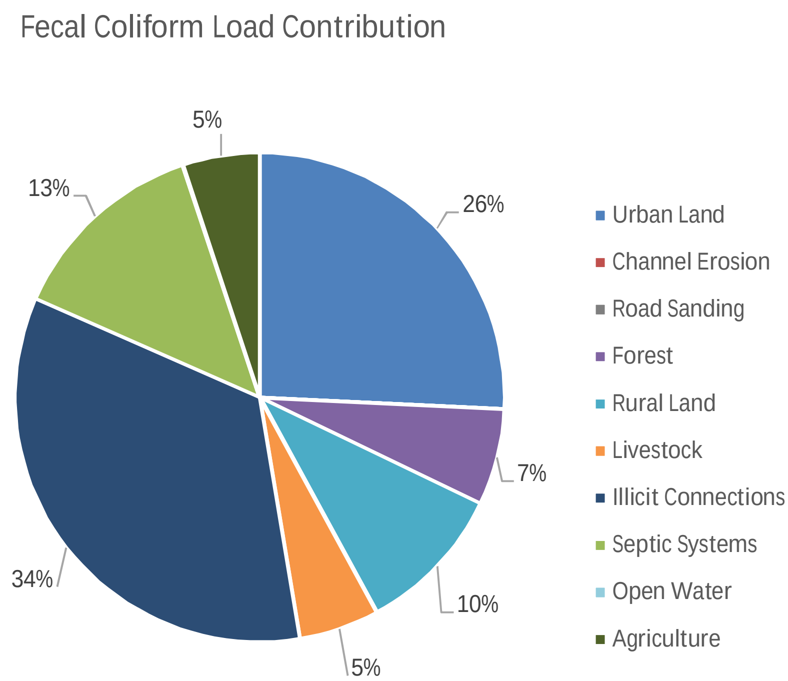
Sources of Modeled Pollutant Loads

Sources of bacteria, nutrients, and sediment loads in the watershed include both the underlying land use (i.e., agriculture, forest, residential, etc.) and specific activities (e.g., livestock, septic system failures, illicit discharges) that generate pollutant loads. The relative contribution of bacteria, nutrients, and sediment from different land uses and activities is illustrated in *Figure 5-9*, which aggregates results of each local basin to represent relative load contributions by pollutant source for the entire Farm River watershed. *Tables 5-3* through *5*-6 present a similar breakdown of pollutant load contributions by source for each local basin. Key findings include:

- Bacteria – 26% of the annual fecal coliform load is from urban land uses (residential, commercial, industrial, and roadways), 34% is from illicit connections in sewered areas of the watershed, and another 13% is from septic systems in unsewered areas. Forested and rural areas contribute 17% of the annual load, while agriculture and livestock account for the remaining 10% of the annual fecal coliform load.
- Nutrients – urban land is the single highest contributor of TN and TP loads, accounting for just under one-third of the annual nutrient load in the watershed. Agriculture and livestock account for approximately 20-30% of the annual nutrient load, while rural land and forest contribute 24-28% of the load.
- Sediment – the major contributors of TSS loads include channel erosion (28%), urban land (23%), forest (20%, and agriculture (15%).

The comparison of pollutant loading by source type points out some of the opportunities and challenges in a watershed with mixed land use. The modeled TN, TP, and bacteria loads for the Farm River watershed as a whole illustrate the benefits of management measures that focus on sources of pollutants associated with urban stormwater runoff (which can carry pet waste, fertilizer, and other potential pollutants), 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 pollutants could substantially reduce fecal indicator bacteria loads 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 local basins, agricultural practices are key drivers of bacteria loads, though areas of residential and commercial development in these areas also contribute pollutant loads from urban stormwater runoff. Agricultural sources of TN, TP, and 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 and farming operations in particular represent a considerable bacteria source in the 5112-03, 5112-08, and 5112-09 local basins.



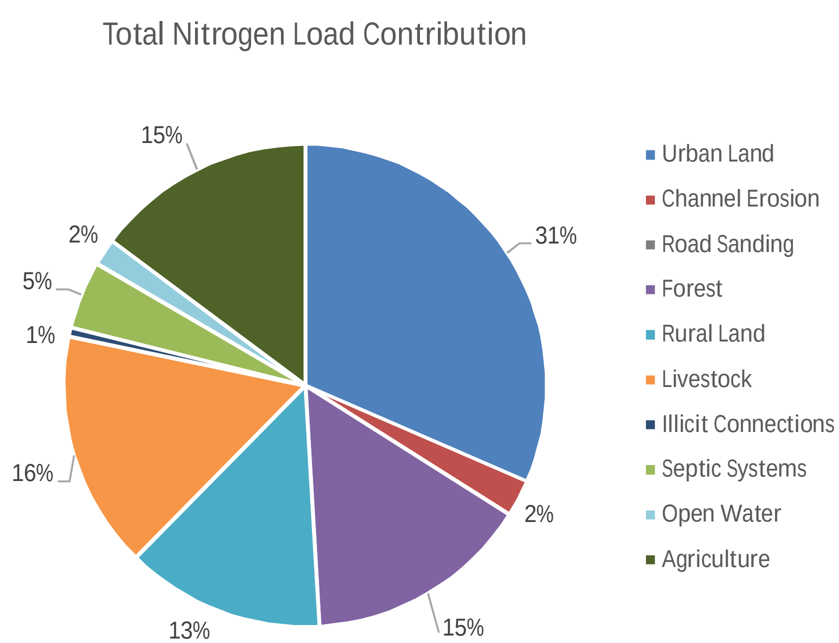
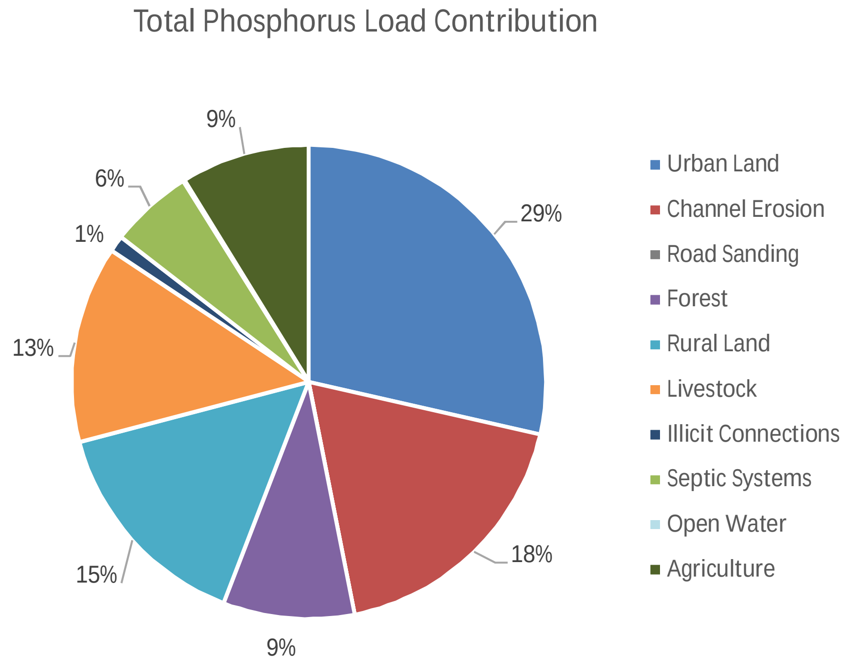


Figure 5-9. Modeled bacteria, TN, TP, and TSS annual load contributions by source



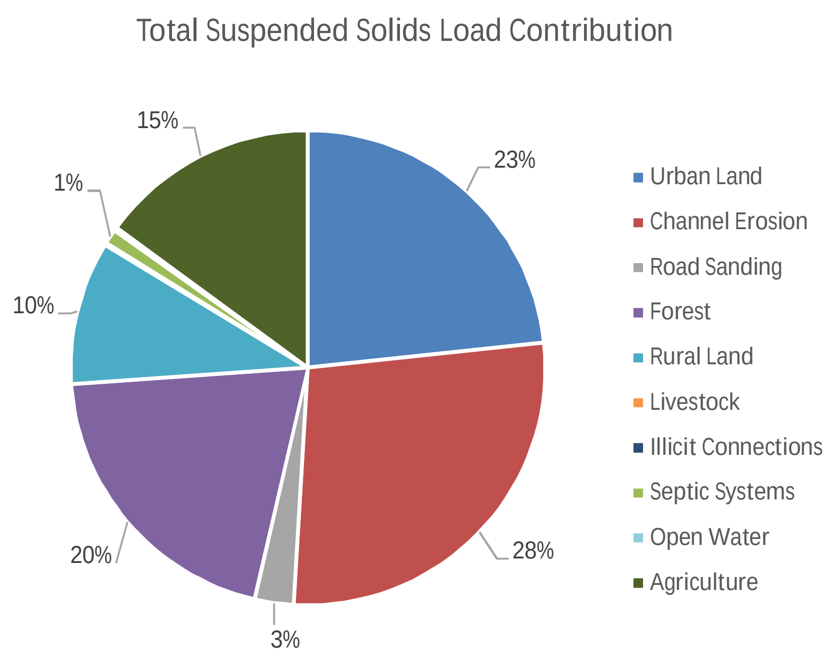


Figure 5-9 (cont.). Modeled bacteria, TN, TP, and TSS annual load contributions by source

Table 5-3. Annual fecal coliform load contribution by source and local basin

Local Basin	Urban Land	Forest	Rural Land	Livestock	Illicit Connections	Septic Systems	Open Water	Agriculture
5112-00	27%	6%	10%	3%	33%	16%	0%	5%
5112-01	20%	18%	13%	0%	24%	25%	0%	0%
5112-02	11%	6%	19%	0%	16%	37%	0%	11%
5112-03	10%	13%	19%	0%	14%	16%	0%	28%
5112-06	17%	6%	11%	0%	22%	42%	0%	2%
5112-07	4%	19%	18%	0%	9%	37%	0%	13%
5112-08	7%	2%	6%	56%	7%	7%	0%	15%
5112-09	9%	6%	4%	59%	15%	1%	0%	6%
5112-10	21%	5%	14%	0%	54%	5%	0%	1%
5112-11	36%	2%	4%	0%	58%	0%	0%	0%
5112-12	17%	10%	22%	0%	32%	15%	0%	4%
5112-13	22%	6%	9%	0%	63%	0%	0%	0%
5112-14	52%	7%	4%	0%	31%	2%	0%	4%
5112-15	36%	23%	5%	0%	31%	4%	1%	0%

Table 5-4. Annual TN load contribution by source and local basin

Local Basin	Urban Land	Channel Erosion	Forest	Rural Land	Livestock	Illicit Connections	Septic Systems	Open Water	Agriculture
5112-00	36%	2%	14%	14%	11%	1%	6%	0%	16%
5112-01	36%	7%	34%	15%	0%	0%	6%	0%	0%
5112-02	18%	2%	13%	22%	0%	0%	11%	8%	26%
5112-03	11%	2%	18%	15%	0%	0%	6%	0%	47%
5112-06	38%	2%	15%	16%	0%	0%	21%	0%	7%
5112-07	6%	3%	36%	20%	0%	0%	6%	0%	31%
5112-08	5%	1%	2%	3%	69%	0%	1%	0%	18%
5112-09	8%	1%	6%	2%	76%	0%	0%	0%	7%
5112-10	46%	2%	15%	25%	0%	2%	3%	2%	5%
5112-11	73%	6%	7%	12%	0%	2%	0%	0%	0%
5112-12	26%	6%	23%	28%	0%	1%	5%	0%	11%
5112-13	44%	7%	26%	21%	0%	2%	0%	0%	1%
5112-14	54%	7%	19%	7%	0%	1%	1%	0%	12%
5112-15	21%	2%	42%	6%	0%	1%	1%	28%	0%

Table 5-5. Annual TP load contribution by source and local basin

Local Basin	Urban Land	Channel Erosion	Forest	Rural Land	Livestock	Illicit Connections	Septic Systems	Open Water	Agriculture
5112-00	33%	15%	9%	16%	9%	1%	7%	0%	10%
5112-01	25%	41%	15%	13%	0%	0%	6%	0%	0%
5112-02	18%	16%	8%	27%	0%	0%	14%	0%	17%
5112-03	12%	20%	12%	18%	0%	0%	8%	0%	30%
5112-06	32%	14%	9%	17%	0%	0%	24%	0%	4%
5112-07	5%	21%	23%	24%	0%	0%	7%	0%	20%
5112-08	5%	6%	1%	5%	68%	0%	2%	0%	13%
5112-09	9%	5%	4%	3%	74%	0%	0%	0%	5%
5112-10	38%	16%	8%	27%	0%	4%	4%	0%	3%
5112-11	51%	33%	3%	10%	0%	3%	0%	0%	0%
5112-12	18%	36%	11%	24%	0%	1%	5%	0%	5%
5112-13	32%	37%	12%	17%	0%	2%	0%	0%	0%
5112-14	36%	41%	9%	6%	0%	1%	1%	0%	6%
5112-15	26%	23%	36%	9%	0%	2%	2%	2%	0%

Table 5-6. Annual TSS load contribution by source and local basin

Local Basin	Urban Land	Channel Erosion	Road Sanding	Forest	Rural Land	Septic Systems	Open Water	Agriculture
5112-00	28%	23%	0%	20%	11%	1%	0%	17%
5112-01	18%	48%	0%	27%	6%	1%	0%	0%
5112-02	15%	23%	0%	17%	16%	2%	1%	26%
5112-03	6%	23%	0%	21%	9%	1%	0%	40%
5112-06	33%	23%	0%	20%	12%	5%	0%	7%
5112-07	4%	23%	0%	37%	11%	1%	0%	24%
5112-08	9%	23%	0%	7%	7%	1%	0%	53%
5112-09	18%	23%	0%	29%	6%	0%	0%	24%
5112-10	35%	24%	0%	18%	17%	1%	0%	5%
5112-11	38%	49%	0%	7%	6%	0%	0%	0%
5112-12	7%	35%	27%	15%	10%	1%	0%	5%
5112-13	12%	30%	38%	14%	6%	0%	0%	0%
5112-14	25%	48%	0%	16%	3%	0%	0%	8%
5112-15	13%	22%	7%	51%	4%	0%	3%	0%

5.2 Pollutant Load Reductions

Pollutant load reductions were estimated for the watershed plan recommendations for which pollutant loads can be reasonably quantified. Load reductions were calculated using WTM for the recommended management actions described below. Load reductions were calculated relative to modeled existing annual pollutant loads presented in *Section 5.1*.

- Green infrastructure and Low Impact Development (LID): Implementation of green infrastructure and Low Impact Development (GI/LID) practices is recommended throughout the Farm River watershed. GI/LID should continue to be implemented through retrofits of existing developed sites and roads (i.e., complete streets), and as part of new public and private development and redevelopment in the watershed, as required by existing and future land use regulations and policies. Potential pollutant load and runoff reductions were estimated under multiple scenarios to estimate the effect of varying levels of GI/LID implementation across the watershed, including estimates for implementing GI/LID practices for 2%, 5%, 10%, and 25% of the impervious area watershed-wide using common filtration and infiltration-based stormwater practices (i.e., bioretention, biofiltration, infiltration).

- Vegetated Buffer Restoration: Potential pollutant load reductions were estimated for restoration of impacted vegetated buffers in suburban areas and agricultural uses in the watershed. The total length of streams with impacted buffers was estimated from the UConn CLEAR riparian buffer and land cover data. Under the modeled restoration scenario, a 50-foot vegetative streamside buffer was assumed for 50% of those areas currently with impacted buffers (i.e., 50% restoration scenario).

- Illicit Discharge and Elimination: Although the estimated number of illicit connections in the watershed is modest (0.1% of the population and 5% of the businesses served by sanitary sewer), the elimination of these discrete sources of bacteria could substantially reduce bacteria and nutrient loadings where sanitary-related illicit connections are present.

- Septic System Repairs and Upgrades: Inspection, maintenance, upgrade, and repair of residential septic systems can significantly reduce bacteria and nutrient loading to waterbodies.

- Public Education: Nonpoint source education programs can change behaviors that affect pollutant loads. Pollutant load reductions were estimated for pet waste education programs based on the number of dwellings, average fraction of pet-owners, pet-owners who already clean up after their pets, and an average fraction of those willing to change their behavior. Pollutant load reductions were also estimated for residential impervious cover disconnection and upgrades and repairs to on-site sewage disposal systems. Conservative model assumptions were used to avoid over-estimating the load reduction benefits of these programs.

Other watershed management recommendations identified in this plan were not quantified due to the inherent limitations of screening-level pollutant load models and/or the lack of reliable information on the pollutant removal effectiveness of certain management measures.

5.2.1 Modeled Pollutant Load Reductions

Table 5-7 summarizes the modeled pollutant load reductions for the plan recommendations for which pollutant loads can be reasonably quantified. The load reduction percentages presented in *Table 5-7* are for the overall Farm River watershed.

Table 5-7. Modeled reductions (%) in annual pollutant loads for the Farm River watershed for proposed management recommendations

Watershed Management Recommendation	TN (%)	TP (%)	TSS (%)	Fecal Coliform (%)	Runoff Volume (%)
Green Infrastructure and LID (10% of impervious area)	2.2%	1.8%	1.7%	1.9%	3.9%
Vegetated Buffer Restoration (50% of impacted stream miles)	14.4%	19.0%	9.9%	10.7%	31.7%
Illicit Discharge Detection and Elimination (IDDE)	0.1%	0.1%	0.0%	4.8%	0.0%
Septic System Repairs & Upgrades	0.9%	0.9%	0.2%	2.6%	0.0%
Public Education	0.6%	0.9%	0.0%	0.3%	0.0%
Total	18.2%	22.7%	11.9%	20.3%	35.6%

Vegetated buffer restoration results in the largest load reductions (approximately 10-20%) for all pollutants and a 32% reduction in runoff volume. Elimination of illicit discharges and septic system repairs and upgrades are predicted to reduce annual fecal coliform loads by an additional 7.5%.

Varying levels of GI/LID implementation across the watershed, through retrofit of existing sites or private redevelopment, were modeled to manage runoff from 2%, 5%, 10%, and 25% of the impervious area in urbanized land uses. The 2% implementation scenario corresponds to the 2% Directly Connected Impervious Area (DCIA) disconnection goal in the first 5-year cycle of the MS4 Permit, while the other scenarios reflect longer-term and more widespread adoption of GI/LID. The results for the 10% scenario, which is considered a reasonable future scenario within the 10-year horizon of this Plan, are included in *Table 5-7*. The results for all four scenarios are presented in *Table 5-8*.

Table 5-8. Modeled reductions (%) in annual pollutant loads for varying levels of GI/LID implementation

Green Infrastructure Implementation Scenario	TN (%)	TP (%)	TSS (%)	Fecal Coliform (%)	Runoff Volume (%)
2% of Impervious Area	0.6%	0.7%	0.5%	0.5%	0.8%
5% of Impervious Area	1.2%	1.1%	0.9%	1.0%	2.0%
10% of Impervious Area	2.2%	1.8%	1.7%	1.9%	3.9%
25% of Impervious Area	5.1%	4.1%	4.1%	4.4%	9.7%

The 10% retrofit scenario is predicted to result in an approximately 2% reduction in annual fecal indicator bacteria loads and 4% reduction in annual runoff volume. Higher bacteria load reductions could be achieved in subwatersheds with higher amounts of impervious surfaces and with more widespread implementation of GI/LID (i.e., applied to 25% or more of the impervious areas) in these areas.

5.2.2 Load Reduction Targets

Fecal Indicator Bacteria

A Total Maximum Daily Load (TMDL) analysis for fecal indicator bacteria was completed for the Farm River as part of CTDEEP's Statewide Bacteria TMDL (2012). A TMDL is a "pollution budget" that identifies the reductions in point and nonpoint source pollution that are needed to meet Connecticut water quality standards for a particular waterbody and a strategy to implement those reductions to restore water quality. The impaired segments of the Farm River (CT5112-00_01 and CT5112-00_02) are included in the TMDL.

The TMDL identifies percent reductions (*Table 5-6*) 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 important to note that the impairment and percent reductions for CT5112-00_02 are based on a very limited data set consisting of approximately 3 samples (dry weather) collected at a single station in each river segment in 1998 through 2000. However, the recent USGS bacteria monitoring data collected at the Farm River stream gage in impaired segment CT5112-00_02, which includes 13 samples collected since February 2020, also suggests that significant reductions in *E. coli* concentrations (58% reduction in geometric mean concentrations, and up to a 70% reduction based on the maximum single sample *E. coli* concentration) are needed to consistently attain the Connecticut Water Quality Standards numeric criteria for freshwater non-swimming recreation.

Table 5-6. Statewide Bacteria TMDL bacteria (*E. coli*) reduction targets for impaired segments of the Farm River

Impaired River Segment	Geometric Mean (126 CFU/100 mL)	Single Sample (410 CFU/100 mL)
Farm River (CT5112-00_01)	91%	98%
Farm River (CT5112-00_02)	91%	75%

Assuming that these percent reductions in E. coli concentrations translate to equivalent percent reductions in loads, significant reductions in annual bacteria loads are necessary in the Farm River watershed for the impaired river segments to meet recreational water quality criteria. The pollutant load modeling results indicate that watershed-wide fecal indicator bacteria load reductions of roughly 20% are achievable with full implementation of the watershed management plan recommendations (under the 10% GI/LID implementation scenario). This suggests that additional controls or more targeted control strategies focused on the local basins directly associated with the impaired Farm River segments (local basins 5112-00, 5112-08, and 5112-09) are needed to fully achieve the load reductions specified in the TMDL. Additional load reductions may be possible through implementation of GI/LID over a larger portion of the watershed, additional vegetated buffer restoration, increasing the public awareness in the watershed of certain best management practices and programs, and increased detection and elimination of illicit discharges.

It is important to note several limitations of both the TMDL load reduction estimates and the pollutant load reduction modeling. The TMDL is based on very limited dry weather monitoring data for impaired segment CT5112-00_02, as only three samples were collected. Data collection efforts were more comprehensive for impaired segment CT5112-00_01, with regular samples collected during the summer between 2003 and 2009.

Further, the TMDL and modeled load reductions are not directly comparable since the TMDL load reduction 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.

As indicated in the TMDL, progress in achieving TMDL-established goals through implementation of this watershed plan may be most effectively gauged through ongoing fixed-station water quality monitoring. A key recommendation of this watershed plan is to continue routine bacterial monitoring at the USGS stream gage and implement expanded stream monitoring for fecal indicator bacteria along the mainstem of the Farm River and its major tributaries (refer to *Section 3.8* of this Plan). The bacteria monitoring program will provide an updated baseline of recreational water quality in the watershed, as well as updated bacteria load reduction targets, to support implementation of the watershed management plan and to measure progress toward achieving pollutant load reduction goals.

Nitrogen and Phosphorus

The pollutant load model results suggest that TN and TP load reductions of 18% and 23%, respectively, are achievable for the overall Farm River watershed based on the management recommendations considered.

TMDLs have not been developed for the Farm River Estuary or the downstream embayment of Long Island Sound, which are impaired for recreation and aquatic life due to low dissolved oxygen and excess nutrients/total nitrogen. The Farm River Estuary and embayment is a focus of CT DEEP as part of the ongoing implementation of its Second Generation Nitrogen Strategy for Long Island Sound and is designated as high priority under the CT DEEP Integrated Water Resources Management framework. CT DEEP and other partners are studying nutrient sources and impacts within the Farm River and other coastal watersheds as part of a larger assessment of nutrients in Connecticut coastal embayments and their contributing watersheds. This effort includes development of target nitrogen loads from the watersheds that are supportive of eelgrass and ecosystem integrity in the downstream estuaries and coastal embayments.