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 mixed 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.

- 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 cultivated lands, active hay lands, and pasture can transport nitrogen and phosphorus to the nearest section of the stream.
- The Inkhorn Brook watershed is predominately non-developed (92%). Forested areas (66.9%) within the watershed absorb and filter pollutants helping protect both water quality in the stream and stream channel stability. Wetlands (1.54%) may also help filter nutrients.
- Non-forested areas within the watershed are predominantly agricultural (23.6%) and are located throughout the central portion of the watershed.
- Developed areas (8%) with impervious surfaces in close proximity to the steam may impact water quality.
- Inkhorn Brook is on Maine's 303(d) list of Impaired Streams (Maine DEP, 2012).

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

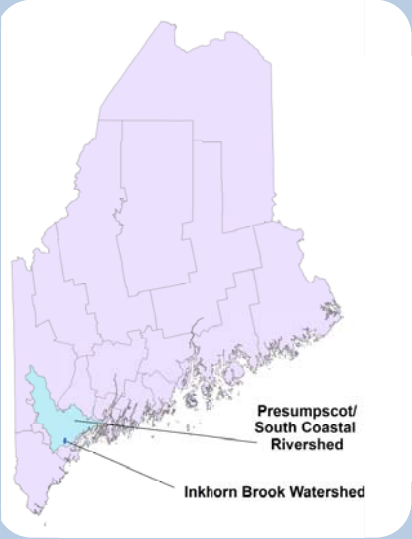
Classification: Class B

Direct Watershed: 3.85 mi^2 (2,464 acres)

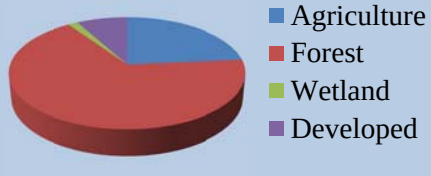
Impairment Listing Cause: Dissolved Oxygen

Watershed Agricultural Land Use: 23.56%

Major Drainage Basin: Presumpscot River



Watershed Land Uses



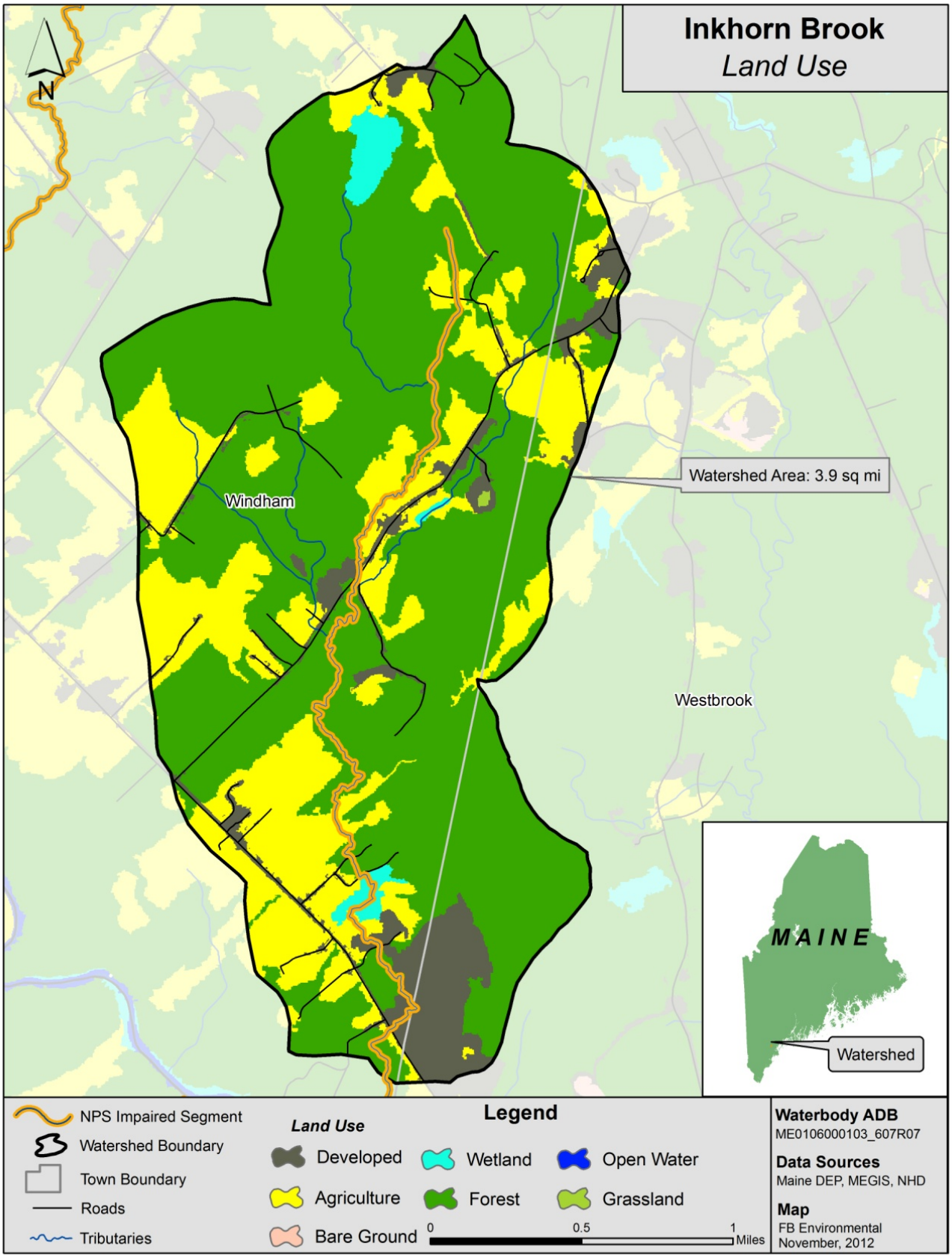


Figure 1: Land Use in the Inkhorn Brook Watershed

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 makes up about 24% of total watershed land area. This is almost three times the area of developed land at 4% of the land area. 22% 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 called Sinclair Research Center 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). 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 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, nutrient 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 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, Inkhorn Brook received a score of 148 out of a total 200 for quality of habitat. Higher scores indicate better habitat.

Chinese Mystery Snails found at the sample site RIK05
Photo: FB Environmental

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 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 clearly 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.

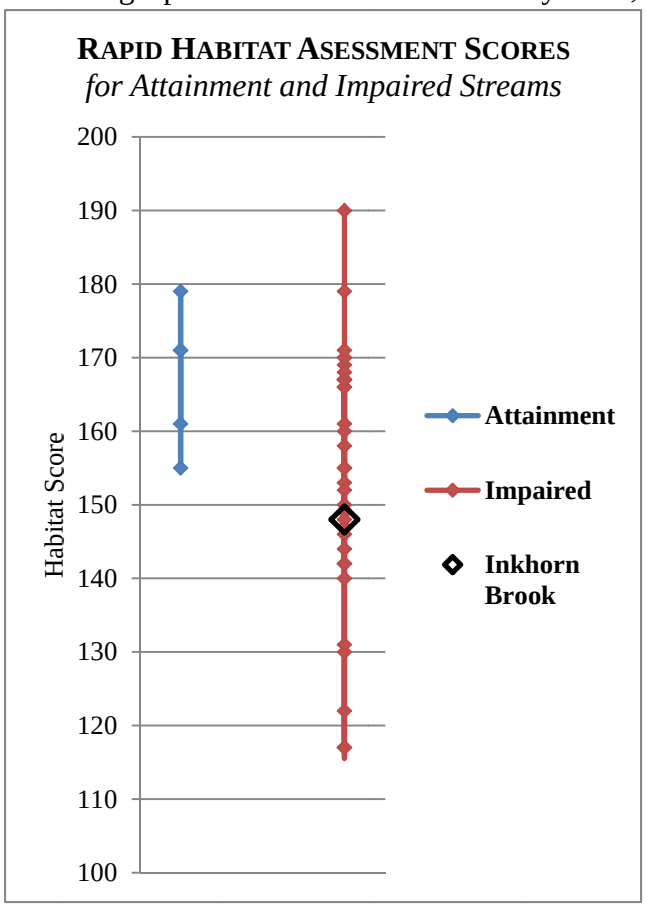


Figure 2: Habitat Assessment Scores

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 on July 11, 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 Inkhorn Brook Watershed

Potential Source			Notes
ID #	**Location**	**Type**	
1	River Road	Road Crossing	• Sample reach location. • Invasive Mystery 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 (dirt). • 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). • An estimated 150 animals located here; Many Manure piles. • Impounded tributary to east of property; Inkhorn Brook to the west.
10	Highland Cliff Rd.	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.

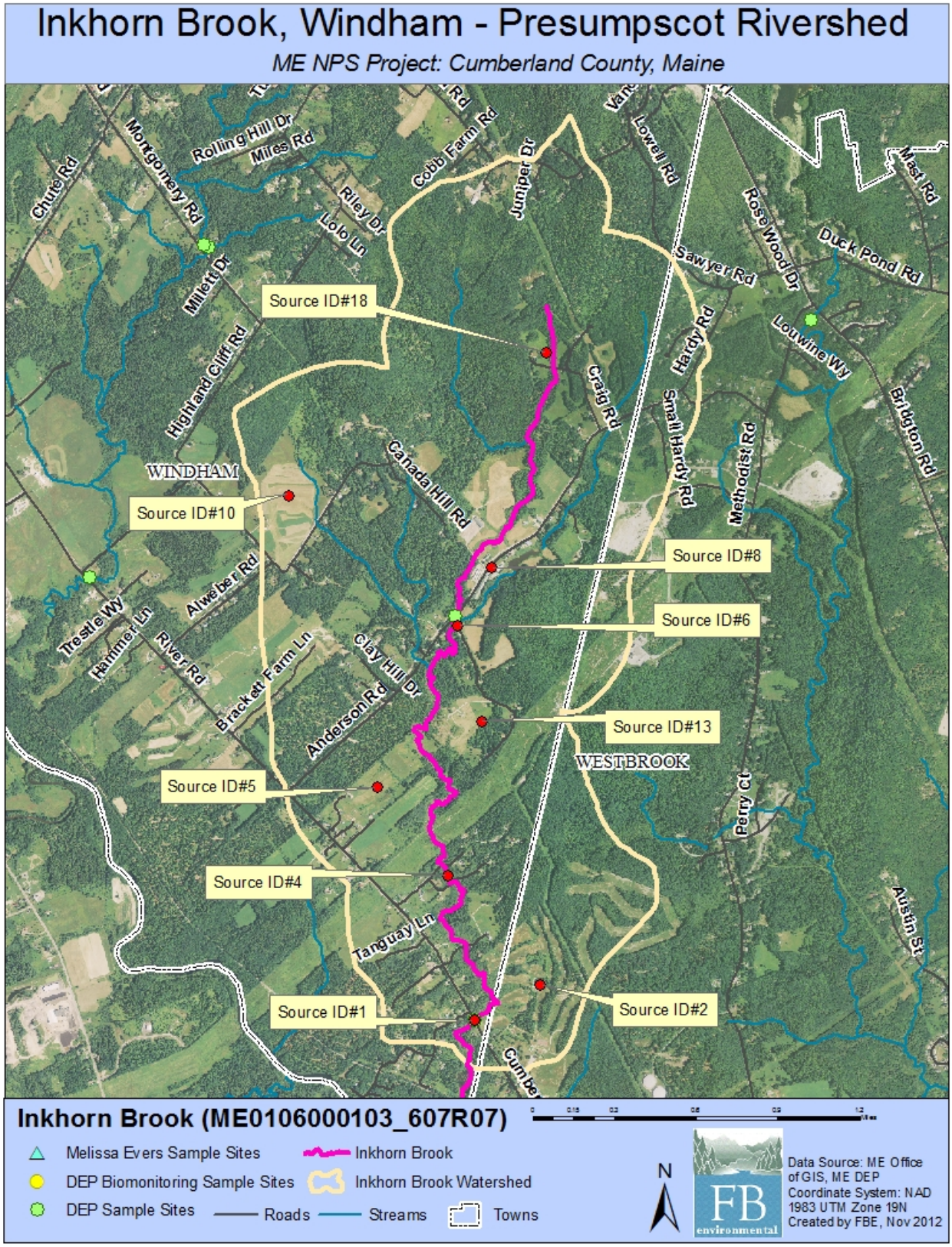


Figure 3: Aerial Photo of Source ID locations in the Inkhorn Brook Watershed

NUTRIENT LOADING – MAPSHED ANALYSIS

The MapShed model was used to estimate stream loading of sediment, total nitrogen and total phosphorus in Inkhorn 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 section 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.

Table 3: Livestock Estimates in the Inkhorn Brook Watershed

Type	Inkhorn Brook
Dairy Cows	
Beef Cows	
Broilers	
Layers	
Hogs/Swine	150
Sheep	20
Horses	
Turkeys	
Other	
Total	**170**

The Inkhorn Brook watershed is predominantly forested, although also has significant agricultural land use 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 observed at a miniature swine breeding facility on Anderson Road, very close to both Inkhorn Brook and an impounded tributary on the east side of the facility. No pigs were observed, and 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. A strong manure smell was noted. The tributary impoundment behind this facility is visible in an aerial photograph (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 & 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

Inkhorn Brook
• 6.3 stream miles in watershed (includes ephemeral streams) • 1.2 stream miles in agricultural areas • **42%** of agricultural stream miles have a vegetated buffer

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 or 42% of the stream shows 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%.

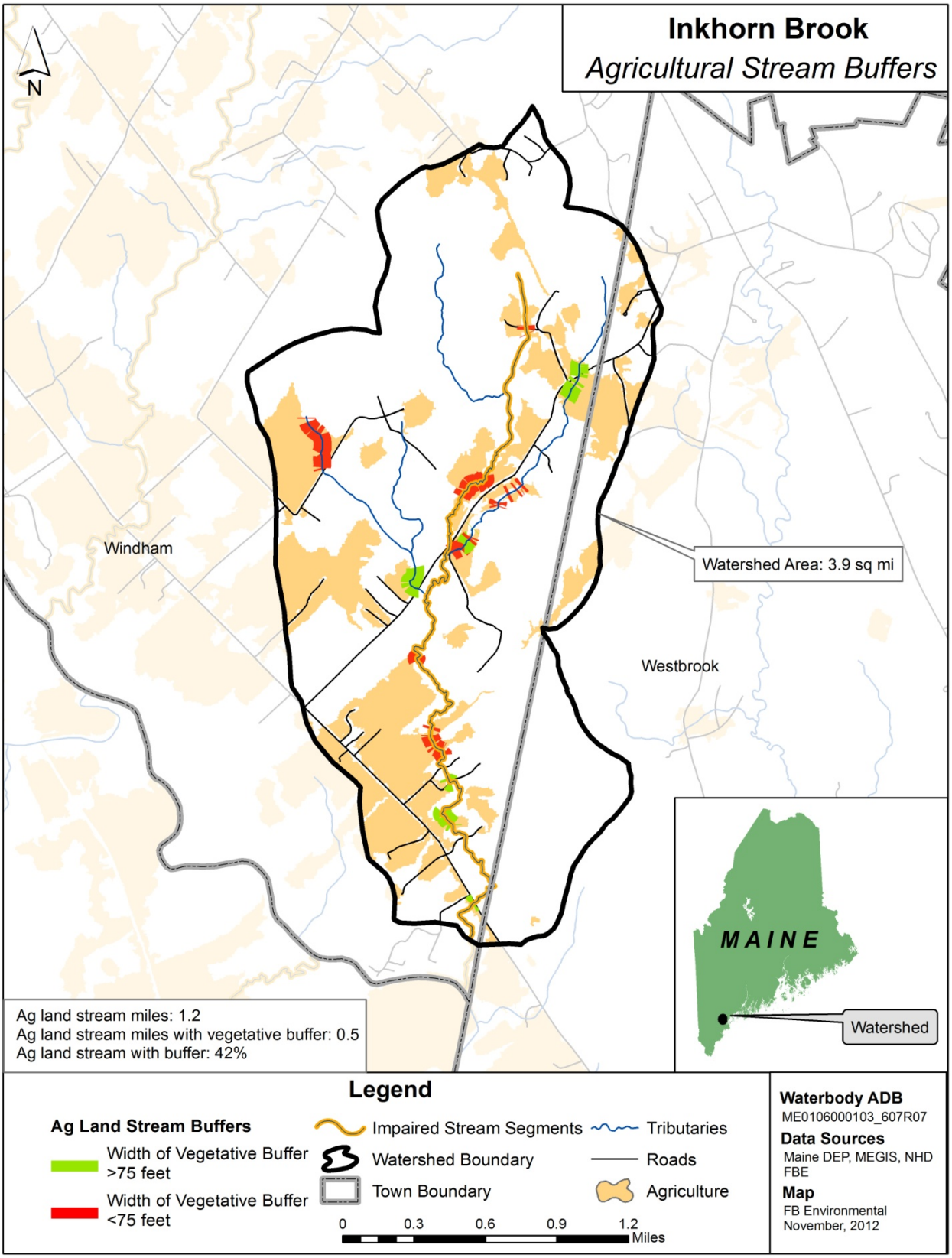


Figure 4: Buffered Agricultural Stream Miles in the Inkhorn Brook Watershed

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 Inkhorn 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 Inkhorn Brook indicate significant reductions of nutrients and sediment are needed to improve water quality. Below, loading for sediment, nitrogen and phosphorus are discussed individually.

Sediment

Sediment loading in the Inkhorn Brook watershed is mainly derived from crop land with combined agricultural sources accounting for 87% of the total sediment load. Forested lands also contribute a significant portion of the load at 17%. Table 5 and Figure 5 (below) display the total sediment load and sources. Total loads by mass cannot be directly compared between watersheds due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Inkhorn Brook* (below) for loading estimates that have been normalized by watershed area.

Table 5: Total Sediment Load by Source

Inkhorn Brook	Sediment (1000kg/year)	Sediment (%)
Source Load		
Hay/Pasture	11.45	13%
Crop land	58.05	64%
Forest	15.48	17%
Wetland	0.07	0%
Disturbed Land	0	0%
Low Density Mixed	2.05	2%
Medium Density Mixed	0	0%
High Density Mixed	3.17	4%
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:	**90.27**	**100%**
Pathway Load		
Stream Banks	8.46	-
Subsurface / Groundwater	0	-
Total Watershed Mass Load:	**98.73**	

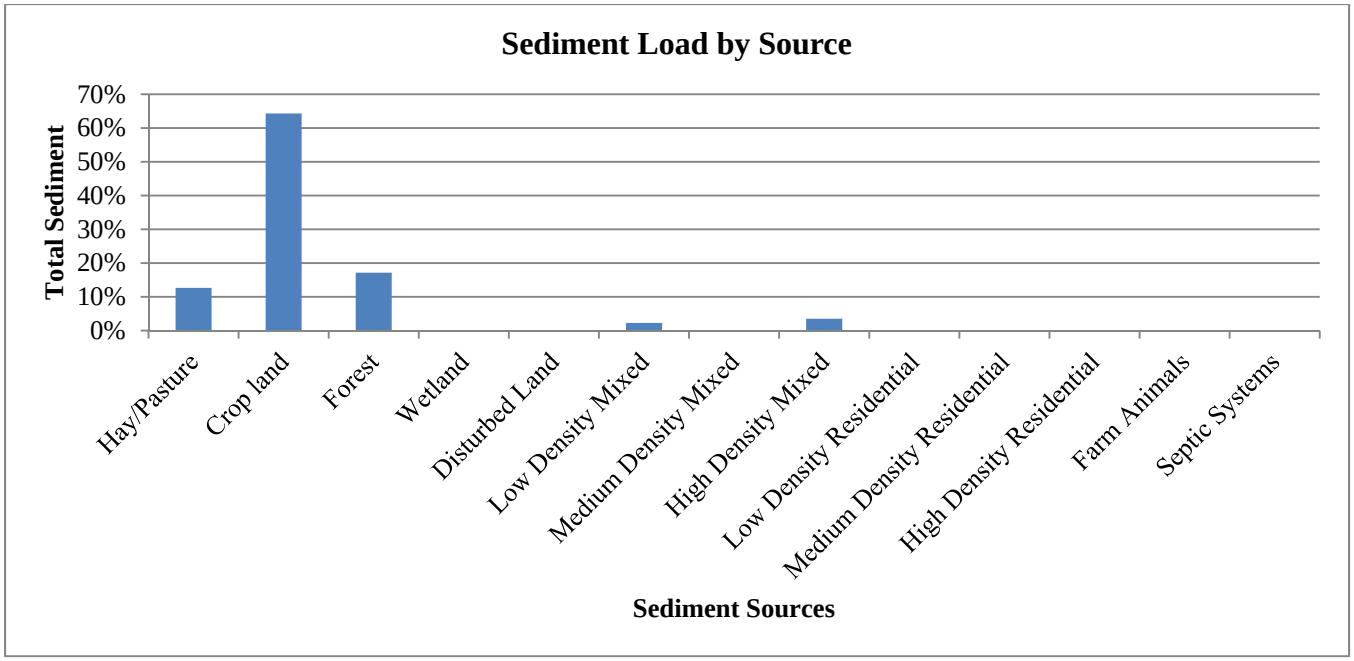


Figure 5: Total Sediment Loads by Source in the Inkhorn Brook Watershed

Total Nitrogen

Nitrogen loading is attributed to septic systems (31%) and agriculture, with combined agricultural sources accounting for 46% of the total nitrogen load. Table 6 and Figure 6 (below) show estimated total nitrogen loads in terms of mass and percent of total, and by source, in Inkhorn Brook. Total loads by mass cannot be directly compared between watersheds due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Inkhorn Brook* (below) for loading estimates that have been normalized by watershed area.

Table 6: Total Nitrogen Loads by Source

Inkhorn Brook	Total N (kg/year)	Total N (%)
Source Load		
Hay/Pasture	371.2	13%
Crop land	804.0	28%
Forest	451.1	16%
Wetland	17.3	1%
Disturbed Land	0	0%
Low Density Mixed	54.1	2%
Medium Density Mixed	0	0%
High Density Mixed	123.0	4%
Low Density Residential	0	0%
Medium Density Residential	0	0%
High Density Residential	0	0%
Farm Animals	153.3	5%
Septic Systems	901.5	31%
Source Load Total:	**2875.4**	**100%**
Pathway Load		
Stream Banks	4.0	-
Subsurface / Groundwater	5387.7	-
Total Watershed Mass Load:	**8267.1**	

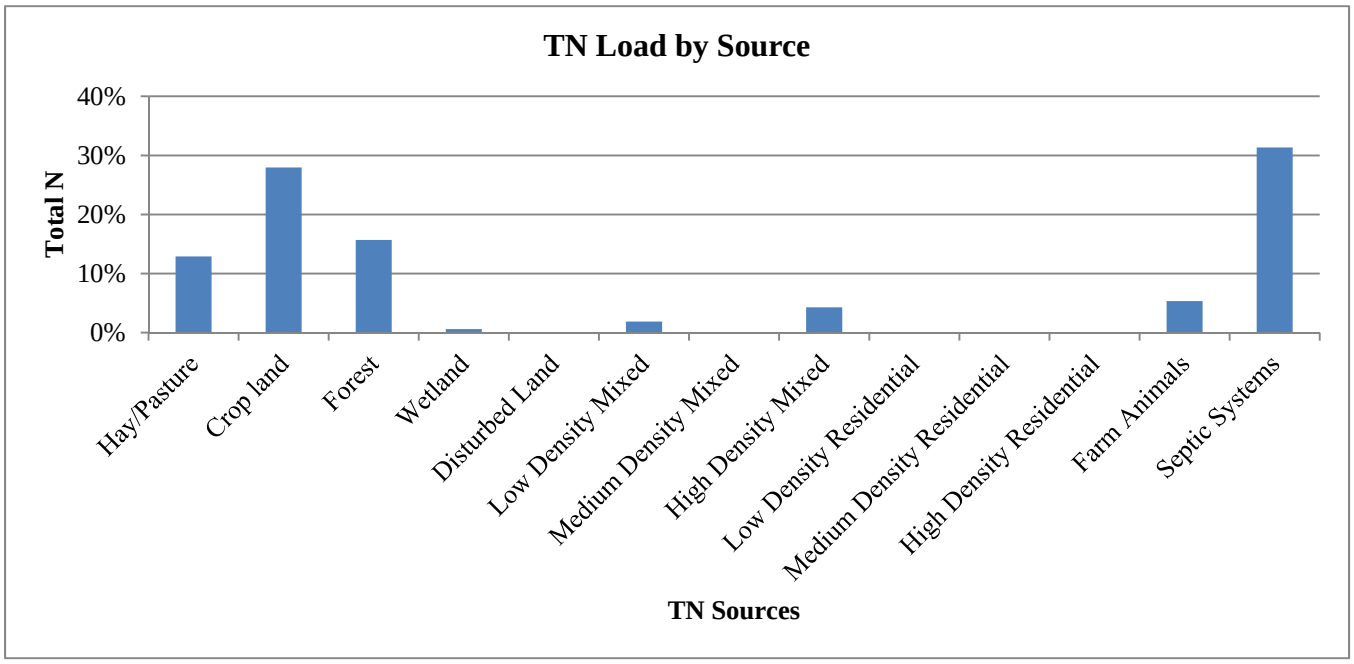


Figure 6: Total Nitrogen Loads by Source in the Inkhorn Brook Watershed

Total Phosphorus

Phosphorus loading within the watershed is attributed primarily to hay/pasture and crop lands, with combined agricultural sources accounting for 81% of the total load. Phosphorus loads are presented in Table 7 and Figure 7. Total loads by mass cannot be directly compared between watersheds due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Inkhorn Brook* (below) for loading estimates that have been normalized by watershed area.

Table 7: Total Phosphorus Loads by Source

Inkhorn Brook	**Total P (kg/year)**	**Total P (%)**
Source Load		
Hay/Pasture	145.6	37%
Crop land	112.5	29%
Forest	34.0	9%
Wetland	1.0	0%
Disturbed Land	0	0%
Low Density Mixed	6.2	2%
Medium Density Mixed	0	0%
High Density Mixed	12.9	3%
Low Density Residential	0	0%
Medium Density Residential	0	0%
High Density Residential	0	0%
Farm Animals	57.4	15%
Septic Systems	20.2	5%
Source Load Total:	**389.7**	**100%**
Pathway Load		
Stream Banks	2.0	-
Subsurface / Groundwater	127.8	-

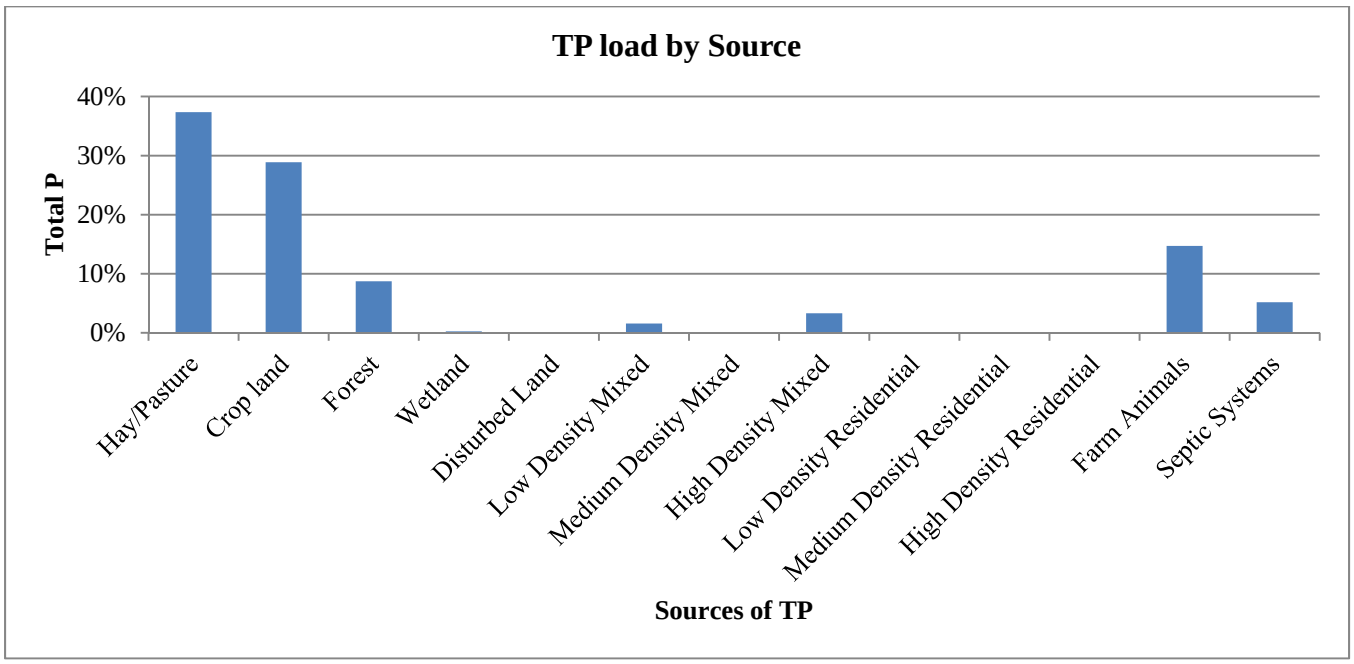


Figure 7: Total Phosphorus Loads by Source in the Inkhorn Brook Watershed

TMDL: TARGET NUTRIENT 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 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 Inkhorn 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 7: TMDL Targets Compared to Inkhorn Brook Pollutant Loading

TMDL POLLUTANT LOADS Annual Loads per Unit Area	**Estimated Loads Inkhorn Brook**	**Total Maximum Daily Load**	**TMDL % REDUCTIONS Inkhorn Brook**
Sediment Load *(1000 kg/ha/year)*	**0.099**	**0.030**	**70%**
Nitrogen Load *(kg/ha/year)*	**8.28**	**5.2**	**37%**
Phosphorus Load *(kg/ha/year)*	**0.52**	**0.24**	**53%**

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 Black Brook. To ensure that the TMDL targets are attained, future agriculture or development activities will need to meet the TMDL targets. Future growth from population increases is a moderate threat in the Black 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 BMP's can reduce sources of polluted runoff in Inkhorn 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 Inkhorn Brook;
- 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: Modeling Results Calculations for Derived Numeric Targets and Reduction Loads for Inkhorn Brook

Inkhorn Brook				
	Area ha	**Sediment 1000kg/yr**	**TN kg/yr**	**TP kg/yr**
Land Uses				
Hay/Pasture	170	11.5	371.1	145.6
Crop land	67	58.1	804.0	112.5
Forest	667	15.5	451.1	34.0
Wetland	15	0.1	17.3	1.0
Disturbed Land	0	0.0	0.0	0.0
Low Density Mixed	55	2.1	54.1	6.2
High Density Mixed	24	3.2	123.0	12.9
Other Sources				
Farm Animals			153.3	57.4
Septic Systems			901.5	20.2
Pathway Loads				
Stream Banks		8.5	4.0	2.0
Groundwater			5387.7	127.8
Total Annual Load		99 x 1000 kg	8267 kg	519 kg
Total Area	998 ha			
Total Maximum Daily Load		**0.099 1000kg/ha/year**	**8.28 kg/ha/year**	**0.52 kg/ha/year**

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