# TMDL Summary



# *Thayer Brook*

## Watershed Description

This **TMDL** applies to a 4.7 mile section of Thayer Brook, located in the town of Gray, Maine. The impaired segment of Thayer Brook begins in the northern portion of the watershed in a predominantly forested area and flows south through two wetlands, then past an agricultural field before crossing West Gray Road (Route 4). The stream continues south through mixed agriculture and forest before crossing Totten Road and converging with the Upper Pleasant River to become Pleasant River. The Thayer Brook watershed covers an area of 5.81 square miles.

- Runoff from development located throughout the southern and eastern portion of the watershed is likely the largest source of **nonpoint source (NPS) pollution** to Thayer Brook.
- The Thayer Brook watershed is predominately non-developed (94.9%). Forested areas (71%) within the watershed absorb and filter pollutants helping protect both water quality in the stream and stream channel stability. Wetlands (8.5%) may also help filter nutrients.
- Non-forested areas within the watershed are predominantly agricultural (6.4%) and developed (12%) and are located throughout the eastern portion of the watershed.
- Developed areas (12%) with impervious surfaces in close proximity to the steam may impact water quality.
- Thayer Brook is on Maine's 303(d) list of Impaired Streams (Maine DEP, 2013).

### *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 is typically transported by rain or snowmelt runoff.*

### *Waterbody Facts*

**Segment ID:** ME0106000103_607R10

**Town:** Gray, ME

**County:** Cumberland

**Impaired Segment Length:** 4.7 miles

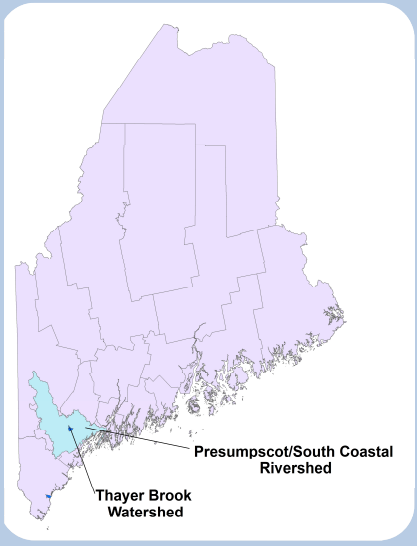
**Classification:** Class B

**Direct Watershed:** 5.81 $mi^2$ (3,718 acres)

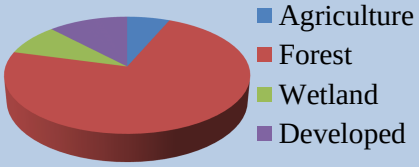
**Impairment Listing Cause:** Dissolved Oxygen

**Watershed Agricultural Land Use:** 6.4%

**Major Drainage Basin:** Presumpscot River




**Watershed Land Uses**



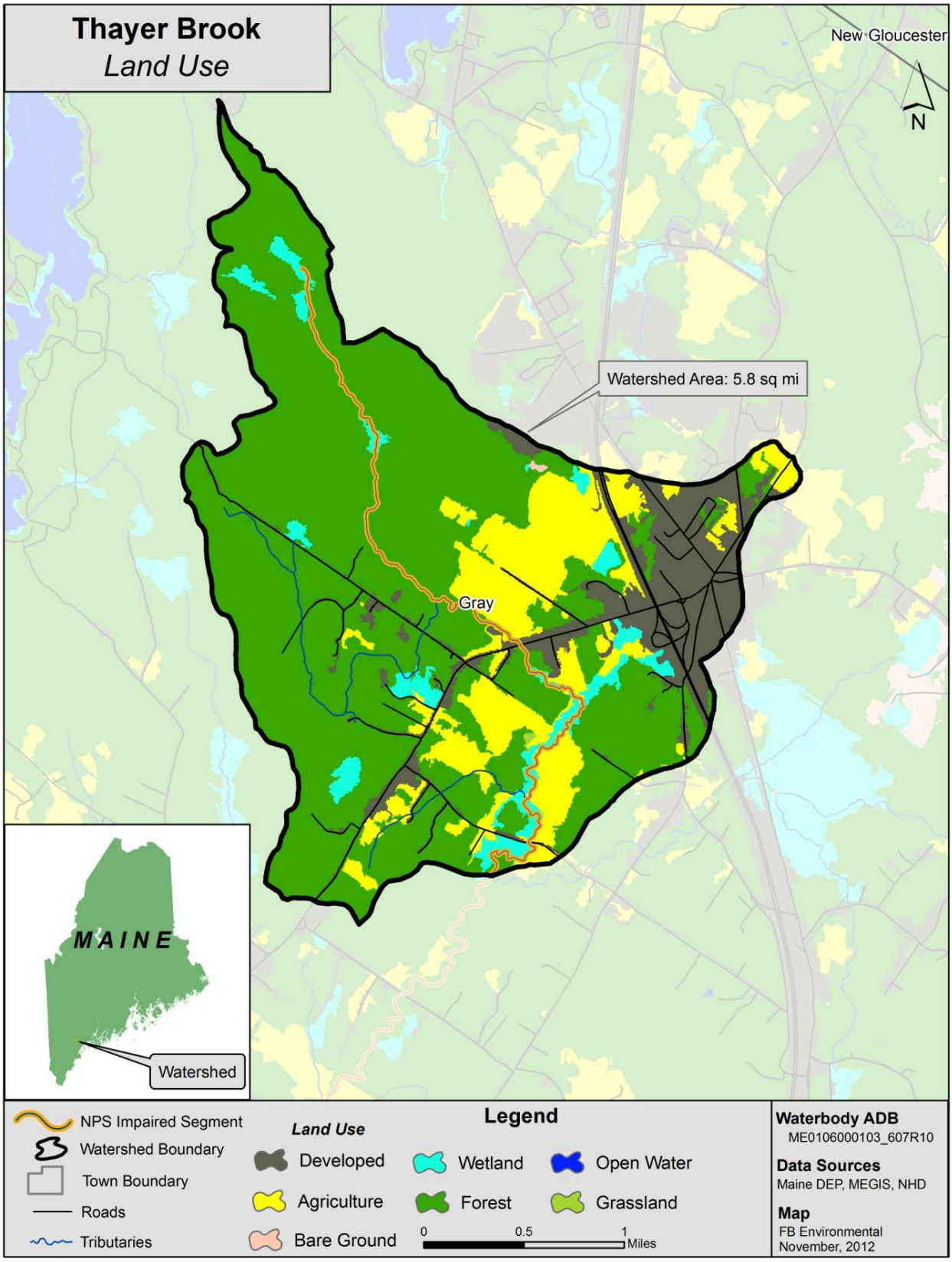



**Figure 1:** Land Use in the Thayer Brook Watershed

## WHY IS A TMDL ASSESSMENT NEEDED?

Thayer 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.

***Thayer Brook** at the habitat assessment reach downstream of Totten Road in Gray.*

Agricultural land area makes up about 6% of in the Thayer Brook watershed. This is less than the area of developed land (12%). Wetlands make up about 9% of the watershed. Less than 1% of Thayer Brook flows through or near agricultural areas, and the watershed is heavily forested making up 71% of the total area (Figure 1). Development, therefore, may be the largest contributor of sediment and nutrient enrichment to the stream. The close proximity of heavily developed lands to the stream further increases the likelihood that nutrients from road runoff and lawns will reach the stream. Wetlands may also play a role in causing naturally low dissolved oxygen levels in Thayer Brook.

## 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 Thayer Brook is based on historic dissolved oxygen 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, Thayer Brook received a score of 168 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.

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 Thayer Brook watershed, the downstream sample station was located at the Totten Road stream crossing. The immediate surrounding riparian zone was dominated by wetland grasses and trees. Water appeared slightly stained within the sample reach, and the stream was embedded.

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

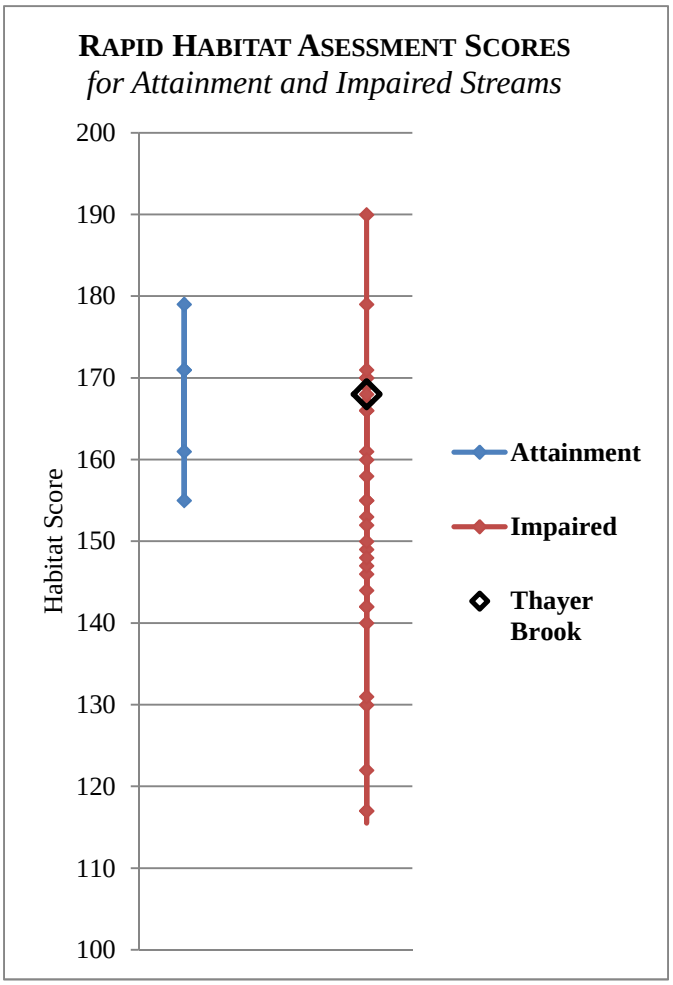



**Figure 2:** Habitat Assessment Scores

### Pollution Source Identification

Pollution source identification assessments were conducted for both Thayer 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 Thayer Brook was completed on July 5, 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 Thayer Brook Watershed

| Potential Source | | | Notes |
|---|---|---|---|
| **ID#** | **Location** | **Type** | |
| **2** | West Gray Road & McConkey Road | Wildlife Sanctuary | • Sign on property indicates this is a state wildlife sanctuary.<br>• Inactive fields, but minimal buffer from Thayer Brook. |
| **4** | Rustic Road | Agriculture | • Potentially active agricultural fields, buffer appears adequate, but may be minimal in some areas. |
| **6** | Totten Road | Agriculture | • Inactive hayfield.<br>• Minimal buffer. |

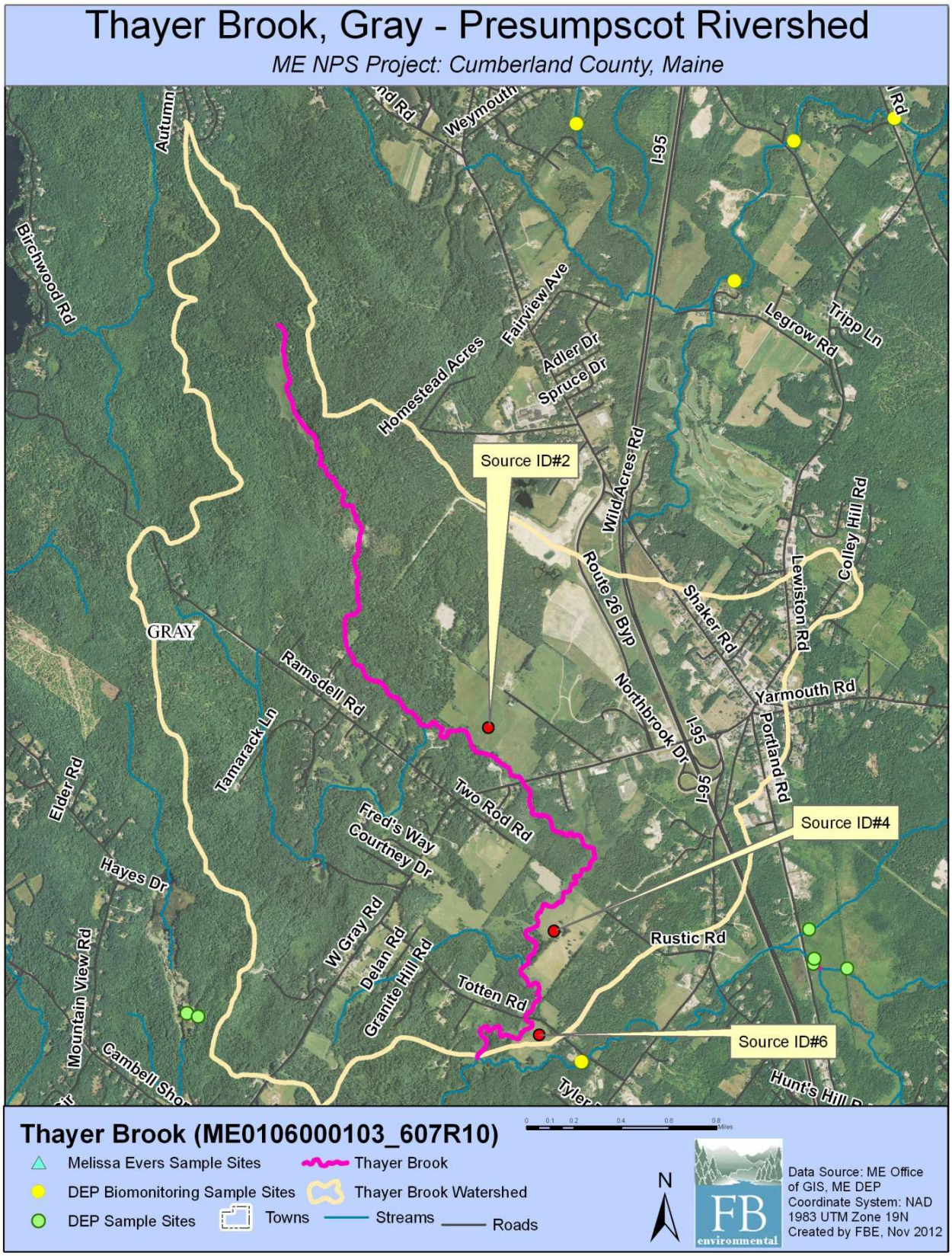



**Figure 3:** Aerial Photo of Source ID Locations in the Thayer Brook Watershed

## NUTRIENT LOADING – MAPSHED ANALYSIS

The MapShed model was used to estimate stream loading of sediment, total phosphorus and total nitrogen in Thayer 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) shows that no livestock (numbers of animals) were found in the watershed, based on direct observations made in the watershed, plus other publicly available data.

The Thayer Brook watershed is predominantly forested, with a small amount of agricultural activity. No livestock was observed within the watershed.

**Table 3:** Livestock Estimates in the Thayer Brook Watershed

| Type | Thayer Brook |
|---|---|
| Dairy Cows | 0 |
| Beef Cows | 0 |
| Broilers | 0 |
| Layers | 0 |
| Hogs/Swine | 0 |
| Sheep | 0 |
| Horses | 0 |
| Turkeys | 0 |
| Other | 0 |
| **Total** | **0** |

### *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.

Thayer Brook is a 4.7 mile-long impaired segment as listed by Maine DEP. As modeled, the total stream miles (including tributaries) within the watershed was calculated as 7.6 miles. Of this total, 0.9 stream miles are located within agricultural areas; of this length, 0.2 miles (22%) show a 75-foot or greater vegetated 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%.

**Table 4:** Summary of Vegetated Buffers in Agricultural Areas

| Thayer Brook |
|---|
| • 7.6 stream miles in watershed (includes ephemeral streams)<br>• 0.9 stream miles in agricultural areas<br>• 22% of agricultural stream miles have a vegetated buffer |

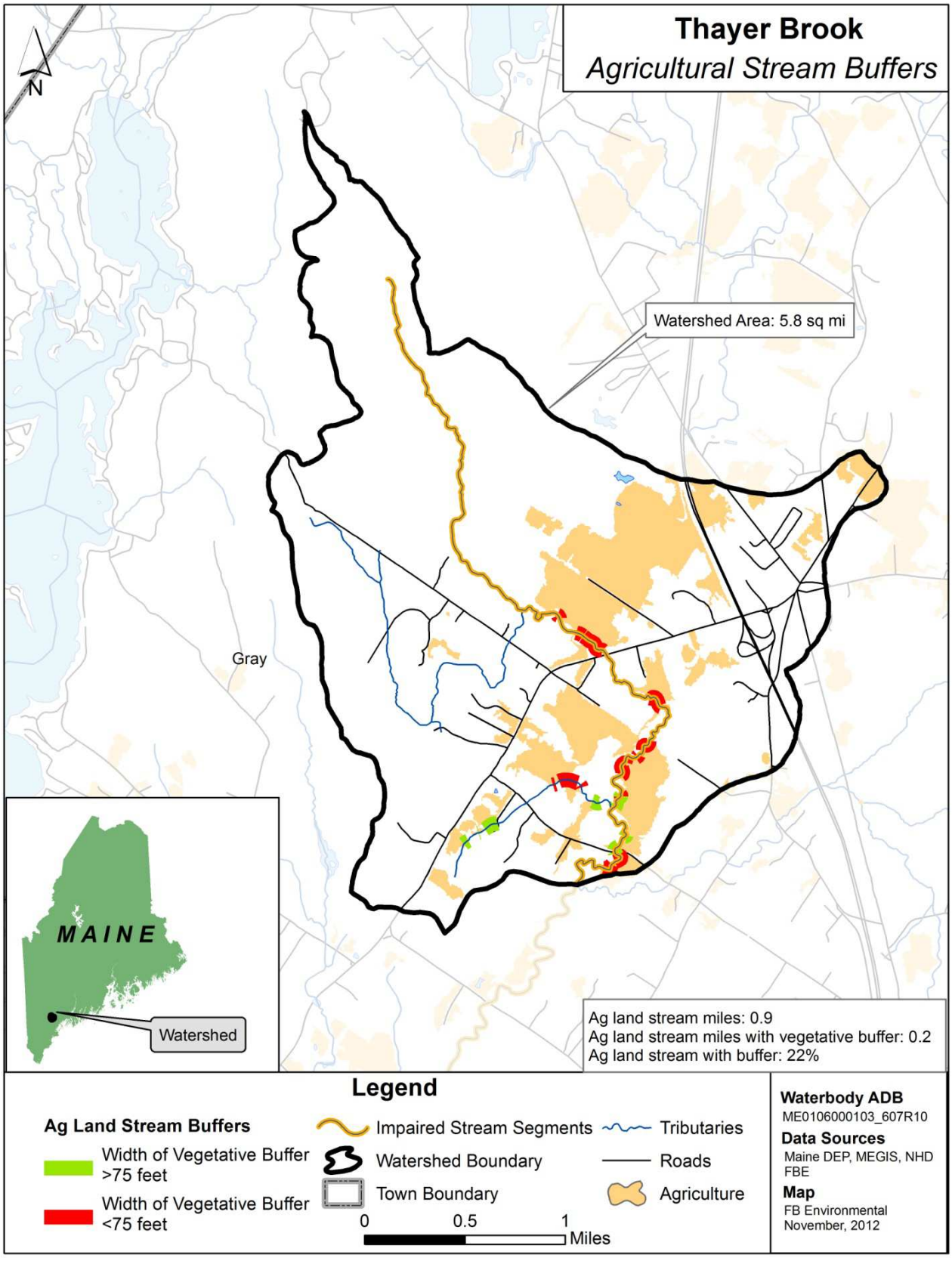



**Figure 4:** Buffered Agricultural Stream miles in the Thayer Brook Watershed

***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 of 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 cropland 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. There are no major wetlands within the Thayer Brook watershed., therefore zero percent of the watershed drains to wetlands. Percent of watershed draining to a wetland in the attainment watersheds ranged from 15% 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 Thayer Brook indicate that significant reductions of sediment and nutrients are needed to improve water quality. Below, loading for sediment, nitrogen and phosphorus are discussed individually.

***Sediment***

Sediment loading in the Thayer Brook watershed is mainly derived from crop land (63%), with combined agricultural sources making up 80% of the sediment load. Development is a secondary source and accounts for 12% of the total load to Thayer Brook (Table 5, Figure 5). Total loads by mass cannot be directly compared between watersheds due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Thayer Brook* (below) for loading estimates that have been normalized by watershed area.

**Table 5:** Total Sediment Loads by Source

| **Thayer Brook** | **Sediment (1000kg/year)** | **Sediment (%)** |
|---|---|---|
| **Source Load** | | |
| *Hay/Pasture* | 15.83 | 17% |
| *Crop land* | 59.80 | 63% |
| *Forest* | 7.47 | 8% |
| *Wetland* | 0.16 | 0% |
| *Disturbed Land* | 0 | 0% |
| *Low Density Mixed* | 5.61 | 6% |
| *Medium Density Mixed* | 0 | 0% |
| *High Density Mixed* | 5.55 | 6% |
| *Low Density Residential* | 0.04 | 0% |
| *Medium Density Residential* | 0 | 0% |
| *High Density Residential* | 0 | 0% |
| *Farm Animals* | 0 | 0% |
| *Septic Systems* | 0 | 0% |
| ***Source Load Total:*** | **94.46** | **100%** |
| | | |
| **Pathway Load** | | |
| *Stream Banks* | 17.32 | - |
| *Subsurface / Groundwater* | 0 | - |
| | | |
| ***Total Watershed Mass Load:*** | **111.78** | |

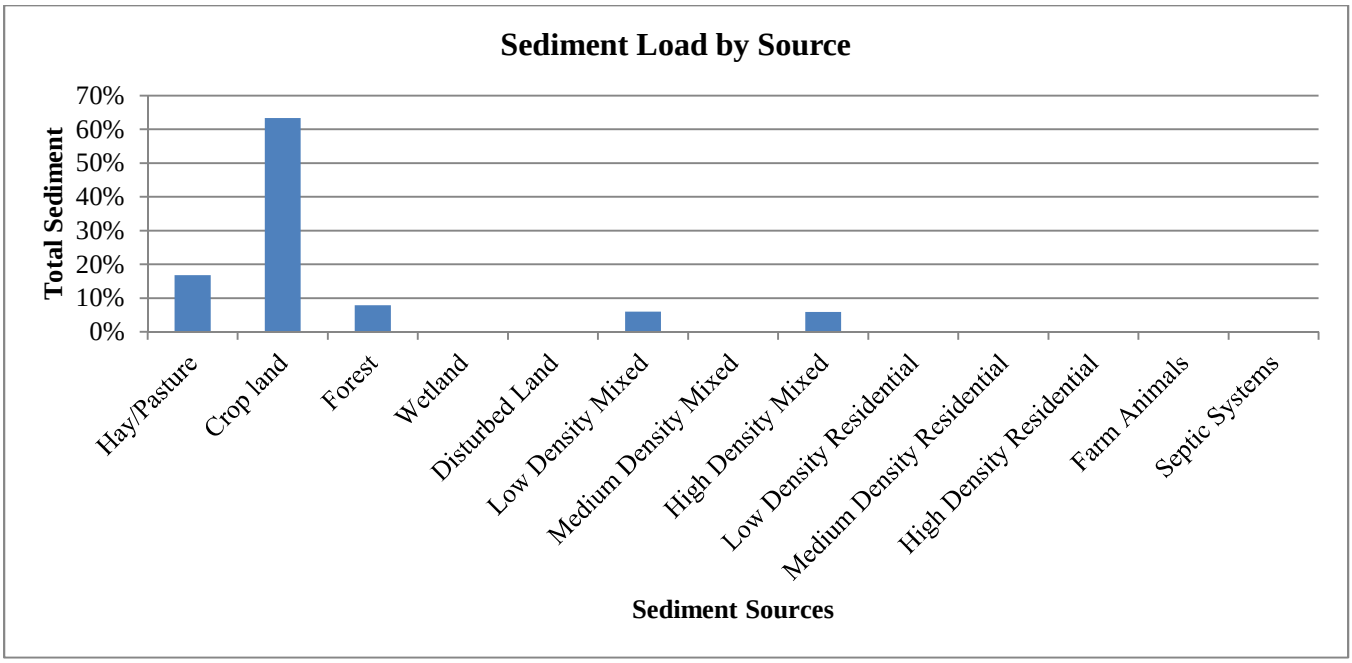



**Figure 4:** Total Sediment Loads by Source in the Thayer Brook Watershed

***Total Nitrogen***

Nitrogen loading is attributed to agricultural sources, with crop land and hay/pasture making up 55% of the total load in Thayer Brook. Forested lands are a secondary source and account for 20% of the sediment load. Table 6 and Figure 6 (below) display the estimated total nitrogen load in terms of mass and percent of total by source in Thayer Brook. Total loads by mass cannot be directly compared between watersheds due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Thayer Brook* (below) for loading estimates that have been normalized by watershed area.

**Table 6:** Total Nitrogen Loads by Source

| **Thayer Brook** | **Total N (kg/year)** | **Total N (%)** |
|---|---|---|
| **Source Load** | | |
| *Hay/Pasture* | 346.1 | 15% |
| *Crop land* | 931.8 | 40% |
| *Forest* | 453.8 | 20% |
| *Wetland* | 75.9 | 3% |
| *Disturbed Land* | 0 | 0% |
| *Low Density Mixed* | 147.4 | 6% |
| *Medium Density Mixed* | 0 | 0% |
| *High Density Mixed* | 215.2 | 9% |
| *Low Density Residential* | 1.0 | 0% |
| *Medium Density Residential* | 0 | 0% |
| *High Density Residential* | 0 | 0% |
| *Farm Animals* | 0 | 0% |
| *Septic Systems* | 151.3 | 7% |
| ***Source Load Total:*** | **2322.5** | **100%** |
| | | |
| **Pathway Load** | | |
| *Stream Banks* | 9.0 | - |
| *Subsurface / Groundwater* | 9645.9 | - |
| | | |
| ***Total Watershed Mass Load:*** | **11977.4** | |

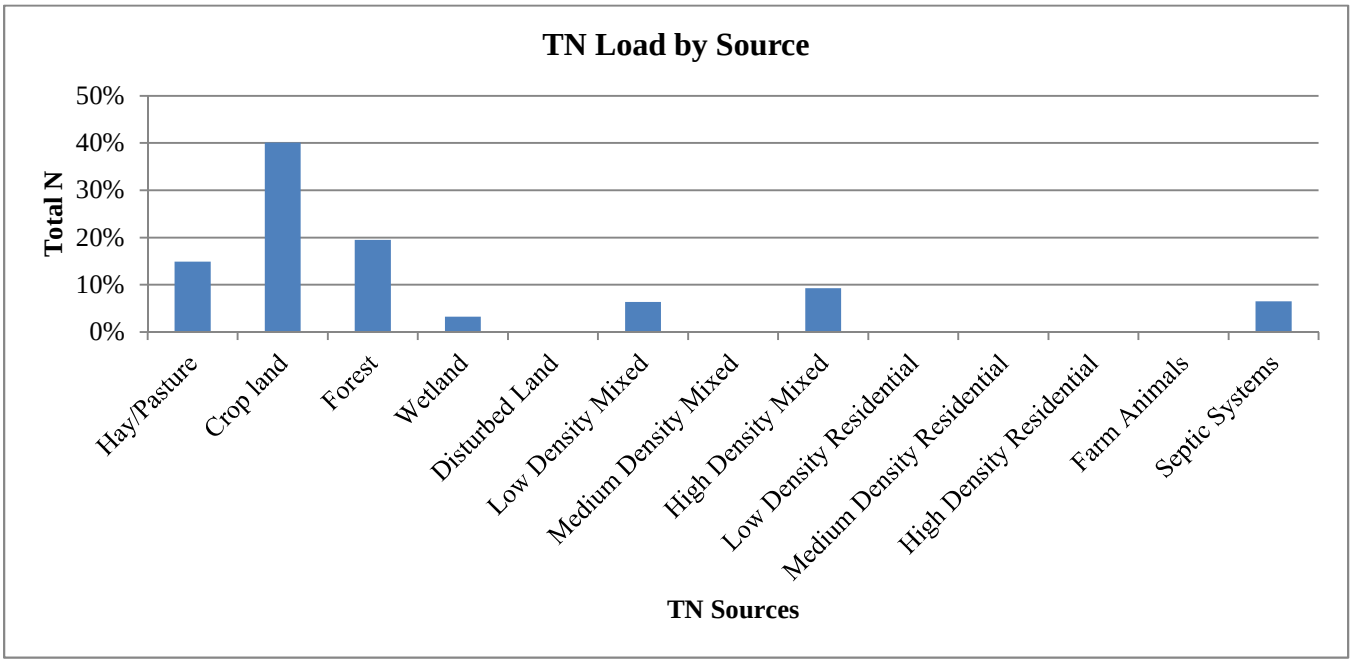



**Figure 5:** Total Nitrogen Loads by Source in the Thayer Brook Watershed

### *Total Phosphorus*

Phosphorus loading in the Thayer Brook watershed is attributed primarily to agricultural sources, with crop land and hay/pasture making up 76% of the total load to. Developed land only accounts for 12% of the 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 Thayer Brook* below for loading estimates that have been normalized by watershed area.

**Table 7:** Total Phosphorus Loads by Source

| **Thayer Brook** | **Total P (kg/year)** | **Total P (%)** |
|---|---|---|
| **Source Load** | | |
| *Hay/Pasture* | 130.7 | 40% |
| *Crop land* | 119.0 | 36% |
| *Forest* | 28.6 | 9% |
| *Wetland* | 4.1 | 1% |
| *Disturbed Land* | 0 | 0% |
| *Low Density Mixed* | 16.8 | 5% |
| *Medium Density Mixed* | 0 | 0% |
| *High Density Mixed* | 22.6 | 7% |
| *Low Density Residential* | 0.1 | 0% |
| *Medium Density Residential* | 0 | 0% |
| *High Density Residential* | 0 | 0% |
| *Farm Animals* | 0 | 0% |
| *Septic Systems* | 5.0 | 2% |
| ***Source Load Total:*** | **326.9** | **100%** |
| | | |
| **Pathway Load** | | |
| *Stream Banks* | 3.0 | - |
| *Subsurface / Groundwater* | 224.9 | - |
| | | |
| ***Total Watershed Mass Load:*** | **554.8** | |

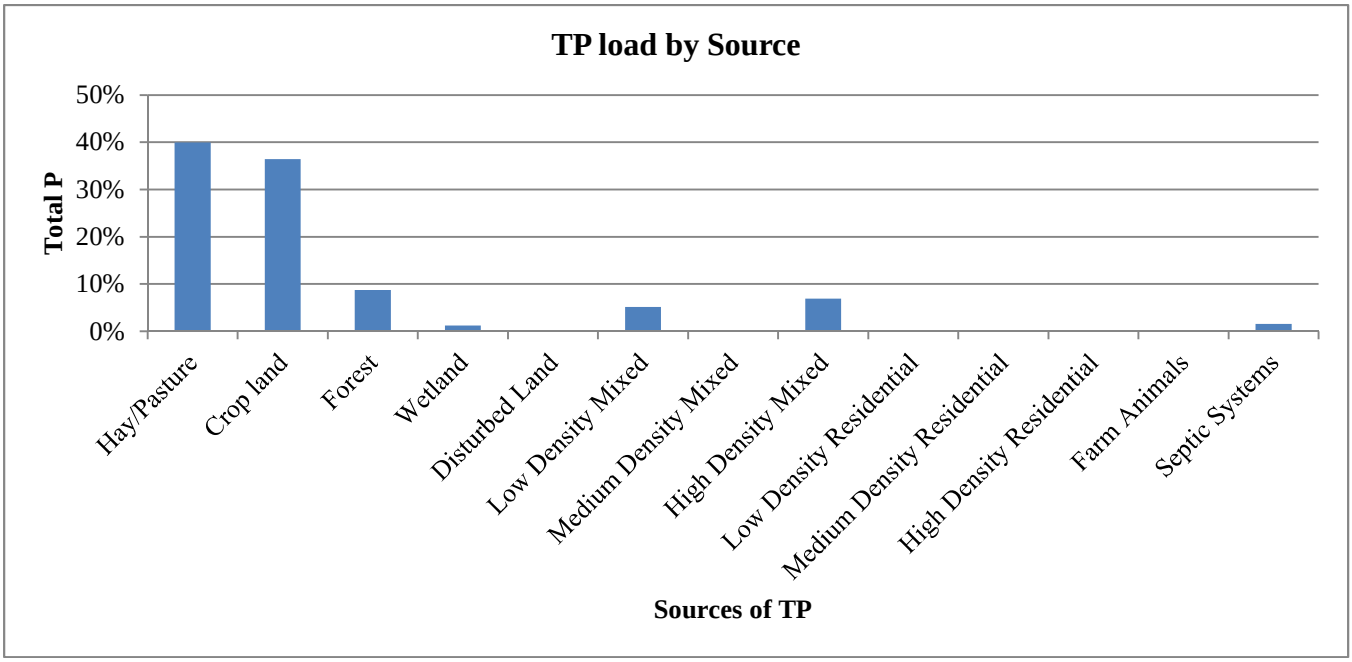



**Figure 7:** Total Phosphorus Loads by Source in the Thayer Brook Watershed

## TMDL: TARGET NUTRIENT LEVELS FOR THAYER BROOK

The existing sediment and nutrient loads for the impaired segment of Thayer 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 Thayer 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 Thayer Brook Pollutant Loading

| **TMDL POLLUTANT LOADS** Annual Loads per Unit Area | **Estimated Loads Thayer Brook** | **Total Maximum Daily Load Numeric Target** | **TMDL % REDUCTIONS Thayer Brook** |
|---|---|---|---|
| ***Sediment Load*** *(1000 kg/ha/year)* | **0.074** | **0.030** | **59%** |
| ***Nitrogen Load*** *(kg/ha/year)* | **7.94** | **5.2** | **35%** |
| ***Phosphorus Load*** *(kg/ha/year)* | **0.37** | **0.24** | **34%** |

### 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 Thayer Brook. 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 Thayer Brook watershed because Cumberland County has increasing population trends, with a 3.9% increase between 2000 and 2008 (USM MSAC, 2009). The growth in agricultural lands is also increasing, with a 6% increase in the total number of farms in Cumberland County between 2002 and 2007. However, a decrease of 5% was seen in the land (acres) in farms between 2002 and 2008, and a 10% 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 BMPs can reduce sources of polluted runoff in Thayer Brook. It is recommended that municipal officials, landowners, and conservation stakeholders in 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 Thayer Brook;
- Address existing nonpoint source problems in the Thayer Brook watershed by instituting BMPs where necessary; and
- Prevent future degradation of Thayer Brook through the development and/or strengthening of a local Nutrient Management Ordinance.

**Table 8:** Modeling Results Calculations for Derived Numeric Targets and Reduction Loads for Thayer Brook

| **Thayer Brook** | | | | |
|---|---|---|---|---|
| | **Area ha** | **Sediment 1000kg/yr** | **TN kg/yr** | **TP kg/yr** |
| **Land Uses** | | | | |
| *Hay/Pasture* | 153 | 15.8 | 346.1 | 130.7 |
| *Crop land* | 73 | 59.8 | 931.8 | 119.0 |
| *Forest* | 1023 | 7.5 | 453.8 | 28.6 |
| *Wetland* | 66 | 0.2 | 76.0 | 4.1 |
| *Disturbed Land* | 0 | 0.0 | 0.0 | 0.0 |
| *Low Density Mixed* | 150 | 5.6 | 147.4 | 16.8 |
| *High Density Mixed* | 42 | 5.6 | 215.2 | 22.6 |
| *Low Density Residential* | 1 | 0.0 | 1.0 | 0.1 |
| **Other Sources** | | | | |
| *Farm Animals* | | | 0.0 | 0.0 |
| *Septic Systems* | | | 151.3 | 5.0 |
| **Pathway Loads** | | | | |
| *Stream Banks* | | 17.3 | 9.0 | 31.0 |
| *Groundwater* | | | 9645.9 | 224.9 |
| Total Annual Load | | 112 x 1000 kg | 11977 kg | 555 kg |
| Total Area | 1508 ha | | | |
| **Total Maximum Daily Load** | | **0.074 1000kg/ha/year** | **7.94 kg/ha/year** | **0.37 kg/ha/year** |

**REFERENCES**

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Conservation Tillage Information Center (CTIC). 2000. Crop Residue Management Survey. National Association of Conservation Districts. Retrieved from: http://www.ctic.purdue.edu

Davies, S. P., and L. Tsomides. 2002. Methods for Biological Sampling of Maine's Rivers and Streams. DEP LW0387-B2002, Maine Department of Environmental Protection, Augusta, ME.

Evans, B.M., & K.J. Corradini. 2012. MapShed Version 1.0 Users Guide. Penn State Institute of Energy and the Environment. Retrieved from: http://www.mapshed.psu.edu/Downloads/MapShedManual.pdf

Lichtenberg, E. 1996. Using Soil and Water Conservation Practices to Reduce Bay Nutrients: How has Agriculture Done? Economic Viewpoints. Maryland Cooperative Extension Service, University of Maryland at College Park and University of Maryland Eastern Shore, Department of Agricultural and Resource Economics, 1(2).

Maine Department of Environmental Protection (Maine DEP). 2013. Draft 2012 Integrated Water Quality Monitoring and Assessment Report. Bureau of Land and Water Quality, Augusta, ME.

Rothwell, N. 2005. Grazing Management in Canada. Farm Environmental Management in Canada. http://publications.gc.ca/Collection/Statcan/21-021-M/21-021-MIE2005001.pdf.

University of Southern Maine Muskie School of Public Service, Maine Statistical Analysis Center (USM MSAC). December, 2009. Retrieved from: http://muskie.usm.maine.edu/justiceresearch/Publications/County/Cumberland.pdf

United States Department of Agriculture (USDA). 2007a. 2007 Census of Agriculture: Cumberland County, Maine. Retrieved from: http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/County_Profiles/Maine/cp23005.pdf

United States Department of Agriculture (USDA). 2007b. 2007 Census of Agriculture: State and County Reports. National Agricultural Statistics Service. Retrieved from: http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_1_State_Level/Maine/st23_1_008_008.pdf

Wright, T., C. Swann, K. Cappiella, and T. Schueler. 2005. Unified Subwatershed and Site Reconnaissance: A User's Manual. Center for Watershed Protection. Ellicott City, MD.