TMDL SUMMARY — APPENDIX 6-4

Warren Brook

WATERSHED DESCRIPTION

This **TMDL** applies to a 6.04 mile section of Warren Brook, located in the Towns of Morrill and Belmont and the City of Belfast, Maine. The impaired segment of Warren Brook begins at the outlet of Cross Pond in the western portion of the watershed in a predominantly forested area and flows south through a wetland, then turns northeast under Cross Pond Road Extension. The stream then enters into mixed agriculture and forest, crossing Park Hill Road, Poors Mill Road, and Shepard Road before joining the Passagassawakeag River. The Warren Brook watershed covers an area of 6.41 square miles.

- Runoff from agricultural land concentrated along Cross Road, Rolerson Road, Poors Mill Road, and Shepard Road is likely the largest sources of **nonpoint source (NPS) pollution** to Warren Brook. Runoff from cultivated lands, active hay lands, and pasture can transport nitrogen and phosphorus to the nearest section of the stream.
- The Warren Brook watershed is predominately non-developed (95.2%). Forested areas (70.9%) within the watershed absorb and filter pollutants helping protect both water quality in the stream and stream channel stability. Wetlands (5%) may also help filter nutrients.
- Non-forested areas within the watershed are predominantly agricultural (19.3%) and are dispersed throughout the watershed.
- Developed areas (4.8%) with impervious surfaces in close proximity to the steam may impact water quality.
- Warren Brook is on the list of Maine's 303(d) list of Impaired Streams (Maine DEP, 2013).

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 is typically transported by rain or snowmelt runoff.*

Waterbody Facts

Segment ID: ME0105000218_521R01

Town: Morrill, Belmont and Belfast, ME

County: Waldo

Impaired Segment Length: 6.04 miles

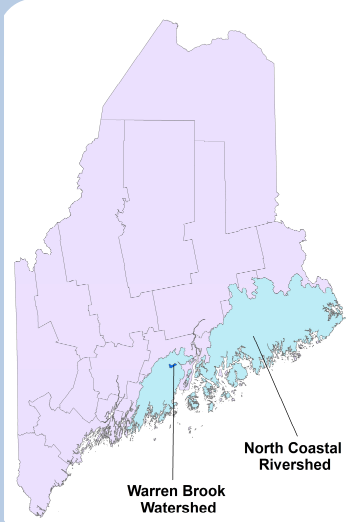
Classification: Class B

Direct Watershed: 6.41 mi^2 (4,102 acres)

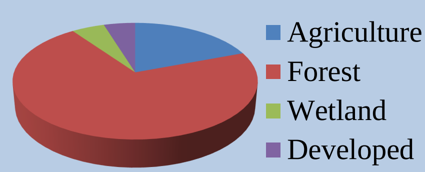
Impairment Listing Cause: Dissolved Oxygen

Watershed Agricultural Land Use: 19.3%

Major Drainage Basin: North Coastal



Watershed Land Uses



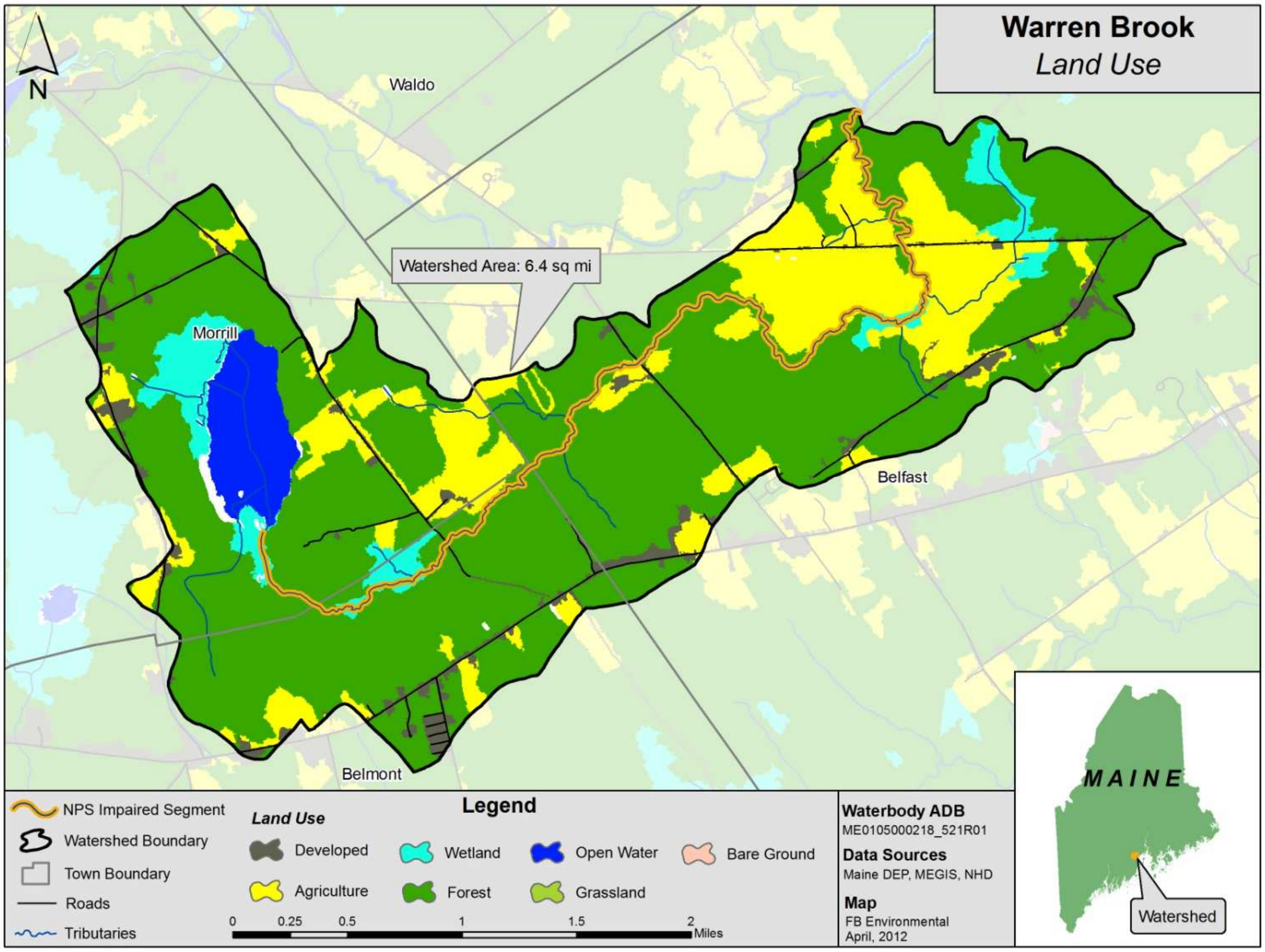


Figure 1: Land Use in the Warren Brook Watershed

WHY IS A TMDL ASSESSMENT NEEDED?

Warren 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.

Agricultural land area in the Warren Brook watershed accounts for about 19% of the land area. The area of developed land is much smaller at about 5% of the watershed (Figure 1). Agriculture is likely to be the largest contributor of sediment and nutrient enrichment to

***Warren Brook** near Shepard Rd.*
Photo: FB Environmental

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). The aquatic life impairment in Warren Brook is based on historic data.

TMDL ASSESSMENT APPROACH: NUTRIENT 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, a nutrient loading model, MapShed, was used to estimate the sources of pollution based on well-established hydrological equations; detailed maps of soil, land use, and slope; many years of daily weather data; and direct observations of agriculture and other land uses within the watershed.

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 MapShed Model Outputs for Attainment Streams

Attainment Streams	**Town**	**TP load (kg/ha/yr)**	**TN load (kg/ha/yr)**	**Sediment load (1000 kg/ha/yr)**
Martin Stream	Fairfield	0.14	3.4	0.008
Footman Brook	Exeter	0.33	6.4	0.058
Upper Kenduskeag Stream	Corinth	0.29	5.6	0.047
Upper Pleasant River	Gray	0.22	4.6	0.016
Moose Brook	Houlton	0.25	5.9	0.022
Total Maximum Daily Load		**0.24**	**5.2**	**0.030**

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 Wadeable Streams and 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, Warren Brook received a score of 170 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.

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. For both impaired and attainment streams, the assessment location was usually near a road crossing for ease of access. The Warren Brook habitat assessment was completed at the Shepard Road crossing. The sample reach was skirted by wetlands, but was also dominated by small trees and shrubs (mainly nanny berry and non-native honey suckle).

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

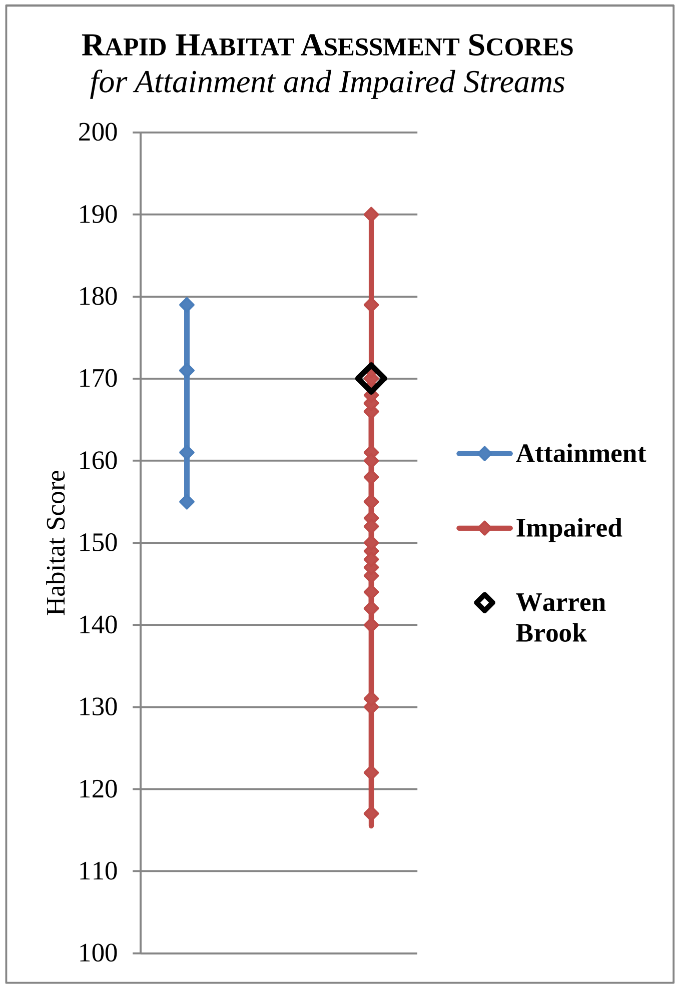


Figure 2: Habitat Assessment Scores

Pollution Source Identification

A pollution source identification assessment was conducted for Warren 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 would 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 Warren Brook was completed on July 18, 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: Pollution Source ID Assessment for the Warren Brook Watershed

Potential Source			**Notes**
ID#	**Location**	**Type**	
2	Poors Mill Road	Agriculture	• Hay and corn crops observed. • Horses were also documented along Poors Mill Road.
3	Rolerson Road	Agriculture	• Active hay fields were documented along Rolerson Road.
3b	Rolerson Road	Road Crossing	• Erosion at road crossing resulting in sediment deposited directly into stream.
4	Cross Road	Agriculture	• Active hay fields.
7	Cross Road	Agriculture	• Patch Cross Farm. • Mixed vegetable crops.
8	Shepard Road	Agriculture	• Dairy farm located on watershed boarder. • Estimated over 60 cows.
9	East of Cross Road	Agriculture	• Tributary flows through agricultural field with minimal buffer.
10	Poors Mill Road	Agriculture	• Tributary flows through agricultural field with minimal buffer.

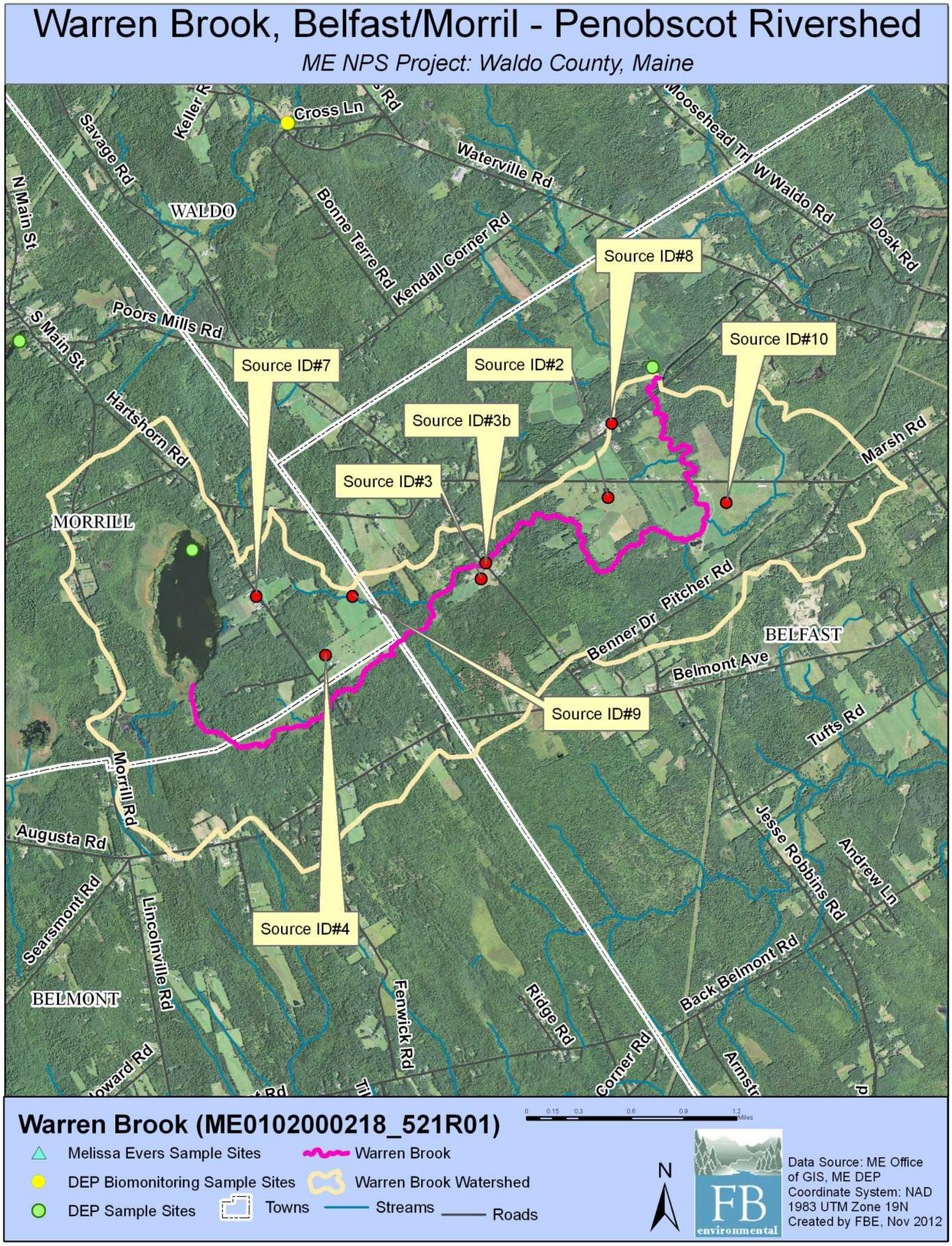


Figure 3: Aerial Photo of Source ID Locations in the Warren Brook Watershed

NUTRIENT LOADING – MAPSHED ANALYSIS

The MapShed model was used to estimate stream loading of sediment, total nitrogen and total phosphorus in Warren Brook (impaired), plus five attainment watersheds throughout the state. The model estimated nutrient loads over a 15-year period (1990-2004), which was determined by the available weather data provided within MapShed. This extended period captures a wide range of hydrologic conditions to account for variations in nutrient and sediment loading over time.

Many quality assured and regionally calibrated input parameters are provided with MapShed. Additional input parameters were manually entered into the model based on desktop research and field observations, as described in the sections on Habitat Assessment and Pollution Source Identification. These manually adjusted parameters included estimates of livestock animal units, agricultural stream miles with intact vegetative buffer, Best Management Practices (BMPs), and estimated wetland retention and/or drainage areas.

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 estimates of livestock (numbers of animals) in the watershed, based on direct observations made in the watershed, plus other publicly available data.

The Warren Brook watershed is predominantly forested, with significant agricultural land in the form of large areas of hay and corn fields along Poors Mill Road, as well as a dairy farm on Shepard Road. An estimated 60 cows were observed, along with two horses and two goats.

Table 3: Livestock Estimates in the Warren Brook Watershed

Type	Warren Brook
Dairy Cows	60
Beef Cows	
Broilers	
Layers	
Hogs/Swine	
Sheep	
Horses	2
Turkeys	
Other	2 (goats)
Total	**64**

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.

Table 4: Summary of Vegetated Buffers in Agricultural Areas

Warren Brook
• 9.9 stream miles in watershed (includes ephemeral streams) • 2.3 stream miles in agricultural areas • 43% of agricultural stream miles have a vegetated buffer

Warren Brook is listed by Maine DEP as a 6.04 mile-long impaired segment. However, as modeled, the total stream miles (including tributaries) within the watershed was calculated by MapShed to be 9.9 miles. Of this total, 2.3 stream miles are located within agricultural areas; of this length, 1.0 mile (43%) shows a 75-foot vegetative buffer (Table 4, Fig. 4). By contrast, agricultural stream miles (as modeled) with a 75 foot vegetated buffer in the attainment stream watersheds ranged from 34% to 92%, with an average of 61%.

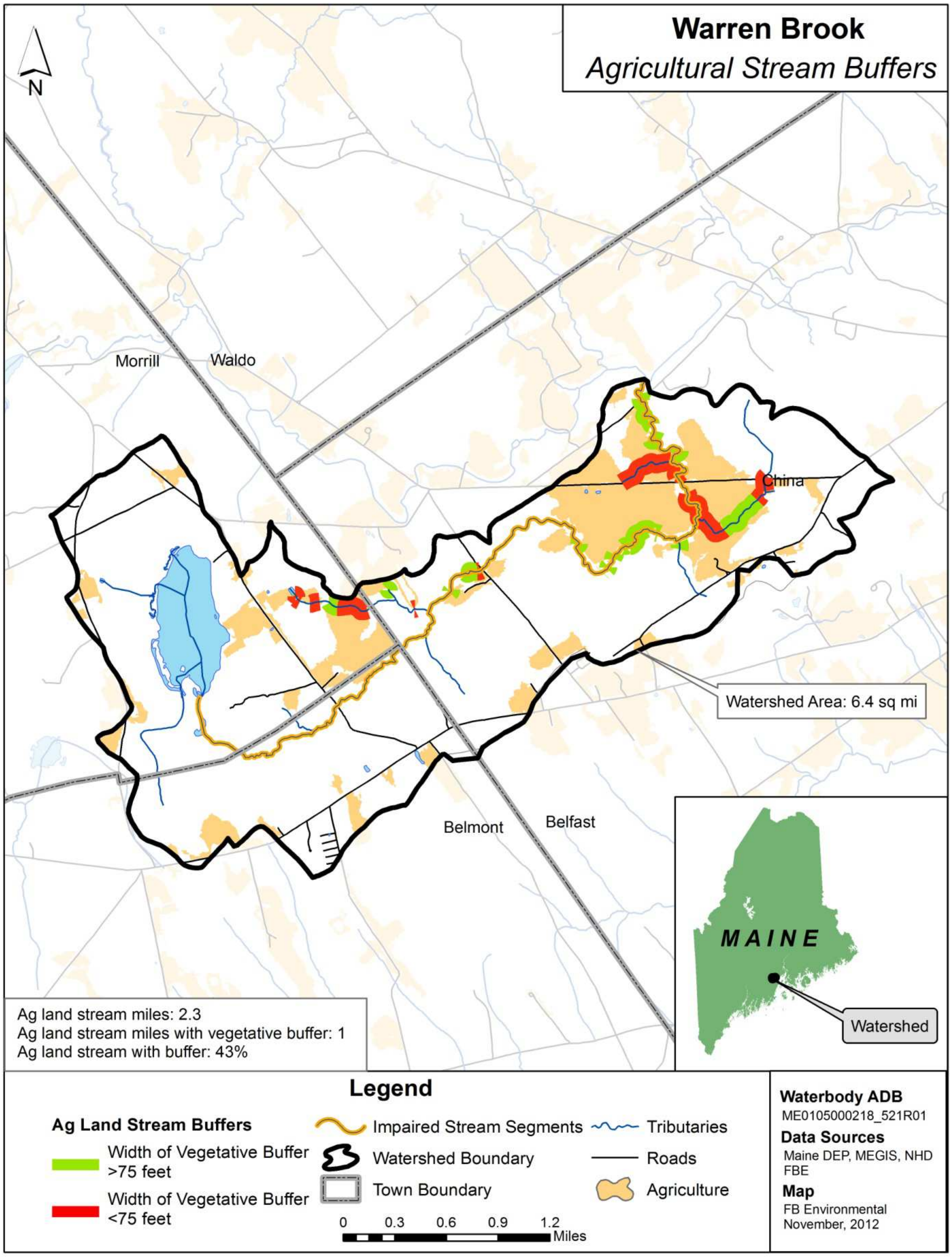


Figure 4: Agricultural Stream Buffers in the Warren Brook Watershed

Best Management Practices (BMPs)

For this modeling effort, four commonly used BMPs were entered based on literature values. These estimates were applied equally to impaired and attainment stream watersheds. More localized data on agricultural practices would improve this component of the model.

- *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 agricultural acres cover crops used within the model is estimated at 4%. This figure is based on information from the 2007 USDA Census stating that 4.1% of crop land acres is left idle or used for cover crops or soil improvement activity, and not pastured or grazed (USDA, 2007b).
- *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 and is one of the most commonly used BMPs. This BMP was assumed to occur in 42% of agricultural land. This figure is based on a number given by the Conservation Tillage Information Center's 2008 Crop Residue Management Survey stating that 41.5% of U.S. acres are currently in conservation tillage (CTIC, 2000).
- *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. This BMP was assumed to occur in 38% of agricultural lands, based on a study done at the University of Maryland (Lichtenberg, 1996).
- *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. In this TMDL, a figure of 75% of hay and pasture land is assumed to utilize grazing land management. This figure is based on a study by Farm Environmental Management Systems of farming operations in Canada (Rothwell, 2005).

Pollutant Load Attenuation by Lakes, Ponds and Wetlands

Depositional environments such as ponds and wetlands can attenuate watershed sediment loading. This information is entered into the nutrient loading model by a simple percentage of watershed area draining to a pond or a wetland. The Warren Brook watershed is 5% wetland. Cross Pond is located in the western portion of the watershed and it is estimated that this wetland drains 20% of land area within the watershed (not accounting for water drained directly by Warren Brook). Percent of watershed draining to a wetland in the attainment watersheds ranged from15% to 60%, with an average of 35%.

NUTRIENT MODELING RESULTS

The MapShed model simulates surface runoff using daily weather inputs of rainfall and temperature. Erosion and sediment yields are estimated using monthly erosion calculations and land use/soil composition values for each source area. 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 Warren Brook indicate that reductions of nutrients are needed to improve water quality but no reduction in sediment is needed. Below, loading for sediment, nitrogen and phosphorus are discussed individually.

Sediment

Sediment loading in the Warren Brook watershed is primarily attributed to agricultural sources which make up 62% of the total sediment load. Development is a secondary source and accounts for 22% of the total load. Forested land also contributes a significant portion of the load at 17% (Table5, Figure 5). Note that total loads by mass cannot be directly compared between watersheds due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Warren Brook* below for loading estimates that have been normalized by watershed area.

Table 5: Total Sediment Loads by Source

Warren Brook	Sediment (1000kg/year)	Sediment (%)
Source Load		
Hay/Pasture	8.15	30%
Crop land	8.74	32%
Forest	4.57	17%
Wetland	0.04	0%
Disturbed Land	0	0%
Sandy Areas	0.02	0%
Low Density Mixed	0.80	3%
Medium Density Mixed	0	0%
High Density Mixed	5.28	19%
Low Density Residential	0	0%
Medium Density Residential	0	0%
High Density Residential	0	0%
Farm Animals	0	0%
Septic Systems	0	0%
Source Load Total:	**27.60**	**100%**
Pathway Load		
Stream Banks	7.41	-
Subsurface / Groundwater	0	-
Total Watershed Mass Load:	**35.01**	

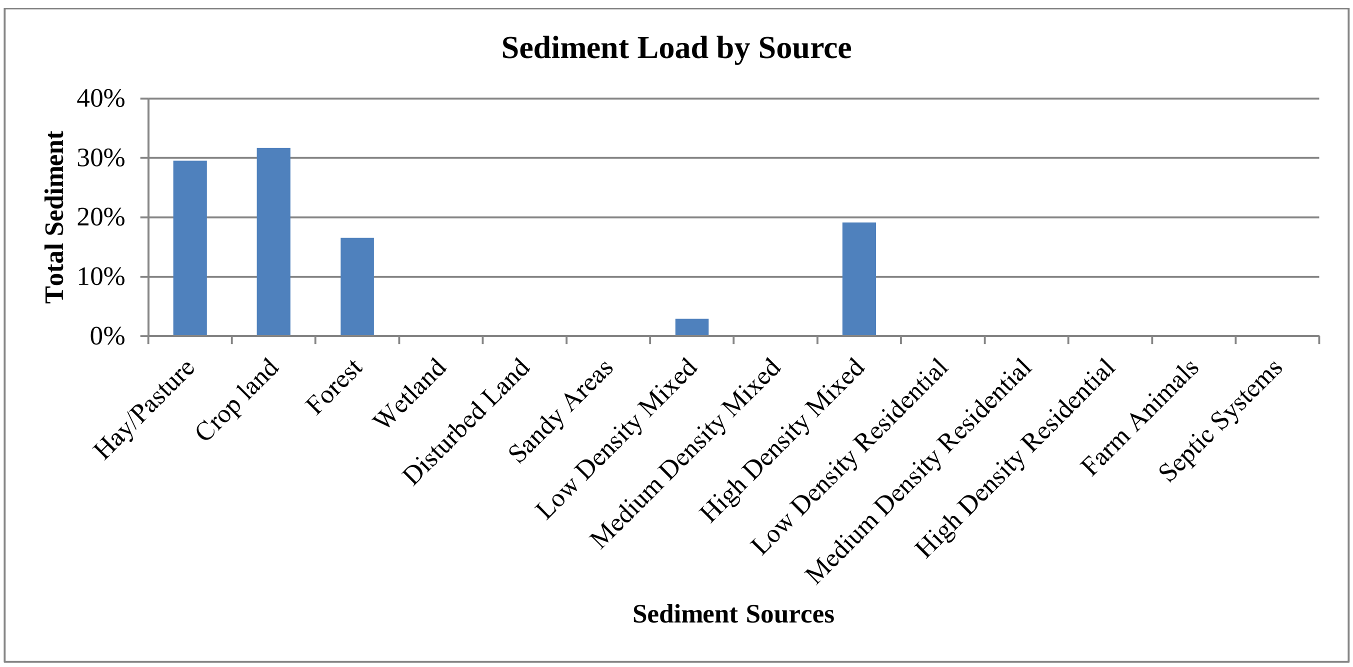


Figure 5: Total Sediment Loads by Source in the Warren Brook Watershed

Total Nitrogen

Nitrogen loading in the Warren Brook watershed is mainly attributed to agricultural sources, with farm animals making up the largest portion of the total load. Combined agricultural sources account for 61% of the nitrogen load. Table 6 and Figure 6 show the estimated total nitrogen load in terms of mass and percent of total by source category. Note that total loads by mass cannot be directly compared between watersheds due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Warren Brook* below for loading estimates that have been normalized by watershed area.

Table 5: Total Nitrogen Loads by Source

Warren Brook	Total N (kg/year)	Total N (%)
Source Load		
Hay/Pasture	295.0	15%
Crop land	290.4	14%
Forest	334.9	17%
Wetland	58.4	3%
Disturbed Land	0	0%
Sandy Areas	0.1	0%
Low Density Mixed	25.2	1%
Medium Density Mixed	0	0%
High Density Mixed	240.5	12%
Low Density Residential	0	0%
Medium Density Residential	0	0%
High Density Residential	0	0%
Farm Animals	641.8	32%
Septic Systems	141.5	7%
Source Load Total:	**2027.7**	**100%**
Pathway Load		
Stream Banks	4.9	-
Subsurface / Groundwater	8443.8	-
Total Watershed Mass Load:	**10476.5**	

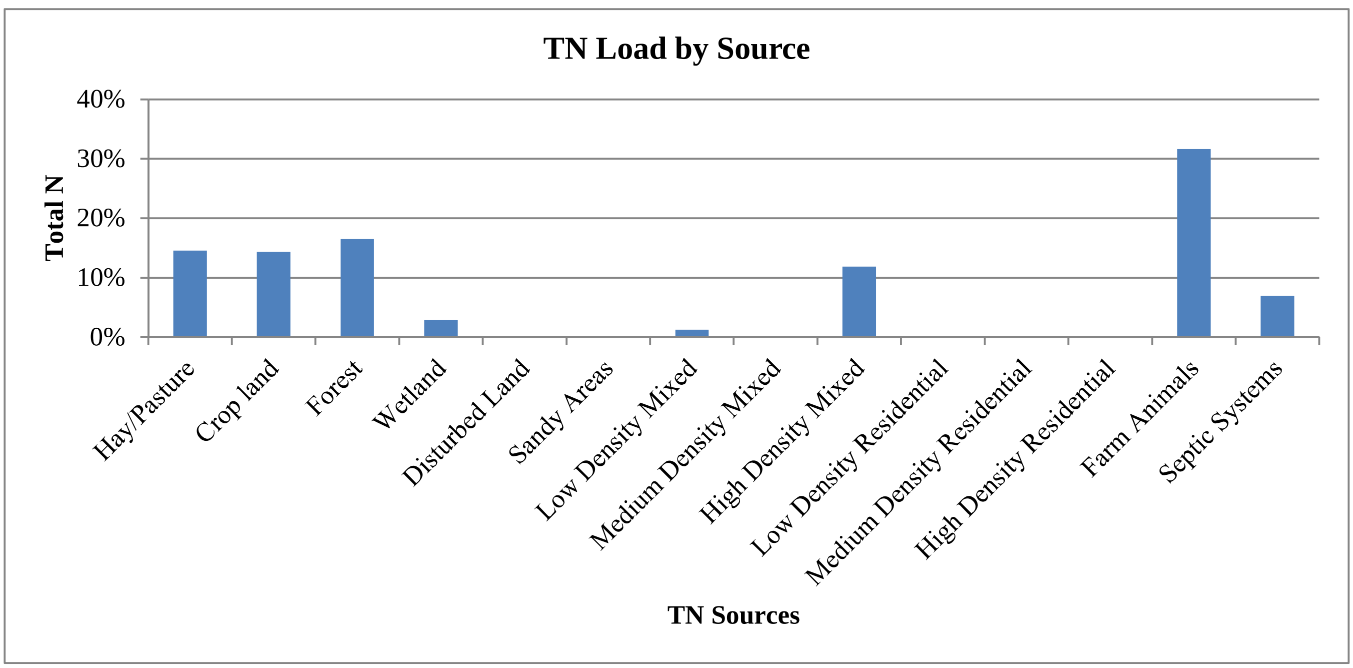


Figure 6: Total Nitrogen Loads by Source in the Warren Brook Watershed

Total Phosphorus

Phosphorus loading in the Warren Brook watershed is mainly attributed to farm animals which contribute 42% of the load. Combined agricultural sources make up 83% of the total phosphorus load. Phosphorus loads are presented in Table 7 and Figure 7. Note that total loads by mass cannot be directly compared between watersheds due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Warren Brook* below for loading estimates that have been normalized by watershed area.

Table 7: Total Phosphorus Loads by Source

Warren Brook	Total P (kg/year)	Total P (%)
Source Load		
Hay/Pasture	91.7	32%
Crop land	26.0	9%
Forest	19.5	7%
Wetland	3.0	1%
Disturbed Land	0	0%
Sandy Areas	0.0	0%
Low Density Mixed	2.8	1%
Medium Density Mixed	0	0%
High Density Mixed	24.4	8%
Low Density Residential	0	0%
Medium Density Residential	0	0%
High Density Residential	0	0%
Farm Animals	121.7	42%
Septic Systems	0.8	0%
Source Load Total:	**289.7**	**100%**
Pathway Load		
Stream Banks	0.9	-
Subsurface / Groundwater	211.1	-
Total Watershed Mass Load:	**501.8**	

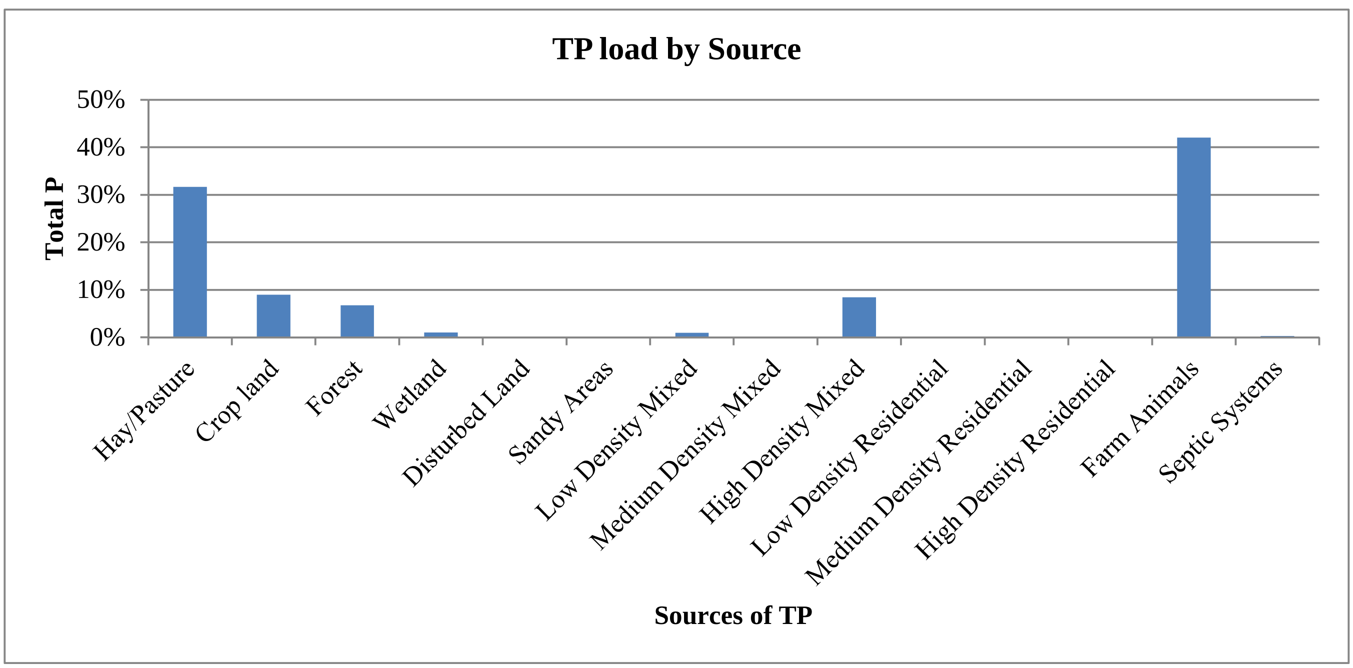


Figure 7: Total Phosphorus Loads by Source in the Warren Brook Watershed

TMDL: TARGET NUTRIENT LEVELS FOR WARREN BROOK

The existing sediment and nutrient loads for the impaired segment of Warren Brook are listed in Table 8, along with the TMDL numeric target 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 sediment and nutrient loads in Warren 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: TMDL Targets Compared to Warren Brook Pollutant Loading

TMDL POLLUTANT LOADS Annual Loads per Unit Area	**Estimated Loads Warren Brook**	**Total Maximum Daily Load Numeric Target**	**TMDL % REDUCTIONS Warren Brook**
Sediment Load *(1000 kg/ha/year)*	**0.022**	**0.030**	**No Reduction Needed**
Nitrogen Load *(kg/ha/year)*	**6.53**	**5.2**	**21%**
Phosphorus Load *(kg/ha/year)*	**0.31**	**0.24**	**22%**

Future Loading

The prescribed reduction in pollutants discussed in this TMDL reflects reduction from estimated existing conditions. Expansion of agricultural and development activities have the potential to increase runoff and associated pollutant loads to the (Impaired stream name). To ensure that the TMDL targets are attained, future agriculture or development activities in the watershed will need to meet the TMDL targets. Future growth from population increases is a moderate threat in the Warren Brook watershed due to an increasing population trends in Waldo County of 5.7% between 2000 and 2008 (USM MSAC, 2009). The growth in agricultural lands is also increasing, with a 2% increase in the total number of farms in Waldo County between 2002 and 2007. However, a decrease of 1% was seen in the land (acres) in farms between 2002 and 2007, and a 4% decrease occurred in the average farm size in this time period as well (USDA, 2007a). 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 Warren Brook. It is recommended that municipal officials, landowners, and conservation stakeholders in Morrill, Belmont and Belfast 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 Warren Brook;
- Address existing nonpoint source problems in the Warren Brook watershed by instituting BMPs where necessary; and
- Prevent future degradation of Warren Brook through the development and/or strengthening of a local Nutrient Management Ordinance.

Table 9: Modeling Results Calculations for Derived Numeric Targets and Reduction Loads for Warren Brook

Warren Brook				
	Area ha	**Sediment 1000kg/yr**	**TN kg/yr**	**TP kg/yr**
Land Uses				
Hay/Pasture	38	8.2	295.0	91.7
Crop land	1129	8.7	290.4	26.0
Forest	80	4.6	334.9	19.5
Wetland	0	0.0	58.4	3.0
Disturbed Land	0	0.0	0.0	0.0
Low Density Mixed	0	0.8	25.2	2.8
High Density Mixed	0	5.3	240.5	24.4
Other Sources				
Farm Animals			641.8	121.7
Septic Systems		0.0	141.5	0.8
Pathway Loads				
Stream Banks		7.4	4.88	1.0
Groundwater			8443.8	211.1
Total Annual Load		35 x 1000 kg	10476 kg	502 kg
Total Area	1605 ha			
Total Maximum Daily Load		**0.022 1000kg/ha/year**	**6.53 kg/ha/year**	**0.31 kg/ha/year**

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