Maine Statewide TMDL for Nonpoint Source Pollution Addendum

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MAINE DEPARTMENT OF ENVIRONMENTAL PROTECTION

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INTRODUCTION

This is an addendum to the *Maine Statewide Total Maximum Daily Load for Nonpoint Source Pollution (NPS TMDL)* (http://www.maine.gov/dep/water/monitoring/tmdl/tmdl2.html), which was prepared by the Maine Department of Environmental Protection (MDEP) and approved by the U.S. Environmental Protection Agency (USEPA) in 2016. This addendum contains the information to develop TMDLs for thirteen streams (Table 1) impaired by nonpoint source pollution (NPS) within their watersheds. Great Lakes Environmental Center, Inc conducted the modeling and drafted the stream-specific summaries for this addendum. This report:

- Contains the watershed-specific information necessary to add NPS TMDLs to the existing 2016 TMDL Report.
- References the basic background information and required TMDL elements from the 2016 TMDL Report.

Table 1. Summary information for impaired streams included in this addendum (from *Maine DEP 2016 Integrated Water Quality Monitoring and Assessment Report Appendices*).

Stream	Town	Segment ID	Class	Listing Cause
Adams Brook	Berwick	ME0106000304_625R01	B	Benthic-Macroinvertebrate Bioassessments
Black Brook	Windham	ME0106000103_607R01	B	Oxygen, Dissolved
Colley Wright Brook	Windham	ME0106000103_607R03	B	Oxygen, Dissolved
Craig Brook	Littleton	ME0101000504_152R02	B	Periphyton Indicator Bioassessments (Proposed)
French Stream	Exeter	ME0102000510_224R03	B	Benthic-Macroinvertebrate Bioassessments; Periphyton Indicator Bioassessments
Halfmoon Stream	Knox, Thorndike, Unity	ME0103000309_326R03 (lower) ME0103000309_326R02 (upper)	B (lower) A (upper)	Periphyton Indicator Bioassessments (lower and upper segments)
Inkhorn Brook	Windham	ME0106000103_607R07	B	Oxygen, Dissolved
Kennedy Brook	Presque Isle	ME0101000412_140R05	B	Periphyton Indicator Bioassessments
Mosher Brook	Gorham	ME0106000103_607R08	B	Oxygen, Dissolved
No Name Brook	Lewiston, Sabattus	ME0104000210_418R02	B	Oxygen, Dissolved
Otter Brook	Windham	ME0106000103_607R09	B	Oxygen, Dissolved
Pleasant River	Windham, Gray	ME0106000103_607R12	B	Oxygen, Dissolved
Stetson Brook	Lewiston, Greene	ME0104000208_413R03	B	Oxygen, Dissolved

These streams are listed on Maine's 303(d) list of impaired waters in Maine DEP's *2016 Integrated Water Quality Monitoring and Assessment Report (MDEP, 2018)*, or are proposed to be listed as impaired in the next Integrated Report. TMDLs are required under the US Clean

Water Act for all impaired waters on the 303(d) list and these will be added to the existing 2016 NPS TMDLs.

The purpose of a TMDL is to calculate the amount of pollutant a receiving water can assimilate without exceeding water quality standards for designated uses. The waterbodies in this report, as listed in Table 1, have been assessed as not meeting the criteria for aquatic life use protection contained within Maine's water quality standards. The waterbodies were included on the 2016 list of impaired waters or are proposed to be included on the next list of impaired waters based on the results of various assessment criteria for aquatic life use support in freshwater streams, primarily dissolved oxygen, benthic-macroinvertebrate bioassessments, and/or periphyton indicator bioassessments.

The waterbodies addressed in this document are impaired by NPS pollution as a result of anthropogenic activities within their watersheds. NPS pollution, also known as stormwater runoff, cannot be traced back to a specific source; rather it often comes from a number of diffuse sources within a watershed. One of the major constituents of NPS pollution is sediment, which contains a mixture of nutrients (such as phosphorus and nitrogen), inorganic and organic material that stimulate algal growth. Excess algal growth consumes oxygen during respiration and leads to a decrease in levels of dissolved oxygen (DO) in a stream. Phosphorus and nitrogen are the limiting nutrients for algal growth and sediment-laden runoff carries these nutrients into streams.

The NPS TMDL addresses nutrients (nitrogen and phosphorus) and sediment in NPS pollution, which have been identified as the primary contributors to the observed and measured degradation of aquatic life use in the impaired waterbodies. Because Maine's water quality standards do not contain numeric criteria specifically for phosphorus, nitrogen, or sediment, a regionally calibrated land-use model known as *Model My Watershed* (previously *MapShed*), and a comparative attainment approach were used to establish pollution reduction targets for each of the impaired waterbodies.

The comparative attainment approach to TMDL development requires identical modeling procedures be applied to impaired watersheds and corresponding watersheds that attain water quality standards for aquatic life and DO. The attainment watersheds share similar characteristics to the impaired watersheds regarding geographic area, climate, soil, topography, watershed size, landscape, development, and land-use patterns. TMDL loading capacity for each of the three surrogate pollutants for each waterbody is calculated by comparing loading results for impaired streams to the appropriate attainment stream values.

Nutrient and Sediment Modeling for this Addendum

The modeling done for the 13 streams and five attainment streams in this NPS TMDL Addendum followed the protocols used in the 2016 NPS TMDL with the following notable differences. All modeling was done using the online *Model My Watershed (v. 1.32.0)*, which replaced the desktop *MapShed* in 2017-2018.

Model My Watershed uses a higher resolution soils layer (gridded SSURGO vs. STATSGO previously in *MapShed*), which often results in seeing higher k-factor (soil erodibility) in some areas of the watershed. This higher k-factor produces higher values for streambank erosion contribution to model sediment load (and to some extent the nitrogen and phosphorus load). *Model My Watershed* has improved subsurface (groundwater) nitrogen estimates resulting in significantly lower total nitrogen per watershed. This version of *Model My Watershed* also uses the USDA National Agricultural Statistics Service (NASS) 2012 county-based livestock inventory, which was subsequently area-weighted to watershed size, and is more current than what was available through *MapShed* for the 2016 NPS TMDL.

Additional enhancements to this modeling effort include:

- Supplied localized (regional) weather (temperature and precipitation) data for the recent time period (2009-2020 or 12 years of record).
- Employed the most current available land use/cover (NLCD 2016). Since both the sensor age and the algorithm were improved from NLCD 2011, this resulted in considerable differences seen in wooded, wetland, and cropland areas compared to NLCD 2011. The wetland/open water attenuation factor that was applied was based on this newer land use/cover data. The stream buffer in agricultural land (hay/pasture land and cropland) was also based on this newer land use/cover data.
- Reduced estimates of agricultural BMP-use based on available feedback. This was local feedback for Craig Brook and Kennedy Brook, regional feedback from Vermont DEP and high BMP-use feedback from the Chesapeake Bay region. The previous *MapShed* 2012 modeling effort suggested very high percentages of cover cropping, conservation tillage, contour farming, and animal grazing rotation. However, because cropland area per watershed is very small for 11 of the 13 watersheds (except Craig Brook and Kennedy Brook), the reduction in estimates of cropland BMP-use would not significantly alter the model results.

To ensure comparability between the non-impaired (attainment) stream loading values and those of the 13 impaired watersheds, the attainment stream watersheds were also simulated with *Model My Watershed* using the same protocols. Below (Tables 2, 3 and 4) are the loading results for each of the five attainment stream watersheds.

The TMDL is the average of these attainment stream loading values for each pollutant. The difference in loading estimates between the impaired and attainment watersheds represents the percent reduction in nutrient loading required under this TMDL.

Table 2. Total Phosphorus Results and Total Maximum Daily Load Calculations for Attainment Streams.

Total Phosphorus kg/yr					
Sources/Pathways	**Footman Brook**	**Martin Stream**	**Moose Brook**	**Upper Kenduskeag Stream**	**Upper Pleasant River**
Source Loads					
Hay/Pasture	64.7	230.0	114.2	253.8	29.5
Cropland	113.0	37.5	390.7	149.8	0.8
Wooded Areas	10.5	57.6	37.5	60.0	12.0
Wetlands	10.3	51.4	36.7	24.6	10.2
Open Land	0.5	3.3	3.5	2.5	0.7
Barren Areas	0.0	0.3	0.0	0.0	0.5
Low-Density Mixed	0.6	15.8	4.8	7.3	9.5
Medium-Density Mixed	0.0	11.1	0.7	4.6	11.3
High-Density Mixed	0.6	0.8	0.0	1.4	2.3
Low-Density Open Space	4.1	23.4	10.4	25.9	13.0
Farm Animals	20.3	110.8	4.3	65.9	24.0
Septic Systems	0.0	0.0	0.0	0.0	0.0
Source Load Total:	224.6	542.0	602.8	595.8	113.8
Pathway Load					
Stream Bank Erosion	7.0	304.0	82.0	211.0	31.0
Subsurface Flow	59.0	536.7	117.4	266.0	100.1
Total Watershed Mass Load:	290.6	1382.7	802.2	1072.8	244.9
Total Watershed Area (ha):	1,729	10,762	4,460	6,698	1,507
Total Maximum Daily Load:	**0.17 kg/ha/yr**	**0.13 kg/ha/yr**	**0.18 kg/ha/yr**	**0.16 kg/ha/yr**	**0.16 kg/ha/yr**
Average:			**0.16 kg/ha/yr**		

Table 3. Total Nitrogen Results and Total Maximum Daily Load Calculations for Attainment Streams.

Total Nitrogen kg/yr					
Sources/Pathways	**Footman Brook**	**Martin Stream**	**Moose Brook**	**Upper Kenduskeag Stream**	**Upper Pleasant River**
Source Loads					
Hay/Pasture	185.4	558.7	223.5	740.7	101.0
Cropland	631.5	195.4	1763.3	916.1	5.3
Wooded Areas	200.0	1120.4	767.5	1120.3	230.4
Wetlands	207.5	1033.4	761.1	480.1	202.4
Open Land	14.3	112.6	104.4	63.2	20.7
Barren Areas	0.0	8.8	0.0	0.8	17.1
Low-Density Mixed	6.2	158.6	50.0	69.9	94.0
Medium-Density Mixed	0.0	117.3	8.2	47.0	118.3
High-Density Mixed	5.9	8.7	0.0	14.1	23.7
Low-Density Open Space	40.4	234.4	107.7	249.0	128.4
Farm Animals	108.1	605.6	18.1	354.3	104.4
Septic Systems	0.0	92.5	6.1	35.2	86.8
Source Load Total:	1399.3	4246.4	3809.9	4090.7	1132.5
Pathway Load					
Stream Bank Erosion	26.0	776.0	204.0	1054.0	125.0
Subsurface Flow	1569.6	27085.1	3086.1	6348.9	5161.5
Total Watershed Mass Load:	2994.9	32107.5	7100.0	11493.6	6419.0
Total Watershed Area (ha):	1,729	10,762	4,460	6,698	1,507
Total Maximum Daily Load:	**1.73 kg/ha/yr**	**2.98 kg/ha/yr**	**1.59 kg/ha/yr**	**1.72 kg/ha/yr**	**4.26 kg/ha/yr**
Average:			**2.46 kg/ha/yr**		

Table 4. Total Sediment Results and Total Maximum Daily Load Calculations for Attainment Streams.

Total Sediment 1000 kg/yr					
Sources/Pathways	**Footman Brook**	**Martin Stream**	**Moose Brook**	**Upper Kenduskeag Stream**	**Upper Pleasant River**
Source Loads					
Hay/Pasture	2.0	11.9	3.9	10.8	7.6
Cropland	40.8	4.7	70.7	48.7	0.3
Wooded Areas	0.5	1.6	0.6	3.6	0.7
Wetlands	0.1	0.6	0.4	0.4	0.2
Open Land	0.1	0.6	0.7	1.0	0.2
Barren Areas	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	0.2	4.4	1.2	2.5	2.8
Medium-Density Mixed	0.0	4.5	0.3	1.9	4.4
High-Density Mixed	0.1	0.3	0.0	0.6	0.9
Low-Density Open Space	1.3	6.5	2.5	8.9	3.8
Farm Animals	0.0	0.0	0.0	0.0	0.0
Septic Systems	0.0	0.0	0.0	0.0	0.0
Source Load Total:	45.2	35.1	80.3	78.3	21.1
Pathway Load					
Stream Bank Erosion	15.7	587.7	136.0	594.9	109.4
Subsurface Flow	0.0	0.0	0.0	0.0	0.0
Total Watershed Mass Load:	60.9	622.7	216.3	673.1	130.4
Total Watershed Area (ha):	1,729	10,762	4,460	6,698	1,507
Total Maximum Daily Load:	**35.2 kg/ha/yr**	**57.9 kg/ha/yr**	**48.5 kg/ha/yr**	**100.5 kg/ha/yr**	**86.5 kg/ha/yr**
Average:			**65.7 kg/ha/yr**		

PUBLIC PARTICIPATION

A virtual informational meeting on the plan to add thirteen (originally fourteen) freshwater streams to the Statewide NPS TMDL was held on January 20, 2021 via Microsoft Teams. Notification of the meeting was sent via email on December 18, 2020 to potential stakeholders including, municipalities, Soil and Water Conservation Districts, Natural Resource Conservation Service regional representatives, Maine Department of Agriculture, Conservation, and Forestry, USEPA, and other interested parties. Nineteen stakeholders attended the meeting live, and the recording of the meeting and copy of the presentation was made available to others who could not attend. The meeting agenda consisted of: Welcome and Introductions; Purpose, Background and Uses of TMDLs; Overview of Maine's Statewide NPS TMDL and Current Update; Statewide NPS TMDL Stream Summary Example; Previous Stakeholder Concerns; Update Process and Project Timeline; Questions and Answers; Wrap-up and Next Steps.

To improve the accuracy of model results, the Maine DEP made a request to the appropriate municipalities, Soil and Water Conservation Districts, Natural Resource Conservation Service regional representatives, and the Maine Department of Agriculture, Conservation, and Forestry for watershed-specific estimates of agricultural and urban/suburban best management practice use, livestock numbers and significant changes in land use. The request was made to seventeen people via email on March 1, 2021. One response to the municipal information request was received and incorporated, as was agricultural information that was provided for two northern watersheds.

This draft introduction and stream summary appendices were made available for public review and comment for thirty days beginning on August 3, 2021 on DEP's 'Opportunity for Comment' webpage, https://www.maine.gov/dep/comment/index.html. E-mail notification was sent the list of stakeholders, which included those who the informational meeting notification went to along with any others who expressed interest, as well as to digital subscribers of the comment webpage.

All written public comments and responses will be submitted to the USEPA as part of the final TMDL submittal documents and posted on DEP's web page 'TMDL approved by EPA' at http://www.maine.gov/dep/water/monitoring/tmdl/tmdl2.html.

REFERENCES

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DRAFT TMDL SUMMARY

Adams Brook

WATERSHED DESCRIPTION

This **TMDL** applies to a 1.2 mile section of Adams Brook, located in the Town of Berwick, Maine. The stream begins just upstream of Blackberry Hill Road and flows southeast through forest. The stream continues across Portland Street (Route 4) and turns east before joining Lover's Brook just upstream of Pond Road. The Adams Brook watershed covers an area of 1.1 square miles. The majority of the watershed is located within the Town of Berwick; however, small portions of the watershed lie within the surrounding Town of South Berwick.

- Adams Brook is on Maine's 303(d) list of Impaired Streams as referenced in the 2016 Integrated Report (Maine DEP, 2018).
- The Adams Brook watershed is predominately non-developed (63%). Wooded areas (34%) within the watershed absorb and filter pollutants helping protect both water quality in the stream and stream channel stability. Wetlands (21%) also filter nutrients.
- Non-forested areas within the watershed include agricultural (29.4%) and are concentrated in the southern portion of the watershed along Blackberry Hill Road, Portland Street, and Pond Road.
- Developed areas (7.1%) with impervious surfaces in close proximity to the stream may impact water quality.
- Runoff from agricultural land located in the areas of Blackberry Hill Road, Portland Street, and Pond Road, have been identified as the largest sources of **nonpoint source (NPS) pollution** to Adams Brook. Runoff from cultivated lands, active hay lands, and grazing areas can transport sediment, nitrogen, and phosphorus to the stream.

Definitions

- ***Total Maximum Daily Load (TMDL)*** *represents the total amount of pollutants that a waterbody can receive and still meet water quality standards.*
- **Nonpoint Source Pollution** *refers to pollution that comes from many diffuse sources across the landscape, and are typically transported by rain or snowmelt runoff.*

Waterbody Facts

Segment ID: ME0106000304_625R01

Town: Berwick, ME

County: York

Impaired Segment Length: 1.2 miles

Classification: Class B

Direct Watershed: 1.1 mi^2 (684 acres)

Impairment Listing Cause: Benthic macroinvertebrates

Watershed Agricultural Land Use: 29.4%

Major Drainage Basin: Piscataqua River

Watershed Land Uses

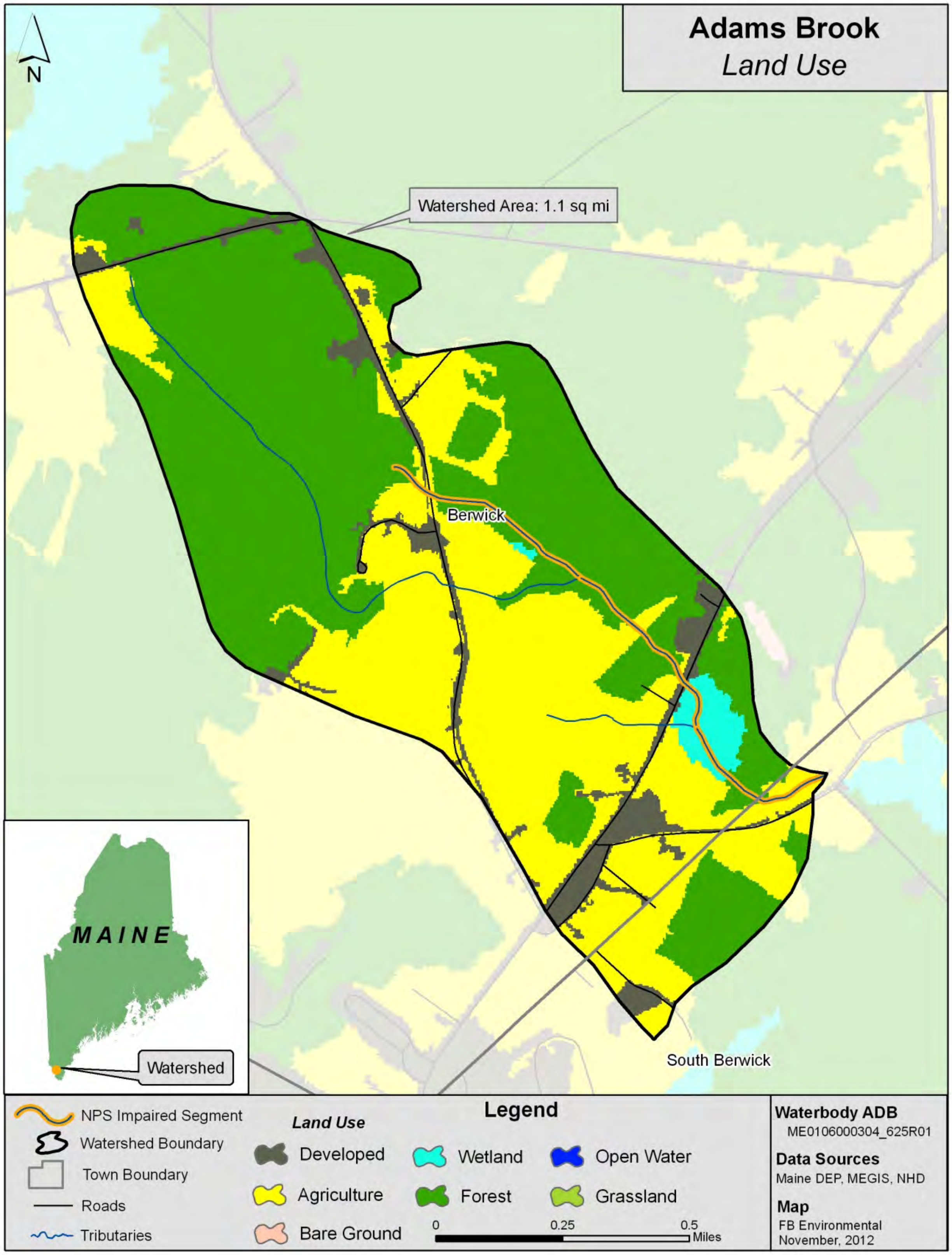


Figure 1: Land Use and Land Cover (from 2011) in the Adams Brook Watershed

WHY IS A TMDL ASSESSMENT NEEDED?

Adams Brook, a Class B freshwater stream, has been assessed by Maine DEP as not meeting water quality standards for the designated use of aquatic life, and placed on the 303(d) list of impaired waters under the Clean Water Act. The Clean Water Act requires that all 303(d)-listed waters undergo a Total Maximum Daily Load (TMDL) assessment that describes the impairments and establishes a target to guide the measures needed to restore water quality. The goal is for all waterbodies to comply with state water quality standards.

***Adams Brook** at DEP Sampling Station 267 (Photo: FB Environmental)*

Agriculture land in the Adams Brook watershed makes up 29.4% of the land area, with 29% being hay/pasture land. However, in the southern portion of the watershed, Adams Brook flows through agricultural areas with little or no vegetated buffer for about 0.25 miles (Figure 1). The close proximity of many agricultural lands to the stream further increases the likelihood that nutrients and sediment from disturbed soils, manure, and fertilizers will reach the stream.

WATER QUALITY DATA ANALYSIS

Maine DEP uses a variety of data types to measure the ability of a stream to adequately support aquatic life, including; dissolved oxygen, benthic macroinvertebrates, and periphyton (algae). For benthic macroinvertebrates, DEP makes aquatic life use determinations using a statistical model that incorporates 30 variables of data collected from rivers and streams, including the richness and abundance of streambed organisms, to determine the probability of a sample meeting Class A, B, or C conditions. Biologists use the model results and supporting information to determine if samples comply with the numeric aquatic life criteria of the class assigned to the stream or river (Davies and Tsomides, 2002). Maine DEP uses an analogous model to aid in the assessment of algal communities but makes aquatic life use determinations based on narrative standards.

The aquatic life impairment in Adams Brook is based on macroinvertebrate data collected at Station S-267 in 1995. The segment does not meet the standards for its Class B designation.

TMDL ASSESSMENT APPROACH: NUTRIENT AND SEDIMENT MODELING OF IMPAIRED AND ATTAINMENT STREAMS

NPS pollution is difficult to measure directly because it comes from many diffuse sources spread across the landscape. For this reason, an online nutrient loading model, *Model My Watershed* (v. 1.32.0), was used to estimate the sources of pollution based on well-established hydrological equations (Stroud Water Research Center 2017). *Model My Watershed* makes use of the GWLF-enhanced model engine. The model incorporates detailed maps of soil, land use, and slope, daily weather and localized weather data (from the period 2009-2020), and direct observations of agriculture and other land uses within the watershed. *Model My Watershed* is derived from its parent MapShed developed by Evans and Corradini (2012). *Model My Watershed* replaced MapShed in 2017-2018.

The nutrient loading estimates for the impaired stream were compared to similar estimates for five non-impaired (attainment) streams of similar watershed land uses across the state. The TMDL for the impaired stream was set as the mean nutrient loading estimate of these attainment stream watersheds, and units of mass per unit watershed area per year (kg/ha/year) were used. The difference in loading estimates between the impaired and attainment watersheds represents the percent reduction in nutrient loading required under this TMDL. The attainment streams and their nutrient and sediment loading estimates and TMDL are presented below in Table 1.

Table 1: Numeric Targets for Pollutant Loading Based on Model My Watershed Outputs (2021) for Attainment Streams

Attainment Streams	Town	Total P Load (kg/ha/yr)	Total N Load (kg/ha/yr)	Sediment Load (kg/ha/yr)
Footman Brook	Exeter	0.17	1.73	35.2
Martin Stream	Fairfield	0.13	2.98	57.9
Moose Brook	Houlton	0.18	1.59	48.5
Upper Kenduskeag Stream	Corinth	0.16	1.72	100.5
Upper Pleasant River	Gray	0.16	4.26	86.5
Total Maximum Daily Load		**0.16**	**2.46**	**65.7**

RAPID WATERSHED ASSESSMENT

Habitat Assessment

A habitat assessment survey was conducted in 2012 on both the impaired and attainment streams. The assessment approach is based on the *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (Barbour et al. 1999), which integrates various parameters relating to the structure of physical habitat. The habitat assessments include a general description of the site and physical characterization and visual assessment of in-stream and riparian habitat quality.

Based on rapid bioassessment protocols for low gradient streams, Adams Brook received a score of 117 out of a total 200 for quality of habitat. Higher scores indicate better habitat. The range of habitat assessment scores for attainment streams was 155 to 179. The habitat assessment was conducted on a relatively short sample reach (about 100-200 meters for a typical small stream) and was located near the most downstream Maine DEP sample station. For both impaired and attainment streams, the assessment location was usually near a road crossing for ease of access. In the Adams Brook watershed, the downstream sample station was located in an inactive pasture with minimal trees within a riparian zone dominated by tall grasses with some small trees.

Figure 2 (right) shows the range of habitat assessment scores for all attainment and impaired streams, as well as for Adams Brook. Though these scores show that habitat is clearly an issue for Adams Brook, but it is also important to look for other potential sources within the watershed leading to the water quality impairment. Consideration should be given to major "hot spots" in the Adams Brook watershed as potential sources of NPS pollution contributing to the water quality impairment.

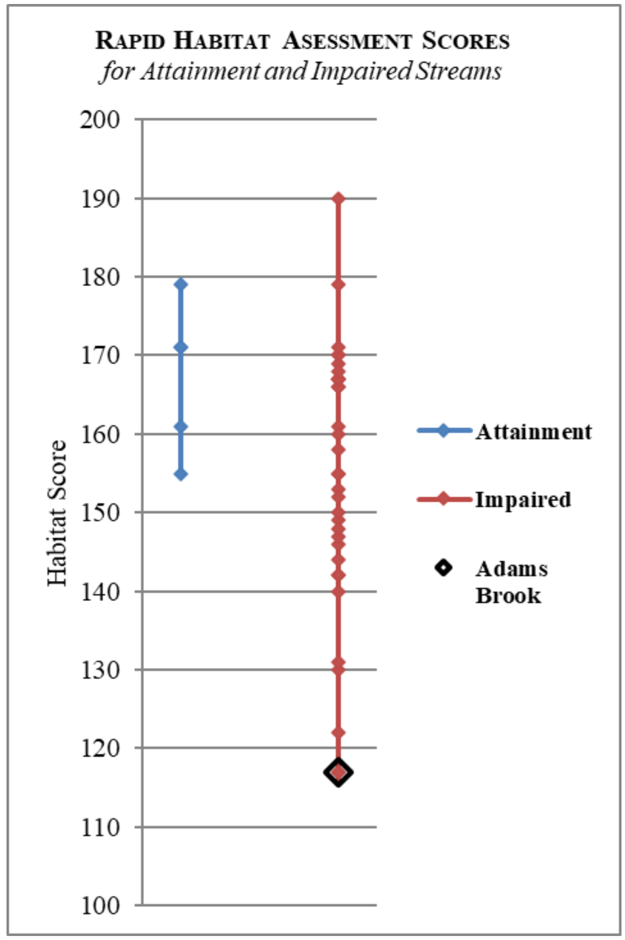


Figure 2: Habitat Assessment Score for Adams Brook (2012) Compared to Region

Pollution Source Identification

Pollution source identification assessments were conducted for both Adams Brook and the attainment streams. The source identification work is based on an abbreviated version of the Center for Watershed Protection's Unified Subwatershed and Site Reconnaissance method (Wright, et al., 2005). The abbreviated method includes both a desktop and field component. The desktop assessment consists of generating and reviewing maps of the watershed boundary, roads, land use and satellite imagery, and then identifying potential NPS pollution locations, such as road crossings, agricultural fields, and large areas of bare soil. When available, multiple sources of satellite imagery were reviewed. Occasionally, the high resolution of the imagery allowed for observations of livestock, row crops, eroding stream banks, sediment-laden water, junkyards, and other potential NPS concerns that could affect stream quality. As many potential pollution sources as possible were visited, assessed, and documented in the field. Field visits were limited to NPS sites that were visible from roads, or within a short walk from a roadway. Neighborhoods were assessed for NPS pollution at the whole neighborhood level including streets and storm drains (where applicable). The assessment does not include a scoring component, but does include a detailed summary of findings and a map indicating documented NPS sites throughout the watershed.

The watershed source assessment for Adams Brook was completed on July 2012. In-field observations of erosion, lack of vegetated stream buffer, extensive impervious surfaces, high-density neighborhoods and agricultural activities were documented throughout the watershed (Table 2, Fig. 3).

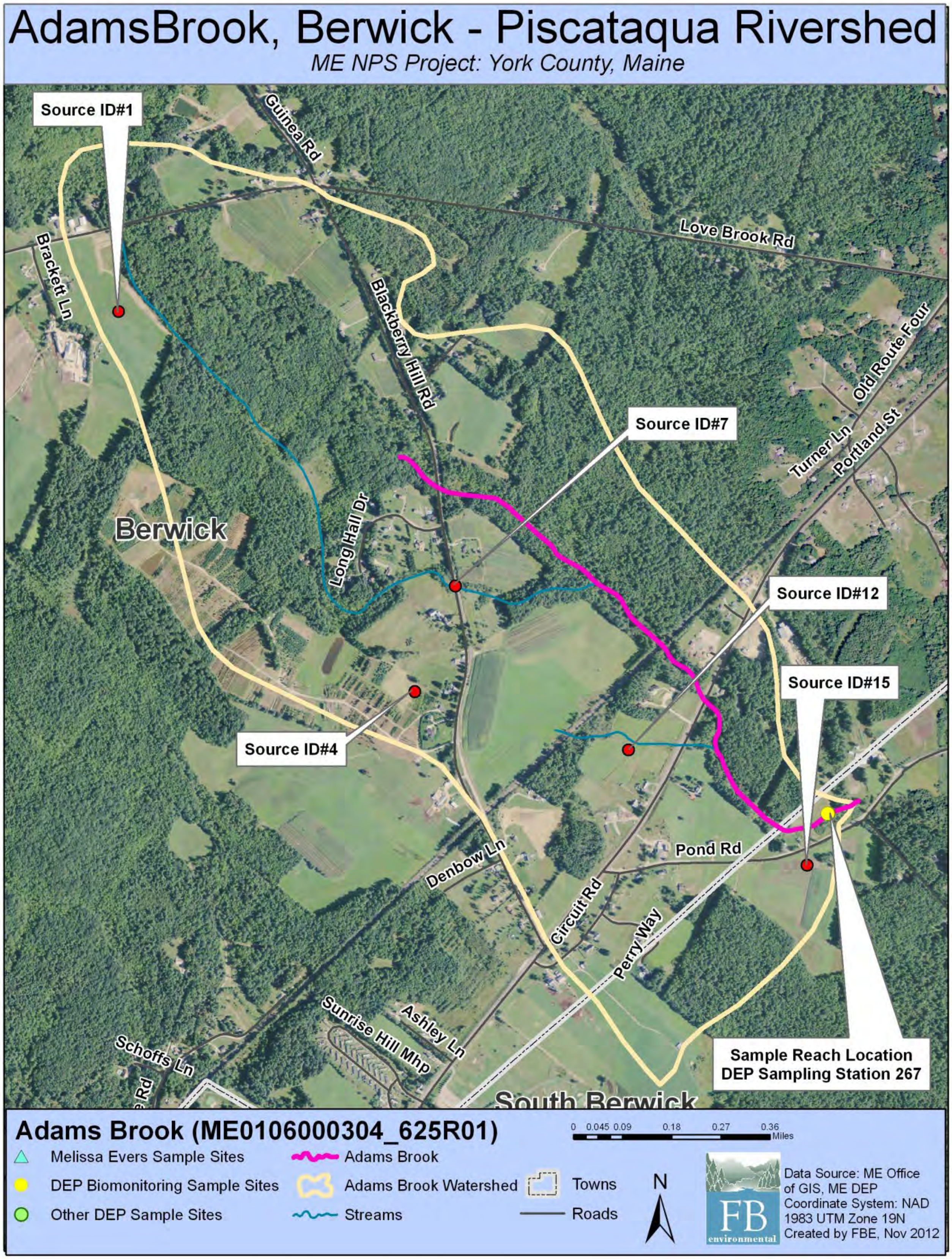
Table 2: Potential Pollution Source ID Assessment (2012) for the Adams Brook Watershed

Potential Source			**Notes**
ID#	**Location**	**Type**	
1	Blackberry Hill Road	Agriculture	• Estimated 25 dairy cows observed.
4	Blackberry Hill Road (just north of RR tracks)	Agriculture	• Active corn crops and hayfields. • Estimated 60 dairy cows observed grazing.
7	Blackberry Hill Road	Road Crossing/ Agriculture	• Active row crops on surrounding properties. • Bare soil. • Nearby electric fence indicates livestock on adjacent property.
12	Portland Street	Agriculture	• Active hayfields. • 2 horses observed grazing. • Tributary is drainage from agricultural fields in Location #4 and flows through active hay fields in location #12. Ephemeral.
15	Pond Road	Agriculture	• 2 horses observed grazing. • Active row crops.
16	Pond Road	Sampling Location	• Location of sample reach. • Inactive fields surrounding. • DEP Sample Station 267.

NUTRIENT AND SEDIMENT LOADING – *MODEL MY WATERSHED* ANALYSIS

The *Model My Watershed* model was used to estimate stream loading of total phosphorus, total nitrogen, and sediment in Adams Brook watershed. The model estimated nutrient loads over a 12-year period (2009-2020), which was determined by local (Sanford 2 NNW USC00177479) weather data inserted into *Model My Watershed*. This extended period captures a recent but wide range of hydrologic conditions to account for variations in nutrient and sediment loading over time. Loads for the attainment watersheds (five total; Table 1) were computed using the same model with the same recent inputs (i.e., regional weather, 2016 land use and land cover, 2016 wetland extent, and BMPs similar to the impaired watersheds).

Figure 3: Aerial Photo of Potential Source Locations (identified in 2012) in the Adams Brook Watershed



Many quality assured and regionally calibrated input parameters are provided with *Model My Watershed*. However, several updates to some of the default parameters were made in this TMDL effort, and namely more recent land use/cover using **MRLC-NLCD 2016** [1], more recent and local weather (precipitation and temperature) data (as described above), and more regional estimates of Best Management Practices (BMPs; see ensuing discussion). Because land use/cover is more recent, the estimated filtration fraction of wetland and open water and the amount of stream buffer in agricultural land should be more accurate. It is also worth noting that improved classification algorithms were employed by MLRC in the NCLD 2016 and these new algorithms were used in the revisions of all previous NLCD versions (including the first version in 2001).

Livestock Estimates

Livestock waste contains nutrients which can cause water quality impairment. The nutrient loading model considers numbers and types of animals. Table 3 (right) provides livestock (numbers of animals) in the watershed based on the USDA National Agricultural Statistics Service (NASS) estimation for 2012. Some of these totals were modified by direct observations made in the watershed in the 2012 survey. To generate watershed-based livestock counts, NASS county-based livestock totals are converted to a per unit area (based on the total area of the county). The unit area amount is then multiplied by the total watershed area to derive a watershed total count (as seen in Table 3).

Table 3: Livestock Count in the Adams Brook Watershed

Type	Adams Brook
Dairy Cows	85
Beef Cows	--
Broilers	2
Layers	--
Hogs/Swine	--
Sheep	1
Horses	4
Turkeys	--
Other	--
Total	**92**

The Adams Brook watershed contains substantial mixed agricultural land uses. Areas of active corn and hayfields were commonly observed, and two dairy farms were documented on Blackberry Hill Road. An estimated total of 85 cows were observed on these properties. Four horses were also observed during the watershed survey.

Vegetated Stream Buffer in Agricultural Areas

Vegetated stream buffers are areas of trees, shrubs, and/or grasses adjacent to streams, lakes, ponds or wetlands which provide nutrient loading attenuation (Evans and Corradini, 2012). *Model My Watershed* considers natural vegetated stream buffers within agricultural land areas as providing nutrient load attenuation. A width of approximately 98 feet (30 m) on one side of a stream is required to be considered a streamside buffer per the *Model My Watershed* technical manual (Stroud Water Research Center 2017). Analysis of recent aerial photos was used to estimate the number of agricultural land stream miles with and without vegetative buffers, and these estimates were directly entered into the model.

Adams Brook is a 1.2 mile-long impaired segment as listed by Maine DEP. As modeled, the total stream miles (including tributaries) within the watershed was calculated as 2.05 miles.

[1] MRLC-NLCD 2016 : Multi-Resolution Land Characteristics – National Land Cover Dataset (version 2016) provided by the MRLC Consortium (Jin et al. 2019).

Of this total, 0.82 stream miles are located within agricultural areas and 0.57 miles of that area *appear* to have a 98 foot or greater vegetated buffer (Table 4, Figure 4). From a watershed perspective, this equates to 0.25 miles or 12.2% of the total stream length running through agricultural land with less than a 98 foot buffer. By contrast, for attainment stream watersheds the percentage of total stream miles running through agricultural land without a 75 foot vegetated buffer ranged from 0% to 3.9% with an average of 1.3%. Note, a minimum vegetated buffer width of *75 feet* was used in an earlier (2012) effort to produce Figure 4 shown here. Differences in stream length estimates using a 98-foot or 75-foot buffer were practically insignificant.

Table 4: Summary of Vegetated Buffers in Agricultural Areas (2012)

Adams Brook
• Agricultural Land Stream Length = 0.82 mi • Agricultural Land Stream Length with Buffer = 0.57 mi (or 70% of total agricultural land stream length) • Percentage of total stream length flowing through non-buffered agricultural land = 12.2%

Home Septic System Loads

Loads for "normally functioning" septic systems are calculated in *Model My Watershed* using an estimate of the average number of persons per acre in "Low-Density Mixed" areas. In these areas, it is assumed that the populations therein are served by septic systems rather than centralized sewage systems. All homes in such areas are assumed to be connected to "normally functioning" systems rather than those that experience "surface breakouts" (surface failures), "short-circuiting" to underlying groundwater (subsurface failures), or have direct conduits to nearby water bodies. Non-functioning systems would be modeled with a higher load contribution to the waterbody.

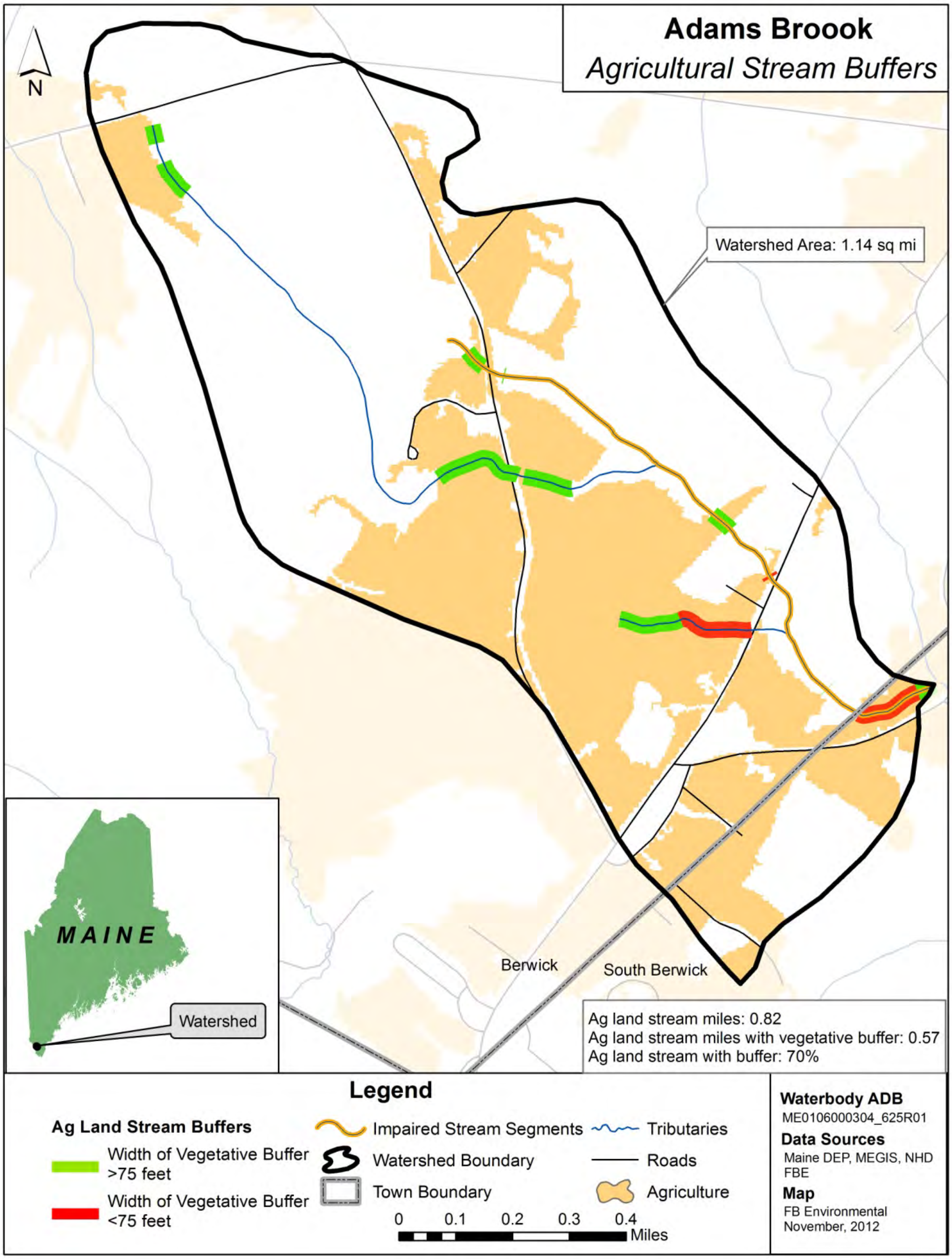
Best Management Practices (BMPs)

Best management practices (BMPs) are typically instituted to reduce the loading of sediment and nutrients from upland (i.e., non-point) sources. Ideally, information on BMPs for a specific watershed from local and regional sources would improve this component of the water quality model. Maine DEP sought information on BMP use in early 2021 from local, regional, and state agricultural agencies for rural BMPs and from nearby municipalities for urban BMPs. Very little to no information was returned in the solicitation. Hence, estimates for typical New England watersheds were derived from information available from Vermont. An upper limit of BMP use was garnered from watersheds entering the Chesapeake Bay where BMP use is intensive.

Four agricultural BMPs were used in this modeling effort and in the following manner:

- *Cover Crops:* Cover crops are the use of annual or perennial crops to protect soil from erosion during time periods between harvesting and planting of the primary crop. The percent of cropland area in a cover crop BMP deployed was estimated at 25% and selected as the low end of the range (25 to 30 percent) expected for cropland in New England. This value was assigned to the five attainment watersheds.
- *Conservation Tillage:* Conservation tillage is any kind of system that leaves at least 30% of the soil surface covered with crop residue after planting. This reduces soil erosion and runoff. This BMP was estimated to occur in 25% of cropland. This value was assigned to the five attainment watersheds.

Figure 4: Agricultural Stream Buffers (from 2012) in the Adams Brook Watershed



- *Strip Cropping / Contour Farming:* This BMP involves tilling, planting and harvesting perpendicular to the gradient of a hill or slope using high levels of plant residue to reduce soil erosion from runoff. Both interview sources suggest this practice is minimal to non-existent for New England watersheds. Hence, no BMP of this type was used in this modeling effort. This value was assigned to the five attainment watersheds.
- *Grazing Land Management:* This BMP consists of ensuring adequate vegetation cover on grazed lands to prevent soil erosion from overgrazing or other forms of over-use. This usually employs a rotational grazing system where hays or legumes are planted for feed and livestock is rotated through several fenced pastures. Both interview sources were not aware of this practice being active and is likely minimal for New England watersheds. Hence, no BMP of this type was used in this modeling effort for both impaired and attaining watersheds.

Note that other agricultural and development BMPs likely exist in the watershed but their location and type were not available in a watershed-wide format that is necessary to include in the model. Agricultural BMPs recommended by Maine DEP to reduce sediment and nutrient loads include vegetated buffers, covered manure storage facilities, and stream exclusion fencing. BMPs for developed areas recommended by the Maine DEP include vegetated buffers, stormwater BMPs, and minimization of impervious cover.

Pollutant Load Attenuation by Lakes, Ponds and Wetlands

Depositional environments such as lakes, ponds, and wetlands can attenuate watershed sediment and nutrient loading. This information is entered into the nutrient loading model by a simple percentage of watershed area draining to a lake, pond, or wetland. The Adams Brook watershed is 20.8% wetland and open water, per the 2016 NLCD land use/cover and including a large wetland south of Portland Street. It is estimated that 41.6% of land area within the watershed drains to wetlands and open water. The percent of watershed draining to a wetland in the attainment watersheds, based on the 2021 analysis, ranged from 26 to 58 percent, with an average of 40%.

NUTRIENT AND SEDIMENT MODELING RESULTS

Selected results from the watershed loading model are presented here. The TMDL itself is expressed in units of kilograms per hectare per year. The additional results shown below assist in better understanding the likely sources of pollution. The model results for Adams Brook watershed indicate significant reductions of phosphorus and nitrogen are needed to improve water quality. No reductions in sediment are needed. Below, loading for nitrogen, phosphorus and sediment are discussed individually.

There are two categories of loads – sources and pathways. Sources are determined by land use/cover and the overland flow they generate, livestock counts by animal type, and home sewage treatment systems in developed areas. Pathways represent additional loads derived from subsurface flow and streambank erosion. Subsurface loads are calculated using dissolved N and P coefficients for shallow groundwater and are mainly derived from atmospheric inputs. Sediment and nutrient loads produced by eroding streambanks are estimated using an approach developed by Evans et al. (2003). This pathway is comprised of loads originating from five sources, and listed in order of decreasing importance: amount of developed land area, soil erodibility (K-factor), density of livestock, runoff curve number, and topographic slope. For any given model run, the amount of developed land in the watershed is responsible for just over 72% of the total streambank load, whereas soil erodibility and animal density are responsible for 21% and 7% of the total streambank load, respectively.

Sediment

Sediment loading in the Adams Brook watershed is mainly derived from stream bank erosion which contributes almost 55% of the total watershed sediment load. Combined agricultural sources (hay/pasture and cropland) make up 67% of the source load (Table 5 and Figure 5). Residential areas contribute 22.4% of the source load.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Adams Brook* below for loading estimates that have been normalized by watershed area.

Table 5: Total Sediment Load by Source

Adams Brook	Sediment (1000 kg/year)	Sediment (%)
Source Load		
Hay/Pasture	4.8	60.9%
Cropland	0.5	5.9%
Wooded Areas	0.2	2.9%
Wetlands	0.1	1.4%
Open Land	0.5	6.4%
Barren Areas	0.001	0.013%
Low-Density Mixed	0.7	9.4%
Medium-Density Mixed	0.5	6.4%
High-Density Mixed	0.1	0.7%
Low-Density Open Space	0.5	5.9%
Farm Animals	0.0	0.0%
Septic Systems	0.0	0.0%
Source Load Total:	**7.9**	**100%**
Pathway Load		
Stream Bank Erosion	9.3	-
Subsurface Flow	0.0	-
Total Watershed Mass Load:	**17**	

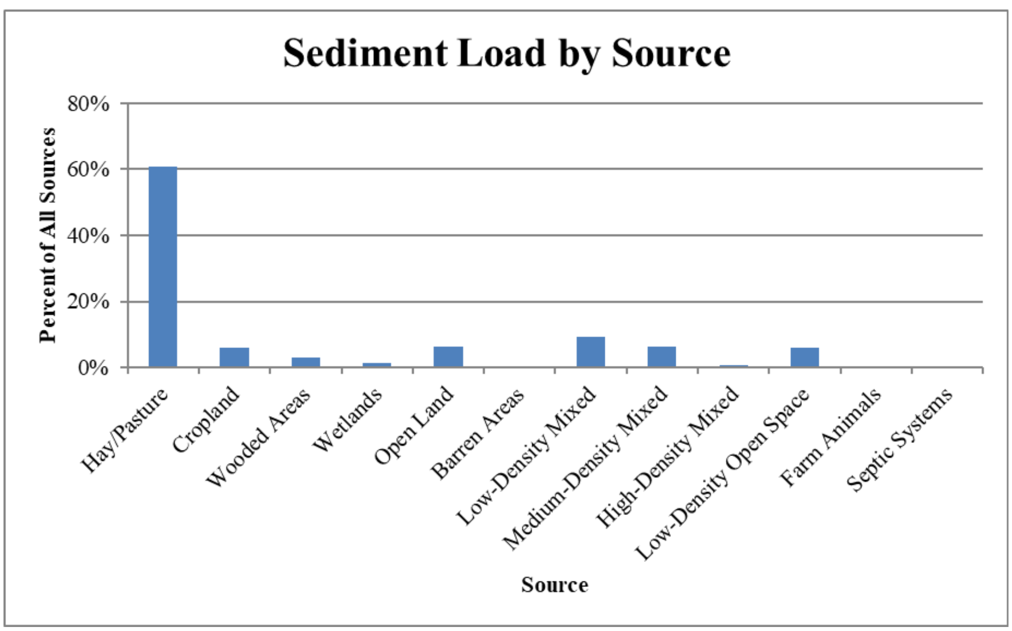


Figure 5: Total Sediment Load by Source in the Adams Brook Watershed

Total Nitrogen

Nitrogen loading is attributed primarily to farm animals (73%) and to some extent hay/pasture land (9.9%) (Table 6 and Figure 6). Residential areas contribute 6.5% of the source load.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Adams Brook* below for loading estimates that have been normalized by watershed area.

Table 6: Total Nitrogen Load by Source

Adams Brook	Total N (kg/year)	Total N (%)
Source Load		
Hay/Pasture	94	9.9%
Cropland	7	0.7%
Wooded Areas	25	2.6%
Wetlands	46	4.9%
Open Land	12	1.3%
Barren Areas	1	0.1%
Low-Density Mixed	29	3.0%
Medium-Density Mixed	14	1.4%
High-Density Mixed	1	0.1%
Low-Density Open Space	18	1.9%
Farm Animals	693	73.0%
Septic Systems	9	1.0%
Source Load Total:	**949**	**100%**
Pathway Load		
Stream Bank Erosion	11	-
Subsurface Flow	326	-
Total Watershed Mass Load:	**1,286**	

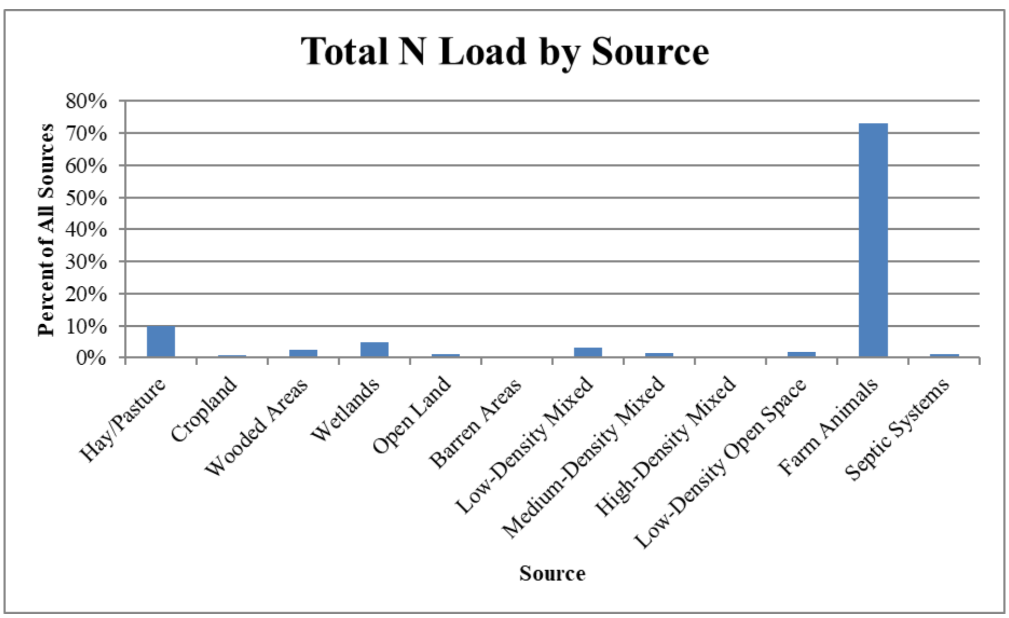


Figure 6: Total Nitrogen Load by Source in the Adams Brook Watershed

Total Phosphorus

Phosphorus loading within the watershed is attributed primarily to farm animals and hay/pasture land with combined agricultural sources accounting for over 93% of the total phosphorus load to Adams Brook. Residential areas contribute 3.7% of the source load. Phosphorus loads are presented in Table 7 and Figure 7.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Adams Brook* below for loading estimates that have been normalized by watershed area.

Table 7: Total Phosphorus Load by Source

Adams Brook	**Total P (kg/year)**	**Total P (%)**
Source Load		
Hay/Pasture	35.2	21.2%
Cropland	1.4	0.8%
Wooded Areas	1.5	0.9%
Wetlands	2.4	1.4%
Open Land	1.0	0.6%
Barren Areas	0.0	0.00%
Low-Density Mixed	2.9	1.8%
Medium-Density Mixed	1.3	0.8%
High-Density Mixed	0.1	0.1%
Low-Density Open Space	1.8	1.1%
Farm Animals	118.1	71.3%
Septic Systems	0.0	0.0%
Source Load Total:	**165.7**	**100%**
Pathway Load		
Stream Bank Erosion	4.0	-
Subsurface Flow	12.6	-
Total Watershed Mass Load:	**182**	

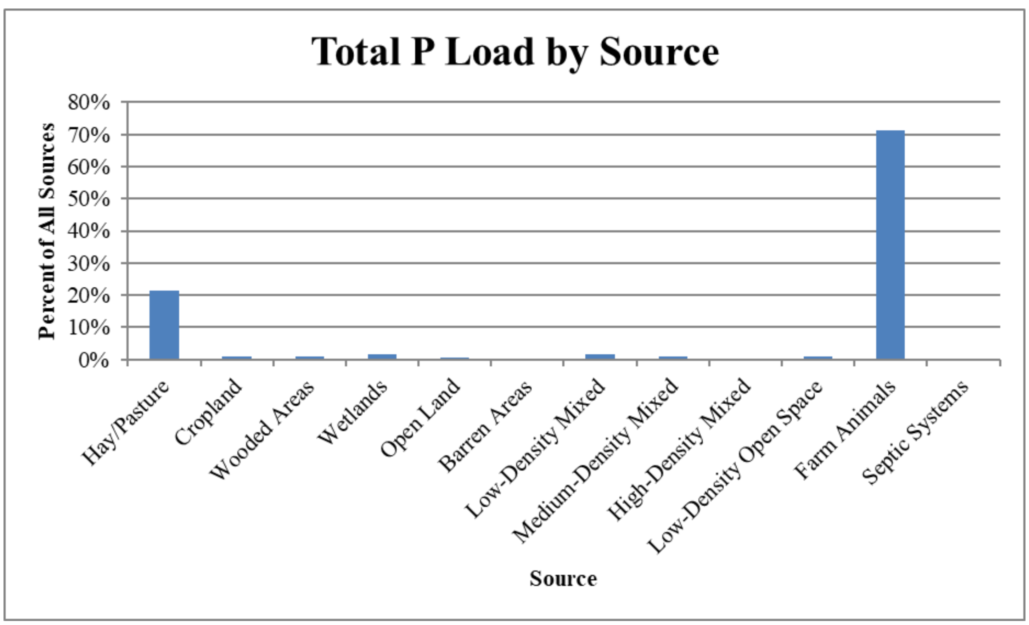


Figure 7: Total Phosphorus Load by Source in the Adams Brook Watershed

TMDL: TARGET NUTRIENT AND SEDIMENT LEVELS FOR ADAMS BROOK

The existing loads for nutrients and sediments in the impaired segment of Adams Brook are listed in Table 8, along with the TMDL (the allowable load) which was calculated from the average loading estimates of five attainment watersheds throughout the state. Table 8 also shows required reductions (as a percent) for each of sediment, total N, and total P pollutants. Table 9 presents a more detailed view of the modeling results and calculations used to compute the existing loads in Table 8. An annual time frame provides a mechanism to address the daily and seasonal variability associated with nonpoint source loads.

Table 8: Adams Brook Pollutant Loading Compared to TMDL Targets

Adams Brook			
Pollutant Load	**Existing Load**	**TMDL**	**Reduction Required**
Total Annual Load per Unit Area		Attainment Streams	
Sediment (kg/ha/yr)	58.8	65.72	None
Total N (kg/ha/yr)	4.40	2.46	44.1%
Total P (kg/ha/yr)	0.62	0.16	74.3%

Future Loading

The prescribed reduction in pollutants discussed in this TMDL reflects reduction from estimated existing conditions. Expansion of agricultural and development activities in the watershed have the potential to increase runoff and associated pollutant loads to Adams Brook. To ensure that the TMDL targets are attained, future agricultural activities will need to meet the TMDL targets. Between 2012 to 2017 in York County, the area of agricultural lands was decreasing, with a 5.6% decrease in the total number of farms and a 5.4% decrease in total farm area. Average farm size did not change during this time period. These values are extracted from the most recent (2017) Census of Agriculture (USDA 2017). Human population in York County increased by 5.3% from 2000 to 2019 (US Census 2020). Future activities and BMPs that achieve TMDL reductions are addressed below.

Next Steps

The use of agricultural and developed area Best Management Practices (BMP's) can reduce sources of polluted runoff in Adams Brook. It is recommended that municipal officials, landowners, and conservation stakeholders in Berwick work together to develop a watershed management plan to:

- Encourage greater citizen involvement through the development of a watershed coalition to ensure the long term protection of Adams Brook;
- Run a "Hot-Spot Analysis" in *Model My Watershed* to determine sub-watershed locations of higher existing contributions of sediment and nutrients to the outlet of Adam Brook watershed; then focus BMP mitigation in these hot-spot sub-areas of the watershed;
- Address existing nonpoint source problems in the Adams Brook watershed by instituting BMPs where necessary; and
- Prevent future degradation of Adams Brook through the development and/or strengthening of a local Nutrient Management Ordinance.

Table 9: Annual Loads by Land Use, Other Sources, and Pathways for Adams Brook Based on Modeling

Adams Brook				
	Area (ha)	**Sediment** (1000 kg/yr)	**Total N** (kg/yr)	**Total P** (kg/yr)
Land Uses				
Hay/Pasture	85	4.8	94	35.2
Cropland	1	0.5	7	1.4
Wooded Areas	99	0.2	25	1.5
Wetlands	61	0.1	46	2.4
Open Land	13	0.5	12	1.0
Barren Areas	1	0.001	1	0.0
Low-Density Mixed	18	0.7	29	2.9
Medium-Density Mixed	2	0.5	14	1.3
High-Density Mixed	0	0.1	1	0.1
Low-Density Open Space	11	0.5	18	1.8
Total Area	293			
Other Sources				
Farm Animals		0.0	693	118.1
Septic Systems		0.0	9	0.0
Pathway Load				
Stream Bank Erosion		9.3	11	4.0
Subsurface Flow		0.0	326	12.6
Total Annual Load		17	1,286	182
Total Annual Load per Unit Area		0.06	4.40	0.62
		1000 kg/ha/yr	kg/ha/yr	kg/ha/yr

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DRAFT TMDL SUMMARY

Black Brook

WATERSHED DESCRIPTION

This **TMDL** applies to a 6.07 mile section of Black Brook, located in the Town of Windham, Maine. Black Brook begins just upstream of Route 302, flows south through agricultural and forested land, then crosses Windham Center Road. The stream continues through forest, crossing Pope Road and Swett Road adjacent to a large agricultural area. The stream then flows through another forested area, and crosses Webb Road and River Road before entering a more developed section of the watershed. Black Brook meets the Presumpscot River just downstream of Main Street. The Black Brook watershed covers an area of 3.91 square miles.

- Black Brook is on Maine's 303(d) list of Impaired Streams as referenced in the 2016 Integrated Report (Maine DEP, 2018).
- The Black Brook watershed is predominately non-developed (70%). Wooded areas (53%) within the watershed absorb and filter pollutants helping protect both water quality in the stream and stream channel stability.
- Non-forested areas within the watershed are predominantly agricultural (20%) and are concentrated in the central portion of the watershed along Swett Road, Town Farm Road, and Pope Road.
- Developed areas (10%) with impervious surfaces in close proximity to the stream may impact water quality.
- Runoff from agricultural land located in the areas of Swett Road, Town Farm Road, and Pope Road are likely the largest sources of nonpoint source (NPS) pollution to Black Brook. Runoff from active hay lands and grazing areas can transport sediment, nitrogen and phosphorus to the stream.

Definitions

- ***Total Maximum Daily Load (TMDL)*** *represents the total amount of pollutants that a waterbody can receive and still meet water quality standards.*
- **Nonpoint Source Pollution** *refers to pollution that comes from many diffuse sources across the landscape, and are typically transported by rain or snowmelt runoff.*

Waterbody Facts

Segment ID: ME0106000103_607R01

Town: Windham, ME

County: Cumberland

Impaired Segment Length: 6.07 miles

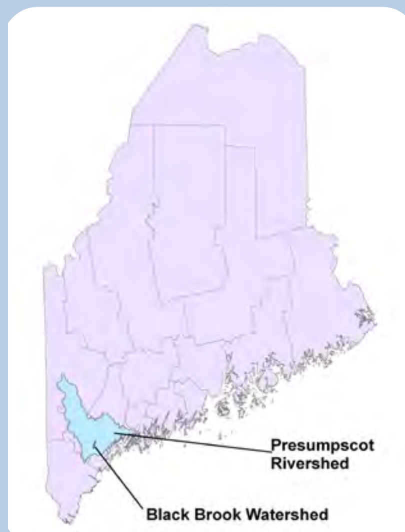
Classification: Class B

Direct Watershed: 3.91 mi^2 (2,502 acres)

Impairment Listing Cause: Dissolved Oxygen

Watershed Agricultural Land Use: 20%

Major Drainage Basin: Presumpscot River



Watershed Land Uses

WHY IS A TMDL ASSESSMENT NEEDED?

Black Brook, a Class B freshwater stream, has been assessed by Maine DEP as not meeting water quality standards for the designated use of aquatic life, and placed on the 303(d) list of impaired waters under the Clean Water Act. The Clean Water Act requires that all 303(d)-listed waters undergo a TMDL assessment that describes the impairments and establishes a target to guide the measures needed to restore water quality. The goal is for all waterbodies to comply with state water quality standards.

***Black Brook** near Main Street crossing. Photo: FB Environmental*

Agriculture (primarily hay/pastureland) makes up 20% of total land area in the Black Brook watershed. This is twice the developed land area (10%). Ten percent of the impaired stream segment passes through agricultural land (Figure 1). Agriculture is therefore likely to be the largest contributor of sediment and nutrient enrichment to the stream. The close proximity of many agricultural lands to the stream further increases the likelihood that nutrients from disturbed soils, manure, and fertilizers will reach the stream.

WATER QUALITY DATA ANALYSIS

Maine DEP uses a variety of data types to measure the ability of a stream to adequately support aquatic life, including; dissolved oxygen, benthic macroinvertebrates, and periphyton (algae). For benthic macroinvertebrates, DEP makes aquatic life use determinations using a statistical model that incorporates 30 variables of data collected from rivers and streams, including the richness and abundance of streambed organisms, to determine the probability of a sample meeting Class A, B, or C conditions. Biologists use the model results and supporting information to determine if samples comply with the numeric aquatic life criteria of the class assigned to the stream or river (Davies and Tsomides, 2002). Maine DEP uses an analogous model to aid in the assessment of algal communities but makes aquatic life use determinations based on narrative standards.

The aquatic life impairment in Black Brook is based on historic dissolved oxygen data. Additionally, dissolved oxygen data collected at stations RBK24 in 2007 and RBK05 in 2011 corroborates the impairment.

TMDL ASSESSMENT APPROACH: NUTRIENT AND SEDIMENT MODELING OF IMPAIRED AND ATTAINMENT STREAMS

NPS pollution is difficult to measure directly because it comes from many diffuse sources spread across the landscape. For this reason, an online nutrient loading model, *Model My Watershed* (v. 1.32.0), was used to estimate the sources of pollution based on well-established hydrological equations (Stroud Water Research Center 2017). *Model My Watershed* makes use of the GWLF-enhanced model engine. The model incorporates detailed maps of soil, land use, and slope, daily weather and localized weather data (from the period 2009-2020), and direct observations of agriculture and other land uses within the watershed. *Model My Watershed* is derived from its parent MapShed developed by Evans and Corradini (2012). *Model My Watershed* replaced MapShed in 2017-2018.

The nutrient loading estimates for the impaired stream were compared to similar estimates for a non-impaired (attainment) streams of similar watershed land uses across the state. The TMDL target for the impaired stream was set as the mean nutrient loading estimate of these attainment stream watersheds, and units of mass per unit watershed area per year (kg/ha/year) were used. The difference in loading estimates between the impaired and attainment watersheds represents the percent reduction in nutrient loading required under this TMDL. The attainment streams and their nutrient and sediment loading estimates and TMDL are presented below in Table 1.

Table 1: Numeric Targets for Pollutant Loading Based on Model My Watershed Outputs (2021) for Attainment Streams

Attainment Streams	Town	Total P Load (kg/ha/yr)	Total N Load (kg/ha/yr)	Sediment Load (kg/ha/yr)
Footman Brook	Exeter	0.17	1.73	35.2
Martin Stream	Fairfield	0.13	2.98	57.9
Moose Brook	Houlton	0.18	1.59	48.5
Upper Kenduskeag Stream	Corinth	0.16	1.72	100.5
Upper Pleasant River	Gray	0.16	4.26	86.5
Total Maximum Daily Load		**0.16**	**2.46**	**65.7**

RAPID WATERSHED ASSESSMENT

Habitat Assessment

A habitat assessment survey was conducted in 2012 on both the impaired and attainment streams. The assessment approach is based on the *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (Barbour et al. 1999), which integrates various parameters relating to the structure of physical habitat. The habitat assessments include a general description of the site and physical characterization and visual assessment of in-stream and riparian habitat quality.

Based on rapid bioassessment protocols for low gradient streams, Black Brook received a score of 167 out of a total 200 for quality of habitat. Higher scores indicate better habitat. The range of habitat assessment scores for attainment streams was 155 to 179, with an average of 167.

Habitat assessments were conducted on a relatively short sample reach (about 100-200 meters for a typical small stream) near the most downstream Maine DEP sample station in the watershed. For both impaired and attainment streams, the assessment location was usually near a road crossing for ease of access. In the Black Brook watershed, the downstream sample station was located at the Webb Road stream crossing and DEP sample station RBK24. Minor erosion was documented at the crossing due to stormwater runoff from Webb Road. The immediate surrounding riparian zone was dominated by shrubs and grasses, but forest was surrounding this area of the reach.

Figure 1: Land Use and Land Cover (from 2011) in the Black Brook Watershed

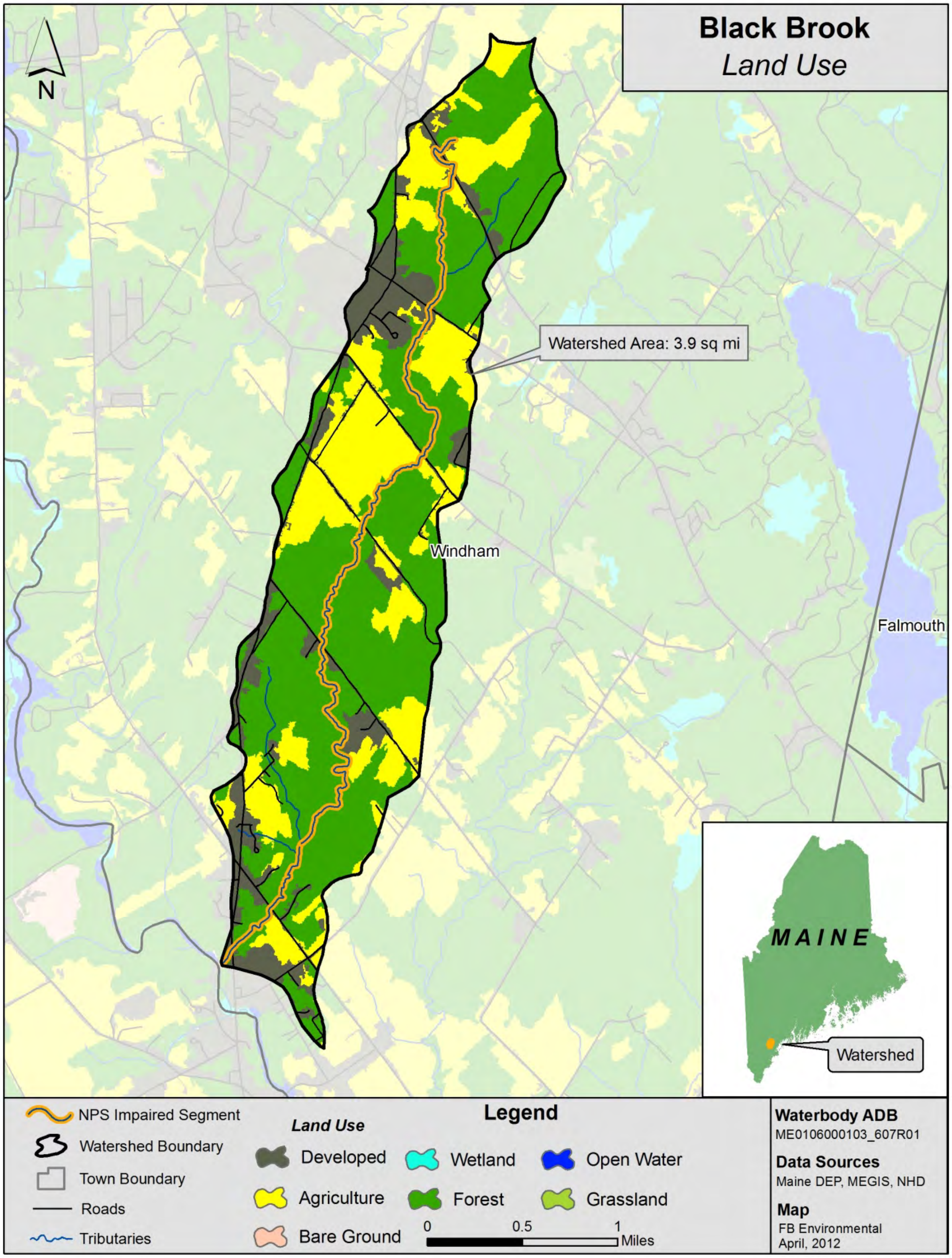


Figure 2 (right) shows the range of habitat assessment scores for all attainment and impaired streams, as well as for Black Brook. The overlapping attainment and impaired stream scores indicate that factors other than habitat should be considered when addressing the impairments in Black Brook. Consideration should be given to major "hot spots" in the Black Brook watershed as potential sources of NPS pollution contributing to the water quality impairment.

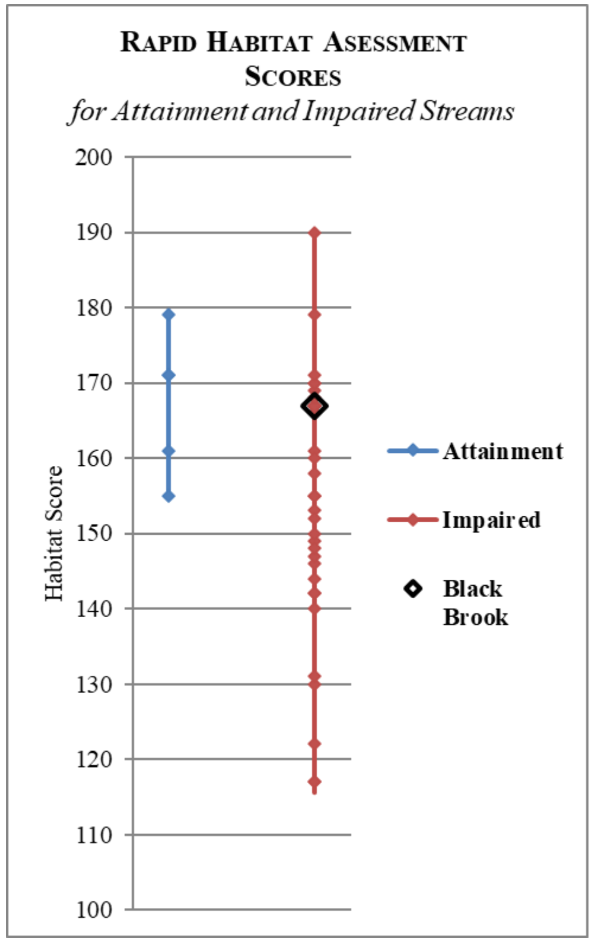


Figure 2: Habitat Assessment Score for Black Brook (2012) Compared to Region

Pollution Source Identification

Pollution source identification assessments were conducted for both Black Brook (impaired) and the attainment streams. The source identification work is based on an abbreviated version of the Center for Watershed Protection's Unified Subwatershed and Site Reconnaissance method (Wright, et al. 2005). The abbreviated method includes both a desktop and field component. The desktop assessment consists of generating and reviewing maps of the watershed boundary, roads, land use and satellite imagery and then identifying potential NPS pollution locations, such as road crossings, agricultural fields, and large areas of bare soil. When available, multiple sources of satellite imagery were reviewed. Occasionally, the high resolution of the imagery allowed for observations of livestock, row crops, eroding stream banks, sediment laden water, junkyards, and other potential NPS concerns that could affect stream quality.

As many potential pollution sources as possible were visited, assessed and documented in the field. Field visits were limited to NPS sites that were visible from roads or a short walk from a roadway. Neighborhoods were assessed for NPS pollution at the whole neighborhood level including streets and storm drains (where applicable). The assessment does not include a scoring component but does include a detailed summary of findings and a map indicating documented NPS sites throughout the watershed.

The watershed source assessment for Black Brook was completed in July 2012. In-field observations of erosion, lack of vegetated stream buffer, extensive impervious surfaces, high-density neighborhoods and agricultural activities were documented throughout the watershed (Table 2, Figure 3).

Table 2: Potential Pollution Source ID Assessment (2012) for the Black Brook Watershed

Potential Source			**Notes**
ID#	**Location**	**Type**	
4	Barnes Road	Residential	• Tributary flows through mowed lawn with no buffer.
6	Webb Road	Road Crossing	• Minor erosion at bridge. • Sample Reach Location; DEP station RBK24. • Immediate riparian zone composed of grasses & shrubs.
7	Off Webb Road	Agriculture	• Christmas tree farm and active hayfields.
9	Swett Road	Road Crossing	• Immediate riparian zone composed of predominantly of grasses.
10	Swett Road	Agriculture	• Active hayfields. • Swett Road is an unpaved dirt road.
11	Between Pope Road & Swett Road	Agriculture	• Active hayfields. • Black Brook follows forest perimeter and is bordered to the west by hayfields with minimal buffer.
12	Pope Road	Road Crossing/ Agriculture	• Hayfields near crossing.
16	North of Windham Center Road	Recreation	• Sign reads *Black Brook Preserve*. • Evidence of ATV trails. • Small bridge over Black Brook. • Field seems inactive.
20	Roosevelt Trail	Impervious Surfaces/	• An auto repair shop is located at the headwaters of Black Brook. • Impervious parking and working areas.
24	Roosevelt Trail	Forestry	• Logging business located on the south side of Roosevelt Trail. • Tree/log piles visible. • Activity in immediate area is unknown.

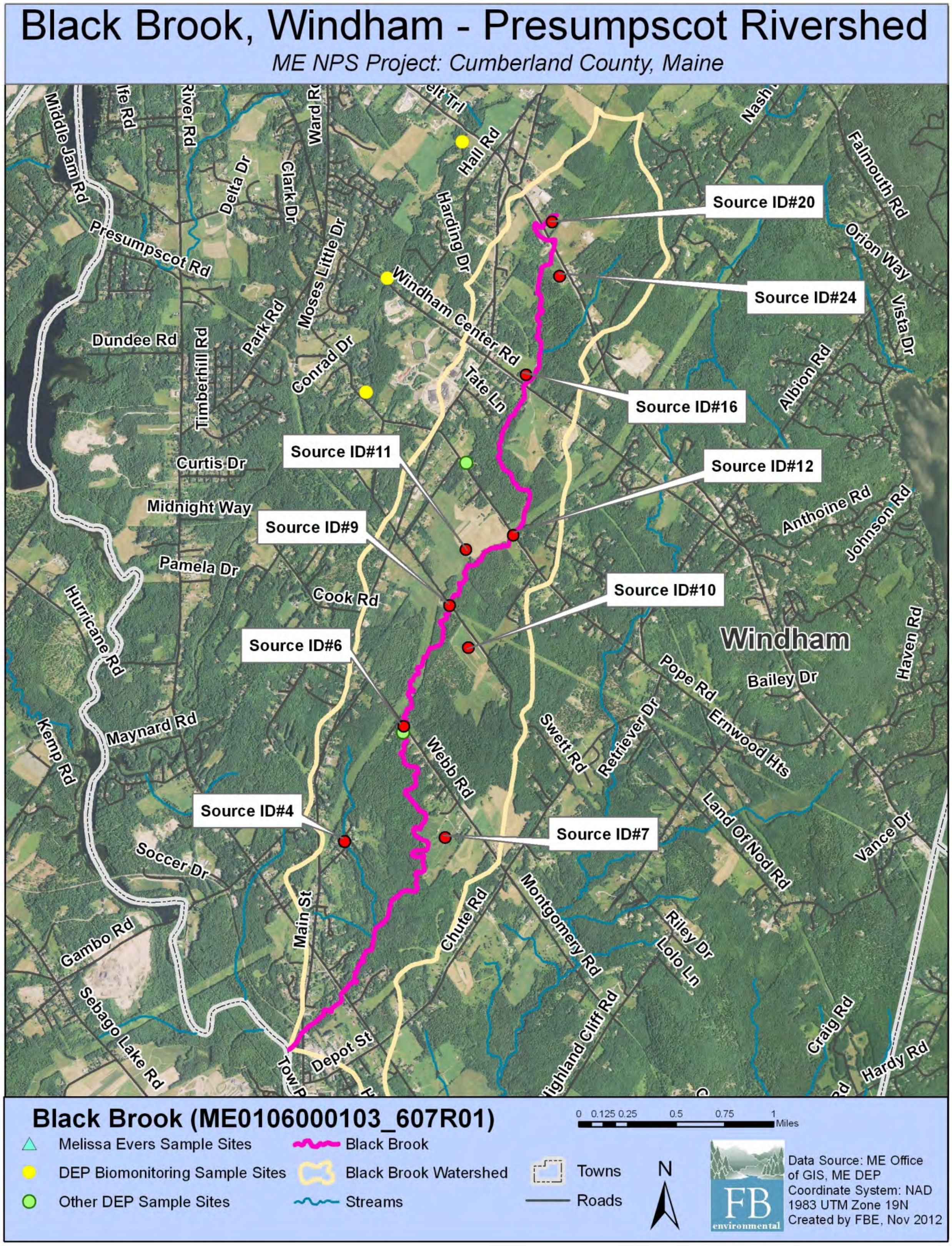


Figure 3: Aerial Photo of Potential Source ID Locations (identified in 2012) in Black Brook Watershed

NUTRIENT AND SEDIMENT LOADING – *MODEL MY WATERSHED* ANALYSIS

The *Model My Watershed* model was used to estimate stream loading of total phosphorus, total nitrogen, and sediment in Black Brook watershed. The model estimated nutrient loads over a 12-year period (2009-2020), which was determined by local (Portland Jetport USW00014764) weather data inserted into *Model My Watershed*. This extended period captures a recent but wide range of hydrologic conditions to account for variations in nutrient and sediment loading over time. Loads for the attainment watersheds (five total; Table 1) were computed using the same model with the same recent inputs (i.e., regional weather, 2016 land use and land cover, 2016 wetland extent, and BMPs similar to the impaired watersheds).

Many quality assured and regionally calibrated input parameters are provided with *Model My Watershed*. However, several updates to some of the default parameters were made in this TMDL effort, and namely more recent land use/cover using **MRLC-NLCD 2016** [1], more recent and local weather (precipitation and temperature) data (as described above), and more regional estimates of Best Management Practices (BMPs; see ensuing discussion). Because land use/cover is more recent, the estimated filtration fraction of wetland and open water and the amount of stream buffer in agricultural land should be more accurate. It is also worth noting that improved classification algorithms were employed by MLRC in the NCLD 2016 and these new algorithms were used in the revisions of all previous NLCD versions (including the first version in 2001).

Livestock Estimates

Livestock waste contains nutrients which can cause water quality impairment. The nutrient loading model considers numbers and types of animals. Table 3 (right) provides livestock (numbers of animals) in the watershed based on the USDA National Agricultural Statistics Service (NASS) estimation for 2012. Some of these totals were modified by direct observations made in the watershed in the 2012 survey. To generate watershed-based livestock counts, NASS county-based livestock totals are converted to a per unit area (based on the total area of the county). The unit area amount is then multiplied by the total watershed area to derive a watershed total count (as seen in Table 3).

Table 3: Livestock Count in Black Brook Watershed

Type	Black Brook
Dairy Cows	3
Beef Cows	3
Broilers	4
Layers	18
Hogs/Swine	4
Sheep	12
Horses	6
Turkeys	1
Other	--
Total	**51**

[1] MRLC-NLCD 2016 : Multi-Resolution Land Characteristics – National Land Cover Dataset (version 2016) provided by the MRLC Consortium (Jin et al. 2019).

Vegetated Stream Buffer in Agricultural Areas

Table 4: Summary of Vegetated Buffers in Agricultural Areas (2012)

Black Brook
• Agricultural Land Stream Length = 0.83 mi • Agricultural Land Stream Length with Buffer = 0.7 mi (or 84% of total agricultural land stream length) • Percentage of total stream length flowing through non-buffered agricultural land = 1.9%

Vegetated stream buffers are areas of trees, shrubs, and/or grasses adjacent to streams, lakes, ponds or wetlands which provide nutrient loading attenuation (Evans and Corradini, 2012). *Model My Watershed* considers natural vegetated stream buffers within agricultural land areas as providing nutrient load attenuation. A width of approximately 98 feet (30 m) on one side of a stream is required to be considered a streamside buffer per the *Model My Watershed* technical manual (Stroud Water Research Center 2017). Analysis of recent aerial photos was used to estimate the number of agricultural land stream miles with and without vegetative buffers, and these estimates were directly entered into the model.

Black Brook is a 6.07 mile-long impaired segment as listed by Maine DEP. As modeled, the total stream miles (including tributaries) within the watershed was calculated as 6.8 miles. Of this total, 0.83 stream miles are located within agricultural areas and 0.7 miles or 84% of that area *appear* to have a 98 foot or greater vegetated buffer (Table 4, Figure 4). From a watershed perspective, this equates to 0.13 miles or 1.9% of the total stream length running through agricultural land with less than a 98 foot buffer. By contrast, for attainment stream watersheds the percentage of total stream miles running through agricultural land without a 75 foot vegetated buffer ranged from 0% to 3.9% with an average of 1.3%. Note, a minimum vegetated buffer width of *75 feet* was used in an earlier (2012) effort to produce Figure 4 shown here. Differences in stream length estimates using a 98-foot or 75-foot buffer were practically insignificant.

Home Septic System Loads

Loads for "normally functioning" septic systems are calculated in *Model My Watershed* using an estimate of the average number of persons per acre in "Low-Density Mixed" areas. In these areas, it is assumed that the populations therein are served by septic systems rather than centralized sewage systems. All homes in such areas are assumed to be connected to "normally functioning" systems rather than those that experience "surface breakouts" (surface failures), "short-circuiting" to underlying groundwater (subsurface failures), or have direct conduits to nearby water bodies. Non-functioning systems would be modeled with a higher load contribution to the waterbody.

Best Management Practices (BMPs)

Best management practices (BMPs) are typically instituted to reduce the loading of sediment and nutrients from upland (i.e., non-point) sources. Ideally, information on BMPs for a specific watershed from local and regional sources would improve this component of the water quality model. Maine DEP sought information on BMP use in early 2021 from local, regional, and state agricultural agencies for rural BMPs and from nearby municipalities for urban BMPs. Very little to no information was returned in the solicitation. Hence, estimates for typical New England watersheds were derived from information available from Vermont. An upper limit of BMP use was garnered from watersheds entering the Chesapeake Bay where BMP use is intensive.

Four agricultural BMPs were used in this modeling effort and in the following manner:

- *Cover Crops:* Cover crops are the use annual or perennial crops to protect soil from erosion during time periods between harvesting and planting of the primary crop. The percent of cropland area in a cover crop BMP deployed was estimated at 25% and selected as the low end of the range (25 to 30 percent) expected for cropland in New England. This value was assigned to the five attainment watersheds.
- *Conservation Tillage:* Conservation tillage is any kind of system that leaves at least 30% of the soil surface covered with crop residue after planting. This reduces soil erosion and runoff. This BMP was estimated to occur in 25% of cropland. This value was assigned to the five attainment watersheds.
- *Strip Cropping / Contour Farming:* This BMP involves tilling, planting and harvesting perpendicular to the gradient of a hill or slope using high levels of plant residue to reduce soil erosion from runoff. Both interview sources suggest this practice is minimal to non-existent for New England watersheds. Hence, no BMP of this type was used in this modeling effort. This value was assigned to the five attainment watersheds.
- *Grazing Land Management:* This BMP consists of ensuring adequate vegetation cover on grazed lands to prevent soil erosion from overgrazing or other forms of over-use. This usually employs a rotational grazing system where hays or legumes are planted for feed and livestock is rotated through several fenced pastures. Both interview sources were not aware of this practice being active and is likely minimal for New England watersheds. Hence, no BMP of this type was used in this modeling effort for both impaired and attaining watersheds.

Note that other agricultural and development BMPs likely exist in the watershed but their location and type were not available in a watershed-wide format that is necessary to include in the model. Agricultural BMPs recommended by Maine DEP to reduce sediment and nutrient loads include vegetated buffers, covered manure storage facilities, and stream exclusion fencing. BMPs for developed areas recommended by the Maine DEP include vegetated buffers, stormwater BMPs, and minimization of impervious cover.

Pollutant Load Attenuation by Lakes, Ponds and Wetlands

Depositional environments such as lakes, ponds, and wetlands can attenuate watershed sediment and nutrient loading. This information is entered into the nutrient loading model by a simple percentage of watershed area draining to a lake, pond, or wetland. The Black Brook watershed is 8.9% wetland and open water, per the 2016 NLCD land use/cover. There are a few wetlands that surround tributaries throughout the watershed. It is estimated that 17.9% of land area within the watershed drains to wetlands and open water. The percent of watershed draining to a wetland in the attainment watersheds, based on the 2021 analysis, ranged from 26 to 58 percent, with an average of 40%.

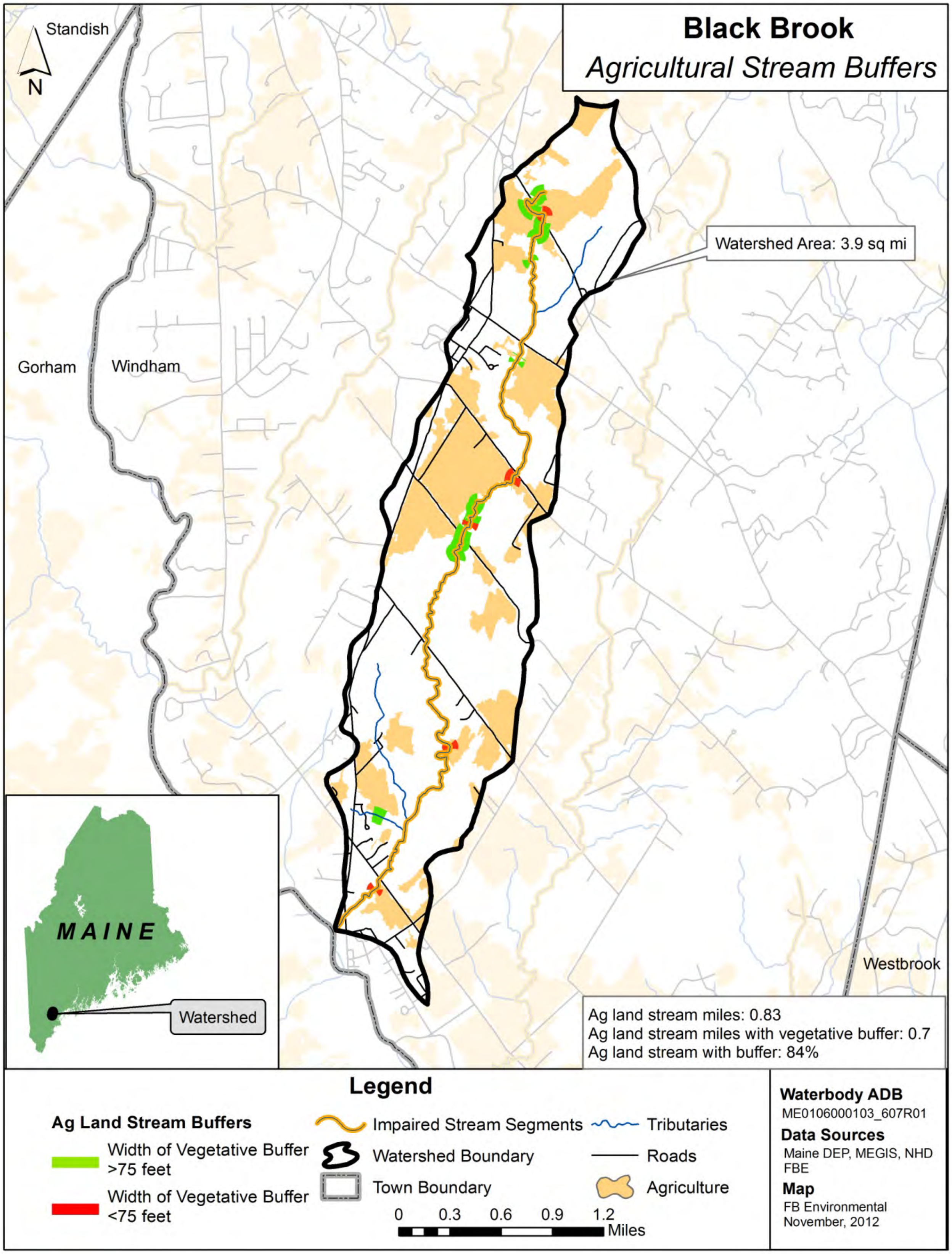


Figure 4: Agricultural Stream Buffers (from 2012) in the Black Brook Watershed

NUTRIENT AND SEDIMENT MODELING RESULTS

Selected results from the watershed loading model are presented here. The TMDL itself is expressed in units of kilograms per hectare per year. The additional results shown below assist in better understanding the likely sources of pollution. The model results for Black Brook watershed indicate significant reductions of phosphorus and sediment and a moderately small reduction of nitrogen are needed to improve water quality. Below, loading for nitrogen, phosphorus and sediment are discussed individually.

There are two categories of loads – sources and pathways. Sources are determined by land use/cover and the overland flow they generate, livestock counts by animal type, and home sewage treatment systems in developed areas. Pathways represent additional loads derived from subsurface flow and streambank erosion. Subsurface loads are calculated using dissolved N and P coefficients for shallow groundwater and are mainly derived from atmospheric inputs. Sediment and nutrient loads produced by eroding streambanks are estimated using an approach developed by Evans et al. (2003). This pathway is comprised of loads originating from five sources, and listed in order of decreasing importance: amount of developed land area, soil erodibility (K-factor), density of livestock, runoff curve number, and topographic slope. For any given model run, the amount of developed land in the watershed is responsible for just over 72% of the total streambank load, whereas soil erodibility and animal density are responsible for 21% and 7% of the total streambank load, respectively.

Sediment

Sediment loading in the Black Brook watershed is mainly derived from stream bank erosion which contributes almost 60% of the total watershed sediment load. Hay/pasture land makes up 81% of the source load (Table 5 and Figure 5). Residential areas contribute 15.7% of the source load.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Black Brook* below for loading estimates that have been normalized by watershed area.

Table 5: Total Sediment Load by Source

Black Brook	Sediment (1000 kg/year)	Sediment (%)
Source Load		
Hay/Pasture	64.4	80.6%
Cropland	0.8	1.0%
Wooded Areas	1.5	1.8%
Wetlands	0.2	0.3%
Open Land	0.4	0.5%
Barren Areas	0	0
Low-Density Mixed	3.8	4.7%
Medium-Density Mixed	4.4	5.5%
High-Density Mixed	0.9	1.1%
Low-Density Open Space	3.5	4.4%
Farm Animals	0	0
Septic Systems	0	0
Source Load Total:	**79.9**	**100%**
Pathway Load		
Stream Bank Erosion	117.9	-
Subsurface Flow	0	-
Total Watershed Mass Load:	**198**	

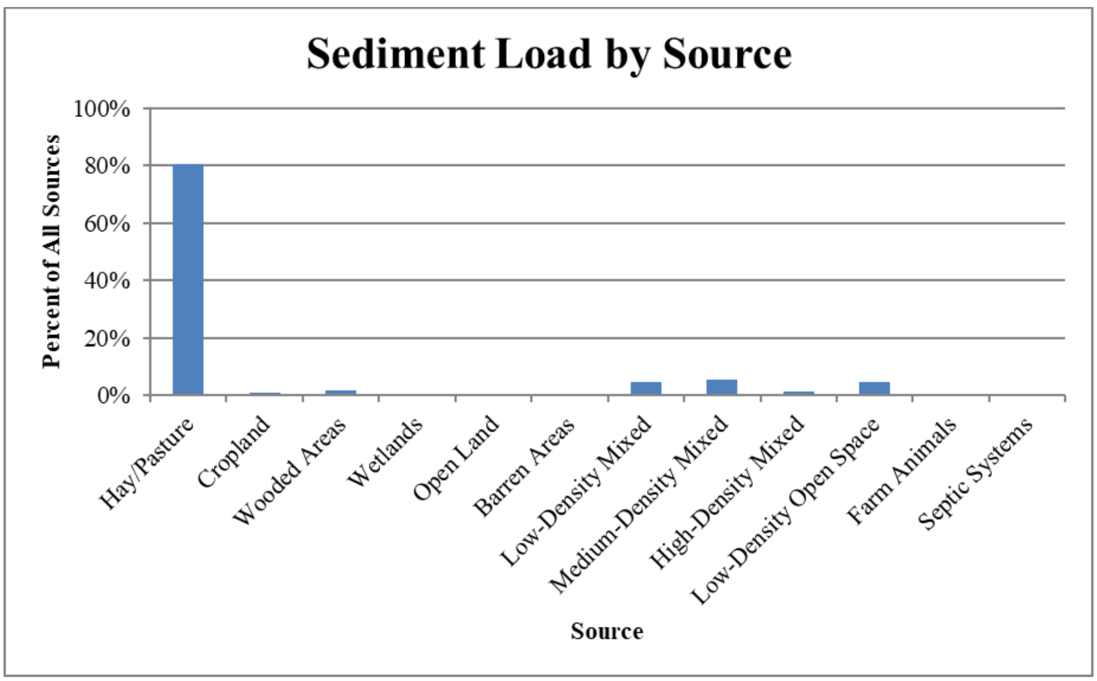


Figure 5: Total Sediment Load by Source in the Black Brook Watershed

Total Nitrogen

Table 6 and Figure 6 (below) show the estimated total nitrogen load, in terms of mass and percent of total by source, in the Black Brook watershed. Hay and pasture lands are the largest source of nitrogen loading to Black Brook, contributing about 43% of the source load of total N. Residential areas combined contribute 24.4% of the source load. Lastly, both septic systems and farm animals each contribute about 5% of the source load.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Black Brook* below for loading estimates that have been normalized by watershed area.

Table 6: Total Nitrogen Load by Source

Black Brook	Total N (kg/year)	Total N (%)
Source Load		
Hay/Pasture	588	43.1%
Cropland	12	0.9%
Wooded Areas	200	14.7%
Wetlands	78	5.7%
Open Land	13	1.0%
Barren Areas	0	0
Low-Density Mixed	111	8.1%
Medium-Density Mixed	98	7.2%
High-Density Mixed	19	1.4%
Low-Density Open Space	105	7.7%
Farm Animals	68	5.0%
Septic Systems	73	5.3%
Source Load Total:	**1,364**	**100%**
Pathway Load		
Stream Bank Erosion	112	-
Subsurface Flow	1,178	-
Total Watershed Mass Load:	**2,654**	

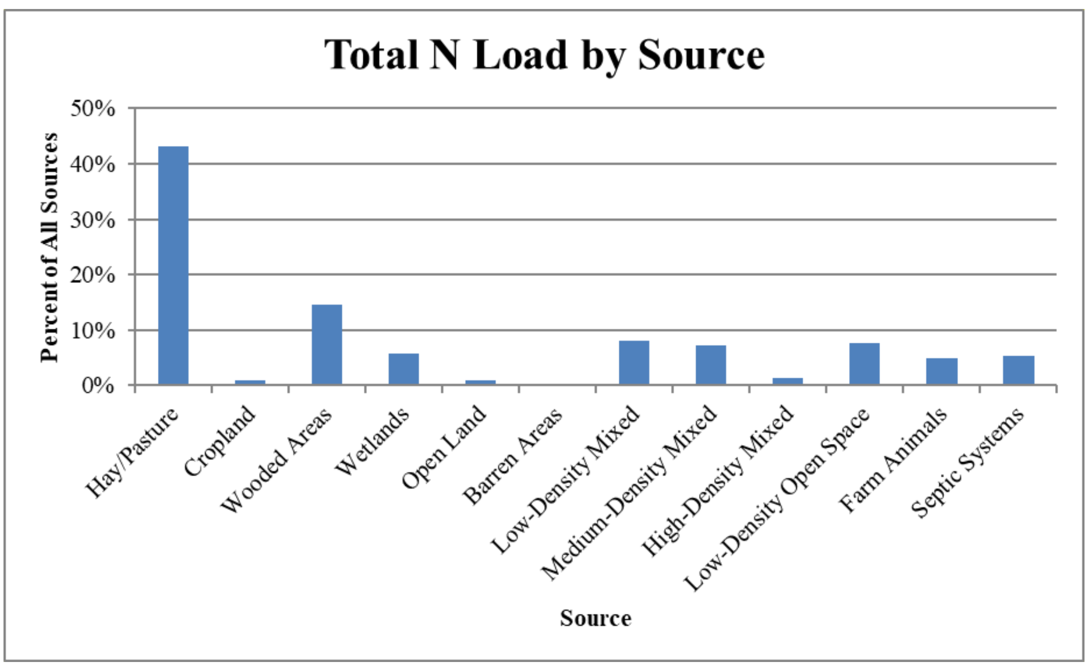


Figure 6: Total Nitrogen Load by Source in the Black Brook Watershed

Total Phosphorus

Table 7 and Figure 7 (below) show the estimated total phosphorus load in terms of mass and percent of total by source, in the Black Brook watershed. Hay and pasture lands are the largest source of phosphorus loading to Black Brook contributing over 68% of the source load. Residential areas combined contribute 16% of the source load. Farm animals contribute about 8% of the source load of total P. Stream bank erosion contributes 8.6% of the total watershed load.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Black Brook* below for loading estimates that have been normalized by watershed area.

Table 7: Total Phosphorus Load by Source

Black Brook	Total P (kg/year)	Total P (%)
Source Load		
Hay/Pasture	145.6	68.3%
Cropland	1.5	0.7%
Wooded Areas	11.0	5.2%
Wetlands	4.1	1.9%
Open Land	0.5	0.2%
Barren Areas	0	0
Low-Density Mixed	11.6	5.4%
Medium-Density Mixed	9.7	4.5%
High-Density Mixed	1.9	0.9%
Low-Density Open Space	10.9	5.1%
Farm Animals	16.4	7.7%
Septic Systems	0	0
Source Load Total:	**213.2**	**100%**
Pathway Load		
Stream Bank Erosion	23.0	-
Subsurface Flow	29.9	-
Total Watershed Mass Load:	**266**	

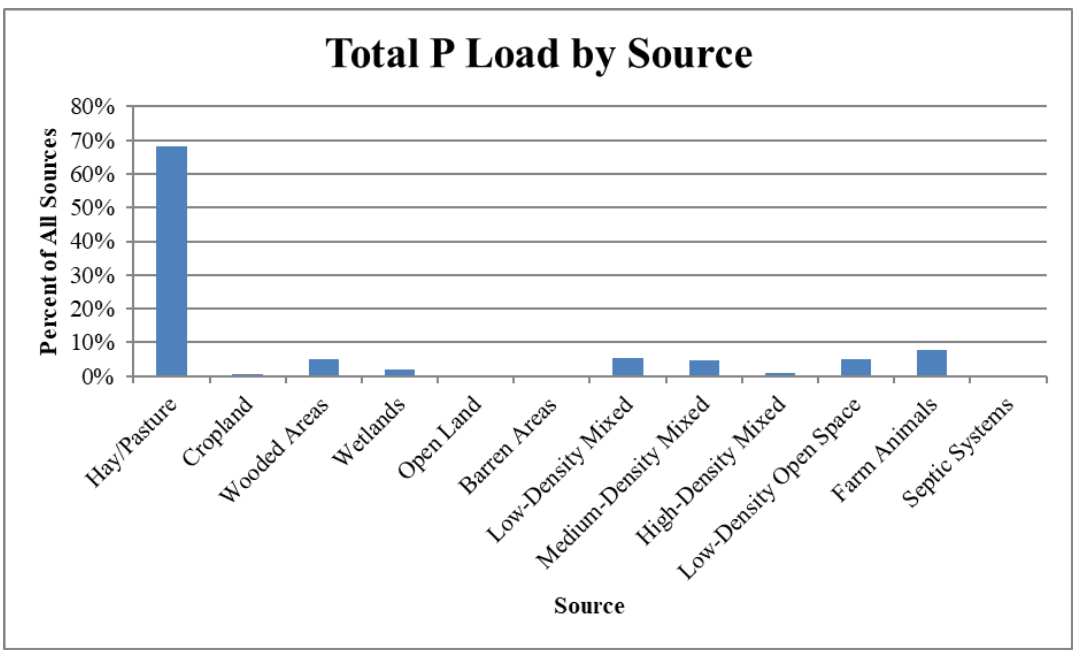


Figure 7: Total Phosphorus Load by Source in the Black Brook Watershed

TMDL: TARGET NUTRIENT AND SEDIMENT LEVELS FOR BLACK BROOK

The existing loads for nutrients and sediments in the impaired segment of Black Brook are listed in Table 8, along with the TMDL (the allowable load) which was calculated from the average loading estimates of five attainment watersheds throughout the state. Table 8 also shows required reductions (as a percent) for each of sediment, total N, and total P pollutants. Table 9 presents a more detailed view of the modeling results and calculations used to compute the existing loads in Table 8. An annual time frame provides a mechanism to address the daily and seasonal variability associated with nonpoint source loads.

Table 8: Black Brook Pollutant Loading Compared to TMDL Targets

Black Brook			
Pollutant Load	**Existing Load**	**TMDL**	**Reduction Required**
Total Annual Load per Unit Area		Attainment Streams	
Sediment (kg/ha/yr)	195.9	65.72	66.5%
Total N (kg/ha/yr)	2.63	2.46	6.5%
Total P (kg/ha/yr)	0.26	0.16	39.4%

Future Loading

The prescribed reduction in pollutants discussed in this TMDL reflects reduction from estimated existing conditions. Expansion of agricultural and development activities in the watershed have the potential to increase runoff and associated pollutant loads to Black Brook. To ensure that the TMDL targets are attained, future agricultural and development activities will need to meet the TMDL targets. Between 2012 to 2017 in Cumberland County, the growth in agricultural lands was decreasing, with a 7% decrease in the total number of farms and a 20.2% decrease in total farm area. Average farm size has also declined significantly (13.8%) during this time period. These values are extracted from the most recent (2017) Census of Agriculture (USDA 2017). Human population in Cumberland County increased by 4.8% from 2000 to 2019 (US Census 2020). Future activities and BMPs that achieve TMDL reductions are addressed below.

Next Steps

The use of agricultural and developed area BMP's can reduce sources of polluted runoff in the Black Brook. It is recommended that municipal officials, landowners, and conservation stakeholders in Windham work together to develop and implement the watershed management plan currently under development to:

- Address existing nonpoint source problems in the Black Brook watershed by instituting BMPs where necessary;
- Run a "Hot-Spot Analysis" in *Model My Watershed* to determine sub-watershed locations of higher existing contributions of sediment and nutrients to the outlet of Black Brook watershed; then focus BMP mitigation in these hot-spot sub-areas of the watershed;

- Encourage greater citizen involvement through the development of a watershed coalition to ensure the long term protection of Black Brook; and

- Prevent future degradation of Black Brook through the development and/or strengthening of a local Nutrient Management Ordinance.

Table 9: Annual Loads by Land Use, Other Sources, and Pathways for Black Brook Based on Modeling

Black Brook				
	Area (ha)	**Sediment** (1000 kg/yr)	**Total N** (kg/yr)	**Total P** (kg/yr)
Land Uses				
Hay/Pasture	198	64.4	588	145.6
Cropland	1	0.8	12	1.5
Wooded Areas	540	1.5	200	11.0
Wetlands	90	0.2	78	4.1
Open Land	6	0.4	13	0.5
Barren Areas	2	0.000	0	0.0
Low-Density Mixed	77	3.8	111	11.6
Medium-Density Mixed	21	4.4	98	9.7
High-Density Mixed	4	0.9	19	1.9
Low-Density Open Space	72	3.5	105	10.9
Total Area	1,010			
Other Sources				
Farm Animals		0.0	68	16.4
Septic Systems		0.0	73	0.0
Pathway Load				
Stream Bank Erosion		117.9	112	23.0
Subsurface Flow		0.0	1,178	29.9
Total Annual Load		198	2,654	266
Total Annual Load per Unit Area		0.20	2.63	0.26
		1000 kg/ha/yr	kg/ha/yr	kg/ha/yr

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DRAFT TMDL SUMMARY

Colley Wright Brook

WATERSHED DESCRIPTION

This **TMDL** applies to an 8.2 mile section of Colley Wright Brook, located in the Town of Windham, Maine. The impaired segment of Colley Wright Brook begins in the northern portion of the watershed, flows south through forest until crossing Route 302, then passes through agriculture. The stream continues through woods bordered by residential development, crossing Brick Hill Road, Pope Road, and Chute Road. The stream then enters into more dense agriculture, crossing Montgomery Road and River Road before meeting the Presumpscot River. The Colley Wright Brook watershed covers an area of 7.65 square miles.

- Colley Wright Brook is on Maine's 303(d) list of Impaired Streams as referenced in the 2016 Integrated Report (Maine DEP, 2018).
- The Colley Wright Brook watershed is predominately non-developed (69%). Of the non-developed area, wooded areas (60.4%) within the watershed absorb and filter pollutants helping protect both water quality in the stream and stream channel stability. Wetlands (7.8%) may also help filter nutrients.
- Non-forested areas within the watershed are predominantly agricultural (18%) and are located in the southern portion of the watershed.
- Developed areas containing impervious surfaces (13%) in close proximity to the stream may impact water quality.
- Runoff from hay/pasture is modeled as the largest source of nonpoint source (NPS) pollution to Colley Wright Brook. Runoff from cultivated lands, active hay lands, and pasture can transport sediment, nitrogen and phosphorus to the stream.

Definitions

- ***Total Maximum Daily Load (TMDL)*** *represents the total amount of pollutants that a waterbody can receive and still meet water quality standards.*
- **Nonpoint Source Pollution** *refers to pollution that comes from many diffuse sources across the landscape, and are typically transported by rain or snowmelt runoff.*

Waterbody Facts

Segment ID: ME0106000103_607R03

Town: Windham, ME

County: Cumberland

Impaired Segment Length: 8.2 miles

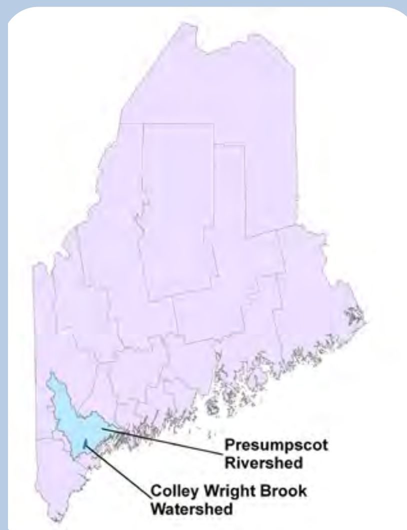
Classification: Class B

Direct Watershed: 7.65 mi^2 (4,896 acres)

Impairment Listing Cause: Dissolved Oxygen

Watershed Agricultural Land Use: 18%

Major Drainage Basin: Presumpscot River



Watershed Land Uses

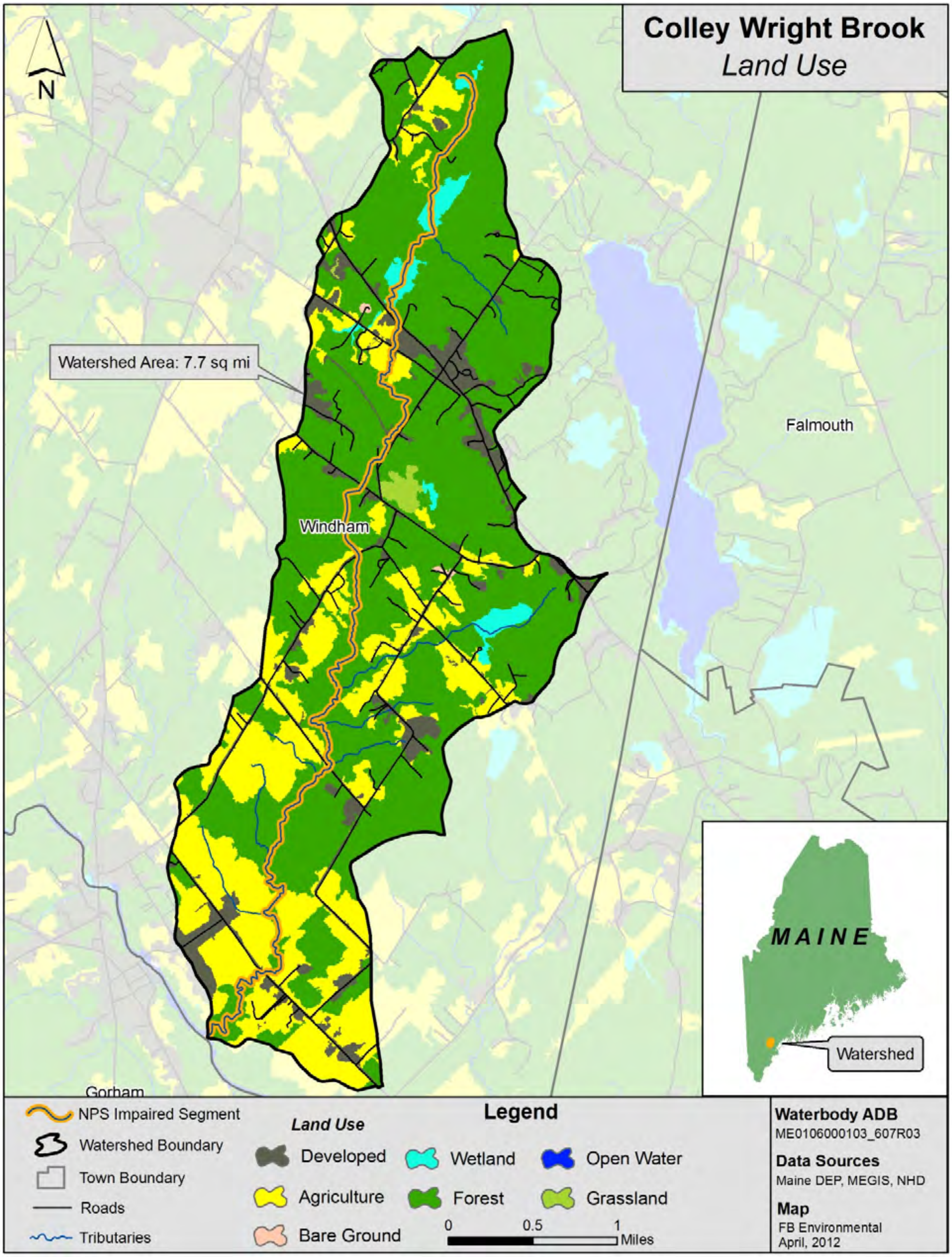


Figure 1: Land Use and Land Cover (from 2011) in the Colley Wright Brook Watershed

WHY IS A TMDL ASSESSMENT NEEDED?

Colley Wright Brook, a Class B freshwater stream, has been assessed by Maine DEP as not meeting water quality standards for the designated use of aquatic life, and placed on the 303(d) list of impaired waters under the Clean Water Act. The Clean Water Act requires that all 303(d)-listed waters undergo a TMDL assessment that describes the impairments and establishes a target to guide the measures needed to restore water quality. The goal is for all waterbodies to comply with state water quality standards.

***Colley Wright Brook** near Station RCW10 – River Road crossing. Photo: FB Environmental*

Agriculture in the Colley Wright Brook watershed makes up 18% of the total land area. This is more than the area of developed land which makes up only 13% of the watershed. Twenty-four percent of the impaired segment length passes through agricultural areas (Figure 1) making agriculture the likely largest contributor of sediment and nutrient enrichment to the stream. The close proximity of many agricultural lands, including a horse farm on River Road, to the stream further increases the likelihood that nutrients from disturbed soils, manure, and fertilizers will reach the stream.

WATER QUALITY DATA ANALYSIS

Maine DEP uses a variety of data types to measure the ability of a stream to adequately support aquatic life, including; dissolved oxygen, benthic macroinvertebrates, and periphyton (algae). For benthic macroinvertebrates, DEP makes aquatic life use determinations using a statistical model that incorporates 30 variables of data collected from rivers and streams, including the richness and abundance of streambed organisms, to determine the probability of a sample meeting Class A, B, or C conditions. Biologists use the model results and supporting information to determine if samples comply with the numeric aquatic life criteria of the class assigned to the stream or river (Davies and Tsomides, 2002). Maine DEP uses an analogous model to aid in the assessment of algal communities but makes aquatic life use determinations based on narrative standards.

The aquatic life impairment in Colley Wright Brook is based on historic dissolved oxygen data, which includes data collected at stations RCW10 and RCW11 in 2011, and station RCW24 in 2007.

TMDL ASSESSMENT APPROACH: NUTRIENT AND SEDIMENT MODELING OF IMPAIRED AND ATTAINMENT STREAMS

NPS pollution is difficult to measure directly because it comes from many diffuse sources spread across the landscape. For this reason, an online nutrient loading model, *Model My Watershed* (v. 1.32.0), was used to estimate the sources of pollution based on well-established hydrological equations (Stroud Water Research Center 2017). *Model My Watershed* makes use of the GWLF-enhanced model engine. The model incorporates detailed maps of soil, land use, and slope, daily weather and localized weather data (from the period 2009-2020), and direct observations of agriculture and other land uses within the watershed. *Model My Watershed* is derived from its parent MapShed developed by Evans and Corradini (2012). *Model My Watershed* replaced MapShed in 2017-2018.

The nutrient loading estimates for the impaired stream were compared to similar estimates for non-impaired (attainment) streams of similar watershed land uses across the state. The TMDL target for the impaired stream was set as the mean nutrient loading estimate of these attainment stream watersheds, and units of mass per unit watershed area per year (kg/ha/year) were used. The difference in loading estimates between the impaired and attainment watersheds represents the percent reduction in nutrient loading required under this TMDL. The attainment streams and their nutrient and sediment loading estimates and TMDL are presented below in Table 1.

Table 1: Numeric Targets for Pollutant Loading Based on Model My Watershed Outputs (2021) for Attainment Streams

Attainment Streams	Town	Total P Load (kg/ha/yr)	Total N Load (kg/ha/yr)	Sediment Load (kg/ha/yr)
Footman Brook	Exeter	0.17	1.73	35.2
Martin Stream	Fairfield	0.13	2.98	57.9
Moose Brook	Houlton	0.18	1.59	48.5
Upper Kenduskeag Stream	Corinth	0.16	1.72	100.5
Upper Pleasant River	Gray	0.16	4.26	86.5
Total Maximum Daily Load		**0.16**	**2.46**	**65.7**

RAPID WATERSHED ASSESSMENT

Habitat Assessment

A habitat assessment survey was conducted on both the impaired and attainment stream. The assessment approach is based on the *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (Barbour et al., 1999), which integrates various parameters relating to the structure of physical habitat. The habitat assessments include a general description of the site and physical characterization and visual assessment of in-stream and riparian habitat quality.

Based on rapid bioassessment protocols for low gradient streams, Colley Wright Brook received a score of 152 out of a total 200 for quality of habitat. Higher scores indicate better habitat. The range of habitat assessment scores for attainment streams was 155 to 179.

Habitat assessments were conducted in 2012 on a relatively short sample reach (about 100-200 meters for a typical small stream) near the most downstream Maine DEP sample station in the watershed. For both impaired and attainment streams, the assessment location was usually near a road crossing for ease of access. In the Colley Wright Brook watershed, the downstream sample station was located at the River Road stream crossing and DEP sample station RCW10. Water was documented as turbid and many sand and fine sediment deposits were observed throughout the reach. An agricultural field was located near the stream reach with a minimal buffer to the east. Trees dominated the surrounding riparian zone of Willow, Alder, Maple and Ash.

Figure 2 (right) shows the range of habitat assessment scores for all attainment and impaired streams, as well as for Colley Wright Brook. Though these scores show that habitat is clearly an issue in the impairment of Colley Wright Brook, it is important to look for other potential sources within the watershed lending to impairment. Consideration should be given to major "hot spots" in the Colley Wright Brook watershed as potential sources of NPS pollution contributing to the water quality impairment.

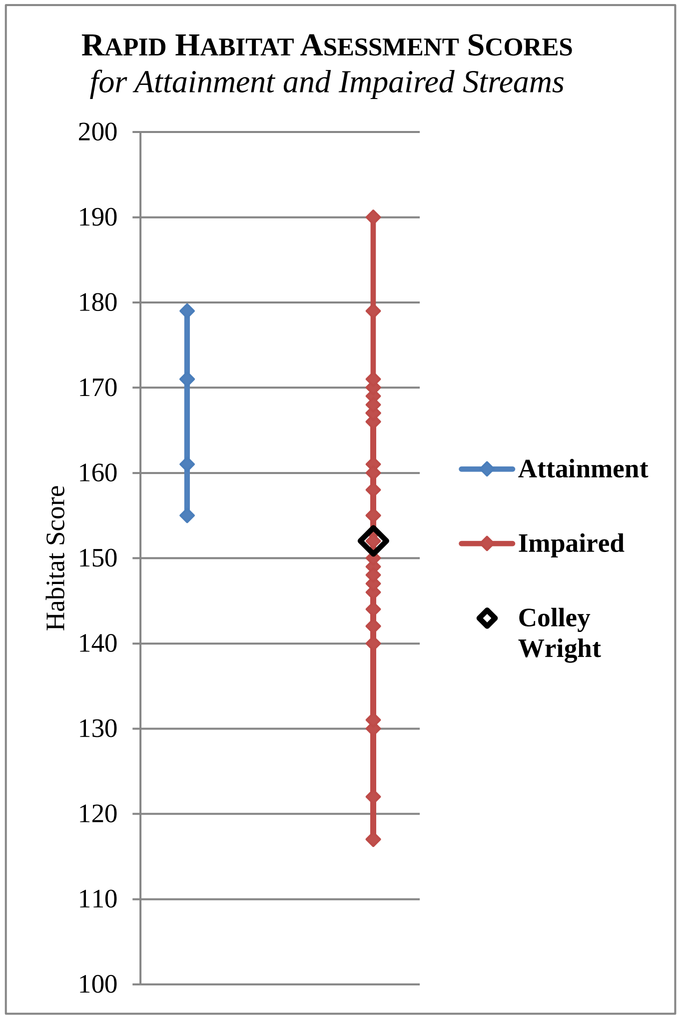


Figure 2: Habitat Assessment Scores for Colley Wright Brook (2012) Compared to Region

Pollution Source Identification

Pollution source identification assessments were conducted for both Colley Wright Brook (impaired) and the attainment streams. The source identification work is based on an abbreviated version of the Center for Watershed Protection's Unified Subwatershed and Site Reconnaissance method (Wright, et al., 2005). The abbreviated method includes both a desktop and field component. The desktop assessment consists of generating and reviewing maps of the watershed boundary, roads, land use and satellite imagery, and then identifying potential NPS pollution locations, such as road crossings, agricultural fields, and large areas of bare soil. When available, multiple sources of satellite imagery were reviewed. Occasionally, the high resolution of the imagery allowed for observations of livestock, row crops, eroding stream banks, sediment laden water, junkyards, and other potential NPS concerns that could affect stream quality. As many potential pollution sources as possible were visited, assessed and documented in the field. Field visits were limited to NPS sites that were visible from roads or a short walk from a roadway. Neighborhoods were assessed for NPS pollution at the whole neighborhood level including streets and storm drains (where applicable). The assessment does not include a scoring component, but does include a detailed summary of findings and a map indicating documented NPS sites throughout the watershed.

The watershed source assessment for Colley Wright Brook was completed in July 2012. In-field observations of erosion, lack of vegetated stream buffer, extensive impervious surfaces, high-density neighborhoods and agricultural activities were documented throughout the watershed (Table 2, Figure 3).

Table 2: Potential Pollution Source ID Assessment (2012) for the Colley Wright Brook Watershed

Potential Source			Notes
ID#	**Location**	**Type**	
3	River Road/Chute Road	Agriculture	• Large active hay field.
3b	River Road	Agriculture	• Active hay field.
3c	River Road	Agriculture	• Horse stables; estimated 20 horses observed. • Active hay fields surrounding.
3d	River Road	Agriculture	• Large hay field. • Adjacent to stream with limited buffer.
4	Highland Cliff Road	Agriculture	• Active hay fields.
4b	Highland Cliff Road	Agriculture	• Large active hay field adjacent to stream with small wooded buffer.
6	Montgomery Road/Chute Road	Agriculture	• Miniature horse breeder with about 24 horses. • Hay fields and pastures. • Greenhouses and Maple house.
6b	Montgomery Road/Chute Road	Agriculture	• Property on Montgomery Road raises Charolais cattle. • About 3 cows estimated.
7	Chute Road	Agriculture	• Hay fields
10	Highland Cliff Road/Land of Nod Road	Forestry	• Active cutting
16	Windham Center Road	Road Crossings/ Agriculture	• Multiple road crossings on major roads. • No erosion issues observed. • Active hay land in immediate surrounding area.
18	Nash Road	Agriculture	• Sand pit
21	River Road	Agriculture	• Cattle, sheep, pigs, chickens, crops, hay. • None observed, information acquired from farm website.

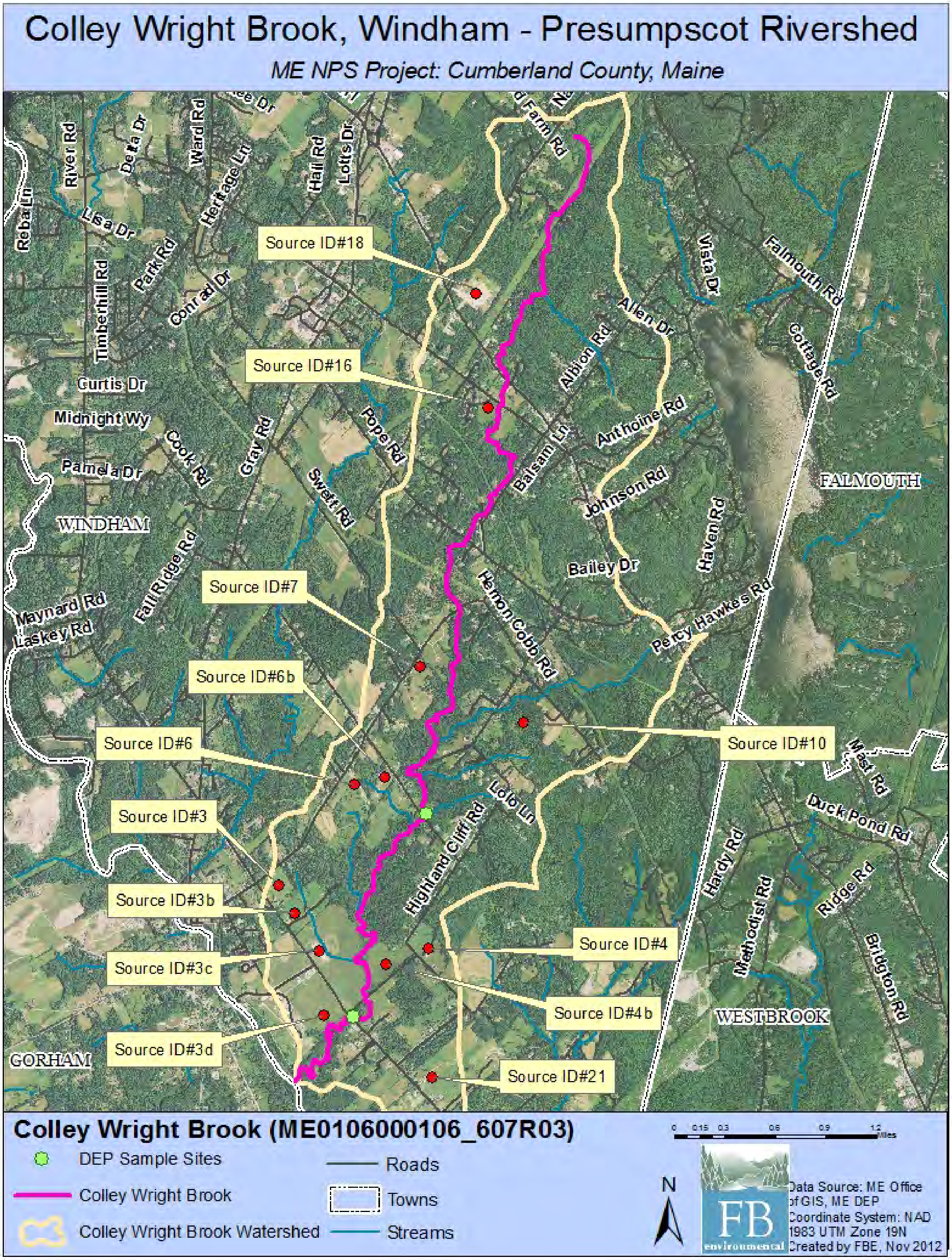


Figure 3: Aerial Photo of Potential Source ID Locations (identified in 2012) in the Colley Wright Brook Watershed

NUTRIENT AND SEDIMENT LOADING – *MODEL MY WATERSHED* ANALYSIS

The *Model My Watershed* model was used to estimate stream loading of total phosphorus, total nitrogen, and sediment in Colley Wright Brook watershed. The model estimated nutrient loads over a 12-year period (2009-2020), which was determined by local (Portland Jetport USW00014764) weather data inserted into *Model My Watershed*. This extended period captures a recent but wide range of hydrologic conditions to account for variations in nutrient and sediment loading over time. Loads for the attainment watersheds (five total; Table 1) were computed using the same model with the same recent inputs (i.e., regional weather, 2016 land use and land cover, 2016 wetland extent, and BMPs similar to the impaired watersheds).

Many quality assured and regionally calibrated input parameters are provided with *Model My Watershed*. However, several updates to some of the default parameters were made in this TMDL effort, and namely more recent land use/cover using **MRLC-NLCD 2016** [1], more recent and local weather (precipitation and temperature) data (as described above), and more regional estimates of Best Management Practices (BMPs; see ensuing discussion). Because land use/cover is more recent, the estimated filtration fraction of wetland and open water and the amount of stream buffer in agricultural land should be more accurate. It is also worth noting that improved classification algorithms were employed by MLRC in the NCLD 2016 and these new algorithms were used in the revisions of all previous NLCD versions (including the first version in 2001).

Livestock Estimates

Livestock waste contains nutrients which can cause water quality impairment. The nutrient loading model considers numbers and types of animals. Table 3 (right) provides livestock (numbers of animals) in the watershed based on the USDA National Agricultural Statistics Service (NASS) estimation for 2012. Some of these totals were modified by direct observations made in the watershed in the 2012 survey. To generate watershed-based livestock counts, NASS county-based livestock totals are converted to a per unit area (based on the total area of the county). The unit area amount is then multiplied by the total watershed area to derive a watershed total count (as seen in Table 3).

Table 3: Livestock Estimates in the Colley Wright Watershed

Type	Colley Wright Brook
Dairy Cows	6
Beef Cows	7
Broilers	9
Layers	37
Hogs/Swine	9
Sheep	24
Horses	44
Turkeys	3
Other	--
Total	**139**

The Colley Wright Brook watershed is predominantly forested, with substantial mixed agricultural land uses scattered through watershed, and consisted of large hay fields and some pasture. A miniature horse farm is home to about 24 horses. The same owners also have Charolais cattle with 3 cows estimated. A horse stable is located on River Road in close proximity to a tributary of Colley Wright Brook. About 20 horses were observed here. A large farm is also located on River Road just southeast of the sample reach station. Another farm and farm stand is located to the north and south of River Road. From the farm's website, they raise and sell cattle, pigs, lamb, turkey and chicken along with growing various vegetable crops. It is unknown whether all animals

[1] MRLC-NLCD 2016 : Multi-Resolution Land Characteristics – National Land Cover Dataset (version 2016) provided by the MRLC Consortium (Jin et al. 2019).

are raised in this location as no livestock or clear signs of pasture were observed during the field visit. No estimates were made for this potential source.

Vegetated Stream Buffer in Agricultural Areas

Vegetated stream buffers are areas of trees, shrubs, and/or grasses adjacent to streams, lakes, ponds or wetlands which provide nutrient loading attenuation (Evans and Corradini 2012). *Model My Watershed* considers natural vegetated stream buffers within agricultural land areas as providing nutrient load attenuation. A width of approximately 98 feet (30 m) on one side of a stream is required to be considered a streamside buffer per the *Model My Watershed* technical manual (Stroud Water Research Center 2017). Analysis of recent aerial photos was used to estimate the number of agricultural land stream miles with and without vegetative buffers, and these estimates were directly entered into the model.

Table 4: Summary of Vegetated Buffers in Agricultural Areas (2012)

Colley Wright Brook
• Agricultural Land Stream Length = 1.9 mi • Agricultural Land Stream Length with Buffer = 1.2 mi (or 63% of total agricultural land stream length) • Percentage of total stream length flowing through non-buffered agricultural land = 7.5%

Colley Wright Brook is an 8.2 mile-long impaired segment as listed by Maine DEP. As modeled, the total stream miles (including tributaries) within the watershed was calculated as 9.3 miles. Of this total, 1.9 stream miles are located within agricultural areas and 1.2 miles or 63% of that area *appear* to have a 98 foot or greater vegetated buffer (Table 4, Figure 4). From a watershed perspective, this equates to 0.7 miles or 7.5% of the total stream length running through agricultural land with less than a 98 foot buffer. By contrast, for attainment stream watersheds, the percentage of total stream miles running through agricultural land without a 75 foot vegetated buffer ranged from 0% to 3.9% with an average of 1.3%. Note, a minimum vegetated buffer width of *75 feet* was used in an earlier (2012) effort to produce Figure 4 shown here. Differences in stream length estimates using a 98-foot or 75-foot buffer were practically insignificant.

Home Septic System Loads

Loads for “normally functioning” septic systems are calculated in *Model My Watershed* using an estimate of the average number of persons per acre in “Low-Density Mixed” areas. In these areas, it is assumed that the populations therein are served by septic systems rather than centralized sewage systems. All homes in such areas are assumed to be connected to “normally functioning” systems rather than those that experience “surface breakouts” (surface failures), “short-circuiting” to underlying groundwater (subsurface failures), or have direct conduits to nearby water bodies. Non-functioning systems would be modeled with a higher load contribution to the waterbody.

Best Management Practices (BMPs)

Best management practices (BMPs) are typically instituted to reduce the loading of sediment and nutrients from upland (i.e., non-point) sources. Ideally, information on BMPs for a specific watershed from local and regional sources would improve this component of the water quality model. Maine DEP sought information on BMP use in early 2021 from local, regional, and state agricultural agencies for rural BMPs and from nearby municipalities for urban BMPs. Very little to no information was returned in the solicitation. Hence, estimates for typical New England watersheds were derived from information available from Vermont. An upper limit of BMP use was garnered from watersheds entering the Chesapeake Bay where BMP use is intensive.

Four agricultural BMPs were used in this modeling effort and in the following manner:

- *Cover Crops:* Cover crops are the use annual or perennial crops to protect soil from erosion during time periods between harvesting and planting of the primary crop. The percent of cropland area in a cover crop BMP deployed was estimated at 25% and selected as the low end of the range (25 to 30 percent) expected for cropland in New England. This value was assigned to the five attainment watersheds.
- *Conservation Tillage:* Conservation tillage is any kind of system that leaves at least 30% of the soil surface covered with crop residue after planting. This reduces soil erosion and runoff. This BMP was estimated to occur in 25% of cropland. This value was assigned to the five attainment watersheds.
- *Strip Cropping / Contour Farming:* This BMP involves tilling, planting and harvesting perpendicular to the gradient of a hill or slope using high levels of plant residue to reduce soil erosion from runoff. Both interview sources suggest this practice is minimal to non-existent for New England watersheds. Hence, no BMP of this type was used in this modeling effort. This value was assigned to the five attainment watersheds.
- *Grazing Land Management:* This BMP consists of ensuring adequate vegetation cover on grazed lands to prevent soil erosion from overgrazing or other forms of over-use. This usually employs a rotational grazing system where hays or legumes are planted for feed and livestock is rotated through several fenced pastures. Both interview sources were not aware of this practice being active and is likely minimal for New England watersheds. Hence, no BMP of this type was used in this modeling effort for both impaired and attaining watersheds.

Note that other agricultural and development BMPs likely exist in the watershed but their location and type were not available in a watershed-wide format that is necessary to include in the model. Agricultural BMPs recommended by Maine DEP to reduce sediment and nutrient loads include vegetated buffers, covered manure storage facilities, and stream exclusion fencing. BMPs for developed areas recommended by the Maine DEP include vegetated buffers, stormwater BMPs, and minimization of impervious cover.

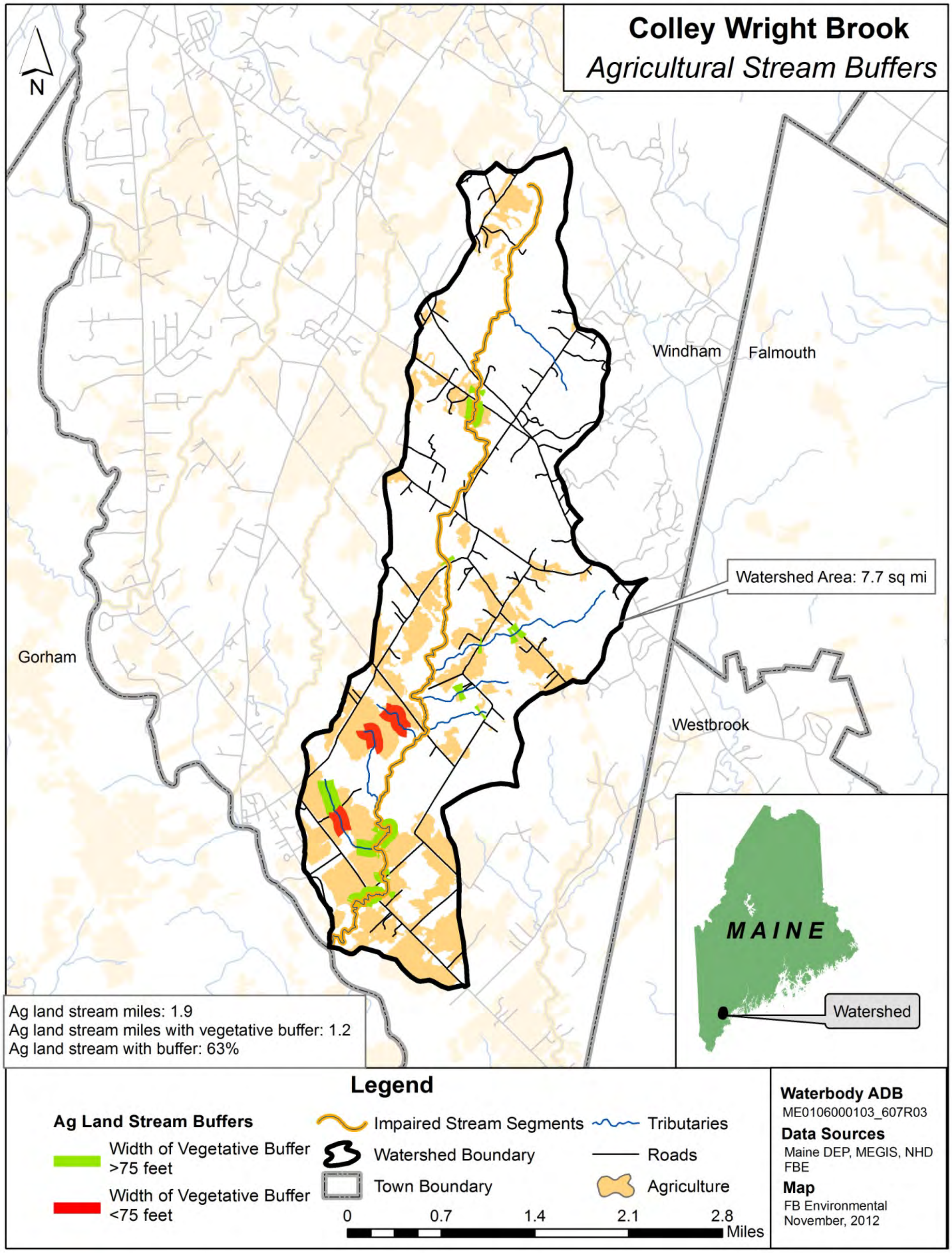


Figure 4: Agricultural Stream Buffers (from 2012) in the Colley Wright Brook Watershed

Pollutant Load Attenuation by Lakes, Ponds and Wetlands

Depositional environments such as lakes, ponds, and wetlands can attenuate watershed sediment and nutrient loading. This information is entered into the nutrient loading model by a simple percentage of watershed area draining to a lake, pond, or wetland. The Colley Wright Brook watershed is 7.9% wetland and open water, per the 2016 NLCD land use/cover. There are a few wetlands that surround tributaries throughout the watershed. It is estimated that 15.7% of land area within the watershed drains to wetlands and open water. The percent of watershed draining to a wetland in the attainment watersheds, based on the 2021 analysis, ranged from 26 to 58 percent, with an average of 40%.

NUTRIENT AND SEDIMENT MODELING RESULTS

Selected results from the watershed loading model are presented here. The TMDL itself is expressed in units of kilograms per hectare per year. The additional results shown below assist in better understanding the likely sources of pollution. The model results for Colley Wright Brook watershed indicate significant reductions of phosphorus and sediment and a small reduction of nitrogen are needed to improve water quality. Below, loading for nitrogen, phosphorus and sediment are discussed individually.

There are two categories of loads – sources and pathways. Sources are determined by land use/cover and the overland flow they generate, livestock counts by animal type, and home sewage treatment systems in developed areas. Pathways represent additional loads derived from subsurface flow and streambank erosion. Subsurface loads are calculated using dissolved N and P coefficients for shallow groundwater and are mainly derived from atmospheric inputs. Sediment and nutrient loads produced by eroding streambanks are estimated using an approach developed by Evans et al. (2003). This pathway is comprised of loads originating from five sources, and listed in order of decreasing importance: amount of developed land area, soil erodibility (K-factor), density of livestock, runoff curve number, and topographic slope. For any given model run, the amount of developed land in the watershed is responsible for just over 72% of the total streambank load, whereas soil erodibility and animal density are responsible for 21% and 7% of the total streambank load, respectively.

Sediment

Aside from stream bank erosion which contributes 60% of the total sediment load, the major source load in Colley Wright Brook watershed originates from hay/pasture land (84.5% of total sources). Residential sources contribute 12.2% of the source load.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient and Sediment Levels for Colley Wright Brook* below for loading estimates that have been normalized by watershed area.

Table 5: Total Sediment Load by Source

Colley Wright Brook	Sediment (1000 kg/year)	Sediment (%)
Source Load		
Hay/Pasture	108.8	84.5%
Cropland	0.4	0.3%
Wooded Areas	2.6	2.0%
Wetlands	0.3	0.2%
Open Land	0.9	0.7%
Barren Areas	0	0
Low-Density Mixed	4.7	3.7%
Medium-Density Mixed	3.9	3.1%
High-Density Mixed	0.6	0.5%
Low-Density Open Space	6.4	5.0%
Farm Animals	0	0
Septic Systems	0	0
Source Load Total:	**128.8**	**100%**
Pathway Load		
Stream Bank Erosion	194.0	-
Subsurface Flow	0	-
Total Watershed Mass Load:	**323**	

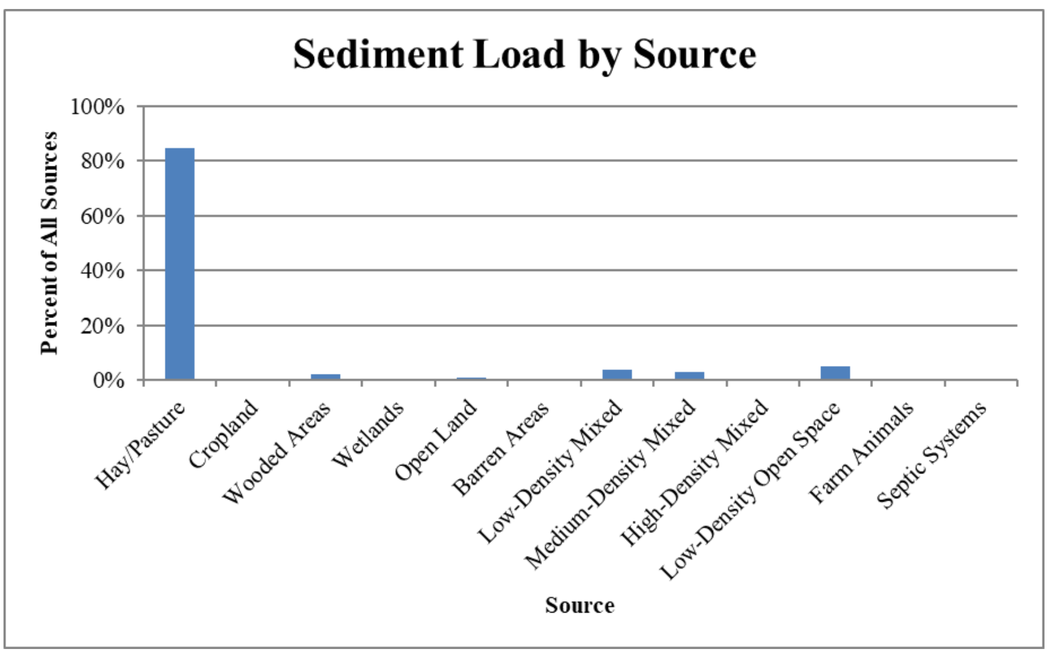


Figure 5: Total Sediment Load by Source in the Colley Wright Brook Watershed

Total Nitrogen

Table 6 and Figure 6 (below) show the estimated total nitrogen load, in terms of mass and percent of total by source, in the Colley Wright Brook watershed. Hay and pasture lands are the largest source of nitrogen loading contributing about 43% of the source load of total N. Residential areas combined (including septic systems) contribute just under 20% of the source load whereas wooded areas and wetlands contribute 22.5% of the source load. Lastly, farm animals contribute about 12% of the source load.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient and Sediment Levels for Colley Wright Brook* below for loading estimates that have been normalized by watershed area.

Table 6: Total Nitrogen Load by Source

Colley Wright Brook	Total N (kg/year)	Total N (%)
Source Load		
Hay/Pasture	1,028	43.5%
Cropland	5	0.2%
Wooded Areas	399	16.9%
Wetlands	134	5.6%
Open Land	45	1.9%
Barren Areas	3	0.1%
Low-Density Mixed	132	5.6%
Medium-Density Mixed	84	3.6%
High-Density Mixed	14	0.6%
Low-Density Open Space	179	7.5%
Farm Animals	282	11.9%
Septic Systems	62	2.6%
Source Load Total:	**2,365**	**100%**
Pathway Load		
Stream Bank Erosion	182	-
Subsurface Flow	2,515	-
Total Watershed Mass Load:	**5,061**	

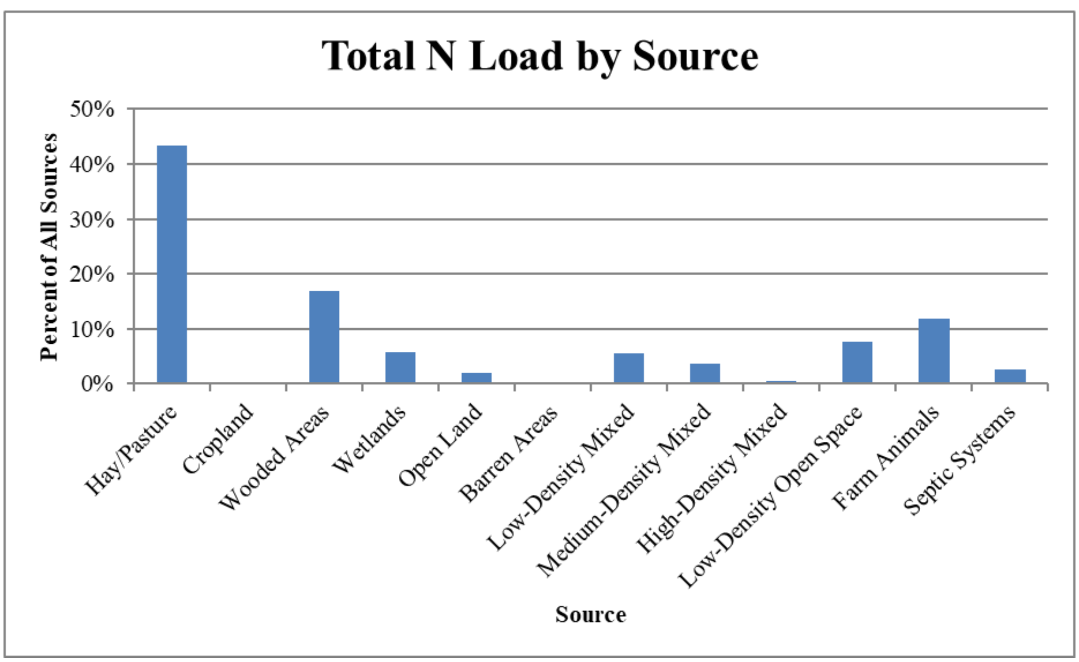


Figure 6: Total Nitrogen Load by Source in the Colley Wright Brook Watershed

Total Phosphorus

Table 7 and Figure 7 (below) show the estimated total phosphorus load in terms of mass and percent of total by source, in the Colley Wright Brook watershed. Hay and pasture lands are the largest source of phosphorus loading contributing almost 65% of the source load. Residential areas combined contribute 10.5% of the source load. Farm animals contribute almost 17% of the source load of total P. Stream bank erosion contributes 7% of the total watershed P load.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient and Sediment Levels for Colley Wright Brook* below for loading estimates that have been normalized by watershed area.

Table 7: Total Phosphorus Load by Source

Colley Wright Brook	Total P (kg/year)	Total P (%)
Source Load		
Hay/Pasture	262.2	64.9%
Cropland	0.7	0.2%
Wooded Areas	21.9	5.4%
Wetlands	7.0	1.7%
Open Land	1.5	0.4%
Barren Areas	0.1	0.02%
Low-Density Mixed	13.9	3.4%
Medium-Density Mixed	8.4	2.1%
High-Density Mixed	1.3	0.3%
Low-Density Open Space	18.8	4.7%
Farm Animals	68.3	16.9%
Septic Systems	0	0
Source Load Total:	**404.1**	**100%**
Pathway Load		
Stream Bank Erosion	38.0	-
Subsurface Flow	99.6	-
Total Watershed Mass Load:	**542**	

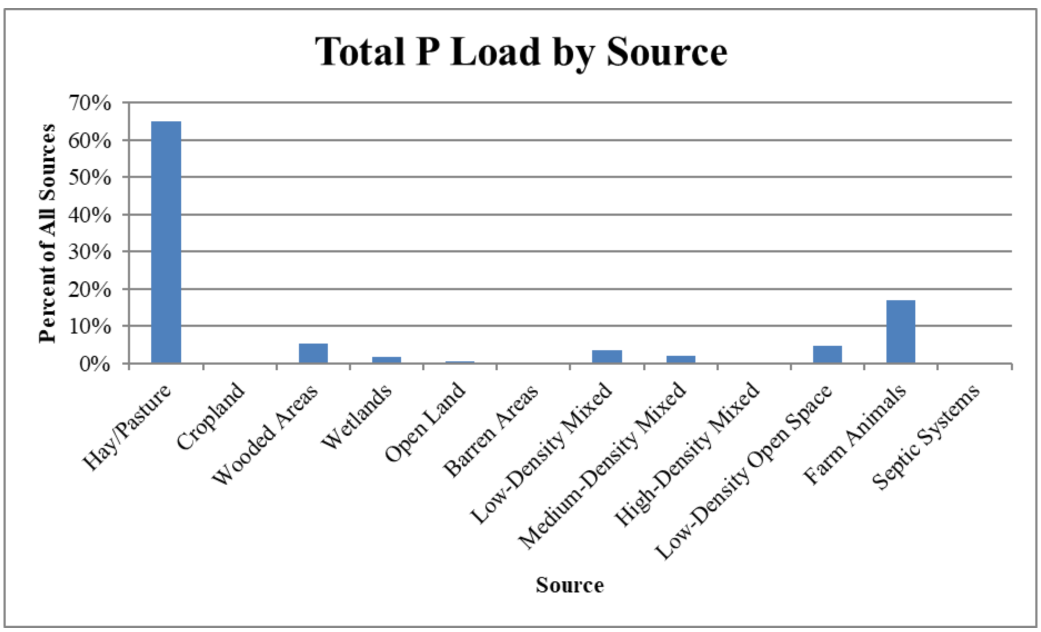


Figure 7: Total Phosphorus Load by Source in the Colley Wright Brook Watershed

TMDL: TARGET NUTRIENT AND SEDIMENT LEVELS FOR COLLEY WRIGHT BROOK

The existing loads for nutrients and sediments in the impaired segment of Colley Wright Brook are listed in Table 8, along with the TMDL (the allowable load) which was calculated from the average loading estimates of five attainment watersheds throughout the state. Table 8 also shows required reductions (as a percent) for each of sediment, total N, and total P pollutants. Table 9 presents a more detailed view of the modeling results and calculations used to compute the existing loads in Table 8. An annual time frame provides a mechanism to address the daily and seasonal variability associated with nonpoint source loads.

Table 8: Colley Wright Brook Pollutant Loading Compared to TMDL Targets

Colley Wright Brook			
Pollutant Load	**Existing Load**	**TMDL**	**Reduction Required**
Total Annual Load per Unit Area		Attainment Streams	
Sediment (kg/ha/yr)	163.3	65.72	59.7%
Total N (kg/ha/yr)	2.56	2.46	4.0%
Total P (kg/ha/yr)	0.27	0.16	41.7%

Future Loading

The prescribed reduction in pollutants discussed in this TMDL reflects reduction from estimated existing conditions. Expansion of agricultural and development activities in the watershed have the potential to increase runoff and associated pollutant loads to Colley Wright Brook. To ensure that the TMDL targets are attained, future agricultural, and to some extent development, activities will need to meet the TMDL targets. Between 2012 to 2017 in Cumberland County, the growth in agricultural lands was decreasing, with a 7% decrease in the total number of farms and a 20.2% decrease in total farm area. Average farm size has also declined significantly (13.8%) during this time period. These values are extracted from the most recent (2017) Census of Agriculture (USDA 2017). Human population in Cumberland County increased by 4.8% from 2000 to 2019 (US Census 2020). Future activities and BMPs that achieve TMDL reductions are addressed below.

Next Steps

The use of agricultural and developed area BMP’s can reduce sources of polluted runoff in Colley Wright Brook. It is recommended that municipal officials, landowners, and conservation stakeholders in Windham work together to develop a watershed management plan to:

- Encourage greater citizen involvement through the development of a watershed coalition to ensure the long term protection of Colley Wright Brook;
- Run a “Hot-Spot Analysis” in *Model My Watershed* to determine sub-watershed locations of higher existing contributions of sediment and nutrients to the outlet of Colley Wright Brook watershed; then focus BMP mitigation in these hot-spot sub-areas of the watershed;
- Address existing nonpoint source problems in the Colley Wright Brook watershed by instituting BMPs where necessary; and

- Prevent future degradation of Colley Wright Brook through the development and/or strengthening of local Nutrient Management Ordinance.

Table 9: Annual Loads by Land Use, Other Sources, and Pathways for Colley Wright Brook Based on Modeling

Colley Wright Brook				
	Area (ha)	**Sediment** (1000 kg/yr)	**Total N** (kg/yr)	**Total P** (kg/yr)
Land Uses				
Hay/Pasture	355	108.8	1,028	262.2
Cropland	1	0.4	5	0.7
Wooded Areas	1,195	2.6	399	21.9
Wetlands	154	0.3	134	7.0
Open Land	22	0.9	45	1.5
Barren Areas	2	0.000	3	0.1
Low-Density Mixed	97	4.7	132	13.9
Medium-Density Mixed	17	3.9	84	8.4
High-Density Mixed	3	0.6	14	1.3
Low-Density Open Space	131	6.4	179	18.8
Total Area	1,977			
Other Sources				
Farm Animals		0.0	282	68.3
Septic Systems		0.0	62	0.0
Pathway Load				
Stream Bank Erosion		194.0	182	38.0
Subsurface Flow		0.0	2,515	99.6
Total Annual Load		323	5,061	542
Total Annual Load per Unit Area		0.16	2.56	0.27
		1000 kg/ha/yr	kg/ha/yr	kg/ha/yr

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DRAFT TMDL SUMMARY

Craig Brook

WATERSHED DESCRIPTION

This TMDL applies to the entire 7.2 mile (11.6 km) length of Craig Brook, which includes its north and south branches and a small tributary, and encompasses the village of Littleton, Maine. Craig Brook enters the Meduxnekeag River just downstream of Framingham Road. The Brook flows southeast from its headwaters. At 1.6 mile upstream of its mouth, Craig Brook splits into a north and south branch with both branches collecting nearly equal drainage areas (Figure 1). The watershed of the north branch has more wetland and wooded area relative to that of the mainstem or south branch. There exists a small length (0.8 mi) un-named tributary joining from the south end of the south branch and is considered part of the impaired segment. The Craig Brook watershed covers an area of 7.4 square miles.

- Craig Brook is on Maine's 303(d) list of Impaired Streams as referenced in the 2016 Integrated Report (Maine DEP, 2018).
- Runoff from row-crop agriculture (potato-grain rotation) and small livestock operations are likely the largest contributor of nutrients and sediment to Craig Brook. Agriculture is the largest and most intense land use comprising 44% of the watershed and is mostly situated in the periphery and near the watershed boundary (Figure 1).
- Just over half (51%) of the Craig Brook watershed is non-developed land (34% wetlands and 16% wooded). Wetlands both border and encompass the Craig Brook stream channel which can act as a buffer and potential filter for the stream from nutrients and sediment originating from the agricultural or developed land. Woodlands can also filter nutrients depending on their location. Timber harvesting has occurred on some of the woodlands; it does not appear to be clear-cutting or conversion from hardwood to softwood.
- Developed areas (5%) contain impervious surfaces (rooftops and roads) and home septic systems and when in close proximity to the stream may impact water quality.

Definitions

- ***Total Maximum Daily Load (TMDL)*** *represents the total amount of a pollutant that a waterbody can receive and still meet water quality standards.*
- **Nonpoint Source Pollution** *refers to pollution that comes from many diffuse sources across the landscape, and are typically transported by rain or snowmelt runoff.*

Waterbody Facts

Segment ID:
ME0101000504_152R02

Towns: Littleton, ME

County: Aroostook (southern)

Impaired Segment Length: 7.2 mi (includes north and south branches, un-named tributary)

Classification: Class B

Direct Watershed: 7.4 mi^2 (4,736 acres)

Impairment Listing Cause: Periphyton

Watershed Agricultural Land Use: 44%

Major Drainage Basin: Saint John River

Watershed Land Uses

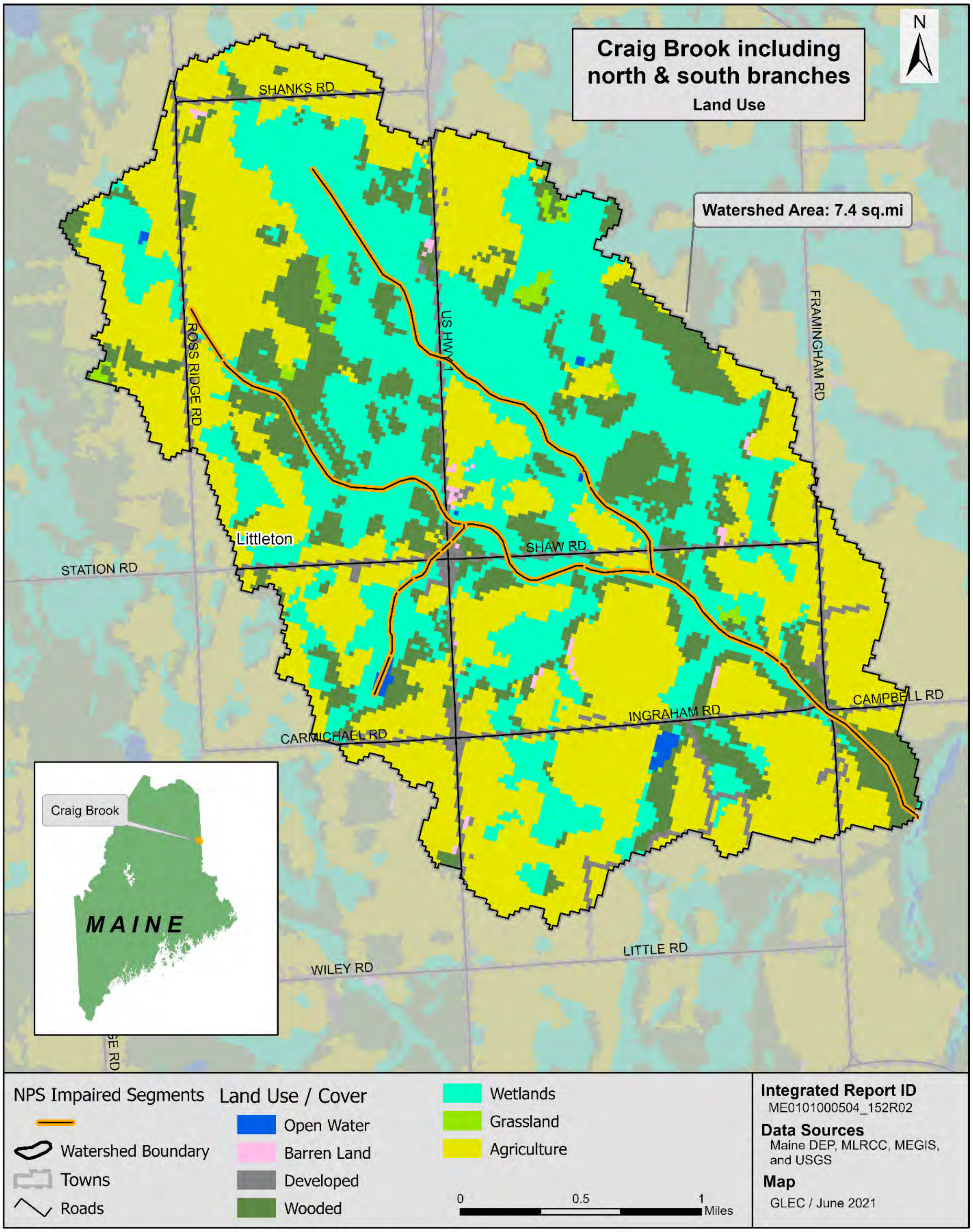

Figure 1: Land Use and Land Cover (2016) in the Craig Brook Watershed

WHY IS A TMDL ASSESSMENT NEEDED?

Craig Brook is a Class B Stream and has been assessed by Maine DEP as not meeting water quality standards for the designated use of aquatic life and placed on the 303(d) list of impaired waters under the Clean Water Act. The Clean Water Act requires that all 303(d)-listed waters undergo a Total Maximum Daily Load (TMDL) assessment that describes the impairments and establishes a target to guide the actions needed to restore water quality. The goal is for all waterbodies to comply with state water quality standards.

Agriculture (cropland and hay/pasture), 44% of the watershed, is an intense land use activity. Due to the northern Maine climate with its short growing season, cultivated crop land is often left bare from harvest (September/October) to planting and emergence (May/June), resulting in long periods of soil exposure. In contrast, development which is also an intense land use activity is only 5% of the watershed. Concentrated flow in and around cropland (34% of the watershed) further increases the likelihood that nutrients and sediment will reach Craig Brook.

***Craig Brook** looking upstream at the upper part of the habitat assessment segment, just downstream of the Ingraham Road bridge. Photo: GLEC 2021*

***Craig Brook** in the middle of the habitat assessment segment, upstream of the Framingham Road bridge. Photo: GLEC 2021*

WATER QUALITY DATA ANALYSIS

Maine DEP uses a variety of data types to measure the ability of a stream to adequately support aquatic life, including; dissolved oxygen, benthic macroinvertebrates, and periphyton (algae). For benthic macroinvertebrates, DEP makes aquatic life use determinations using a statistical model that incorporates 30 variables of data collected from rivers and streams, including the richness and abundance of streambed organisms, to determine the probability of a sample meeting Class A, B, or C conditions. Biologists use the model results and supporting information to determine if samples comply with the numeric aquatic life criteria of the class assigned to the stream or river (Davies and Tsomides, 2002). Maine DEP uses an analogous model to aid in the assessment of algal communities but makes aquatic life use determinations based on narrative standards.

The aquatic life impairment in Craig Brook is based on macroinvertebrate and periphyton (algae) data collected from 2014 to 2017. The entire length of Craig Brook, including both north and south branches, has a Class B designation. Station S-1006 is located just downstream of Framingham Road (Figure 3). Here periphyton did not meet in both 2014 and 2017, and thus the segment is impaired. Macroinvertebrates met a *higher* designation (Class A) in 2014. As macroinvertebrate and algae data measure different trophic levels, it is not unusual in agriculturally dominated watersheds for the results of these assessments to differ.

TMDL Assessment Approach: Nutrient and Sediment Modeling of Impaired and Attainment Streams

NPS pollution is difficult to measure directly because it comes from many diffuse sources spread across the landscape. For this reason, an online nutrient loading model, *Model My Watershed* (v. 1.32.0), was used to estimate the sources of pollution based on well-established hydrological equations (Stroud Water Research Center 2017). *Model My Watershed* makes use of the GWLF-enhanced model engine. The model incorporates detailed maps of soil, land use, and slope, daily weather and localized weather data (from the period 2009-2020), and direct observations of agriculture and other land uses within the watershed. *Model My Watershed* is derived from its parent MapShed developed by Evans and Corradini (2012). *Model My Watershed* replaced MapShed in 2017-2018.

The nutrient loading estimates for the impaired stream were compared to similar estimates for five non-impaired (attainment) streams of similar watershed land uses across the state. The TMDL for the impaired stream was set as the mean nutrient loading estimate of these attainment stream watersheds, and units of mass per unit watershed area per year (kg/ha/year) were used. The difference in loading estimates between the impaired and attainment watersheds represents the percent reduction in nutrient loading required under this TMDL. The attainment streams and their nutrient and sediment loading estimates and TMDL are presented below in Table 1.

Table 1: Numeric Targets for Pollutant Loading Based on Model My Watershed Outputs (2021) for Attainment Streams

Attainment Streams	Town	Total P Load (kg/ha/yr)	Total N Load (kg/ha/yr)	Sediment Load (kg/ha/yr)
Footman Brook	Exeter	0.17	1.73	35.2
Martin Stream	Fairfield	0.13	2.98	57.9
Moose Brook	Houlton	0.18	1.59	48.5
Upper Kenduskeag Stream	Corinth	0.16	1.72	100.5
Upper Pleasant River	Gray	0.16	4.26	86.5
Total Maximum Daily Load		**0.16**	**2.46**	**65.7**

RAPID WATERSHED ASSESSMENT

Habitat Assessment

Habitat assessment surveys were conducted on both impaired and attainment streams (Figure 2). The assessment approach is based on the *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (Barbour et al. 1999), which integrates various parameters relating to the structure of physical habitat. The habitat assessments include a 1) general description of the site and physical characterization and a 2) visual assessment of in-stream and riparian habitat quality. For both impaired and attainment streams, the assessment locations are typically near a road crossing for ease of access.

Craig Brook is an impaired stream (ME0101000504_152R02; Class B) and was surveyed just upstream (approximately 20 m) from the Framingham Road bridge crossing for a length of 100 m. The upstream-most point was approximately 20 m downstream of the Ingraham Road bridge crossing. The surveyed reach was clear of any obvious habitat alteration due to bridge structure at its downstream and upstream terminals. Based on the higher frequency of riffles versus runs or pools, a *high gradient* habitat assessment was performed on this 100 m length of stream segment. Craig Brook was biologically assessed just downstream of the Framingham Road bridge crossing. Craig Brook at Framingham Road is approximately 0.6 mi upstream from its confluence with the Meduxnekeag River.

The habitat survey for this impaired segment was located in dense vegetated riparian cover, while the overall watershed land use contained a mixture of cropland, wetlands, wooded, and some pasture with very small areas of developed land. However, the surveyed segment matches most of the Craig Brook riparian corridor which is wetland or wooded throughout its approximately 7.2 mi length, including the north and south branches.

Figure 2 (right) shows the range of habitat assessment scores for all attainment and impaired streams, as well as for Craig Brook segment discussed here.

Based on the *Rapid Bioassessment Protocols*, Craig Brook earned a score of 167. A higher score indicates better habitat. The range of habitat scores for attainment streams was 155 to 179.

Habitat parameters that scored high for Craig Brook include width of riparian vegetative zone, vegetated protection of streambank, and frequency of riffles. Parameters that scored low include velocity/depth regime and channel flow status.

Habitat does not appear to be an issue in the impairment of Craig Brook. Hence, it is important to look for other potential sources within the watershed leading to impairment. Consideration should be given to major "hot spots" in the Craig Brook watershed as potential sources of NPS pollution contributing to the water quality impairment.

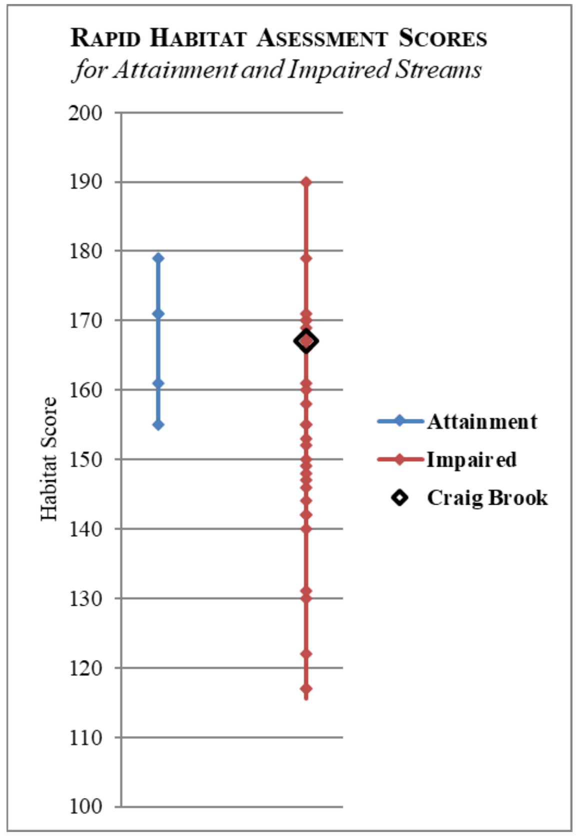

Figure 2: Habitat Assessment Score for Craig Brook (2021) Compared to Region

Pollution Source Identification

Pollution source identification assessments were conducted in May 2021 for the entire Craig Brook watershed. Attainment stream watersheds were assessed in 2012. The source identification work is based on an abbreviated version of the Center for Watershed Protection's Unified Subwatershed and Site Reconnaissance method (Wright et al. 2005). The abbreviated method includes both a desktop and field component. The desktop assessment consists of generating and reviewing maps of the watershed boundary, roads, land use and satellite imagery; and then identifying potential NPS pollution locations, such as road crossings, agricultural fields, and large areas of bare soil. When available, multiple sources of satellite imagery were reviewed. Occasionally, the high resolution of the imagery allowed for observations of livestock, row crops, eroding stream banks, sediment laden water, junkyards, and other potential NPS concerns that could affect stream quality. As many potential pollution sources as possible were visited, assessed, and documented in the field. Field visits were limited to NPS sites that were visible from roads or a short walk from a roadway. Neighborhoods were assessed for NPS pollution at the whole neighborhood level including streets and storm drains (where applicable). The assessment does not include a scoring component, but does include a detailed summary of findings and a map indicating documented NPS sites throughout the watershed.

Based on the May 2021 field and desktop assessment, several generalizations of the watershed land use for Craig Brook can be made. The stream riparian area is dominated by woods and wetlands with few fields immediately adjacent to the stream. Field observations confirmed extensive row crop agricultural activities, limited (usually less than seven animals), but still present, livestock and low density rural development (Table 2, Figure 3). All of these more intensive uses of the landscape contribute sediment and nutrients through runoff that eventually makes its way to Craig Brook.

Table 2: Potential Pollution Source ID Assessment (2021) for the Craig Brook Watershed

Potential Source			Notes
ID#	**Location**	**Type**	
1	Framingham Rd	Agriculture	Pasture of moderate spatial extent
2	Framingham Rd	Agriculture	Active cropping (grain) & tilled fields
3	US 1 & Shaw/Station Rds	Hotspot	Tractor-trailer wash
4	US 1 & Shaw/Station Rds	Hotspot	Trailer service & towing; numerous abandoned vehicles & trailers
5	Shaw Rd	Agriculture	Fenced pasture - horses; several abandoned vehicles
6	US 1 & Shaw/Station Rds	Hotspot	Fuel station
7	Station Rd	Agriculture	Potato storage
8	Station Rd	Hotspot	Collapsed house & extended structures; abandoned vehicles
9	Ross Ridge Rd	Agriculture	Several barns & manure piles present
10	Ross Ridge Rd	Agriculture	Vegetable crop storage facility (potato house)
12	Shank & Ross Ridge Rds	Agriculture	Several types of farm animals present; small pasture
14	US 1	Agriculture	Large livestock barns (4 total); covered & baled hay
15	US 1	Residential	Neighborhood (pre-1980) - home septic systems - minimal lawn care
16	US 1	Hotspot	Heavy equipment parking & storage; septic & slab installer; fuel tanks; abandoned vehicles
17	US 1	Residential	Neighborhood (pre-1980) - home septic systems - minimal lawn care
18	US 1	Hotspot	Fire department; vehicle washing
19	Ingraham Rd	Municipal	Sand storage piles - municipal origin
20	US 1	Agriculture	Barn with small pasture
21	Campbell Rd	Agriculture	Farm - seed potatoes, residue cover, other root crop or possibly cover crop, recent plowing
22	Carmichael Rd	Agriculture	Large pasture

Potential Source			Notes
ID#	**Location**	**Type**	
--	Throughout watershed	Agriculture	Row crop agriculture has the potential to deliver a significant load of sediment and nutrients. Soil often bare for 8 months of the year (crop canopy cover at best during June-September).
--	Throughout watershed	Municipal /Private	Numerous un-paved (gravel, sand, "dirt") roads where several cross Craig Brook and its tributary branches

NUTRIENT AND SEDIMENT LOADING – *MODEL MY WATERSHED* ANALYSIS

The *Model My Watershed* model was used to estimate stream loading of total phosphorus, total nitrogen, and sediment in Craig Brook watershed. The model estimated nutrient loads over a 12-year period (2009-2020), which was determined by local (Bangor International Airport USW00014606) weather data inserted into *Model My Watershed*. This extended period captures a recent but wide range of hydrologic conditions to account for variations in nutrient and sediment loading over time. Loads for the attainment watersheds (five total; Table 1) were computed using the same model with the same recent inputs (i.e., regional weather, 2016 land use and land cover, 2016 wetland extent, and BMPs similar to the impaired watersheds).

Many quality assured and regionally calibrated input parameters are provided with *Model My Watershed*. However, several updates to some of the default parameters were made in this TMDL effort, and namely more recent land use/cover using **MRLC-NLCD 2016** [1], more recent and local weather (precipitation and temperature) data (as described above), and more regional estimates of Best Management Practices (BMPs; see ensuing discussion). Because land use/cover is more recent, the estimated filtration fraction of wetland and open water and the amount of stream buffer in agricultural land should be more accurate. It is also worth noting that improved classification algorithms were employed by MLRC in the NCLD 2016 and these new algorithms were used in the revisions of all previous NLCD versions (including the first version in 2001).

[1] MRLC-NLCD 2016 : Multi-Resolution Land Characteristics – National Land Cover Dataset (version 2016) provided by the MRLC Consortium (Jin et al. 2019).

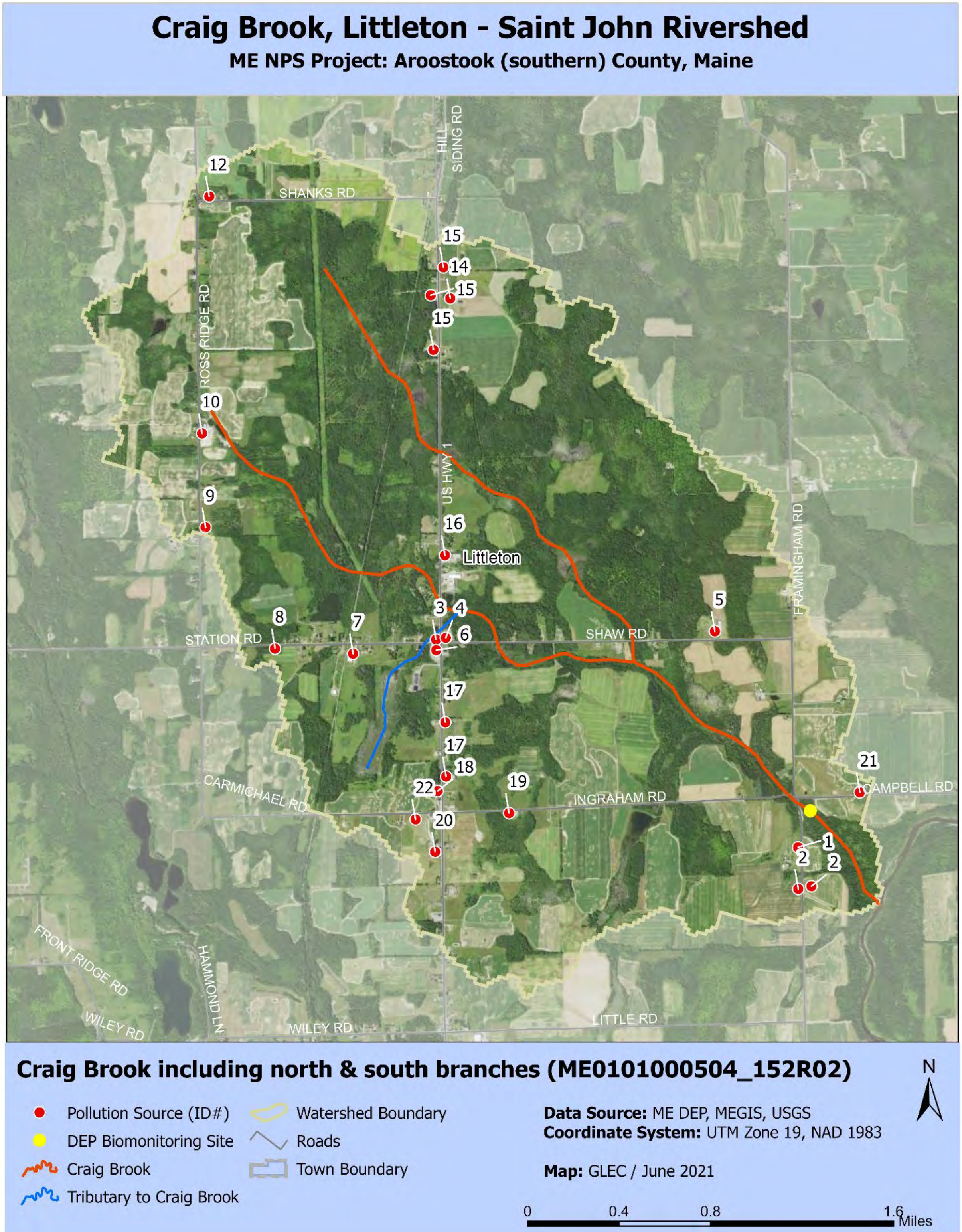

Figure 3: Aerial Photo of Potential Source Locations (identified in 2021) in the Craig Brook Watershed

Livestock Estimates

Livestock waste contains nutrients which can cause water quality impairment. The nutrient loading model considers numbers and types of animals. Table 3 (right) provides livestock (numbers of animals) in the watershed based on the USDA National Agricultural Statistics Service (NASS) estimation for 2012. Some of these totals were modified by direct observations made in the watershed in the 2021 survey. To generate watershed-based livestock counts, NASS county-based livestock totals are converted to a per unit area (based on the total area of the county). The unit area amount is then multiplied by the total watershed area to derive a watershed total count (as seen in Table 3).

Table 3: Livestock Count in the Craig Brook Watershed

Type	Craig Brook
Dairy Cows	0
Beef Cows	70
Broilers	20
Layers	3
Hogs/Swine	0
Sheep	0
Horses	18
Turkeys	0
Other	--
Total	**111**

The May 2021 field survey, for the most part, supports the livestock totals estimated through NASS as shown in Table 3. However, a local agricultural advisor (described in BMPs below) stated that 70 beef cattle exist from two operations in the watershed so Table 3 and the model inputs were updated. The same advisor also stated both operations have agricultural waste management systems, and that all livestock have access to pasture land in the watershed. All of this information was used in the current modeling effort.

Vegetated Stream Buffer in Agricultural Areas

Vegetated stream buffers are areas of trees, shrubs, and/or grasses adjacent to streams, lakes, ponds or wetlands which provide nutrient loading attenuation (Evans and Corradini, 2012). *Model My Watershed* considers natural vegetated stream buffers within agricultural land areas as providing nutrient load attenuation. A width of approximately 98 feet (30 m) on one side of a stream is required to be considered a streamside buffer per the *Model My Watershed* technical manual (Stroud Water Research Center 2017). Analysis of recent aerial photos was used to estimate the number of agricultural land stream miles with and without vegetative buffers, and these estimates were directly entered into the model.

Table 4: Summary of Vegetated Buffers in Agricultural Areas

Craig Brook
• Agricultural Land Stream Length = 1.19 mi (6,280 ft) • Agricultural Land Stream Length *with Buffer* = (0.344 mi) 1,818 ft (or 28.9% of total agricultural land stream length) • Percentage of total stream length flowing through non-buffered agricultural land = 11.7%

Craig Brook is a 7.2 mile-long impaired segment. The total stream miles (including tributaries) modeled within the watershed is also 7.2 miles (i.e., no other tributaries were considered). Of this total, 1.19 stream miles (6,280 ft) are located within agricultural areas and 0.34 miles (1,818 ft) of that area showed a 98 foot or greater vegetated buffer (Table 4, Figure 4). From a watershed perspective, this equates to 0.85 miles or 11.7% of the total stream length running through agricultural land with less than a 98 foot buffer. By contrast, for attainment stream watersheds, the percentage of total stream miles running through agricultural land without a 75 foot vegetated buffer ranged from 0% to 3.9% with an average of 1.3%. Note, a minimum vegetated buffer width of 75 feet was used in an earlier (2012) effort to produce Figure 4 shown below. Differences in stream length estimates using a 98-foot or 75-foot buffer were practically insignificant.

Home Septic System Loads

Loads for "normally functioning" septic systems are calculated in *Model My Watershed* using an estimate of the average number of persons per acre in "Low-Density Mixed" areas. In these areas, it is assumed that the populations therein are served by septic systems rather than centralized sewage systems. All homes in such areas are assumed to be connected to "normally functioning" systems rather than those that experience "surface breakouts" (surface failures), "short-circuiting" to underlying groundwater (subsurface failures), or have direct conduits to nearby water bodies. Non-functioning systems would be modeled with a higher load contribution to the waterbody.

Best Management Practices (BMPs)

Best management practices (BMPs) are typically instituted to reduce the loading of sediment and nutrients from upland (i.e., non-point) sources. Information on BMP use was based on an interview with a local agricultural advisor in May 2021 who provided estimates for cover crops, conservation tillage, and strip cropping. Information on BMP use for the attainment watersheds was based on interviews from two sources (both made in February 2021). Estimates for attainment watersheds were based on typical New England watersheds and derived from information available from Vermont. An upper limit of BMP use in attainment watersheds was garnered from watersheds entering the Chesapeake Bay where BMP use is intensive.

Four agricultural BMPs were used in this modeling effort and in the following manner:

- *Cover Crops:* Cover crops are the use annual or perennial crops to protect soil from erosion during time periods between harvesting and planting of the primary crop. The percent of cropland area in a cover crop BMP deployed was estimated, from the local interview source, at 80%. For the five attainment watersheds, an estimate of 25% was used and selected as the low end of the range (25 to 30 percent) expected for cropland in New England.
- *Conservation Tillage:* Conservation tillage is any kind of system that leaves at least 30% of the soil surface covered with crop residue after planting. This reduces soil erosion and runoff. This BMP was estimated, from the local interview source, to occur in 40% of cropland. A value of 25% was assigned to the five attainment watersheds as suggested by the other (non-local) two interview sources named above.
- *Strip Cropping / Contour Farming:* This BMP involves tilling, planting and harvesting perpendicular to the gradient of a hill or slope using high levels of plant residue to reduce soil erosion from runoff. The local interview source suggested this practice does not exist in Craig Brook watershed. Hence, no BMP of this type was used in this modeling effort. This estimate was also assigned to the five attainment watersheds as suggested by the other (non-local) two interview sources named above.
- *Grazing Land Management:* This BMP consists of ensuring adequate vegetation cover on grazed lands to prevent soil erosion from overgrazing or other forms of over-use. This usually employs a rotational grazing system where hays or legumes are planted for feed and livestock is rotated through several fenced pastures. The local agricultural advisor did not suggest this practice exists, though livestock do graze freely on pasture land in the Craig Brook watershed. The other (non-local) interview sources were not aware of this practice being active in New England watersheds. No BMP of this type was used in this modeling effort for both impaired and attaining watersheds.

Agricultural BMPs recommended by Maine DEP to reduce sediment and nutrient loads include vegetated buffers, covered manure storage facilities, and stream exclusion fencing. BMPs for developed areas recommended by the Maine DEP include vegetated buffers, stormwater BMPs, and minimization of impervious cover.

Pollutant Load Attenuation by Lakes, Ponds and Wetlands

Depositional environments such as lakes, ponds, and wetlands can attenuate watershed sediment and nutrient loading. This information is entered into the nutrient loading model by a simple percentage of watershed area draining to a lake, pond, or wetland. The Craig Brook watershed is 34.1% wetland and open water (less than 1% is open water). Multiple wetlands surround most of Craig Brook throughout the watershed, but most notably in the north and south branches (Figure 1). It is estimated that 68% of land area within the watershed drains to wetlands and open water. The percent of watershed draining to a wetland in the attainment watersheds, based on the 2021 analysis, ranged from 26 to 58 percent, with an average of 40%.

NUTRIENT AND SEDIMENT MODELING RESULTS

Selected results from the watershed loading model are presented here. The TMDL itself is expressed in units of kilograms per hectare per year. The additional results shown below assist in better understanding the likely sources of pollution. The model results for Craig Brook indicate a significant reduction of phosphorus and a moderate reduction in sediment are needed to improve water quality. Below, loading for nitrogen, phosphorus and sediment are discussed individually.

There are two categories of loads – sources and pathways. Sources are determined by land use/cover and the overland flow they generate, livestock counts by animal type, and home sewage treatment systems in developed areas. Pathways represent additional loads derived from subsurface flow and streambank erosion. Subsurface loads are calculated using dissolved N and P coefficients for shallow groundwater and are mainly derived from atmospheric inputs. Sediment and nutrient loads produced by eroding streambanks are estimated using an approach developed by Evans et al. (2003). This pathway is comprised of loads originating from five sources, and listed in order of decreasing importance: amount of developed land area, soil erodibility (K-factor), density of livestock, runoff curve number, and topographic slope. For any given model run, the amount of developed land in the watershed is responsible for just over 72% of the total streambank load, whereas soil erodibility and animal density are responsible for 21% and 7% of the total streambank load, respectively.

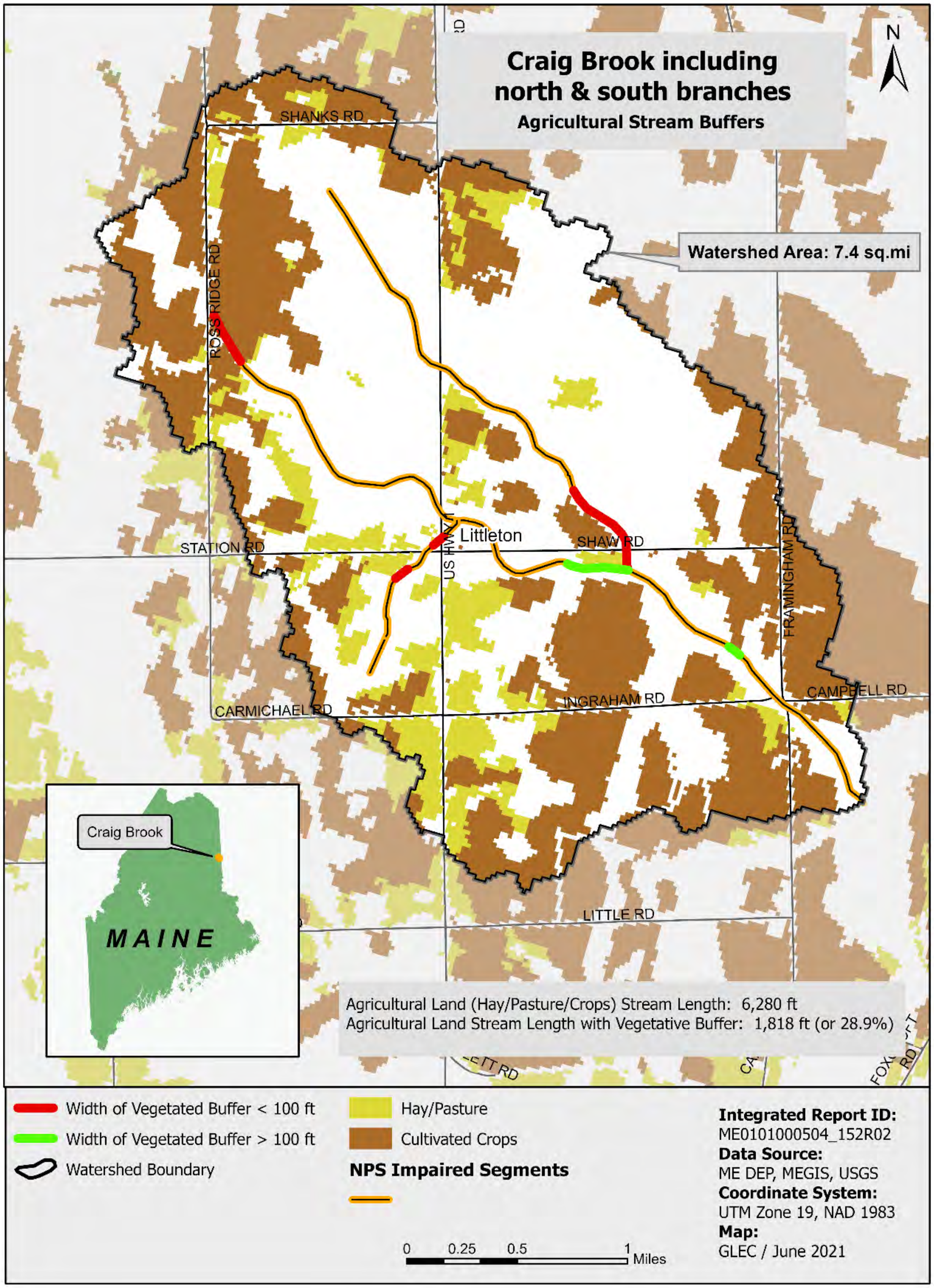

Figure 4: Agricultural Stream Buffers (from 2021) in the Craig Brook Watershed

Sediment

Sediment loading in the Craig Brook watershed is predominantly derived from agricultural land which makes up almost 98% of the total sediment load from sources (Table 5 and Figure 5). Developed land contributes less than 2% of the total source load. Of the entire watershed sediment load, stream bank erosion contributes 17%.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Craig Brook* below for loading estimates that have been normalized by watershed area.

Table 5: Total Sediment Load by Source

Craig Brook	**Sediment** (1000 kg/year)	**Sediment** (%)
Source Load		
Hay/Pasture	4.1	2.7%
Cropland	145.4	95.0%
Wooded Areas	0.1	0.1%
Wetlands	0.2	0.2%
Open Land	0.1	0.1%
Barren Areas	0	0
Low-Density Mixed	0.9	0.6%
Medium-Density Mixed	0.9	0.6%
High-Density Mixed	0.2	0.1%
Low-Density Open Space	1.0	0.6%
Farm Animals	0	0
Septic Systems	0	0
Source Load Total:	**153.1**	**100%**
Pathway Load		
Stream Bank Erosion	31.4	-
Subsurface Flow	0	-
Total Watershed Mass Load:	**185**	

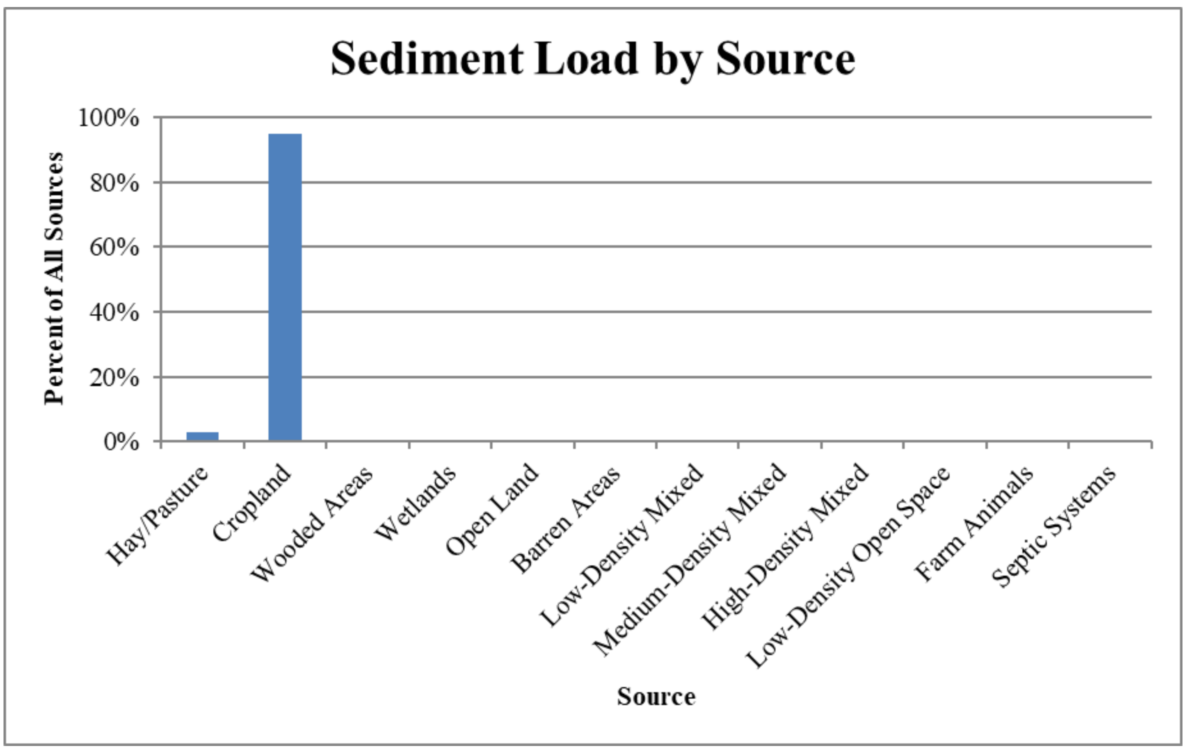

Figure 5: Total Sediment Load by Source in the Craig Brook Watershed

Total Nitrogen

Nitrogen loading is attributed primarily to cropland (59.3%) and farm animals (11.3%) (Table 6 and Figure 6). Combined agricultural sources account for over 77% of the total nitrogen load to Craig Brook. Note that from natural sources, wetlands contribute 14% of the total source load because of their extensive area in Craig Brook watershed.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Craig Brook* below for loading estimates that have been normalized by watershed area.

Table 6: Total Nitrogen Load by Source

Craig Brook	Total N (kg/year)	Total N (%)
Source Load		
Hay/Pasture	201	6.7%
Cropland	1,791	59.3%
Wooded Areas	65	2.1%
Wetlands	422	14.0%
Open Land	18	0.6%
Barren Areas	0	0
Low-Density Mixed	51	1.7%
Medium-Density Mixed	40	1.3%
High-Density Mixed	9	0.3%
Low-Density Open Space	53	1.8%
Farm Animals	340	11.3%
Septic Systems	30	1.0%
Source Load Total:	**3,019**	**100%**
Pathway Load		
Stream Bank Erosion	9	-
Subsurface Flow	1,555	-
Total Watershed Mass Load:	**4,583**	

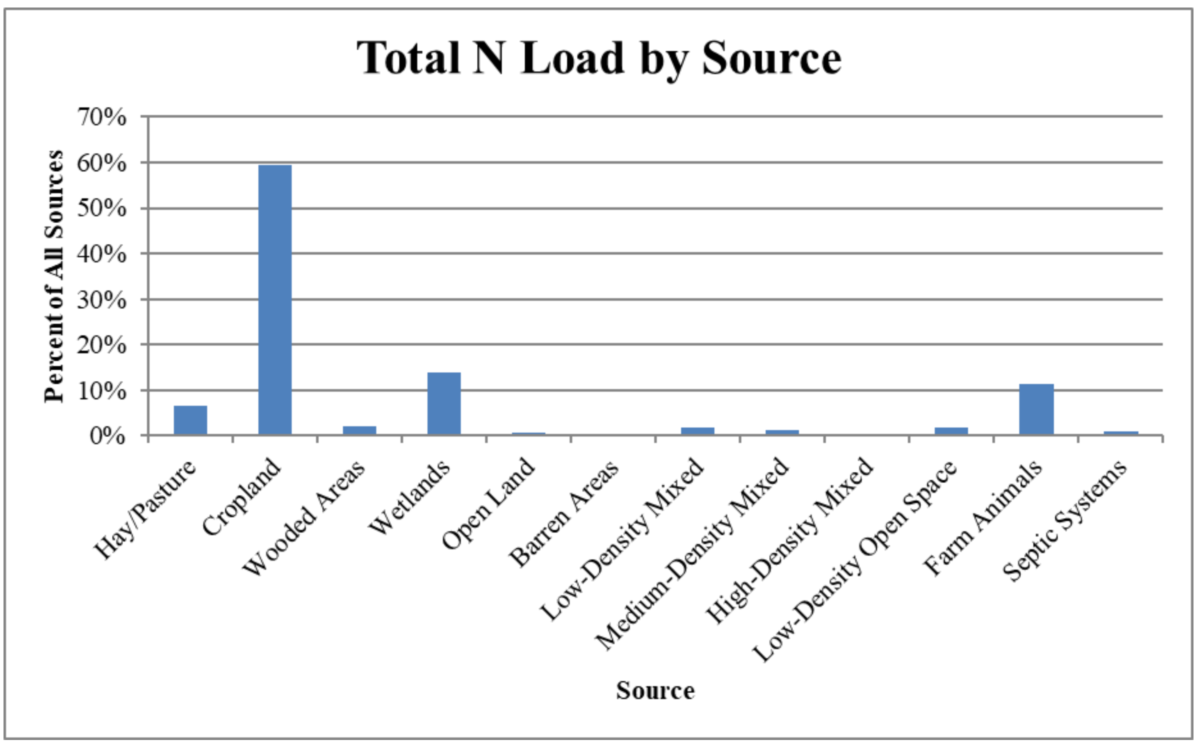

Figure 6: Total Nitrogen Load by Source in the Craig Brook Watershed

Total Phosphorus

Phosphorus loading within the watershed is attributed primarily to cropland (72.9%), hay/pasture land, and farm animals with combined agricultural sources accounting for 95% of the total phosphorus load. Developed land only accounts for just under 2% of the source load. Wetlands and wooded areas account for 3% of the total source load. Phosphorus loads are presented in Table 7 and Figure 7.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Craig Brook* below for loading estimates that have been normalized by watershed area.

Table 7: Total Phosphorus Load by Source

Craig Brook	Total P (kg/year)	Total P (%)
Source Load		
Hay/Pasture	110.5	14.6%
Cropland	550.0	72.9%
Wooded Areas	3.3	0.4%
Wetlands	20.0	2.6%
Open Land	0.6	0.1%
Barren Areas	0	0
Low-Density Mixed	4.8	0.6%
Medium-Density Mixed	3.6	0.5%
High-Density Mixed	0.8	0.1%
Low-Density Open Space	5.0	0.7%
Farm Animals	56.3	7.5%
Septic Systems	0	0
Source Load Total:	**754.9**	**100%**
Pathway Load		
Stream Bank Erosion	21.0	-
Subsurface Flow	55.9	-
Total Watershed Mass Load:	**832**	

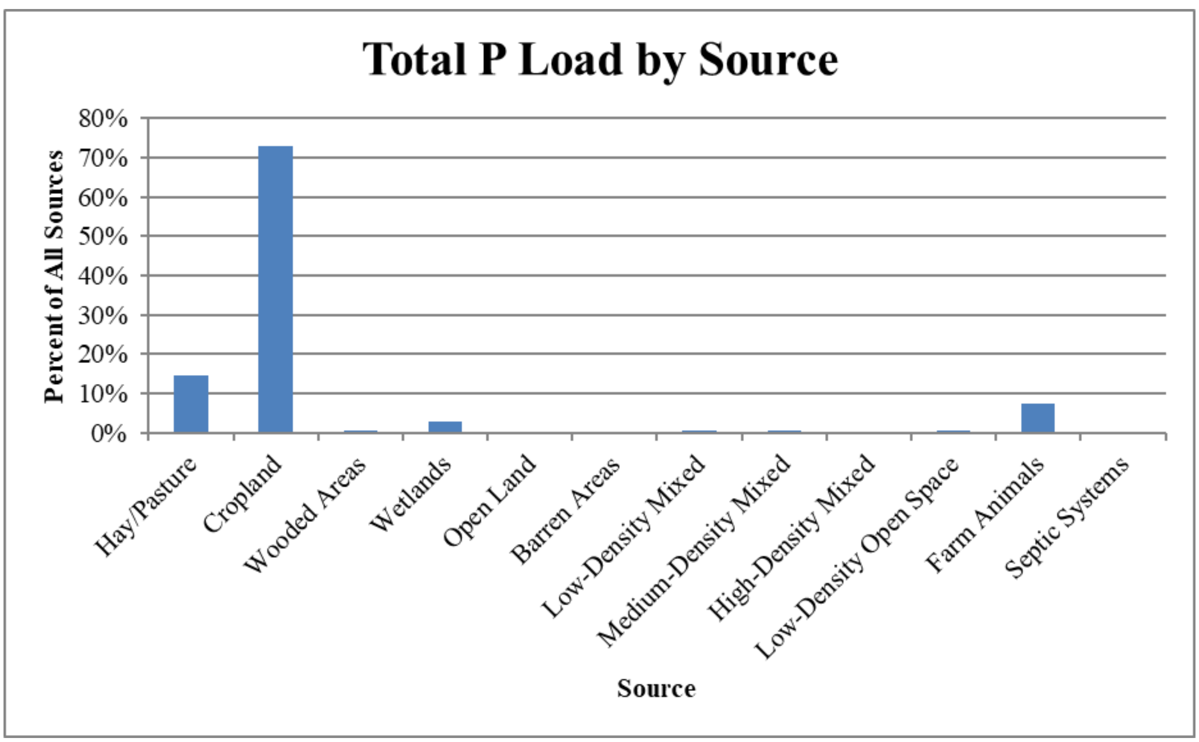

Figure 7: Total Phosphorus Load by Source in the Craig Brook Watershed

TMDL: TARGET NUTRIENT AND SEDIMENT LEVELS FOR CRAIG BROOK

The existing loads for nutrients and sediments in the impaired segment of Craig Brook are listed in Table 8, along with the TMDL (the allowable load) which was calculated from the average loading estimates of five attainment watersheds throughout the state. Table 8 also shows required reductions (as a percent) for each of sediment, total N, and total P pollutants. Table 9 presents a more detailed view of the modeling results and calculations used to compute the existing loads in Table 8. An annual time frame provides a mechanism to address the daily and seasonal variability associated with nonpoint source loads.

Table 8: Craig Brook Pollutant Loading Compared to TMDL Targets

Craig Brook			
Pollutant Load	**Existing Load**	**TMDL**	**Reduction Required**
Total Annual Load per Unit Area		Attainment Streams	
Sediment (kg/ha/yr)	96.2	65.72	31.7%
Total N (kg/ha/yr)	2.39	2.46	None
Total P (kg/ha/yr)	0.43	0.16	63.2%

Future Loading

The prescribed reduction in pollutants discussed in this TMDL reflects reduction from estimated existing conditions. With farmable land area at a premium and under high demand it is very likely that any tillable acreage in Craig Brook watershed is already in production. Between 2012 to 2017 in Aroostook County, the number of farms decreased by 14.4% and the number of acres decreased by 9.6% (USDA 2017). However, the average farm size increased by 5.6% in this time period. The County has seen a consolidation of farmland under fewer landowners with farms becoming larger. Human population in Aroostook County decreased by 6.48% from 2000 to 2019 (US Census 2020). To meet TMDL targets, current and future farm management practices will need to employ a combination of conservation practices.

Next Steps

The use of agricultural and developed land best management practices (BMP's) can reduce sources of polluted runoff in Craig Brook. It is recommended that municipal officials in Littleton and southern Aroostook county, landowners, and conservation stakeholders work together to:

- Implement the Meduxnekeag 2015 Watershed Management Plan.
- Run a "Hot-Spot Analysis" in *Model My Watershed* to determine sub-watershed locations of higher existing contributions of sediment and nutrients to the outlet of Craig Brook watershed; then focus BMP mitigation in these hot-spot sub-areas of the watershed.
- Southern Aroostook Soil & Water Conservation District and USDA's Natural Resource Conservation Service work with agricultural landowners to implement BMPs through EQIP and CWA 319 grants program.
- Address existing nonpoint source problems in the Craig Brook watershed by implementing (e.g. increased crop rotations) or installing (e.g. grassed waterways) BMPs where necessary.

Table 9: Annual Loads by Land Use, Other Sources, and Pathways for Craig Brook Based on Modeling

Craig Brook				
	Area (ha)	**Sediment** (1000 kg/yr)	**Total N** (kg/yr)	**Total P** (kg/yr)
Land Uses				
Hay/Pasture	189	4.1	201	110.5
Cropland	657	145.4	1,791	550.0
Wooded Areas	310	0.1	65	3.3
Wetlands	649	0.2	422	20.0
Open Land	13	0.1	18	0.6
Barren Areas	6	0.000	0	0.0
Low-Density Mixed	40	0.9	51	4.8
Medium-Density Mixed	9	0.9	40	3.6
High-Density Mixed	2	0.2	9	0.8
Low-Density Open Space	42	1.0	53	5.0
Total Area	1,918			
Other Sources				
Farm Animals		0.0	340	56.3
Septic Systems		0.0	30	0.0
Pathway Load				
Stream Bank Erosion		31.4	9	21.0
Subsurface Flow		0.0	1,555	55.9
Total Annual Load		185	4,583	832
Total Annual Load per Unit Area		0.096	2.39	0.43
		1000 kg/ha/yr	kg/ha/yr	kg/ha/yr

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DRAFT TMDL SUMMARY

French Stream

WATERSHED DESCRIPTION

This **TMDL** applies to a 12.75 mile section of French Stream located in the Town of Exeter, Maine. French Stream begins near Chamberlain Meetinghouse Road. The stream flows east through a predominately forested area then crossing Stetson Road into a heavy agricultural area. The stream continues across Avenue Road and Mill Road before converging with Allen Stream at the intersection of Route 43 and Crane Road. It joins Kenduskeag Stream about 1 mi downstream. French Stream watershed covers an area of 38 square miles. The majority of the watershed is located within the Town of Exeter; small portions of the watershed lie within the surrounding towns of Garland, Corinth, Corinna and Dexter.

- French Stream is on Maine's 303(d) list of Impaired Streams as referenced in the 2016 Integrated Report (Maine DEP, 2018).
- The French Stream watershed is predominately non-developed (77.4%). Forested areas (60.6%) within the watershed absorb and filter pollutants helping protect both water quality in the stream and stream channel stability. Wetlands (16.8%) also help filter nutrients.
- Non-forested areas within the watershed are predominantly agricultural (17.7%, 10% is cropland) and concentrated in the center of the watershed along Stetson Road, Fogler Road, and Between the Mills Road.
- Developed areas (1.7%) with impervious surfaces in close proximity to the stream may impact water quality.
- Runoff from agricultural land located in the areas of Stetson Road, Fogler Road, and Between the Mills Road, are likely the largest sources of nonpoint source (NPS) pollution to French Stream. Runoff from cultivated lands, active hay lands, and grazing areas can transport sediment, nitrogen and phosphorus to the stream.

Definitions

- ***Total Maximum Daily Load (TMDL)*** *represents the total amount of a pollutant that a waterbody can receive and still meet water quality standards.*
- **Nonpoint Source Pollution** *refers to pollution that comes from many diffuse sources across the landscape, and are typically transported by rain or snowmelt runoff.*

Waterbody Facts

Segment ID: ME0102000510_224R03

Town: Exeter, ME

County: Penobscot

Impaired Segment Length: 12.75 miles

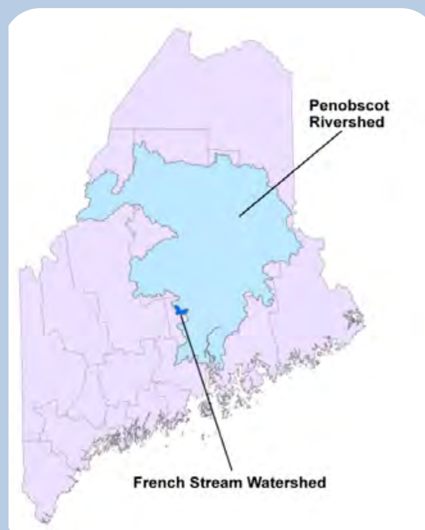
Classification: Class B

Direct Watershed: 38 mi^2 (24,320 acres)

Impairment Listing Cause: Benthic macroinvertebrate and periphyton

Watershed Agricultural Land Use: 17.7%

Major Drainage Basin: Penobscot River



Watershed Land Uses

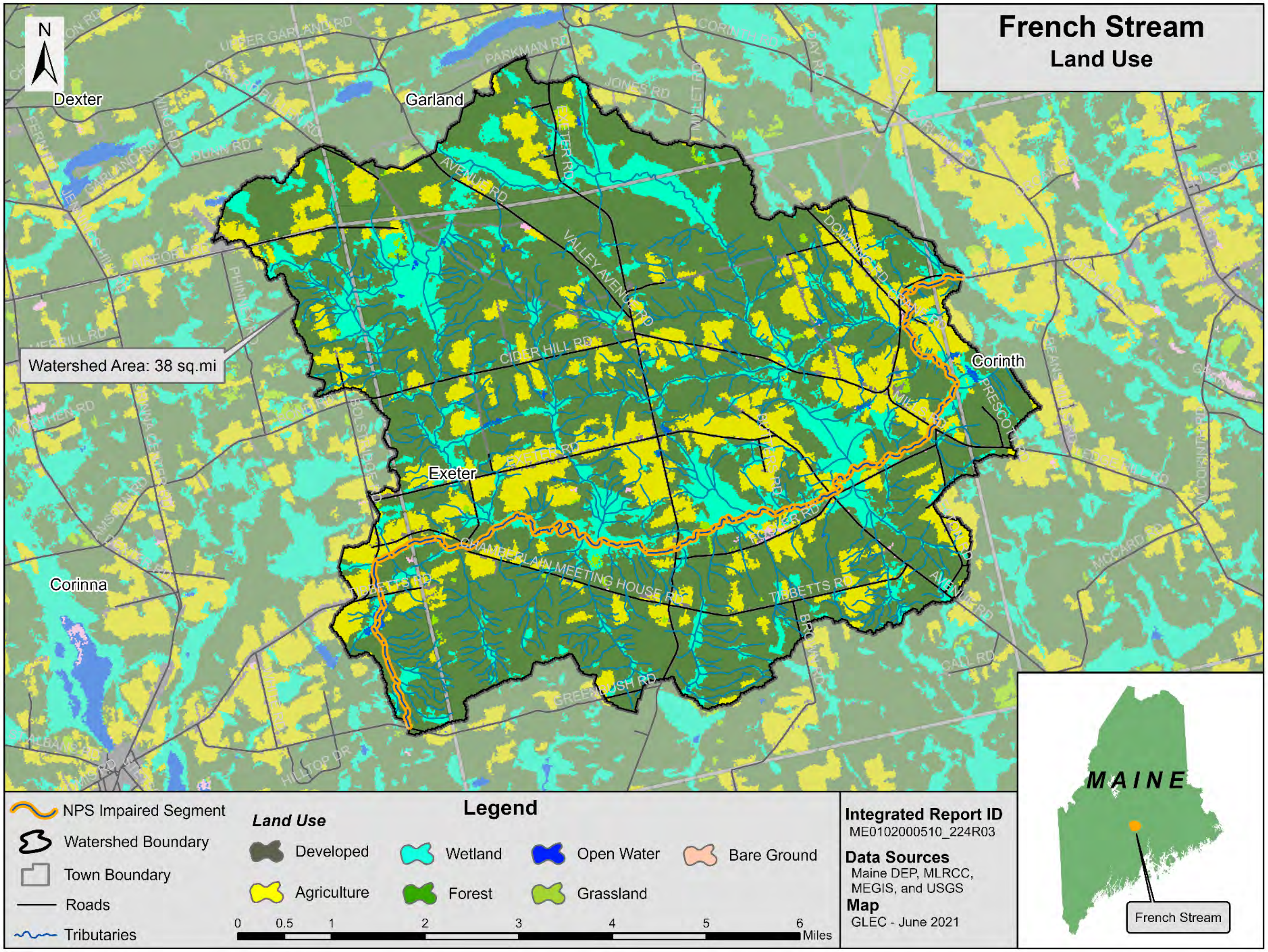


Figure 1: Land Use and Land Cover (from 2016) in the French Stream Watershed

WHY IS A TMDL ASSESSMENT NEEDED?

French Stream, a Class B freshwater stream, has been assessed by Maine DEP as not meeting water quality standards for the designated use of aquatic life, and placed on the 303(d) list of impaired waters under the Clean Water Act. The Clean Water Act requires that all 303(d)-listed waters undergo a Total Maximum Daily Load (TMDL) assessment that describes the impairments and establishes a target to guide the measures needed to restore water quality. The goal is for all waterbodies to comply with state water quality standards.

French Stream *near Mill Road crossing. Photo: FB Environmental*

Agriculture (cropland, hay and pasture land) in the French Stream watershed makes up about 17.7% of the land area. This is approximately five times the developed land area in the French Stream watershed. Agriculture is therefore likely to be the largest contributor of sediment and nutrient enrichment to the stream. The close proximity of many agricultural lands to the stream further increases the likelihood that nutrients from disturbed soils, manure, and fertilizers will reach the stream.

WATER QUALITY DATA ANALYSIS

Maine DEP uses a variety of data types to measure the ability of a stream to adequately support aquatic life, including; dissolved oxygen, benthic macroinvertebrates, and periphyton (algae). For benthic macroinvertebrates, DEP makes aquatic life use determinations using a statistical model that incorporates 30 variables of data collected from rivers and streams, including the richness and abundance of streambed organisms, to determine the probability of a sample meeting Class A, B, or C conditions. Biologists use the model results and supporting information to determine if samples comply with the numeric aquatic life criteria of the class assigned to the stream or river (Davies and Tsomides, 2002). Maine DEP uses an analogous model to aid in the assessment of algal communities but makes aquatic life use determinations based on narrative standards.

The aquatic life impairment in French Stream and its tributaries is based on macroinvertebrate and periphyton (algae) data collected from 2001 to 2016. All segments in the watershed have a Class B designation. At station S-505 on French Stream in 2016, periphyton did not meet (attained Class C) whereas macroinvertebrates did meet its Class B designation. At station S-308 on Allen Stream in 2011 and 2016, macroinvertebrates did meet its Class B designation. Allen Stream is the main tributary to French Stream and occupies the northern half of the watershed area. Station S-310 on French Stream was last sampled in 2001 and did meets its Class B designation. In addition to these stream stations, the wetland station W-142 in 2006 showed attainment of class A standards.

TMDL ASSESSMENT APPROACH: NUTRIENT AND SEDIMENT MODELING OF IMPAIRED AND ATTAINMENT STREAMS

NPS pollution is difficult to measure directly because it comes from many diffuse sources spread across the landscape. For this reason, an online nutrient loading model, *Model My Watershed* (v. 1.32.0), was used to estimate the sources of pollution based on well-established hydrological equations (Stroud Water Research Center 2017). *Model My Watershed* makes use of the GWLF-enhanced model engine. The model incorporates detailed maps of soil, land use, and slope, daily weather and localized weather data (from the period 2009-2020), and direct observations of agriculture and other land uses within the watershed. *Model My Watershed* is derived from its parent MapShed developed by Evans and Corradini (2012). *Model My Watershed* replaced MapShed in 2017-2018.

The nutrient loading estimates for the impaired stream were compared to similar estimates for five non-impaired (attainment) streams of similar watershed land uses across the state. The TMDL for the impaired stream was set as the mean nutrient loading estimate of these attainment stream watersheds, and units of mass per unit watershed area per year (kg/ha/year) were used. The difference in loading estimates between the impaired and attainment watersheds represents the percent reduction in nutrient loading required under this TMDL. The attainment streams and their nutrient and sediment loading estimates and TMDL are presented below in Table 1.

Table 1: Numeric Targets for Pollutant Loading Based on Model My Watershed Outputs (2021) for Attainment Streams

Attainment Streams	Town	Total P Load (kg/ha/yr)	Total N Load (kg/ha/yr)	Sediment Load (kg/ha/yr)
Footman Brook	Exeter	0.17	1.73	35.2
Martin Stream	Fairfield	0.13	2.98	57.9
Moose Brook	Houlton	0.18	1.59	48.5
Upper Kenduskeag Stream	Corinth	0.16	1.72	100.5
Upper Pleasant River	Gray	0.16	4.26	86.5
Total Maximum Daily Load		**0.16**	**2.46**	**65.7**

RAPID WATERSHED ASSESSMENT

Habitat Assessment

A habitat assessment survey was conducted (in 2012) on both the impaired and attainment stream. The assessment approach is based on the *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (Barbour et al. 1999), which integrates various parameters relating to the structure of physical habitat. The habitat assessments include a general description of the site and physical characterization and visual assessment of in-stream and riparian habitat quality.

Based on rapid bioassessment protocols for low gradient streams, French Stream received a score of 167 out of a total 200 for quality of habitat. Higher scores indicate better habitat. The range of habitat scores for attainment streams was 155 to 179.

The habitat assessment was conducted on a relatively short sample reach (about 100-200 meters for a typical small stream), and was located near the most downstream Maine DEP sample station. For both impaired and attainment streams, the assessment location was usually near a road crossing for ease of access. In the French Stream watershed, the downstream sample station was located in a forested portion of the stream with a thick buffer, while the majority of the stream and associated tributaries flow in close proximity to agricultural lands.

Figure 2: Habitat Assessment Score for French Stream (2012) Compared to Region

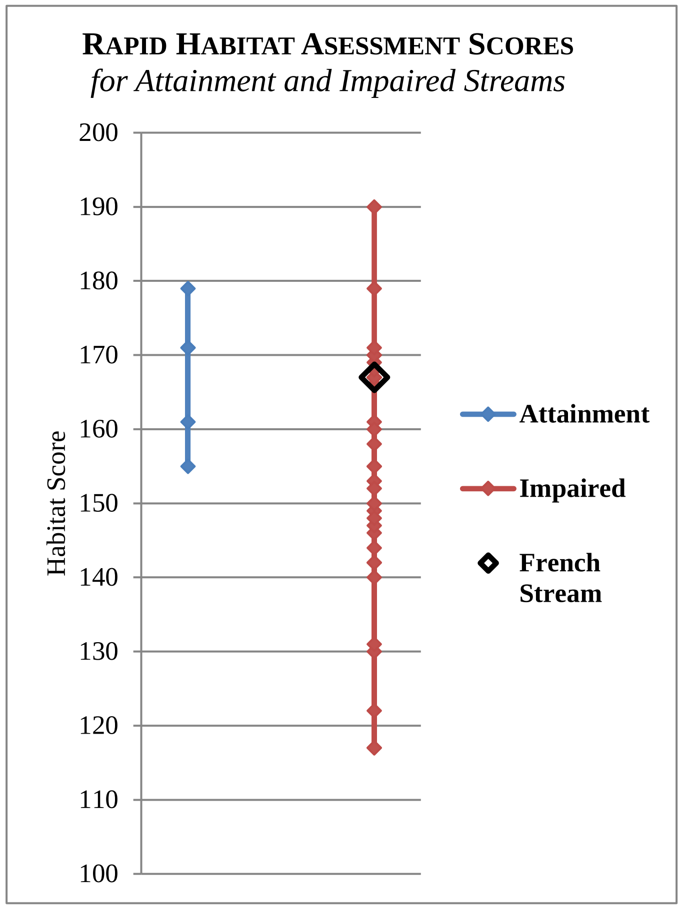


Figure 2 (right) shows the range of habitat assessment scores for all attainment and impaired streams, as well as for French Stream. Stream habitat for this portion of French Stream is in the upper range of performing well, but it is also important to look for other potential sources within the watershed leading to impairment. Consideration should be given to major “hot spots” in the French Stream watershed as potential sources of NPS pollution contributing to the water quality impairment.

Pollution Source Identification

Pollution source identification assessments were conducted in 2012 for both French Stream (impaired) and the attainment streams. The source identification work is based on an abbreviated version of the Center for Watershed Protection’s Unified Subwatershed and Site Reconnaissance method (Wright et al. 2005). The abbreviated method includes both a desktop and field component. The desktop assessment consists of generating and reviewing maps of the watershed boundary, roads, land use and satellite imagery; and then identifying potential NPS pollution locations, such as road crossings, agricultural fields, and large areas of bare soil. When available, multiple sources of satellite imagery were reviewed. Occasionally, the high resolution of the imagery allowed for observations of livestock, row crops, eroding stream banks, sediment laden water, junkyards, and other potential NPS concerns that could affect stream quality. As many potential pollution sources as possible were visited, assessed, and documented in the field. Field visits were limited to NPS sites that were visible from roads or a short walk from a roadway. Neighborhoods were assessed for NPS pollution at the whole neighborhood level including streets and storm drains (where applicable). The assessment does not include a scoring component, but does include a detailed summary of findings and a map indicating documented NPS sites throughout the watershed.

The watershed source assessment for French Stream was completed in July 2012. In-field observations of erosion, lack of vegetated stream buffer, extensive impervious surfaces, high-density neighborhoods and agricultural activities were documented throughout the watershed (Table 2, Figure 3).

Table 2: Potential Pollution Source ID Assessment (2012) for the French Stream Watershed

Potential Source			**Notes**
ID#	**Location**	**Type**	
1	Crane Road	Ag	• Large active cropland in close proximity to stream; corn and hay. • Stream flows adjacent to fields to the west and north of farm property located just south of Crane Road/Rte. 43 intersection. • Adequate forested buffer along most of stream length.
2	Exeter Road	Ag	• Very large agricultural fields located north and south of Exeter Road. • Large scale irrigation systems were observed in use during assessment. • Corn and potato fields observed.
3	Mill Road	Ag, Road crossing	• No erosion was observed at road crossing. • Adequate buffer exists between stream and surrounding agricultural fields. • Farm pond located on adjacent property displaying signs of eutrophication.
8	Avenue Road & Fogler Road	Ag, Road crossing	• Farm observed adjacent to stream with 5 horses and a stable observed in close proximity. • Corn and hay fields surrounding.
9	Fogler Road	Ag	• Large dairy farm located on the north side of Fogler Road. • Grazing areas, cropland, and hay land surrounding on both sides of road. • Large manure piles observed; very strong manure odor in this area.
11	Stetson Road	Ag	• Large corn and potato fields. • Irrigation systems in use during visit. • Tributaries run through fields and associated hay lands.
13	Stetson Road	Ag, Road crossing	• No major erosion observed at road crossing. • Agricultural fields surround crossing area to the north and south of French Stream. • Large fields of potatoes and corn to the north. • Industrialized irrigation systems were observed in use.
15	Chamberlain Meetinghouse Road	Ag	• 10 cows observed; more may be present.
17	Exeter Road	Ag	• Large corn and potato fields north and south of Exeter Road. • Tributaries run through fields and associated hay lands.
19	Exeter Road & Avenue Road	Ag	• Large agricultural fields surrounding Exeter Road, Avenue Road and Valley Avenue Road. • Tributaries run through fields.

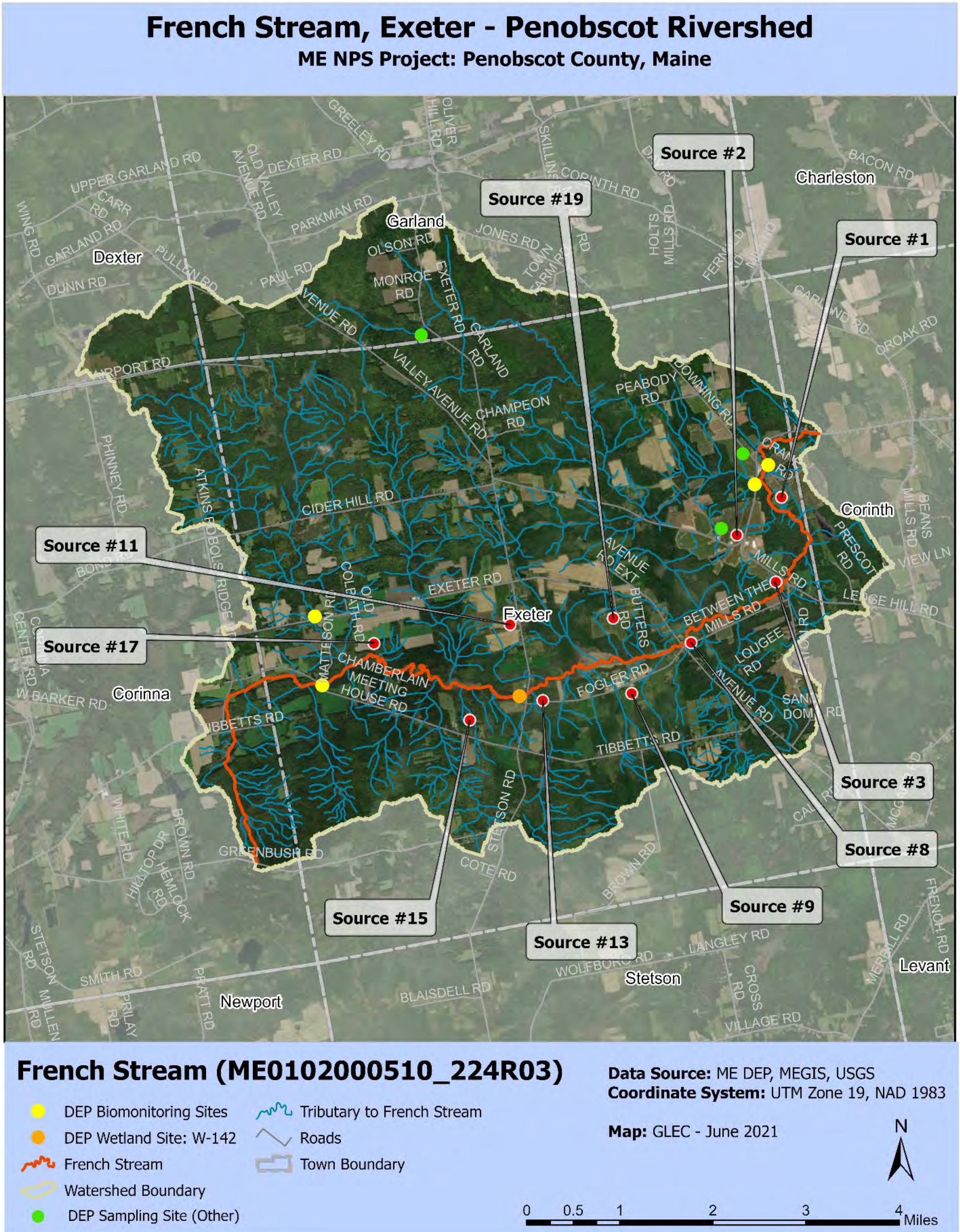


Figure 3: Aerial Photo of Potential Source Locations (identified in 2012) in the French Stream Watershed

NUTRIENT AND SEDIMENT LOADING – *MODEL MY WATERSHED* ANALYSIS

The *Model My Watershed* model was used to estimate stream loading of total phosphorus, total nitrogen, and sediment in French Stream watershed. The model estimated nutrient loads over a 12-year period (2009-2020), which was determined by local (Bangor International Airport USW00014606) weather data inserted into *Model My Watershed*. This extended period captures a recent but wide range of hydrologic conditions to account for variations in nutrient and sediment loading over time. Loads for the attainment watersheds (five total; Table 1) were computed using the same model with the same recent inputs (i.e., regional weather, 2016 land use and land cover, 2016 wetland extent, and BMPs similar to the impaired watersheds).

Many quality assured and regionally calibrated input parameters are provided with *Model My Watershed*. However, several updates to some of the default parameters were made in this TMDL effort, and namely more recent land use/cover using **MRLC-NLCD 2016** [1], more recent and local weather (precipitation and temperature) data (as described above), and more regional estimates of Best Management Practices (BMPs; see ensuing discussion). Because land use/cover is more recent, the estimated filtration fraction of wetland and open water and the amount of stream buffer in agricultural land should be more accurate. It is also worth noting that improved classification algorithms were employed by MLRC in the NCLD 2016 and these new algorithms were used in the revisions of all previous NLCD versions (including the first version in 2001).

Livestock Estimates

Livestock waste contains nutrients which can cause water quality impairment. The nutrient loading model considers numbers and types of animals. Table 3 (right) provides livestock (numbers of animals) in the watershed based on the USDA National Agricultural Statistics Service (NASS) estimation for 2012. Some of these totals were modified by direct observations made in the watershed in the 2012 survey. To generate watershed-based livestock counts, NASS county-based livestock totals are converted to a per unit area (based on the total area of the county). The unit area amount is then multiplied by the total watershed area to derive a watershed total count (as seen in Table 3).

Table 3: Livestock Count in the French Stream Watershed

Type	French Stream
Dairy Cows	2,000
Beef Cows	6
Broilers	230
Layers	--
Hogs/Swine	7
Sheep	26
Horses	11
Turkeys	1
Other	--
Total	**2,281**

Based on the 2012 field survey, French Stream watershed is predominantly forested, but also contains substantial mixed agriculture. Large areas of potato and corn fields were documented throughout the watershed, as well as a large dairy farm on Fogler Road. This dairy farm has approximately 2,000 cows, according to the website of its subsidiary (accessed July 2021). The dairy farm's subsidiary has an anaerobic digestion system used for turning manure and other organic matter into energy, recycled animal bedding, and liquid fertilizer. In addition to this farm, another ten cows were observed on Chamberlain Meetinghouse Road in Exeter, and five horses were noted at a farm at the corner of Avenue Road and Fogler Road.

[1] MRLC-NLCD 2016 : Multi-Resolution Land Characteristics – National Land Cover Dataset (version 2016) provided by the MRLC Consortium (Jin et al. 2019).

Vegetated Stream Buffer in Agricultural Areas

Table 4: Summary of Vegetated Buffers in Agricultural Areas

French Stream
• Agricultural Land Stream Length = 2,006 ft • Agricultural Land Stream Length with Buffer = 201 ft (or 10% of total agricultural land stream length) • Percentage of total stream length flowing through non-buffered agricultural land = 0.6%

Vegetated stream buffers are areas of trees, shrubs, and/or grasses adjacent to streams, lakes, ponds or wetlands which provide nutrient loading attenuation (Evans and Corradini, 2012). *Model My Watershed* considers natural vegetated stream buffers within agricultural land areas as providing nutrient load attenuation. A width of approximately 98 feet (30 m) on one side of a stream is required to be considered a streamside buffer per the *Model My Watershed* technical manual (Stroud Water Research Center 2017). Analysis of recent aerial photos was used to estimate the number of agricultural land stream miles with and without vegetative buffers, and these estimates were directly entered into the model.

French stream is a 12.75 mile-long impaired segment. The total stream miles (including tributaries) modeled within the watershed is 33.5 miles. Of this total, 0.38 stream miles (2,006 ft) were located within agricultural areas (hay/pasture and cropland), and 201 ft (10%) of those stream miles showed a 98 foot or greater vegetated buffer (Table 4 and Figure 4). From a watershed perspective, this equates to 1,805 ft or 0.6% of the total stream length running through agricultural land with less than a 98 foot buffer. By contrast, for attainment stream watersheds, the percentage of total stream miles running through agricultural land without a 75 foot vegetated buffer ranged from 0% to 3.9% with an average of 1.3%. Differences in stream length estimates using a 98-foot or 75-foot buffer were practically insignificant.

Home Septic System Loads

Loads for "normally functioning" septic systems are calculated in *Model My Watershed* using an estimate of the average number of persons per acre in "Low-Density Mixed" areas. In these areas, it is assumed that the populations therein are served by septic systems rather than centralized sewage systems. All homes in such areas are assumed to be connected to "normally functioning" systems rather than those that experience "surface breakouts" (surface failures), "short-circuiting" to underlying groundwater (subsurface failures), or have direct conduits to nearby water bodies. Non-functioning systems would be modeled with a higher load contribution to the waterbody.

Best Management Practices (BMPs)

Best management practices (BMPs) are typically instituted to reduce the loading of sediment and nutrients from upland (i.e., non-point) sources. Ideally, information on BMPs for a specific watershed from local and regional sources would improve this component of the water quality model. Maine DEP sought information on BMP use in early 2021 from local, regional, and state agricultural agencies for rural BMPs and from nearby municipalities for urban BMPs. Very little to no information was returned in the solicitation. Hence, estimates for typical New England watersheds were derived from information available from Vermont. An upper limit of BMP use was garnered from watersheds entering the Chesapeake Bay where BMP use is intensive.

Four agricultural BMPs were used in this modeling effort and in the following manner:

- *Cover Crops:* Cover crops are the use annual or perennial crops to protect soil from erosion during time periods between harvesting and planting of the primary crop. The percent of cropland area in a cover crop BMP deployed was estimated at 25% and selected as the low end of the range (25 to 30 percent) expected for cropland in New England. These same values were assigned to the five attainment watersheds.
- *Conservation Tillage:* Conservation tillage is any kind of system that leaves at least 30% of the soil surface covered with crop residue after planting. This reduces soil erosion and runoff. This BMP was estimated to occur in 25% of cropland. These same values were assigned to the five attainment watersheds.
- *Strip Cropping / Contour Farming:* This BMP involves tilling, planting and harvesting perpendicular to the gradient of a hill or slope using high levels of plant residue to reduce soil erosion from runoff. Both interview sources suggest this practice is minimal to non-existent for New England watersheds. Hence, no BMP of this type was used in this modeling effort. These same values were assigned to the five attainment watersheds.
- *Grazing Land Management:* This BMP consists of ensuring adequate vegetation cover on grazed lands to prevent soil erosion from overgrazing or other forms of over-use. This usually employs a rotational grazing system where hays or legumes are planted for feed and livestock is rotated through several fenced pastures. Both interview sources were not aware of this practice being active and is likely minimal for New England watersheds. Hence, no BMP of this type was used in this modeling effort for both impaired and attaining watersheds.

Note that other agricultural and development BMPs likely exist in the watershed but their location and type were not available in a watershed-wide format that is necessary to include in the model. Agricultural BMPs recommended by Maine DEP to reduce sediment and nutrient loads include vegetated buffers, covered manure storage facilities, and stream exclusion fencing. BMPs for developed areas recommended by the Maine DEP include vegetated buffers, stormwater BMPs, and minimization of impervious cover.

Pollutant Load Attenuation by Lakes, Ponds and Wetlands

Depositional environments such as lakes, ponds, and wetlands can attenuate watershed sediment and nutrient loading. This information is entered into the nutrient loading model by a simple percentage of watershed area draining to a lake, pond, or wetland. The French Stream watershed is 16.9% wetland and open water. Multiple wetlands and open water surround tributaries throughout the watershed. It is estimated that 55% of land area within the watershed drains to wetlands and open water. The percent of watershed draining to a wetland in the attainment watersheds, based on the 2021 analysis, ranged from 26 to 58 percent, with an average of 40%.

NUTRIENT AND SEDIMENT MODELING RESULTS

Selected results from the watershed loading model are presented below. The TMDL itself is expressed in units of kilograms per hectare per year. The additional results shown below assist in better understanding the likely sources of pollution. The model results for French Stream indicate significant reduction of phosphorus, a moderate reduction of nitrogen, and a smaller reduction in sediment are needed to improve water quality. Below, loading for nitrogen, phosphorus and sediment are discussed individually.

There are two categories of loads – sources and pathways. Sources are determined by land use/cover and the overland flow they generate, livestock counts by animal type, and home sewage treatment systems in developed areas. Pathways represent additional loads derived from subsurface flow and streambank erosion. Subsurface loads are calculated using dissolved N and P coefficients for shallow groundwater and are mainly derived from atmospheric inputs. Sediment and nutrient loads produced by eroding streambanks are estimated using an approach developed by Evans et al. (2003). This pathway is comprised of loads originating from five sources, and listed in order of decreasing importance: amount of developed land area, soil erodibility (K-factor), density of livestock, runoff curve number, and topographic slope. For any given model run, the amount of developed land in the watershed is responsible for just over 72% of the total streambank load, whereas soil erodibility and animal density are responsible for 21% and 7% of the total streambank load, respectively.

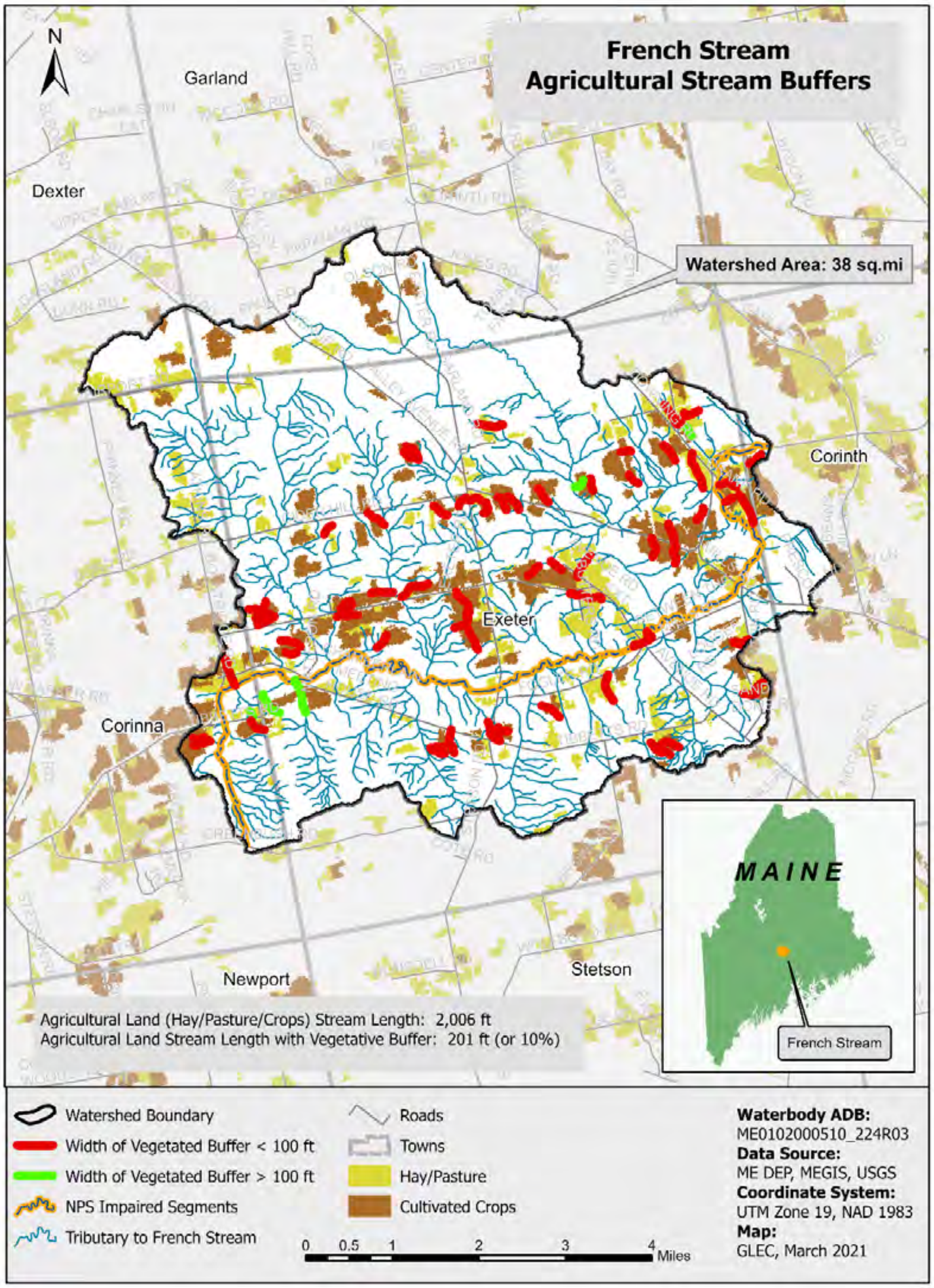


Figure 4: Agricultural Stream Buffers (from 2021) in the French Stream Watershed

Sediment

Sediment loading in the French Stream watershed is mainly derived from cropland which makes up almost 92% of the total sediment load from sources (Table 5 and Figure 5). Hay/pasture and low-density open space comprise about 2% each. Of the entire watershed sediment load, stream bank erosion contributes 61.5%.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section TMDL: Target Nutrient Levels for French Stream below for loading estimates that have been normalized by watershed area.

Table 5: Total Sediment Load by Source

French Stream	Sediment (1000 kg/year)	Sediment (%)
Source Load		
Hay/Pasture	7.1	2.3%
Cropland	278.3	91.9%
Wooded Areas	2.2	0.7%
Wetlands	0.7	0.2%
Open Land	0.6	0.2%
Barren Areas	0.003	0.001%
Low-Density Mixed	3.7	1.2%
Medium-Density Mixed	3.1	1.0%
High-Density Mixed	0.6	0.2%
Low-Density Open Space	6.5	2.1%
Farm Animals	0	0
Septic Systems	0	0
Source Load Total:	**302.8**	**100%**
Pathway Load		
Stream Bank Erosion	483.0	-
Subsurface Flow	0	-
Total Watershed Mass Load:	**786**	

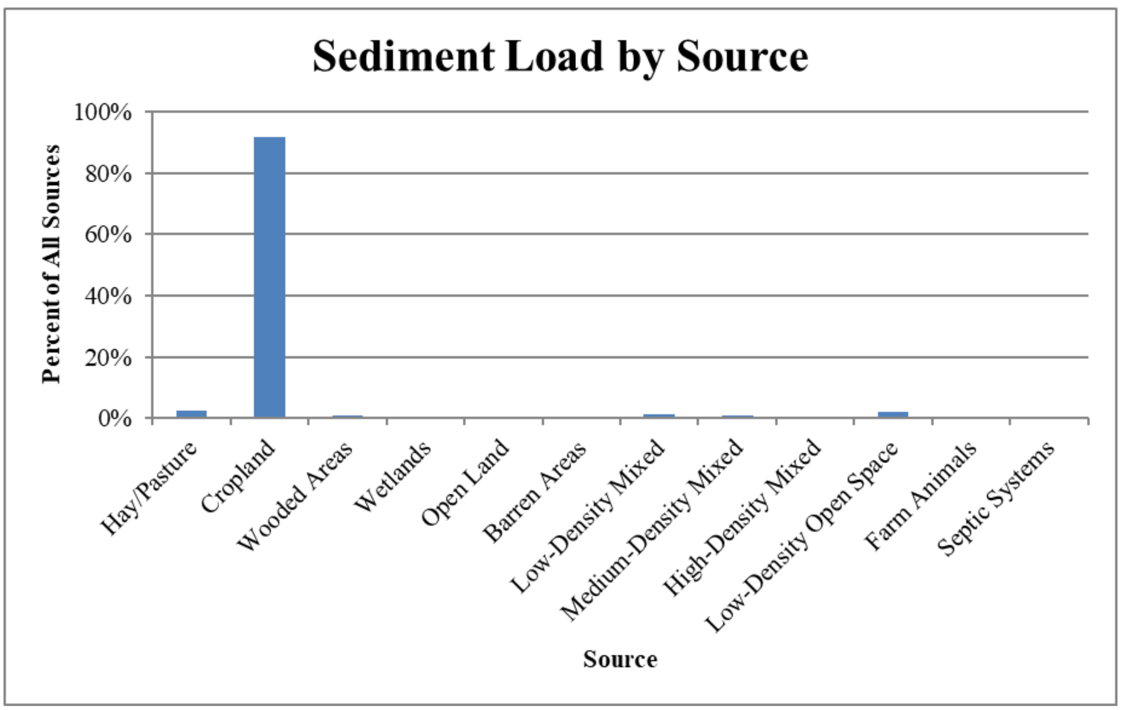


Figure 5: Total Sediment Load by Source in the French Stream Watershed

Total Nitrogen

Nitrogen loading is attributed primarily to farm animals (67.5%) and cropland (19.9%) (Table 6 and Figure 6). Combined agricultural sources account for almost 91% of the total nitrogen load to French Stream. This load calculation incorporated the exceptional waste management of the large dairy farm.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient Levels for French Stream* below for loading estimates that have been normalized by watershed area.

Table 6: Total Nitrogen Load by Source

French Stream	Total N (kg/year)	Total N (%)
Source Load		
Hay/Pasture	942	3.3%
Cropland	5,645	19.9%
Wooded Areas	1,085	3.8%
Wetlands	852	3.0%
Open Land	70	0.2%
Barren Areas	9	0.0%
Low-Density Mixed	156	0.5%
Medium-Density Mixed	103	0.4%
High-Density Mixed	20	0.1%
Low-Density Open Space	274	1.0%
Farm Animals	19,156	67.5%
Septic Systems	82	0.3%
Source Load Total:	**28,394**	**100%**
Pathway Load		
Stream Bank Erosion	875	-
Subsurface Flow	9,168	-
Total Watershed Mass Load:	**38,436**	

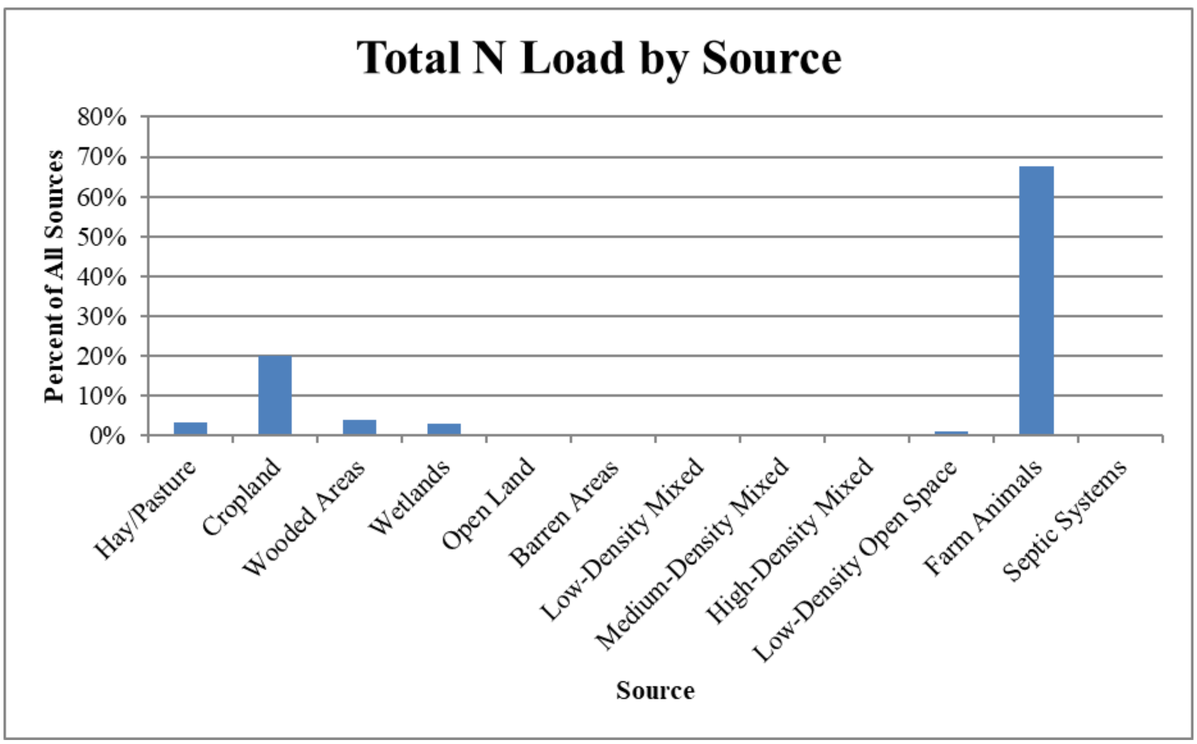


Figure 6: Total Nitrogen Load by Source in the French Stream Watershed

Total Phosphorus

Phosphorus loading within the watershed is attributed primarily to farm animals and cropland with combined agricultural sources accounting for almost 96% of the total phosphorus load to French Stream. This load calculation incorporated the exceptional waste management of the large dairy farm. The number of farm animals and high density and large size of croplands account for these sources. Phosphorus loads are presented in Table 7 and Figure 7.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient Levels for French Stream* below for loading estimates that have been normalized by watershed area.

Table 7: Total Phosphorus Load by Source

French Stream	Total P (kg/year)	Total P (%)
Source Load		
Hay/Pasture	316.3	9.3%
Cropland	966.2	28.3%
Wooded Areas	54.8	1.6%
Wetlands	41.4	1.2%
Open Land	2.4	0.1%
Barren Areas	0.3	0.01%
Low-Density Mixed	15.1	0.4%
Medium-Density Mixed	9.5	0.3%
High-Density Mixed	1.8	0.1%
Low-Density Open Space	26.6	0.8%
Farm Animals	1,984.4	58.0%
Septic Systems	0	0
Source Load Total:	**3,418.8**	**100%**
Pathway Load		
Stream Bank Erosion	228.0	-
Subsurface Flow	362.8	-
Total Watershed Mass Load:	**4,010**	

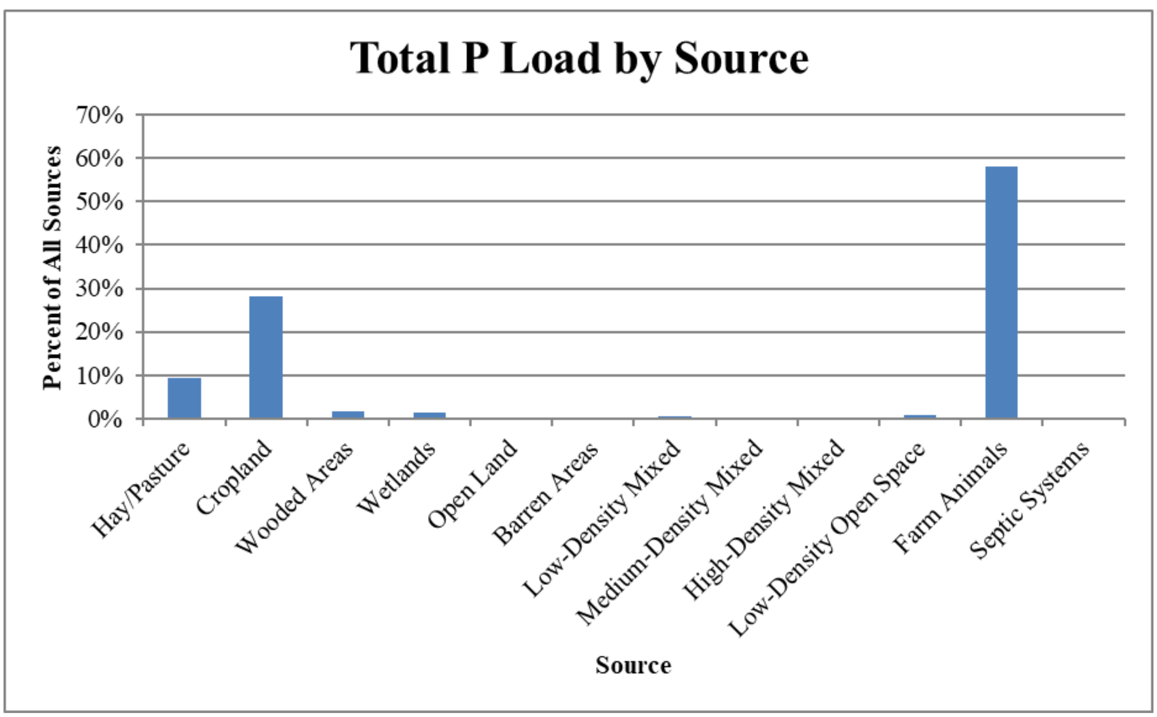


Figure 7: Total Phosphorus Load by Source in the French Stream Watershed

TMDL: TARGET NUTRIENT AND SEDIMENT LEVELS FOR FRENCH STREAM

The existing loads for nutrients and sediments in the impaired segment of French Stream are listed in Table 8, along with the TMDL (the allowable load) which was calculated from the average loading estimates of five attainment watersheds throughout the state. Table 8 also shows required reductions (as a percent) for each of sediment, total N, and total P pollutants. Table 9 presents a more detailed view of the modeling results and calculations used to compute the existing loads in Table 8. An annual time frame provides a mechanism to address the daily and seasonal variability associated with nonpoint source loads.

Table 8: French Stream Pollutant Loading Compared to TMDL Targets

French Stream			
Pollutant Load	**Existing Load**	**TMDL**	**Reduction Required**
Total Annual Load per Unit Area		Attainment Streams	
Sediment (kg/ha/yr)	80.1	65.72	17.9%
Total N (kg/ha/yr)	3.92	2.46	37.3%
Total P (kg/ha/yr)	0.41	0.16	60.9%

Future Loading

The prescribed reduction in pollutants discussed in this TMDL reflects reduction from estimated existing conditions. Expansion of agricultural and development activities in the watershed have the potential to increase runoff and associated pollutant loads to French Stream. To ensure that the TMDL targets are attained, future agricultural activities will need to meet the TMDL targets. Between 2012 to 2017 in Penobscot County, the growth in agricultural lands was decreasing, with an 11.2% decrease in the total number of farms and a 6.6% decrease in total farm area. However, a 4.8% increase in the average farm size occurred in this time period. These values are extracted from the most recent (2017) Census of Agriculture (USDA 2017). Human population in Penobscot County declined by slightly more than 1% from 2000 to 2019 (US Census 2020). Future activities and BMPs that achieve TMDL reductions are addressed below.

Next Steps

The use of agricultural and developed area Best Management Practices (BMP's) can reduce sources of polluted runoff in French Stream. It is recommended that municipal officials, landowners, and conservation stakeholders in Exeter work together to develop a watershed management plan to:

- Encourage greater citizen involvement through the development of a watershed coalition to ensure the long term protection of French Stream;
- Run a "Hot-Spot Analysis" in *Model My Watershed* to determine sub-watershed locations of higher existing contributions of sediment and nutrients to the outlet of French Stream watershed; then focus BMP mitigation in these hot-spot sub-areas of the watershed;
- Address existing nonpoint source problems in the French Stream watershed by instituting BMPs where necessary; and

- Prevent future degradation of French Stream through the development and/or strengthening of local Nutrient Management Ordinance.

Table 9: Annual Loads by Land Use, Other Sources, and Pathways for French Stream Based on Modeling

French Stream				
	Area (ha)	**Sediment** (1000 kg/yr)	**Total N** (kg/yr)	**Total P** (kg/yr)
Land Uses				
Hay/Pasture	760	7.1	942	316.3
Cropland	979	278.3	5,645	966.2
Wooded Areas	5,943	2.2	1,085	54.8
Wetlands	1,647	0.7	852	41.4
Open Land	53	0.6	70	2.4
Barren Areas	12	0.003	9	0.3
Low-Density Mixed	143	3.7	156	15.1
Medium-Density Mixed	23	3.1	103	9.5
High-Density Mixed	4	0.6	20	1.8
Low-Density Open Space	249	6.5	274	26.6
Total Area	9,812			
Other Sources				
Farm Animals		0.0	19,156	1,984.4
Septic Systems		0.0	82	0.0
Pathway Load				
Stream Bank Erosion		483.0	875	228.0
Subsurface Flow		0.0	9,168	362.8
Total Annual Load		786	38,436	4,010
Total Annual Load per Unit Area		0.080	3.92	0.41
		1000 kg/ha/yr	kg/ha/yr	kg/ha/yr

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DRAFT TMDL SUMMARY

Halfmoon Stream

WATERSHED DESCRIPTION

This TMDL applies to an 8.5 mile section of Halfmoon Stream, encompassing the Villages of Thorndike and Knox and the watershed just upstream of the Town of Unity, Maine. Halfmoon Stream flows northeast in its headwaters, then due north, and northwest in its lower reaches, joining Sandy Stream just upstream of Berry Road. The upper portion of the stream in Monteville is predominately forested area, while the lower portion is a mixture of agricultural and forest. Major tributaries are Hall and Wing Brooks which join the mainstem downstream and upstream of Thorndike, respectively. The Halfmoon Stream watershed covers an area of 38.0 square miles.

- Halfmoon Stream is on the list of Maine's Impaired Streams as referenced in the 2016 Integrated Report (Maine DEP, 2018).
- The Halfmoon Stream watershed is predominately non-developed (81%). Wooded areas (73%) within the watershed absorb and filter pollutants helping protect both water quality in the stream and stream channel stability. The filtering ability is particularly functional in the riparian corridor, which Halfmoon Stream experiences. Wetlands also filter nutrients and are present in 5% of the watershed.
- Non-forested areas within the watershed are predominantly agricultural (14%, 12% of which is hay/pasture land).
- Developed areas (5%) contain impervious surfaces and when in close proximity to the stream may impact water quality.
- Runoff from land with applied manure originating from dairy farms is likely the largest contributor of nutrients to Halfmoon Stream. The central portion of the watershed is where managed hay fields and grazing areas exist.

Definitions

- ***Total Maximum Daily Load (TMDL)*** *represents the total amount of a pollutant that a waterbody can receive and still meet water quality standards.*
- **Nonpoint Source Pollution** *refers to pollution that comes from many diffuse sources across the landscape, and are typically transported by rain or snowmelt runoff.*

Waterbody Facts

Segment ID:
ME0103000309_326R03 (lower)
ME0103000309_326R02 (upper)

Towns: Unity/Thorndike/Knox, ME

County: Waldo

Impaired Segment Length: 1.6 miles (lower), 6.9 miles (upper)

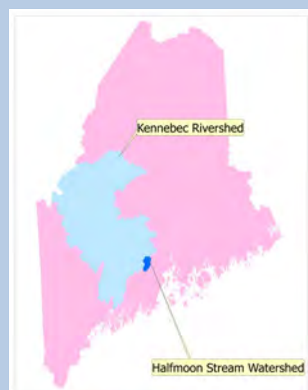
Classification: Class B (lower), Class A (upper)

Direct Watershed: 38 mi^2 (24,320 acres)

Impairment Listing Cause: Periphyton (both lower & upper)

Watershed Agricultural Land Use: 14%

Major Drainage Basin: Kennebec River



Watershed Land Uses

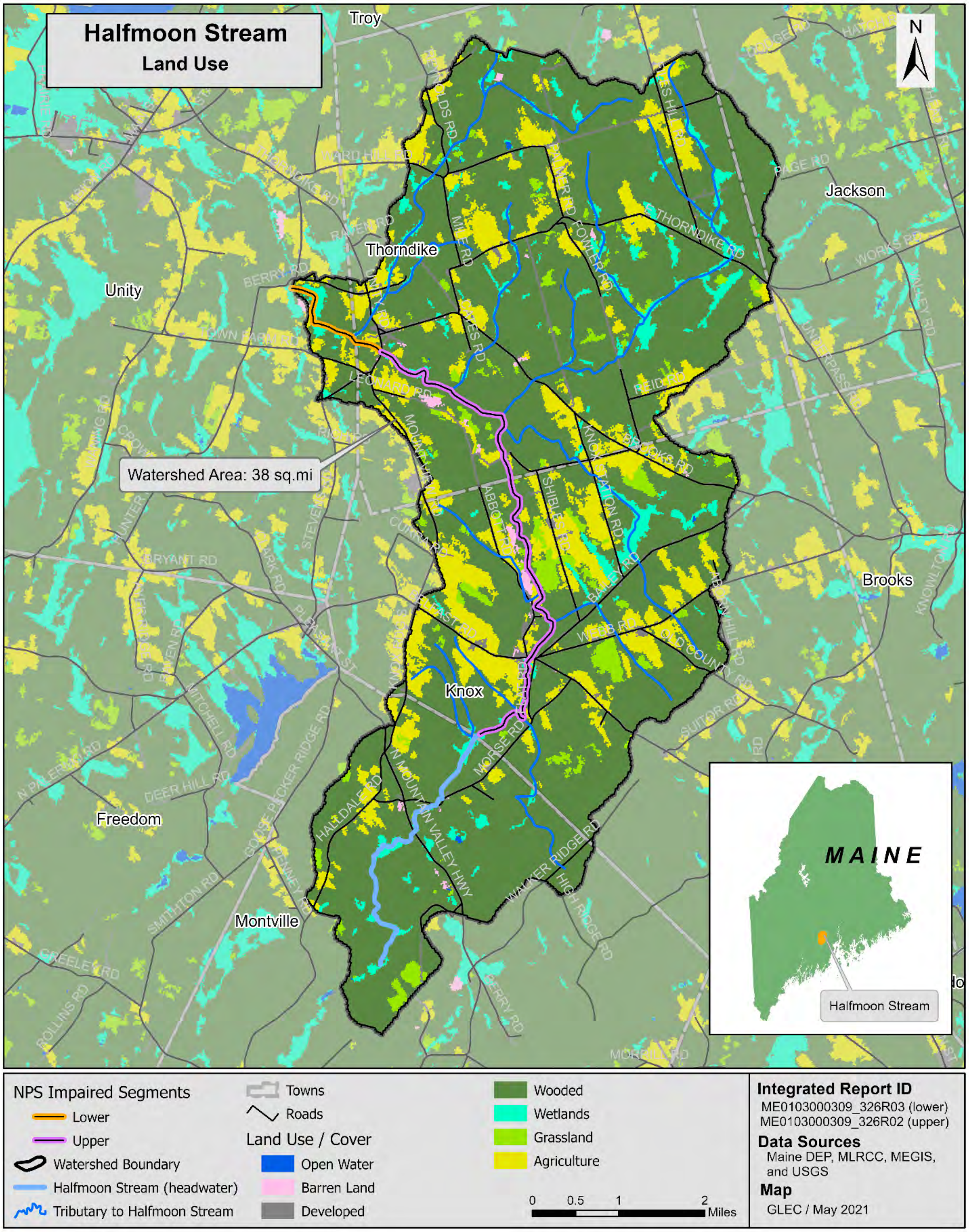


Figure 1: Land Use and Land Cover (from 2016) in the Halfmoon Stream Watershed

WHY IS A TMDL ASSESSMENT NEEDED?

Halfmoon Stream, predominantly a Class A freshwater stream (with a lower segment in Class B), has been assessed by Maine DEP as not meeting water quality standards for the designated use of aquatic life, and placed on the 303(d) list of impaired waters under the Clean Water Act. The Clean Water Act requires that all 303(d)-listed waters undergo a Total Maximum Daily Load (TMDL) assessment that describes the impairments and establishes a target to guide the measures needed to restore water quality. The goal is for all waterbodies to comply with state water quality standards.

Agriculture (hay/pasture and cropland) in the Halfmoon Stream watershed comprises 14% of the land area. This is almost three times the developed land area in the watershed. Agriculture is therefore likely to be the largest contributor of sediment and nutrient enrichment to the stream. Any close proximity of agricultural land, particularly hay crop with applied manure, to Halfmoon Stream further increases the likelihood that nutrients will reach the stream.

Halfmoon Stream (lower impaired segment; Class B) *looking upstream and just upstream of the confluence with Sandy Stream and the Berry Road bridge (Unity). Photo: GLEC 2021*

Halfmoon Stream (upper impaired segment; Class A) *just upstream of SR 220 (Mount View Rd, Thorndike). Photo: GLEC 2021*

WATER QUALITY DATA ANALYSIS

Maine DEP uses a variety of data types to measure the ability of a stream to adequately support aquatic life, including; dissolved oxygen, benthic macroinvertebrates, and periphyton (algae). For benthic macroinvertebrates, DEP makes aquatic life use determinations using a statistical model that incorporates 30 variables of data collected from rivers and streams, including the richness and abundance of streambed organisms, to determine the probability of a sample meeting Class A, B, or C conditions. Biologists use the model results and supporting information to determine if samples comply with the numeric aquatic life criteria of the class assigned to the stream or river (Davies and Tsomides, 2002). Maine DEP uses an analogous model to aid in the assessment of algal communities but makes aquatic life use determinations based on narrative standards.

The aquatic life impairment in Halfmoon Stream is based on periphyton (algae) data collected from 2002 to 2017. The lower segment in the watershed has a Class B designation but the upper segment has a Class A designation. At station S-603, located on the lower segment, in 2002 periphyton did meet its designation and macroinvertebrates exceeded its designation and met Class A. At station S-697, located on the upper segment, in 2003 and 2007 macroinvertebrates met its designation of Class A while in 2007 periphyton did not meet its Class A designation (it met Class C). In 2012, 2013, 2014, and 2017 both macroinvertebrates and periphyton did not meet its Class A designation at this same station (S-697). In 2015, 2016, and 2018 periphyton was not sampled for, but macroinvertebrates did not meet Class A designation. In 2019 periphyton did not meet its Class A designation (it met Class B) while macroinvertebrates did meet.

TMDL ASSESSMENT APPROACH: NUTRIENT AND SEDIMENT MODELING OF IMPAIRED AND ATTAINMENT STREAMS

NPS pollution is difficult to measure directly, because it comes from many diffuse sources spread across the landscape. For this reason, an online nutrient loading model, *Model My Watershed* (v. 1.32.0), was used to estimate the sources of pollution based on well-established hydrological equations (Stroud Water Research Center 2017). *Model My Watershed* makes use of the GWLF-enhanced model engine. The model incorporates detailed maps of soil, land use, and slope, daily weather and localized weather data (from the period 2009-2020), and direct observations of agriculture and other land uses within the watershed. *Model My Watershed* is derived from its parent MapShed developed by Evans and Corradini (2012). *Model My Watershed* replaced MapShed in 2017-2018.

The nutrient loading estimates for the impaired stream were compared to similar estimates for five non-impaired (attainment) streams of similar watershed land uses across the state. The TMDL for the impaired stream was set as the mean nutrient loading estimate of these attainment stream watersheds, and units of mass per unit watershed area per year (kg/ha/year) were used. The difference in loading estimates between the impaired and attainment watersheds represents the percent reduction in nutrient loading required under this TMDL. The attainment streams and their nutrient and sediment loading estimates and TMDL are presented below in Table 1.

Table 1: Numeric Targets for Pollutant Loading Based on Model My Watershed Outputs (2021) for Attainment Streams

Attainment Streams	Town	Total P Load (kg/ha/yr)	Total N Load (kg/ha/yr)	Sediment Load (kg/ha/yr)
Footman Brook	Exeter	0.17	1.73	35.2
Martin Stream	Fairfield	0.13	2.98	57.9
Moose Brook	Houlton	0.18	1.59	48.5
Upper Kenduskeag Stream	Corinth	0.16	1.72	100.5
Upper Pleasant River	Gray	0.16	4.26	86.5
Total Maximum Daily Load		**0.16**	**2.46**	**65.7**

RAPID WATERSHED ASSESSMENT

Habitat Assessment

Habitat assessment surveys were conducted on both impaired and attainment streams (Figure 2). The assessment approach is based on the *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (Barbour et al. 1999), which integrates various parameters relating to the structure of physical habitat. The habitat assessments include a 1) general description of the site and physical characterization and a 2) visual assessment of in-stream and riparian habitat quality. For both impaired and attainment streams, the assessment locations are typically near a road crossing for ease of access.

Halfmoon Stream contains two impaired, but contiguous, segments. The lower impaired segment (ME0103000309_326R03; Class B) was surveyed starting at approximately 70 m upstream from its confluence with Sandy Stream; the endpoint was 100 m upstream from this starting point. Because this segment was practically an entire run structure, a *low gradient* habitat assessment was performed on this 100 m length. A biomonitoring station exists at the upstream end of this impaired reach.

The upstream impaired segment (ME0103000309_326R02; Class A) begins near the State Route 220 bridge crossing (Mount View Rd) and continues a considerable distance (approximately 11 km) upstream. Based on the higher frequency of riffles versus runs or pools, a *high gradient* habitat assessment was performed on a 100 m length of the upper segment. The assessed segment began approximately 175 m upstream of the State Route 220 bridge to ensure clearance of any confining flow or modified habitat caused by this bridge. This beginning point was approximately 80 m upstream of the biomonitoring station (S-697).

The habitat surveys for both impaired segments were located in moderately dense vegetated riparian covers, especially for the upper segment, while the overall watershed land use is predominantly wooded yet contains a mixture of pasture, wetlands, and commercial or residential land. It is worth noting that a large quarry/aggregate operation is active in the local drainage area of the lower segment.

Figure 2 (right) shows the range of habitat assessment scores for all attainment and impaired streams, as well as for both segments of Halfmoon Stream discussed here.

Based on the *Rapid Bioassessment Protocols*, the lower (low gradient) segment earned a score of 125 while the upper (high gradient) segment earned a 175. Higher scores indicate better habitat. The range of habitat scores for attainment streams was 155 to 179.

The low score for the lower segment was attributed to lack of pool variability and channel sinuosity and poor bank stability. All habitat parameters scored high in the upper segment, but were especially optimal for channel flow status, frequency of riffles, and low channel alteration. The entire run structure of this lower segment plus unusually high bank heights (possibly incised) suggests this reach has been intentionally channelized in its past.

Habitat is clearly an issue in the impairment of the lower segment of Halfmoon Stream. But for both upper and lower segments, it is important to look for other potential sources within the watershed leading to impairment. Consideration should be given to major "hot spots" in the Halfmoon Stream watershed as potential sources of NPS pollution contributing to the water quality impairment.

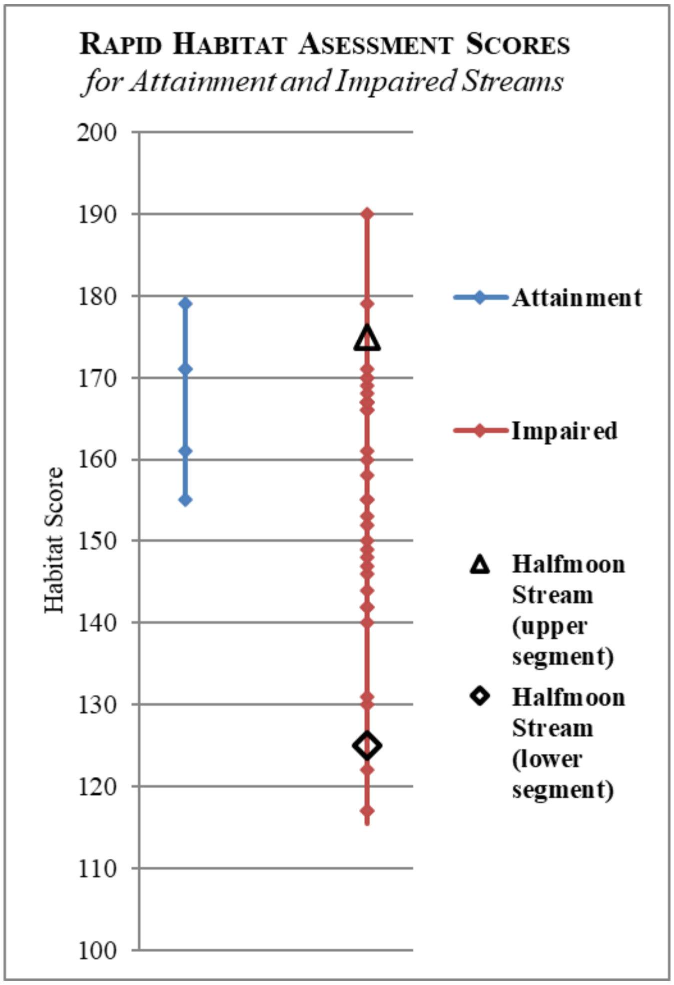


Figure 2: Habitat Assessment Score for Halfmoon Stream (2021) Compared to Region

Pollution Source Identification

Pollution source identification assessments were conducted in May 2021 for the entire Halfmoon Stream watershed. Attainment stream watersheds were assessed in 2012. The source identification work is based on an abbreviated version of the Center for Watershed Protection's Unified Subwatershed and Site Reconnaissance method (Wright et al. 2005). The abbreviated method includes both a desktop and field component. The desktop assessment consists of generating and reviewing maps of the watershed boundary, roads, land use and satellite imagery; and then identifying potential NPS pollution locations, such as road crossings, agricultural fields, and large areas of bare soil. When available, multiple sources of satellite imagery were reviewed. Occasionally, the high resolution of the imagery allowed for observations of livestock, row crops, eroding stream banks, sediment laden water, junkyards, and other potential NPS concerns that could affect stream quality. As many potential pollution sources as possible were visited, assessed, and documented in the field. Field visits were limited to NPS sites that were visible from roads or a short walk from a roadway. Neighborhoods were assessed for NPS pollution at the whole neighborhood level including streets and storm drains (where applicable). The assessment does not include a scoring component but does include a detailed summary of findings and a map indicating documented NPS sites throughout the watershed.

Based on the May 2021 field and desktop assessment, several generalizations on watershed land use for Halfmoon Stream can be made. While most of the headwater portions of the watershed are densely forested, and mainly in tributaries such as Half Brook, Wing Brook, and the upper mainstem, there is considerable intensive land operations in the central and lower segment of the mainstem that likely disturb the integrity of the stream system (Table 2, Figure 3). The village of Thorndike is situated in the lower watershed and the corresponding existence of any failing home sewage treatment systems should be explored. Knox Center village is situated in the center of the watershed, though smaller in residential use. Several junkyards occur but their contribution to nutrient enrichment or sedimentation is indirect, at most. Most attention should focus on several dairy operations throughout the central portion of the watershed. Supporting these operations are extensive hayfields throughout this portion of the watershed. The hayfields are likely nourished by land applied manure, where on occasion this was observed in the field. Winter wheat production was also observed, though not as extensive as hayfield. Also, regarding impacts to sedimentation in Halfmoon Stream, the extensive quarrying operations and any lagoon captures on the west-central flank of the mainstem should be examined.

Table 2: Potential Pollution Source ID Assessment (2021) for the Halfmoon Stream Watershed

Potential Source			Notes
ID#	**Location**	**Type**	
4	Crosby Brook Rd & Berry Rd	Hotspot	Gravel piles; several large trucks; scattered debris; sediment exposed w/o containment; brush cleared
5	Crosby Brook Rd	Municipal	Fairgrounds - partly within watershed - several barns - mowed fields
6	Crosby Brook Rd	Municipal	Municipal road facility; transfer station
7	Crosby Brook Rd	Residential	House with small farm; large hayfield; chickens observed; mowed grasses
8	Berry Rd	Agriculture	Organic farm fields; plowed
9	SR 139 & SR 220 (Unity Rd & Gordon Hill Rd)	Residential / Hotspot	Thorndike – no apparent managed lawn care; older residential structures; not sewered; no new construction; 10-25% tree/shrub coverage; no curbs/gutters/drains present; Auto parts & service center (main commercial hotspot)
10	SR 220 (Unity Rd)	Agriculture	Agricultural research station - several greenhouses
14	Stevens Rd & Town Farm Rd	Agriculture	Extensive planting winter wheat; 15 barns; clearing of woodlots
16	Leonard Rd	Agriculture	Barns – alum piles – mowed hayfields

Potential Source			**Notes**
ID#	**Location**	**Type**	
17	Leonard Rd / Abbott Rd	Hotspot	Quarry - gravel pit - several large equipment pieces - extensive
18	Leonard Rd	Agriculture	Plowed - previously corn - no till - extensive odor chicken manure applied to field
20	Leonard Rd	Forestry	Managed forest – selective cutting
24	Abbott Rd & Joe Bryant Rd	Hotspot	Junked vehicles – extensively scattered
25	Abbott Rd & Clark Ln	Agriculture / Municipal	Equine riding club – horse show arena – paddock – large municipal sand pile
27	Shibles Rd	Agriculture	Dairy farm – extensive barns – manure applied to local yet extensive hayfields
28	Belfast Rd	Municipal	Salt storage – covered with tarp
29	Belfast Rd & Webb Rd	Agriculture	12 chickens observed (free roam) – scattered junk and vehicles
30	Shibles Rd	Residential / Hotspot	Houses with several junked vehicles and trailers – extensive over several residential lots
31	Morse Rd	Agriculture	Organic vegetable farm – horses in paddock (6 observed)
32	Near Morse Rd & Flat Rd	Construction / Hotspot	Cleared vegetation and wide road foundation forming to cul-de-sac
34	E Thorndike Rd & Flies Hill Rd	Agriculture	Small sheep farm (over 10 animals observed)
36	Brooks Rd	Agriculture	Marijuana farm – fencing over hayfield present

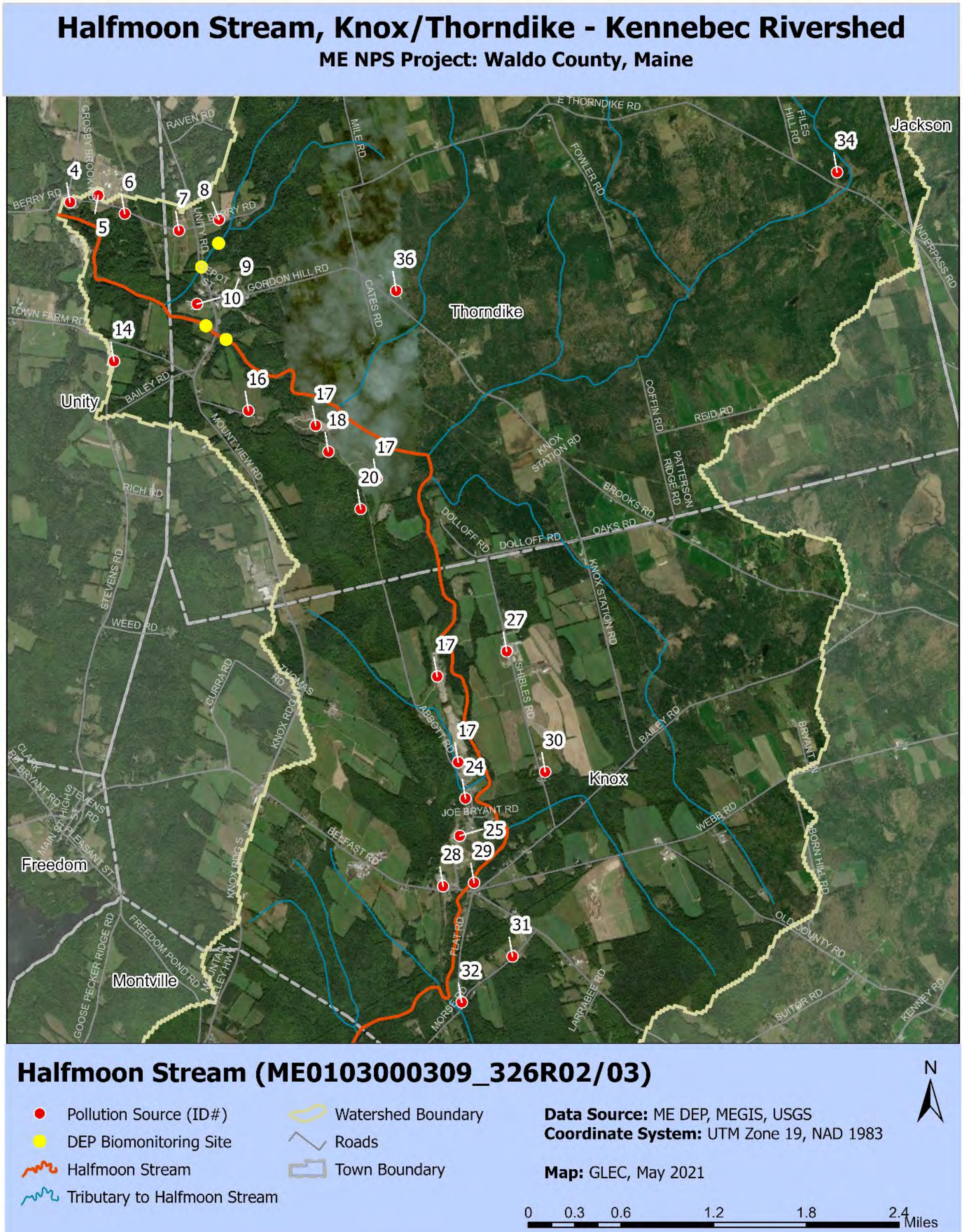


Figure 3: Aerial Photo of Potential Source Locations (identified in 2021) in the Halfmoon Stream Watershed

NUTRIENT LOADING – *MODEL MY WATERSHED* ANALYSIS

The *Model My Watershed* model was used to estimate stream loading of total phosphorus, total nitrogen, and sediment in Halfmoon Stream watershed. The model estimated nutrient loads over a 12-year period (2009-2020), which was determined by local (Bangor International Airport USW00014606) weather data inserted into *Model My Watershed*. This extended period captures a recent but wide range of hydrologic conditions to account for variations in nutrient and sediment loading over time. Loads for the attainment watersheds (five total; Table 1) were computed using the same model with the same recent inputs (i.e., regional weather, 2016 land use and land cover, 2016 wetland extent, and BMPs similar to the impaired watersheds).

Many quality assured and regionally calibrated input parameters are provided with *Model My Watershed*. However, several updates to some of the default parameters were made in this TMDL effort, and namely more recent land use/cover using **MRLC-NLCD 2016** [1], more recent and local weather (precipitation and temperature) data (as described above), and more regional estimates of Best Management Practices (BMPs; see ensuing discussion). Because land use/cover is more recent, the estimated filtration fraction of wetland and open water and the amount of stream buffer in agricultural land should be more accurate. It is also worth noting that improved classification algorithms were employed by MLRC in the NCLD 2016 and these new algorithm were used in the revisions of all previous NLCD versions (including the first version in 2001).

Livestock Estimates

Livestock waste contains nutrients which can cause water quality impairment. The nutrient loading model considers numbers and types of animals. Table 3 (right) provides livestock (numbers of animals) in the watershed based on the USDA National Agricultural Statistics Service (NASS) estimation for 2012. Some of these totals were modified by direct observations made in the watershed in the 2012 survey. To generate watershed-based livestock counts, NASS county-based livestock totals are converted to a per unit area (based on the total area of the county). The unit area amount is then multiplied by the total watershed area to derive a watershed total count (as seen in Table 3).

Table 3: Livestock Count in the Halfmoon Stream Watershed

Type	Halfmoon Stream
Dairy Cows	198
Beef Cows	29
Broilers	27
Layers	--
Hogs/Swine	19
Sheep	62
Horses	29
Turkeys	10
Other	--
Total	**374**

The May 2021 field survey supports the livestock totals estimated through NASS as shown in Table 3. The dairy farm on Shibles Road (Site #27 on Figure 3 and Table 2) appears to be the most extensive operation and based on the areal extent of housing barns, the dairy cow estimate in Table 3 is likely too small. Unfortunately, the drive-by survey could not reasonably estimate this larger estimate. Several small farms did show 6-10 chickens roaming in the yard, and several larger farms had horses in pasture.

[1] MRLC-NLCD 2016 : Multi-Resolution Land Characteristics – National Land Cover Dataset (version 2016) provided by the MRLC Consortium (Jin et al. 2019).

Vegetated Stream Buffer in Agricultural Areas

Vegetated stream buffers are areas of trees, shrubs, and/or grasses adjacent to streams, lakes, ponds or wetlands which provide nutrient loading attenuation (Evans and Corradini, 2012). *Model My Watershed* considers natural vegetated stream buffers within agricultural land areas as providing nutrient load attenuation. A width of approximately 98 feet (30 m) on one side of a stream is required to be considered a streamside buffer per the *Model My Watershed* technical manual (Stroud Water Research Center 2017). Analysis of recent aerial photos was used to estimate the number of agricultural land stream miles with and without vegetative buffers, and these estimates were directly entered into the model.

Halfmoon Stream is an 8.5 mile-long impaired segment. The total stream miles (including tributaries) modeled within the watershed is 46.2 miles. Of this total, 2.48 stream miles are located within agricultural areas and 1.15 miles (6,097 ft; 46.6%) of that area have a 98 foot or greater vegetated buffer (Table 4, Figure 4). From a watershed perspective, this equates to 1.33 miles or 2.9% of the total stream length running through agricultural land with less than a 98 foot buffer. By contrast, for attainment stream watersheds, the percentage of total stream miles running through agricultural land without a 75 foot vegetated buffer (calculated in 2012) ranged from 0% to 3.9% with an average of 1.3%. Differences in stream length estimates using a 98-foot or 75-foot buffer were practically insignificant.

Table 4: Summary of Vegetated Buffers in Agricultural Areas

Halfmoon Stream
• Agricultural Land Stream Length = 2.48 mi (13,075 ft) • Agricultural Land Stream Length *with Buffer* = 1.15 mi (6,097 ft) (or 46.6% of total agricultural land stream length) • Percentage of total stream length flowing through non-buffered agricultural land = 2.9%

Home Septic System Loads

Loads for "normally functioning" septic systems are calculated in *Model My Watershed* using an estimate of the average number of persons per acre in "Low-Density Mixed" areas. In these areas, it is assumed that the populations therein are served by septic systems rather than centralized sewage systems. All homes in such areas are assumed to be connected to "normally functioning" systems rather than those that experience "surface breakouts" (surface failures), "short-circuiting" to underlying groundwater (subsurface failures), or have direct conduits to nearby water bodies. Non-functioning systems would be modeled with a higher load contribution to the waterbody.

Best Management Practices (BMPs)

Best management practices (BMPs) are typically instituted to reduce the loading of sediment and nutrients from upland (i.e., non-point) sources. Ideally, information on BMPs for a specific watershed from local and regional sources would improve this component of the water quality model. Maine DEP sought information on BMP use in early 2021 from local, regional, and state agricultural agencies for rural BMPs and from nearby municipalities for urban BMPs. Very little to no information was returned in the solicitation. Hence, estimates for typical New England watersheds were derived from information available from Vermont. An upper limit of BMP use was garnered from watersheds entering the Chesapeake Bay where BMP use is intensive.

Four agricultural BMPs were used in this modeling effort and in the following manner:

- *Cover Crops:* Cover crops are the use annual or perennial crops to protect soil from erosion during time periods between harvesting and planting of the primary crop. The percent of cropland area in a cover crop BMP deployed was estimated at 25% and selected as the low end of the range (25 to 30 percent) expected for cropland in New England. These same values were assigned to the five attainment watersheds.
- *Conservation Tillage:* Conservation tillage is any kind of system that leaves at least 30% of the soil surface covered with crop residue after planting. This reduces soil erosion and runoff. This BMP was estimated to occur in 25% of cropland. These same values were assigned to the five attainment watersheds.
- *Strip Cropping / Contour Farming:* This BMP involves tilling, planting and harvesting perpendicular to the gradient of a hill or slope using high levels of plant residue to reduce soil erosion from runoff. Both interview sources suggest this practice is minimal to non-existent for New England watersheds. Hence, no BMP of this type was used in this modeling effort. These same values were assigned to the five attainment watersheds.
- *Grazing Land Management:* This BMP consists of ensuring adequate vegetation cover on grazed lands to prevent soil erosion from overgrazing or other forms of over-use. This usually employs a rotational grazing system where hays or legumes are planted for feed and livestock is rotated through several fenced pastures. Both interview sources were not aware of this practice being active and is likely minimal for New England watersheds. Hence, no BMP of this type was used in this modeling effort for both impaired and attaining watersheds.

Note that other agricultural and development BMPs likely exist in the watershed but their location and type were not available in a watershed-wide format that is necessary to include in the model. Agricultural BMPs recommended by Maine DEP to reduce sediment and nutrient loads include vegetated buffers, covered manure storage facilities, and stream exclusion fencing. BMPs for developed areas recommended by the Maine DEP include vegetated buffers, stormwater BMPs, and minimization of impervious cover.

Pollutant Load Attenuation by Lakes, Ponds and Wetlands

Depositional environments such as lakes, ponds, and wetlands can attenuate watershed sediment and nutrient loading. This information is entered into the nutrient loading model by a simple percentage of watershed area draining to a lake, pond, or wetland. The Halfmoon Stream watershed is 5% wetland and open water (less than 1% is open water). Multiple wetlands surround tributaries throughout the watershed, but most notably in the eastern and northeastern sections. It is estimated that 10% of land area within the watershed drains to wetlands and open water. The percent of watershed draining to a wetland in the attainment watersheds, based on the 2021 analysis, ranged from 26 to 58 percent, with an average of 40%.

NUTRIENT AND SEDIMENT MODELING RESULTS

Selected results from the watershed loading model are presented here. The TMDL itself is expressed in units of kilograms per hectare per year. The additional results shown below assist in better understanding the likely sources of pollution. The model results for Halfmoon Stream indicate significant reductions of phosphorus and sediment are needed to improve water quality. Below, loading for nitrogen, phosphorus and sediment are discussed individually.

There are two categories of loads – sources and pathways. Sources are determined by land use/cover and the overland flow they generate, livestock counts by animal type, and home sewage treatment systems in developed areas. Pathways represent additional loads derived from subsurface flow and streambank erosion. Subsurface loads are calculated using dissolved N and P coefficients for shallow groundwater and are mainly derived from atmospheric inputs. Sediment and nutrient loads produced by eroding streambanks are estimated using an approach developed by Evans et al. (2003). This pathway is comprised of loads originating from five sources, and listed in order of decreasing importance: amount of developed land area, soil erodibility (K-factor), density of livestock, runoff curve number, and topographic slope. For any given model run, the amount of developed land in the watershed is responsible for just over 72% of the total streambank load, whereas soil erodibility and animal density are responsible for 21% and 7% of the total streambank load, respectively.

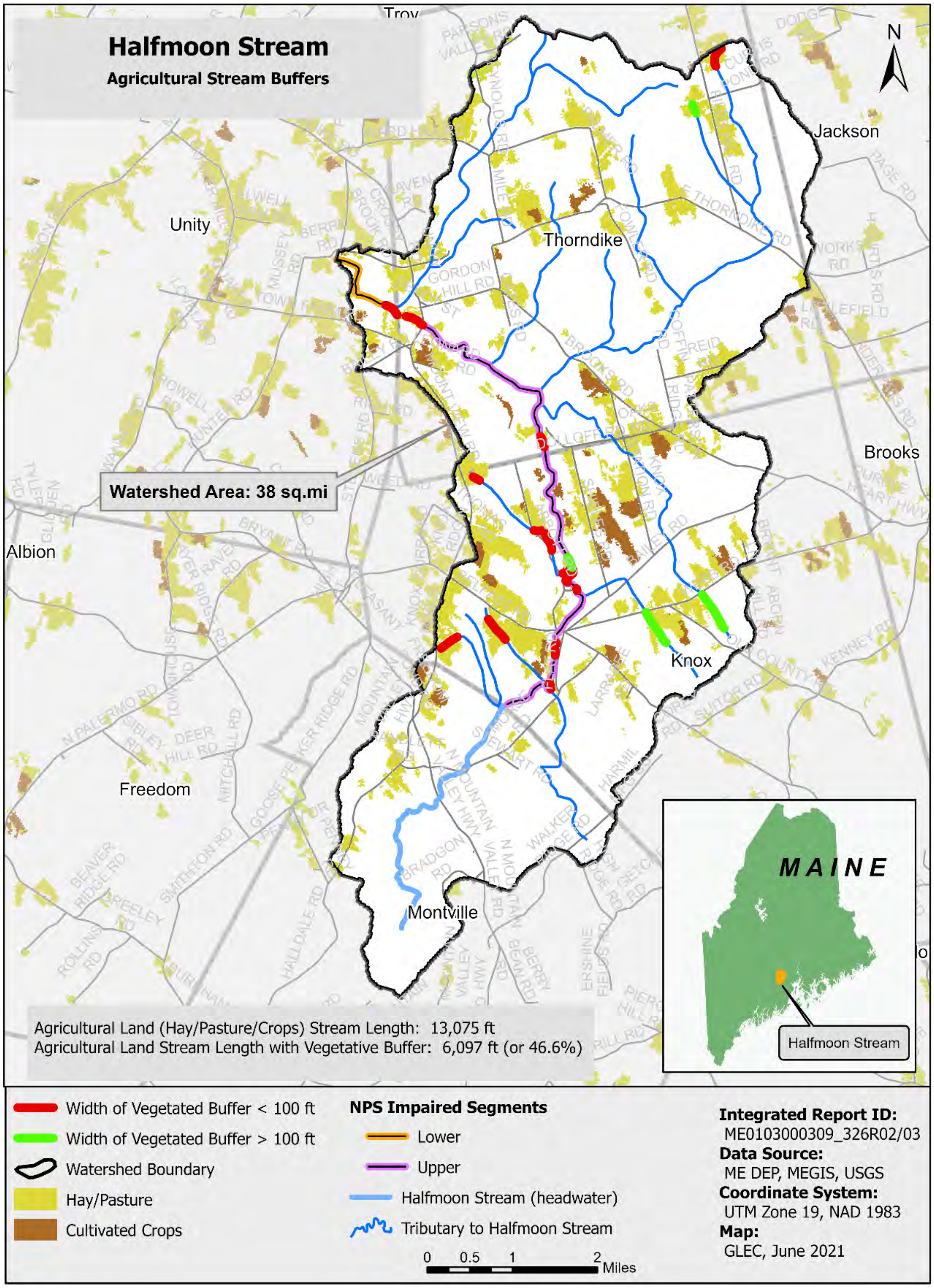


Figure 4: Agricultural Stream Buffers (from 2021) in the Halfmoon Stream Watershed

Sediment

Sediment loading in the Halfmoon Stream watershed is mainly derived from agricultural land which makes up almost 82% of the total sediment load from sources (Table 5 and Figure 5). Developed land contributes over 12% of the total source load. Of the entire watershed sediment load, stream bank erosion contributes 83.5%.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Halfmoon Stream* below for loading estimates that have been normalized by watershed area.

Table 5: Total Sediment Load by Source

Halfmoon Stream	Sediment (1000 kg/year)	Sediment (%)
Source Load		
Hay/Pasture	111.3	51.1%
Cropland	66.9	30.7%
Wooded Areas	4.1	1.9%
Wetlands	0.2	0.1%
Open Land	8.3	3.8%
Barren Areas	0.025	0.011%
Low-Density Mixed	5.7	2.6%
Medium-Density Mixed	7.1	3.3%
High-Density Mixed	0.9	0.4%
Low-Density Open Space	13.2	6.1%
Farm Animals	0	0
Septic Systems	0	0
Source Load Total:	**217.8**	**100%**
Pathway Load		
Stream Bank Erosion	1100.5	-
Subsurface Flow	0	-
Total Watershed Mass Load:	**1318**	

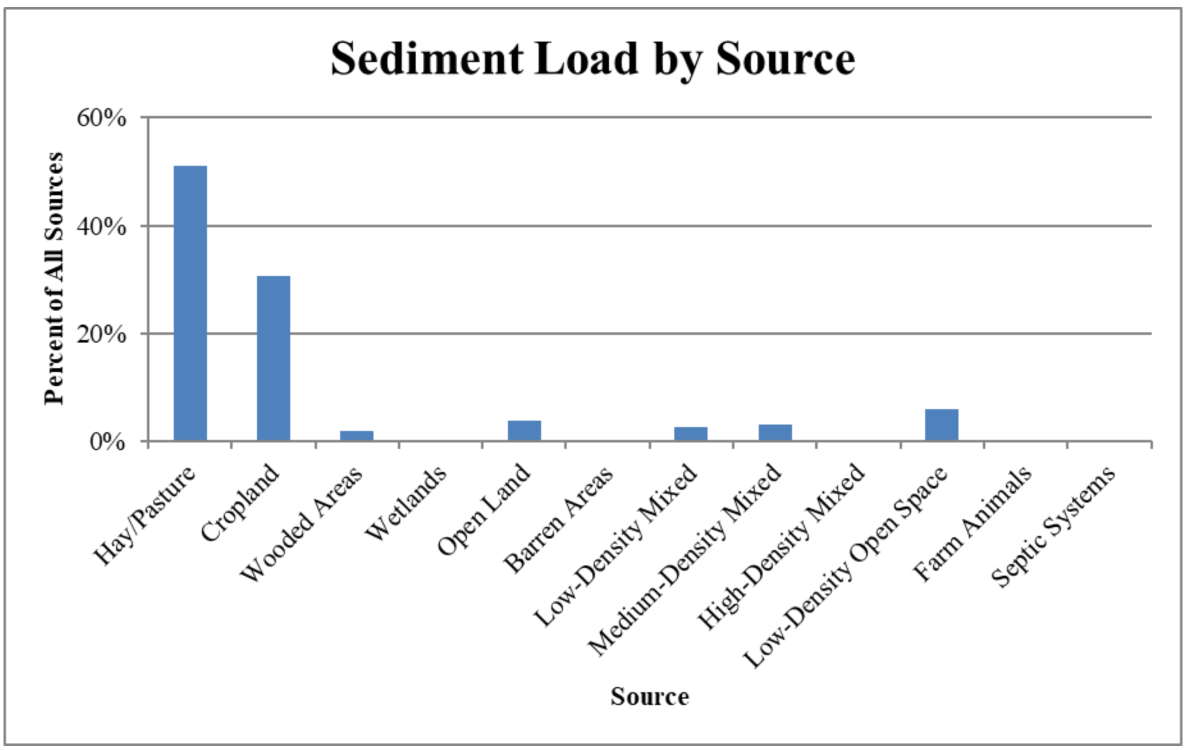


Figure 5: Total Sediment Load by Source in the Halfmoon Stream Watershed

Total Nitrogen

Nitrogen loading is attributed primarily to farm animals (22.6%) and hay/pasture land (26.7%) (Table 6 and Figure 6). Combined agricultural sources account for over 62% of the total nitrogen source load to Halfmoon Stream.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Halfmoon Stream* below for loading estimates that have been normalized by watershed area.

Table 6: Total Nitrogen Load by Source

Halfmoon Stream	Total N (kg/year)	Total N (%)
Source Load		
Hay/Pasture	2,012	26.7%
Cropland	993	13.2%
Wooded Areas	1,385	18.4%
Wetlands	237	3.1%
Open Land	431	5.7%
Barren Areas	19	0.3%
Low-Density Mixed	147	2.0%
Medium-Density Mixed	142	1.9%
High-Density Mixed	18	0.2%
Low-Density Open Space	339	4.5%
Farm Animals	1,701	22.6%
Septic Systems	111	1.5%
Source Load Total:	**7,536**	**100%**
Pathway Load		
Stream Bank Erosion	1,381	-
Subsurface Flow	14,501	-
Total Watershed Mass Load:	**23,417**	

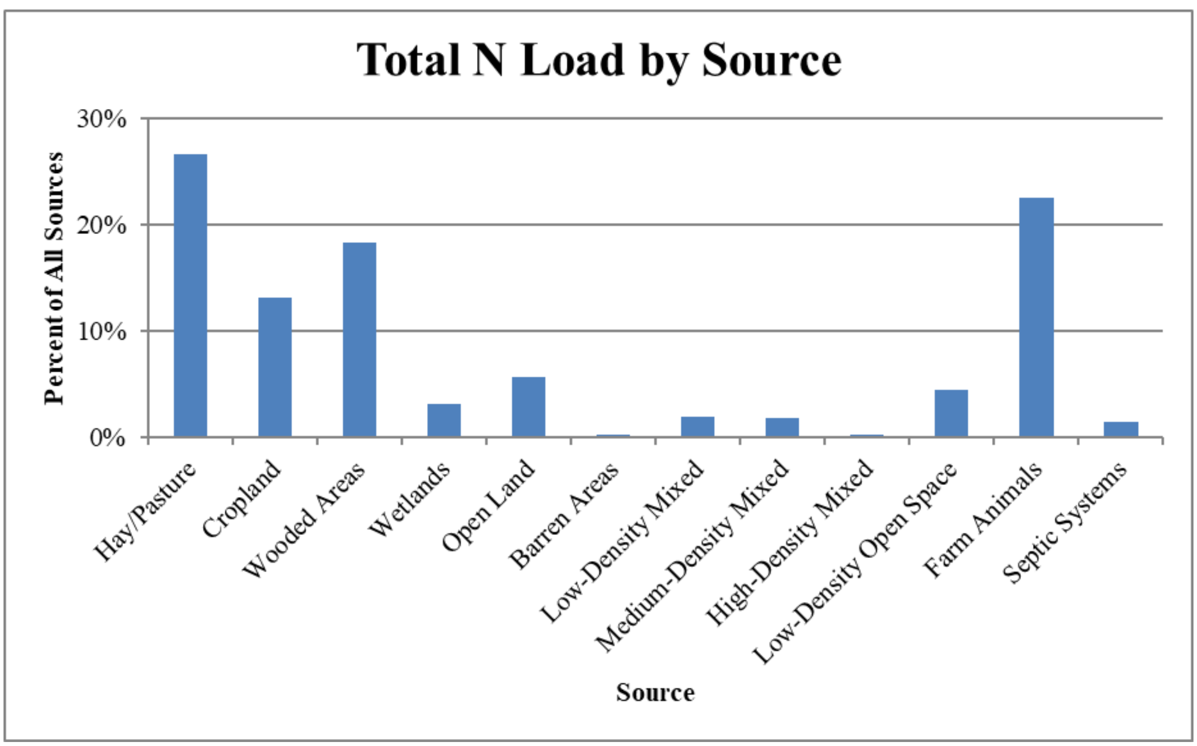


Figure 6: Total Nitrogen Load by Source in the Halfmoon Stream Watershed

Total Phosphorus

Phosphorus loading within the watershed is attributed primarily to hay/pasture land and farm animals with combined agricultural sources accounting for almost 88% of the total phosphorus load to Halfmoon Stream. Developed land only accounts for just under 5% of the source load. Phosphorus loads are presented in Table 7 and Figure 7.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Halfmoon Stream* below for loading estimates that have been normalized by watershed area.

Table 7: Total Phosphorus Load by Source

Halfmoon Stream	Total P (kg/year)	Total P (%)
Source Load		
Hay/Pasture	729.0	50.9%
Cropland	190.1	13.3%
Wooded Areas	76.4	5.3%
Wetlands	12.5	0.9%
Open Land	19.3	1.3%
Barren Areas	0.7	0.05%
Low-Density Mixed	15.6	1.1%
Medium-Density Mixed	14.3	1.0%
High-Density Mixed	1.8	0.1%
Low-Density Open Space	36.1	2.5%
Farm Animals	336.3	23.5%
Septic Systems	0	0
Source Load Total:	**1,432.1**	**100%**
Pathway Load		
Stream Bank Erosion	385.0	-
Subsurface Flow	505.6	-
Total Watershed Mass Load:	**2,323**	

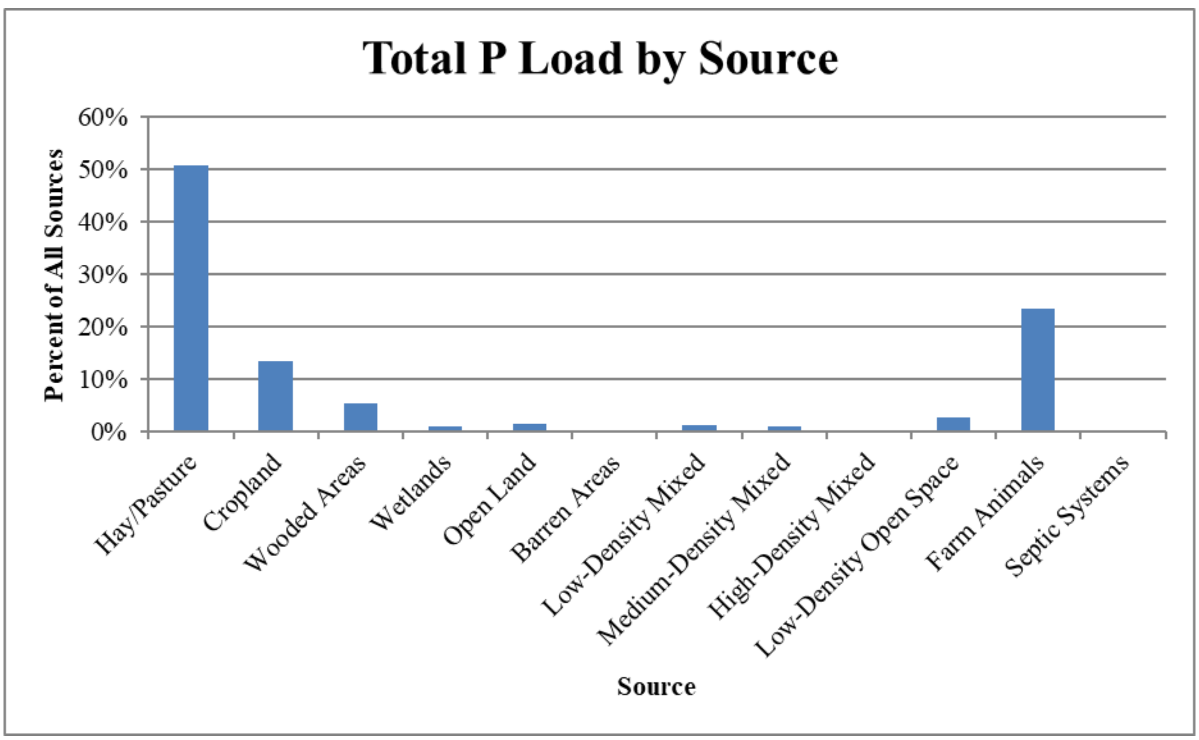


Figure 7: Total Phosphorus Load by Source in the Halfmoon Stream Watershed

TMDL: TARGET NUTRIENT AND SEDIMENT LEVELS FOR HALFMOON STREAM

The existing loads for nutrients and sediments in the impaired segment of Halfmoon Stream are listed in Table 8, along with the TMDL (the allowable load) which was calculated from the average loading estimates of five attainment watersheds throughout the state. Table 8 also shows required reductions (as a percent) for each of sediment, total N, and total P pollutants. Table 9 presents a more detailed view of the modeling results and calculations used to compute the existing loads in Table 8. An annual time frame provides a mechanism to address the daily and seasonal variability associated with nonpoint source loads.

Table 8: Halfmoon Stream Pollutant Loading Compared to TMDL Targets

Halfmoon Stream			
Pollutant Load	**Existing Load**	**TMDL**	**Reduction Required**
Total Annual Load per Unit Area		Attainment Streams	
Sediment (kg/ha/yr)	133.8	65.72	50.9%
Total N (kg/ha/yr)	2.38	2.46	None
Total P (kg/ha/yr)	0.24	0.16	32.2%

Future Loading

The prescribed reduction in pollutants discussed in this TMDL reflects reduction from estimated existing conditions. Expansion of agricultural activities in the watershed have the potential to increase runoff and associated pollutant loads to Halfmoon Stream. To ensure that the TMDL targets are attained, future agricultural activities will need to meet the TMDL targets. However, between 2012 to 2017 in Waldo County, the growth in agricultural lands was decreasing, with an 18.3% decrease in the total number of farms and a 5.4% decrease in total farm area. Yet no change in the average farm size occurred in this time period. These values are extracted from the most recent (2017) Census of Agriculture (USDA 2017). Human population in Waldo County increased by 2.31% from 2000 to 2019 (US Census 2020). Future activities and BMPs that achieve TMDL reductions are addressed below.

Next Steps

The use of agricultural and developed area Best Management Practices (BMP's) can reduce sources of polluted runoff in Halfmoon Stream. It is recommended that municipal officials in the Thorndike, Knox, and Unity villages, landowners, and conservation stakeholders work together to develop a watershed management plan to:

- Encourage greater citizen involvement through the development of a watershed coalition to ensure the long term protection of Halfmoon Stream;
- Run a "Hot-Spot Analysis" in *Model My Watershed* to determine sub-watershed locations of higher existing contributions of sediment and nutrients to the outlet of Halfmoon Stream watershed; then focus BMP mitigation in these hot-spot sub-areas of the watershed;
- Address existing nonpoint source problems in the Halfmoon Stream watershed by instituting BMPs where necessary; and

- Prevent <u>future</u> degradation of Halfmoon Stream through the development and/or strengthening of local Nutrient Management Ordinance.

Table 9: Annual Loads by Land Use, Other Sources, and Pathways for Halfmoon Stream Based on Modeling

Halfmoon Stream				
	Area (ha)	**Sediment** (1000 kg/yr)	**Total N** (kg/yr)	**Total P** (kg/yr)
Land Uses				
Hay/Pasture	1,175	111.3	2,012	729.0
Cropland	193	66.9	993	190.1
Wooded Areas	7,179	4.1	1,385	76.4
Wetlands	487	0.2	237	12.5
Open Land	305	8.3	431	19.3
Barren Areas	35	0.025	19	0.7
Low-Density Mixed	135	5.7	147	15.6
Medium-Density Mixed	31	7.1	142	14.3
High-Density Mixed	4	0.9	18	1.8
Low-Density Open Space	311	13.2	339	36.1
Total Area	9,855			
Other Sources				
Farm Animals		0.0	1,701	336.3
Septic Systems		0.0	111	0.0
Pathway Load				
Stream Bank Erosion		1100.5	1,381	385.0
Subsurface Flow		0.0	14,501	505.6
Total Annual Load		1,318	23,417	2,323
Total Annual Load per Unit Area		0.134	2.38	0.24
		1000 kg/ha/yr	kg/ha/yr	kg/ha/yr

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DRAFT TMDL SUMMARY

Inkhorn Brook

WATERSHED DESCRIPTION

This **TMDL** applies to a 4.32 mile section of Inkhorn Brook, located in the Town of Windham, Maine. The impaired segment of Inkhorn Brook begins in the northern portion of the watershed just north of agricultural land off of Craig Road. The stream flows south through a mixture of agriculture and forest, crossing Anderson Road and Batchelder Road. The stream turns southeast and passes under power lines, Aroostook Drive, Aspen Lane, and River Road in a predominantly residential area. The impaired segment of Inkhorn Brook then meets the Presumpscot River. The Inkhorn Brook watershed covers an area of 3.85 square miles. The majority of the watershed is located within the Town of Windham; however, small portions of the watershed lie within the surrounding town of Westbrook.

- Inkhorn Brook is on Maine’s 303(d) list of Impaired Streams as referenced in the 2016 Integrated Report (Maine DEP, 2018).
- The Inkhorn Brook watershed is predominately non-developed (72%). Forested areas (63%) within the watershed absorb and filter pollutants helping protect both water quality in the stream and stream channel stability. Wetlands (7.4%) also help filter nutrients.
- Non-forested areas within the watershed are predominantly agricultural (16%) and are located throughout the central portion of the watershed.
- Developed areas (12%) with impervious surfaces in close proximity to the stream may impact water quality.
- Runoff from agricultural land located throughout the central portion of watershed is likely the largest source of **nonpoint source (NPS) pollution** to Inkhorn Brook. Runoff from active hay lands and pasture can transport sediment, nitrogen and phosphorus to the stream.

Definitions

- ***Total Maximum Daily Load (TMDL)*** *represents the total amount of pollutants that a waterbody can receive and still meet water quality standards.*
- **Nonpoint Source Pollution** *refers to pollution that comes from many diffuse sources across the landscape, and are typically transported by rain or snowmelt runoff.*

Waterbody Facts

Segment ID: ME0106000103_607R07

Town: Windham, ME

County: Cumberland

Impaired Segment Length: 4.32 miles

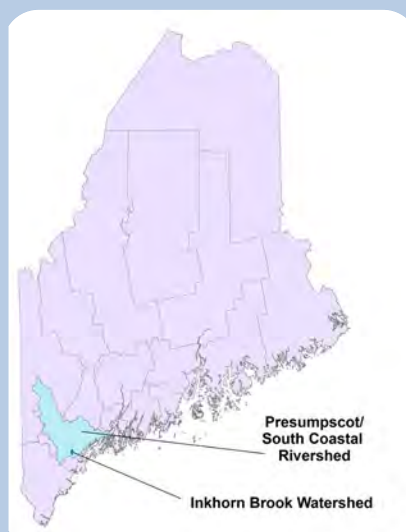
Classification: Class B

Direct Watershed: 3.9 mi^2 (2,464 acres)

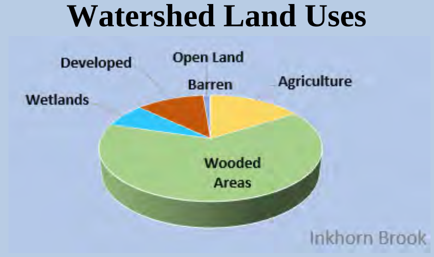
Impairment Listing Cause: Dissolved Oxygen

Watershed Agricultural Land Use: 16%

Major Drainage Basin: Presumpscot River



Watershed Land Uses



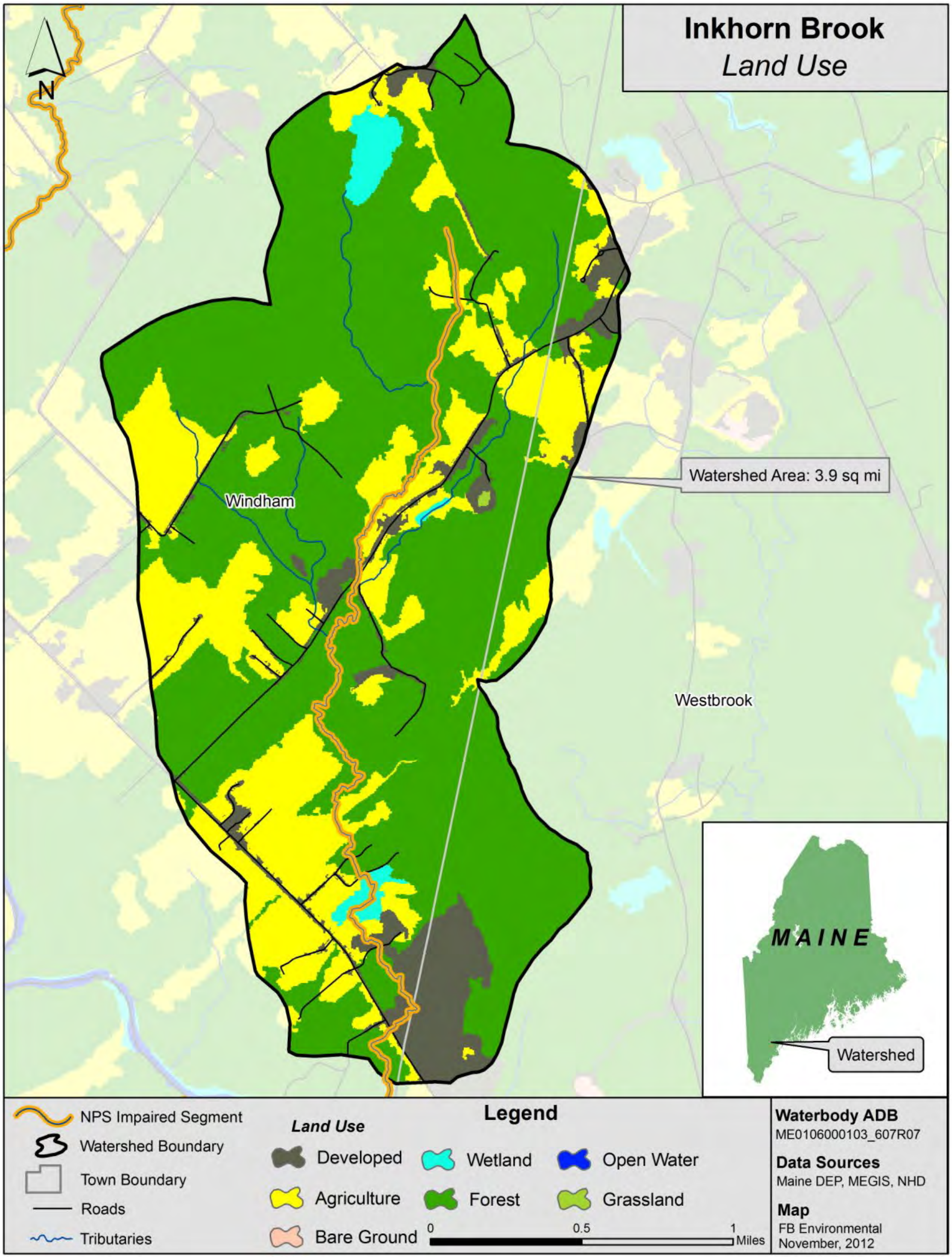


Figure 1: Land Use and Land Cover (from 2011) in the Inkhorn Brook Watershed

WHY IS A TMDL ASSESSMENT NEEDED?

Inkhorn Brook, a Class B freshwater stream, has been assessed by Maine DEP as not meeting water quality standards for the designated use of aquatic life, and placed on the 303(d) list of impaired waters under the Clean Water Act. The Clean Water Act requires that all 303(d)-listed waters undergo a TMDL assessment that describes the impairments and establishes a target to guide the measures needed to restore water quality. The goal is for all waterbodies to comply with state water quality standards.

Inkhorn Brook *near the River Road crossing – Station RIK05. Photo: FB Environmental*

Agricultural land in the Inkhorn Brook watershed comprises 16% of total watershed land area. This is 1.3 times the area of developed land at 12% of the land area. Twenty-two percent of the impaired segment length passes through agricultural land (Figure 1). Agriculture is therefore likely to be the largest contributor of sediment and nutrient enrichment to the stream. A large livestock operation/ animal testing laboratory was observed on Anderson Road. Many livestock were observed on the property and the smell of manure was noted. This site may be a hotspot for nonpoint source pollution. The close proximity of many agricultural lands to the stream further increases the likelihood that nutrients from disturbed soils, manure, and fertilizers will reach the stream.

WATER QUALITY DATA ANALYSIS

Maine DEP uses a variety of data types to measure the ability of a stream to adequately support aquatic life, including; dissolved oxygen, benthic macroinvertebrates, and periphyton (algae). For benthic macroinvertebrates, DEP makes aquatic life use determinations using a statistical model that incorporates 30 variables of data collected from rivers and streams, including the richness and abundance of streambed organisms, to determine the probability of a sample meeting Class A, B, or C conditions. Biologists use the model results and supporting information to determine if samples comply with the numeric aquatic life criteria of the class assigned to the stream or river (Davies and Tsomides, 2002). Maine DEP uses an analogous model to aid in the assessment of algal communities but makes aquatic life use determinations based on narrative standards.

The aquatic life impairment in Inkhorn Brook is based on historic dissolved oxygen data. Additionally, dissolved oxygen data collected at stations RIK05 in 2011 and RIK 25 in 2007 corroborates the impairment.

TMDL ASSESSMENT APPROACH: NUTRIENT AND SEDIMENT MODELING OF IMPAIRED AND ATTAINMENT STREAMS

NPS pollution is difficult to measure directly, because it comes from many diffuse sources spread across the landscape. For this reason, an online nutrient loading model, *Model My Watershed* (v. 1.32.0), was used to estimate the sources of pollution based on well-established hydrological equations (Stroud Water Research Center 2017). *Model My Watershed* makes use of the GWLF-enhanced model engine. The model incorporates detailed maps of soil, land use, and slope, daily weather and localized weather data (from the period 2009-2020), and direct observations of agriculture and other land uses within the watershed. *Model*

My Watershed is derived from its parent MapShed developed by Evans and Corradini (2012). *Model My Watershed* replaced MapShed in 2017-2018.

The nutrient loading estimates for the impaired stream were compared to similar estimates for five non-impaired (attainment) streams of similar watershed land uses across the state. The TMDL for the impaired stream was set as the mean nutrient loading estimate of these attainment stream watersheds, and units of mass per unit watershed area per year (kg/ha/year) were used. The difference in loading estimates between the impaired and attainment watersheds represents the percent reduction in nutrient loading required under this TMDL. The attainment streams and their nutrient and sediment loading estimates and TMDL are presented below in Table 1.

Table 1: Numeric Targets for Pollutant Loading Based on Model My Watershed Outputs (2021) for Attainment Streams

Attainment Streams	Town	Total P Load (kg/ha/yr)	Total N Load (kg/ha/yr)	Sediment Load (kg/ha/yr)
Footman Brook	Exeter	0.17	1.73	35.2
Martin Stream	Fairfield	0.13	2.98	57.9
Moose Brook	Houlton	0.18	1.59	48.5
Upper Kenduskeag Stream	Corinth	0.16	1.72	100.5
Upper Pleasant River	Gray	0.16	4.26	86.5
Total Maximum Daily Load		**0.16**	**2.46**	**65.7**

RAPID WATERSHED ASSESSMENT

Habitat Assessment

A habitat assessment survey was conducted on both the impaired and attainment stream. The assessment approach is based on the *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (Barbour et al. 1999), which integrates various parameters relating to the structure of physical habitat. The habitat assessments include a general description of the site and physical characterization and visual assessment of in-stream and riparian habitat quality.

Chinese Mystery Snails found at the sample site RIK05.

Photo: FB Environmental

Based on rapid bioassessment protocols for low gradient streams, Inkhorn Brook received a score of 148 out of a total 200 for quality of habitat. Higher scores indicate better habitat.

Habitat assessments were conducted on a relatively short sample reach (about 100-200 meters for a typical small stream) in 2012 near the most downstream Maine DEP sample station in the watershed. For both impaired and attainment streams, the assessment location was usually near a road crossing for ease of access. In the Inkhorn Brook watershed, the downstream sample station was located at the River Road stream crossing and DEP sample station RIK05. The immediate surrounding riparian zone was dominated by alder, birch and ash trees though an agricultural field and an old golf course are located nearby upstream of the road crossing. Chinese Mystery snails were heavily concentrated throughout the reach, and water was documented as very turbid. A sandbar formation was observed with significant sand and fine sediment deposits.

Figure 2 (right) shows the range of habitat assessment scores for all attainment and impaired streams, as well as for Inkhorn Brook. Though these scores show that habitat is an issue in the impairment of Inkhorn Brook, it is important to look for other potential sources within the watershed leading to impairment. Consideration should be given to major "hot spots" in the Inkhorn Brook watershed as potential sources of NPS pollution contributing to the water quality impairment.

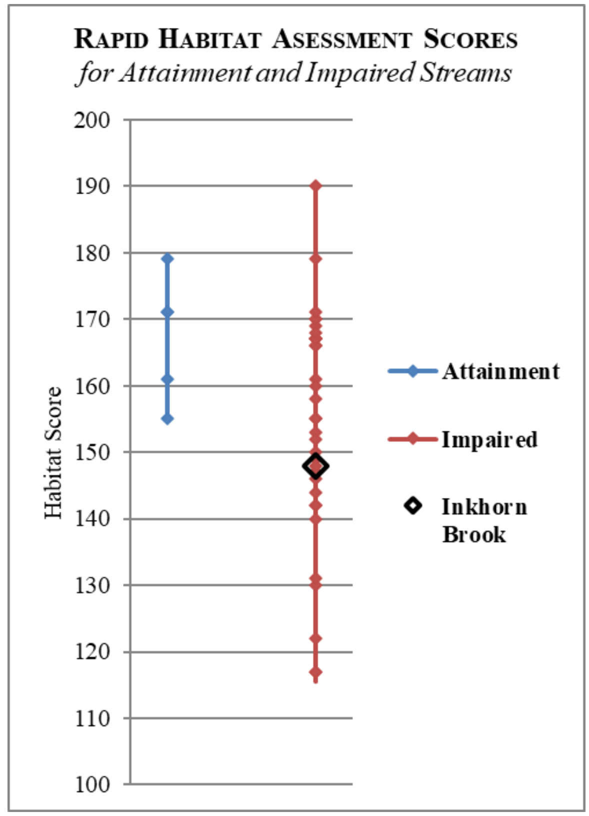


Figure 2: Habitat Assessment Scores for Inkhorn Brook (2012) Compared to Region

Pollution Source Identification

Pollution source identification assessments were conducted for Inkhorn Brook (impaired) and all attainment streams. The source identification work is based on an abbreviated version of the Center for Watershed Protection's Unified Subwatershed and Site Reconnaissance method (Wright, et al. 2005). The abbreviated method includes both a desktop and field component. The desktop assessment consists of generating and reviewing maps of the watershed boundary, roads, land use and satellite imagery, and then identifying potential NPS pollution locations, such as road crossings, agricultural fields, and large areas of bare soil. When available, multiple sources of satellite imagery were reviewed. Occasionally, the high resolution of the imagery allowed for observations of livestock, row crops, eroding stream banks, sediment laden water, junkyards, and other potential NPS concerns that could affect stream quality. As many potential pollution sources as possible were visited, assessed and documented in the field. Field visits were limited to NPS sites that were visible from roads or a short walk from a roadway. Neighborhoods were assessed for NPS pollution at the whole neighborhood level including streets and storm drains (where applicable). The assessment does not include a scoring component, but does include a detailed summary of findings and a map indicating documented NPS sites throughout the watershed.

The watershed source assessment for Inkhorn Brook was completed in July 2012. In-field observations of erosion, lack of vegetated stream buffer, extensive impervious surfaces, high-density neighborhoods and agricultural activities were documented throughout the watershed (Table 2, Figure 3).

Table 2: Potential Pollution Source ID Assessment (2012) for the Inkhorn Brook Watershed

Potential Source			Notes
ID #	**Location**	**Type**	
1	River Road	Road Crossing	• Sample reach location. • Invasive snail species concentrated throughout reach.
2	River Road	Golf Course	• Golf course has been closed for some time; lawns seem to be hayed/maintained.
4	Jacques Lane & Aroostook Lane	Road Crossing	• Erosion at road crossing on Jacques Lane.
5	Hereford Lane Phoenix Lane Elliott Drive	Agriculture	• Active hay fields.
6	Anderson Road/ Batchelder Road	Road Crossing	• Fairly new culvert at Anderson Road crossing. • Considerable amount of sediment deposited into stream from Batchelder Road (unpaved road). • No buffer between road and stream.
8	Anderson Road	Agriculture	• Miniature swine breeder for medical research; sheep were observed in stalls on east side of Anderson Road. Facility is an enclosed breeding operation (no grazing). • Estimated 150 animals located here - several manure piles. • Impounded tributary to east of property and Inkhorn Brook to the west.
10	Highland Cliff Road	Agriculture	• Active hay fields.
13	Batchelder Road	Agriculture/ Lot clearing	• Hay fields seem inactive. • Active lot clearing along Batchelder Road – exposed soils.
18	Craig Road off Anderson Road	Agriculture	• Hay fields to the east; no access to the west.

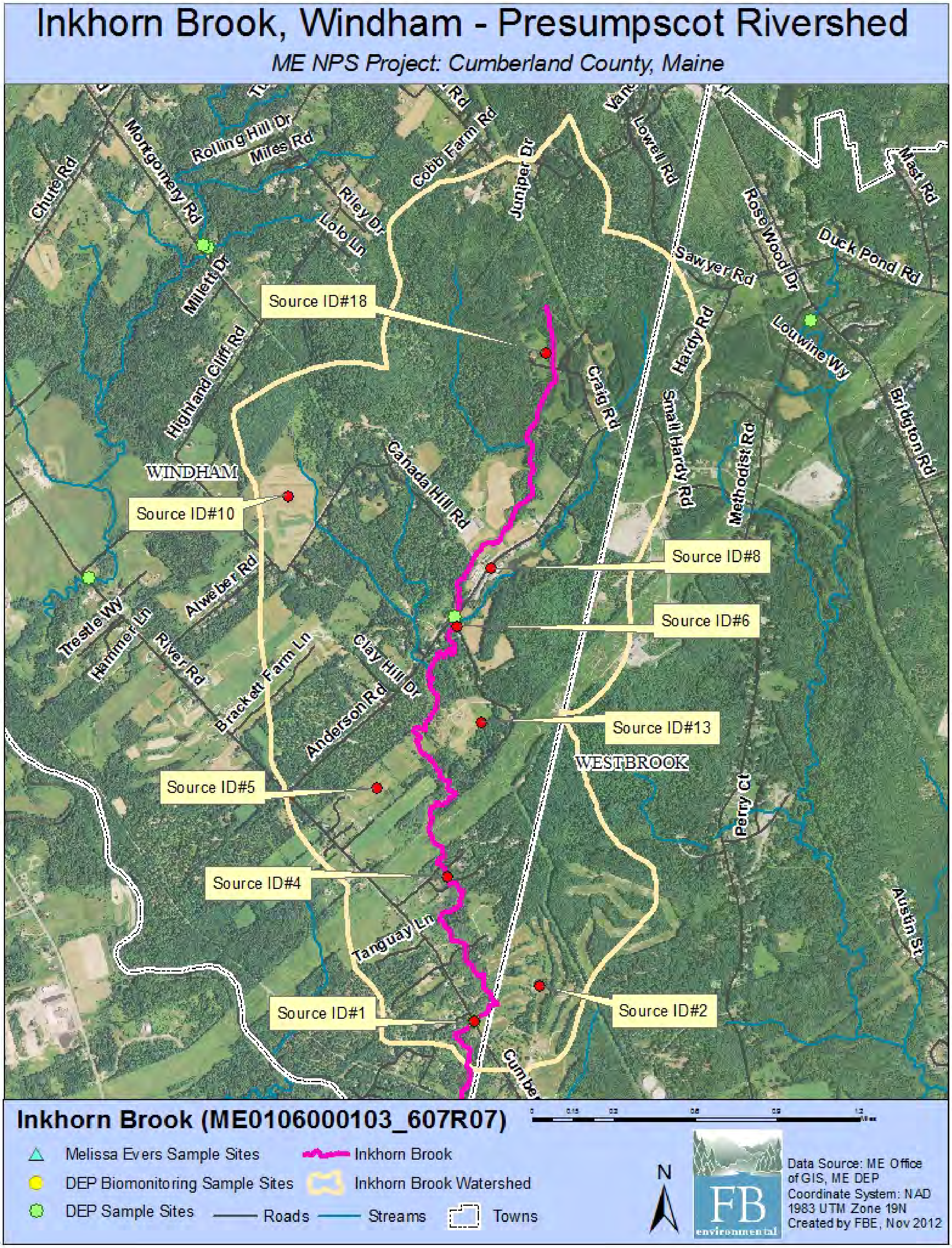


Figure 3: Aerial Photo of Potential Source ID Locations (identified in 2012) in the Inkhorn Brook Watershed

NUTRIENT AND SEDIMENT LOADING – *MODEL MY WATERSHED* ANALYSIS

The *Model My Watershed* model was used to estimate stream loading of total phosphorus, total nitrogen, and sediment in Inkhorn Brook watershed. The model estimated nutrient loads over a 12-year period (2009-2020), which was determined by local (Portland Jetport USW00014764) weather data inserted into *Model My Watershed*. This extended period captures a recent but wide range of hydrologic conditions to account for variations in nutrient and sediment loading over time. Loads for the attainment watersheds (five total; Table 1) were computed using the same model with the same recent inputs (i.e., regional weather, 2016 land use and land cover, 2016 wetland extent, and BMPs similar to the impaired watersheds).

Many quality assured and regionally calibrated input parameters are provided with *Model My Watershed*. However, several updates to some of the default parameters were made in this TMDL effort, and namely more recent land use/cover using **MRLC-NLCD 2016** [1], more recent and local weather (precipitation and temperature) data (as described above), and more regional estimates of Best Management Practices (BMPs; see ensuing discussion). Because land use/cover is more recent, the estimated filtration fraction of wetland and open water and the amount of stream buffer in agricultural land should be more accurate. It is also worth noting that improved classification algorithms were employed by MLRC in the NCLD 2016 and these new algorithms were used in the revisions of all previous NLCD versions (including the first version in 2001).

Livestock Estimates

Livestock waste contains nutrients which can cause water quality impairment. The nutrient loading model considers numbers and types of animals. Table 3 (right) provides livestock (numbers of animals) in the watershed based on the USDA National Agricultural Statistics Service (NASS) estimation for 2012. Some of these totals were modified by direct observations made in the watershed in the 2012 survey. To generate watershed-based livestock counts, NASS county-based livestock totals are converted to a per unit area (based on the total area of the county). The unit area amount is then multiplied by the total watershed area to derive a watershed total count (as seen in Table 3).

Table 3: Livestock Estimates in the Inkhorn Brook Watershed

Type	Inkhorn Brook
Dairy Cows	3
Beef Cows	3
Broilers	4
Layers	18
Hogs/Swine	150
Sheep	20
Horses	6
Turkeys	1
Other	--
Total	**205**

The Inkhorn Brook watershed is predominantly forested, although it also has significant agricultural land in close proximity to the Brook. Active hay fields were most common throughout the watershed along with a Christmas tree farm on the western edge located on Brackett Farm Lane. Livestock were

[1] MRLC-NLCD 2016 : Multi-Resolution Land Characteristics – National Land Cover Dataset (version 2016) provided by the MRLC Consortium (Jin et al. 2019).

observed at a small swine breeding facility on Anderson Road, very close to both Inkhorn Brook and an impounded tributary on the east side of the facility. It appeared the operation was conducted entirely indoors without pig grazing. About 20 sheep were observed on this property to the east in outside stalls. Large manure piles were also visible from Anderson Road. The tributary impoundment behind this facility is visible in an aerial photograph (above left).

Vegetated Stream Buffer in Agricultural Areas

Vegetated stream buffers are areas of trees, shrubs, and/or grasses adjacent to streams, lakes, ponds or wetlands which provide nutrient loading attenuation (Evans and Corradini 2012). *Model My Watershed* considers natural vegetated stream buffers within agricultural land areas as providing nutrient load attenuation. A width of approximately 98 feet (30 m) on one side of a stream is required to be considered a streamside buffer per the *Model My Watershed* technical manual (Stroud Water Research Center 2017). Analysis of recent aerial photos was used to estimate the number of agricultural land stream miles with and without vegetative buffers, and these estimates were directly entered into the model.

Table 4: Summary of Vegetated Buffers in Agricultural Areas (2012)

Inkhorn Brook
• Agricultural Land Stream Length = 1.2 mi • Agricultural Land Stream Length with Buffer = 0.5 mi (or 42% of total agricultural land stream length) • Percentage of total stream length flowing through non-buffered agricultural land = 11.1%

Inkhorn Brook is a 4.32 mile-long impaired segment as listed by Maine DEP. As modeled, the total stream miles (including tributaries) within the watershed was calculated as 6.3 miles.
Of this total, 1.2 stream miles are located within agricultural areas and 0.5 miles of that area *appear* to have a 98 foot or greater vegetated buffer (Table 4, Figure 4). From a watershed perspective, this equates to 0.7 miles or 11.1% of the total stream length running through agricultural land with less than a 98 foot buffer. By contrast, for attainment stream watersheds, the percentage of total stream miles running through agricultural land without a 75 foot vegetated buffer ranged from 0% to 3.9% with an average of 1.3%. Note, a minimum vegetated buffer width of *75 feet* was used in an earlier (2012) effort to produce Figure 4 shown here. Differences in stream length estimates using a 98-foot or 75-foot buffer were practically insignificant.

Home Septic System Loads

Loads for "normally functioning" septic systems are calculated in *Model My Watershed* using an estimate of the average number of persons per acre in "Low-Density Mixed" areas. In these areas, it is assumed that the populations therein are served by septic systems rather than centralized sewage systems. All homes in such areas are assumed to be connected to "normally functioning" systems rather than those that experience "surface breakouts" (surface failures), "short-circuiting" to underlying groundwater (subsurface failures), or have direct conduits to nearby water bodies. Non-functioning systems would be modeled with a higher load contribution to the waterbody.

Best Management Practices (BMPs)

Best management practices (BMPs) are typically instituted to reduce the loading of sediment and nutrients from upland (i.e., non-point) sources. Ideally, information on BMPs for a specific watershed from local and regional sources would improve this component of the water quality model. Maine DEP sought information on BMP use in early 2021 from local, regional, and state agricultural agencies for rural BMPs and from nearby municipalities for urban BMPs. Very little to no information was returned in the solicitation. Hence, estimates for typical New England watersheds were derived from information available from Vermont. An upper limit of BMP use was garnered from watersheds entering the Chesapeake Bay where BMP use is intensive.

Four agricultural BMPs were used in this modeling effort and in the following manner:

- *Cover Crops:* Cover crops are the use annual or perennial crops to protect soil from erosion during time periods between harvesting and planting of the primary crop. The percent of cropland area in a cover crop BMP deployed was estimated at 25% and selected as the low end of the range (25 to 30 percent) expected for cropland in New England. This value was assigned to the five attainment watersheds.
- *Conservation Tillage:* Conservation tillage is any kind of system that leaves at least 30% of the soil surface covered with crop residue after planting. This reduces soil erosion and runoff. This BMP was estimated to occur in 25% of cropland. This value was assigned to the five attainment watersheds.
- *Strip Cropping / Contour Farming:* This BMP involves tilling, planting and harvesting perpendicular to the gradient of a hill or slope using high levels of plant residue to reduce soil erosion from runoff. Both interview sources suggest this practice is minimal to non-existent for New England watersheds. Hence, no BMP of this type was used in this modeling effort. This value was assigned to the five attainment watersheds.
- *Grazing Land Management:* This BMP consists of ensuring adequate vegetation cover on grazed lands to prevent soil erosion from overgrazing or other forms of over-use. This usually employs a rotational grazing system where hays or legumes are planted for feed and livestock is rotated through several fenced pastures. Both interview sources were not aware of this practice being active and is likely minimal for New England watersheds. Hence, no BMP of this type was used in this modeling effort for both impaired and attaining watersheds.

Note that other agricultural and development BMPs likely exist in the watershed but their location and type were not available in a watershed-wide format that is necessary to include in the model. Agricultural BMPs recommended by Maine DEP to reduce sediment and nutrient loads include vegetated buffers, covered manure storage facilities, and stream exclusion fencing. BMPs for developed areas recommended by the Maine DEP include vegetated buffers, stormwater BMPs, and minimization of impervious cover.

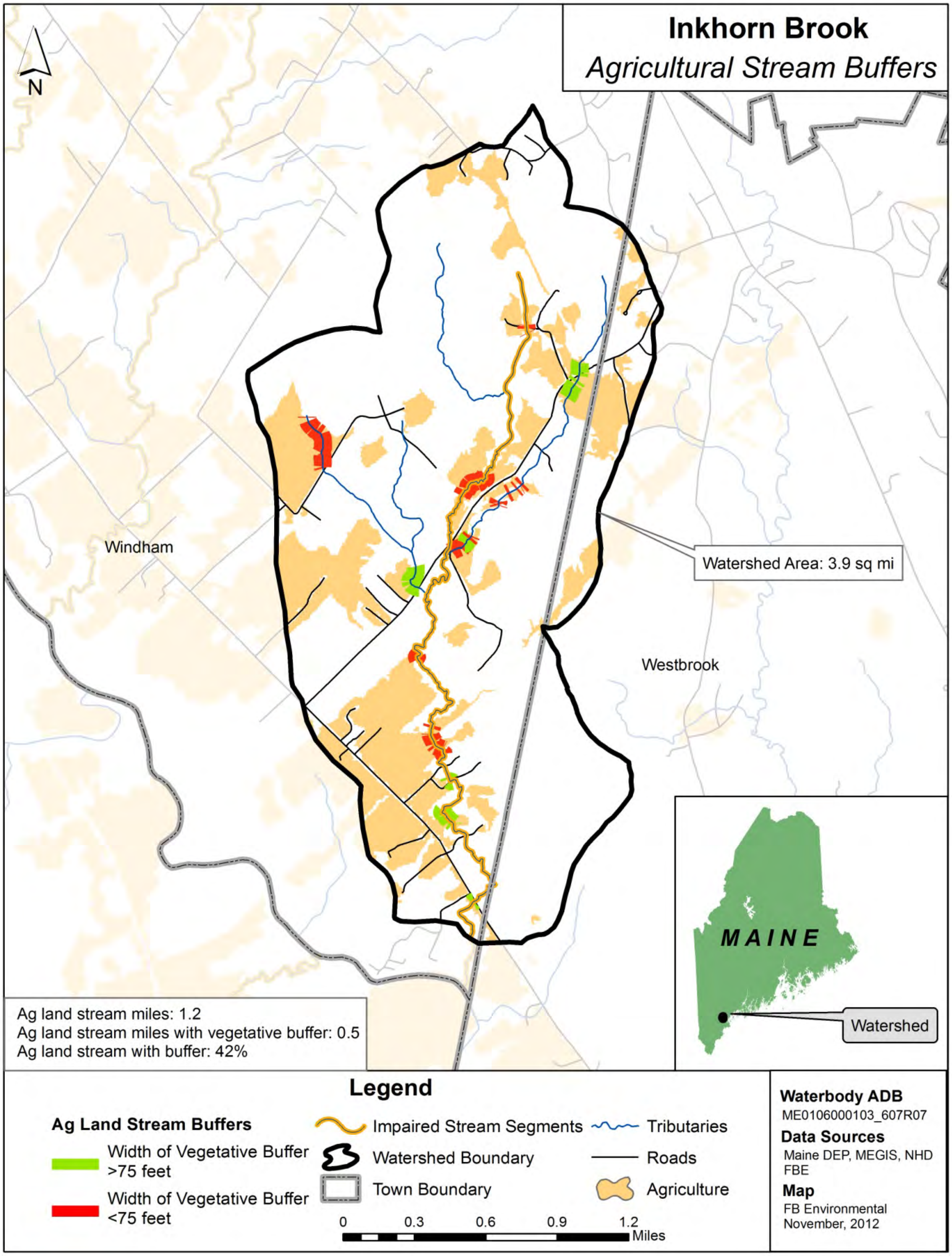


Figure 4: Agricultural Stream Buffers (from 2012) in the Inkhorn Brook Watershed

Pollutant Load Attenuation by Lakes, Ponds and Wetlands

Depositional environments such as lakes, ponds, and wetlands can attenuate watershed sediment and nutrient loading. This information is entered into the nutrient loading model by a simple percentage of watershed area draining to a lake, pond, or wetland. The Inkhorn Brook watershed is 7.5% wetland and open water, per the 2016 NLCD land use/cover. There are a few wetlands that surround tributaries throughout the watershed. It is estimated that 15% of land area within the watershed drains to wetlands and open water. The percent of watershed draining to a wetland in the attainment watersheds, based on the 2021 analysis, ranged from 26 to 58 percent, with an average of 40%.

NUTRIENT AND SEDIMENT MODELING RESULTS

Selected results from the watershed loading model are presented here. The TMDL itself is expressed in units of kilograms per hectare per year. The additional results shown below assist in better understanding the likely sources of pollution. The model results for Inkhorn Brook watershed indicate significant reductions of phosphorus and sediment and a minor reduction of nitrogen are needed to improve water quality. Below, loading for nitrogen, phosphorus and sediment are discussed individually.

There are two categories of loads – sources and pathways. Sources are determined by land use/cover and the overland flow they generate, livestock counts by animal type, and home sewage treatment systems in developed areas. Pathways represent additional loads derived from subsurface flow and streambank erosion. Subsurface loads are calculated using dissolved N and P coefficients for shallow groundwater and are mainly derived from atmospheric inputs. Sediment and nutrient loads produced by eroding streambanks are estimated using an approach developed by Evans et al. (2003). This pathway is comprised of loads originating from five sources, and listed in order of decreasing importance: amount of developed land area, soil erodibility (K-factor), density of livestock, runoff curve number, and topographic slope. For any given model run, the amount of developed land in the watershed is responsible for just over 72% of the total streambank load, whereas soil erodibility and animal density are responsible for 21% and 7% of the total streambank load, respectively.

Sediment

Aside from stream bank erosion which contributes 60% of the total sediment load, the major source load in Inkhorn Brook watershed originates from hay/pasture land (84.2% of total sources). Residential sources contribute 10.5% of the source load.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient and Sediment Levels for Inkhorn Brook* below for loading estimates that have been normalized by watershed area.

Table 5: Total Sediment Load by Source

Inkhorn	Sediment (1000 kg/year)	Sediment (%)
Source Load		
Hay/Pasture	49.7	84.2%
Cropland	0	0
Wooded Areas	2.0	3.5%
Wetlands	0.2	0.4%
Open Land	0.8	1.4%
Barren Areas	0.002	0.003%
Low-Density Mixed	1.5	2.5%
Medium-Density Mixed	0.7	1.2%
High-Density Mixed	0.2	0.3%
Low-Density Open Space	3.8	6.5%
Farm Animals	0	0
Septic Systems	0	0
Source Load Total:	**59.0**	**100%**
Pathway Load		
Stream Bank Erosion	88.3	-
Subsurface Flow	0	-
Total Watershed Mass Load:	**147**	

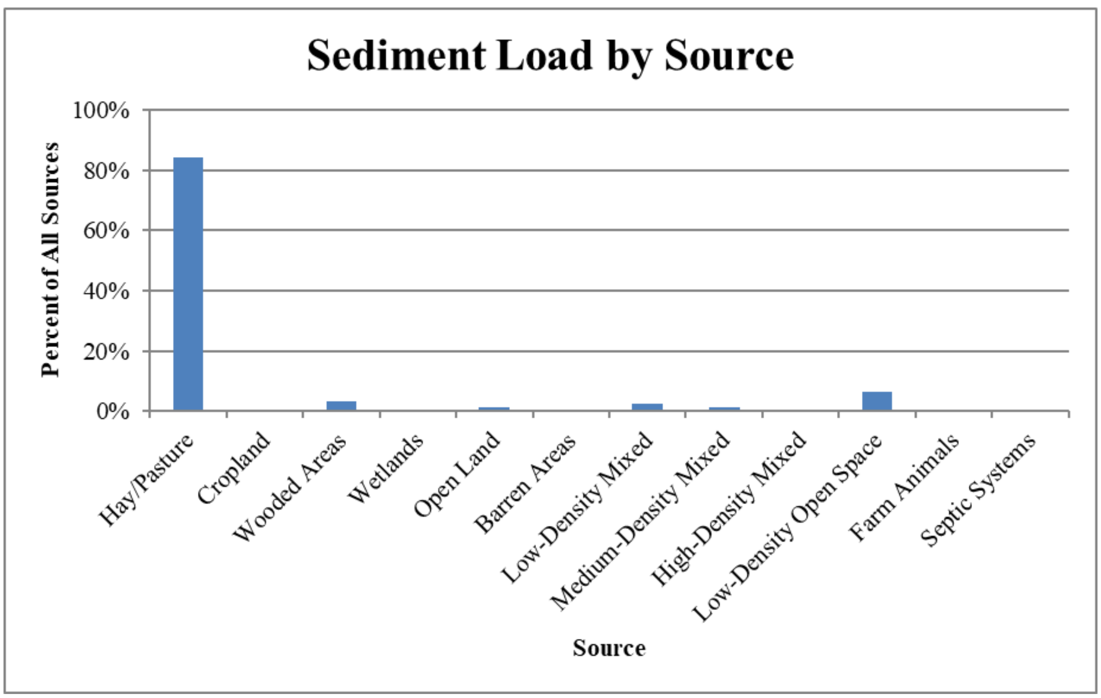


Figure 5: Total Sediment Load by Source in the Inkhorn Brook Watershed

Total Nitrogen

Table 6 and Figure 6 (below) show the estimated total nitrogen load, in terms of mass and percent of total by source, in the Inkhorn Brook watershed. Hay and pasture lands are the largest source of nitrogen loading contributing a little over 42% of the source load of total N. Livestock contributes about 17.6% of the source load. Residential areas combined (including home septic systems) contribute 15.1% of the source load. Lastly, wooded areas and wetlands contribute 22.4% of the source load.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient and Sediment Levels for Inkhorn Brook* below for loading estimates that have been normalized by watershed area.

Table 6: Total Nitrogen Load by Source

Inkhorn	Total N (kg/year)	Total N (%)
Source Load		
Hay/Pasture	464	42.3%
Cropland	0	0
Wooded Areas	193	17.6%
Wetlands	52	4.8%
Open Land	27	2.4%
Barren Areas	1	0.1%
Low-Density Mixed	37	3.4%
Medium-Density Mixed	16	1.4%
High-Density Mixed	4	0.4%
Low-Density Open Space	98	8.9%
Farm Animals	193	17.6%
Septic Systems	11	1.0%
Source Load Total:	**1,097**	**100%**
Pathway Load		
Stream Bank Erosion	82	-
Subsurface Flow	1,368	-
Total Watershed Mass Load:	**2,547**	

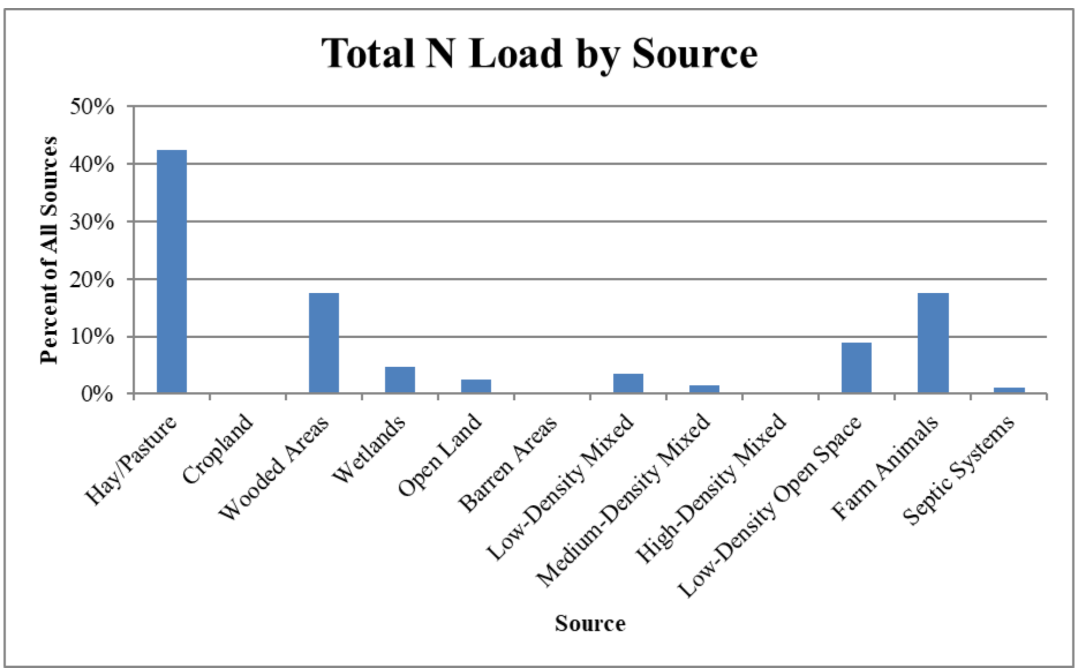


Figure 6: Total Nitrogen Load by Source in the Inkhorn Brook Watershed

Total Phosphorus

Table 7 and Figure 7 (below) show the estimated total phosphorus load in terms of mass and percent of total by source, in the Inkhorn Brook watershed. Hay and pasture lands are the largest source of phosphorus loading contributing a little over 57% of the source load. Farm animals contribute over 28% of the source load of total P. Residential areas combined contribute only 7.6% of the source load. Stream bank erosion contributes 6.2% of the total watershed P load.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient and Sediment Levels for Inkhorn Brook* below for loading estimates that have been normalized by watershed area.

Table 7: Total Phosphorus Load by Source

Inkhorn	Total P (kg/year)	Total P (%)
Source Load		
Hay/Pasture	122.8	57.1%
Cropland	0	0
Wooded Areas	11.2	5.2%
Wetlands	2.8	1.3%
Open Land	1.2	0.6%
Barren Areas	0	0
Low-Density Mixed	4.0	1.9%
Medium-Density Mixed	1.6	0.7%
High-Density Mixed	0.4	0.2%
Low-Density Open Space	10.4	4.8%
Farm Animals	60.8	28.3%
Septic Systems	0	0
Source Load Total:	**215.2**	**100%**
Pathway Load		
Stream Bank Erosion	18.0	-
Subsurface Flow	54.1	-
Total Watershed Mass Load:	**287**	

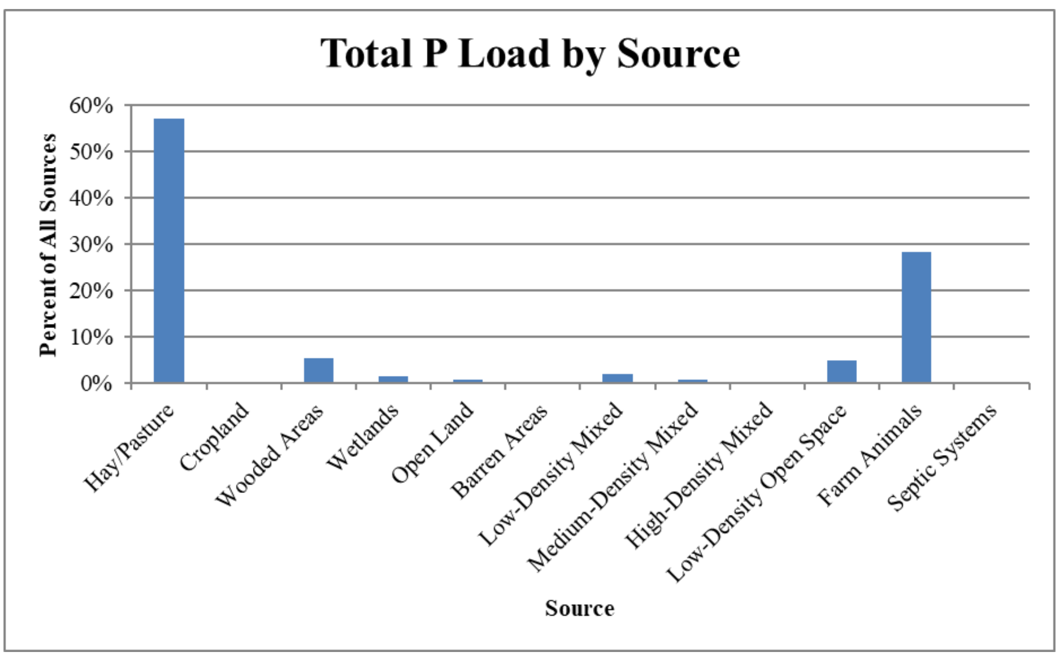


Figure 7: Total Phosphorus Load by Source in the Inkhorn Brook Watershed

TMDL: TARGET NUTRIENT AND SEDIMENT LEVELS FOR INKHORN BROOK

The existing loads for nutrients and sediments in the impaired segment of Inkhorn Brook are listed in Table 8, along with the TMDL (the allowable load) which was calculated from the average loading estimates of five attainment watersheds throughout the state. Table 8 also shows required reductions (as a percent) for each of sediment, total N, and total P pollutants. Table 9 presents a more detailed view of the modeling results and calculations used to compute the existing loads in Table 8. An annual time frame provides a mechanism to address the daily and seasonal variability associated with nonpoint source loads.

Table 8: Inkhorn Brook Pollutant Loading Compared to TMDL Targets

Inkhorn Brook			
Pollutant Load	**Existing Load**	**TMDL**	**Reduction Required**
Total Annual Load per Unit Area		Attainment Streams	
Sediment (kg/ha/yr)	148.1	65.72	55.6%
Total N (kg/ha/yr)	2.56	2.46	4.1%
Total P (kg/ha/yr)	0.29	0.16	44.7%

Future Loading

The prescribed reduction in pollutants discussed in this TMDL reflects reduction from estimated existing conditions. Expansion of agricultural and development activities in the watershed have the potential to increase runoff and associated pollutant loads to Inkhorn Brook. To ensure that the TMDL targets are attained, future agricultural activities will need to meet the TMDL targets. Between 2012 to 2017 in Cumberland County, the growth in agricultural lands was decreasing, with a 7% decrease in the total number of farms and a 20.2% decrease in total farm area. Average farm size has also declined significantly (13.8%) during this time period. These values are extracted from the most recent (2017) Census of Agriculture (USDA 2017). Human population in Cumberland County increased by 4.8% from 2000 to 2019 (US Census 2020). Future activities and BMPs that achieve TMDL reductions are addressed below.

Next Steps

The use of agricultural and developed area BMP's can reduce sources of polluted runoff in Inkhorn Brook. It is recommended that municipal officials, landowners, and conservation stakeholders in Windham and Westbrook work together to develop a watershed management plan to:

- Encourage greater citizen involvement through the development of a watershed coalition to ensure the long term protection of Inkhorn Brook;
- Run a "Hot-Spot Analysis" in *Model My Watershed* to determine sub-watershed locations of higher existing contributions of sediment and nutrients to the outlet of Inkhorn Brook watershed; then focus BMP mitigation in these hot-spot sub-areas of the watershed;
- Address existing nonpoint source problems in the Inkhorn Brook watershed by instituting BMPs where necessary; and
- Prevent future degradation of Inkhorn Brook through the development and/or strengthening of local Nutrient Management Ordinance.

Table 9: Annual Loads by Land Use, Other Sources, and Pathways for Inkhorn Brook Based on Modeling

Inkhorn Brook				
	Area (ha)	**Sediment** (1000 kg/yr)	**Total N** (kg/yr)	**Total P** (kg/yr)
Land Uses				
Hay/Pasture	160	49.7	464	122.8
Cropland	0	0.0	0	0.0
Wooded Areas	631	2.0	193	11.2
Wetlands	74	0.2	52	2.8
Open Land	12	0.8	27	1.2
Barren Areas	1	0.002	1	0.0
Low-Density Mixed	31	1.5	37	4.0
Medium-Density Mixed	3	0.7	16	1.6
High-Density Mixed	1	0.2	4	0.4
Low-Density Open Space	82	3.8	98	10.4
Total Area	994			
Other Sources				
Farm Animals		0.0	193	60.8
Septic Systems		0.0	11	0.0
Pathway Load				
Stream Bank Erosion		88.3	82	18.0
Subsurface Flow		0.0	1,368	54.1
Total Annual Load		147	2,547	287
Total Annual Load per Unit Area		0.148	2.56	0.29
		1000 kg/ha/yr	kg/ha/yr	kg/ha/yr

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DRAFT TMDL SUMMARY

Kennedy Brook

WATERSHED DESCRIPTION

This TMDL applies to the entire 1.75 mile length of Kennedy Brook, which lies entirely in the city of Presque Isle, Maine. Kennedy Brook begins in a wooded wetland in the eastern agricultural area of Presque Isle. The brook flows westerly before being impounded, creating Mantle Lake. It then flows through a residential area before crossing under Route 1 where the watershed is dominated by heavy development. Kennedy Brook is highly channelized in this lower stretch. While not shown on the maps in this document, a small but significant tributary, Alder Brook, originates south of the urbanized area, flows north through agricultural land, the University of Maine at Presque Isle, and residential development before discharging to Kennedy Brook just above Route 1. The Kennedy Brook watershed covers an area of 2.7 square miles.

- Kennedy Brook is on the list of Maine's Impaired Streams as referenced in the 2016 Integrated Report (Maine DEP, 2018).

- Runoff from row crop agriculture (potatoes, broccoli, grain) and hay fields is likely one of the largest contributors of nutrients to Kennedy Brook. Agricultural land use comprises a full 48% of the watershed with most of the agricultural land in the upper or eastern portion and southern watershed area (Figure 1).
- Developed areas occupy 32% of the watershed and are mostly in the lower half of the watershed. Developed areas contain impervious surfaces (rooftops) and home septic systems and when in close proximity to the stream will impact water quality.
- The remainder of the watershed is 11% wooded and 8% wetlands.

Definitions

- ***Total Maximum Daily Load (TMDL)*** *represents the total amount of a pollutant that a waterbody can receive and still meet water quality standards.*
- **Nonpoint Source Pollution** *refers to pollution that comes from many diffuse sources across the landscape, and are typically transported by rain or snowmelt runoff.*

Waterbody Facts

Segment ID: ME0101000412_140R05

Towns: Presque Isle, ME

County: Aroostook (central)

Impaired Segment Length: 1.75 mi

Classification: Class B

Direct Watershed: 2.7 mi^2 (1,728 acres)

Impairment Listing Cause: Periphyton

Watershed Agricultural Land Use: 48%

Major Drainage Basin: Saint John River

Watershed Land Uses

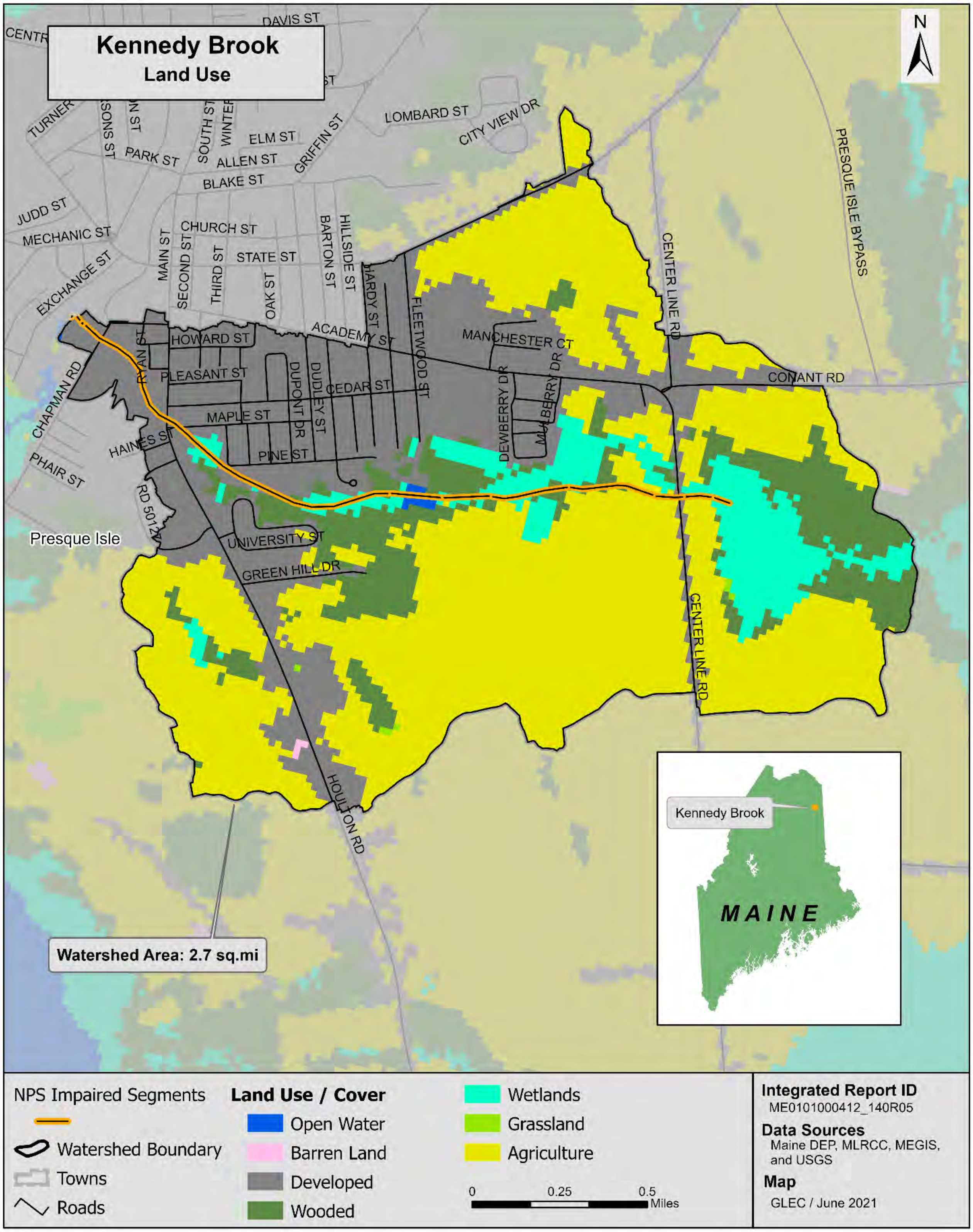

Figure 1: Land Use and Land Cover (from 2016) in the Kennedy Brook Watershed

Why Is a TMDL Assessment Needed?

Kennedy Brook is a Class B stream and has been assessed by Maine DEP as not meeting water quality standards for the designated use of aquatic life and placed on the 303(d) list of impaired waters under the Clean Water Act. The Clean Water Act requires that all 303(d)-listed waters undergo a Total Maximum Daily Load (TMDL) assessment that describes the impairments and establishes a target to guide the measures needed to restore water quality. The goal is for all waterbodies to comply with state water quality standards.

Agriculture (cropland and hay/pasture) in the Kennedy Brook watershed comprises 48% (34% cropland) of the land area. However, developed land also occupies a large amount of watershed area (32%). The industrialized area east of Route 1 contains several industries that have the potential to contribute significant nutrients and toxic chemicals (e.g., agricultural equipment manufacturer, farm chemical distribution center, rail yard). This area has significant impervious areas and no stormwater treatment systems. Any spill or accident is likely to discharge directly into Kennedy Brook.

Agriculture is likely to be the largest contributor of sediment and nutrient enrichment to the brook. Concentrated flow in and around cropland (34% of the watershed) further increases the likelihood that nutrients and sediment will reach Kennedy Brook.

Kennedy Brook *looking upstream at the upper part of the assessed segment and just downstream of the community park footbridge. Photo: GLEC 2021*

Kennedy Brook *in the middle of the assessed segment showing woody debris, which was observed with heavy density throughout the assessed segment. Photo: GLEC 2021*

WATER QUALITY DATA ANALYSIS

Maine DEP uses a variety of data types to measure the ability of a stream to adequately support aquatic life, including; dissolved oxygen, benthic macroinvertebrates, and periphyton (algae). For benthic macroinvertebrates, DEP makes aquatic life use determinations using a statistical model that incorporates 30 variables of data collected from rivers and streams, including the richness and abundance of streambed organisms, to determine the probability of a sample meeting Class A, B, or C conditions. Biologists use the model results and supporting information to determine if samples comply with the numeric aquatic life criteria of the class assigned to the stream or river (Davies and Tsomides, 2002). Maine DEP uses an analogous model to aid in the assessment of algal communities but makes aquatic life use determinations based on narrative standards.

The aquatic life impairment in Kennedy Brook is based on periphyton (algae) data collected from 2009 and 2014. Kennedy Brook has a Class B designation. Station S-646 exists just upstream of the Chapman Road bridge and downstream of the railroad thruway (Figure 3). Here periphyton did not meet class in either 2009 or 2014.

TMDL ASSESSMENT APPROACH: NUTRIENT AND SEDIMENT MODELING OF IMPAIRED AND ATTAINMENT STREAMS

NPS pollution is difficult to measure directly, because it comes from many diffuse sources spread across the landscape. For this reason, an online nutrient loading model, *Model My Watershed* (v. 1.32.0), was used to estimate the sources of pollution based on well-established hydrological equations (Stroud Water Research Center 2017). *Model My Watershed* makes use of the GWLF-enhanced model engine. The model incorporates detailed maps of soil, land use, and slope, daily weather and localized weather data (from the period 2009-2020), and direct observations of agriculture and other land uses within the watershed. *Model My Watershed* is derived from its parent MapShed developed by Evans and Corradini (2012). *Model My Watershed* replaced MapShed in 2017-2018.

The nutrient loading estimates for the impaired stream were compared to similar estimates for five non-impaired (attainment) streams of similar watershed land uses across the state. The TMDL for the impaired stream was set as the mean nutrient loading estimate of these attainment stream watersheds, and units of mass per unit watershed area per year (kg/ha/year) were used. The difference in loading estimates between the impaired and attainment watersheds represents the percent reduction in nutrient loading required under this TMDL. The attainment streams and their nutrient and sediment loading estimates and TMDL are presented below in Table 1.

Table 1: Numeric Targets for Pollutant Loading Based on Model My Watershed Outputs (2021) for Attainment Streams

Attainment Streams	Town	Total P Load (kg/ha/yr)	Total N Load (kg/ha/yr)	Sediment Load (kg/ha/yr)
Footman Brook	Exeter	0.17	1.73	35.2
Martin Stream	Fairfield	0.13	2.98	57.9
Moose Brook	Houlton	0.18	1.59	48.5
Upper Kenduskeag Stream	Corinth	0.16	1.72	100.5
Upper Pleasant River	Gray	0.16	4.26	86.5
Total Maximum Daily Load		**0.16**	**2.46**	**65.7**

RAPID WATERSHED ASSESSMENT

Habitat Assessment

Habitat assessment surveys were conducted on both impaired and attainment streams (Figure 2). The assessment approach is based on the *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (Barbour et al. 1999), which integrates various parameters relating to the structure of physical habitat. The habitat assessments include a 1) general description of the site and physical characterization and a 2) visual assessment of in-stream and riparian habitat quality. For both impaired and attainment streams, the assessment locations are typically near a road crossing for ease of access.

Kennedy Brook is an impaired segment (ME0101000412_140R05; Class B) and was surveyed just upstream (approximately 100 m) from the Chapman Road bridge crossing for a length of 100 m. The starting point of the surveyed reach was 20 m upstream of the biological monitoring station and just 10 m upstream of a recent footbridge that crosses Kennedy Brook. The upstream-most point was approximately 20 m downstream of a culvert that lies under multiple railroad track bed. The surveyed reach was clear of any obvious habitat alteration due to the footbridge structure at its downstream and culvert at its upstream terminals. Based on the higher frequency of riffles versus runs or pools, a *high gradient* habitat assessment was performed on this 100 m length of stream segment. Kennedy Brook at the footbridge is approximately 265 m upstream from its confluence with Presque Isle Stream.

The habitat survey for this impaired segment was located in a narrow corridor of vegetated riparian cover and this represents a quarter of its entire length. The wooded corridor becomes increasingly wide travelling upstream approximately 5 km to its headwater area. Beyond this wooded riparian corridor, the overall watershed land use contains considerable area of cropland and pasture and mixed development.

Figure 2 (right) shows the range of habitat assessment scores for all attainment and impaired streams, as well as for Kennedy Brook segment discussed here.

Based on the *Rapid Bioassessment Protocols*, Kennedy Brook earned a score of 146. A higher score indicates better habitat. The range of habitat scores for attainment streams was 155 to 179.

Habitat parameters that scored low for Kennedy Brook include sediment deposition, bank stability, channel alteration, and especially riparian vegetative zone width. The sole parameter that scored high was protection of the immediate bank by vegetation.

Habitat appears to be an issue in the impairment of Kennedy Brook. However, it is also important to look for other potential sources within the watershed leading to impairment. Consideration should be given to major “hot spots” in the Kennedy Brook watershed as potential sources of NPS pollution contributing to the water quality impairment.

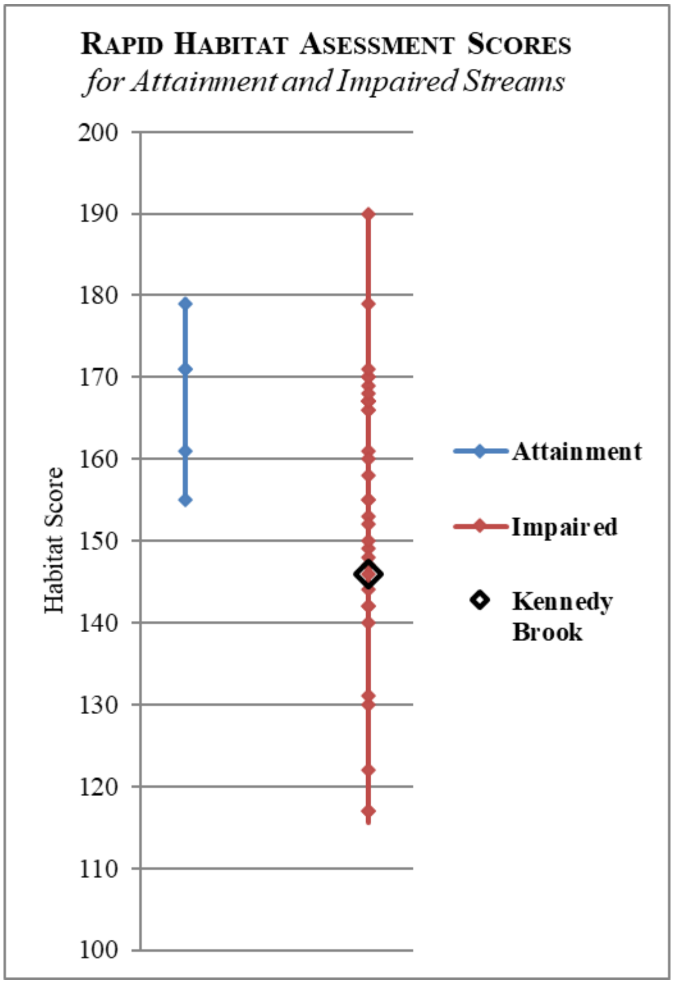

Figure 2: Habitat Assessment Score for Kennedy Brook (2021) Compared to Region

Pollution Source Identification

Pollution source identification assessments were conducted in May 2021 for the entire Kennedy Brook watershed. Attainment stream watersheds were assessed in 2012. The source identification work is based on an abbreviated version of the Center for Watershed Protection’s Unified Subwatershed and Site Reconnaissance method (Wright et al. 2005). The abbreviated method includes both a desktop and field component. The desktop assessment consists of generating and reviewing maps of the watershed boundary, roads, land use and satellite imagery; and then identifying potential NPS pollution locations, such as road crossings, agricultural fields, and large areas of bare soil. When available, multiple sources of satellite imagery were reviewed. Occasionally, the high resolution of the imagery allowed for observations of livestock, row crops, eroding stream banks, sediment laden water, junkyards, and other potential NPS concerns that could affect stream quality. As many potential pollution sources as possible were visited, assessed, and documented in the field. Field visits were limited to NPS sites that were visible from roads or a short walk from a roadway. Neighborhoods were assessed for NPS pollution at the whole neighborhood level including streets and storm drains (where applicable). The assessment does not include a scoring component but does include a detailed summary of findings and a map indicating documented NPS sites throughout the watershed.

Based on the May 2021 field and desktop assessment, several generalizations on watershed land use for Kennedy Brook can be made (Table 2, Figure 3). The upper three-quarters of the impaired segment length is protected by a wide riparian corridor. But the lower quarter of the segment is extensively modified by culverting and commercial development. The brook is underground for a section immediately west of US 1 highway (Main Street in the City of Presque Isle).

Extensive residential development is situated in the northwestern section of the watershed. The stormwater collection system is a mix of open ditches, storm drains, and underground piping with nearly the entire northeast development area discharging to Kennedy Brook below Route 1 via two large stormwater discharge pipes. Residential lawns are modestly maintained suggesting that lawn chemicals are rarely applied.

About two-thirds of the watershed, eastern and southern, is in row-crop (potato and broccoli) agriculture Due to the short growing season, this often leaves large sections of the watershed with exposed soil from September through May or June.

US 1 highway (Main Street) is a commercial corridor that bisects the lower part of the watershed. The University of Maine at Presque Isle (UMPI) is located in the Alder Brook watershed, a tributary to Kennedy Brook. Although UMPI has extensive mowed lawns, the presence of numerous weeds suggest lawn chemicals are used at a minimum or not at all.

The northern part of the watershed has a large hospital, church, residential area and school farm. Both the church and hospital have stormwater treatment structures. As mentioned earlier there is an industrial section below Route 1 with numerous potential pollution sources.

Table 2: Potential Pollution Source ID Assessment (2021) for the Kennedy Brook Watershed

Potential Source			Notes
ID#	**Location**	**Type**	
1	Main St (Houlton Rd or US 1)	Municipal	University of Maine – Presque Isle campus – mowed lawns – no apparent weed control used – extensive parking lots
2	Main St (Houlton Rd or US 1)	Neighborhood	Manicured lawns – none; approximately 15 acres; homes likely on municipal sewer system; no curbs or storm drains
3	Primarily east of US 1 extending to Center Line Rd and then east to watershed boundary; north of Academy St & Conant Rd	Agriculture	Extensive plowed fields – primarily row crops; soil often bare for 8 months of the year (crop canopy cover at best during June-September)
4	Main St (Houlton Rd or US 1)	Cemetery	Cemetery
5	Main St (Houlton Rd or US 1)	Commercial – Hotspot	Several commercial operations – truck and auto sales, truck maintenance, small hotel, agricultural department store; restaurants
6	Chapman Rd	Municipal	Public playfields (Bicentennial Park) – lawn chemicals on paved walkways
7	Center Line Rd	Agriculture	Pasture near veterinary services building
8	State St	Agriculture	School educational farm (orchards – fruits – vegetables)
9	Academy St	Commercial	Hospital – extensive parking lots, stormwater detention ponds, manicured lawns absent
10	Pine St	Municipal	School (elementary) building with a large parking lot and managed playfields
11	Fleetwood St	Church	Church with extensive area of managed lawn and large parking lot
12	Academy St south to Pine St; Main St (US 1) east to Fleetwood St	Neighborhood	Small to mid-size houses; curb-free; managed lawns absent; likely on municipal sewage system
13	Ryan St (near Main St)	Agriculture - Hotspot	Crop services industry – fertilizer, lime, grass seed

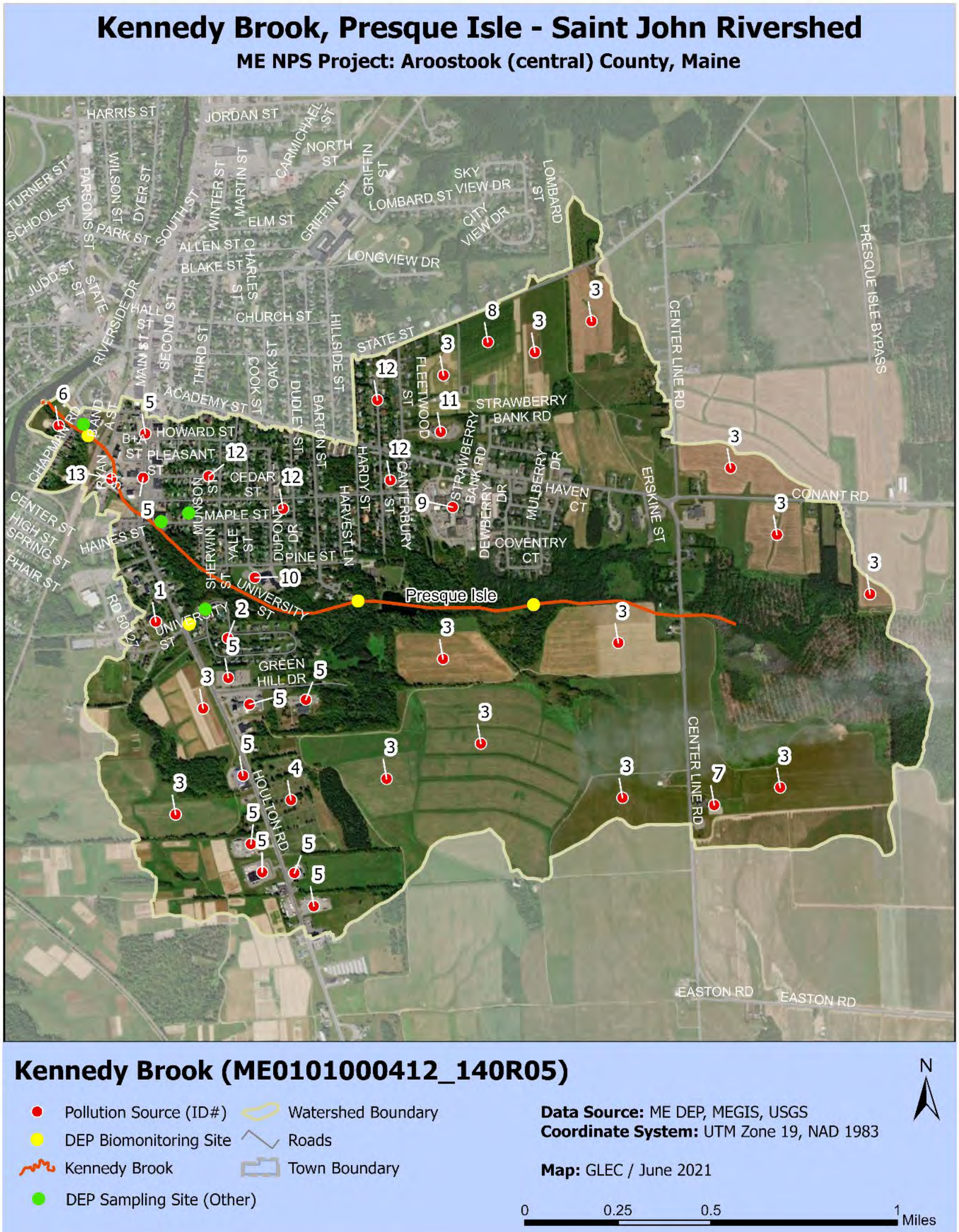

Figure 3: Aerial Photo of Potential Source Locations (identified in 2021) in the Kennedy Brook Watershed

NUTRIENT AND SEDIMENT LOADING – *MODEL MY WATERSHED* ANALYSIS

The *Model My Watershed* model was used to estimate stream loading of total phosphorus, total nitrogen, and sediment in Kennedy Brook watershed. The model estimated nutrient loads over a 12-year period (2009-2020), which was determined by local (Caribou Weather Forecast Office USW00014607) weather data inserted into *Model My Watershed*. This extended period captures a recent but wide range of hydrologic conditions to account for variations in nutrient and sediment loading over time. Loads for the attainment watersheds (five total; Table 1) were computed using the same model with the same recent inputs (i.e., regional weather, 2016 land use and land cover, 2016 wetland extent, and BMPs similar to the impaired watersheds).

Many quality assured and regionally calibrated input parameters are provided with *Model My Watershed*. However, several updates to some of the default parameters were made in this TMDL effort, and namely more recent land use/cover using **MRLC-NLCD 2016** [1], more recent and local weather (precipitation and temperature) data (as described above), and more regional estimates of Best Management Practices (BMPs; see ensuing discussion). Because land use/cover is more recent, the estimated filtration fraction of wetland and open water and the amount of stream buffer in agricultural land should be more accurate. It is also worth noting that improved classification algorithms were employed by MLRC in the NCLD 2016 and these new algorithms were used in the revisions of all previous NLCD versions (including the first version in 2001).

Livestock Estimates

Livestock waste contains nutrients which can cause water quality impairment. The nutrient loading model considers numbers and types of animals. Table 3 (right) provides livestock (numbers of animals) in the watershed based on the USDA National Agricultural Statistics Service (NASS) estimation for 2012. Some of these totals were modified by direct observations made in the watershed in the 2021 watershed survey. To generate watershed-based livestock counts, NASS county-based livestock totals are converted to a per unit area (based on the total area of the county). The unit area amount is then multiplied by the total watershed area to derive a watershed total count (as seen in Table 3).

Table 3: Livestock Count in the Kennedy Brook Watershed

Type	Kennedy Brook
Dairy Cows	--
Beef Cows	--
Broilers	--
Layers	10
Hogs/Swine	--
Sheep	10
Horses	--
Turkeys	--
Other	--
Total	**20**

The May 2021 field survey, for the most part, supports the livestock totals estimated through NASS as shown in Table 3. However, a local agricultural advisor (described in BMPs below) stated that several small hobby farms having chickens and goats exist in the watershed. Hence, Table 3 and the model inputs were updated for layer chickens and sheep (a substitute for goats since they are not a livestock option in the model).

[1] MRLC-NLCD 2016 : Multi-Resolution Land Characteristics – National Land Cover Dataset (version 2016) provided by the MRLC Consortium (Jin et al. 2019).

Vegetated Stream Buffer in Agricultural Areas

Vegetated stream buffers are areas of trees, shrubs, and/or grasses adjacent to streams, lakes, ponds or wetlands which provide nutrient loading attenuation (Evans and Corradini, 2012). *Model My Watershed* considers natural vegetated stream buffers within agricultural land areas as providing nutrient load attenuation. A width of approximately 98 feet (30 m) on one side of a stream is required to be considered a streamside buffer per the *Model My Watershed* technical manual (Stroud Water Research Center 2017). Analysis of recent aerial photos was used to estimate the number of cropland stream miles with and without vegetative buffers, and these estimates were directly entered into the model.

Table 4: Summary of Vegetated Buffers in Agricultural Areas

Kennedy Brook
• Agricultural Land Stream Length = 0.77 mi (4,077 ft) • Agricultural Land Stream Length *with Buffer* = 0.29 mi (1,534 ft) (or 37.6% of total agricultural land stream length) • Percentage of total stream length flowing through non-buffered agricultural land = 10.9%

Kennedy Brook is a 1.75 mile-long impaired segment. The total stream miles (including tributaries) modeled within the watershed is 4.4 miles (i.e., no other tributaries were considered). Of this total, 0.77 stream miles (4,077 ft) are located within agricultural areas and 0.29 miles (1,534 ft) of that show a 98 foot or greater vegetated buffer (Table 4, Figure 4). From a watershed perspective, this equates to 0.48 miles or 10.9% of the total stream length running through agricultural land with less than a 98 foot buffer.

By contrast, for attainment stream watersheds, the percentage of total stream miles running through agricultural land without a 75 foot vegetated buffer (calculated in 2012) ranged from 0% to 3.9% with an average of 1.3%. Differences in stream length estimates using a 98-foot or 75-foot buffer were practically insignificant.

Home Septic System Loads

Loads for "normally functioning" septic systems are calculated in *Model My Watershed* using an estimate of the average number of persons per acre in "Low-Density Mixed" areas. In "Low-Density Mixed" areas, it is typically assumed that the populations therein are served by septic systems rather than centralized sewage systems. However in Kennedy Brook watershed, nearly all of the residential and small business structures are connected to public sewer. Hence, the model fraction setting was reduced to 10 percent of typical for this watershed. The 10 percent area is assumed to be connected to "normally functioning" septic systems rather than those that experience "surface breakouts" (surface failures), "short-circuiting" to underlying groundwater (subsurface failures), or have direct conduits to nearby water bodies. Non-functioning systems would be modeled with a higher load contribution to the waterbody.

Best Management Practices (BMPs)

Best management practices (BMPs) are typically instituted to reduce the loading of sediment and nutrients from upland (i.e., non-point) sources. Information on BMP use was based on an interview with a local agricultural advisor in May 2021 who provided estimates for cover crops, conservation tillage, and strip cropping. Information on BMP use for the attainment watersheds was based on interviews from two sources (both made in February 2021). Estimates for attainment watersheds were based on typical New England watersheds and derived from information available from Vermont. An upper limit of BMP use in attainment watersheds was garnered from watersheds entering the Chesapeake Bay where BMP use is intensive.

Four agricultural BMPs were used in this modeling effort and in the following manner:

- *Cover Crops:* Cover crops are the use annual or perennial crops to protect soil from erosion during time periods between harvesting and planting of the primary crop. The percent of cropland area in a cover crop BMP deployed was estimated, from the local interview source, at 50%. For the five attainment watersheds, an estimate of 25% was used and selected as the low end of the range (25 to 30 percent) expected for cropland in New England.
- *Conservation Tillage:* Conservation tillage is any kind of system that leaves at least 30% of the soil surface covered with crop residue after planting. This reduces soil erosion and runoff. This BMP was estimated, from the local interview source, to occur in none (0%) of cropland area. This same source also commented that uncontrolled gully erosion exists in the watershed. A value of 25% was assigned to the five attainment watersheds as suggested by the other (non-local) two interview sources named above.
- *Strip Cropping / Contour Farming:* This BMP involves tilling, planting and harvesting perpendicular to the gradient of a hill or slope using high levels of plant residue to reduce soil erosion from runoff. The local interview source suggested this practice occurs in 15% of the cropland area in Kennedy Brook watershed. The Vermont and Chesapeake Bay (non-local) sources suggest this practice is minimal to non-existent for New England watersheds. Hence, no BMP of this type was used in this modeling effort for attaining watersheds.
- *Grazing Land Management:* This BMP consists of ensuring adequate vegetation cover on grazed lands to prevent soil erosion from overgrazing or other forms of over-use. This usually employs a rotational grazing system where hays or legumes are planted for feed and livestock is rotated through several fenced pastures. The local agricultural advisor did not suggest this practice in the Kennedy Brook watershed. The other (non-local) interview sources were not aware of this practice being active in New England watersheds. No BMP of this type was used in this modeling effort for both impaired and attaining watersheds.

Agricultural BMPs recommended by Maine DEP to reduce sediment and nutrient loads include vegetated buffers, covered manure storage facilities, and stream exclusion fencing. BMPs for developed areas recommended by the Maine DEP include vegetated buffers, stormwater BMPs, and minimization of impervious cover.

Pollutant Load Attenuation by Lakes, Ponds and Wetlands

Depositional environments such as lakes, ponds, and wetlands can attenuate watershed sediment and nutrient loading. This information is entered into the nutrient loading model by a simple percentage of watershed area draining to a lake, pond, or wetland. The Kennedy Brook watershed is 8% wetland and open water (0.2% is open water from Mantle Lake). Multiple wetlands surround most of the upper two-thirds of Kennedy Brook, with increasing area as one moves toward its headwaters (Figure 1). It is estimated that 16% of land area within the watershed drains to wetlands and open water. The percent of watershed draining to a wetland in the attainment watersheds, based on the 2021 analysis, ranged from 26 to 58 percent, with an average of 40%.

NUTRIENT AND SEDIMENT MODELING RESULTS

Selected results from the watershed loading model are presented here. The TMDL itself is expressed in units of kilograms per hectare per year. The additional results shown below assist in better understanding the likely sources of pollution. The model results for Kennedy Brook indicate significant reductions of phosphorus and sediment are needed, and a moderately significant reduction in nitrogen is needed to improve water quality (Table 8). Below, loading for nitrogen, phosphorus and sediment are discussed individually. There are two categories of loads, sources and pathways.

There are two categories of loads – sources and pathways. Sources are determined by land use/cover and the overland flow they generate, livestock counts by animal type, and home sewage treatment systems in developed areas. Pathways represent additional loads derived from subsurface flow and streambank erosion. Subsurface loads are calculated using dissolved N and P coefficients for shallow groundwater and are mainly derived from atmospheric inputs. Sediment and nutrient loads produced by eroding streambanks are estimated using an approach developed by Evans et al. (2003). This pathway is comprised of loads originating from five sources, and listed in order of decreasing importance: amount of developed land area, soil erodibility (K-factor), density of livestock, runoff curve number, and topographic slope. For any given model run, the amount of developed land in the watershed is responsible for just over 72% of the total streambank load, whereas soil erodibility and animal density are responsible for 21% and 7% of the total streambank load, respectively.

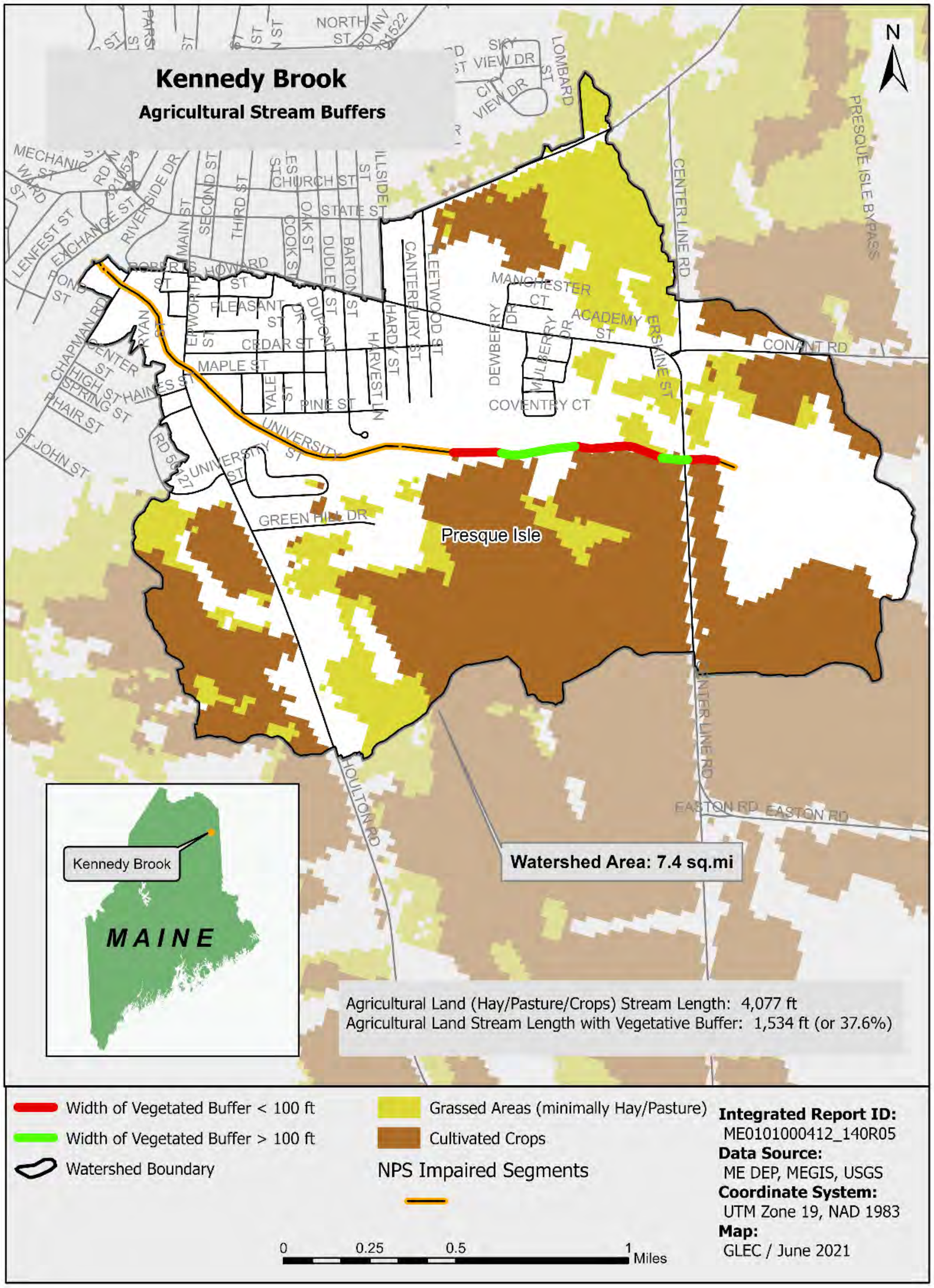

Figure 4: Agricultural Stream Buffers (from 2021) in the Kennedy Brook Watershed

Sediment

Sediment loading in the Kennedy Brook watershed is primarily derived from cropland (80% of source load) (Table 5 and Figure 5). Developed land contributes almost 18% of the total source load. Of the entire watershed sediment load, stream bank erosion contributes 26% which originates mostly from developed land, and to some extent cropland.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Kennedy Brook* below for loading estimates that have been normalized by watershed area.

Table 5: Total Sediment Load by Source

Kennedy Brook	Sediment (1000 kg/year)	Sediment (%)
Source Load		
Hay/Pasture	3.0	2.2%
Cropland	107.1	79.9%
Wooded Areas	0.1	0.0%
Wetlands	0.1	0.1%
Open Land	0.0	0.0%
Barren Areas	0	0
Low-Density Mixed	4.3	3.2%
Medium-Density Mixed	11.2	8.3%
High-Density Mixed	5.6	4.2%
Low-Density Open Space	2.8	2.1%
Farm Animals	0	0
Septic Systems	0	0
Source Load Total:	**134.1**	**100%**
Pathway Load		
Stream Bank Erosion	46.4	-
Subsurface Flow	0	-
Total Watershed Mass Load:	**180**	

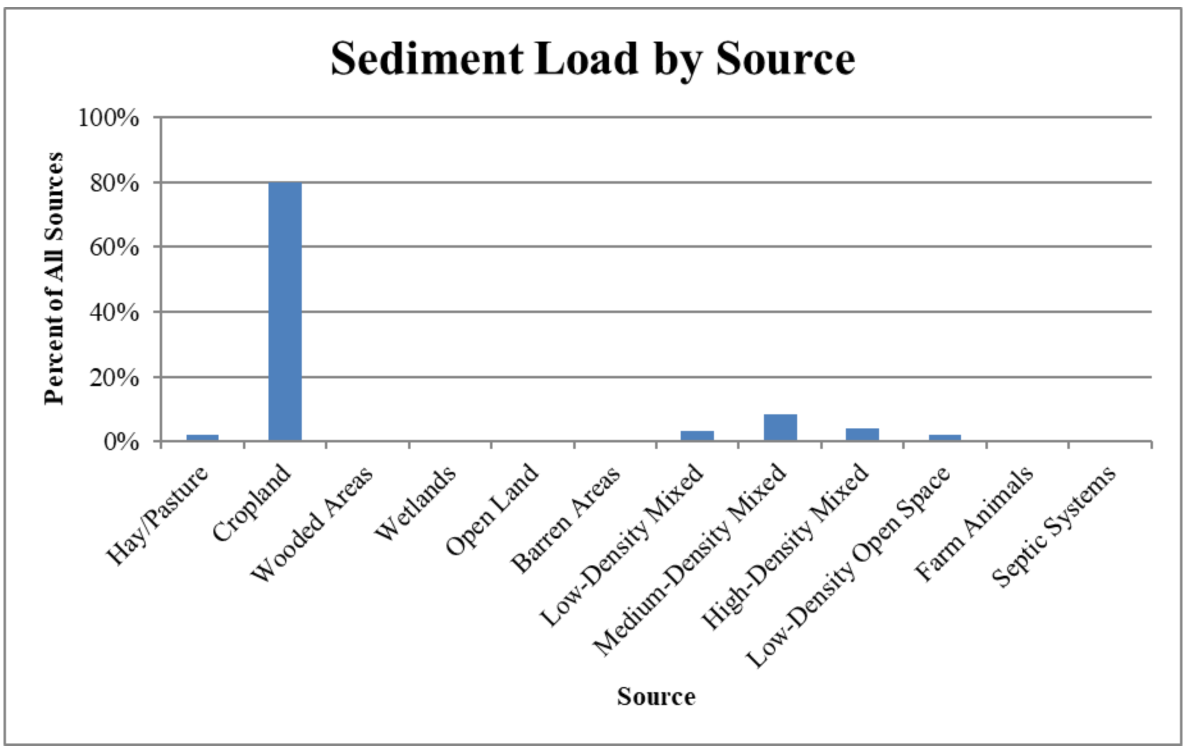

Figure 5: Total Sediment Load by Source in the Kennedy Brook Watershed

Total Nitrogen

Nitrogen loading is attributed primarily to cropland (55.7%). Developed land contributes 38.5% through overland flow (Table 6 and Figure 6). Because most of the residences and small businesses are connected to public sewer, the load from septic systems is rather small.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Kennedy Brook* below for loading estimates that have been normalized by watershed area.

Table 6: Total Nitrogen Load by Source

Kennedy Brook	Total N (kg/year)	Total N (%)
Source Load		
Hay/Pasture	17	1.0%
Cropland	922	55.7%
Wooded Areas	15	0.9%
Wetlands	39	2.4%
Open Land	1	0.1%
Barren Areas	0	0
Low-Density Mixed	130	7.9%
Medium-Density Mixed	281	17.0%
High-Density Mixed	140	8.5%
Low-Density Open Space	86	5.2%
Farm Animals	5	0.3%
Septic Systems	20	1.2%
Source Load Total:	**1,655**	**100%**
Pathway Load		
Stream Bank Erosion	43	-
Subsurface Flow	1,012	-
Total Watershed Mass Load:	**2,710**	

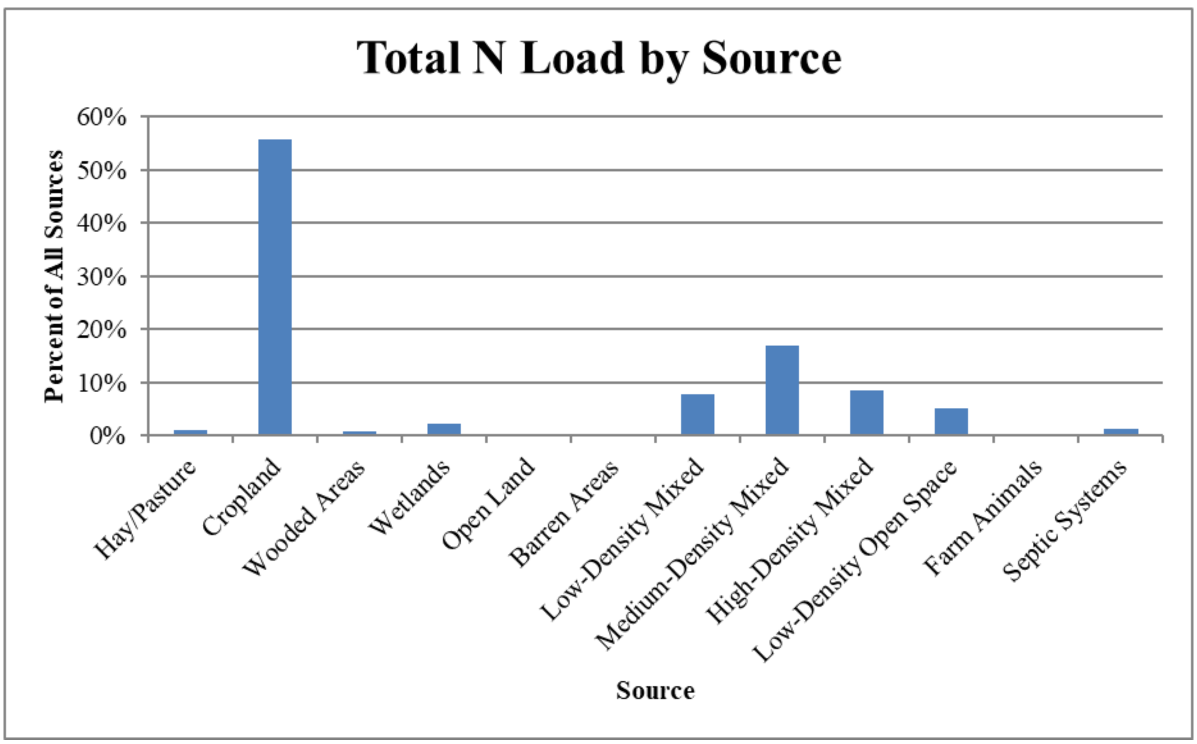

Figure 6: Total Nitrogen Load by Source in the Kennedy Brook Watershed

Total Phosphorus

Agricultural cropland contributes 79.3% of the phosphorus load. Development contributes just under 17%. Phosphorus loads are presented in Table 7 and Figure 7.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Kennedy Brook* below for loading estimates that have been normalized by watershed area.

Table 7: Total Phosphorus Load by Source

Kennedy Brook	Total P (kg/year)	Total P (%)
Source Load		
Hay/Pasture	10.2	2.7%
Cropland	304.1	79.3%
Wooded Areas	0.8	0.2%
Wetlands	2.1	0.5%
Open Land	0	0
Barren Areas	0	0
Low-Density Mixed	13.5	3.5%
Medium-Density Mixed	28.1	7.3%
High-Density Mixed	14.0	3.7%
Low-Density Open Space	8.9	2.3%
Farm Animals	1.7	0.4%
Septic Systems	0	0
Source Load Total:	**383.4**	**100%**
Pathway Load		
Stream Bank Erosion	23.0	-
Subsurface Flow	33.6	-
Total Watershed Mass Load:	**440**	

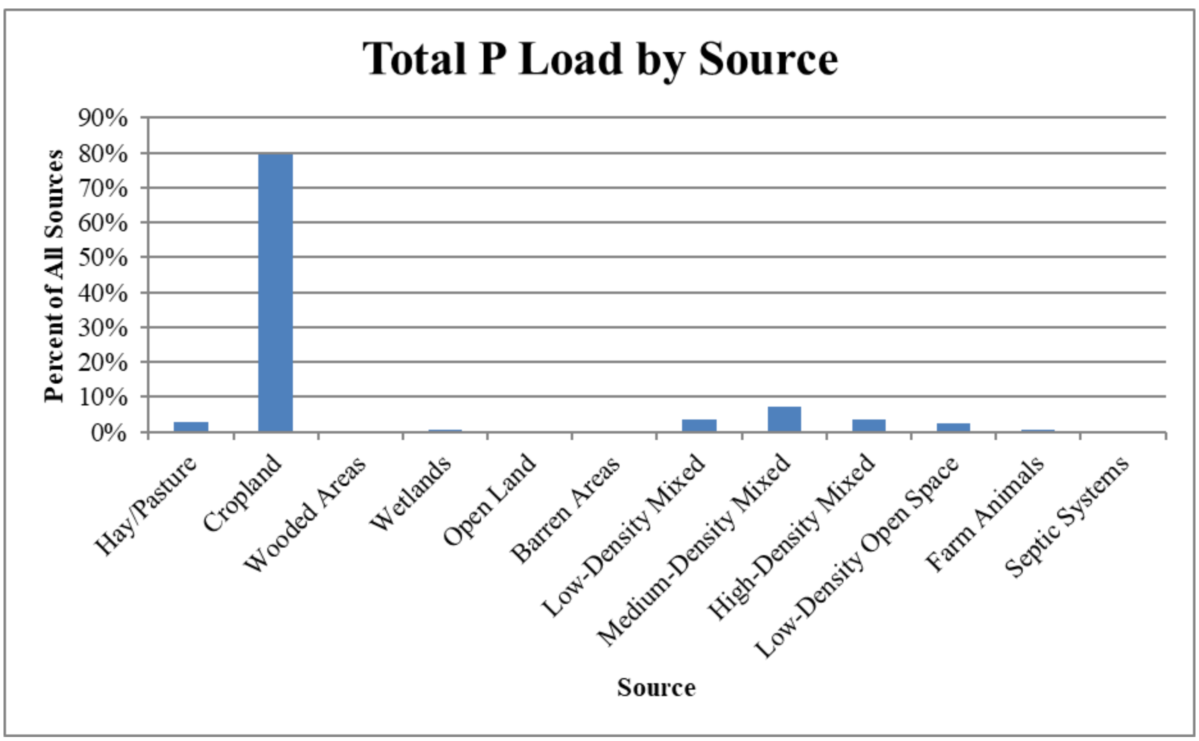

Figure 7: Total Phosphorus Load by Source in the Kennedy Brook Watershed

TMDL: TARGET NUTRIENT AND SEDIMENT LEVELS FOR KENNEDY BROOK

The existing loads for nutrients and sediments in the impaired segment of Kennedy Brook are listed in Table 8, along with the TMDL (the allowable load) which was calculated from the average loading estimates of five attainment watersheds throughout the state. Table 8 also shows required reductions (as a percent) for each of sediment, total N, and total P pollutants. Table 9 presents a more detailed view of the modeling results and calculations used to compute the existing loads in Table 8. An annual time frame provides a mechanism to address the daily and seasonal variability associated with nonpoint source loads.

Table 8: Kennedy Brook Pollutant Loading Compared to TMDL Targets

Kennedy Brook			
Pollutant Load	**Existing Load**	**TMDL**	**Reduction Required**
Total Annual Load per Unit Area		Attainment Streams	
Sediment (kg/ha/yr)	254.6	65.72	74.2%
Total N (kg/ha/yr)	3.82	2.46	35.8%
Total P (kg/ha/yr)	0.62	0.16	74.3%

Future Loading

The prescribed reduction in pollutants discussed in this TMDL reflects reduction from estimated existing conditions. With farmable land area at a premium and under high demand it is very likely that any tillable acreage in Kennedy Brook watershed is already in production. Between 2012 to 2017 in Aroostook County, the number of farms decreased by 14.4% and the number of acres decreased by 9.6% (USDA 2017). However, the average farm size increased by 5.6% in this time period. The County has seen a consolidation of farmland under fewer landowners with farms becoming larger. Human population in Aroostook County decreased by 6.48% from 2000 to 2019 (US Census 2020). To meet TMDL targets, current and future farm management practices will need to employ a combination of conservation practices.

Next Steps

The use of agricultural and developed land best management practices (BMP's) can reduce sources of polluted runoff in Kennedy Brook. It is recommended that municipal officials in Presque Isle and central Aroostook county, landowners, and conservation stakeholders work together to:

- Implement the Kennedy Brook Watershed Based Plan (2018);
- Reach out to landowners and make them aware of impairment issues and actions they can take to protect and improve Kennedy Brook water quality;
- Encourage greater citizen involvement through the development of a watershed coalition to ensure the long-term protection of Kennedy Brook;
- Run a "Hot-Spot Analysis" in *Model My Watershed* to determine sub-watershed locations of higher existing contributions of sediment and nutrients to the outlet of Kennedy Brook watershed; then focus BMP mitigation in these hot-spot sub-areas of the watershed;

- Address existing nonpoint source problems in the Kennedy Brook watershed by working with Central Aroostook Soil and Water Conservation District and the Natural Resource Conservation Service to access technical assistance, CWA 319 grant funds and EQIP to encourage BMPs; and
- Prevent future degradation of Kennedy Brook through the development and/or strengthening of a local ordinances.

Table 9: Annual Loads by Land Use, Other Sources, and Pathways for Kennedy Brook Based on Modeling

Kennedy Brook				
	Area (ha)	**Sediment** (1000 kg/yr)	**Total N** (kg/yr)	**Total P** (kg/yr)
Land Uses				
Hay/Pasture	99	3.0	17	10.2
Cropland	243	107.1	922	304.1
Wooded Areas	80	0.1	15	0.8
Wetlands	56	0.1	39	2.1
Open Land	1	0.0	1	0.0
Barren Areas	0	0.000	0	0.0
Low-Density Mixed	88	4.3	130	13.5
Medium-Density Mixed	56	11.2	281	28.1
High-Density Mixed	28	5.6	140	14.0
Low-Density Open Space	58	2.8	86	8.9
Total Area	709			
Other Sources				
Farm Animals		0.0	5	1.7
Septic Systems		0.0	20	0.0
Pathway Load				
Stream Bank Erosion		46.4	43	23.0
Subsurface Flow		0.0	1,012	33.6
Total Annual Load		180	2,710	440
Total Annual Load per Unit Area		0.255	3.82	0.62
		1000 kg/ha/yr	kg/ha/yr	kg/ha/yr

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DRAFT TMDL SUMMARY

Mosher Brook

WATERSHED DESCRIPTION

This **TMDL** applies to a 2.03 mile section of Mosher Brook, located in the Town of Gorham, Maine. The impaired segment of Mosher Brook begins in the western portion of the watershed in a wooded area. The brook then flows east crossing Mosher Road, agricultural land, another forested area and outlets to the Presumpscot River. The Mosher Brook watershed covers an area of 1.26 square miles.

- Mosher Brook is on Maine's 303(d) list of Impaired Streams as referenced in the 2016 Integrated Report (Maine DEP, 2018).
- The Mosher Brook watershed is predominately non-developed (46.3%). Forested areas (43%) within the watershed absorb and filter pollutants helping protect both water quality in the stream and stream channel stability.
- Non-forested areas within the watershed are predominantly developed (27.7%) and are located in the western portion of the watershed.
- Agricultural areas (25%) comprised predominantly of hay/pasture land exists in the eastern end of the watershed.
- Runoff from agricultural land concentrated along Mosher Road and Dolloff Road is likely the largest source of nonpoint source (NPS) pollution to Mosher Brook. Runoff from developed areas and active hay/pasture lands can transport sediment, nitrogen and phosphorus to the stream.

Definitions

- ***Total Maximum Daily Load (TMDL)*** *represents the total amount of pollutants that a waterbody can receive and still meet water quality standards.*
- **Nonpoint Source Pollution** *refers to pollution that comes from many diffuse sources across the landscape, and are typically transported by rain or snowmelt runoff.*

Waterbody Facts

Segment ID: ME0106000103_607R08

Town: Gorham, ME

County: Cumberland

Impaired Segment Length: 2.03 miles

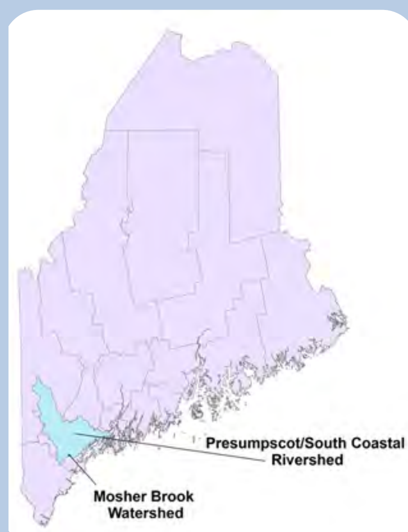
Classification: Class B

Direct Watershed: 1.26 mi^2 (806 acres)

Impairment Listing Cause: Dissolved Oxygen

Watershed Agricultural Land Use: 25%

Major Drainage Basin: Presumpscot River



Watershed Land Uses

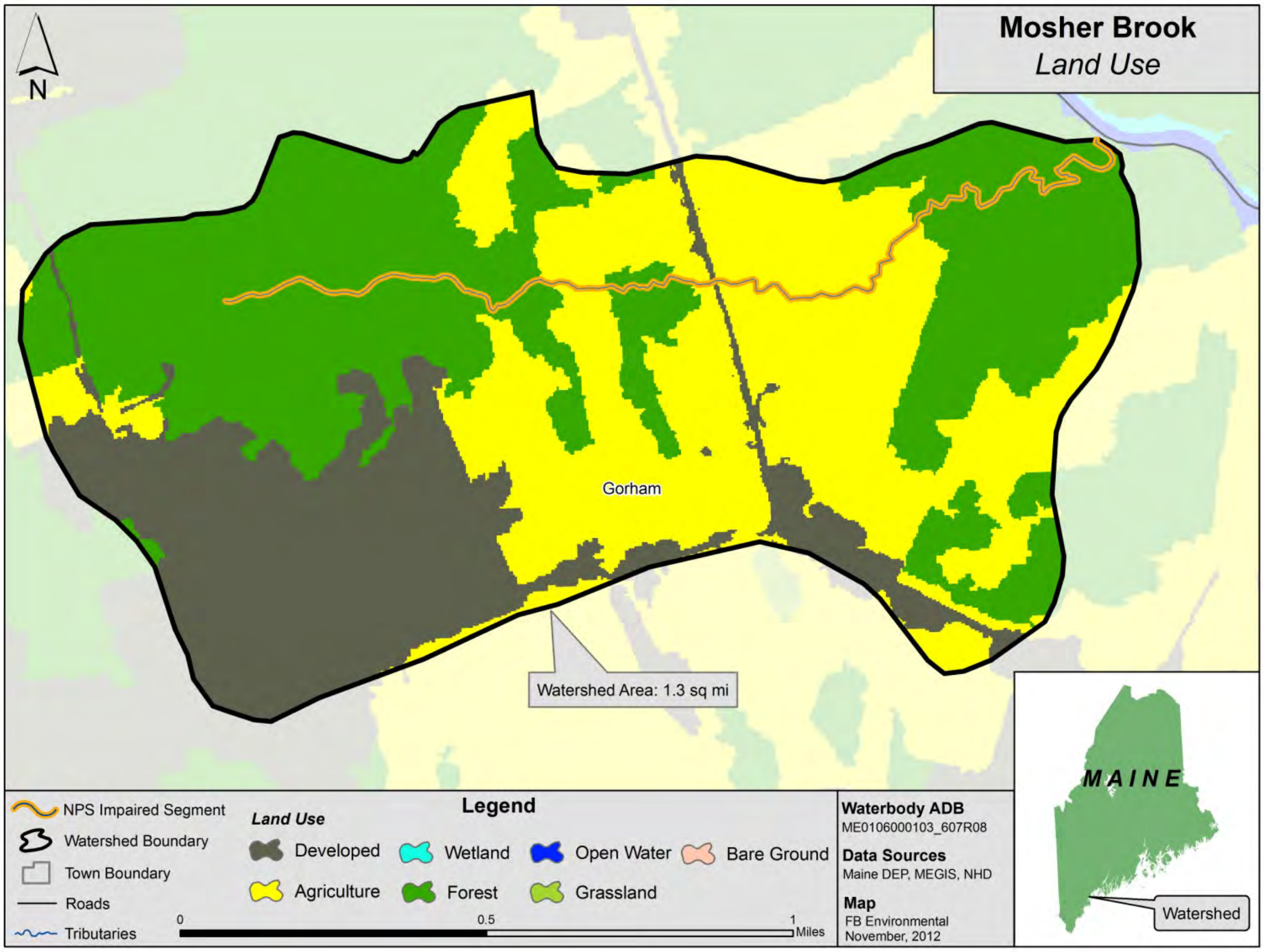


Figure 1: Land Use and Land Cover (from 2011) in the Mosher Brook Watershed

WHY IS A TMDL ASSESSMENT NEEDED?

Mosher Brook, a Class B freshwater stream, has been assessed by Maine DEP as not meeting water quality standards for the designated use of aquatic life, and placed on the 303(d) list of impaired waters under the Clean Water Act. The Clean Water Act requires that all 303(d)-listed waters undergo a TMDL assessment that describes the impairments and establishes a target to guide the measures needed to restore water quality. The goal is for all waterbodies to comply with state water quality standards.

***Mosher Brook** at Station RMS11 near the Mosher Road crossing. Photo: FB Environmental*

Agricultural land in the Mosher Brook watershed makes up 25% of the total watershed area. Developed land comprises slightly more than half of that (14%). However, the majority of the developed land area is located in the southwestern corner of the watershed, furthest away from the impaired segment of Mosher Brook (Figure 1). Furthermore, 48% of the impaired stream segment length passes through agricultural land. Agriculture is therefore likely to be the largest contributor of sediment and nutrient enrichment to the stream. The close proximity of many agricultural lands to the stream further increases the likelihood that nutrients from disturbed soils, manure, and fertilizers will reach the stream.

WATER QUALITY DATA ANALYSIS

Maine DEP uses a variety of data types to measure the ability of a stream to adequately support aquatic life, including; dissolved oxygen, benthic macroinvertebrates, and periphyton (algae). For benthic macroinvertebrates, DEP makes aquatic life use determinations using a statistical model that incorporates 30 variables of data collected from rivers and streams, including the richness and abundance of streambed organisms, to determine the probability of a sample meeting Class A, B, or C conditions. Biologists use the model results and supporting information to determine if samples comply with the numeric aquatic life criteria of the class assigned to the stream or river (Davies and Tsomides, 2002). Maine DEP uses an analogous model to aid in the assessment of algal communities but makes aquatic life use determinations based on narrative standards.

The aquatic life impairment in Mosher Brook is based on historic dissolved oxygen data. Additionally, dissolved oxygen data collected at station RMS11 in 2007 corroborates the impairment.

TMDL ASSESSMENT APPROACH: NUTRIENT AND SEDIMENT MODELING OF IMPAIRED AND ATTAINMENT STREAMS

NPS pollution is difficult to measure directly because it comes from many diffuse sources spread across the landscape. For this reason, an online nutrient loading model, *Model My Watershed* (v. 1.32.0), was used to estimate the sources of pollution based on well-established hydrological equations (Stroud Water Research Center 2017). *Model My Watershed* makes use of the GWLF-enhanced model engine. The model incorporates detailed maps of soil, land use, and slope, daily weather and localized weather data (from the period 2009-2020), and direct observations of agriculture and other land uses within the watershed. *Model My Watershed* is derived from its parent MapShed developed by Evans and Corradini (2012). *Model My Watershed* replaced MapShed in 2017-2018.

The nutrient loading estimates for the impaired stream were compared to similar estimates for five non-impaired (attainment) streams of similar watershed land uses across the state. The TMDL for the impaired stream was set as the mean nutrient loading estimate of these attainment stream watersheds, and units of mass per unit watershed area per year (kg/ha/year) were used. The difference in loading estimates between the impaired and attainment watersheds represents the percent reduction in nutrient loading required under this TMDL. The attainment streams and their nutrient and sediment loading estimates and TMDL are presented below in Table 1.

Table 1: Numeric Targets for Pollutant Loading Based on Model My Watershed Outputs (2021) for Attainment Streams

Attainment Streams	Town	Total P Load (kg/ha/yr)	Total N Load (kg/ha/yr)	Sediment Load (kg/ha/yr)
Footman Brook	Exeter	0.17	1.73	35.2
Martin Stream	Fairfield	0.13	2.98	57.9
Moose Brook	Houlton	0.18	1.59	48.5
Upper Kenduskeag Stream	Corinth	0.16	1.72	100.5
Upper Pleasant River	Gray	0.16	4.26	86.5
Total Maximum Daily Load		**0.16**	**2.46**	**65.7**

RAPID WATERSHED ASSESSMENT

Habitat Assessment

A habitat assessment survey was conducted on both the impaired and attainment streams. The assessment approach is based on the *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (Barbour et al. 1999), which integrates various parameters relating to the structure of physical habitat. The habitat assessments include a general description of the site, physical characterization and visual assessment of in-stream and riparian habitat quality.

Based on rapid bioassessment protocols for low gradient streams, Mosher Brook received a score of 144 out of a total 200 for quality of habitat. Higher scores indicate better habitat. The range in habitat assessment scores of attainment streams was 155 to 179.

Habitat assessments were conducted on a relatively short sample reach (about 100-200 meters for a typical small stream) near the most downstream Maine DEP sample station in the watershed. For both impaired and attainment streams, the assessment location was usually near a road crossing for ease of access. In the Mosher Brook watershed, the downstream sample station was located in a small, isolated area of forest. Immediate riparian zone was that of a floodplain wetland. However dominant surrounding vegetation was maple, alder and pine. The stream here was very embedded and water was documented as quite turbid. Velocity was very slow, and aquatic vegetation included pickerelweed and sedges with lily pads observed is pool areas. New residential developments were observed to the west of Mosher Brook and may be a source of sedimentation to the stream.

Figure 2 shows the range of habitat assessment scores for all attainment and impaired streams, as well as for Mosher Brook. Though these scores show that habitat is clearly an issue in the impairment of Mosher Brook, it is important to look for other potential sources within the watershed lending to impairment. Consideration should be given to major "hot spots" in the Mosher Brook watershed as potential sources of NPS pollution contributing to the water quality impairment.

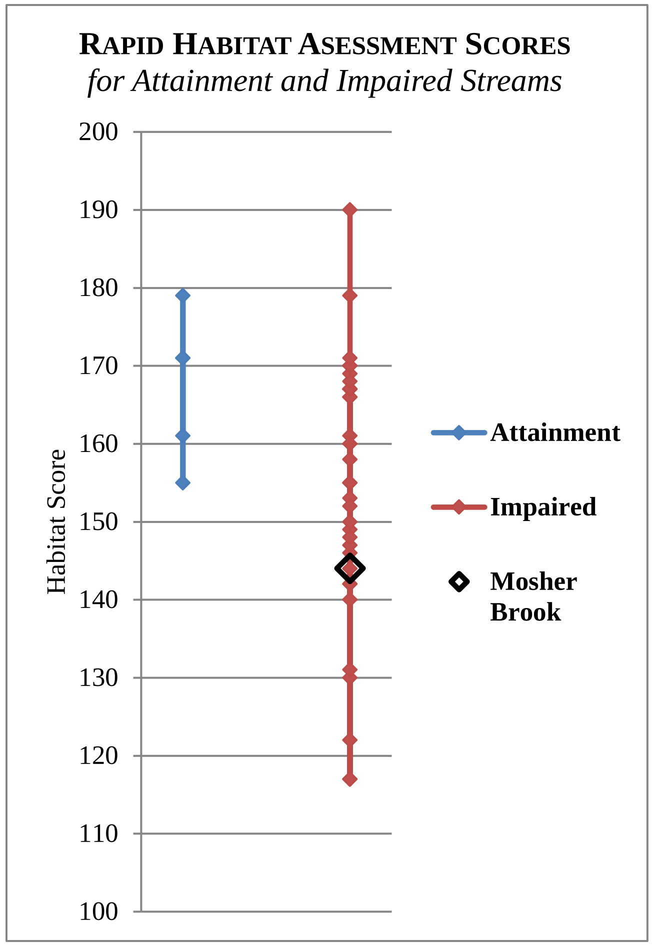


Figure 2: Habitat Assessment Scores for Mosher Brook (2012) Compared to Region

Pollution Source Identification

Pollution source identification assessments were conducted for Mosher Brook (impaired) and all attainment streams. The source identification work is based on an abbreviated version of the Center for Watershed Protection's Unified Subwatershed and Site Reconnaissance method (Wright, et al. 2005). The abbreviated method includes both a desktop and field component. The desktop assessment consists of generating and reviewing maps of the watershed boundary, roads, land use and satellite imagery, and then identifying potential NPS pollution locations, such as road crossings, agricultural fields, and large areas of bare soil. When available, multiple sources of satellite imagery were reviewed. Occasionally, the high resolution of the imagery allowed for observations of livestock, row crops, eroding stream banks, sediment laden water, junkyards, and other potential NPS concerns that could affect stream quality. As many potential pollution sources as possible were visited, assessed and documented in the field. Field visits were limited to NPS sites that were visible from roads or a short walk from a roadway. Neighborhoods were assessed for NPS pollution at the whole neighborhood level including streets and storm drains (where applicable). The assessment does not include a scoring component, but does include a detailed summary of findings and a map indicating documented NPS sites throughout the watershed.

The watershed source assessment for Mosher Brook was completed in July 2012. In-field observations of erosion, lack of vegetated stream buffer, extensive impervious surfaces, high-density neighborhoods and agricultural activities were documented throughout the watershed (Table 2, Figure 3).

Table 2: Potential Pollution Source ID Assessment (2012) for the Mosher Brook Watershed

Potential Source			Notes
ID#	**Location**	**Type**	
1	Gateview Commons Drive	Residential Development	• Newer development. Trees in most areas, but not densely forested. • Storm drains and manholes observed.
3	Wagner Farm Road	Residential Development	• Brand new development with current construction observed. • Only a few small trees in development. • No sewers.
4	Dolloff Road	Agriculture	• Inactive fields and hay fields.
5	Mosher Road	Agriculture	• Hay and corn fields adjacent to Mosher Brook to the south with minimal buffer.
5b		Agriculture & Power Lines	• Large hay fields and power line crossing to the north of Mosher Brook. • No buffer.
7	Dolloff Road	Road Crossing	• Minimal buffer. • Turbid.
9	Mosher Road	Gravel Pit	• Large gravel operation on northern border of watershed.

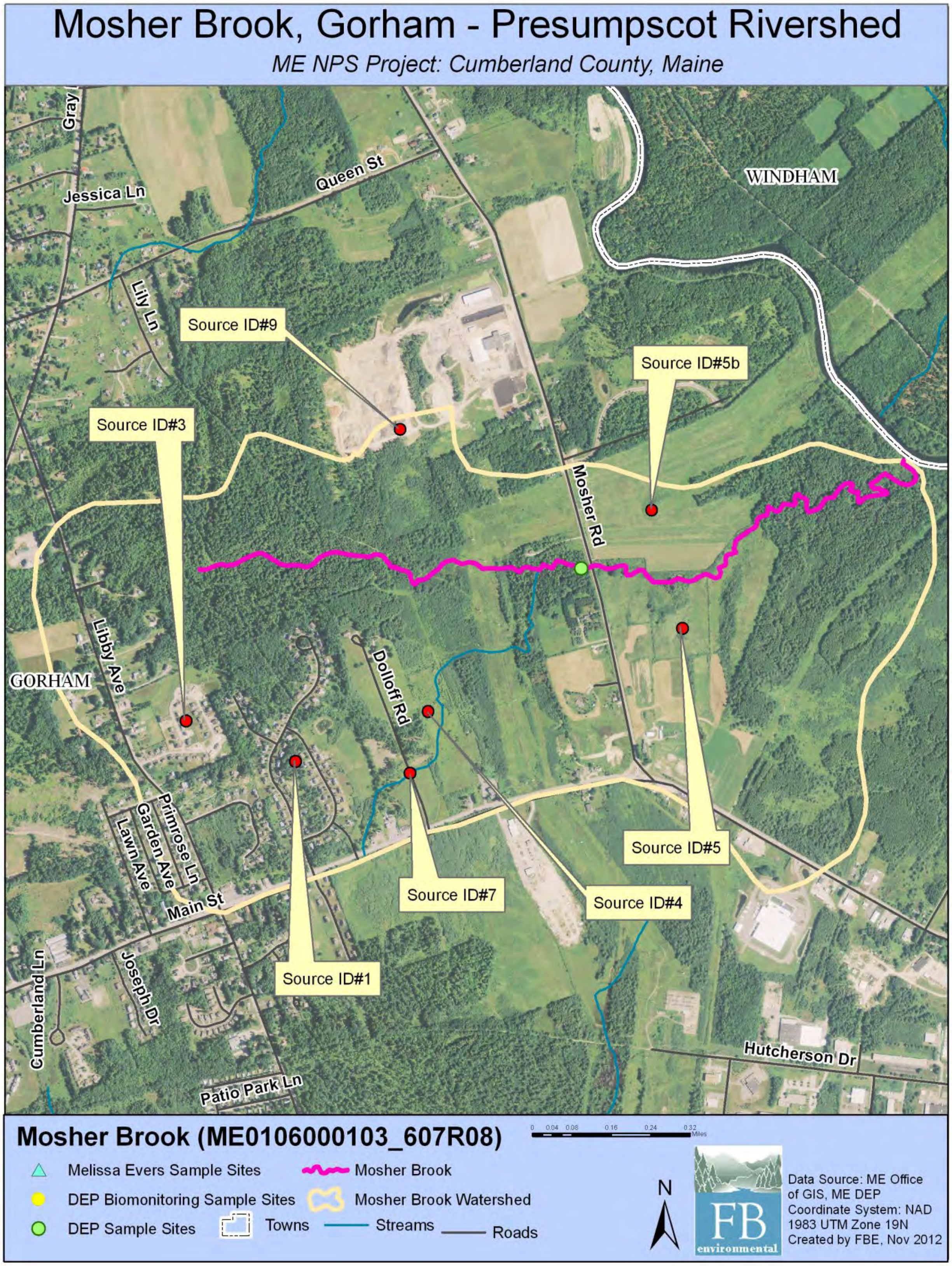


Figure 3: Aerial Photo of Potential Source ID Locations (identified in 2012) in the Mosher Brook Watershed

NUTRIENT AND SEDIMENT LOADING – *MODEL MY WATERSHED* ANALYSIS

The *Model My Watershed* model was used to estimate stream loading of total phosphorus, total nitrogen, and sediment in Mosher Brook watershed. The model estimated nutrient loads over a 12-year period (2009-2020), which was determined by local (Portland Jetport USW00014764) weather data inserted into *Model My Watershed*. This extended period captures a recent but wide range of hydrologic conditions to account for variations in nutrient and sediment loading over time. Loads for the attainment watersheds (five total; Table 1) were computed using the same model with the same recent inputs (i.e., regional weather, 2016 land use and land cover, 2016 wetland extent, and BMPs similar to the impaired watersheds).

Many quality assured and regionally calibrated input parameters are provided with *Model My Watershed*. However, several updates to some of the default parameters were made in this TMDL effort, and namely more recent land use/cover using **MRLC-NLCD 2016** [1], more recent and local weather (precipitation and temperature) data (as described above), and more regional estimates of Best Management Practices (BMPs; see ensuing discussion). Because land use/cover is more recent, the estimated filtration fraction of wetland and open water and the amount of stream buffer in agricultural land should be more accurate. It is also worth noting that improved classification algorithms were employed by MLRC in the NCLD 2016 and these new algorithms were used in the revisions of all previous NLCD versions (including the first version in 2001).

Livestock Estimates

Livestock waste contains nutrients which can cause water quality impairment. The nutrient loading model considers numbers and types of animals. Table 3 (right) provides livestock (numbers of animals) in the watershed based on the USDA National Agricultural Statistics Service (NASS) estimation for 2012. Some of these totals were modified by direct observations made in the watershed in the 2012 survey. To generate watershed-based livestock counts, NASS county-based livestock totals are converted to a per unit area (based on the total area of the county). The unit area amount is then multiplied by the total watershed area to derive a watershed total count (as seen in Table 3).

The Mosher Brook watershed is forested, with significant areas of hay/pasture land and residential development. Minimal amounts of livestock exist (via NASS estimation) but none was observed.

Table 3: Livestock Estimates in the Mosher Brook Watershed

Type	Mosher Brook
Dairy Cows	1
Beef Cows	1
Broilers	1
Layers	6
Hogs/Swine	1
Sheep	4
Horses	2
Turkeys	--
Other	--
Total	**16**

[1] MRLC-NLCD 2016 : Multi-Resolution Land Characteristics – National Land Cover Dataset (version 2016) provided by the MRLC Consortium (Jin et al. 2019).

Vegetated Stream Buffer in Agricultural Areas

Vegetated stream buffers are areas of trees, shrubs, and/or grasses adjacent to streams, lakes, ponds or wetlands which provide nutrient loading attenuation (Evans and Corradini 2012). *Model My Watershed* considers natural vegetated stream buffers within agricultural land areas as providing nutrient load attenuation. A width of approximately 98 feet (30 m) on one side of a stream is required to be considered a streamside buffer per the *Model My Watershed* technical manual (Stroud Water Research Center 2017). Analysis of recent aerial photos was used to estimate the number of agricultural stream miles with and without vegetative buffers, and these estimates were directly entered into the model.

Mosher Brook is a 2.0 mile-long impaired segment as listed by Maine DEP. As modeled, the total stream miles (including tributaries) within the watershed was calculated as 2.6 miles.

Of this total, one stream mile is located within agricultural areas and 0.06 miles of that area *appear* to have a 98 foot or greater vegetated buffer (Table 4, Figure 4). From a watershed perspective, this equates to 0.94 miles or 36.2% of the total stream length running through agricultural land with less than a 98 foot buffer. By contrast, for attainment stream watersheds, the percentage of total stream miles running through agricultural land without a 75 foot vegetated buffer ranged from 0% to 3.9% with an average of 1.3%. Note, a minimum vegetated buffer width of *75 feet* was used in an earlier (2012) effort to produce Figure 4 shown here. Differences in stream length estimates using a 98-foot or 75-foot buffer were practically insignificant.

Table 4: Summary of Vegetated Buffers in Agricultural Areas (2012)

Mosher Brook
• Agricultural Land Stream Length = 1.0 mi • Agricultural Land Stream Length with Buffer = 0.06 mi (or 6% of total agricultural land stream length) • Percentage of total stream length flowing through non-buffered agricultural land = 36.2%

Home Septic System Loads

Loads for “normally functioning” septic systems are calculated in *Model My Watershed* using an estimate of the average number of persons per acre in “Low-Density Mixed” areas. In these areas, it is assumed that the populations therein are served by septic systems rather than centralized sewage systems. All homes in such areas are assumed to be connected to “normally functioning” systems rather than those that experience “surface breakouts” (surface failures), “short-circuiting” to underlying groundwater (subsurface failures), or have direct conduits to nearby water bodies. Non-functioning systems would be modeled with a higher load contribution to the waterbody.

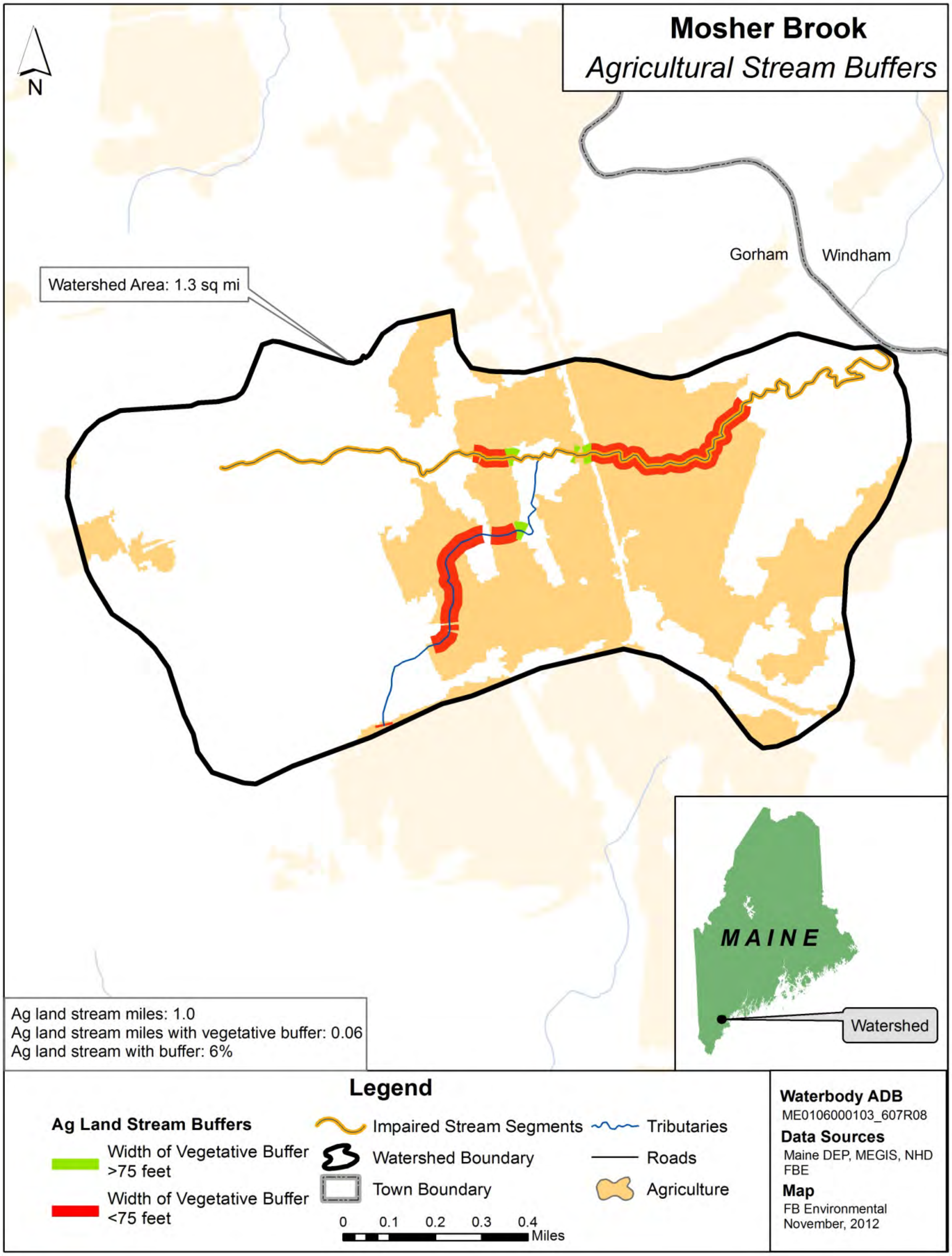


Figure 4: Agricultural Stream Buffers (from 2012) in the Mosher Brook Watershed

Best Management Practices (BMPs)

Best management practices (BMPs) are typically instituted to reduce the loading of sediment and nutrients from upland (i.e., non-point) sources. Ideally, information on BMPs for a specific watershed from local and regional sources would improve this component of the water quality model. Maine DEP sought information on BMP use in early 2021 from local, regional, and state agricultural agencies for rural BMPs and from nearby municipalities for urban BMPs. Very little to no information was returned in the solicitation. Hence, estimates for typical New England watersheds were derived from information available from Vermont. An upper limit of BMP use was garnered from watersheds entering the Chesapeake Bay where BMP use is intensive.

Four agricultural BMPs were used in this modeling effort and in the following manner:

- *Cover Crops:* Cover crops are the use annual or perennial crops to protect soil from erosion during time periods between harvesting and planting of the primary crop. The percent of cropland area in a cover crop BMP deployed was estimated at 25% and selected as the low end of the range (25 to 30 percent) expected for cropland in New England. This value was assigned to the five attainment watersheds.
- *Conservation Tillage:* Conservation tillage is any kind of system that leaves at least 30% of the soil surface covered with crop residue after planting. This reduces soil erosion and runoff. This BMP was estimated to occur in 25% of cropland. This value was assigned to the five attainment watersheds.
- *Strip Cropping / Contour Farming:* This BMP involves tilling, planting and harvesting perpendicular to the gradient of a hill or slope using high levels of plant residue to reduce soil erosion from runoff. Both interview sources suggest this practice is minimal to non-existent for New England watersheds. Hence, no BMP of this type was used in this modeling effort. This value was assigned to the five attainment watersheds.
- *Grazing Land Management:* This BMP consists of ensuring adequate vegetation cover on grazed lands to prevent soil erosion from overgrazing or other forms of over-use. This usually employs a rotational grazing system where hays or legumes are planted for feed and livestock is rotated through several fenced pastures. Both interview sources were not aware of this practice being active and is likely minimal for New England watersheds. Hence, no BMP of this type was used in this modeling effort for both impaired and attaining watersheds.

Note that other agricultural and development BMPs likely exist in the watershed but their location and type were not available in a watershed-wide format that is necessary to include in the model. Agricultural BMPs recommended by Maine DEP to reduce sediment and nutrient loads include vegetated buffers, covered manure storage facilities, and stream exclusion fencing. BMPs for developed areas recommended by the Maine DEP include vegetated buffers, stormwater BMPs, and minimization of impervious cover.

Pollutant Load Attenuation by Lakes, Ponds and Wetlands

Depositional environments such as lakes, ponds, and wetlands can attenuate watershed sediment and nutrient loading. This information is entered into the nutrient loading model by a simple percentage of watershed area draining to a lake, pond, or wetland. The Mosher Brook watershed is 3.5% wetland and open water, per the 2016 NLCD land use/cover. There are a few wetlands that surround tributaries throughout the watershed. It is estimated that 17% of land area within the watershed drains to wetlands and open water. The percent of watershed draining to a wetland in the attainment watersheds, based on the 2021 analysis, ranged from 26 to 58 percent, with an average of 40%.

NUTRIENT AND SEDIMENT MODELING RESULTS

Selected results from the watershed loading model are presented here. The TMDL itself is expressed in units of kilograms per hectare per year. The additional results shown below assist in better understanding the likely sources of pollution. The model results for Mosher Brook watershed indicate very high reductions of phosphorus and sediment and a high reduction of nitrogen are needed to improve water quality. Below, loading for nitrogen, phosphorus and sediment are discussed individually.

There are two categories of loads – sources and pathways. Sources are determined by land use/cover and the overland flow they generate, livestock counts by animal type, and home sewage treatment systems in developed areas. Pathways represent additional loads derived from subsurface flow and streambank erosion. Subsurface loads are calculated using dissolved N and P coefficients for shallow groundwater and are mainly derived from atmospheric inputs. Sediment and nutrient loads produced by eroding streambanks are estimated using an approach developed by Evans et al. (2003). This pathway is comprised of loads originating from five sources, and listed in order of decreasing importance: amount of developed land area, soil erodibility (K-factor), density of livestock, runoff curve number, and topographic slope. For any given model run, the amount of developed land in the watershed is responsible for just over 72% of the total streambank load, whereas soil erodibility and animal density are responsible for 21% and 7% of the total streambank load, respectively.

Sediment

Aside from stream bank erosion which contributes 49% of the total sediment load, the major source load in Mosher Brook watershed originates from hay/pasture land (78.5% of total sources). Residential sources contribute 17.5% of the source load.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient and Sediment Levels for Mosher Brook* below for loading estimates that have been normalized by watershed area.

Table 5: Total Sediment Load by Source

Mosher Brook	Sediment (1000 kg/year)	Sediment (%)
Source Load		
Hay/Pasture	30.9	78.5%
Cropland	1.0	2.5%
Wooded Areas	0.4	1.1%
Wetlands	0.0	0.1%
Open Land	0.2	0.4%
Barren Areas	0	0
Low-Density Mixed	1.7	4.4%
Medium-Density Mixed	2.3	5.8%
High-Density Mixed	0.5	1.2%
Low-Density Open Space	2.4	6.1%
Farm Animals	0	0
Septic Systems	0	0
Source Load Total:	**39.4**	**100%**
Pathway Load		
Stream Bank Erosion	38.4	-
Subsurface Flow	0	-
Total Watershed Mass Load:	**78**	

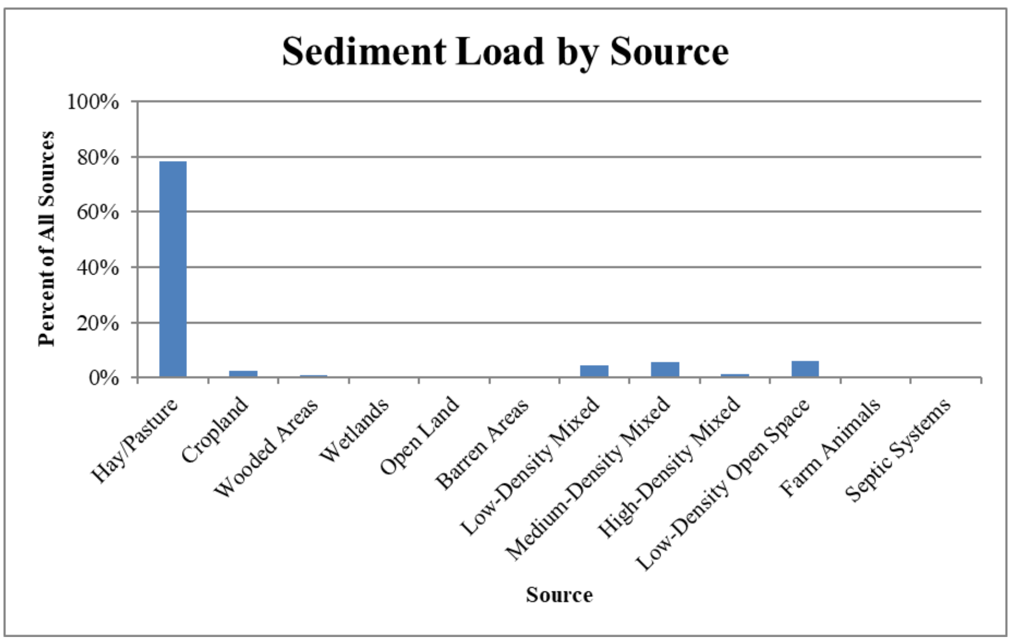


Figure 5: Total Sediment Load by Source in the Mosher Brook Watershed

Total Nitrogen

Table 6 and Figure 6 (below) show the estimated total nitrogen load, in terms of mass and percent of total by source, in the Mosher Brook watershed. Hay and pasture lands are the largest source of nitrogen loading contributing a little over 51% of the source load of total N. Residential areas (including septic systems) combined contribute 32.7% of the source load. Wooded areas and wetlands contribute 9.1% of the source load. Farm animals contribute 4.3% of the source load.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient and Sediment Levels for Mosher Brook* below for loading estimates that have been normalized by watershed area.

Table 6: Total Nitrogen Load by Source

Mosher Brook	Total N (kg/year)	Total N (%)
Source Load		
Hay/Pasture	312	51.3%
Cropland	11	1.7%
Wooded Areas	47	7.8%
Wetlands	8	1.3%
Open Land	6	1.0%
Barren Areas	0	0
Low-Density Mixed	45	7.4%
Medium-Density Mixed	47	7.7%
High-Density Mixed	10	1.6%
Low-Density Open Space	62	10.3%
Farm Animals	26	4.3%
Septic Systems	34	5.7%
Source Load Total:	**607**	**100%**
Pathway Load		
Stream Bank Erosion	33	-
Subsurface Flow	379	-
Total Watershed Mass Load:	**1,020**	

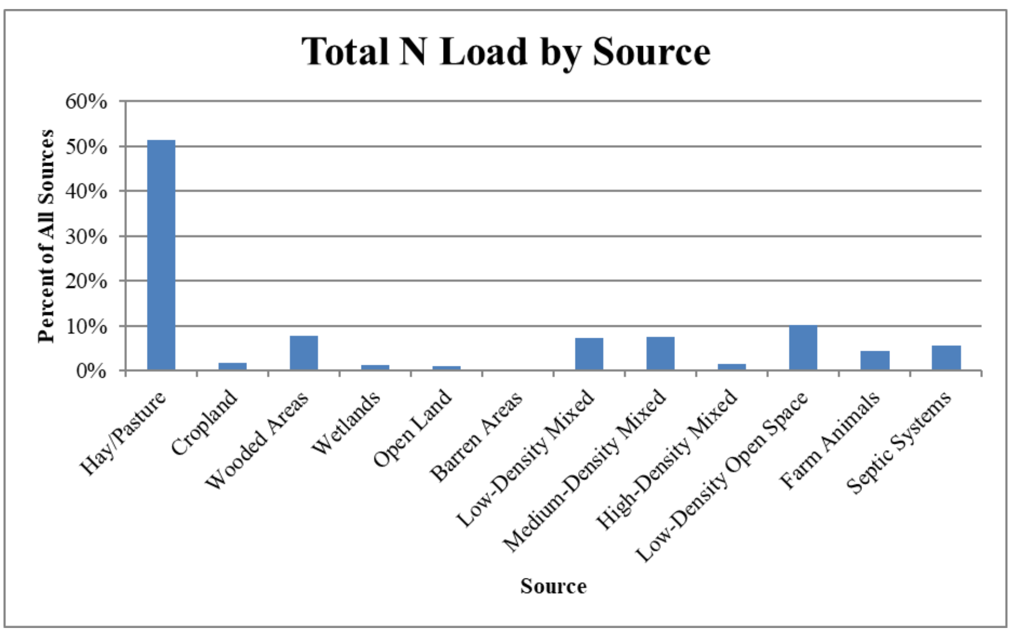


Figure 6: Total Nitrogen Load by Source in the Mosher Brook Watershed

Total Phosphorus

Table 7 and Figure 7 (below) show the estimated total phosphorus load in terms of mass and percent of total by source, in the Mosher Brook watershed. Hay and pasture lands are the largest source of phosphorus loading contributing a little over 75% of the source load. Residential areas combined contribute 14.9% of the source load. Farm animals contribute 5.7% of the source load of total P. The pathway of stream bank erosion contributes 5.7% of the total watershed load.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient and Sediment Levels for Mosher Brook* below for loading estimates that have been normalized by watershed area.

Table 7: Total Phosphorus Load by Source

Mosher Brook	Total P (kg/year)	Total P (%)
Source Load		
Hay/Pasture	86.5	75.2%
Cropland	1.5	1.3%
Wooded Areas	2.7	2.3%
Wetlands	0.4	0.3%
Open Land	0.2	0.2%
Barren Areas	0	0
Low-Density Mixed	4.8	4.2%
Medium-Density Mixed	4.7	4.1%
High-Density Mixed	1.0	0.9%
Low-Density Open Space	6.7	5.8%
Farm Animals	6.6	5.7%
Septic Systems	0	0
Source Load Total:	**115.1**	**100%**
Pathway Load		
Stream Bank Erosion	8.0	-
Subsurface Flow	15.2	-
Total Watershed Mass Load:	**138**	

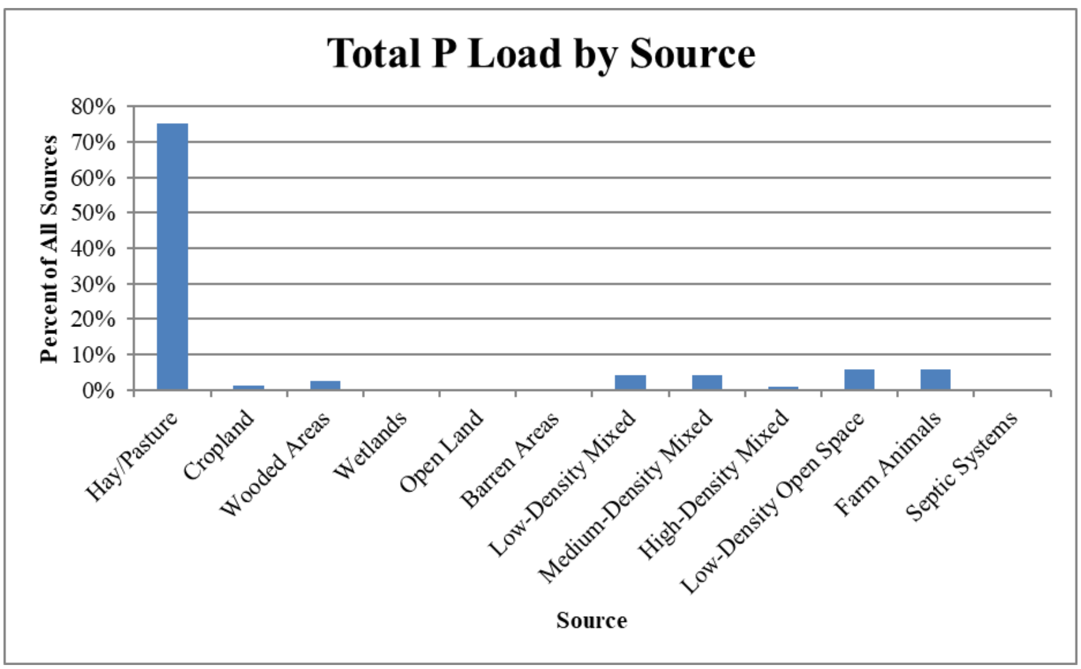


Figure 7: Total Phosphorus Load by Source in the Mosher Brook Watershed

TMDL: TARGET NUTRIENT AND SEDIMENT LEVELS FOR MOSHER BROOK

The existing loads for nutrients and sediments in the impaired segment of Mosher Brook are listed in Table 8, along with the TMDL which was calculated from the average loading estimates of five attainment watersheds throughout the state. Table 9 presents a more detailed view of the modeling results and calculations used in Table 8 to define TMDL reductions, and compares the existing nutrient and sediment loads in Mosher Brook to TMDL endpoints derived from the attainment waterbodies. An annual time frame provides a mechanism to address the daily and seasonal variability associated with nonpoint source loads.

Table 8: Mosher Brook Pollutant Loading Compared to TMDL Targets

Mosher Brook			
Pollutant Load	**Existing Load**	**TMDL**	**Reduction Required**
Total Annual Load per Unit Area		Attainment Streams	
Sediment (kg/ha/yr)	240.6	65.72	72.7%
Total N (kg/ha/yr)	3.15	2.46	22.1%
Total P (kg/ha/yr)	0.43	0.16	62.6%

Future Loading

The prescribed reduction in pollutants discussed in this TMDL reflects reduction from estimated existing conditions. Expansion of agricultural and development activities in the watershed have the potential to increase runoff and associated pollutant loads to Mosher Brook. To ensure that the TMDL targets are attained, future agricultural and development activities will need to meet the TMDL targets. Between 2012 to 2017 in Cumberland County, the growth in agricultural lands was decreasing, with a 7% decrease in the total number of farms and a 20.2% decrease in total farm area. Average farm size has also declined significantly (13.8%) during this time period. These values are extracted from the most recent (2017) Census of Agriculture (USDA 2017). Human population in Cumberland County increased by 4.8% from 2000 to 2019 (US Census 2020). Future activities and BMPs that achieve TMDL reductions are addressed below.

Next Steps

The use of agricultural and developed area BMP's can reduce sources of polluted runoff in Mosher Brook. It is recommended that municipal officials, landowners, and conservation stakeholders in Gorham work together to develop a watershed management plan to:

- Encourage greater citizen involvement through the development of a watershed coalition to ensure the long term protection of Mosher Brook;
- Run a "Hot-Spot Analysis" in *Model My Watershed* to determine sub-watershed locations of higher existing contributions of sediment and nutrients to the outlet of Mosher Brook watershed; then focus BMP mitigation in these hot-spot sub-areas of the watershed;
- Address existing nonpoint source problems in the Mosher Brook watershed by instituting BMPs where necessary; and

- Prevent future degradation of Mosher Brook through the development and/or strengthening of local Nutrient Management Ordinance.

Table 9: Annual Loads by Land Use, Other Sources, and Pathways for Mosher Brook Based on Modeling

Mosher Brook				
	Area (ha)	**Sediment** (1000 kg/yr)	**Total N** (kg/yr)	**Total P** (kg/yr)
Land Uses				
Hay/Pasture	81	30.9	312	86.5
Cropland	0.36	1.0	11	1.5
Wooded Areas	138	0.4	47	2.7
Wetlands	11	0.0	8	0.4
Open Land	3	0.2	6	0.2
Barren Areas	0	0.000	0	0.0
Low-Density Mixed	32	1.7	45	4.8
Medium-Density Mixed	10	2.3	47	4.7
High-Density Mixed	2	0.5	10	1.0
Low-Density Open Space	45	2.4	62	6.7
Total Area	323			
Other Sources				
Farm Animals		0.0	26	6.6
Septic Systems		0.0	34	0.0
Pathway Load				
Stream Bank Erosion		38.4	33	8.0
Subsurface Flow		0.0	379	15.2
Total Annual Load		78	1,020	138
Total Annual Load per Unit Area		0.241	3.15	0.43
		1000 kg/ha/yr	kg/ha/yr	kg/ha/yr

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DRAFT TMDL SUMMARY

No Name Brook

WATERSHED DESCRIPTION

This **TMDL** applies to a 10.02 mile section of No Name Brook, located in the City of Lewiston. The impaired segment begins in the northern corner of the watershed in a forested area and flows south crossing Lane Road, Old Greene Road, and No Name Pond Road before flowing into No Name Pond. At the outlet of the pond, No Name Brook continues south through a wetland, crossing Sabattus Street and Grove Street. The stream continues through a forest with sparse development, crossing Randall Road, power lines, Old Webster Road, I-95, Crowley Road, Foss Road, and Jordan Road. The stream then skirts multiple residential developments, crosses under Littlefield Road, and converges with the Sabattus River. The No Name Brook watershed covers an area of 15.42 square miles. The majority of the watershed is located within the City of Lewiston; however, small portions of the watershed lie within the surrounding towns of Greene, Sabattus, and Lisbon.

- No Name Brook is on Maine's 303(d) list of Impaired Streams as referenced in the 2016 Integrated Report (Maine DEP, 2018).
- The No Name Brook watershed is predominately non-developed (70.3%). Forested areas (56.3%) within the watershed absorb and filter pollutants helping protect both water quality in the stream and stream channel stability. Wetlands (12.4%) also help filter nutrients.
- Non-forested areas within the watershed are predominantly developed (19%) and agricultural (10.4%) and are located throughout the watershed.
- Developed areas (19%) with impervious surfaces in close proximity to the stream and runoff from agricultural land located throughout the eastern portion of the watershed are sources of nonpoint source (NPS) pollution to No Name Brook. Runoff from developed land, active hay lands, and pasture can transport sediment, nitrogen and phosphorus to the Brook.

Definitions

- ***Total Maximum Daily Load (TMDL)*** *represents the total amount of pollutants that a waterbody can receive and still meet water quality standards.*
- **Nonpoint Source Pollution** *refers to pollution that comes from many diffuse sources across the landscape, and are typically transported by rain or snowmelt runoff.*

Waterbody Facts

Segment ID: ME0104000210_418R02

City: Lewiston, ME

County: Androscoggin

Impaired Segment Length: 10.02 miles

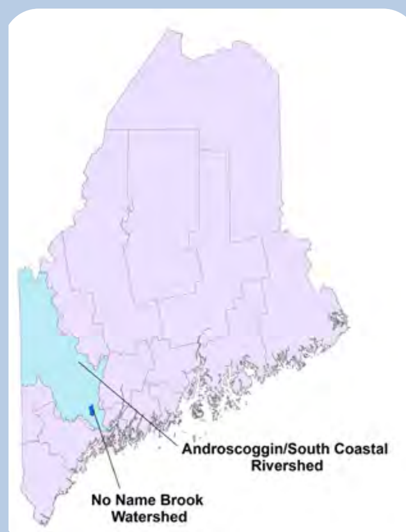
Classification: Class B

Direct Watershed: 15.42 mi^2 (9,869 acres)

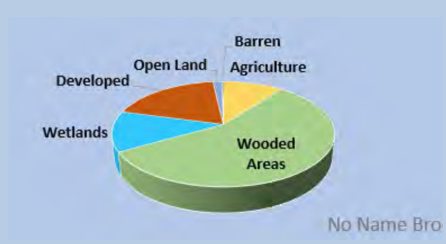
Impairment Listing Cause: Dissolved Oxygen

Watershed Agricultural Land Use: 10.4%

Major Drainage Basin: Androscoggin River



Watershed Land Uses



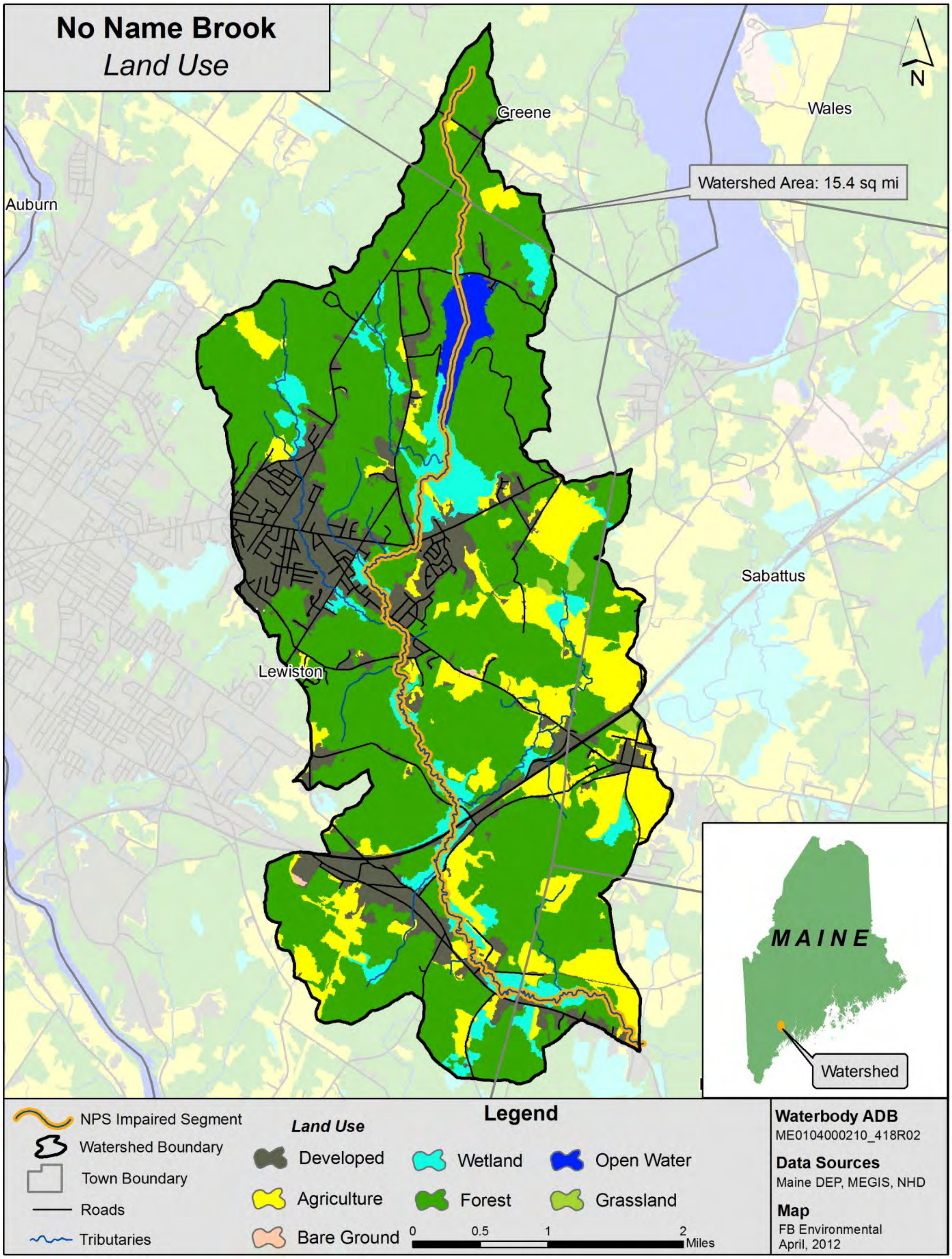


Figure 1: Land Use and Land Cover (from 2011) in the No Name Brook Watershed

WHY IS A TMDL ASSESSMENT NEEDED?

No Name Brook, a Class B freshwater stream, has been assessed by Maine DEP as not meeting water quality standards for the designated use of aquatic life, and placed on the 303(d) list of impaired waters under the Clean Water Act. The Clean Water Act requires that all 303(d)-listed waters undergo a TMDL assessment that describes the impairments and establishes a target to guide the measures needed to restore water quality. The goal is for all waterbodies to comply with state water quality standards.

***No Name Brook** near Mill Road crossing. Photo: FB Environmental*

Developed land makes up 19% of the total watershed area while agriculture makes up 10%. Runoff from impervious surfaces in developed areas as well as agriculture, may be the largest contributors of sediment and nutrient enrichment to the stream. The close proximity of some agricultural lands to the stream further increases the likelihood that nutrients from disturbed soils, manure, and fertilizers will reach the stream. Other potential contributors of nonpoint source pollution included a landscaping/auto repair facility off Lisbon Road and undersized culverts causing sedimentation in the stream. The No Name Brook wetland also has naturally low dissolved oxygen concentrations and may be effecting the concentrations within the stream.

WATER QUALITY DATA ANALYSIS

Maine DEP uses a variety of data types to measure the ability of a stream to adequately support aquatic life, including; dissolved oxygen, benthic macroinvertebrates, and periphyton (algae). For benthic macroinvertebrates, DEP makes aquatic life use determinations using a statistical model that incorporates 30 variables of data collected from rivers and streams, including the richness and abundance of streambed organisms, to determine the probability of a sample meeting Class A, B, or C conditions. Biologists use the model results and supporting information to determine if samples comply with the numeric aquatic life criteria of the class assigned to the stream or river (Davies and Tsomides, 2002). Maine DEP uses an analogous model to aid in the assessment of algal communities but makes aquatic life use determinations based on narrative standards.

The aquatic life impairment in No Name Brook is based on historic data. Dissolved oxygen data collected from 2009-2011 also found low values at many sampling stations. In addition to the stream stations, there were two wetland stations sampled in 2013 (W-101 and W-102) which were both were impaired for macroinvertebrates (only attained Class C).

TMDL ASSESSMENT APPROACH: NUTRIENT AND SEDIMENT MODELING OF IMPAIRED AND ATTAINMENT STREAMS

NPS pollution is difficult to measure directly, because it comes from many diffuse sources spread across the landscape. For this reason, an online nutrient loading model, *Model My Watershed* (v. 1.32.0), was used to estimate the sources of pollution based on well-established hydrological equations (Stroud Water Research Center 2017). *Model My Watershed* makes use of the GWLF-enhanced model engine. The model incorporates detailed maps of soil, land use, and slope, daily weather and localized weather data (from the period 2009-2020), and direct observations of agriculture and other land uses within the watershed. *Model My Watershed* is derived from its parent MapShed developed by Evans and Corradini (2012). *Model My Watershed* replaced MapShed in 2017-2018.

The nutrient loading estimates for the impaired stream were compared to similar estimates for five non-impaired (attainment) streams of similar watershed land uses across the state. The TMDL for the impaired stream was set as the mean nutrient loading estimate of these attainment stream watersheds, and units of mass per unit watershed area per year (kg/ha/year) were used. The difference in loading estimates between the impaired and attainment watersheds represents the percent reduction in nutrient loading required under this TMDL. The attainment streams and their nutrient and sediment loading estimates and TMDL are presented below in Table 1.

Table 1: Numeric Targets for Pollutant Loading Based on Model My Watershed Outputs (2021) for Attainment Streams

Attainment Streams	Town	Total P Load (kg/ha/yr)	Total N Load (kg/ha/yr)	Sediment Load (kg/ha/yr)
Footman Brook	Exeter	0.17	1.73	35.2
Martin Stream	Fairfield	0.13	2.98	57.9
Moose Brook	Houlton	0.18	1.59	48.5
Upper Kenduskeag Stream	Corinth	0.16	1.72	100.5
Upper Pleasant River	Gray	0.16	4.26	86.5
Total Maximum Daily Load		**0.16**	**2.46**	**65.7**

RAPID WATERSHED ASSESSMENT

Habitat Assessment

A habitat assessment survey was conducted on both the impaired and attainment streams. The assessment approach is based on the *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (Barbour et al. 1999), which integrates various parameters relating to the structure of physical habitat. The habitat assessments include a general description of the site, physical characterization and visual assessment of in-stream and riparian habitat quality.

Based on rapid bioassessment protocols for low gradient streams, No Name Brook received a score of 147 out of a total 200 for quality of habitat. Higher scores indicate better habitat. The range of habitat assessment scores for attainment streams was 155 to 179.

Habitat assessments were conducted on a relatively short sample reach (about 100-200 meters for a typical small stream) near the most downstream Maine DEP sample station in the watershed. For both impaired and attainment streams, the assessment location was usually near a road crossing for ease of access. In the No Name Brook watershed, the downstream sample station was located just upstream on the Foss Road crossing in Lewiston. Pathway Vineyard Church with a large surrounding parking area is nearby to the north of the sample reach. The sample reach was surrounded by a forested buffer through the majority of the reach area. However, a minimal buffer was documented near the Foss Road culvert and the Vineyard Church parking lot.

Figure 2 (right) shows the range of habitat assessment scores for all attainment and impaired streams, as well as for No Name Brook. Though these scores show that habitat is clearly an issue in the impairment of No Name Brook, it is important to look for other potential sources within the watershed leading to impairment. Consideration should be given to major "hot spots" in the No Name Brook watershed as potential sources of NPS pollution contributing to the water quality impairment.

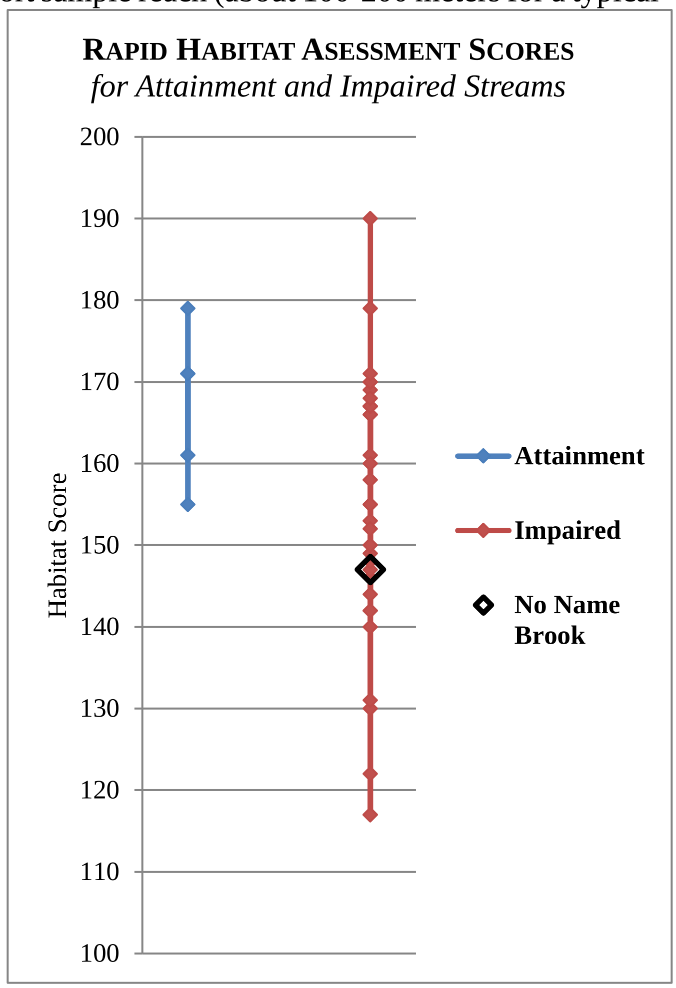


Figure 2: Habitat Assessment Scores for No Name Brook (2012) Compared to Region

Pollution Source Identification

Pollution source identification assessments were conducted for both No Name Brook (impaired) and all attainment streams. The source identification work is based on an abbreviated version of the Center for Watershed Protection's Unified Subwatershed and Site Reconnaissance method (Wright, et al. 2005). The abbreviated method includes both a desktop and field component. The desktop assessment consists of generating and reviewing maps of the watershed boundary, roads, land use and satellite imagery, and then identifying potential NPS pollution locations, such as road crossings, agricultural fields, and large areas of bare soil. When available, multiple sources of satellite imagery were reviewed. Occasionally, the high resolution of the imagery allowed for observations of livestock, row crops, eroding stream banks, sediment laden water, junkyards, and other potential NPS concerns that could affect stream quality. As many potential pollution sources as possible were visited, assessed and documented in the field. Field visits were limited to NPS sites that were visible from roads or a short walk from a roadway. Neighborhoods were assessed for NPS pollution at the whole neighborhood level including streets and storm drains (where applicable). The assessment does not include a scoring component, but does include a detailed summary of findings and a map indicating documented NPS sites throughout the watershed.

The watershed source assessment for No Name Brook was completed in June 2012. In-field observations of erosion, lack of vegetated stream buffer, extensive impervious surfaces, high-density neighborhoods and agricultural activities were documented throughout the watershed (Table 2, Figure 3).

Table 2: Potential Pollution Source ID Assessment (2012) for the No Name Brook Watershed

Potential Source			Notes
ID#	**Location**	**Type**	
16	Jordan Road (Town Farm Road)	Agriculture	• Active row crops. • Evidence of manure/fertilizing application. • Bare soil observed in some areas.
24	Grove Street	Road Crossing	• A culvert on Grove Street has recently been replaced, yet high flow and flooding was evident from the significant sediment deposition on the south side (downstream) end of the culvert, and heavy accumulation of large woody debris deposited high on the rip-rap almost to the road. • Woody debris considered possible result of collapse of beaver activity upstream due to flooding. • The local landowner told of recent flooding since the replacement of the culvert and that water overtopped the roadway. • Two unknown pipes were documented emerging from the rip-rap into the stream. • A narrow buffer was documented between the stream and adjacent lawns.
26	Sabattus Street & Golder Road	Road Crossings/ Residential	• Multiple stream crossings indicate potential stormwater impacts to the stream. • Rooted emergent vegetation was documented growing immediately downstream toward Golder Road crossing. • Water flowing in from the storm drains appeared slightly turbid.
32	Old Webster Road	Road Crossing	• Undersized culvert resulting in widening of the stream. • Small area of erosion observed off roadway due to storm water runoff.
38	Lisbon Road	Commercial Development	• Auto sales business. • Potential hot spot. • Many junked vehicles on property.
39	Lisbon Road	Commercial Development	• Landscape/truck repair business. • Oil barrels, sand, and mulch piles located behind building. • Large waste oil tank without secondary containment. • Trash observed throughout area. • A white hose was seen running to adjacent tributary. Pumping or draining activity unknown.
40	South Lisbon Road	Town Sewage Station/Road Crossing	• Road crossing with south west tributary to No Name Brook. • Sewage pump station located nearby road crossing. • Strong septic odor at road crossing.
42	Lisbon Road	Agriculture	• Two horses observed grazing with hayfields surrounding. Fields do not look active.
43	Lisbon Road	Commercial Development	• Pools and spas business. • Quite close to No Name Brook. Large parking lot and building. • Possible chemical runoff from pool chemicals.

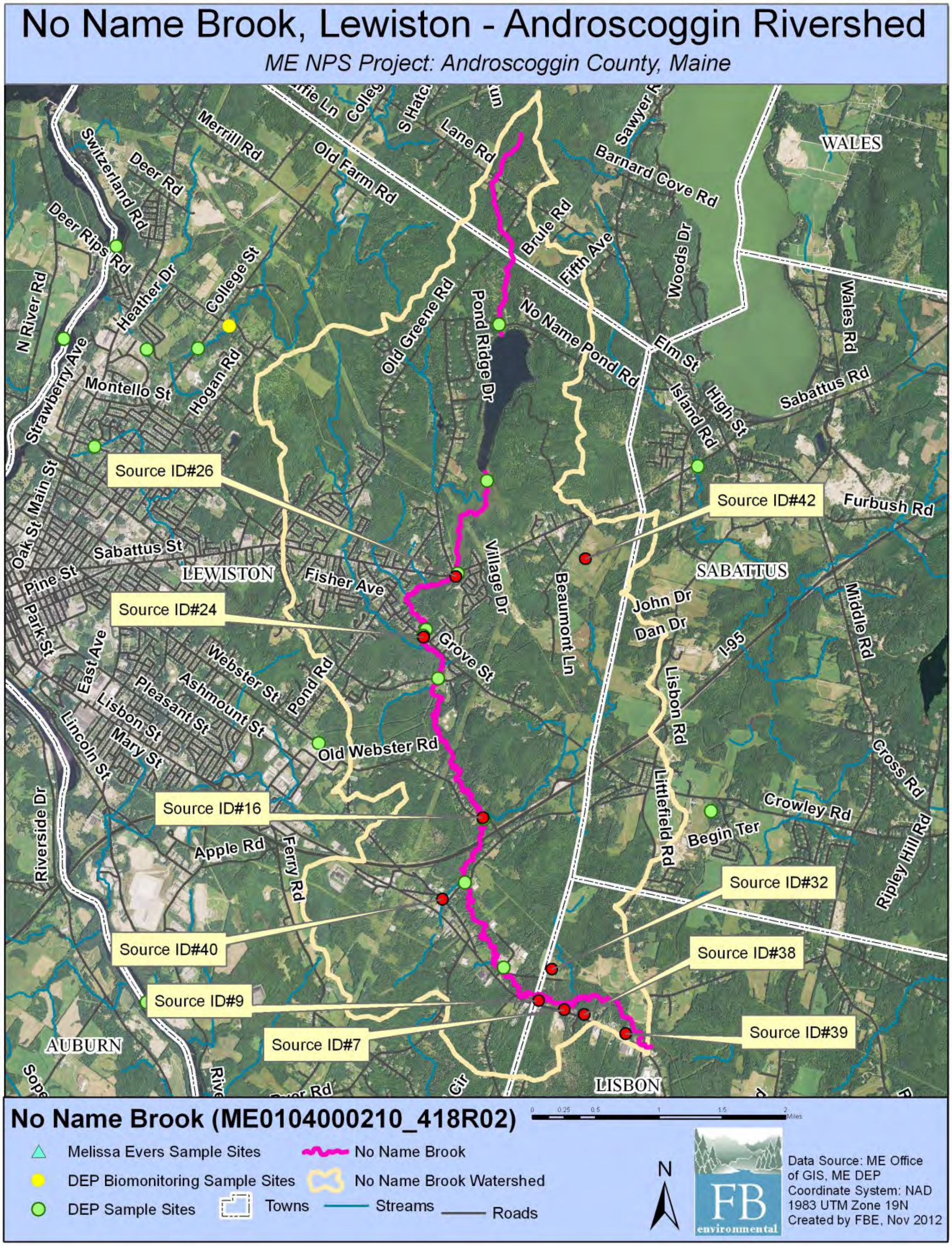


Figure 3: Aerial Photo of Potential Source ID Locations (identified in 2012) in the No Name Brook Watershed

NUTRIENT AND SEDIMENT LOADING – *MODEL MY WATERSHED* ANALYSIS

The *Model My Watershed* model was used to estimate stream loading of total phosphorus, total nitrogen, and sediment in No Name Brook watershed. The model estimated nutrient and sediment loads over a 12-year period (2009-2020), which was determined by local (Poland ME USC00176856) weather data inserted into *Model My Watershed*. This extended period captures a recent but wide range of hydrologic conditions to account for variations in nutrient and sediment loading over time. Loads for the attainment watersheds (five total; Table 1) were computed using the same model with the same recent inputs (i.e., regional weather, 2016 land use and land cover, 2016 wetland extent, and BMPs similar to the impaired watersheds).

Many quality assured and regionally calibrated input parameters are provided with *Model My Watershed*. However, several updates to some of the default parameters were made in this TMDL effort, and namely more recent land use/cover using **MRLC-NLCD 2016** [1], more recent and local weather (precipitation and temperature) data (as described above), and more regional estimates of Best Management Practices (BMPs; see ensuing discussion). Because land use/cover is more recent, the estimated filtration fraction of wetland and open water and the amount of stream buffer in agricultural land should be more accurate. It is also worth noting that improved classification algorithms were employed by MLRC in the NCLD 2016 and these new algorithm were used in the revisions of all previous NLCD versions (including the first version in 2001).

Livestock Estimates

Livestock waste contains nutrients which can cause water quality impairment. The nutrient loading model considers numbers and types of animals. Table 3 (right) provides livestock (numbers of animals) in the watershed based on the USDA National Agricultural Statistics Service (NASS) estimation for 2017. To generate watershed-based livestock counts, NASS county-based livestock totals are converted to a per unit area (based on the total area of the county). The unit area amount is then multiplied by the total watershed area to derive a watershed total count (as seen in Table 3).

Table 3: Livestock Estimates in the No Name Brook Watershed

Type	No Name Brook
Dairy Cows	75
Beef Cows	28
Broilers	39
Layers	--
Hogs/Swine	21
Sheep	27
Horses	12
Turkeys	8
Other	--
Total	**208**

The No Name Brook watershed is predominantly forested, with substantial amount of development and some agriculture. Agricultural land use is dominated by active hay fields, though some row crops were observed. Two horses were observed grazing in a pasture off of Old Chadbourn Road.

[1] MRLC-NLCD 2016 : Multi-Resolution Land Characteristics – National Land Cover Dataset (version 2016) provided by the MRLC Consortium (Jin et al. 2019).

Vegetated Stream Buffer in Agricultural Areas

Vegetated stream buffers are areas of trees, shrubs, and/or grasses adjacent to streams, lakes, ponds or wetlands which provide nutrient loading attenuation (Evans and Corradini, 2012). *Model My Watershed* considers natural vegetated stream buffers within agricultural land areas as providing nutrient load attenuation. A width of approximately 98 feet (30 m) on one side of a stream is required to be considered a streamside buffer per the *Model My Watershed* technical manual (Stroud Water Research Center 2017). Analysis of recent aerial photos was used to estimate the number of agricultural land stream miles with and without vegetative buffers, and these estimates were directly entered into the model.

Table 4: Summary of Vegetated Buffers in Agricultural Areas

No Name Brook
• Agricultural Land Stream Length = 2.7 mi • Agricultural Land Stream Length with Buffer = 1.3 mi (or 48% of total agricultural land stream length) • Percentage of total stream length flowing through non-buffered agricultural land = 14%

No Name Brook is a 10.0 mile-long impaired segment as listed by Maine DEP. As modeled, the total stream miles (including tributaries) within the watershed was calculated as 13.7 miles. Of this total, 2.7 stream miles are located within agricultural areas and 1.3 miles of that area *appear* to have a 98 foot or greater vegetated buffer (Table 4, Figure 4). From a watershed perspective, this equates to 1.4 miles or 14% of the total stream length running through agricultural land with less than a 98 foot buffer. By contrast, for attainment stream watersheds, the percentage of total stream miles running through agricultural land without a 75 foot vegetated buffer ranged from 0% to 3.9% with an average of 1.3%. Note, a minimum vegetated buffer width of *75 feet* was used in an earlier (2012) effort to produce Figure 4 shown here. Differences in stream length estimates using a 98-foot or 75-foot buffer were practically insignificant.

Home Septic System Loads

Loads for "normally functioning" septic systems are calculated in *Model My Watershed* using an estimate of the average number of persons per acre in "Low-Density Mixed" areas. In these areas, it is assumed that the populations therein are served by septic systems rather than centralized sewage systems. All homes in such areas are assumed to be connected to "normally functioning" systems rather than those that experience "surface breakouts" (surface failures), "short-circuiting" to underlying groundwater (subsurface failures), or have direct conduits to nearby water bodies. Non-functioning systems would be modeled with a higher load contribution to the waterbody.

Best Management Practices (BMPs)

Best management practices (BMPs) are typically instituted to reduce the loading of sediment and nutrients from upland (i.e., non-point) sources. Ideally, information on BMPs for a specific watershed from local and regional sources would improve this component of the water quality model. Maine DEP sought information on BMP use in early 2021 from local, regional, and state agricultural agencies for rural BMPs and from nearby municipalities for urban BMPs. Very little to no information was returned in the solicitation. Hence, estimates for typical New England watersheds were derived from information available from Vermont. An upper limit of BMP use was garnered from watersheds entering the Chesapeake Bay where BMP use is intensive.

Four agricultural BMPs were used in this modeling effort and in the following manner:

- *Cover Crops:* Cover crops are the use annual or perennial crops to protect soil from erosion during time periods between harvesting and planting of the primary crop. The percent of cropland area in a cover crop BMP deployed was estimated at 25% and selected as the low end of the range (25 to 30 percent) expected for cropland in New England. This value was assigned to the five attainment watersheds.
- *Conservation Tillage:* Conservation tillage is any kind of system that leaves at least 30% of the soil surface covered with crop residue after planting. This reduces soil erosion and runoff. This BMP was estimated to occur in 25% of cropland. This value was assigned to the five attainment watersheds.
- *Strip Cropping / Contour Farming:* This BMP involves tilling, planting and harvesting perpendicular to the gradient of a hill or slope using high levels of plant residue to reduce soil erosion from runoff. Both interview sources suggest this practice is minimal to non-existent for New England watersheds. Hence, no BMP of this type was used in this modeling effort. This value was assigned to the five attainment watersheds.
- *Grazing Land Management:* This BMP consists of ensuring adequate vegetation cover on grazed lands to prevent soil erosion from overgrazing or other forms of over-use. This usually employs a rotational grazing system where hays or legumes are planted for feed and livestock is rotated through several fenced pastures. Both interview sources were not aware of this practice being active and is likely minimal for New England watersheds. Hence, no BMP of this type was used in this modeling effort for both impaired and attaining watersheds.

Note that other agricultural and development BMPs likely exist in the watershed but their location and type were not available in a watershed-wide format that is necessary to include in the model. Agricultural BMPs recommended by Maine DEP to reduce sediment and nutrient loads include vegetated buffers, covered manure storage facilities, and stream exclusion fencing. BMPs for developed areas recommended by the Maine DEP include vegetated buffers, stormwater BMPs, and minimization of impervious cover.

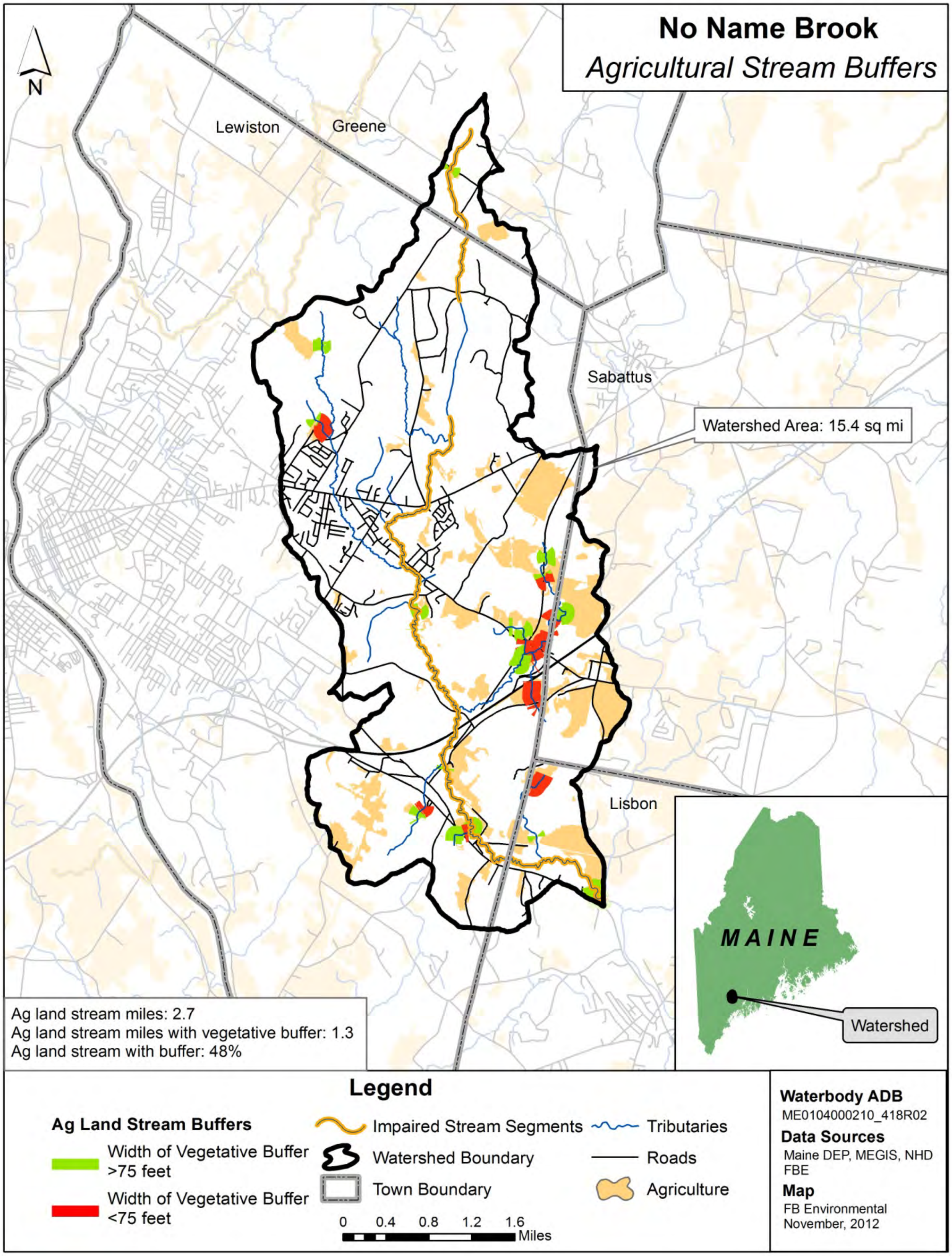


Figure 4: Agricultural Stream Buffers (from 2012) in the No Name Brook Watershed

Pollutant Load Attenuation by Lakes, Ponds and Wetlands

Depositional environments such as lakes, ponds, and wetlands can attenuate watershed sediment and nutrient loading. This information is entered into the nutrient loading model by a simple percentage of watershed area draining to a lake, pond, or wetland. The No Name Brook watershed is 13.1% wetland and open water (per the 2016 NLCD land use/cover) which includes No Name Pond. Multiple wetlands and open water surround tributaries throughout the watershed. Because of this proximity to streams, it is estimated that 90% of land area within the watershed drains to wetlands and open water. The percent of watershed draining to a wetland in the attainment watersheds, based on the 2021 analysis, ranged from 26 to 58 percent, with an average of 40%.

NUTRIENT AND SEDIMENT MODELING RESULTS

Selected results from the watershed loading model are presented here. The TMDL itself is expressed in units of kilograms per hectare per year. The additional results shown below assist in better understanding the likely sources of pollution. The model results for No Name Brook indicate moderate reductions of phosphorus and smaller reductions in nitrogen and sediment are needed to improve water quality. Below, loading for nitrogen, phosphorus and sediment are discussed individually.

There are two categories of loads – sources and pathways. Sources are determined by land use/cover and the overland flow they generate, livestock counts by animal type, and home sewage treatment systems in developed areas. Pathways represent additional loads derived from subsurface flow and streambank erosion. Subsurface loads are calculated using dissolved N and P coefficients for shallow groundwater and are mainly derived from atmospheric inputs. Sediment and nutrient loads produced by eroding streambanks are estimated using an approach developed by Evans et al. (2003). This pathway is comprised of loads originating from five sources, and listed in order of decreasing importance: amount of developed land area, soil erodibility (K-factor), density of livestock, runoff curve number, and topographic slope. For any given model run, the amount of developed land in the watershed is responsible for just over 72% of the total streambank load, whereas soil erodibility and animal density are responsible for 21% and 7% of the total streambank load, respectively.

Sediment

Aside from stream bank erosion which contributes 72.3% of the total watershed sediment load, the major source load in No Name Brook watershed originates from hay/pasture land (51% of total sources). Residential sources also contribute a significant source load (almost 40%). Note that residential sources also comprise 71% of the stream bank erosion load.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient and Sediment Levels for No Name Brook* below for loading estimates that have been normalized by watershed area.

Table 5: Total Sediment Load by Source

No Name Brook	Sediment (1000 kg/year)	Sediment (%)
Source Load		
Hay/Pasture	39.4	51.0%
Cropland	2.2	2.8%
Wooded Areas	2.9	3.8%
Wetlands	0.3	0.4%
Open Land	1.7	2.3%
Barren Areas	0.003	0.003%
Low-Density Mixed	5.7	7.3%
Medium-Density Mixed	17.3	22.4%
High-Density Mixed	2.5	3.2%
Low-Density Open Space	5.3	6.9%
Farm Animals	0	0
Septic Systems	0	0
Source Load Total:	**77.3**	**100%**
Pathway Load		
Stream Bank Erosion	208.5	-
Subsurface Flow	0	-
Total Watershed Mass Load:	**286**	

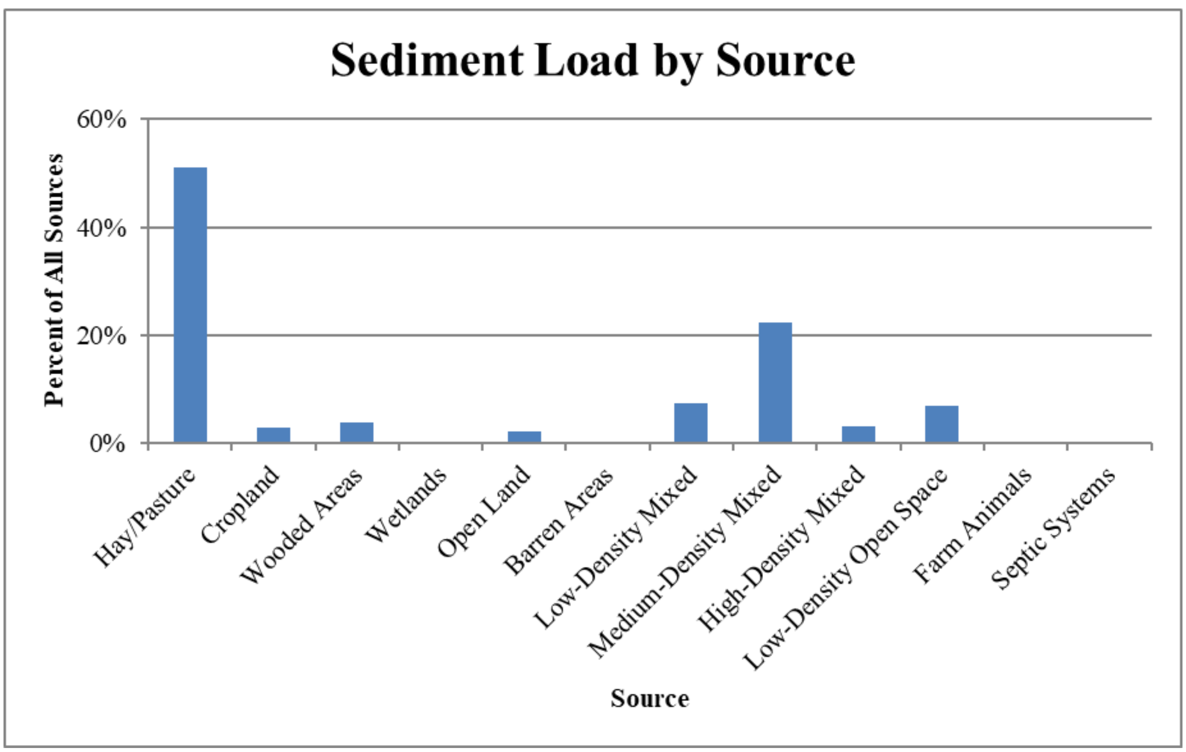


Figure 5: Total Sediment Load by Source in the No Name Brook Watershed

Total Nitrogen

Table 6 and Figure 6 (below) show the estimated total nitrogen load, in terms of mass and percent of total by source, in the No Name Brook watershed. Sources of N originate from several sources where all have an equivalent contribution. Residential areas contribute the most (34%). Home septic systems contribute 11.4%. Hay/pasture land and farm animals contribute a combined 33.3%.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient and Sediment Levels for No Name Brook* below for loading estimates that have been normalized by watershed area.

Table 6: Total Nitrogen Load by Source

No Name Brook	Total N (kg/year)	Total N (%)
Source Load		
Hay/Pasture	974	18.1%
Cropland	52	1.0%
Wooded Areas	641	11.9%
Wetlands	355	6.6%
Open Land	124	2.3%
Barren Areas	3	0.1%
Low-Density Mixed	403	7.5%
Medium-Density Mixed	894	16.6%
High-Density Mixed	127	2.4%
Low-Density Open Space	378	7.0%
Farm Animals	815	15.2%
Septic Systems	614	11.4%
Source Load Total:	**5,381**	**100%**
Pathway Load		
Stream Bank Erosion	450	-
Subsurface Flow	5,696	-
Total Watershed Mass Load:	**11,527**	

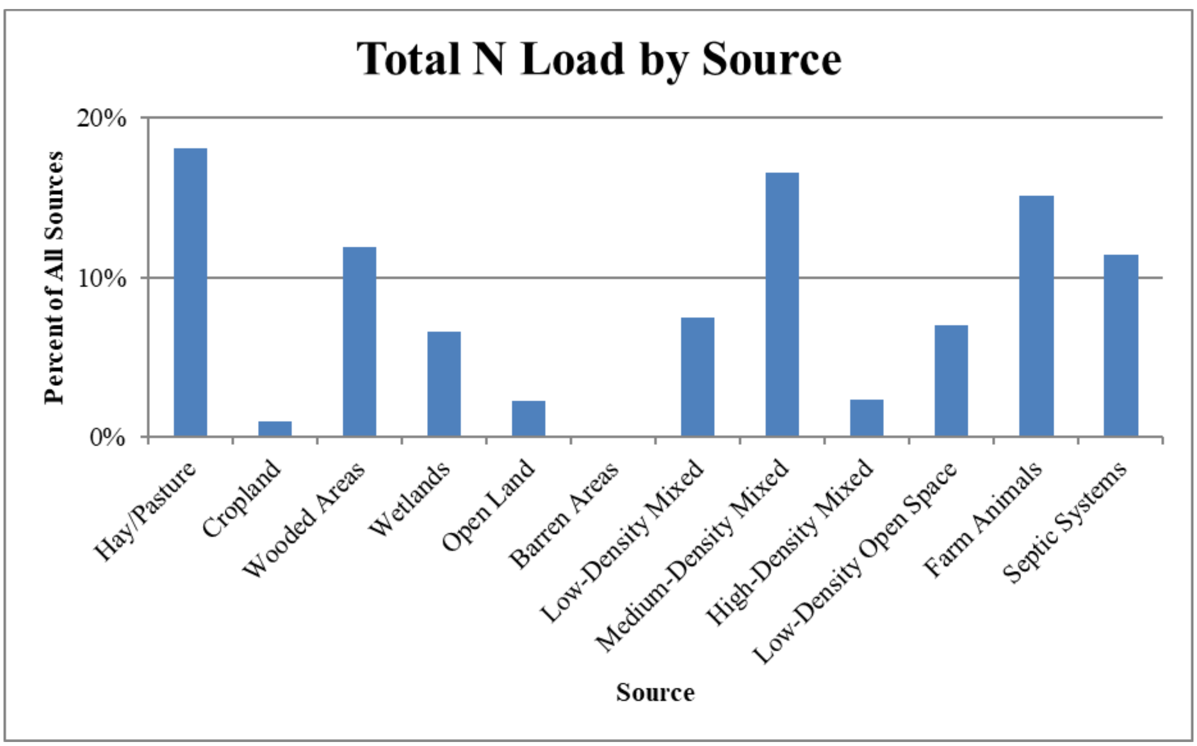


Figure 6: Total Nitrogen Load by Source in the No Name Brook Watershed

Total Phosphorus

Table 7 and Figure 7 (below) show the estimated total phosphorus load in terms of mass and percent of total by source, in the No Name Brook watershed. Hay/pasture land contributes a little over 50% of the source load. Farm animals contribute 19.6% whereas residential areas contribute 20.8%

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient and Sediment Levels for No Name Brook* below for loading estimates that have been normalized by watershed area.

Table 7: Total Phosphorus Load by Source

No Name Brook	Total P (kg/year)	Total P (%)
Source Load		
Hay/Pasture	384.6	50.1%
Cropland	11.0	1.4%
Wooded Areas	36.9	4.8%
Wetlands	16.8	2.2%
Open Land	7.4	1.0%
Barren Areas	0.1	0.01%
Low-Density Mixed	36.8	4.8%
Medium-Density Mixed	77.6	10.1%
High-Density Mixed	11.0	1.4%
Low-Density Open Space	34.5	4.5%
Farm Animals	150.8	19.6%
Septic Systems	0	0
Source Load Total:	**767.5**	**100%**
Pathway Load		
Stream Bank Erosion	167.0	-
Subsurface Flow	183.4	-
Total Watershed Mass Load:	**1,118**	

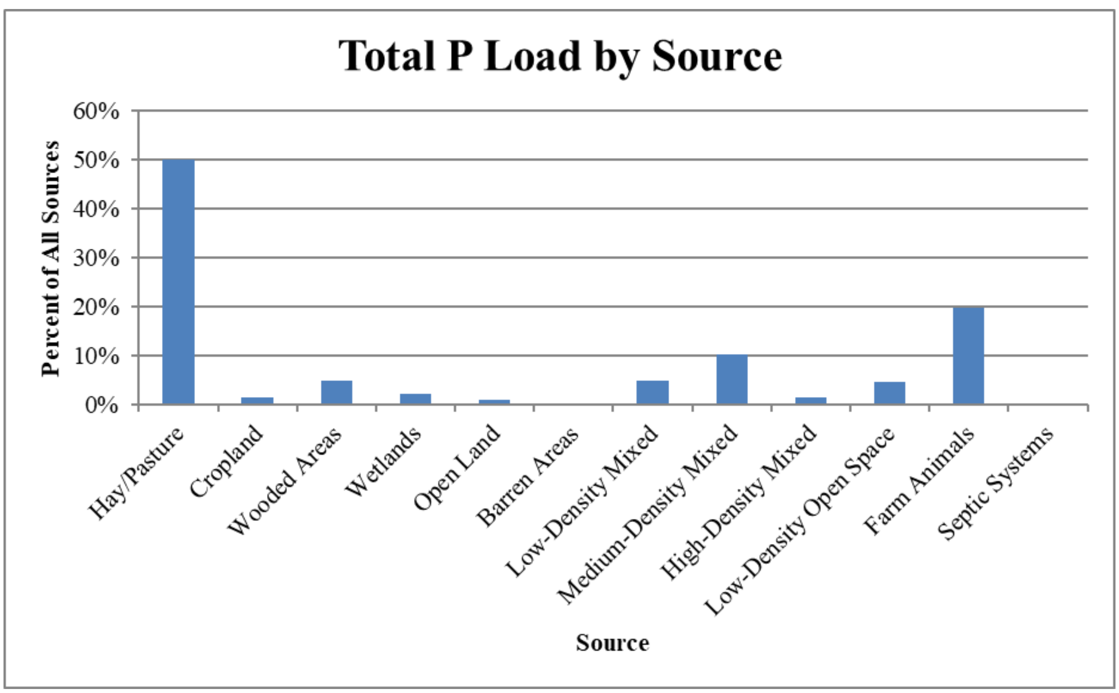


Figure 7: Total Phosphorus Load by Source in the No Name Brook Watershed

TMDL: TARGET NUTRIENT AND SEDIMENT LEVELS FOR NO NAME BROOK

The existing loads for nutrients and sediments in the impaired segment of No Name Brook are listed in Table 8, along with the TMDL which was calculated from the average loading estimates of five attainment watersheds throughout the state. Table 9 presents a more detailed view of the modeling results and calculations used in Table 8 to define TMDL reductions, and compares the existing nutrient and sediment loads in No Name Brook to TMDL endpoints derived from the attainment waterbodies. An annual time frame provides a mechanism to address the daily and seasonal variability associated with nonpoint source loads.

Table 8: No Name Brook Pollutant Loading Compared to TMDL Targets

No Name Brook			
Pollutant Load	**Existing Load**	**TMDL**	**Reduction Required**
Total Annual Load per Unit Area		Attainment Streams	
Sediment (kg/ha/yr)	72.8	65.72	9.8%
Total N (kg/ha/yr)	2.94	2.46	16.4%
Total P (kg/ha/yr)	0.28	0.16	43.9%

Future Loading

The prescribed reduction in pollutants discussed in this TMDL reflects reduction from estimated existing conditions. Expansion of agricultural and development activities in the watershed have the potential to increase runoff and associated pollutant loads to No Name Brook. To ensure that the TMDL targets are attained, future agricultural and development activities will need to meet the TMDL targets. Between 2012 to 2017 in Androscoggin County, the growth in agricultural lands was generally decreasing as both total land area in farms (6.4%) and average farm size (12.5%) have declined. However, the total number of farms has increased 7.1%. These values are extracted from the most recent (2017) Census of Agriculture (USDA 2017). Human population in Androscoggin County increased only slightly by 0.53% from 2000 to 2019 (US Census 2020). Future activities and BMPs that achieve TMDL reductions are addressed below.

Next Steps

The use of developed area and agricultural Best Management Practices (BMP's) can reduce sources of polluted runoff in No Name Brook. It is recommended that municipal officials, landowners, and conservation stakeholders in Lewiston work together to develop a watershed management plan to:

- Encourage greater citizen involvement through the development of a watershed coalition to ensure the long term protection of No Name Brook;
- Run a "Hot-Spot Analysis" in *Model My Watershed* to determine sub-watershed locations of higher existing contributions of sediment and nutrients to the outlet of No Name Brook watershed; then focus BMP mitigation in these hot-spot sub-areas of the watershed;
- Address existing nonpoint source problems in the No Name Brook watershed by instituting BMPs where necessary; and

- Prevent <u>future</u> degradation of No Name Brook through the development and/or strengthening of local Nutrient Management Ordinance.

Table 9: Annual Loads by Land Use, Other Sources, and Pathways for No Name Brook Based on Modeling

No Name Brook				
	Area (ha)	**Sediment** (1000 kg/yr)	**Total N** (kg/yr)	**Total P** (kg/yr)
Land Uses				
Hay/Pasture	404	39.4	974	384.6
Cropland	6	2.2	52	11.0
Wooded Areas	2,209	2.9	641	36.9
Wetlands	487	0.3	355	16.8
Open Land	63	1.7	124	7.4
Barren Areas	8	0.003	3	0.1
Low-Density Mixed	277	5.7	403	36.8
Medium-Density Mixed	185	17.3	894	77.6
High-Density Mixed	26	2.5	127	11.0
Low-Density Open Space	259	5.3	378	34.5
Total Area	3,923			
Other Sources				
Farm Animals		0.0	815	150.8
Septic Systems		0.0	614	0.0
Pathway Load				
Stream Bank Erosion		208.5	450	167.0
Subsurface Flow		0.0	5,696	183.4
Total Annual Load		286	11,527	1,118
Total Annual Load per Unit Area		0.073	2.94	0.28
		1000 kg/ha/yr	kg/ha/yr	kg/ha/yr

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DRAFT TMDL SUMMARY

Otter Brook

WATERSHED DESCRIPTION

This **TMDL** applies to a 2.16 mile section of Otter Brook, located in the Town of Windham, Maine. The impaired segment of Otter Brook begins in the northern portion of the watershed just upstream of Pope Road and flows south through residential neighborhoods and agriculture. It crosses Center Brook Drive, Windham Center Road, and River Road. Otter Brook meets the Presumpscot River just upstream of Dundee Pond. The Otter Brook watershed covers an area of 2.14 square miles.

- Otter Brook is on Maine's 303(d) list of Impaired Streams as referenced in the 2016 Integrated Report (Maine DEP, 2018).
- The Otter Brook watershed is predominately non-developed (51%). Forested areas (38%) within the watershed absorb and filter pollutants helping protect both water quality in the stream and stream channel stability. Wetlands (11%) also help filter nutrients.
- Non-forested areas within the watershed are predominantly developed (30.4%) and agricultural (18.3%).
- Developed areas (30.4%) exist on the periphery of the watershed; those areas with impervious surfaces in close proximity to the stream, or which create concentrated flow are likely sources of **nonpoint source (NPS) pollution** to the stream.
- Runoff from agricultural land located throughout the central portion of the watershed where Otter Brook flows is also a likely source of nonpoint source pollution to the stream. Runoff from active hay lands and pasture can transport sediment, nitrogen, and phosphorus to the stream.

Definitions

- ***Total Maximum Daily Load (TMDL)*** *represents the total amount of pollutants that a waterbody can receive and still meet water quality standards.*
- **Nonpoint Source Pollution** *refers to pollution that comes from many diffuse sources across the landscape, and are typically transported by rain or snowmelt runoff.*

Waterbody Facts

Segment ID: ME0106000103_607R09

Town: Windham, ME

County: Cumberland

Impaired Segment Length: 2.16 miles

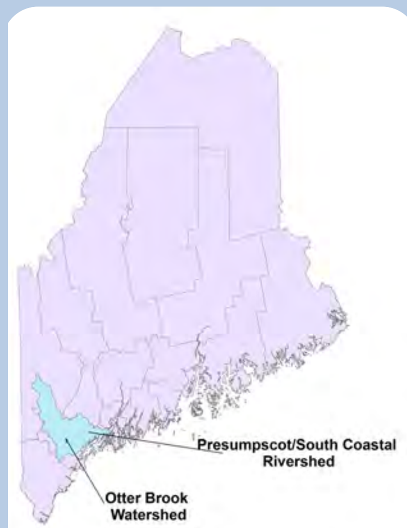
Classification: Class B

Direct Watershed: 2.14 mi^2 (1,370 acres)

Impairment Listing Cause: Dissolved Oxygen

Watershed Agricultural Land Use: 18%

Major Drainage Basin: Presumpscot River



Watershed Land Uses

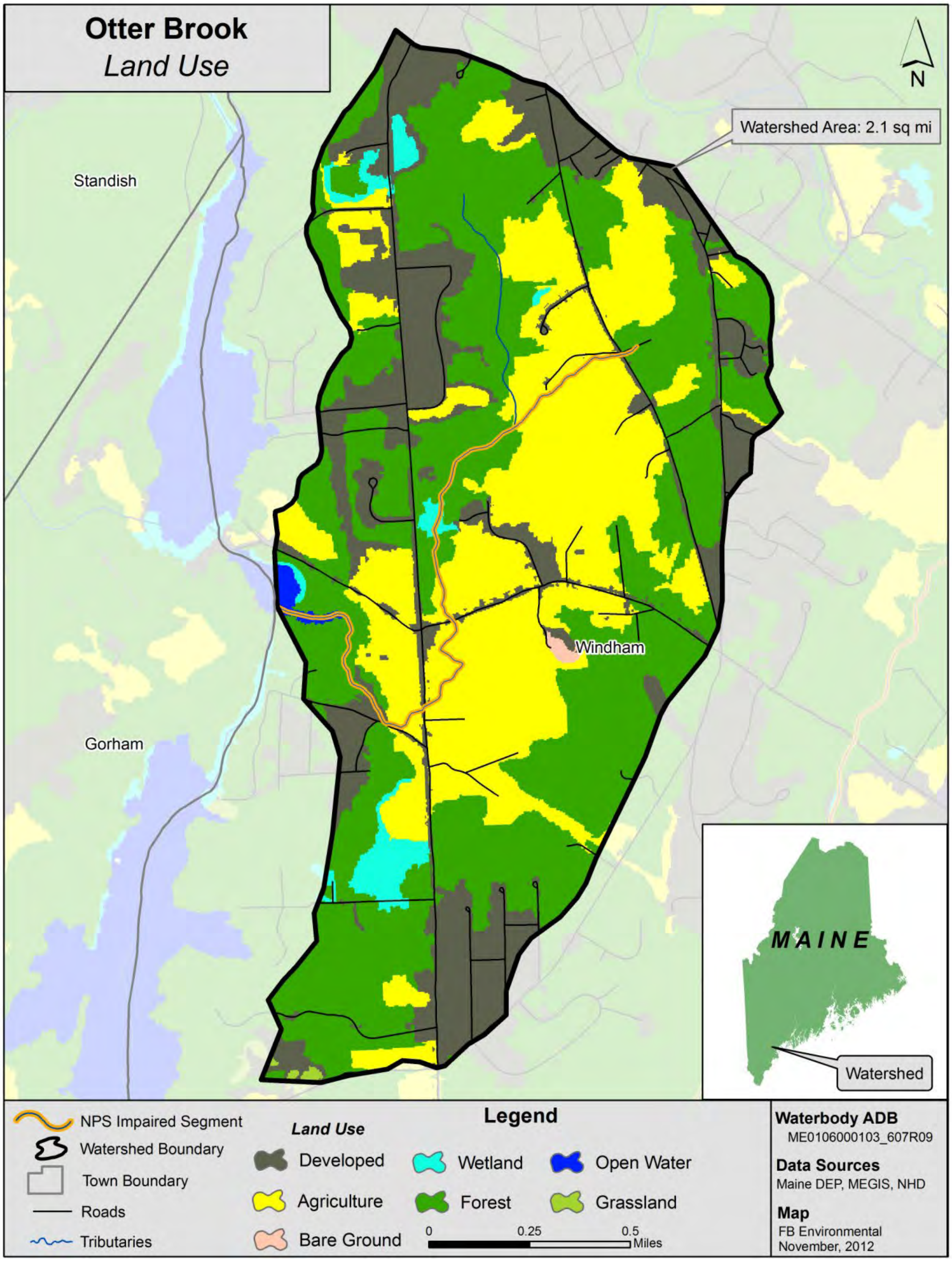


Figure 1: Land Use and Land Cover (from 2011) in the Otter Brook Watershed

WHY IS A TMDL ASSESSMENT NEEDED?

Otter Brook, a Class B freshwater stream, has been assessed by Maine DEP as not meeting water quality standards for the designated use of aquatic life, and placed on the 303(d) list of impaired waters under the Clean Water Act. The Clean Water Act requires that all 303(d)-listed waters undergo a TMDL assessment that describes the impairments and establishes a target to guide the measures needed to restore water quality. The goal is for all waterbodies to comply with state water quality standards.

***Otter Brook** sample reach near Presumpscot Road. Photo: FB Environmental*

Agricultural land area (primarily hay/pastureland) in the Otter Brook watershed makes up about 18% of the watershed. This is slightly larger than the one-half of developed land area (30.4%). However, 41% of the impaired stream segment length passes through agricultural land (Figure 1). Agriculture and developed areas therefore, are likely the largest contributors of sediment and nutrient enrichment to the stream. The close proximity of many agricultural lands to the stream further increases the likelihood that nutrients from disturbed soils, manure, and fertilizers will reach the stream. A horse stable located on Windham Center Road and significant erosion and lack of riparian buffer at a stream crossing at Windham Center Road adjacent to active hay land are potential hotspots for nonpoint source pollution.

WATER QUALITY DATA ANALYSIS

Maine DEP uses a variety of data types to measure the ability of a stream to adequately support aquatic life, including; dissolved oxygen, benthic macroinvertebrates, and periphyton (algae). For benthic macroinvertebrates, DEP makes aquatic life use determinations using a statistical model that incorporates 30 variables of data collected from rivers and streams, including the richness and abundance of streambed organisms, to determine the probability of a sample meeting Class A, B, or C conditions. Biologists use the model results and supporting information to determine if samples comply with the numeric aquatic life criteria of the class assigned to the stream or river (Davies and Tsomides, 2002). Maine DEP uses an analogous model to aid in the assessment of algal communities but makes aquatic life use determinations based on narrative standards.

The aquatic life impairment in Otter Brook is based on historic data. Additionally, dissolved oxygen data collected at station ROT06 in 2009-2011 and ROT07 in 2007 corroborates the impairment.

TMDL ASSESSMENT APPROACH: NUTRIENT AND SEDIMENT MODELING OF IMPAIRED AND ATTAINMENT STREAMS

NPS pollution is difficult to measure directly because it comes from many diffuse sources spread across the landscape. For this reason, an online nutrient loading model, *Model My Watershed* (v. 1.32.0), was used to estimate the sources of pollution based on well-established hydrological equations (Stroud Water Research Center 2017). *Model My Watershed* makes use of the GWLF-enhanced model engine. The model incorporates detailed maps of soil, land use, and slope, daily weather and localized weather data (from the period 2009-2020), and direct observations of agriculture and other land uses within the watershed. *Model My Watershed* is derived from its parent MapShed developed by Evans and Corradini (2012). *Model My Watershed* replaced MapShed in 2017-2018.

The nutrient loading estimates for the impaired stream were compared to similar estimates for five non-impaired (attainment) streams of similar watershed land uses across the state. The TMDL for the impaired stream was set as the mean nutrient loading estimate of these attainment stream watersheds, and units of mass per unit watershed area per year (kg/ha/year) were used. The difference in loading estimates between the impaired and attainment watersheds represents the percent reduction in nutrient loading required under this TMDL. The attainment streams and their nutrient and sediment loading estimates and TMDL are presented below in Table 1.

Table 1: Numeric Targets for Pollutant Loading Based on Model My Watershed Outputs (2021) for Attainment Streams

Attainment Streams	Town	Total P Load (kg/ha/yr)	Total N Load (kg/ha/yr)	Sediment Load (kg/ha/yr)
Footman Brook	Exeter	0.17	1.73	35.2
Martin Stream	Fairfield	0.13	2.98	57.9
Moose Brook	Houlton	0.18	1.59	48.5
Upper Kenduskeag Stream	Corinth	0.16	1.72	100.5
Upper Pleasant River	Gray	0.16	4.26	86.5
Total Maximum Daily Load		**0.16**	**2.46**	**65.7**

RAPID WATERSHED ASSESSMENT

Habitat Assessment

A habitat assessment survey was conducted on both the impaired and attainment streams. The assessment approach is based on the *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (Barbour et al., 1999), which integrates various parameters relating to the structure of physical habitat. The habitat assessments include a general description of the site, physical characterization and visual assessment of in-stream and riparian habitat quality.

Based on rapid bioassessment protocols for low gradient streams, Otter Brook received a score of 160 out of a total 200 for quality of habitat. Higher scores indicate better habitat. The range in habitat assessment scores for attainment streams is 155 to 179.

Habitat assessments were conducted on a relatively short sample reach (about 100-200 meters for a typical small stream) near the most downstream Maine DEP sample station in the watershed. For both impaired and attainment streams, the assessment location was usually near a road crossing for ease of access. In the Otter Brook watershed, the downstream sample station was located downstream of the River Road stream crossing and DEP sample station ROT06. The sample reach was accessed via Presumpscot Road. The immediate surrounding riparian zone is dominated by grasses and is adjacent to a power line corridor. The water was documented as being slightly turbid and minimal sediment deposits were observed.

Figure 2 (right) shows the range of habitat assessment scores for all attainment and impaired streams, as well as for Otter Brook. The overlapping attainment and impaired stream scores indicate that factors other than habitat should be considered when addressing the impairments in Otter Brook. Consideration should be given to major "hot spots" in the Otter Brook watershed as potential sources of NPS pollution contributing to the water quality impairment.

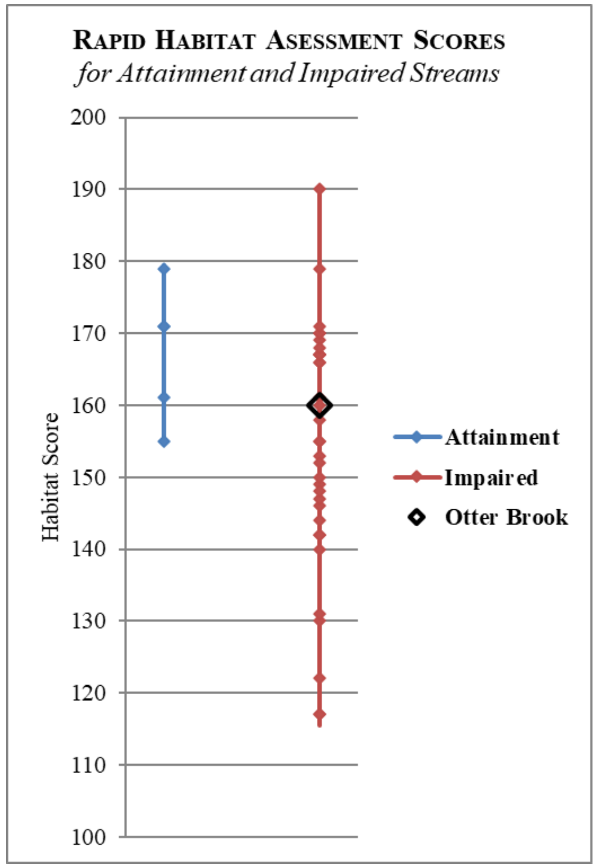


Figure 2: Habitat Assessment Scores for Otter Brook (2012) Compared to Region

Pollution Source Identification

Pollution source identification assessments were conducted for both Otter Brook (impaired) and the attainment streams. The source identification work is based on an abbreviated version of the Center for Watershed Protection's Unified Subwatershed and Site Reconnaissance method (Wright, et al., 2005). The abbreviated method includes both a desktop and field component. The desktop assessment consists of generating and reviewing maps of the watershed boundary, roads, land use and satellite imagery, and then identifying potential NPS pollution locations, such as road crossings, agricultural fields, and large areas of bare soil. When available, multiple sources of satellite imagery were reviewed. Occasionally, the high resolution of the imagery allowed for observations of livestock, row crops, eroding stream banks, sediment laden water, junkyards, and other potential NPS concerns that could affect stream quality. As many potential pollution sources as possible were visited, assessed and documented in the field. Field visits were limited to NPS sites that were visible from roads or a short walk from a roadway. Neighborhoods were assessed for NPS pollution at the whole neighborhood level including streets and storm drains (where applicable). The assessment does not include a scoring component, but does include a detailed summary of findings and a map indicating documented NPS sites throughout the watershed.

The watershed source assessment for Otter Brook was completed in July 2012. In-field observations of erosion, lack of vegetated stream buffer, extensive impervious surfaces, high-density neighborhoods and agricultural activities were documented throughout the watershed (Table 2, Figure 3).

Table 2: Potential Pollution Source ID Assessment (2012) for the Otter Brook Watershed

Potential Source			Notes
ID#	**Location**	**Type**	
2	River Road & Windham Center Road	Agriculture	• A large horse stable was observed off Windham Center Road. • A training areas/paddock and barn are located on the property. Construction was taking place during visit. • Pasture and hay fields surround facilities.
4	Windham Center Road	Road Crossing	• Significant gully erosion along Windham Center road transports runoff directly into stream. • Limited buffers were noted here. • Hay land on adjacent horse stable property (ID# 2) is actively harvested to the streams edge.
6	Center Brook Drive	Neighborhood	• Lush, green lawns. • Established buffer in most places.
7	Pope Road & Center Brook Drive	Agriculture	• Large hay field in close proximity to stream. • Unknown width of buffers in most places (marked private – no trespassing).
11	River Road	Wetland/inactive field	• The stream flows through field with minimal shading is most areas. Fields on the horse stable property are close by.

NUTRIENT AND SEDIMENT LOADING – *MODEL MY WATERSHED* ANALYSIS

The *Model My Watershed* model was used to estimate stream loading of total phosphorus, total nitrogen, and sediment in Otter Brook watershed. The model estimated nutrient loads over a 12-year period (2009-2020), which was determined by local (Portland Jetport USW00014764) weather data inserted into *Model My Watershed*. This extended period captures a recent but wide range of hydrologic conditions to account for variations in nutrient and sediment loading over time. Loads for the attainment watersheds (five total; Table 1) were computed using the same model with the same recent inputs (i.e., regional weather, 2016 land use and land cover, 2016 wetland extent, and BMPs similar to the impaired watersheds).

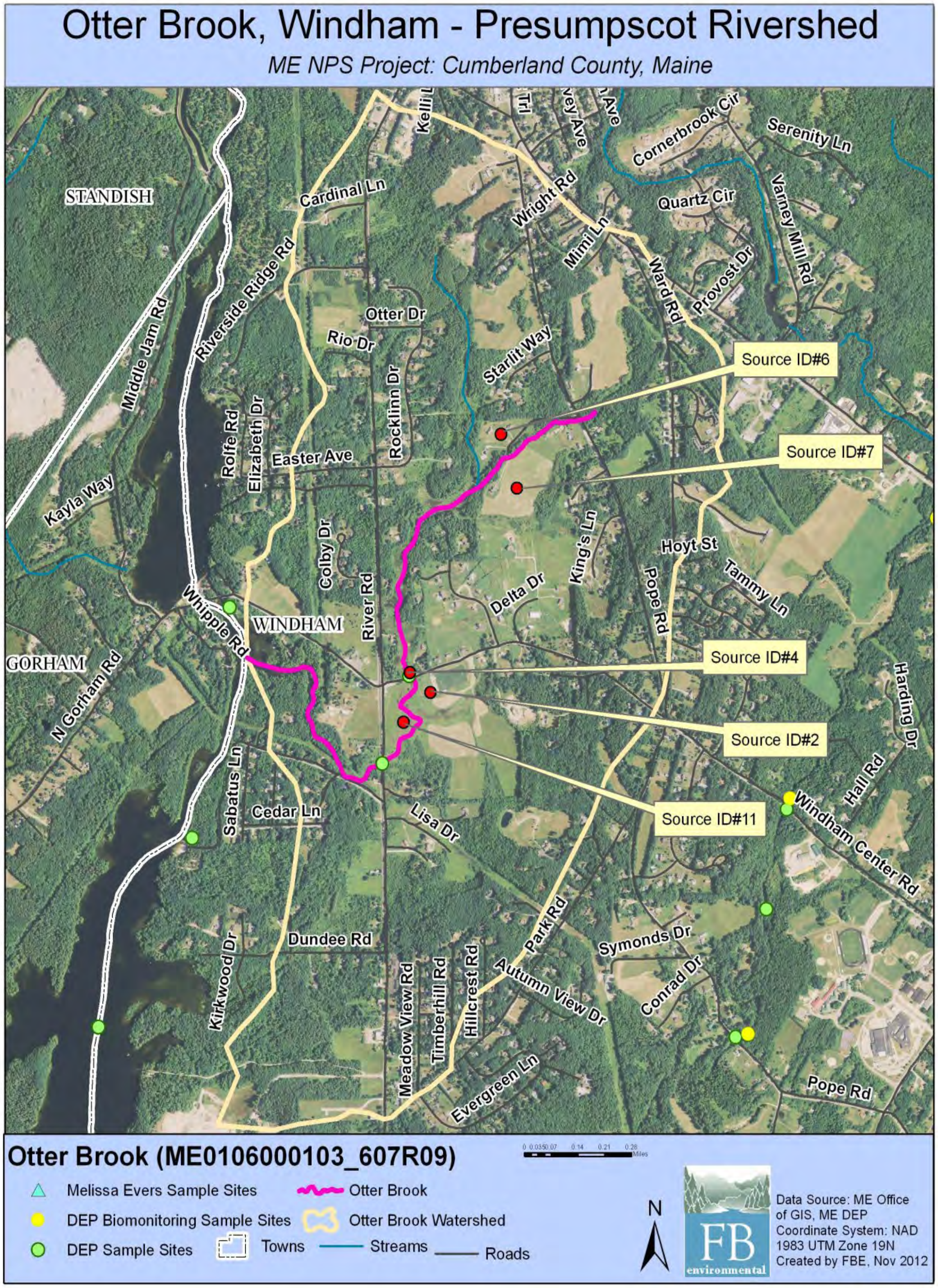


Figure 3: Aerial Photo of Potential Source ID Locations (identified in 2012) in Otter Brook Watershed

Many quality assured and regionally calibrated input parameters are provided with *Model My Watershed*. However, several updates to some of the default parameters were made in this TMDL effort, and namely more recent land use/cover using **MRLC-NLCD 2016** [1], more recent and local weather (precipitation and temperature) data (as described above), and more regional estimates of Best Management Practices (BMPs; see ensuing discussion). Because land use/cover is more recent, the estimated filtration fraction of wetland and open water and the amount of stream buffer in agricultural land should be more accurate. It is also worth noting that improved classification algorithms were employed by MLRC in the NCLD 2016 and these new algorithms were used in the revisions of all previous NLCD versions (including the first version in 2001).

Livestock Estimates

Livestock waste contains nutrients which can cause water quality impairment. The nutrient loading model considers numbers and types of animals. Table 3 (right) provides livestock (numbers of animals) in the watershed based on the USDA National Agricultural Statistics Service (NASS) estimation for 2012. Some of these totals were modified by direct observations made in the watershed in the 2012 survey. To generate watershed-based livestock counts, NASS county-based livestock totals are converted to a per unit area (based on the total area of the county). The unit area amount is then multiplied by the total watershed area to derive a watershed total count (as seen in Table 3).

Table 3: Livestock Estimates in the Otter Brook Watershed

Type	Otter Brook
Dairy Cows	1
Beef Cows	2
Broilers	2
Layers	10
Hogs/Swine	2
Sheep	6
Horses	12
Turkeys	0
Other	8 (goats)
Total	**43**

The Otter Brook watershed contains large areas of agriculture. Hay fields were the dominant agricultural use, and few animals were observed. A horse stable and training facility is located on the corner of River Road and Windham Center Road. About 12 horses were observed grazing in pasture here, but number of horses may fluctuate due to nature of the horse boarding business. Hay on this property had been cut to the banks of Otter Brook near Windham Center Road. Eight goats were also observed on a property on the west side of Pope Road; however, this area was well set back from Otter Brook and surrounded by forest.

[1] MRLC-NLCD 2016 : Multi-Resolution Land Characteristics – National Land Cover Dataset (version 2016) provided by the MRLC Consortium (Jin et al. 2019).

Vegetated Stream Buffer in Agricultural Areas

Vegetated stream buffers are areas of trees, shrubs, and/or grasses adjacent to streams, lakes, ponds or wetlands which provide nutrient loading attenuation (Evans and Corradini 2012). *Model My Watershed* considers natural vegetated stream buffers within agricultural land areas as providing nutrient load attenuation. A width of approximately 98 feet (30 m) on one side of a stream is required to be considered a streamside buffer per the *Model My Watershed* technical manual (Stroud Water Research Center 2017). Analysis of recent aerial photos was used to estimate the number of agricultural land stream miles with and without vegetative buffers, and these estimates were directly entered into the model.

Table 4: Summary of Vegetated Buffers in Agricultural Areas (2012)

Otter Brook
• Agricultural Land Stream Length = 0.9 mi • Agricultural Land Stream Length with Buffer = 0.3 mi (or 33.3% of total agricultural land stream length) • Percentage of total stream length flowing through non-buffered agricultural land = 27.3%

Otter Brook is a 2.2 mile-long impaired segment as listed by Maine DEP. As modeled, the total stream miles (including tributaries) within the watershed was calculated as 2.5 miles. Of this total, 0.9 stream miles are located within agricultural areas and 0.3 miles of that area *appear* to have a 98 foot or greater vegetated buffer (Table 4, Figure 4). From a watershed perspective, this equates to 0.6 miles or 27.3% of the total stream length running through agricultural land with less than a 98 foot buffer. By contrast, for attainment stream watersheds, the percentage of total stream miles running through agricultural land without a 75 foot vegetated buffer ranged from 0% to 3.9% with an average of 1.3%. Note, a minimum vegetated buffer width of *75 feet* was used in an earlier (2012) effort to produce Figure 4 shown here. Differences in stream length estimates using a 98-foot or 75-foot buffer were practically insignificant.

Home Septic System Loads

Loads for “normally functioning” septic systems are calculated in *Model My Watershed* using an estimate of the average number of persons per acre in “Low-Density Mixed” areas. In these areas, it is assumed that the populations therein are served by septic systems rather than centralized sewage systems. All homes in such areas are assumed to be connected to “normally functioning” systems rather than those that experience “surface breakouts” (surface failures), “short-circuiting” to underlying groundwater (subsurface failures), or have direct conduits to nearby water bodies. Non-functioning systems would be modeled with a higher load contribution to the waterbody.

Best Management Practices (BMPs)

Best management practices (BMPs) are typically instituted to reduce the loading of sediment and nutrients from upland (i.e., non-point) sources. Ideally, information on BMPs for a specific watershed from local and regional sources would improve this component of the water quality model. Maine DEP sought information on BMP use in early 2021 from local, regional, and state agricultural agencies for rural BMPs and from nearby municipalities for urban BMPs. Very little to no information was returned in the solicitation. Hence, estimates for typical New England watersheds were derived from information available from Vermont. An upper limit of BMP use was garnered from watersheds entering the Chesapeake Bay where BMP use is intensive.

Four agricultural BMPs were used in this modeling effort and in the following manner:

- *Cover Crops:* Cover crops are the use annual or perennial crops to protect soil from erosion during time periods between harvesting and planting of the primary crop. The percent of cropland area in a cover crop BMP deployed was estimated at 25% and selected as the low end of the range (25 to 30 percent) expected for cropland in New England. This value was assigned to the five attainment watersheds.
- *Conservation Tillage:* Conservation tillage is any kind of system that leaves at least 30% of the soil surface covered with crop residue after planting. This reduces soil erosion and runoff. This BMP was estimated to occur in 25% of cropland. This value was assigned to the five attainment watersheds.
- *Strip Cropping / Contour Farming:* This BMP involves tilling, planting and harvesting perpendicular to the gradient of a hill or slope using high levels of plant residue to reduce soil erosion from runoff. Both interview sources suggest this practice is minimal to non-existent for New England watersheds. Hence, no BMP of this type was used in this modeling effort. This value was assigned to the five attainment watersheds.
- *Grazing Land Management:* This BMP consists of ensuring adequate vegetation cover on grazed lands to prevent soil erosion from overgrazing or other forms of over-use. This usually employs a rotational grazing system where hays or legumes are planted for feed and livestock is rotated through several fenced pastures. Both interview sources were not aware of this practice being active and is likely minimal for New England watersheds. Hence, no BMP of this type was used in this modeling effort for both impaired and attaining watersheds.

Note that other agricultural and development BMPs likely exist in the watershed but their location and type were not available in a watershed-wide format that is necessary to include in the model. Agricultural BMPs recommended by Maine DEP to reduce sediment and nutrient loads include vegetated buffers, covered manure storage facilities, and stream exclusion fencing. BMPs for developed areas recommended by the Maine DEP include vegetated buffers, stormwater BMPs, and minimization of impervious cover.

Pollutant Load Attenuation by Lakes, Ponds and Wetlands

Depositional environments such as lakes, ponds, and wetlands can attenuate watershed sediment and nutrient loading. This information is entered into the nutrient loading model by a simple percentage of watershed area draining to a lake, pond, or wetland. The Otter Brook watershed is 11.1% wetland and open water, per the 2016 NLCD land use/cover. There are a few wetlands that surround tributaries throughout the watershed. It is estimated that 22.2% of land area within the watershed drains to wetlands and open water. The percent of watershed draining to a wetland in the attainment watersheds, based on the 2021 analysis, ranged from 26 to 58 percent, with an average of 40%.

NUTRIENT AND SEDIMENT MODELING RESULTS

Below, selected results from the watershed loading model are presented. The TMDL itself is expressed in units of kilograms per hectare per year. The additional results shown below assist in better understanding the likely sources of pollution. The model results for Otter Brook watershed indicate significant reductions for sediment and phosphorus and a moderate reduction for nitrogen are needed to improve water quality. Below, loading for nitrogen, phosphorus and sediment are discussed individually. There are two categories of loads, sources and pathways. The pathways represent additional loads from streambank erosion and subsurface flow. Sediment and nutrient loads produced by eroding streambanks are estimated using an approach developed by Evans et al. (2003). Subsurface losses are calculated using dissolved N and P coefficients for shallow groundwater contributions to stream nutrient loads.

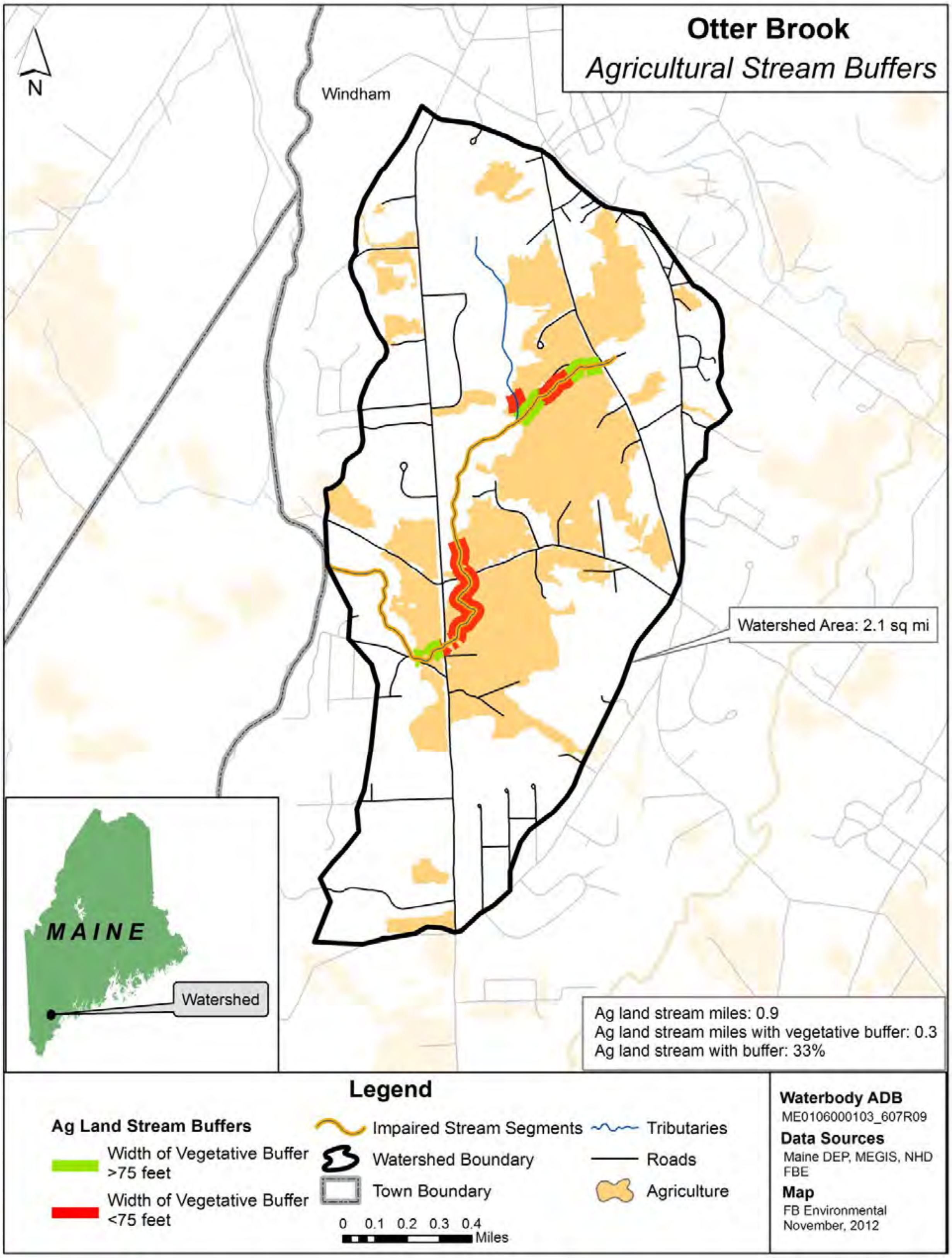


Figure 4: Agricultural Stream Buffers (from 2012) in the Otter Brook Watershed

Sediment

Aside from stream bank erosion which contributes 53% of the total sediment load, the major source load in Otter Brook watershed originates from hay/pasture land (71.7% of total sources). Residential sources contribute 25.5% of the source load.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient and Sediment Levels for Otter Brook* below for loading estimates that have been normalized by watershed area.

Table 5: Total Sediment Load by Source

Otter Brook	**Sediment** (1000 kg/year)	**Sediment** (%)
Source Load		
Hay/Pasture	26.3	71.7%
Cropland	0	0
Wooded Areas	0.4	1.1%
Wetlands	0.1	0.4%
Open Land	0.5	1.2%
Barren Areas	0.002	0.005%
Low-Density Mixed	2.7	7.4%
Medium-Density Mixed	2.1	5.8%
High-Density Mixed	0.2	0.4%
Low-Density Open Space	4.3	11.8%
Farm Animals	0	0
Septic Systems	0	0
Source Load Total:	**36.7**	**100%**
Pathway Load		
Stream Bank Erosion	42.1	-
Subsurface Flow	0	-
Total Watershed Mass Load:	**79**	

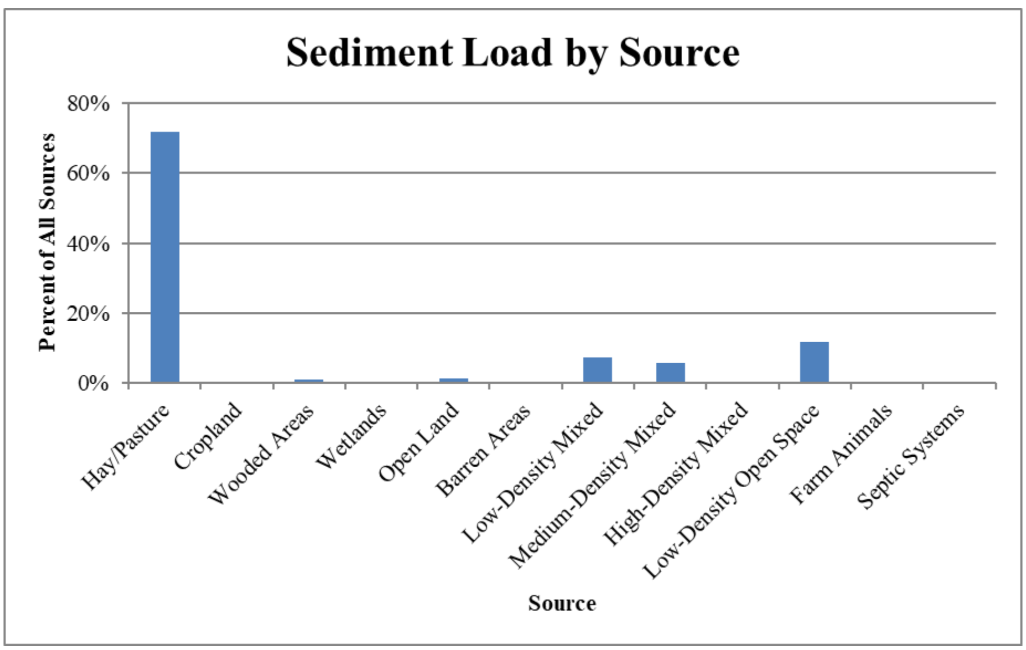


Figure 5: Total Sediment Load by Source in the Otter Brook Watershed

Total Nitrogen

Table 6 and Figure 6 (below) show the estimated total nitrogen load, in terms of mass and percent of total by source, in the Otter Brook watershed. Hay and pasture lands are the largest source of nitrogen loading contributing 37.3% of the source load of total N. Residential areas combined contribute equally with 34.2% of the source load, or if septic systems are included, 39.2%. Farm animals contribute 10% of the source load. Lastly, wetlands contribute 7% and wooded areas contribute 3.9% of the source load.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient and Sediment Levels for Otter Brook* below for loading estimates that have been normalized by watershed area.

Table 6: Total Nitrogen Load by Source

Otter Brook	Total N (kg/year)	Total N (%)
Source Load		
Hay/Pasture	277	37.3%
Cropland	0	0
Wooded Areas	29	3.9%
Wetlands	52	7.0%
Open Land	17	2.3%
Barren Areas	2	0.3%
Low-Density Mixed	79	10.6%
Medium-Density Mixed	46	6.2%
High-Density Mixed	4	0.5%
Low-Density Open Space	125	16.9%
Farm Animals	74	10.0%
Septic Systems	37	5.0%
Source Load Total:	**742**	**100%**
Pathway Load		
Stream Bank Erosion	41	-
Subsurface Flow	734	-
Total Watershed Mass Load:	**1,517**	

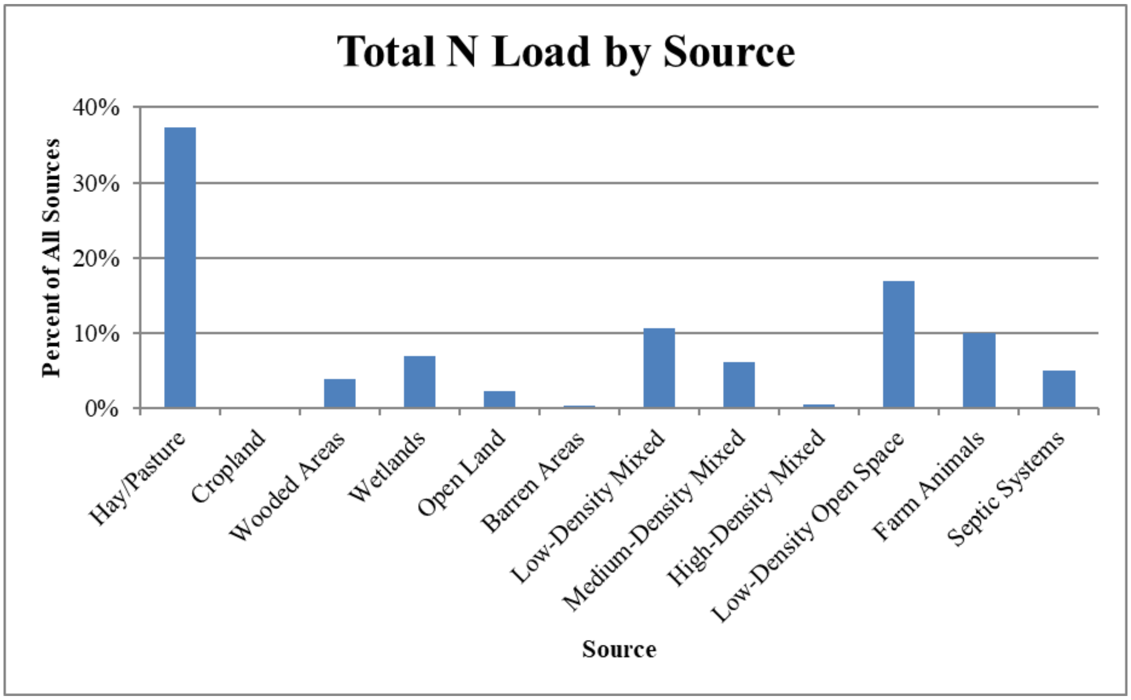


Figure 6: Total Nitrogen Load by Source in the Otter Brook Watershed

Total Phosphorus

Table 7 and Figure 7 (below) show the estimated total phosphorus load in terms of mass and percent of total by source, in the Otter Brook watershed. Hay and pasture lands are the largest source of phosphorus loading contributing just under 60% of the source load. Residential areas combined contribute 22.2% of the source load. Farm animals contribute 15.6% of the source load of total P.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient and Sediment Levels for Otter Brook* below for loading estimates that have been normalized by watershed area.

Table 7: Total Phosphorus Load by Source

Otter Brook	Total P (kg/year)	Total P (%)
Source Load		
Hay/Pasture	68.1	57.9%
Cropland	0	0
Wooded Areas	1.7	1.4%
Wetlands	2.7	2.3%
Open Land	0.6	0.5%
Barren Areas	0.1	0.09%
Low-Density Mixed	8.2	7.0%
Medium-Density Mixed	4.5	3.8%
High-Density Mixed	0.3	0.3%
Low-Density Open Space	13.1	11.1%
Farm Animals	18.3	15.6%
Septic Systems	0	0
Source Load Total:	**117.6**	**100%**
Pathway Load		
Stream Bank Erosion	8.0	-
Subsurface Flow	29.5	-
Total Watershed Mass Load:	**155**	

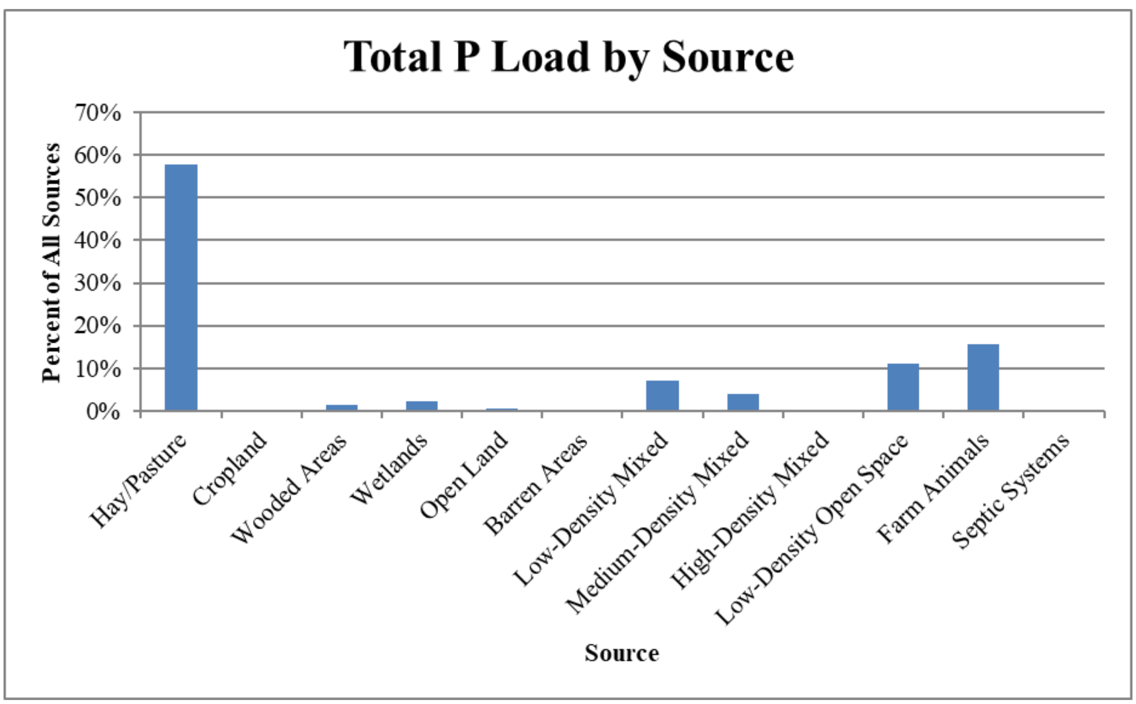


Figure 7: Total Phosphorus Load by Source in the Otter Brook Watershed

TMDL: TARGET NUTRIENT AND SEDIMENT LEVELS FOR OTTER BROOK

The existing loads for nutrients and sediments in the impaired segment of Otter Brook are listed in Table 8, along with the TMDL which was calculated from the average loading estimates of five attainment watersheds throughout the state. Table 9 presents a more detailed view of the modeling results and calculations used in Table 8 to define TMDL reductions, and compares the existing nutrient and sediment loads in Otter Brook to TMDL endpoints derived from the attainment waterbodies. An annual time frame provides a mechanism to address the daily and seasonal variability associated with nonpoint source loads.

Table 8: Otter Brook Pollutant Loading Compared to TMDL Targets

Otter Brook			
Pollutant Load	**Existing Load**	**TMDL**	**Reduction Required**
Total Annual Load per Unit Area		Attainment Streams	
Sediment (kg/ha/yr)	143.1	65.72	54.1%
Total N (kg/ha/yr)	2.75	2.46	10.8%
Total P (kg/ha/yr)	0.28	0.16	43.2%

Future Loading

The prescribed reduction in pollutants discussed in this TMDL reflects reduction from estimated existing conditions. Expansion of agricultural and development activities in the watershed have the potential to increase runoff and associated pollutant loads to Otter Brook. To ensure that the TMDL targets are attained, future agricultural and development activities will need to meet the TMDL targets. Between 2012 to 2017 in Cumberland County, the growth in agricultural lands was decreasing, with a 7% decrease in the total number of farms and a 20.2% decrease in total farm area. Average farm size has also declined significantly (13.8%) during this time period. These values are extracted from the most recent (2017) Census of Agriculture (USDA 2017). Human population in Cumberland County increased by 4.8% from 2000 to 2019 (US Census 2020). Future activities and BMPs that achieve TMDL reductions are addressed below.

Next Steps

The use of agricultural and developed area BMP's can reduce sources of polluted runoff in Otter Brook. It is recommended that municipal officials, landowners, and conservation stakeholders in Windham work together to develop a watershed management plan to:

- Encourage greater citizen involvement through the development of a watershed coalition to ensure the long term protection of Otter Brook;
- Run a "Hot-Spot Analysis" in *Model My Watershed* to determine sub-watershed locations of higher existing contributions of sediment and nutrients to the outlet of Otter Brook watershed; then focus BMP mitigation in these hot-spot sub-areas of the watershed;
- Address existing nonpoint source problems in the Otter Brook watershed by instituting BMPs where necessary; and

- Prevent future degradation of Otter Brook through the development and/or strengthening of local Nutrient Management Ordinance.

Table 9: Annual Loads by Land Use, Other Sources, and Pathways for Otter Brook Based on Modeling

Otter Brook				
	Area (ha)	**Sediment** (1000 kg/yr)	**Total N** (kg/yr)	**Total P** (kg/yr)
Land Uses				
Hay/Pasture	101	26.3	277	68.1
Cropland	0	0.0	0	0.0
Wooded Areas	211	0.4	29	1.7
Wetlands	60	0.1	52	2.7
Open Land	9	0.5	17	0.6
Barren Areas	3	0.002	2	0.1
Low-Density Mixed	60	2.7	79	8.2
Medium-Density Mixed	10	2.1	46	4.5
High-Density Mixed	1	0.2	4	0.3
Low-Density Open Space	96	4.3	125	13.1
Total Area	551			
Other Sources				
Farm Animals		0.0	74	18.3
Septic Systems		0.0	37	0.0
Pathway Load				
Stream Bank Erosion		42.1	41	8.0
Subsurface Flow		0.0	734	29.5
Total Annual Load		79	1,517	155
Total Annual Load per Unit Area		0.143	2.75	0.28
		1000 kg/ha/yr	kg/ha/yr	kg/ha/yr

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DRAFT TMDL SUMMARY

Pleasant River

WATERSHED DESCRIPTION

This **TMDL** applies to a 11.2 mile section of Pleasant River, located in the towns of Windham and Gray, Maine. The impaired segment of Pleasant River begins at the confluence of Thayer Brook and Upper Pleasant River (attainment) in the northern portion of the watershed just south of Totten Road. Pleasant River flows south crossing Lawrence Road, Gray Road (Route 4), Brand Road, Belanger Avenue, Falmouth Road, William Knight Road, Route 302, Windham Center Road, Pope Road, and River Road before its confluence with the Presumpscot River. The Pleasant River watershed covers an area of 48.9 square miles.

- Pleasant River is on Maine's 303(d) list of Impaired Streams as referenced in the 2016 Integrated Report (Maine DEP, 2018).
- The Pleasant River watershed is predominately non-developed (80.3%). Forested areas (68.4%) within the watershed absorb and filter pollutants helping protect both water quality in the stream and stream channel stability. Wetlands (11%) may also help filter nutrients.
- Non-forested areas within the watershed are predominantly agricultural (5.8%) and developed (13.3%) and are located throughout the watershed.
- Developed areas (13.3%) with impervious surfaces in close proximity to the stream or creating concentrated flow may impact water quality.
- Runoff from agricultural land located throughout the southern portion of the watershed is likely a large source of **nonpoint source (NPS) pollution** to Pleasant River. Runoff from cultivated lands, active hay lands, and pasture can transport sediment, nitrogen, and phosphorus to the stream.

Definitions

- ***Total Maximum Daily Load (TMDL)*** *represents the total amount of pollutants that a waterbody can receive and still meet water quality standards.*
- **Nonpoint Source Pollution** *refers to pollution that comes from many diffuse sources across the landscape, and are typically transported by rain or snowmelt runoff.*

Waterbody Facts

Segment ID: ME0106000103_607R12

Town: Windham and Gray, ME

County: Cumberland

Impaired Segment Length: 11.2 miles

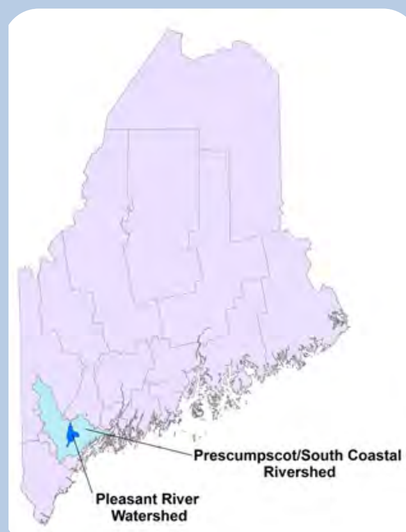
Classification: Class B

Direct Watershed: 48.9 mi^2 (31,309 acres)

Impairment Listing Cause: Dissolved Oxygen

Watershed Agricultural Land Use: 5.8%

Major Drainage Basin: Presumpscot River



Watershed Land Uses

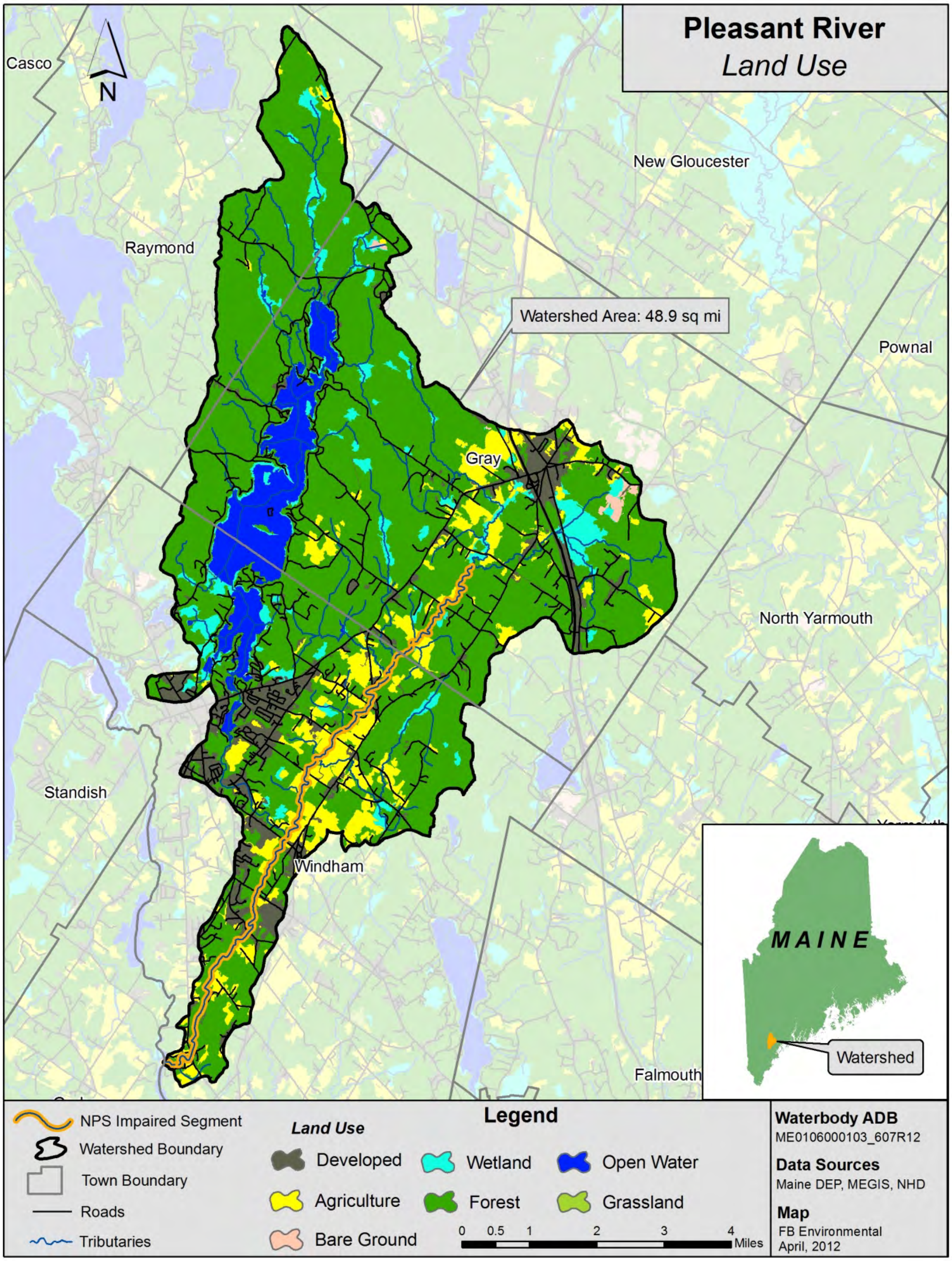


Figure 1: Land Use and Land Cover (from 2011) in the Pleasant River Watershed

WHY IS A TMDL ASSESSMENT NEEDED?

Pleasant River *near Pope Road crossing, Station 27. Photo: FB Environmental*

Pleasant River, a Class B freshwater stream, has been assessed by Maine DEP as not meeting water quality standards for the designated use of aquatic life, and placed on the 303(d) list of impaired waters under the Clean Water Act. The Clean Water Act requires that all 303(d)-listed waters undergo a TMDL assessment that describes the impairments and establishes a target to guide the measures needed to restore water quality. The goal is for all waterbodies to comply with state water quality standards.

Pleasant River watershed is heavily forested as forested lands account for 68.4% of the total area. Developed land (13.3%) is just over two times the area of agricultural land (5.8%) of the watershed. However, 48% of the impaired stream segment length passes through agricultural land (Figure 1). Agriculture, therefore, is still likely to be the largest contributor of sediment and nutrient enrichment to the stream. This is especially evident from farmland on Lotts Drive where a strong smell of manure was documented, 35 cows observed, and heavily-trodden ground on the opposite side of river was observed, indicating a potential cow-crossing. The close proximity of many agricultural lands to the stream further increases the likelihood that nutrients from disturbed soils, manure, and fertilizers will reach the stream.

WATER QUALITY DATA ANALYSIS

Maine DEP uses a variety of data types to measure the ability of a stream to adequately support aquatic life, including; dissolved oxygen, benthic macroinvertebrates, and periphyton (algae). For benthic macroinvertebrates, DEP makes aquatic life use determinations using a statistical model that incorporates 30 variables of data collected from rivers and streams, including the richness and abundance of streambed organisms, to determine the probability of a sample meeting Class A, B, or C conditions. Biologists use the model results and supporting information to determine if samples comply with the numeric aquatic life criteria of the class assigned to the stream or river (Davies and Tsomides, 2002). Maine DEP uses an analogous model to aid in the assessment of algal communities but makes aquatic life use determinations based on narrative standards.

All segments in the watershed have a Class B designation. The aquatic life impairment in Pleasant River is based on dissolved oxygen data collected at station S-544 in 1999, S-548 in 2000, S-549 in 1999-2000, RPL47 in 2009-2011, and RPL06 in 2011. In addition, periphyton data at S-549 in 1999 indicated impairment, although this is not the listing cause. Data from periphyton stations (S-394, S-544, S-548 and S-549) in 2000, 2005, 2010 or 2015 and benthic macroinvertebrate stations (S-155, S-394 and S-548) in 1999, 2005, 2010 or 2020 all indicated class B attainment or better.

TMDL ASSESSMENT APPROACH: NUTRIENT AND SEDIMENT MODELING OF IMPAIRED AND ATTAINMENT STREAMS

NPS pollution is difficult to measure directly, because it comes from many diffuse sources spread across the landscape. For this reason, an online nutrient loading model, *Model My Watershed* (v. 1.32.0), was used to estimate the sources of pollution based on well-established hydrological equations (Stroud Water Research Center 2017). *Model My Watershed* makes use of the GWLF-enhanced model engine. The model incorporates detailed maps of soil, land use, and slope, daily weather and localized weather data (from the period 2009-2020), and direct observations of agriculture and other land uses within the watershed. *Model My Watershed* is derived from its parent MapShed developed by Evans and Corradini (2012). *Model My Watershed* replaced MapShed in 2017-2018.

The nutrient loading estimates for the impaired stream were compared to similar estimates for five non-impaired (attainment) streams of similar watershed land uses across the state. The TMDL for the impaired stream was set as the mean nutrient loading estimate of these attainment stream watersheds, and units of mass per unit watershed area per year (kg/ha/year) were used. The difference in loading estimates between the impaired and attainment watersheds represents the percent reduction in nutrient loading required under this TMDL. The attainment streams and their nutrient and sediment loading estimates and TMDL are presented below in Table 1.

Table 1: Numeric Targets for Pollutant Loading Based on Model My Watershed Outputs (2021) for Attainment Streams

Attainment Streams	Town	Total P Load (kg/ha/yr)	Total N Load (kg/ha/yr)	Sediment Load (kg/ha/yr)
Footman Brook	Exeter	0.17	1.73	35.2
Martin Stream	Fairfield	0.13	2.98	57.9
Moose Brook	Houlton	0.18	1.59	48.5
Upper Kenduskeag Stream	Corinth	0.16	1.72	100.5
Upper Pleasant River	Gray	0.16	4.26	86.5
Total Maximum Daily Load		**0.16**	**2.46**	**65.7**

Habitat Assessment

A habitat assessment survey was conducted on both the impaired and attainment stream. The assessment approach is based on the *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (Barbour et al. 1999), which integrates various parameters relating to the structure of physical habitat. The habitat assessments include a general description of the site, physical characterization and visual assessment of in-stream and riparian habitat quality.

Based on rapid bioassessment protocols for low gradient streams, Pleasant River received a score of 190 out of a total 200 for quality of habitat. Higher scores indicate better habitat. The range in habitat assessment scores for attainment streams was 155 to 179.

There are several possible explanations for why the habitat assessment score for this watershed is higher than the score of its reference stream. First, the habitat assessment was conducted on a relatively short sample reach (about 100-200 meters for a typical small stream), and was located near the most downstream Maine DEP sample station. For both impaired and attainment streams, the assessment location was usually near a road crossing for ease of access. In the Pleasant River watershed, the downstream sample station was located in a forested portion of the stream with a thick buffer, while not all of the stream flows through forested areas within the watershed.

Figure 2 (right) shows the range of habitat assessment scores for all attainment and impaired streams, as well as for the Pleasant River. These scores show that habitat is not a factor in the impairment of the Pleasant River at the sample location, so it is important to look for other potential sources within the watershed leading to impairment. Consideration should be given to major "hot spots" in the Pleasant River watershed as potential sources of NPS pollution contributing to the water quality impairment.

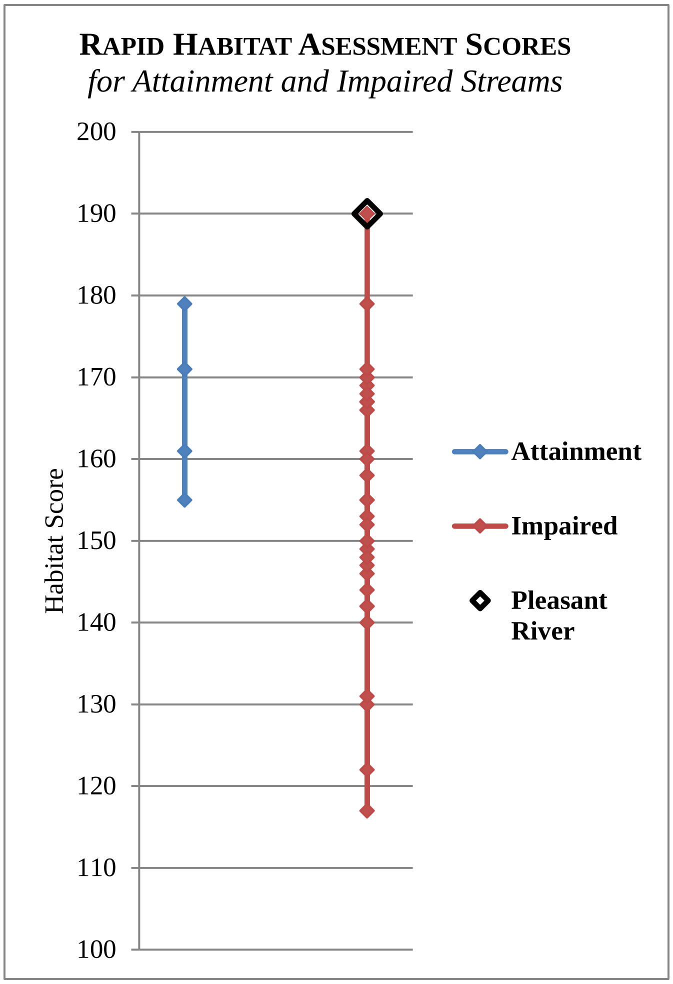


Figure 2: Habitat Assessment Scores for Pleasant River (2012) Compared to Region

Pollution Source Identification

Pollution source identification assessments were conducted for both Pleasant River (impaired) and the attainment streams. The source identification work is based on an abbreviated version of the Center for Watershed Protection's Unified Subwatershed and Site Reconnaissance method (Wright, et al. 2005). The abbreviated method includes both a desktop and field component. The desktop assessment consists of generating and reviewing maps of the watershed boundary, roads, land use and satellite imagery, and then identifying potential NPS pollution locations, such as road crossings, agricultural fields, and large areas of bare soil. When available, multiple sources of satellite imagery were reviewed. Occasionally, the high resolution of the imagery allowed for observations of livestock, row crops, eroding stream banks, sediment laden water, junkyards, and other potential NPS concerns that could affect stream quality. As many potential pollution sources as possible were visited, assessed and documented in the field. Field visits were limited to NPS sites that were visible from roads or a short walk from a roadway. Neighborhoods were assessed for NPS pollution at the whole neighborhood level including streets and storm drains (where applicable). The assessment does not include a scoring component, but does include a detailed summary of findings and a map indicating documented NPS sites throughout the watershed.

The watershed source assessment for the Pleasant River was completed in July 2012. Field observations of erosion, lack of vegetated stream buffer, extensive impervious surfaces, high-density neighborhoods and agricultural activities were documented throughout the watershed (Table 2, Figure 3).

Table 2: Potential Pollution Source ID Assessment (2012) for the Pleasant River Watershed

Potential Source			Notes
ID#	**Location**	**Type**	
1	Falmouth Road	Road Crossing/ Agriculture	• Agricultural fields with row crops, most likely corn, were observed close to the river near the Falmouth Road crossing. • A mowed lawn also exists with minimal buffer to the stream.
3	William Knight Road	Agriculture	• Agricultural fields with row crops were observed near the William Knight Road crossing with adequate buffer. • However, currently inactive fields adjacent to row crops have a very small buffer from the stream.
4	Old Route 202/Lott's Drive	Agriculture	• Active agricultural fields with a strong smell of manure were documented on Lott's Drive on the grounds of Mineral Springs Farm in Windham. • Approximately 30-35 cows were observed on the farm near the river, and have direct access to the river that runs through a grazing area. • This portion of the Pleasant River does not have a buffer, and from aerial photographs, you can see that cows cross the river. Heavily trodden ground and walking trails are visible. • Row crops were also observed within 20 m of the river.
7	Windham Center Road	Road Crossing	• A heavily eroded road shoulder at the Windham Center Road crossing provided evidence of large volumes of runoff at this site. • Riparian buffer is not adequate here as soil travels down slope toward stream.
9	Pope Road	Road Crossing	• Recent road undercutting and erosion was documented at the Pope Road stream crossing. Ditches were vegetated.

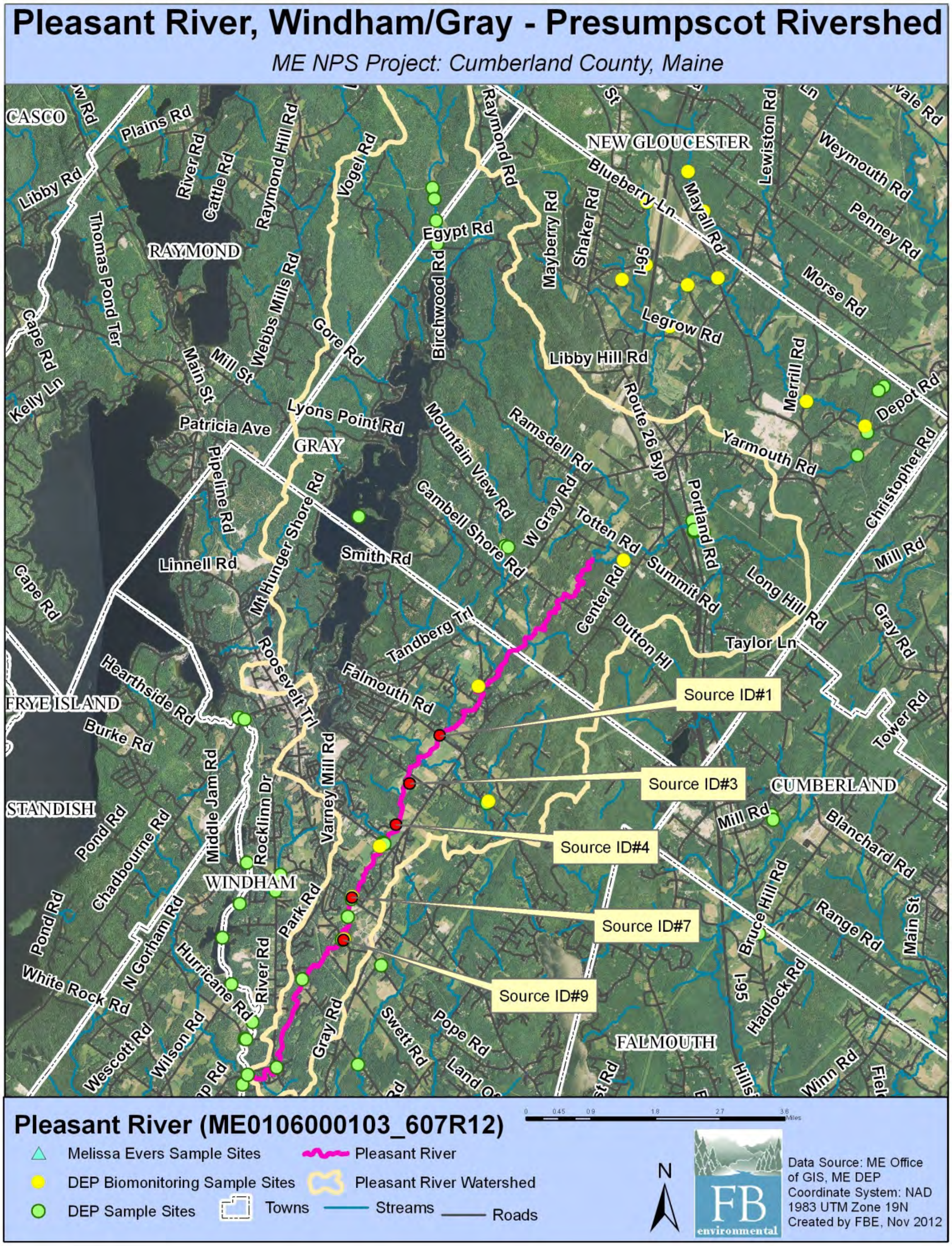


Figure 3: Aerial Photo of Potential Source ID Locations (identified in 2012) in Pleasant River Watershed

NUTRIENT AND SEDIMENT LOADING – *MODEL MY WATERSHED* ANALYSIS

The *Model My Watershed* model was used to estimate stream loading of total phosphorus, total nitrogen, and sediment in Pleasant River watershed. The model estimated nutrient loads over a 12-year period (2009-2020), which was determined by local (Portland Jetport USW00014764) weather data inserted into *Model My Watershed*. This extended period captures a recent but wide range of hydrologic conditions to account for variations in nutrient and sediment loading over time. Loads for the attainment watersheds (five total; Table 1) were computed using the same model with the same recent inputs (i.e., regional weather, 2016 land use and land cover, 2016 wetland extent, and BMPs similar to the impaired watersheds).

Many quality assured and regionally calibrated input parameters are provided with *Model My Watershed*. However, several updates to some of the default parameters were made in this TMDL effort, and namely more recent land use/cover using **MRLC-NLCD 2016** [1], more recent and local weather (precipitation and temperature) data (as described above), and more regional estimates of Best Management Practices (BMPs; see ensuing discussion). Because land use/cover is more recent, the estimated filtration fraction of wetland and open water and the amount of stream buffer in agricultural land should be more accurate. It is also worth noting that improved classification algorithms were employed by MLRC in the NCLD 2016 and these new algorithms were used in the revisions of all previous NLCD versions.

Livestock Estimates

Livestock waste contains nutrients which can cause water quality impairment. The nutrient loading model considers numbers and types of animals. Table 3 (right) provides livestock (numbers of animals) in the watershed based on the USDA National Agricultural Statistics Service (NASS) estimation for 2012. Some of these totals were modified by direct observations made in the watershed in the 2012 survey. To generate watershed-based livestock counts, NASS county-based livestock totals are converted to a per unit area (based on the total area of the county). The unit area amount is then multiplied by the total watershed area to derive a watershed total count (as seen in Table 3).

Table 3: Livestock Estimates in the Pleasant River Watershed

Type	Pleasant River
Dairy Cows	42
Beef Cows	50
Broilers	60
Layers	238
Hogs/Swine	60
Sheep	158
Horses	83
Turkeys	19
Other	--
Total	**710**

The Pleasant River watershed is predominantly forested, but also has substantial mixed agricultural and developed land uses. Large areas of corn fields and hay were documented throughout the watershed, as well as a dairy farm on Old Route 202 (Lotts Drive). At this property, cows have direct access to the Pleasant River near the road crossing. No buffer exists here, exposed banks are heavily trodden by cows, and paths have formed through the river as a result. Row crops are also present within about 20 meters of the river.

[1] MRLC-NLCD 2016 : Multi-Resolution Land Characteristics – National Land Cover Dataset (version 2016) provided by the MRLC Consortium (Jin et al. 2019).

Vegetated Stream Buffer in Agricultural Areas

Table 4: Summary of Vegetated Buffers in Agricultural Areas (2012)

Pleasant River
• Agricultural Land Stream Length = 3.2 mi • Agricultural Land Stream Length with Buffer = 0.5 mi (or 16% of total agricultural land stream length) • Percentage of total stream length flowing through non-buffered agricultural land = 1.72%

Vegetated stream buffers are areas of trees, shrubs, and/or grasses adjacent to streams, lakes, ponds or wetlands which provide nutrient loading attenuation (Evans and Corradini 2012). *Model My Watershed* considers natural vegetated stream buffers within agricultural land areas as providing nutrient load attenuation. A width of approximately 98 feet (30 m) on one side of a stream is required to be considered a streamside buffer per the *Model My Watershed* technical manual (Stroud Water Research Center 2017). Analysis of recent aerial photos was used to estimate the number of agricultural land stream miles with and without vegetative buffers, and these estimates were directly entered into the model.

The Pleasant River is an 11.2 mile-long impaired segment as listed by Maine DEP. As modeled, the total stream miles (including tributaries) within the watershed was calculated as 98.8 miles. Of this total, 3.2 stream miles are located within agricultural areas and 0.5 miles of that area *appear* to have a 98 foot or greater vegetated buffer (Table 4, Figure 4). From a watershed perspective, this equates to 1.7 miles or 1.72% of the total stream length running through agricultural land with less than a 98 foot buffer. By contrast, for attainment stream watersheds, the percentage of total stream miles running through agricultural land without a 75 foot vegetated buffer ranged from 0% to 3.9% with an average of 1.3%. Note, a minimum vegetated buffer width of 75 feet was used in an earlier (2012) effort to produce Figure 4 shown here. Differences in stream length estimates using a 98-foot or 75-foot buffer were practically insignificant.

Home Septic System Loads

Loads for "normally functioning" septic systems are calculated in *Model My Watershed* using an estimate of the average number of persons per acre in "Low-Density Mixed" areas. In these areas, it is assumed that the populations therein are served by septic systems rather than centralized sewage systems. All homes in such areas are assumed to be connected to "normally functioning" systems rather than those that experience "surface breakouts" (surface failures), "short-circuiting" to underlying groundwater (subsurface failures), or have direct conduits to nearby water bodies. Non-functioning systems would be modeled with a higher load contribution to the waterbody.

Best Management Practices (BMPs)

Best management practices (BMPs) are typically instituted to reduce the loading of sediment and nutrients from upland (i.e., non-point) sources. Ideally, information on BMPs for a specific watershed from local and regional sources would improve this component of the water quality model. Maine DEP sought information on BMP use in early 2021 from local, regional, and state agricultural agencies for rural BMPs and from nearby municipalities for urban BMPs. Very little to no information was returned in the solicitation. Hence, estimates for typical New England watersheds were derived from information available from Vermont. An upper limit of BMP use was garnered from watersheds entering the Chesapeake Bay where BMP use is intensive.

Four agricultural BMPs were used in this modeling effort and in the following manner:

- *Cover Crops:* Cover crops are the use annual or perennial crops to protect soil from erosion during time periods between harvesting and planting of the primary crop. The percent of cropland area in a cover crop BMP deployed was estimated at 25% and selected as the low end of the range (25 to 30 percent) expected for cropland in New England. This value was assigned to the five attainment watersheds.
- *Conservation Tillage:* Conservation tillage is any kind of system that leaves at least 30% of the soil surface covered with crop residue after planting. This reduces soil erosion and runoff. This BMP was estimated to occur in 25% of cropland. This value was assigned to the five attainment watersheds.
- *Strip Cropping / Contour Farming:* This BMP involves tilling, planting and harvesting perpendicular to the gradient of a hill or slope using high levels of plant residue to reduce soil erosion from runoff. Both interview sources suggest this practice is minimal to non-existent for New England watersheds. Hence, no BMP of this type was used in this modeling effort. This value was assigned to the five attainment watersheds.
- *Grazing Land Management:* This BMP consists of ensuring adequate vegetation cover on grazed lands to prevent soil erosion from overgrazing or other forms of over-use. This usually employs a rotational grazing system where hays or legumes are planted for feed and livestock is rotated through several fenced pastures. Both interview sources were not aware of this practice being active and is likely minimal for New England watersheds. Hence, no BMP of this type was used in this modeling effort for both impaired and attaining watersheds.

Note that other agricultural and development BMPs likely exist in the watershed but their location and type were not available in a watershed-wide format that is necessary to include in the model. Agricultural BMPs recommended by Maine DEP to reduce sediment and nutrient loads include vegetated buffers, covered manure storage facilities, and stream exclusion fencing. BMPs for developed areas recommended by the Maine DEP include vegetated buffers, stormwater BMPs, and minimization of impervious cover.

Pollutant Load Attenuation by Lakes, Ponds and Wetlands

Depositional environments such as lakes, ponds, and wetlands can attenuate watershed sediment and nutrient loading. This information is entered into the nutrient loading model by a simple percentage of watershed area draining to a lake, pond, or wetland. The Pleasant River watershed is 11.1% wetland and open water, per the 2016 NLCD land use/cover. Little Sebago Lake is located in the northwestern portion of the Pleasant River watershed. It is estimated that 22.2% of land area within the watershed drains to wetlands and open water. The percent of watershed draining to a wetland in the attainment watersheds, based on the 2021 analysis, ranged from 26 to 58 percent, with an average of 40%.

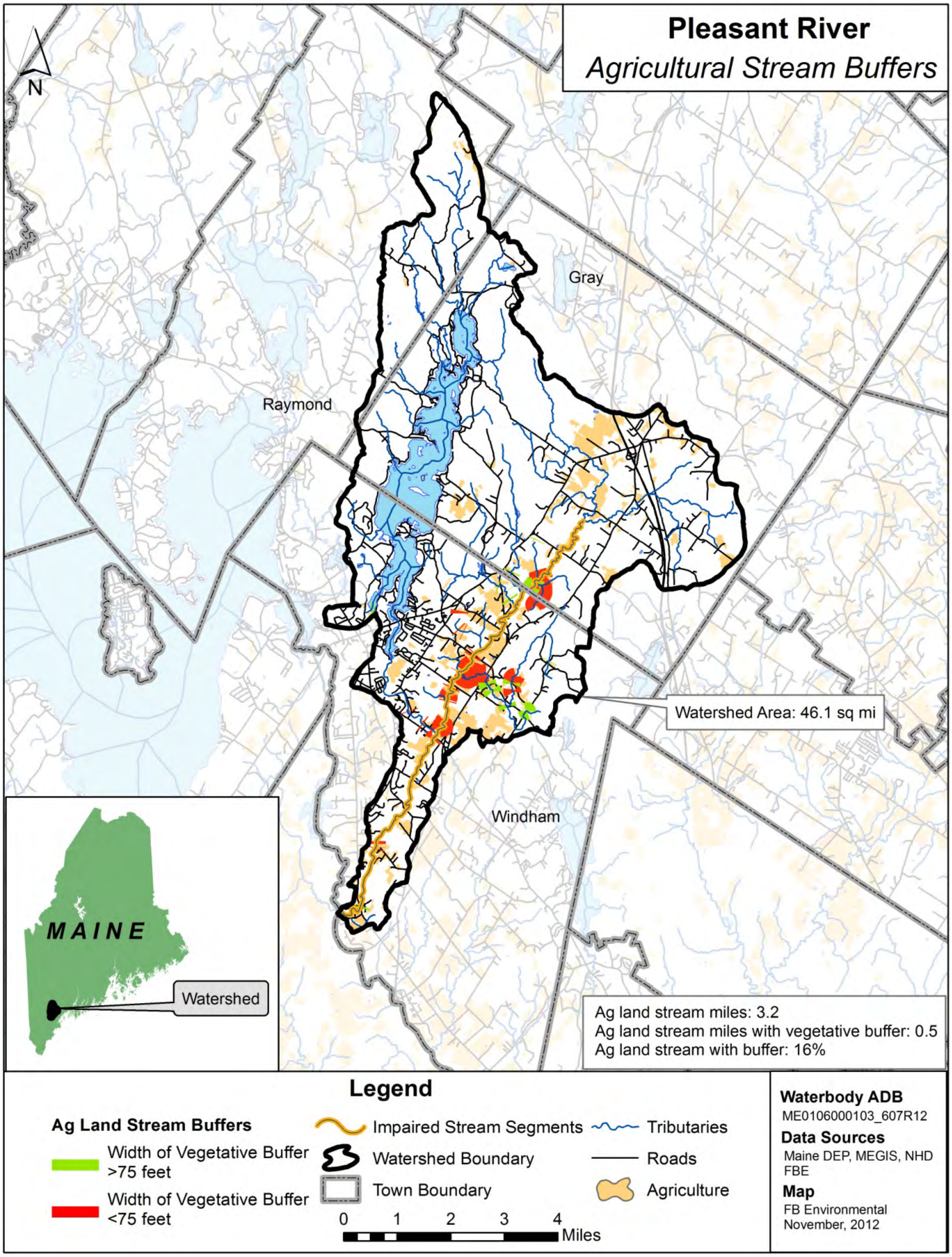


Figure 4: Agricultural Stream Buffers (from 2012) in the Pleasant River Watershed

NUTRIENT AND SEDIMENT MODELING RESULTS

Selected results from the watershed loading model are presented here. The TMDL itself is expressed in units of kilograms per hectare per year. The additional results shown below assist in better understanding the likely sources of pollution. The model results for Pleasant River watershed indicate a very high reduction for sediment and high reductions for both phosphorus and nitrogen are needed to improve water quality. Below, loading for nitrogen, phosphorus and sediment are discussed individually.

There are two categories of loads – sources and pathways. Sources are determined by land use/cover and the overland flow they generate, livestock counts by animal type, and home sewage treatment systems in developed areas. Pathways represent additional loads derived from subsurface flow and streambank erosion. Subsurface loads are calculated using dissolved N and P coefficients for shallow groundwater and are mainly derived from atmospheric inputs. Sediment and nutrient loads produced by eroding streambanks are estimated using an approach developed by Evans et al. (2003). This pathway is comprised of loads originating from five sources, and listed in order of decreasing importance: amount of developed land area, soil erodibility (K-factor), density of livestock, runoff curve number, and topographic slope. For any given model run, the amount of developed land in the watershed is responsible for just over 72% of the total streambank load, whereas soil erodibility and animal density are responsible for 21% and 7% of the total streambank load, respectively.

Sediment

Stream bank erosion contributes almost 96% of the total sediment load in the Pleasant River watershed. Of the remainder, the major source load originates from hay/pasture land (47.1% of total sources) and residential sources (43.8% of the source load).

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient and Sediment Levels for Pleasant River* below for loading estimates that have been normalized by watershed area.

Table 5: Total Sediment Load by Source

Pleasant River	Sediment (1000 kg/year)	Sediment (%)
Source Load		
Hay/Pasture	105.5	47.1%
Cropland	10.0	4.5%
Wooded Areas	7.2	3.2%
Wetlands	1.3	0.6%
Open Land	1.9	0.9%
Barren Areas	0.017	0.007%
Low-Density Mixed	19.1	8.5%
Medium-Density Mixed	29.0	12.9%
High-Density Mixed	12.4	5.5%
Low-Density Open Space	37.6	16.8%
Farm Animals	0	0
Septic Systems	0	0
Source Load Total:	**224.0**	**100%**
Pathway Load		
Stream Bank Erosion	5021.8	-
Subsurface Flow	0	-
Total Watershed Mass Load:	**5246**	

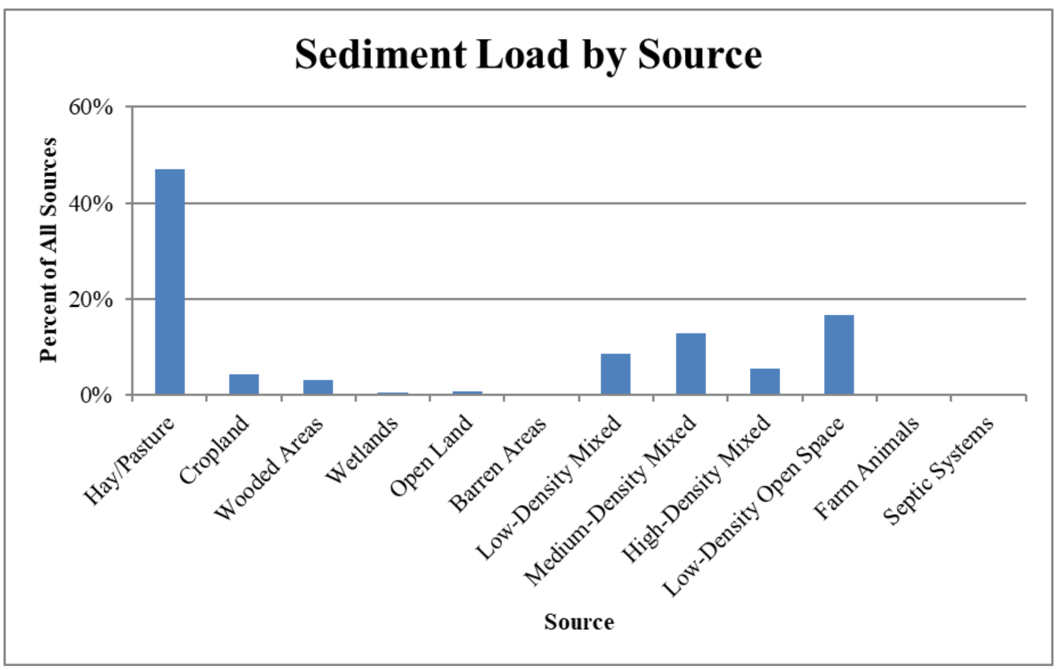


Figure 5: Total Sediment Load by Source in the Pleasant River Watershed

Total Nitrogen

Table 6 and Figure 6 (below) show the estimated total nitrogen load, in terms of mass and percent of total by source, in the Pleasant River watershed. A balanced contribution of load is met by nearly all sources. Hay and pasture lands and farm animals contribute 29.4% and residential areas combined contribute 31%. Wooded and wetland areas contribute a combined 28.7% of the total source load.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient and Sediment Levels for Pleasant River* below for loading estimates that have been normalized by watershed area.

Table 6: Total Nitrogen Load by Source

Pleasant River	**Total N** (kg/year)	**Total N** (%)
Source Load		
Hay/Pasture	1,573	17.3%
Cropland	219	2.4%
Wooded Areas	1,610	17.7%
Wetlands	996	11.0%
Open Land	191	2.1%
Barren Areas	30	0.3%
Low-Density Mixed	568	6.3%
Medium-Density Mixed	790	8.7%
High-Density Mixed	337	3.7%
Low-Density Open Space	1,118	12.3%
Farm Animals	1,093	12.0%
Septic Systems	552	6.1%
Source Load Total:	**9,076**	**100%**
Pathway Load		
Stream Bank Erosion	5,228	-
Subsurface Flow	22,107	-
Total Watershed Mass Load:	**36,411**	

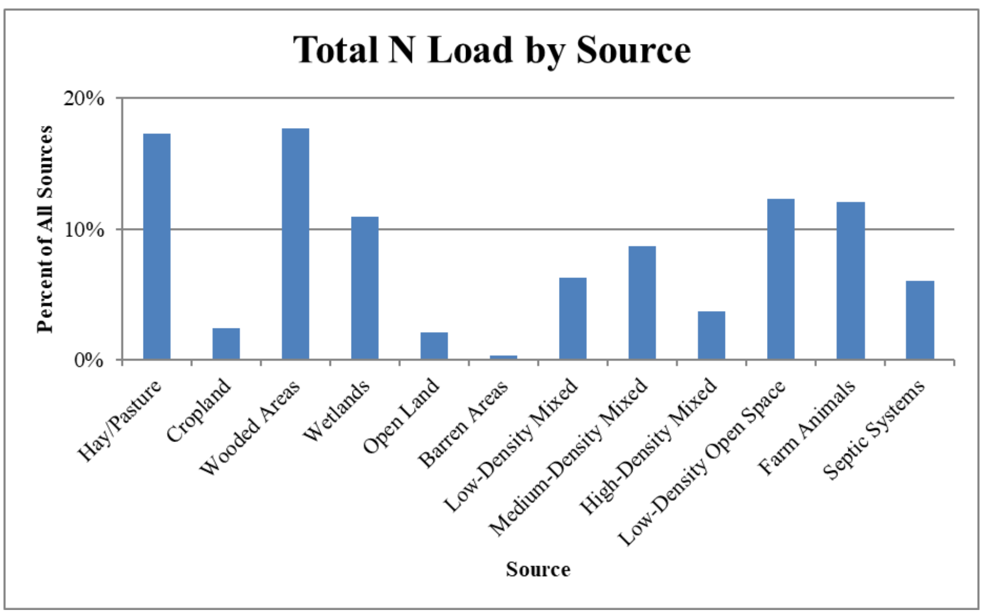


Figure 6: Total Nitrogen Load by Source in the Pleasant River Watershed

Total Phosphorus

Table 7 and Figure 7 (below) show the estimated total phosphorus load in terms of mass and percent of total by source, in the Pleasant River watershed. Hay and pasture lands are the largest source of phosphorus loading contributing 38.6% of the total source load. Residential areas combined contribute 24.2%. Farm animals also contribute considerably at 22.6%.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient and Sediment Levels for Pleasant River* below for loading estimates that have been normalized by watershed area.

Table 7: Total Phosphorus Load by Source

Pleasant River	Total P (kg/year)	Total P (%)
Source Load		
Hay/Pasture	454.0	38.6%
Cropland	28.2	2.4%
Wooded Areas	86.3	7.3%
Wetlands	50.9	4.3%
Open Land	5.4	0.5%
Barren Areas	1.0	0.09%
Low-Density Mixed	58.7	5.0%
Medium-Density Mixed	77.2	6.6%
High-Density Mixed	32.9	2.8%
Low-Density Open Space	115.5	9.8%
Farm Animals	265.3	22.6%
Septic Systems	0	0
Source Load Total:	**1,175.4**	**100%**
Pathway Load		
Stream Bank Erosion	1,259.0	-
Subsurface Flow	885.3	-
Total Watershed Mass Load:	**3,320**	

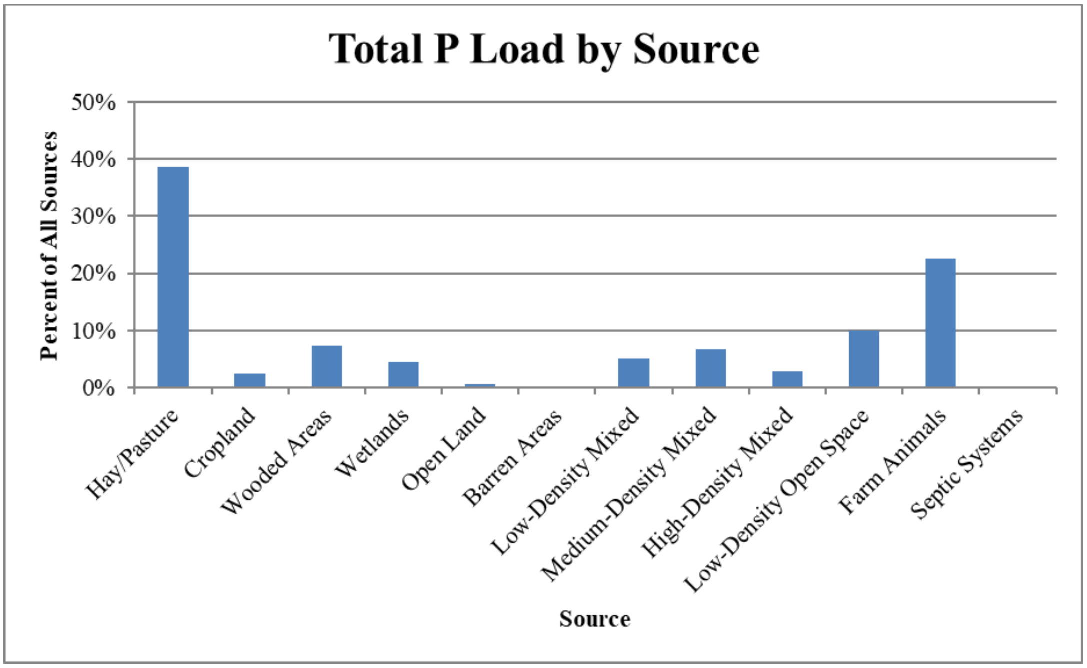


Figure 7: Total Phosphorus Load by Source in the Pleasant River Watershed

TMDL: TARGET NUTRIENT AND SEDIMENT LEVELS FOR PLEASANT RIVER

The existing loads for nutrients and sediments in the impaired segment of Pleasant River are listed in Table 8, along with the TMDL which was calculated from the average loading estimates of five attainment watersheds throughout the state. Table 9 presents a more detailed view of the modeling results and calculations used in Table 8 to define TMDL reductions, and compares the existing nutrient and sediment loads in Pleasant River to TMDL endpoints derived from the attainment waterbodies. An annual time frame provides a mechanism to address the daily and seasonal variability associated with nonpoint source loads.

Table 8: Pleasant River Pollutant Loading Compared to TMDL Targets

Pleasant River			
Pollutant Load	**Existing Load**	**TMDL**	**Reduction Required**
Total Annual Load per Unit Area		Attainment Streams	
Sediment (kg/ha/yr)	443.7	65.72	85.2%
Total N (kg/ha/yr)	3.08	2.46	20.2%
Total P (kg/ha/yr)	0.28	0.16	43.1%

Future Loading

The prescribed reduction in pollutants discussed in this TMDL reflects reduction from estimated existing conditions. Expansion of agricultural and development activities in the watershed have the potential to increase runoff and associated pollutant loads to Pleasant River. To ensure that the TMDL targets are attained, future agricultural and development activities will need to meet the TMDL targets. Between 2012 to 2017 in Cumberland County, the growth in agricultural lands was decreasing, with a 7% decrease in the total number of farms and a 20.2% decrease in total farm area. Average farm size has also declined significantly (13.8%) during this time period. These values are extracted from the most recent (2017) Census of Agriculture (USDA 2017). Human population in Cumberland County increased by 4.8% from 2000 to 2019 (US Census 2020). Future activities and BMPs that achieve TMDL reductions are addressed below.

Next Steps

The use of agricultural and developed area BMP's can reduce sources of polluted runoff in Pleasant River. It is recommended that municipal officials, landowners, and conservation stakeholders in Windham and Gray work together to develop a watershed management plan to:

- Encourage greater citizen involvement through the development of a watershed coalition to ensure the long term protection of Pleasant River;
- Run a "Hot-Spot Analysis" in *Model My Watershed* to determine sub-watershed locations of higher existing contributions of sediment and nutrients to the outlet of Pleasant River watershed; then focus BMP mitigation in these hot-spot sub-areas of the watershed;
- Address existing nonpoint source problems in the Pleasant River watershed by instituting BMPs where necessary; and

- Prevent <u>future</u> degradation of Pleasant River through the development and/or strengthening of local Nutrient Management Ordinance.

Table 9: Annual Loads by Land Use, Other Sources, and Pathways for Pleasant River Based on Modeling

Pleasant River				
	Area (ha)	**Sediment** (1000 kg/yr)	**Total N** (kg/yr)	**Total P** (kg/yr)
Land Uses				
Hay/Pasture	658	105.5	1,573	454.0
Cropland	30	10.0	219	28.2
Wooded Areas	8,093	7.2	1,610	86.3
Wetlands	1,302	1.3	996	50.9
Open Land	100	1.9	191	5.4
Barren Areas	67	0.017	30	1.0
Low-Density Mixed	453	19.1	568	58.7
Medium-Density Mixed	155	29.0	790	77.2
High-Density Mixed	66	12.4	337	32.9
Low-Density Open Space	899	37.6	1,118	115.5
Total Area	11,823			
Other Sources				
Farm Animals		0.0	1,093	265.3
Septic Systems		0.0	552	0.0
Pathway Load				
Stream Bank Erosion		5021.8	5,228	1,259.0
Subsurface Flow		0.0	22,107	885.3
Total Annual Load		5,246	36,411	3,320
Total Annual Load per Unit Area		0.444	3.08	0.28
		1000 kg/ha/yr	kg/ha/yr	kg/ha/yr

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DRAFT TMDL SUMMARY

Stetson Brook

WATERSHED DESCRIPTION

This **TMDL** applies to a 6.82 mile section of Stetson Brook, located in the City of Lewiston. The impaired segment of Stetson Brook begins in the northern portion of the watershed in a predominantly forested area at the outlet of a wetland, and flows south crossing College Road, Lane Road, College Road again, and rail road tracks before entering into another wetland. The stream re-crosses the railroad tracks and enters into mixed agriculture and development, crossing College Street and Hamel Road before entering woods. After crossing Stetson Road and College Street, Stetson Brook flows through a developed area crossing the railroad tracks and Main Street (Route 11), finally flowing into the Androscoggin River just downstream of the dam. The Stetson Brook watershed covers an area of 14.87 square miles. The watershed is located within the City of Lewiston and the town of Greene.

- Stetson Brook is on Maine's 303(d) list of Impaired Streams as referenced in the 2016 Integrated Report (Maine DEP, 2018).
- The Stetson Brook watershed is predominately non-developed (75.7%). Forested areas (64%) within the watershed absorb and filter pollutants helping protect both water quality in the stream and stream channel stability. Wetlands (10%) may also help filter nutrients.
- Non-forested areas within the watershed are predominantly developed (14.6%) and agricultural (9.3%) and are located throughout the watershed.
- Runoff from developed areas and agricultural land are likely the largest sources of **nonpoint source (NPS) pollution** to Stetson Brook. Runoff from cultivated lands, active hay lands, pasture, and impervious surfaces can transport sediment, nitrogen, and phosphorus to the stream.

Definitions

- ***Total Maximum Daily Load (TMDL)*** *represents the total amount of pollutants that a waterbody can receive and still meet water quality standards.*
- ***Nonpoint Source Pollution*** *refers to pollution that comes from many diffuse sources across the landscape, and are typically transported by rain or snowmelt runoff.*

Waterbody Facts

Segment ID: ME0104000208_413R03

City: Lewiston, ME

County: Androscoggin

Impaired Segment Length: 6.82 miles

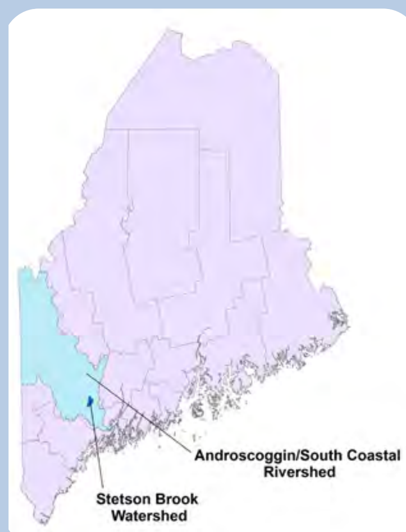
Classification: Class B

Direct Watershed: 14.87 mi^2 (9,517 acres)

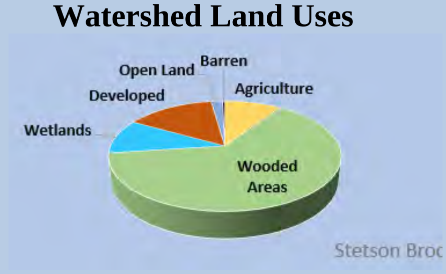
Impairment Listing Cause: Dissolved Oxygen

Watershed Agricultural Land Use: 9.3%

Major Drainage Basin: Androscoggin



Watershed Land Uses



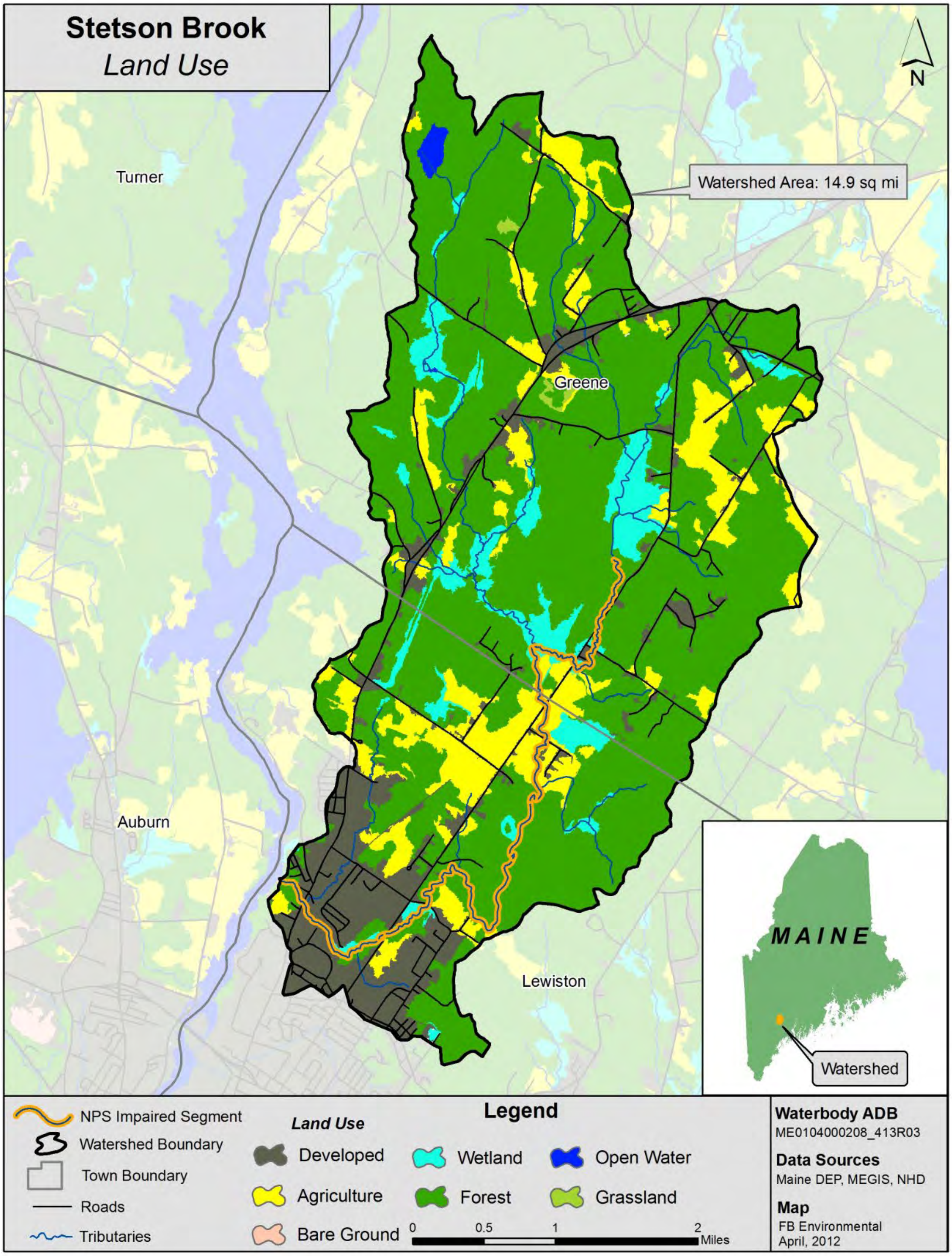


Figure 1: Land Use and Land Cover (from 2011) in the Stetson Brook Watershed

WHY IS A TMDL ASSESSMENT NEEDED?

Stetson Brook *downstream of the Stetson Road crossing – Station 356*
Photo: FB Environmental

Stetson Brook, a Class B freshwater stream, has been assessed by Maine DEP as not meeting water quality standards for the designated use of aquatic life, and placed on the 303(d) list of impaired waters under the Clean Water Act. The Clean Water Act requires that all 303(d)-listed waters undergo a TMDL assessment that describes the impairments and establishes a target to guide the measures needed to restore water quality. The goal is for all waterbodies to comply with state water quality standards.

Developed land makes up 14.6% of the Stetson Brook watershed. This is 1.6 times the area of agricultural land which makes up 9.3% of the total watershed area. The watershed is heavily forested (64%); however, 39% of the impaired stream segment length passes through agricultural land (Figure 1). Agriculture and development, therefore, are likely to be the largest contributors of sediment and nutrient enrichment to the stream. The close proximity of many agricultural lands to the stream further increases the likelihood that nutrients from disturbed soils, manure, and fertilizers will reach the stream. Eroded stream crossings with washouts and collapsed pavement were fairly common throughout the watershed and may be nonpoint source pollution hotspots.

WATER QUALITY DATA ANALYSIS

Maine DEP uses a variety of data types to measure the ability of a stream to adequately support aquatic life, including; dissolved oxygen, benthic macroinvertebrates, and periphyton (algae). For benthic macroinvertebrates, DEP makes aquatic life use determinations using a statistical model that incorporates 30 variables of data collected from rivers and streams, including the richness and abundance of streambed organisms, to determine the probability of a sample meeting Class A, B, or C conditions. Biologists use the model results and supporting information to determine if samples comply with the numeric aquatic life criteria of the class assigned to the stream or river (Davies and Tsomides, 2002). Maine DEP uses an analogous model to aid in the assessment of algal communities but makes aquatic life use determinations based on narrative standards.

The aquatic life impairment in Stetson Brook is based on historic dissolved oxygen. Macroinvertebrate results from site S-356 in 2013 show attainment of Class B. Periphyton results from this same site show attainment of Class B in 2013 and 2015, but does show impairment in 2018 where it only attains Class C. A wetland station (W-183) was attaining Class B in 2013.

TMDL ASSESSMENT APPROACH: NUTRIENT AND SEDIMENT MODELING OF IMPAIRED AND ATTAINMENT STREAMS

NPS pollution is difficult to measure directly, because it comes from many diffuse sources spread across the landscape. For this reason, an online nutrient loading model, *Model My Watershed* (v. 1.32.0), was used to estimate the sources of pollution based on well-established hydrological equations (Stroud Water Research Center 2017). *Model My Watershed* makes use of the GWLF-enhanced model engine. The model incorporates detailed maps of soil, land use, and slope, daily weather and localized weather data (from the period 2009-2020), and direct observations of agriculture and other land uses within the watershed. *Model My Watershed* is derived from its parent MapShed developed by Evans and Corradini (2012). *Model My Watershed* replaced MapShed in 2017-2018.

The nutrient loading estimates for the impaired stream were compared to similar estimates for five non-impaired (attainment) streams of similar watershed land uses across the state. The TMDL for the impaired stream was set as the mean nutrient loading estimate of these attainment stream watersheds, and units of mass per unit watershed area per year (kg/ha/year) were used. The difference in loading estimates between the impaired and attainment watersheds represents the percent reduction in nutrient loading required under this TMDL. The attainment streams and their nutrient and sediment loading estimates and TMDL are presented below in Table 1.

Table 1: Numeric Targets for Pollutant Loading Based on Model My Watershed Outputs (2021) for Attainment Streams

Attainment Streams	Town	Total P Load (kg/ha/yr)	Total N Load (kg/ha/yr)	Sediment Load (kg/ha/yr)
Footman Brook	Exeter	0.17	1.73	35.2
Martin Stream	Fairfield	0.13	2.98	57.9
Moose Brook	Houlton	0.18	1.59	48.5
Upper Kenduskeag Stream	Corinth	0.16	1.72	100.5
Upper Pleasant River	Gray	0.16	4.26	86.5
Total Maximum Daily Load		**0.16**	**2.46**	**65.7**

RAPID WATERSHED ASSESSMENT

Habitat Assessment

A habitat assessment survey was conducted on both the impaired and attainment streams. The assessment approach is based on the *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (Barbour et al. 1999), which integrates various parameters relating to the structure of physical habitat. The habitat assessments include a general description of the site, physical characterization and visual assessment of in-stream and riparian habitat quality.

Based on rapid bioassessment protocols for high gradient streams, Stetson Brook received a score of 179 out of a total 200 for quality of habitat. Higher scores indicate better habitat. The range in habitat assessment scores for attainment stream was 155 to 179.

The habitat assessment for Stetson Brook was conducted on a relatively short sample reach (about 100-200 meters for a typical small stream), and was located near the most downstream Maine DEP sample station. For both impaired and attainment streams, the assessment location was usually near a road crossing for ease of access. In the Stetson Brook watershed, the downstream sample station was located in a forested portion of the stream downstream of the Stetson Road crossing. This area was forested with a thick buffer, while many other sections of the stream and associated tributaries flow near agricultural lands and developed areas with minimal buffers.

Figure 2 (right) shows the range of habitat assessment scores for all attainment and impaired streams, as well as for Stetson Brook. The overlapping attainment and impaired stream scores indicate that factors other than habitat should be considered when addressing the impairments in Stetson Brook. Consideration should be given to major "hot spots" in the Stetson Brook watershed as potential sources of NPS pollution contributing to the water quality impairment.

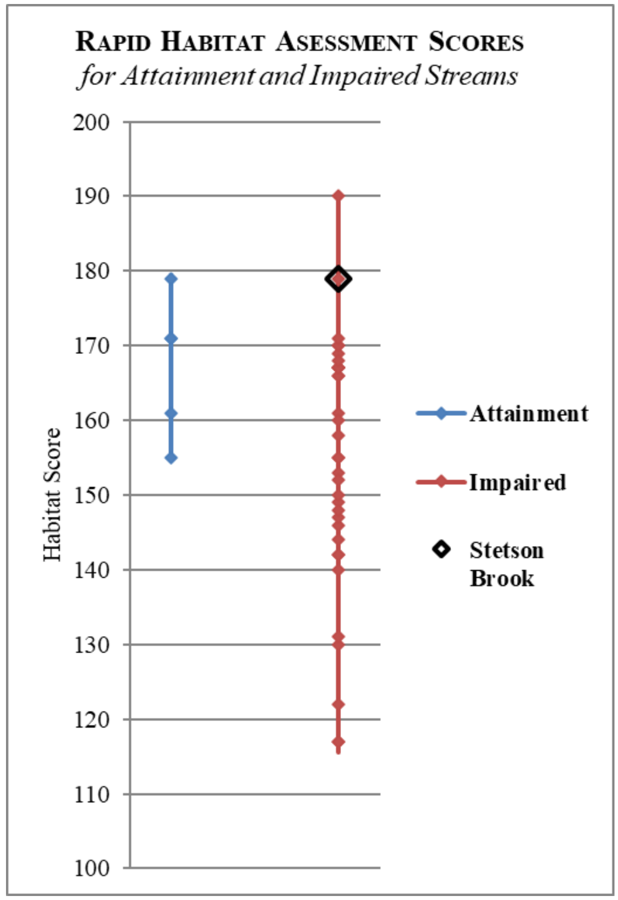


Figure 2: Habitat Assessment Scores for Stetson Brook (2012) Compared to Region

Pollution Source Identification

Pollution source identification assessments were conducted for both Stetson Brook (impaired) and the attainment streams. The source identification work study is based on an abbreviated version of the Center for Watershed Protection's Unified Subwatershed and Site Reconnaissance method (Wright, et al. 2005). The abbreviated method includes both a desktop and field component. The desktop assessment consists of generating and reviewing maps of the watershed boundary, roads, land use and satellite imagery, and then identifying potential NPS pollution locations, such as road crossings, agricultural fields, and large areas of bare soil. When available, multiple sources of satellite imagery were reviewed. Occasionally, the high resolution of the imagery allowed for observations of livestock, row crops, eroding stream banks, sediment laden water, junkyards, and other potential NPS concerns that could affect stream quality. As many potential pollution sources as possible were visited, assessed and documented in the field. Field visits were limited to NPS sites that were visible from roads or a short walk from a roadway. Neighborhoods were assessed for NPS pollution at the whole neighborhood level including streets and storm drains (where applicable). The assessment does not include a scoring component, but does include a detailed summary of findings and a map indicating documented NPS sites throughout the watershed.

The watershed source assessment for Stetson Brook was completed in June 2012. In-field observations of erosion, lack of vegetated stream buffer, extensive impervious surfaces, high-density neighborhoods and agricultural activities were documented throughout the watershed (Table 2, Figure 3).

Table 2: Potential Pollution Source ID Assessment (2012) for the Stetson Brook Watershed

Potential Source			Notes
ID#	**Location**	**Type**	
10	Tekakwitha Drive	Residential	• A large lawn mowed within approximately two feet of stream. • Fertilizer use on the lawn is suspected as it is lush and very green. • A small bridge crossing over stream. • Possible thermal and nutrient impacts.
11	Sawyer Road	Road Crossing	• Slumping road shoulder is eroding directly into stream.
19	College Road	Road crossing	• A small wash out and pavement collapse was observed at an unstable road crossing on College Road.
24	Near College Road crossing	Residential	• Maintained lawn with minimal buffer to stream was identified as a potential source near the College Road crossing in Greene.
34	Daggett Hill Road & Route 11	Road Crossing	• Crumbling pavement and sand and gravel deposits into stream. Excess sediment on road and in ditches.

NUTRIENT AND SEDIMENT LOADING – *MODEL MY WATERSHED* ANALYSIS

The *Model My Watershed* model was used to estimate stream loading of total phosphorus, total nitrogen, and sediment in Stetson Brook watershed. The model estimated nutrient and sediment loads over a 12-year period (2009-2020), which was determined by local (Poland ME USC00176856) weather data inserted into *Model My Watershed*. This extended period captures a recent but wide range of hydrologic conditions to account for variations in nutrient and sediment loading over time. Loads for the attainment watersheds ((five total; Table 1) were computed using the same model with the same recent inputs (i.e., regional weather, 2016 land use and land cover, 2016 wetland extent, and BMPs similar to the impaired watersheds).

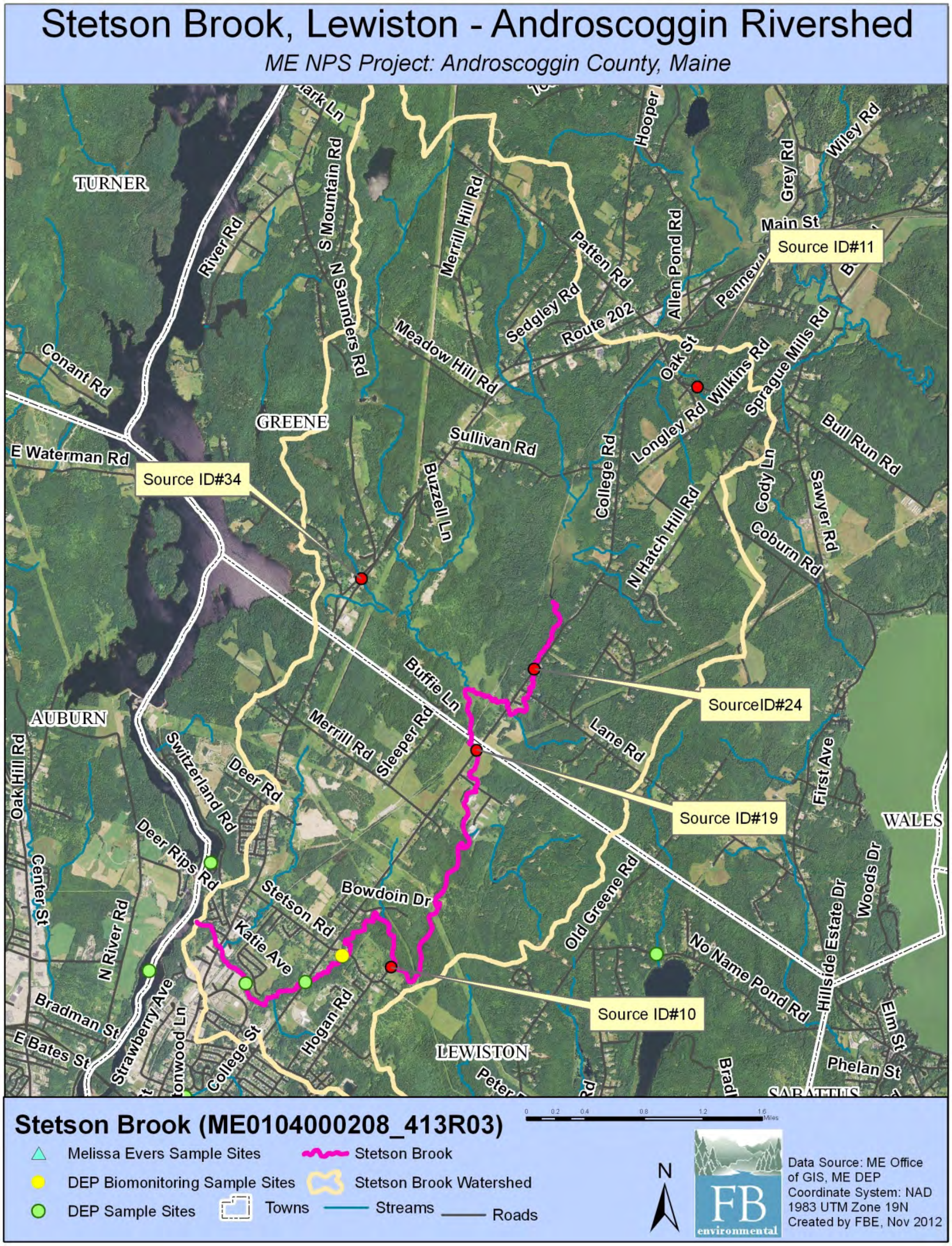


Figure 3: Aerial Photo of Potential Source Locations (identified in 2012) in Stetson Brook Watershed

Many quality assured and regionally calibrated input parameters are provided with *Model My Watershed*. However, several updates to some of the default parameters were made in this TMDL effort, and namely more recent land use/cover using **MRLC-NLCD 2016** [1], more recent and local weather (precipitation and temperature) data (as described above), and more regional estimates of Best Management Practices (BMPs; see ensuing discussion). Because land use/cover is more recent, the estimated filtration fraction of wetland and open water and the amount of stream buffer in agricultural land should be more accurate. It is also worth noting that improved classification algorithms were employed by MLRC in the NCLD 2016 and these new algorithm were used in the revisions of all previous NLCD versions (including the first version in 2001).

Livestock Estimates

Livestock waste contains nutrients which can cause water quality impairment. The nutrient loading model considers numbers and types of animals. Table 3 (right) provides livestock (numbers of animals) in the watershed based on the USDA National Agricultural Statistics Service (NASS) estimation for 2012. Some of these totals were modified by direct observations made in the watershed in the 2012 survey. To generate watershed-based livestock counts, NASS county-based livestock totals are converted to a per unit area (based on the total area of the county). The unit area amount is then multiplied by the total watershed area to derive a watershed total count (as seen in Table 3).

Table 3: Livestock Count in Stetson Brook Watershed

Type	Stetson Brook
Dairy Cows	60
Beef Cows	17
Broilers	49
Layers	--
Hogs/Swine	35
Sheep	13
Horses	23
Turkeys	11
Other	--
Total	**208**

The Stetson Brook watershed is predominantly forested with a substantial amount of development and agriculture. Agricultural areas are concentrated most in the central and upper portion of the watershed away from the Androscoggin River.

Vegetated Stream Buffer in Agricultural Areas

Vegetated stream buffers are areas of trees, shrubs, and/or grasses adjacent to streams, lakes, ponds or wetlands which provide nutrient loading attenuation (Evans & Corradini, 2012). MapShed considers natural vegetated stream buffers within agricultural areas as providing nutrient load attenuation. The width of buffer strips is not defined within the MapShed manual, and was considered to be 75 feet for this analysis. Geographic Information System (GIS) analysis of recent aerial photos along with field reconnaissance observations were used to estimate the number of agricultural stream miles with and without vegetative buffers, and these estimates were directly entered into the model.

[1] MRLC-NLCD 2016 : Multi-Resolution Land Characteristics – National Land Cover Dataset (version 2016) provided by the MRLC Consortium (Jin et al. 2019).

Stetson Brook is a 6.8 mile-long impaired segment as listed by Maine DEP. As modeled, the total stream miles (including tributaries) within the watershed was calculated as 13.7 miles. Of this total, 2.7 stream miles are located within agricultural areas and 1.1 miles of that area appear to have a 98 foot or greater vegetated buffer (Table 4, Figure 4). From a watershed perspective, this equates to 1.6 miles or 11.7% of the total stream length running through agricultural land with less than a 98 foot buffer. By contrast, for attainment stream watersheds, the percentage of total stream miles running through agricultural land without a 75 foot vegetated buffer ranged from 0% to 3.9% with an average of 1.3%. Note, a minimum vegetated buffer width of 75 feet was used in an earlier (2012) effort to produce Figure 4 shown here. Differences in stream length estimates using a 98-foot or 75-foot buffer were practically insignificant.

Table 4: Summary of Vegetated Buffers in Agricultural Areas (2012)

Stetson Brook
• Agricultural Land Stream Length = 2.7 mi • Agricultural Land Stream Length with Buffer = 1.1 mi (or 41% of total agricultural land stream length) • Percentage of total stream length flowing through non-buffered agricultural land = 11.7%

Home Septic System Loads

Loads for “normally functioning” septic systems are calculated in *Model My Watershed* using an estimate of the average number of persons per acre in “Low-Density Mixed” areas. In these areas, it is assumed that the populations therein are served by septic systems rather than centralized sewage systems. All homes in such areas are assumed to be connected to “normally functioning” systems rather than those that experience “surface breakouts” (surface failures), “short-circuiting” to underlying groundwater (subsurface failures), or have direct conduits to nearby water bodies. Non-functioning systems would be modeled with a higher load contribution to the waterbody.

Best Management Practices (BMPs)

Best management practices (BMPs) are typically instituted to reduce the loading of sediment and nutrients from upland (i.e., non-point) sources. Ideally, information on BMPs for a specific watershed from local and regional sources would improve this component of the water quality model. Maine DEP sought information on BMP use in early 2021 from local, regional, and state agricultural agencies for rural BMPs and from nearby municipalities for urban BMPs. Very little to no information was returned in the solicitation. Hence, estimates for typical New England watersheds were derived from information available from Vermont. An upper limit of BMP use was garnered from watersheds entering the Chesapeake Bay where BMP use is intensive.

Four agricultural BMPs were used in this modeling effort and in the following manner:

- *Cover Crops:* Cover crops are the use annual or perennial crops to protect soil from erosion during time periods between harvesting and planting of the primary crop. The percent of cropland area in a cover crop BMP deployed was estimated at 25% and selected as the low end of the range (25 to 30 percent) expected for cropland in New England. This value was assigned to the five attainment watersheds.

- *Conservation Tillage:* Conservation tillage is any kind of system that leaves at least 30% of the soil surface covered with crop residue after planting. This reduces soil erosion and runoff. This BMP was estimated to occur in 25% of cropland. This value was assigned to the five attainment watersheds.
- *Strip Cropping / Contour Farming:* This BMP involves tilling, planting and harvesting perpendicular to the gradient of a hill or slope using high levels of plant residue to reduce soil erosion from runoff. Both interview sources suggest this practice is minimal to non-existent for New England watersheds. Hence, no BMP of this type was used in this modeling effort. This value was assigned to the five attainment watersheds.
- *Grazing Land Management:* This BMP consists of ensuring adequate vegetation cover on grazed lands to prevent soil erosion from overgrazing or other forms of over-use. This usually employs a rotational grazing system where hays or legumes are planted for feed and livestock is rotated through several fenced pastures. Both interview sources were not aware of this practice being active and is likely minimal for New England watersheds. Hence, no BMP of this type was used in this modeling effort for both impaired and attaining watersheds.

Pollutant Load Attenuation by Lakes, Ponds and Wetlands

Depositional environments such as lakes, ponds, and wetlands can attenuate watershed sediment and nutrient loading. This information is entered into the nutrient loading model by a simple percentage of watershed area draining to a lake, pond, or wetland. The Stetson Brook watershed is 10.4% wetland and open water, per the 2016 NLCD land use/cover. A fairly large wetland complex exists at the origin of the impaired segment of Stetson Brook. The major eastern tributaries first drain into this wetland before continuing into Stetson Brook. Smaller wetlands are also found along tributaries in the northwestern portion of the watershed. It is estimated that 20.7% of land area within the watershed drains to wetlands and open water. The percent of watershed draining to a wetland in the attainment watersheds, based on the 2021 analysis, ranged from 26 to 58 percent, with an average of 40%.

NUTRIENT AND SEDIMENT MODELING RESULTS

Selected results from the watershed loading model are presented here. The TMDL itself is expressed in units of kilograms per hectare per year. The additional results shown below assist in better understanding the likely sources of pollution. The model results for Stetson Brook indicate significant reductions of phosphorus and sediment and a small reduction of nitrogen are needed to improve water quality. Below, loading for nitrogen, phosphorus and sediment are discussed individually.

There are two categories of loads – sources and pathways. Sources are determined by land use/cover and the overland flow they generate, livestock counts by animal type, and home sewage treatment systems in developed areas. Pathways represent additional loads derived from subsurface flow and streambank erosion. Subsurface loads are calculated using dissolved N and P coefficients for shallow groundwater and are mainly derived from atmospheric inputs. Sediment and nutrient loads produced by eroding streambanks are estimated using an approach developed by Evans et al. (2003). This pathway is comprised of loads originating from five sources, and listed in order of decreasing importance: amount of developed land area, soil erodibility (K-factor), density of livestock, runoff curve number, and topographic slope. For any given model run, the amount of developed land in the watershed is responsible for just over 72% of the total streambank load, whereas soil erodibility and animal density are responsible for 21% and 7% of the total streambank load, respectively.

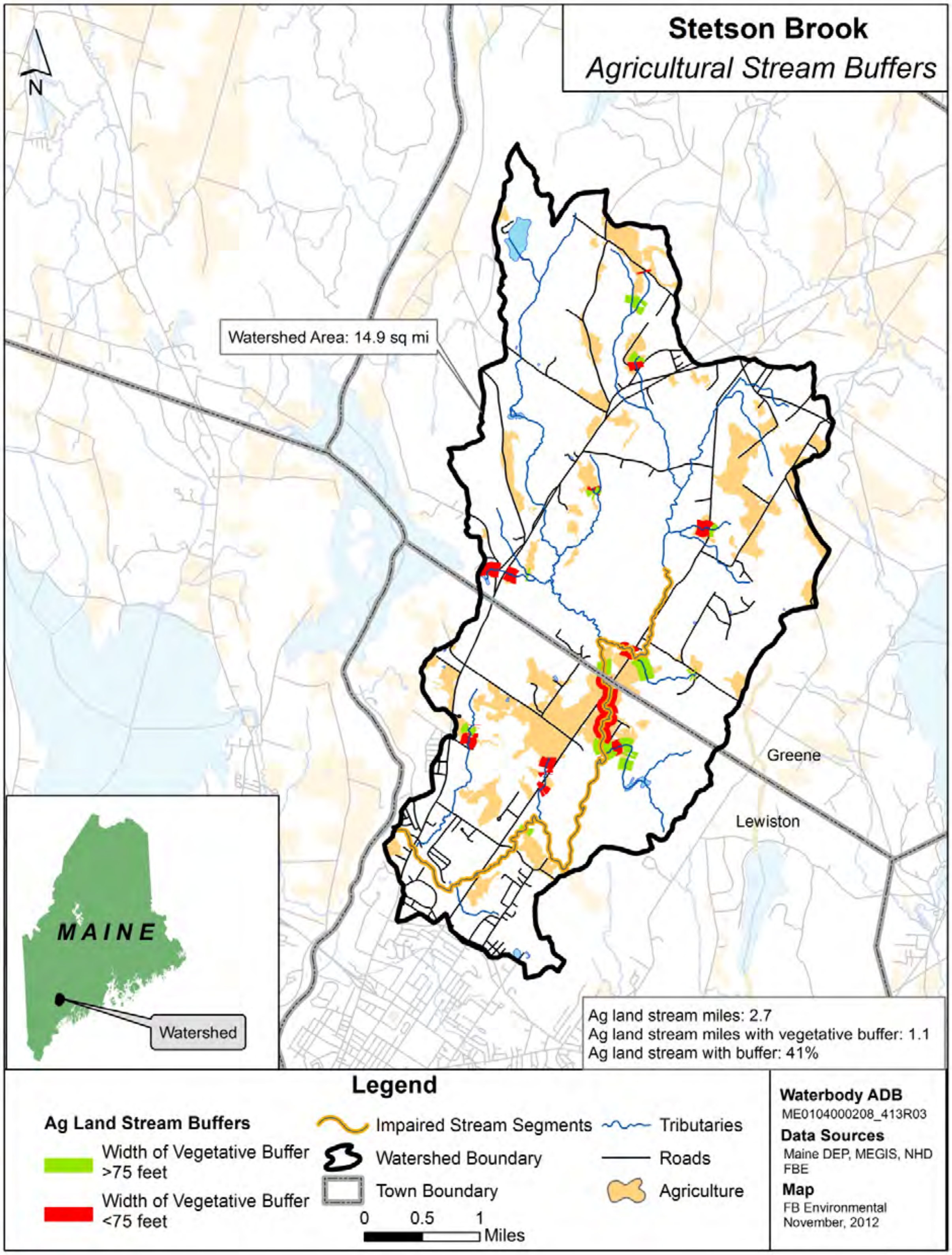


Figure 4: Agricultural Stream Buffers (from 2012) in the Stetson Brook Watershed

Sediment

Aside from stream bank erosion which contributes 76.7% of the total watershed sediment load, the major source load in Stetson Brook watershed originates from hay/pasture land (almost 59% of total sources). Residential sources also contribute a significant source load (32.3%).

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient and Sediment Levels for Stetson Brook* below for loading estimates that have been normalized by watershed area.

Table 5: Total Sediment Load by Source

Stetson Brook	Sediment (1000 kg/year)	Sediment (%)
Source Load		
Hay/Pasture	80.5	58.8%
Cropland	0.3	0.2%
Wooded Areas	6.3	4.6%
Wetlands	0.4	0.3%
Open Land	5.1	3.7%
Barren Areas	0.010	0.008%
Low-Density Mixed	10.3	7.5%
Medium-Density Mixed	15.4	11.2%
High-Density Mixed	5.8	4.2%
Low-Density Open Space	12.8	9.4%
Farm Animals	0	0
Septic Systems	0	0
Source Load Total:	**136.9**	**100%**
Pathway Load		
Stream Bank Erosion	452.7	-
Subsurface Flow	0	-
Total Watershed Mass Load:	**590**	

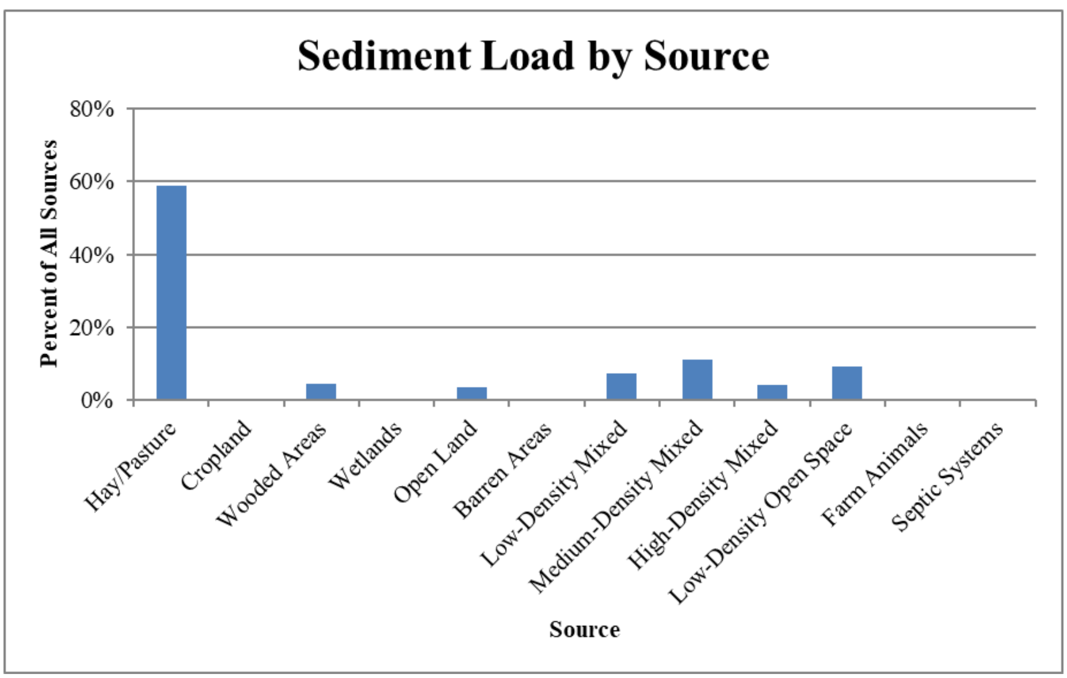


Figure 5: Total Sediment Load by Source in the Stetson Brook Watershed

Total Nitrogen

Table 6 and Figure 6 (below) show the estimated total nitrogen load, in terms of mass and percent of total by source, in the Stetson Brook watershed. Sources of nitrogen originate from several sources where all have an equivalent contribution. The largest combined sources are residential areas (29.8%) and hay/pasture land and farm animals (38.4%).

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient and Sediment Levels for Stetson Brook* below for loading estimates that have been normalized by watershed area.

Table 6: Total Nitrogen Load by Source

Stetson Brook	Total N (kg/year)	Total N (%)
Source Load		
Hay/Pasture	862	21.3%
Cropland	2	0.1%
Wooded Areas	629	15.5%
Wetlands	275	6.8%
Open Land	117	2.9%
Barren Areas	15	0.4%
Low-Density Mixed	302	7.4%
Medium-Density Mixed	383	9.4%
High-Density Mixed	144	3.6%
Low-Density Open Space	378	9.3%
Farm Animals	696	17.2%
Septic Systems	251	6.2%
Source Load Total:	**4,054**	**100%**
Pathway Load		
Stream Bank Erosion	369	-
Subsurface Flow	5,364	-
Total Watershed Mass Load:	**9,787**	

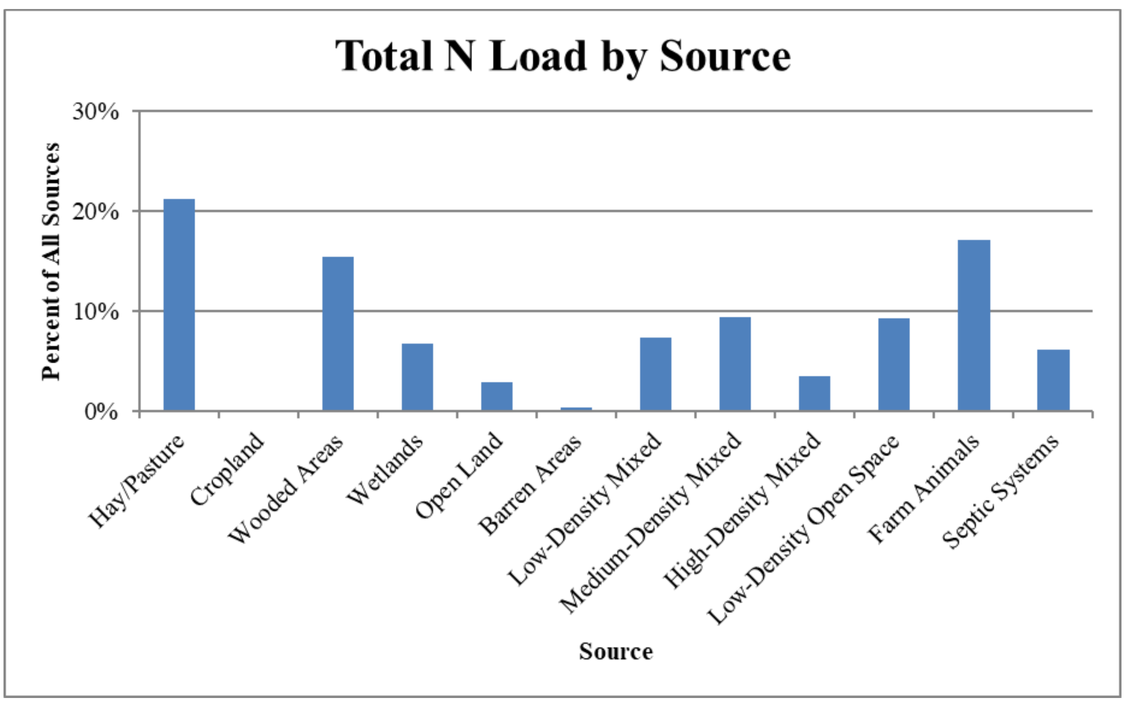


Figure 6: Total Nitrogen Load by Source in the Stetson Brook Watershed

Total Phosphorus

Table 7 and Figure 7 (below) show the estimated total phosphorus load in terms of mass and percent of total by source, in the Stetson Brook watershed. Hay/pasture land contributes almost 56% of the source load. Farm animals contribute 19.1% whereas residential areas contribute 16.1%.

Note that total loads by mass cannot be directly compared between watershed TMDLs due to differences in watershed area. See section *TMDL: Target Nutrient and Sediment Levels for Stetson Brook* below for loading estimates that have been normalized by watershed area.

Table 7: Total Phosphorus Load by Source

Stetson Brook	**Total P** (kg/year)	**Total P** (%)
Source Load		
Hay/Pasture	426.9	55.9%
Cropland	0.7	0.1%
Wooded Areas	41.4	5.4%
Wetlands	14.6	1.9%
Open Land	10.4	1.4%
Barren Areas	0.5	0.07%
Low-Density Mixed	31.4	4.1%
Medium-Density Mixed	37.9	5.0%
High-Density Mixed	14.3	1.9%
Low-Density Open Space	39.3	5.1%
Farm Animals	145.8	19.1%
Septic Systems	0	0
Source Load Total:	**763.2**	**100%**
Pathway Load		
Stream Bank Erosion	189.0	-
Subsurface Flow	224.6	-
Total Watershed Mass Load:	**1,177**	

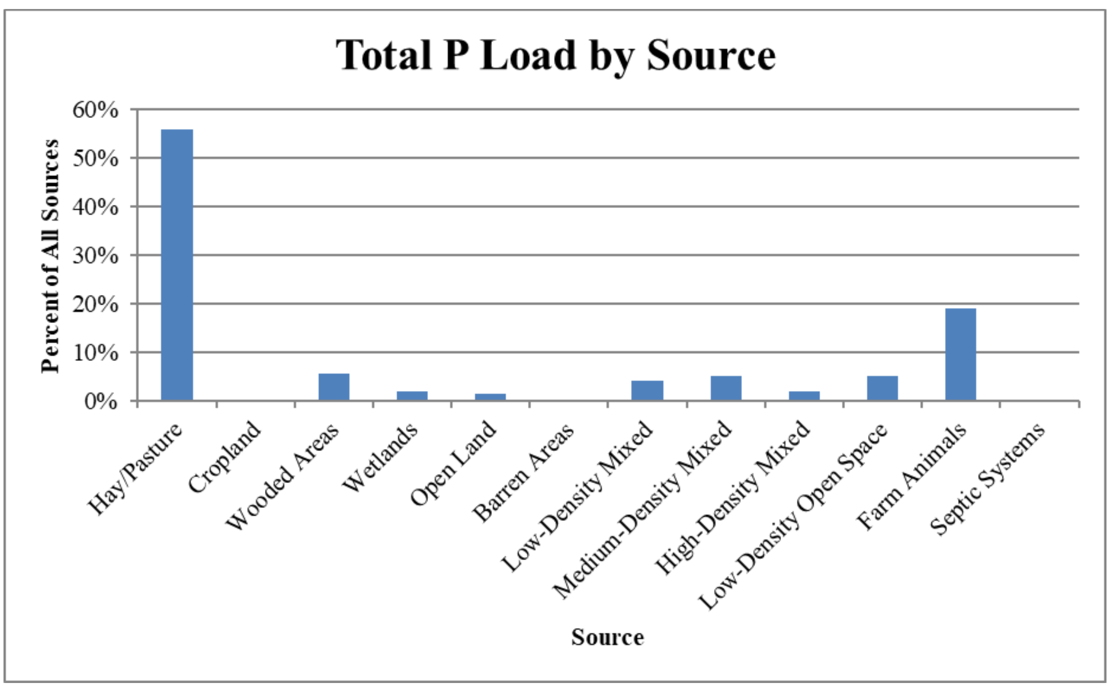


Figure 7: Total Phosphorus Load by Source in the Stetson Brook Watershed

TMDL: TARGET NUTRIENT AND SEDIMENT LEVELS FOR STETSON BROOK

The existing loads for nutrients and sediments in the impaired segment of Stetson Brook are listed in Table 8, along with the TMDL which was calculated from the average loading estimates of five attainment watersheds throughout the state. Table 9 presents a more detailed view of the modeling results and calculations used in Table 8 to define TMDL reductions, and compares the existing nutrient and sediment loads in Stetson Brook to TMDL endpoints derived from the attainment waterbodies. An annual time frame provides a mechanism to address the daily and seasonal variability associated with nonpoint source loads.

Table 8: Stetson Brook Pollutant Loading Compared to TMDL Targets

Stetson Brook			
Pollutant Load	**Existing Load**	**TMDL**	**Reduction Required**
Total Annual Load per Unit Area		Attainment Streams	
Sediment (kg/ha/yr)	154.1	65.72	57.4%
Total N (kg/ha/yr)	2.56	2.46	4.0%
Total P (kg/ha/yr)	0.31	0.16	48.0%

Future Loading

The prescribed reduction in pollutants discussed in this TMDL reflects reduction from estimated existing conditions. Expansion of agricultural and development activities in the watershed have the potential to increase runoff and associated pollutant loads to Stetson Brook. To ensure that the TMDL targets are attained, future agricultural and development activities will need to meet the TMDL targets. Between 2012 to 2017 in Androscoggin County, the growth in agricultural lands is generally decreasing as both total land area in farms (6.4%) and average farm size (12.5%) have declined. However, the total number of farms has increased 7.1%. These values are extracted from the most recent (2017) Census of Agriculture (USDA 2017). Human population in Androscoggin County increased only slightly by 0.53% from 2000 to 2019 (US Census 2020). Future activities and BMPs that achieve TMDL reductions are addressed below.

Next Steps

The use of agricultural and developed area Best Management Practices (BMP's) can reduce sources of polluted runoff in Stetson Brook. It is recommended that municipal officials, landowners, and conservation stakeholders in Lewiston and Greene work together to develop a watershed management plan to:

- Encourage greater citizen involvement through the development of a watershed coalition to ensure the long term protection of Stetson Brook;
- Run a "Hot-Spot Analysis" in *Model My Watershed* to determine sub-watershed locations of higher existing contributions of sediment and nutrients to the outlet of Stetson Brook watershed; then focus BMP mitigation in these hot-spot sub-areas of the watershed;
- Address existing nonpoint source problems in the Stetson Brook watershed by instituting BMPs where necessary; and

- Prevent future degradation of Stetson Brook through the development and/or strengthening of local Nutrient Management Ordinance.

Table 9: Annual Loads by Land Use, Other Sources, and Pathways for Stetson Brook Based on Modeling

Stetson Brook				
	Area (ha)	**Sediment** (1000 kg/yr)	**Total N** (kg/yr)	**Total P** (kg/yr)
Land Uses				
Hay/Pasture	356	80.5	862	426.9
Cropland	0	0.3	2	0.7
Wooded Areas	2,435	6.3	629	41.4
Wetlands	389	0.4	275	14.6
Open Land	74	5.1	117	10.4
Barren Areas	13	0.010	15	0.5
Low-Density Mixed	204	10.3	302	31.4
Medium-Density Mixed	71	15.4	383	37.9
High-Density Mixed	27	5.8	144	14.3
Low-Density Open Space	256	12.8	378	39.3
Total Area	3,826			
Other Sources				
Farm Animals		0.0	696	145.8
Septic Systems		0.0	251	0.0
Pathway Load				
Stream Bank Erosion		452.7	369	189.0
Subsurface Flow		0.0	5,364	224.6
Total Annual Load		590	9,787	1,177
Total Annual Load per Unit Area		0.154	2.56	0.31
		1000 kg/ha/yr	kg/ha/yr	kg/ha/yr

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