PHOSPHORUS CONTROL ACTION PLAN

and Total Maximum Daily (Annual Phosphorus) Load Report

Wilson Pond – Monmouth, Wayne and Winthrop

Kennebec County, Maine

Wilson Pond PCAP - TMDL Report

Maine DEPLW - 0849

Maine Department of Environmental Protection

FB Environmental Consulting & Cobbossee Watershed District

EPA Final Review Document – August 29, 2007

WILSON POND - Monmouth, Wayne and Winthrop

Phosphorus Control Action Plan (PCAP)

Table of Contents

APPENDICES

WILSON POND (Monmouth, Wayne and Winthrop)

Total Maximum Daily (Annual Phosphorus) Load

ACKNOWLEDGMENTS

In addition to Maine DEP (Division of Environmental Assessment - Lakes Assessment Section and Watershed Management Division- Augusta) and U.S. EPA New England Region I staff, the following individuals, groups and agencies were instrumental in the preparation of this Wilson Pond combined Phosphorus Control Action Plan and Total Maximum Daily Load report: FB Environmental staff (Tricia Rouleau, Forrest Bell, Jennifer Jespersen, and Fred Dillon); Cobbossee Watershed District staff (Bill Monagle, Wendy Dennis, and Jim Ellis); Kennebec County Soil and Water Conservation District staff (Jeff Fredenburg); Maine Department of Agriculture (David Rocque); Maine Forest Service (Chris Martin); Maine Department of Inland Fisheries and Wildlife (Bill Woodward); and Cobbossee Watershed Volunteer Lake Monitor, Steve Ames.

Wilson Pond - Monmouth, Wayne and Winthrop Phosphorus Control Action Plan Summary Fact Sheet

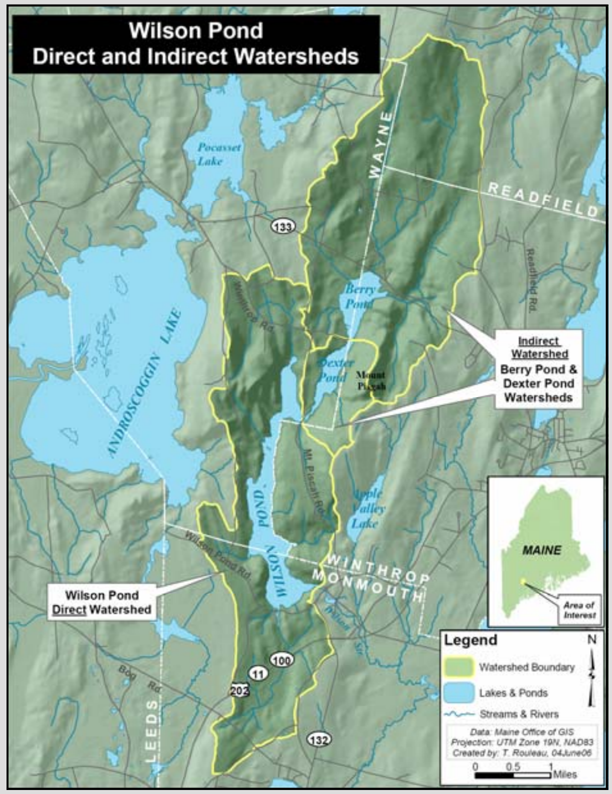
Background

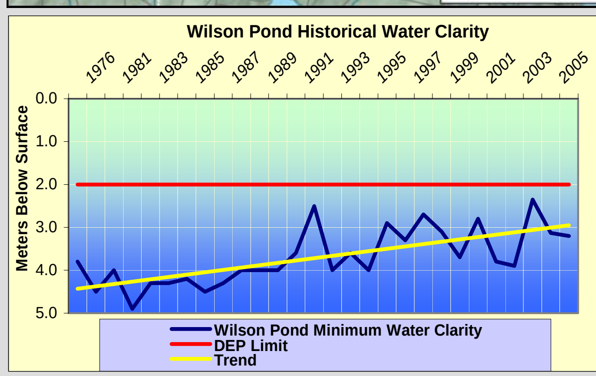
WILSON POND (Midas No. 3832) is a 551 acre, non-**colored** lake located in the towns of Monmouth, Wayne and Winthrop in Kennebec County, Maine. Wilson Pond has a direct drainage area (see map at right and on p.8) of approximately 6.7 square miles (4,304 acres); a maximum depth of 43 feet (13 meters), a mean depth of 23 feet (7 meters); and a **flushing rate** of ~1.8 times per year. The total Wilson Pond watershed drainage area, inclusive of associated sub-watersheds (Berry and Dexter Ponds) is approximately 15.2 square miles.

Historical Information

The primary human uses of Wilson Pond are residential (both seasonal and year-round) and recreational – including low intensity boating, fishing, and swimming. The majority (72%) of the land area around the pond consists of non-developed land. The remaining land is utilized for residential development, agriculture and to a lesser degree, actively managed forest. Although they comprise a relatively small portion of the **watershed** land area, these land uses represent a significant portion of the external **phosphorus** load to the lake.

Until the late 1980's and early 1990's, the water clarity, measured as Secchi disk transparency (SDT), of Wilson Pond had remained relatively consistent from year to year. Prior to this period, the annual mean SDT in the pond generally ranged between 5 and 6 meters, and the maximum SDT occasionally reached 7 meters or more. Since 1992, however, the annual mean SDT generally ranged between 4 and 5 meters, and the maximum SDT has been reduced, in some years not exceeding 5 meters. One of the poorest water quality years occurred in 2004 when the mean SDT was only 3.4 meters. Over the past three decades, the water clarity in Wilson Pond has declined by an average of 1 meter. It was this downward trend in water clarity in Wilson Pond that prompted the Maine DEP to assign "impaired" status to the pond and place it on the state's 303(d) list.





Minimum water clarity measurements have met DEP standards in all of the sampling years. Yet, the trend shows decreasing clarity since the 1980's.

Key Terms

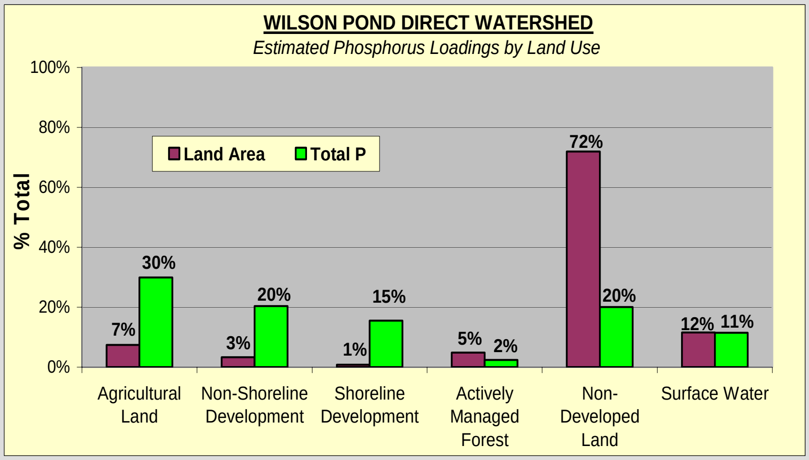
- ***Colored*** *lakes or ponds occur when dissolved organic acids, such as tannins or lignins, impart a tea color to the water, reflected in reduced water transparencies and increased phosphorus values.*
- ***Flushing rate*** *refers to how often the water in the entire lake is replaced on an annual basis.*
- ***Watershed*** *is a drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.*
- ***Phosphorus****: is one of the major nutrients needed for plant growth. It is naturally present in small amounts and limits the plant growth in lakes. Generally, as phosphorus increases, the amount of algae also increases.*

Many factors may be contributing to the declining water quality in Wilson Pond, including soil erosion, fertilizers, upstream waterbodies, and accumulated phosphorus in bottom sediments. Soil erosion can have far reaching impacts, as soil particles effectively transport phosphorus, which serves to "fertilize" the lake and decreases water clarity. Nutrient rich bottom sediments can be a source of high phosphorus as a result of internal loading especially during the warm summer months. Excess phosphorus can also harm fish habitat and lead to nuisance blue-green algae blooms—floating mats of green scum—or dead and dying algae.

What We Learned

The land use assessment conducted for the Wilson Pond watershed helped to determine the potential sources of phosphorus that may run off from land areas during storm events and springtime snow melting. This assessment utilized many resources, including generating and interpreting land cover maps, inspecting and verifying aerial photos, driving the watershed, and conducting a shoreline survey via boat.

An estimated 314 kg (691 lbs) of phosphorus is exported annually to Wilson Pond from the direct watershed. The bar chart (right) illustrates the land area representative land uses as compared to the phosphorus export load for each land use. The lake's natural capacity for in-lake phosphorus assimilation is 638 kg/year (assuming a target goal of 13 ppb). According to sampling data, the amount of total phosphorus being recycled internally from Wilson Pond bottom sediments during the summer-time (2006) is approximately 90 kg/year.



Agricultural land uses make up the greatest proportion of total phosphorus exported to Wilson Pond. Residential development and roads on the shoreline and throughout the watershed are the next greatest contributors.

Phosphorus Reduction Needed

Wilson Pond's average summertime TP concentration approximates 15 ppb - equal to an additional 2 ppb more than the lake's natural capacity. Including a 37 kg allocation for future development, the total annual amount of phosphorus needed to be reduced to support Maine water quality standards (algal bloom-free total phosphorus concentrations of 13 ppb or less) in Wilson Pond approximates 135 kg.

What You Can Do To Help!

As a watershed resident, there are many things you can do to protect the water quality of Wilson Pond, including maintaining areas of natural vegetation, getting septic systems pumped regularly, and using phosphorus-free fertilizer. Under Maine law, effective January 2008, phosphorus fertilizers may only be used on new lawns or lawns that show a phosphorus deficiency on a soil test. Agricultural land users can consult the USDA/Natural Resources Conservation Service, the Maine Department of Environmental Protection, or the Maine Department of Agriculture, Food, and Rural Resources for information regarding **Best Management Practices** (BMPs) for reducing phosphorus loads. Watershed residents can always become involved by participating in events sponsored by State agencies and local organizations. The estimated phosphorus loading to Wilson Pond originates from both shoreline and non-shoreline areas, so all watershed residents must take ownership of maintaining suitable water quality.

Lake stakeholders and watershed residents can learn more about their lake and the many resources available, including review of this Wilson Pond Phosphorus Control Action Plan and **TMDL** report. Following final EPA approval, copies of this detailed report, with recommendations for future BMP work, will be available online at www.maine.gov/dep/blwq/docmonitoring/tmdl2.htm, or can be viewed and/or copied (at cost) at the Maine DEP office in Augusta (Bureau of Land and Water Quality, Ray Building, AMHI Campus).

- ***Best Management Practices* (BMPs)** *are techniques to reduce sources of polluted runoff and their impacts. BMPs are low cost, common sense approaches to reduce storm runoff and velocity to keep soil out of lakes and tributaries.*
- ***TMDL***, *an acronym for Total Maximum Daily Load, represents the total amount of a pollutant (e.g., phosphorus) that a waterbody can receive on an annual basis and still meet water quality standards.*

Project Premise

This lake's PCAP-TMDL project, funded through a Clean Water Act Section 319-grant from the United States Environmental Protection Agency (EPA), was directed and administered by the Maine Department of Environmental Protection (Maine DEP) under contract with FB Environmental Consulting and Cobbossee Watershed District (2007).

The objectives of this project were twofold: First, a comprehensive land use inventory was undertaken to assist Maine DEP in developing a Phosphorus Control Action Plan (PCAP) and a Total Maximum Daily Load (TMDL) report for the Wilson Pond watershed. Simply stated, a TMDL is the total amount of phosphorus that a lake can receive without harming water quality. Maine DEP, with assistance from FB Environmental staff, will fully address and incorporate public comments before final submission to the US EPA. *(For more specific information on the TMDL process and results, refer to the Appendices or contact Dave Halliwell at the Maine DEP Augusta Office at 287-7649 or david.halliwell@maine.gov*).

Secondly, watershed assessment work was conducted by the Cobbossee Watershed District to help assess **total phosphorus** reduction techniques that would be beneficial for the Wilson Pond watershed. The results of this assessment include recommendations for future conservation work in the watershed to help citizens, organizations, and agencies restore and protect Wilson Pond. **Note:** *To protect the confidentiality of landowners in the Wilson Pond watershed, site-specific information has not generally been provided as part of this PCAP-TMDL report.*

Total Phosphorus (TP) - *is one of the major nutrients needed for plant growth. It is generally present in small amounts and limits the plant growth in lakes. Generally, as the amount of lake phosphorus increases, the amount of algae also increases.*

This Phosphorus Control Action Plan (PCAP) report compiles and refines land use data derived from the Maine Office of Geographic Information Systems as compiled and prepared by the Kennebec County Soil & Water Conservation District (KC-SWCD). Local citizens, active and/or developing watershed organizations, and conservation agencies will benefit from this compilation of both historical and recently collected data as well as the watershed assessment and the NPS Best Management Practice (BMP) recommendations. Above all, this document is intended to help Wilson Pond stakeholder groups to effectively prioritize future BMP work in order to obtain the funding resources necessary for further **NPS pollution** mitigation work in their watershed.

Nonpoint Source (NPS) Pollution *- is polluted runoff that cannot be traced to a specific origin or starting point, but accumulates from overland flow from many different watershed sources.*


View of Wilson Pond from Dexter Pond outlet. Photo: B. Monagle

Study Methodology

Wilson Pond background information was obtained from the Cobbossee Watershed District. The CWD staff compiled and summarized historical water quality data, analyzed land use maps, reviewed watershed survey results, and conducted a shoreline survey of Wilson Pond (Spring 2007).

Land use data were determined using several methods, including (1) **Geographic Information System (GIS)** map analysis, (2) analysis of aerial photographs and (3) field verification. Watershed boundaries, as well as developed and non-developed land use area (i.e., forest, wetland, grassland) were initially determined using a combination of steps 1 and 2. The GIS land cover layer used for this analysis was created at the request of the Maine DEP Bureau of Land and Water Quality (BLWQ). It includes those classes in each layer which are best suited to calculating impermeability of watersheds. Though released in 2006, the Maine Land Cover Data (MELCD) used for this analysis is a land cover map for Maine primarily derived from Landsat Thematic Mapping imagery from the years 1999-2001, which was further refined using panchromatic imagery from the spring and summer months of 2004. Land uses within these maps were further refined by the Cobbossee Watershed District based on field verification using ground-truthing.

> ***GIS****—or* ***geographic information system*** *combines layers of information about a place to give you a better understanding of that place. The information is often represented as computer generated maps.*

> ***Ground-truthing*** *involves conducting field reconnaissance in a watershed to confirm the relative accuracy of computer generated maps.*

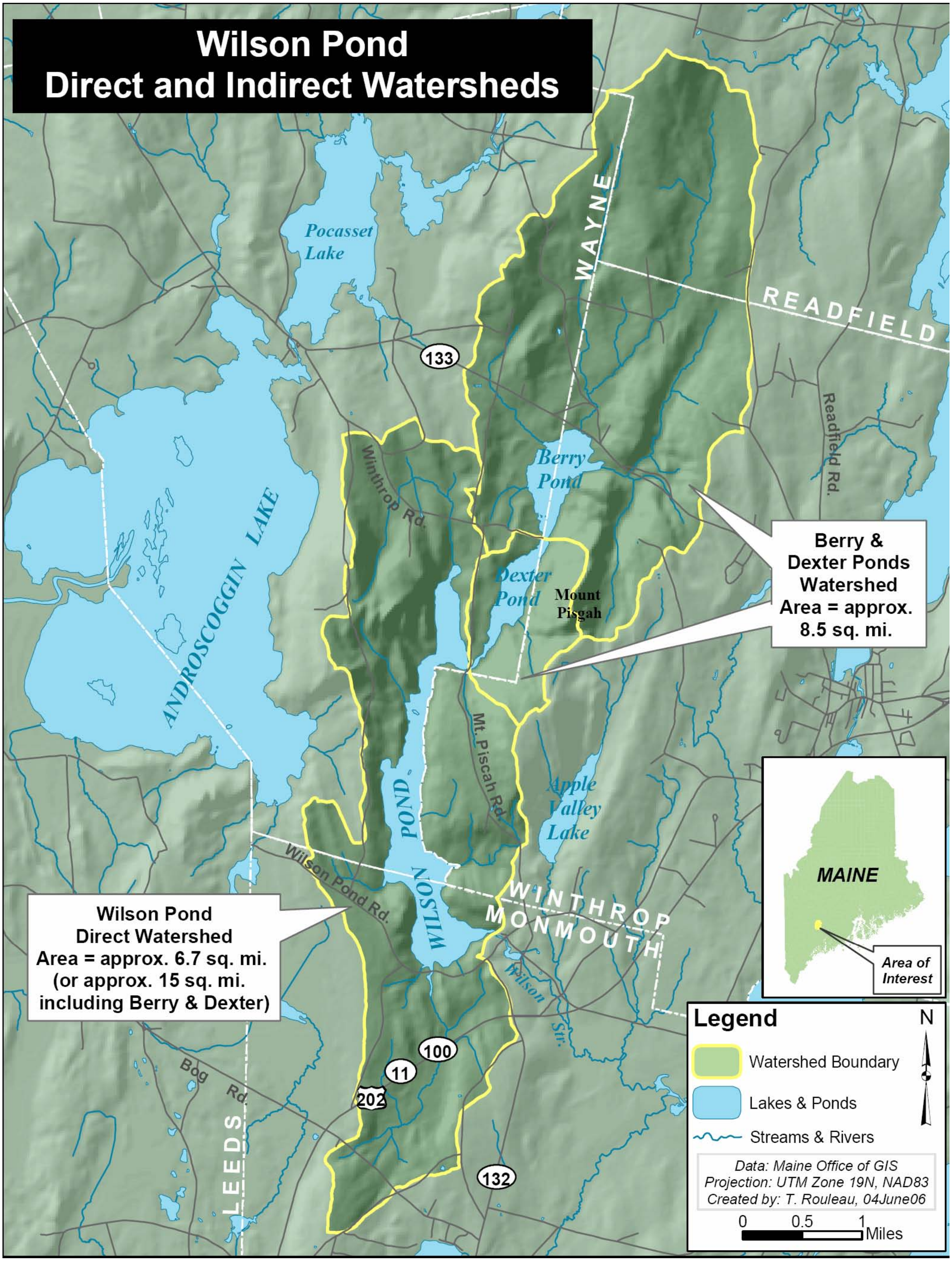
Final adjusted phosphorus loading numbers (see Table 3, page 29) were calculated in a spreadsheet, using estimated export coefficients, as found in Reckhow et al. (1980), ME-DEP (1999), Dennis (1986), Dennis et al. (1992), Dennis et al. (1981) Bouchard et al. (1995), and Monagle (1995) for low and high density residential properties; agriculture; roadways; and other types of developments (recreational, commercial, and timber harvesting).

Roadway widths were estimated by Cobbossee Watershed District staff by taking actual measurements for the various road types. In general, town and state-owned roads were found to be either 26 feet wide or 40 feet wide (Route 202 only); camp roads were found to be an average of 16 feet wide; and unimproved roads were found to average 25 feet wide.

<u>Study Limitations</u>

Land use data gathered for the Wilson Pond watershed is as accurate as possible given all of the available information and resources utilized. However, final numbers for the land use analysis and phosphorus loading numbers are approximate, and should be viewed only as carefully researched estimations.

Figure 1. Map of Wilson Pond Direct & Indirect Watersheds



WILSON POND Phosphorus Control Action Plan

DESCRIPTION of WATERBODY (MIDAS Number 3832) and WATERSHED

WILSON POND is a 551-acre (90 hectare) non-colored waterbody situated in the towns of Winthrop, Monmouth and Wayne (DeLorme Atlas, Map 12), within Kennebec County, Maine. Wilson Pond has a **direct watershed** area (see Figure 1) of approximately 4,304 acres (6.7 square miles) exclusive of lake surface area. The Wilson Pond direct watershed is located within three towns, including: Winthrop (43%), Monmouth (40%), and Wayne (17%). Wilson Pond has maximum depth of 43 feet (13 meters), a mean depth of 23 feet (7 meters); and a flushing rate approximately 1.8 times per year.

Direct Watershed: *The direct watershed refers to the land area that drains to a waterbody without first passing through an associated lake or pond.*

Drainage System: There a four small unnamed tributaries that contribute to the hydrologic and nutrient budgets of Wilson Pond. The major external water load to the pond enters as the outflow from Dexter pond, immediately upstream along the northeast portion of the pond. Wilson Pond drains via a dam along the southeast portion of the pond. The dam is owned and operated by Tex-Tech Industries. The outlet, Wilson Stream, flows southerly to Annabessacook Lake.

There are two public access locations on Wilson Pond: A state-operated public boat launch on the south shore of the pond along Wilson Pond Road in the Town of Monmouth; and a public beach on Wilson Pond Road, owned by the North Monmouth Community Club.

Wilson Pond Water Quality Information

Wilson Pond is listed on the Maine DEP's 2006 303(d) list of lakes that do not meet State water quality standards. Therefore, a combined Phosphorus Control Action Plan and TMDL report was prepared for Wilson Pond during the spring/summer of 2007.

The Cobbossee Watershed District has been monitoring the water quality of Wilson Pond since the 1970's. During this period, basic chemical information, including total phosphorus, **chlorophyll-a**, dissolved oxygen, pH, and total alkalinity was collected, in addition to **Secchi disk transparencies (SDT).** Sampling was performed primarily on a monthly basis during ice-free conditions (May – Oct) at the deepest portion of the pond.

Together, measures of Secchi disk transparency, total phosphorus (TP), and chlorophyll-a (Chla) document a trend of increasing **trophic state** in Wilson Pond, in direct violation of the Maine DEP Class GPA lakes water quality criteria requiring a stable or decreasing trophic state.

A variety of nonpoint sources of pollution may be contributing to the declining water quality in Wilson Pond. The water quality of Wilson Pond is influenced by runoff events from the watershed. Nonpoint sources of pollution such as erosion from land uses such as development, agriculture, and roads in the watershed may contribute to the declining water

Chlorophyll-a *is a measurement of the green pigment found in all plants including microscopic plants such as algae. It is used as an estimate of algal biomass; the higher the Chl-a number, the higher the amount of algae in the lake.*

Secchi Disk Transparency - *a vertical measure of the transparency of water (ability of light to penetrate water) obtained by lowering a black and white disk into the water until it is no longer visible.*

Trophic state - *the degree of eutrophication of a lake. Transparency, chlorophyll-a levels, phosphorus concentrations, amount of macrophytes, and quantity of dissolved oxygen in the hypolimnion can all be used to assess trophic state.*

quality in Wilson Pond. During storm events, nutrients, such as phosphorus—naturally found in Maine soils– drain into the lake from the surrounding watershed by way of streams and overland flow and are deposited and stored in the lake, primarily in bottom sediments. Phosphorus can be released from sediment and re-suspended through biological or chemical means (90 kg based on 2006 measurements). Phosphorus is naturally limited in lakes and can be thought of as a fertilizer, a primary food for plants, including algae. When lakes receive excess phosphorus from NPS pollution, it "fertilizes" the lake by feeding the algae. Too much phosphorus can result in nuisance blue-green algae blooms, which can damage the ecology and aesthetics of a lake, as well as the economic well-being of the entire lake watershed.

Principle Uses & Human Development:

Developed and managed land in the Wilson Pond watershed includes agricultural land, actively managed forest, residential areas, and roads. The most prevalent of these human uses in the watershed are agricultural land (7%) and actively managed forest (5%). Together, shoreline and non-shoreline residential development account for approximately 4% of the watershed land area. The shoreline of Wilson Pond is lightly to moderately developed in comparison to other regional lakes and ponds of the CWD. The eastern shoreline is more intensely developed than the west shore. Much of the land along the western shore of the pond is either prohibitively steep for development, under private ownership, or lacks access to land along the shoreline. As is discussed later in this report, there are 118 structures located along the approximate 9 mile shoreline. Of these, 59 percent are seasonal camps and 41 percent are year-round dwellings (CWD project staff, 2007). The total population of the watershed of Wilson Pond is estimated at 691 based on a count of residential structures, the residency status of these structures (i.e., seasonal or year-round), and an average occupancy of 2.7 per household (US-EPA 2001b).

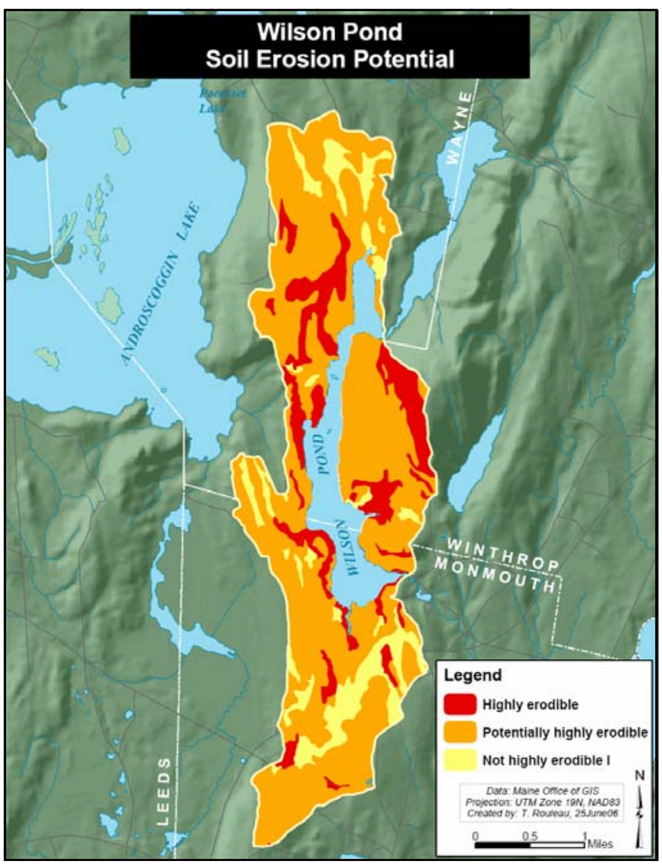


__Figure 2 (left).__ If not properly managed, soils in the Wilson Pond have the potential to be highly erodible.

General Soils Description

The Wilson Pond watershed is characterized by the Dixfield-Colonel-Lyman-Brayton soil association (Ferwerda, 1997) which consists of soils formed in till derived from schist, granite, and gneiss.

The greatest land area in the Wilson Pond watershed is comprised of soils in hydrologic group C (77%) which are soils with slow and very slow infiltration capacity and rapid runoff if not vegetated. Land under intensive uses, and on steep slopes may be particularly vulnerable to erosion.

Approximately 14% of soils in the watershed are highly erodible. Some large areas of erodible soils are found on steep slopes along the western shoreline of the pond. The majority of soils in the watershed (63%) are potentially highly erodible.

Land Use Inventory

The results of the Wilson Pond watershed land use inventory are depicted in Figure 3 (below) and Table 1 (p.13). The majority of the watershed consists of non-developed land. The dominant human uses in the watershed are actively managed forest land and agricultural land (primarily non-manured hayland). The most significant land use change in the watershed has been agricultural. Until 2004, agricultural land in the watershed included hayland, a dairy farm, corn fields, and apple orchards. Since 2004, the majority of corn fields have been converted to non-manured hayland, with a portion used as horse pasture, and the dairy farm is no longer in operation (see p.14). In terms of residential development, although very little activity has occurred in the watershed over the past several years, it is predicted that the region will experience relatively high developmental growth rates in the near future.

In Table 1, watershed land uses are categorized by developed land vs. non-developed land. The developed and managed land area comprises approximately 16% of the watershed and the undeveloped area, including the water surface area of Wilson Pond, comprises the remaining 84% of the watershed. These numbers may be used to help make future planning and conservation decisions relating to the Wilson Pond watershed. The information in Table 1 was also used as a basis for preparing the Total Maximum Daily (Annual Phosphorus) Load report (see Appendices).

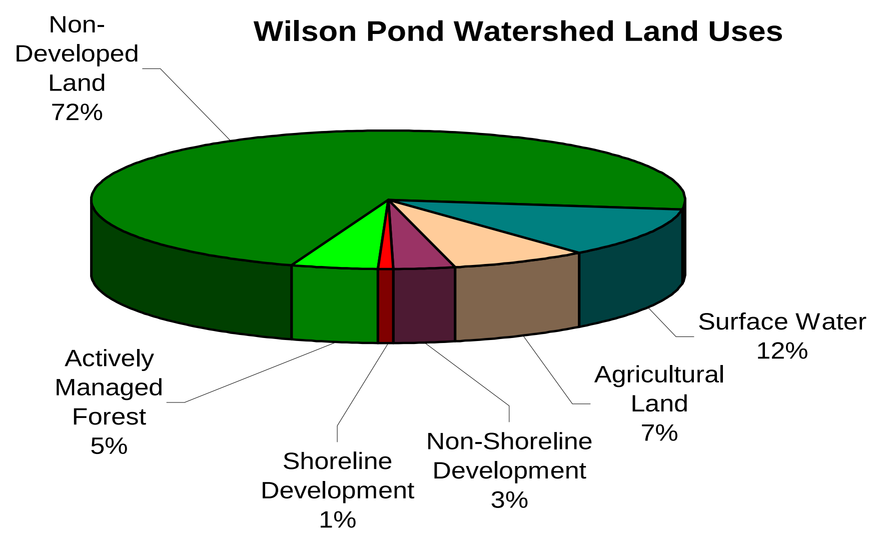


Figure 3. *Managed and developed land uses in the Wilson Pond watershed consist of actively managed forest land, agricultural land, and residential development. Although these land uses cover a relatively small portion of the watershed (16%), they account for 68% of the phosphorus load to Wilson Pond.*

<u>Wilson Pond</u> Fish Assemblage & Fisheries Status

Based on records provided by the Maine Department of Inland Fisheries and Wildlife (Maine DIF&W) and a recent conversation with fish biologist Bill (Woody) Woodward (Region B, Sidney DIF&W office), **Wilson Pond** (towns of Monmouth, Wayne and Winthrop - Kennebec River drainage) is currently managed as a mixed cold/warmwater fishery (brown trout and black bass) and was last field surveyed in 2000 (1940, revised 1963 and 2001). A total of **15** fish species are listed, including: **8** native indigenous fishes (American eel, golden shiner, white sucker, brown bullhead, chain pickerel, redbreast sunfish, pumpkinseed, and yellow perch); **6** introduced fishes (white perch, rainbow smelt, smallmouth and largemouth bass, brown and brook trout), and **1** illegally stocked fish species – northern pike. Transient catches of stocked brook and brown trout may occur, as these two species are annually stocked by MDIF&W to support the put-grow-and take trout fishery in the absence of suitable salmonid spawning and nursery areas. Principal warmwater fisheries, in addition to black (large and smallmouth) bass, include white perch, yellow perch and chain pickerel. Northern pike were illegally stocked into headwater Berry/Dexter Pond as early as 1997 and have emmigrated directly down into Wilson Pond in recent years.

Brown trout

Largemouth bass

Improvements in water quality, reducing the prevalence of nuisance summertime algal blooms, can serve to enhance fisheries conditions in Wilson Pond. Given that the trophic state of Wilson Pond has been disturbed by cumulative human impacts over the past several decades - then a significant reduction in the total phosphorus loading from the Wilson Pond watershed may lead to maintaining in-lake nutrient levels within the natural assimilative capacity of this lake to effectively process total phosphorus - and possibly enhance existing put-take-and grow trout and associated warmwater fisheries.

**Table 1. Wilson Pond Direct Watershed—
Land Use Inventory and External Phosphorus Loads**

LAND USE CLASS	Total Area Acres	Land Area %	TP Coeff. Avg. kg/P/ha	TP Coeff. Range kg/P/ha	Land Area Hectares	TP Export Load kg TP	TP Export Total %
Agriculture							
Hayland (non-manured)	234	5%	0.64	0.35-1.81	94	60	19%
Cultivated Crops (Post 2004)	0	0%	2.24	0.26 -18.6	0	0	0%
Pasture	38	<1%	0.81	0.14 - 4.90	15	13	4%
Orchard	88	<1%	0.60	0.06 - 0.75	36	21	7%
Sub-totals	360	7%			145	94	30%
Actively Managed Forest							
Light-Cut Forest	236	5%	0.08	0.01 - 0.2	96	8	2%
Sub-totals	236	5%			96	8	2%
Shoreline Development							
Low Impact residential	12	<1%	0.5	0.25 - 1.75	5	2	<1%
Medium Impact residential	3	<1%	1.0	0.4 - 2.2	1	1	<1%
High Impact residential	14	<1%	1.4	0.4 - 2.2	6	8	3%
Shoreline Septic Systems	seasonal	0%				9	3%
Shoreline Septic Systems	year-round	0%				19	6%
Unimproved Roads	10	<1%	2	0.60 - 10.0	4	8	3%
Sub-totals	39	1%			16	49	16%
Non-Shoreline Development							
Low Impact Residential	88	2%	0.5	0.25 - 1.75	36	18	6%
Medium Impact Residential	8	<1%	1	0.25 - 1.75	3	3	1%
Commercial	7	<1%	1.92	0.8 - 4.20	3	5	2%
Institutional	11	<1%	1.92	0.8 - 4.20	4	8	3%
Town and State Roads	38	<1%	1.5	0.60 - 10.0	16	23	7%
Unimproved Roads	7	<1%	2	0.60 - 10.0	3	6	2%
Parks, Cemeteries	2	<1%	0.8	0.25 - 0.98	0.8	<1	<1%
Sub-totals	161	3%			65	64	20%
Total: DEVELOPED LAND	796	16%			322	215	68%
Non-Developed Land							
Inactive/Passively Managed Forest	3,273	67%	0.04	0.01 - 0.2	1,324	53	17%
Scrub-Shrub	7	<1%	0.15	0.01 - 0.2	3	<1	<1%
Grassland/Reverting Fields	158	3%	0.15	0.01 - 0.2	64	10	3%
Wetlands	58	1%	0.01	0.02 - 0.83	24	<1	<1%
Total: NON-DEVELOPED LAND	3,496	72%			1,415	63	21%
Total: Surface Water (Atmospheric)	562	12%	0.16		228	36	11%
Totals: DIRECT WATERSHED	4,855	100%			1,965	314	100%

Descriptive Land Use and Phosphorus Export Estimates

Agriculture: Limited agricultural activity takes place in the Wilson Pond watershed. The main agricultural uses in the watershed are non-manured hayland. Apple orchards are also a prominent agricultural land use, with approximately 88 acres in production. A dairy farm in close proximity to the north end of the pond was in operation until 2004 when it went out of business. Associated with this dairy farm were approximately 65 acres dedicated to corn production. Manure produced by the herd was applied as fertilizer for corn growth. Since 2004, the majority of the land in corn growth has been converted to non-manured hayland, with a portion used as horse pasture.

To estimate the contribution of agriculture to the phosphorus load to Wilson Pond, annual loads were estimated for both pre- and post-2004 to account for the relative portion of dairy farm and associated corn fields. As 2004 was the worst water quality year that the CWD has recorded for Wilson Pond, both pre- and post-2004 phosphorus loads were modeled in order to establish a reference point for future planning.

In summary, the extent of land used for agricultural purposes in the watershed remains substantial when compared to other culturally based land uses. Today, the amount of land used for agriculture in the watershed of Wilson Pond accounts for 7% of the total direct watershed area and 30% of the total external phosphorus load. Until 2004, approximately 38% of the total phosphorus loading to the pond, based on land use phosphorus export coefficients, was attributable to agriculture. Based on current land use (i.e., post-2004), the phosphorus load from agriculture has declined by approximately 41 kg TP/yr (8%). Of the various agricultural practices, hayland is now estimated to contribute the most phosphorus (19%), with orchard (7%) and pasture (4%) contributing the remainder of the annual total phosphorus load.

- *To convert kilograms (kg) of total phosphorus to pounds - multiply by 2.2046*

Actively Managed Forest Land: The estimated operated forest land for the Wilson Pond direct watershed consists of 236 acres. This estimate is based on a GIS analysis of land uses and represents 5% of the total land area, contributing about 2% of the total phosphorus load to Wilson Pond. Properly managed forestry operations prevent erosion and sedimentation from logging sites by using well thought out skidding systems, proper placing of log landings, and seeding and stabilizing bare soils following harvest operations. Sustainable forest management can enhance water quality through sequestering excess nutrients, particularly in forested riparian areas

Shoreline Development consists of all developed lands within the immediate shoreland zone (250 feet) of Wilson Pond. A complete shoreline survey was conducted in the spring of 2007 by the Cobbossee Watershed District. This survey was conducted via boat and the results represent subjective determinations of potential impact ratings based on best professional judgment. The survey included a residential structure tally along with an estimated potential impact rating ranging from 1 to 5, with 1 being low and 5 being high. A residential lot assigned a rating of 1 would likely have minimal disturbance, limited developed area, or have full natural vegetation. Conversely, a rating of 5 would indicate little or no vegetative buffer and/or exposed soil on the parcel, or other visible source of phosphorus input to the lake. In addition to the impact rating, project staff estimated the residency status of the dwelling (seasonal vs. year-round) when the status was unknown, the distance of the dwelling to the lake, the percent slope of the lot, the presence or lack of vegetated buffers, presence of bare soils, existing rip rap, and other notable features such as retaining walls or boat launches. A similar rating system for vegetated buffer status was established. A summary of the findings of the survey on Wilson Pond appears below:

Table 2: Results of 2007 Wilson Pond Shoreline Survey

Potential Impact Rating	Vegetated Buffers (# lots within rating category)	Vegetated Buffers (% lots within rating category)	NPS Severity (# lots within rating category)	NPS Severity (% lots within rating category)
1 (low)	20	17%	20	17%
2	20	17%	28	24%
3	12	10%	13	11%
4	35	30%	29	25%
5 (high)	31	26%	28	24%

The shoreline of the Wilson Pond supports 118 dwellings. The eastern shoreline is more intensely developed than the west shore. Much of the land along the western shore of the pond is either prohibitively steep for development, under private ownership, or lacks access to land along the shoreline. Of the 118 dwellings, it is estimated that 48 are year-round residences and 70 are seasonal. Around the nearly 9-mile long shoreline, there were very few lots with adequate vegetative buffers. As such, inadequate wooded shoreline buffers contribute most to the high number of sites categorized as moderate to high impact (i.e., 4 to 5 impact rating) NPS contributors.

Estimation of phosphorus loading to Wilson Pond from shoreline residential areas is categorized into Low, Medium, and High Impact ratings. These ratings are derived directly from the shoreline survey impact ratings where a lot receiving a score of 1-2 is considered “low impact”, a lot receiving a score of 3 is considered “medium impact”, and a lot receiving a score of 4-5 is considered “high impact”. To estimate the phosphorus load to the lake from shoreline dwellings, each lot was subjectively assigned a phosphorus export coefficient corresponding to a residential lot with clearing limits of 10,000 square feet and situated on HSG-C soils (sandy clay loams with low infiltration) as presented in *Phosphorus Control in Lake Watersheds: A Technical Guide to Evaluating New Development* (Dennis et al. 1992). These values, 0.34 lbs/lot/yr, were then subjected to buffer treatment factors 1.0, 0.9 and 0.75 based on whether they were high, medium, or low impact lots.

View from Wilson Pond boat launch, 2007. Photo: B. Monagle

In total, shoreline residential sites are estimated to contribute 11 kg to the total external phosphorus load of Wilson Pond. Low impact sites contribute 34.6% of this total, medium impact sites contribute 10.7%, and high impact sites contribute 54.7% of P loading to Wilson Pond from shorefront properties.

Shoreline Septic Systems: Total phosphorus export loading from residential septic systems within the Wilson Pond shoreline zone was estimated using a simple calculation based on the results from the shoreline survey. Export coefficients of 0.05 and 0.15 kg P per capita for seasonal and year-round residences were taken from Dennis and McPhedran (1991). Occupancy was estimated to be 2.7 persons per household, based on the East Pond standard (US-EPA 2001b). Based on these factors, the total phosphorus load to Wilson Pond from shoreline septic systems is estimated at 28 kg/yr. This represents approximately 9% of the annual land use-based total phosphorus load to the pond from the direct watershed area.

Shoreline Roads: NPS pollution associated with shoreline roads (roads within 250 feet of the shoreline) can vary widely, depending upon road type, slope and proximity to a surface water resource. Shoreline roads in the Wilson Pond watershed consist of unimproved, camp and private roads. The average dimensions of these roads were measured by CWD project staff in the field and total lengths were determined using a map measure and wheel. Based on field measurements, the average road width for shoreline roads in the Wilson Pond watershed is 4.9 meters (16 ft). There are approximately 5 miles of camp and private roads within the watershed. When multiplied by the average road width, these roads cover 4 hectares (10 acres). In total, shoreline roads currently contribute an estimated 3% (8 kg/yr) to the total phosphorus load to Wilson Pond.

As part of the Section 319 watershed survey (project #ME-2005R-02), volunteers from the Berry, Dexter and Wilson Watershed Association, as well as from a local high school, Monmouth Academy were trained by CWD and KC-SWCD technical staff and embarked on a survey of the camp roads in the immediate vicinity of Wilson Pond. CWD staff completed the watershed survey, verifying previously surveyed NPS sites. Results were tallied and photo-documented. Common problems included erosion of the road surface, insufficient road crown, and presence of shoulder berms. Common recommendations for improvements include road crowning, removal of shoulder berms, and armoring of culvert inlets/outlets.

Overall, shoreline development comprises ~1% of the total watershed area, yet this type of development contributes approximately 49 kg of total phosphorus annually, accounting for 16% of the estimated phosphorus load.

View of Wilson Pond outlet dam at the southeast portion of the pond. The dam is owned and operated by Tex-Tech Industries.

Photo: B. Monagle

Non-Shoreline Development and Land Uses

Non-Shoreline Development consists of all lands outside the immediate shoreline of Wilson Pond - including roads, residential areas, commercial and institutional lands, parks and cemeteries. The total land area covered by these land-uses was calculated with GIS land use data and corrected using ground-truthing by the Cobbossee Watershed District.

Roads: Roadway widths were estimated by Cobbossee Watershed District staff using a combination of GIS based information and actual measurements for the various road types. In general, town and state-owned roads were found to average either 26 feet wide or 40 feet wide (Route 202 only); camp roads were found to be 16 feet wide; and unimproved roads were found to be 25 feet wide. The total loading for State and Town Roads (23 kg/yr) and unimproved roads (6 kg/yr) of Total P, combine to total 9% (29 kg/yr) of the total phosphorus load to Wilson Pond.

Residential: Low impact residential consists of approximately 88 acres and contributes an estimated 18 kg/year of the total phosphorus loading to the Wilson Pond direct watershed. Medium impact residential covers approximately 8 acres and accounts for 3 kg/yr. Combined, these land use classes account for just over 2% of the land area and approximately 7% of the total phosphorus load to Wilson Pond.

Other Developed Land Areas: The remaining developed land uses include a small cemetery, a few commercial enterprises, and a high school. The total Phosphorus loading of these uses is just over 13 kg/yr or approximately 5% of the total phosphorus loading to Wilson Pond.

Phosphorus Loading from Non-Developed Lands and Water

Inactive/Passively Managed Forests: Of the total non-developed land area within the Wilson Pond watershed, 3,273 acres are forested. Approximately 17% of the phosphorus load (53 kg/year) is estimated to be derived from non-commercial forested areas within Wilson Pond’s direct drainage area.

Other Non-Developed Land Areas: Combined grasslands/reverting fields, scrub-shrub, and wetlands account for approximately 4% of the land area in the Wilson Pond watershed. A total of approximately 10 kg/yr (~3%) of the total phosphorus load to the lake is derived from these sources.

Atmospheric Deposition (Open Water): Surface waters (including Wilson Pond) in the direct watershed comprise 12% of the total land area (562 acres) and account for an estimated 36 kg of total phosphorus per year, representing 11% of the total direct watershed load entering Wilson Pond. The total phosphorus loading coefficient chosen (0.16 kg/ha) is similar to that used for central Maine lakes in Kennebec County. This value represents the median of a range of values from Reckhow (1980) of 0.11 kg/ha to 0.21 kg/ha. The upper range generally reflects a watershed that is 50 percent forested, combined with agricultural areas interspersed with suburban land uses.

PHOSPHORUS LOADS – Watershed, Sediment and In-Lake Capacity

Supporting documentation for the phosphorus loading analysis includes water quality monitoring data from the Cobbossee Watershed District, and the development of a phosphorus retention model (see Appendices for detailed information). Please note that two methods were used in our total phosphorus loading analysis to assist with the preparation of this report: 1) a loading GIS-based export coefficient spreadsheet to provide a relative estimation of impacts from watershed land uses for the development of phosphorus reduction strategies by stakeholders; and 2) an in-lake phosphorus concentration model to determine the phosphorus reduction needed for the Wilson Pond TMDL. These two methods may yield different overall phosphorus loading results depending on the available water quality data and particular characteristics of the watersheds and water bodies being modeled.

1. GIS-Based Land Use and Indirect Load Method

Watershed Land Uses: Total phosphorus loadings to Wilson Pond originate from a combination of external watershed and internal lake sediment sources. Watershed total phosphorus sources, totaling approximately 314 kg (691 lbs) annually have been identified and accounted for by land use (See Table 3 - page 29).

Internal Loading: Annual internal lake sediment P-loading of 90 kg was estimated from 2006 data.

Loading from the Indirect Watershed: Total phosphorus loading from the associated upstream watersheds of Berry and Dexter Ponds accounts for an estimated indirect watershed average load of 132 kg annually, determined on the basis of flushing rate x volume x TP concentration (see pages 28 and 30 for more information).

The sum of these two potential sources of TP indicates that an estimated 446 kg/yr may be contributing to the current in-lake phosphorus levels of Wilson Pond. However, these models do not take into account many of the complex factors that affect lake water quality. Instead, these figures provide stakeholders with relative estimates that should assist with targeting implementation measures in the watershed.

2. In-Lake Concentration Method (TMDL)

Lake Capacity: The assimilative capacity for all existing and future non-point pollution sources for Wilson Pond is 638 kg of total phosphorus per year, based on a target goal of 13 ppb (See Phosphorus Retention Model - page 33).

Target Goal: A change in 1 ppb in phosphorus concentration in Wilson Pond is equivalent to 49 kg of watershed loading. The difference between the target goal of 13 ppb and the measured average summertime total phosphorus concentration (15 ppb) is 2 ppb or 98 kg (2 ppb x 49 kg).

Future Development: The annual total phosphorus contribution to account for future development for Wilson Pond is 37 kg (0.75 x 49) (see page 32 for more information).

Reduction Needed: Given the target goal and a 37 kg allocation for future development, the total amount of phosphorus needed to be reduced, on an annual basis, to restore water quality standards in Wilson Pond approximates 135 kg (98 + 37).

PHOSPHORUS CONTROL ACTION PLAN

Recent and Current NPS/BMP Efforts

The Cobbossee Watershed District and the Kennebec County Soil and Water Conservation District have an ongoing relationship with land owners in the Wilson Pond watershed. This cooperation has helped them support actions to reduce nutrient export from existing residential and agricultural operations.

In 2004, a formal watershed survey of Wilson Pond was initiated. The project was supported by a nonpoint source pollution (NPS) grant to CWD from the Maine Department of Environmental Protection. The survey included the direct watersheds of Dexter and Berry Ponds, two smaller waterbodies upstream of Wilson Pond. The survey, which identified and prioritized Nonpoint Source (NPS) pollution sites in terms of runoff, erosion, nutrient loading and sedimentation, was completed in fall of 2006. As of this writing, the results are being compiled and summarized. The results of this survey may be used to acquire 319 funding that would target many of the "chronic" problems in the watershed, such as agricultural sites and erosion on town and state roadways.

The CWD has for years offered technical assistance to the Planning Boards of District towns regarding the review of proposed subdivisions and commercial uses. Little, if any, need has arisen in recent years in the watershed of Wilson Pond with respect to scrutinizing large developments and their prospective phosphorus export to the pond. Of the three District towns in the watershed of Wilson Pond, the CWD has been called on most frequently by Monmouth to review phosphorus control plans for projects in the Wilson Pond watershed as required by the Town's Planning Board. The low frequency of technical review is reflected in the few subdivisions and commercial operations in the watershed. The CWD is poised, however, to provide technical oversight to support local planning board review of any future projects.

The Cobbossee Watershed District has been working for more than 30 years throughout the CWD to support the implementation of BMPs in the watershed. During the summer of 2002, the CWD began a coordinated effort with a newly formed non-profit organization, *Friends of the Cobbossee Watershed* (Friends) to expand current outreach to lakeshore owners and boaters. The Friends launch their vessel, the "OTTER II", on several of the lakes of the CWD, including Wilson Pond, to disseminate lake protective education material and educate citizens about such BMPs as vegetated buffers, proper camp road maintenance and shoreline erosion control.

View of Wilson Pond looking north from the boat launch.
Photo: B. Monagle

Recommendations for Future NPS/BMP Work

Wilson Pond has impaired water quality primarily due to phosphorus inputs from nonpoint source (NPS) pollution, associated upstream sources, and resultant internal lake sediment recycling of phosphorus. Specific recommendations regarding recent and current efforts in the watershed, best management practices (BMPs), and actions to reduce (1) external watershed and (2) accumulated bottom sediment phosphorus total phosphorus loadings in order to improve water quality conditions in Wilson Pond are described below. Additional recommendations will be outlined in the Wilson Pond Watershed Survey.

Watershed Management: Several agencies (i.e., primarily CWD, in addition to Maine DEP, KC-SWCD, USDA/NRCS, watershed Towns) have been involved in attempting to restore and monitor the water quality of Wilson Pond. This PCAP-MDL report will serve as a compilation of existing information about the past and present projects that have been undertaken in order to adequately assess future NPS BMP needs in the watershed.

Action Item #1 : Support existing watershed management efforts		
Activity	**Participants**	**Schedule & Cost**
Resource agencies should continue to support the Cobbossee Watershed District.	KC-SWCD, USDA/NRCS, Maine DEP, Cobbossee Watershed District, Towns of Monmouth, Wayne, and Winthrop, interested watershed citizens-stakeholders.	Annual roundtable meetings—beginning in Spring 2008—minimal cost

Agriculture: Now that a large dairy farm has ceased operation (2004), agriculture appears to have become a relatively minor source of phosphorus loading to the pond. The once cultivated row crops that are now hayland should be monitored by CWD staff occasionally to verify their non-manured status, but without a manure-generating herd nearby that is unlikely to change anytime soon. The CWD should inquire as to manure management on one commercial riding stable in close proximity to the pond and a small tributary.

Action Item # 2: Monitor manure management		
Activity	**Participants**	**Schedule & Cost**
• Periodically monitor hayland to confirm non-manured status. • Recommend manure management strategies for nearby horse stable.	Cobbossee Watershed District	Annually beginning in 2008 Variable cost depending on type of activities

Shoreline Residential: Shoreline residential sites have been determined to have a moderate impact on the water quality of Wilson Pond. The 118 identified shoreland area residences are estimated to contribute >3% of the annual watershed-based phosphorus load to the pond, exclusive of septic systems. In order to improve efforts to mitigate phosphorus export from shoreline residential lots, actions should be taken to encourage landowners to implement BMPs and adopt more responsible watershed behavior. The CWD will continue to work in a coordinated effort with *Friends of the Cobbossee Watershed* to expand current outreach to lakeshore owners and boaters by distributing informational material about lake protection and educating citizens about such NPS best management practices. Based solely on the shoreline survey results, the most common BMP to be prescribed for shorefront-based protection should be the planting of shoreline buffer strips. With homes in close proximity to the water's edge, it is critical that adequate and effective vegetative buffers are in place to decrease and slow down run-off from shoreland sites.

An effort should be undertaken to encourage landowners to establish adequate and effective vegetated buffers along the shoreline. For a copy of The Buffer Handbook, contact the Maine DEP's Bureau of Land & Water Quality in Augusta (287-2112) or for technical assistance regarding buffers, contact the KC-SWCD or CWD.

Action Item # 3: Educate watershed citizens about shoreline buffers		
Activity	**Participants**	**Schedule & Cost**
• Continue Buffer Awareness Campaign. • Provide demonstration buffer plantings. • Vegetate unbuffered shoreline areas around Wilson Pond.	Maine DEP, *Friends of the Cobbossee Watershed*, Cobbossee Watershed District, watershed citizens	Begin immediately - Cost is variable, depending on projects

Non-Shoreline Residential Development: Non-shoreline development is estimated to contribute more total phosphorus to Wilson Pond than shoreline land uses. Therefore, non-shoreline development should also be regarded as a potential problem, especially areas near drainage brooks and streams. The educational campaign conducted by the CWD and *Friends* (see above) should be expanded to include a watershed-wide outreach program. Actions that should be encouraged include establishing or maintaining vegetated buffer strips down-gradient of developed areas, changing lawn practices by encouraging compliance with a recently passed State law to ban high phosphorus fertilizers on non-agricultural lawns, and practicing proper erosion control during any construction activities, however minor.

Action Item # 4: Expand homeowner education & technical assistance programs		
Activity	**Participants**	**Schedule & Cost**
Provide stormwater management education to small business owners and residents in the Watershed.	Maine DEP, *Friends of the Cobbossee Watershed*, Cobbossee Watershed District, watershed citizens	Begin immediately- $2,000

Roadways: There has been substantial information gathered regarding the condition and potential NPS influence of the roadways in the watershed of Wilson Pond, particularly in close proximity to the pond itself. The majority of this information was gathered as part of the Wilson Pond Watershed Survey Project (#ME-2005R-02).

In general, the CWD has, and will, continue to make available to local camp road associations and member municipalities technical advice on proper road design and maintenance. Recommendations generally include the installation of typical roadside BMPs such as reshaping of ditches, culvert maintenance, proper crowning of roads, and installing plunge pools and turnouts.

The municipalities of the CWD, and in this watershed, Winthrop and Monmouth in particular, have cooperated with the CWD in the past on town road-related problems as they become apparent. The CWD will continue to seek this cooperation when erosion or drainage related problems arise on town roads in the watershed.

Action Item # 5: Continue to establish & maintain roadway BMP's		
Activity	**Participants**	**Schedule & Cost**
• Provide technical assistance to municipalities and camp road associations. • Monitor and maintain BMPs on culverts, ditches and roads.	Towns of Monmouth, Wayne, and Winthrop, Cobbossee Watershed District, local Road Associations	Immediately & ongoing-Variable cost depending on extent of projects and assistance

Septic Systems: Antiquated and/or poorly designed and installed septic systems within the shoreland zone may contribute substantially to the annual total phosphorus load to adjacent lake water, adding to the cumulative phosphorus load to Wilson Pond. While Wilson Pond septic systems – when properly sited, constructed, maintained, and set back from the water – should have a minimal effect on lake water quality, systems that do not meet all of these criteria have the potential to contribute phosphorus and other contaminants to lake water. Systems around Wilson Pond which are sited in coarse, sandy soils with minimal filtering capacity, and which are situated in zones where groundwater in-seepage is significant, are especially likely to contribute nutrients to lake waters. This is particularly true for old systems which pre-date Maine's 1974 Plumbing Code.

Available options for reducing septic system-related phosphorus loading to Wilson Pond include seeking the replacement of pre-Plumbing Code septic systems and other poorly functioning systems within the shoreland zone of Wilson Pond. Identification of potential problem systems can be accomplished through a combination of shorefront property owner questionnaire surveys and/or formal sanitary surveys (e.g., dye testing). Educational efforts should make residents aware of impending problems and possible cost-effective solutions. Lakeshore residents who believe they may have problems with their septic systems are encouraged to contact their town office for possible technical and/or financial assistance.

Action Item # 6: Conduct septic system inspections and/or surveys		
Activity	**Participants**	**Schedule & Cost**
Conduct septic system inspections/ surveys to identify any potential malfunctions and promote regular pumping to ensure proper septic system operation.	Maine DEP, Towns of Monmouth, Wayne, and Winthrop, Cobbossee Watershed District, and watershed citizens.	Annually beginning in 2008 $1,500/yr

Municipal Action: Municipal officials ongoing training in current erosion and sediment control methods will ensure public compliance with local and state water quality laws and ordinances (Shoreland Zoning, Erosion and Sedimentation Control Law, plumbing code). This can be achieved through education and enforcement action, when necessary.

Action Item # 7: Ongoing BMP training for municipal officials		
Activity	**Participants**	**Schedule & Cost**
Municipal officials should continue to ensure compliance with local and State water quality laws and ordinances.	Maine DEP, Maine DOT, KC-SWCD, Towns of Monmouth, Wayne, and Winthrop, Cobbossee Watershed District, interested watershed citizens	Annually beginning 2008- $1000

Forest Land: Since forested land in the watershed contributes a relatively low amount of phosphorus, landowners should be encouraged to retain land as forest land. Given that future development potential in the Wilson Pond watershed is expected to be relatively high, permanent land conservation easements or landowner incentives may provide additional water quality protection. Maine Forest Service can provide on the ground technical assistance to get landowners started on long-term forest management strategies, cost-share opportunities, and information on current use tax laws including tree growth tax law (C. Martin, personal comm.).

Action Item # 7: Forest Land Conservation and Management		
Activity	**Participants**	**Schedule & Cost**
• Provide technical assistance to forest land owners. • Inform landowners of incentives, cost-share opportunities, management strategies, and relevant tax laws. • Work with KLT to continue to protect land in the watershed.	Maine Forest Service, Kennebec Land Trust (KLT), CWD, interested watershed citizens	Immediately & Ongoing - Minimal cost

In-Lake Nutrient Inactivation – Phosphorus release from Wilson Pond sediments during periods of thermal stratification and hypolimnetic anoxia appear to be substantial on a relative basis. Phosphorus release from oxic sediments in Wilson Pond may also be contributor as well. The 90 kg of TP presumably released from Wilson Pond sediments during the summer of 2006 may have resulted in an approximately 7 ppb increase in in-lake total phosphorus.

Applying aluminum compounds to Wilson Pond sediments to reduce the internal release of phosphorus during periods of anoxia may offer some reduction in the internal loading component, but such a costly effort may offer no visible signs of improvement during the summer period. Generally, the phosphorus released from Wilson Pond sediments becomes available in the photic zone during the fall period, and even then has yet to trigger a nuisance algae bloom as defined by the Maine DEP. It is anticipated that through reducing the external sources of phosphorus to Wilson Pond, that the magnitude of the internal load will eventually be reduced as well.

WATER QUALITY MONITORING PLAN

Historically, the water quality of Wilson Pond has been monitored on a monthly basis during open water periods by the CWD since 1976. The monitoring program has been augmented through the effort of local volunteers who provide frequent Secchi disk transparency data (Maine DEP and VLMP). Continued long-term water quality monitoring of Wilson Pond will be conducted, between the months of May to October, through the continued efforts of the CWD. Under this planned, post-TMDL water quality-monitoring scenario, sufficient data will be acquired to adequately track future seasonal and inter-annual variation and long-term trends in water quality in Wilson Pond.

PCAP CLOSING STATEMENT

The Cobbossee Watershed District (CWD) has worked diligently since the early to mid-1970's addressing nonpoint source pollution in the watershed of Wilson Pond and other CWD lakes. Technical assistance by the CWD is available to all District towns to mitigate phosphorus export from existing NPS pollution sources and the prevention of excess loading from future sources through the CWD's technical advice to local planning boards. The CWD Towns, including The Towns of Monmouth, Wayne, and Winthrop have long recognized the value of local water resources to the local way of life in the respective communities as well as the local economies, and provide strong support to lake restoration and protection efforts. These Towns should be commended for their continued support of, and cooperation with, the CWD in the pursuit of lake protection and improvement. The CWD also works closely with the Natural Resource Conservation Service to collaboratively address agricultural based nutrient loading. The Cobbossee Watershed District regularly joins forces with the Kennebec County Soil and Water Conservation District to identify NPS sites and develop effective mitigation strategies, and works closely with the recently formed *Friends of the Cobbossee Watershed* to thwart the threat posed by invasive aquatic species and to promote education and outreach. Based on the teamwork approach to lake improvement demonstrated over the past 34 years, there is a very high probability that the CWD will continue to garner support from the local community, regional agencies, and the Maine DEP to advance the Wilson Pond restoration efforts.

APPENDICES

WILSON POND (Monmouth, Wayne and Winthrop)

Total Maximum Daily (Annual Phosphorus) Load

Maine Lake TMDLs and Phosphorus Control Action Plans (PCAPs)

You may be wondering what the acronym 'TMDL' represents and what it is all about. TMDL is actually short for 'Total Maximum Daily Load' as historically applied to point-source pollutants. This information, no doubt, does little to clarify TMDLs in most people's minds. However, when we think of this as an annual phosphorus load (*Annual Total Phosphorus Load),* it begins to make more sense, for nonpoint source pollution. Following EPA guidance (Spring 2006), we now report daily and annual phosphorus loads.

Simply stated, excess nutrients or phosphorus in lakes promote nuisance algae growth/blooms - resulting in the violation of water quality standards as measured by water clarity depths of less than 2 meters. A lake TMDL is prepared to estimate the total amount of total phosphorus that a lake can accept on an annual basis without harming water quality. Historically, development of TMDLs was first mandated by the Clean Water Act in 1972, and was applied primarily to *point sources* of water pollution. As a result of public pressure to further clean up water bodies, lake and stream TMDLs are now being prepared for watershed-generated *Non-Point Sources* (NPS) of pollution.

Nutrient enrichment of lakes through excess total phosphorus originating from watershed soil erosion has been generally recognized as the primary source of NPS pollution. Major land use activities contributing to the external phosphorus load in lakes include residential-commercial developments, roadways, agriculture, and commercial forestry. Statewide, there are 32 lakes in Maine which do not meet water quality standards due to excessive amounts of in-lake total phosphorus - the great majority of which are located in south-central Maine.

The first Maine lake TMDL was developed (1995) for Cobbossee Lake by the Cobbossee Watershed District (CWD) - under contract with Maine DEP and U.S. EPA. Recently (June 2006), Cobbossee Lake was officially removed from the TMDL listing of "impaired" waterbodies, in light of 9 years of above standard water clarity measures. TMDLs have been approved by U.S. EPA for Madawaska Lake (Aroostook County), Sebasticook Lake, East Pond (Belgrade Lakes), China Lake, Webber, Threemile and Threecornered ponds (Kennebec County), Mousam Lake, the Highland lakes in Falmouth and Bridgton, Annabessacook Lake, Pleasant Pond, Upper Narrows Pond and Little Cobbossee Lake (under contract with CWD), Sabattus, Toothaker, and Unity ponds and Long Lake (with assistance from Lakes Environmental Association), Togus Pond, Duckpuddle Pond, Lovejoy Pond, Lilly Pond, Sewall Pond, Cross Lake, Daigle Pond, Trafton Lake, and Monson Pond, Arnold Brook Lake, and Echo Lake. A PCAP-TMDL for Long Pond is presently being prepared by Maine DEP, with assistance from FB Environmental Consulting. PCAP-TMDL studies have also been initiated for Long Pond and for Christina Reservoir, the last of the remaining 2004 303(d) listed PCAP-TMDL waterbodies in Aroostook County.

Lake PCAP-TMDL reports are based in part on available water quality data, including seasonal measures of total phosphorus, chlorophyll-a, Secchi disk transparencies, and dissolved oxygen-water temperature profiles. Actual reports include: a lake description; watershed GIS assessment and estimation of NPS pollutant sources; selection of a total phosphorus target goal (acceptable amount); allocation of watershed/land-use phosphorus loadings, and a public participation component to allow for stakeholder review.

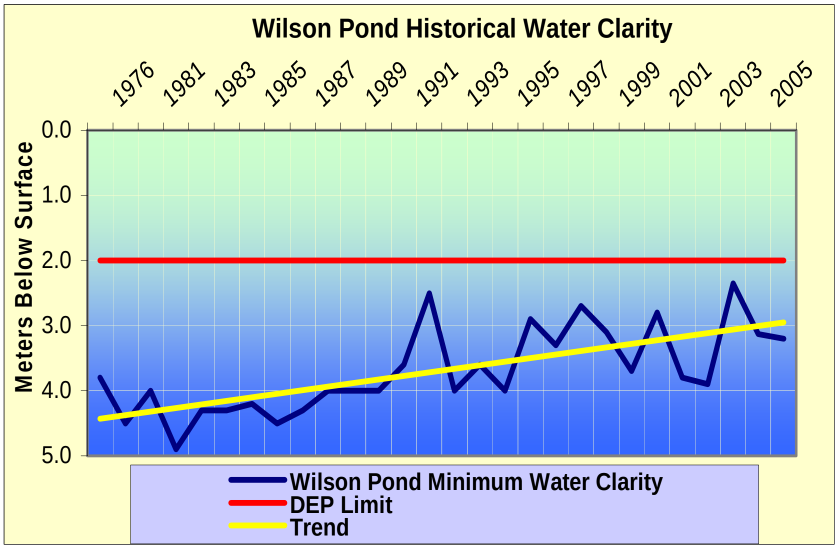
PCAP-TMDLs are important tools for maintaining and protecting acceptable lake water quality and are designed to 'get a handle' on the magnitude of the NPS pollution problem and to develop plans for implementing Best Management Practices (BMPs) to effectively address the lake's water pollution problem. Landowners and watershed groups are eligible to receive technical and financial assistance from state and federal natural resource agencies to reduce watershed total phosphorus loadings to the lake. **Note:** for non-stormwater regulated lake watersheds, the *development of phosphorus-based lake PCAP-TMDLs are not generally intended by Maine DEP to be used for regulatory purposes*.

For further information, contact Dave Halliwell, Maine Department of Environmental Protection,
Lakes PCAP-TMDL Program Manager, SHS #17, Augusta, ME 04333 (207-287-7649).
E-mail: david.halliwell@maine.gov

Water Quality, Priority Ranking, and Algae Bloom History

Water Quality Monitoring: (Source: Cobbossee Watershed District) The Cobbossee Watershed District (CWD) in conjunction with the Maine Department of Environmental Protection (Maine DEP) and the Volunteer Lake Monitoring Program (VLMP) have collaborated in the collection of lake data to evaluate present water quality, track algae blooms, and determine water quality trends in Wilson Pond. Water quality monitoring data for Wilson Pond (station 1, deep hole) has been collected since 1976 (76, 79, 81-06). Hence, this present water quality assessment is based on twenty-eight years of water quality data including 28 years of Secchi disk transparency (SDT) measures, combined with 24 years of epilimnion core and/or profile total phosphorus (TP) data, and 19 years of chlorophyll-a measures.

Water Quality Measures: (Source: Cobbossee Watershed District) Historically, Wilson Pond has had a range of SDT measures from 2.4 to 7.7 m, with an average of 5.0 m; an epilimnion TP range of 7 to 18 with an average of 12 parts per billion (ppb), and chlorophyll-a measures ranging from 1.6 to 26.7 ppb, with an average of 6.2 ppb.



The water clarity readings for Wilson Pond, although consistently above minimum standards, have gradually declined since the 1980's. Over the past three decades, the water clarity in Wilson Pond has declined by an average of 1 meter.

Chlorophyll-a, an indicator of algal biomass, had been consistently below the Maine state standard, 8 ppb until 1990. Since that time, the maximum value for Chl-a has exceeded 8 ppb during 11 of 14 years that Chl-a was monitored in the pond. During this same period, the annual average Chl-a exceeded the 8 ppb standard 4 times.

As Wilson Pond is a dimictic lake, it completely mixes, or "turns over", twice per year, once in the fall and once in the spring. Thermal stratification becomes established usually by the end of May and continues through October. During this period, oxygen commonly becomes depleted in the hypolimnion by August or September. Recent dissolved oxygen (DO) profiles show high DO depletion in deep areas of the lake. The potential for TP to leave the bottom sediments and become available to algae in the water column (internal loading) is high. Oxygen levels below 5 parts per million stress certain cold water fish, and a persistent loss of oxygen may eliminate or reduce habitat for sensitive cold water species (see Fish Assemblage & Fisheries Status - p.12).

Phosphorus, the nutrient that limits algal growth in the pond, has maintained a fairly consistent concentration since the 1970's. Based on epilimnetic values, springtime concentrations have ranged from 9 to 15 ppb with a general trend toward the higher values over the past 15 years. The seasonal means have generally been between 11 and 18 ppb, with 2004 having both the springtime and annual averages, 15 and 18 ppb, respectively.

As indicated by the chart above, the water quality of Wilson Pond has generally declined over the historical monitoring period. Following two "bloom" events in 1991 and 1992, water clarity in the pond improved slightly for a brief period, but has since continued a gradual, downward trend. The potential for nuisance blue-green algal blooms on Wilson Pond is moderate.

Priority Ranking, Pollutant of Concern and Algae Bloom History: Wilson Pond is listed on the State's 2006 303(d) list of impaired waterbodies. This Wilson Pond TMDL has been developed for total phosphorus, the major limiting nutrient to algae growth in freshwater lakes in Maine.

Total phosphorus loading to Wilson Pond from associated upstream sources, Dexter Pond (132 kg/ year), accounts for loading from the indirect watershed, determined on the basis of flushing rate x volume x TP concentration.

Natural Environmental Background levels for Wilson Pond were not separated from the total non-point source load because of the limited and general nature of available information. Without more and detailed site-specific information on nonpoint source loading, it is very difficult to separate natural background from the total nonpoint source load (US-EPA 1999).

WATER QUALITY STANDARDS & TARGET GOALS

Maine State Water Quality Standard for nutrients which are narrative, are as follows *(July 1994 Maine Revised Statutes Title 38, Article 4-A)*: "Great Ponds Class A (GPA) waters shall have a stable or decreasing trophic state (based on appropriate measures, e.g., total phosphorus, chlorophyll-a, Secchi disk transparency) subject only to natural fluctuations, and be free of culturally induced algae blooms which impair their potential use and enjoyment."

Maine DEP's functional definition of nuisance algae blooms include episodic occurrence of Secchi disk transparencies (SDTs) < 2 meters for lakes with low levels of apparent color (<30 SPU) and for higher color lakes where low SDT readings are accompanied by elevated chlorophyll-a levels (>8 ppb). Wilson Pond is a non-colored lake (average color 17 SPUs), with declining minimum transparency measures. Currently, Wilson Pond does not meet water quality standards primarily due to increasing trophic state. This water quality assessment uses historic documented conditions as the primary basis for comparison.

Designated Uses and Antidegradation Policy: Wilson Pond is designated as a GPA (Great Pond Class A) water in the Maine DEP state water quality regulations. Designated uses for GPA waters in general include: water supply; primary/secondary contact recreation (swimming and fishing); hydro-electric power generation; navigation; and fish and wildlife habitat. No change of land use in the watershed of a Class GPA water body may, by itself or in combination with other activities, cause water quality degradation that would impair designated uses of downstream GPA waters or cause an increase in their trophic state. Maine's anti-degradation policy requires that "existing in-stream water uses, and the level of water quality necessary to sustain those uses, must be maintained and protected."

Numeric Water Quality Target: The numeric (in-lake) water quality target for Wilson Pond is set at 13 ppb total phosphorus (638 kg/yr). Since numeric criteria for phosphorus do not exist in Maine's state water quality regulations - and would be less accurate targets than those derived from this study - we employed best professional judgment to select a target in-lake total phosphorus concentration that would allow for the attainment of the State's narrative standard by reversing the declining trend in Wilson Pond water quality. This goal is based on available lake-specific water quality data as Wilson Pond has at times attained this standard based on available historical water quality records.

ESTIMATED PHOSPHORUS EXPORT BY LAND USE CLASS

Table 3 details the numerical data used to determine external phosphorus loading for the Wilson Pond watershed. The key below Table 3 on the next page explains the columns and the narrative that follows (pages 29-30) relative to each of the representative land use classes.

Table 3. Wilson Pond Direct Watershed - Estimated Phosphorus Export by Land Use Class

LAND USE CLASS	Total Area Acres	Land Area %	TP Coeff. Avg. kg/P/ha	TP Coeff. Range kg/P/ha	Land Area Hectares	TP Export Load kg TP	TP Export Total %
Agriculture							
Hayland (non-manured)	234	4.8%	0.64	0.35 -1.81	94	60	19%
Cultivated Crops (post 2004)	0	0%	2.24	0.26 -18.6	0	0	0%
Pasture	38	0.8%	0.81	0.14 - 4.90	15	13	4%
Orchard	88	1.8%	0.60	0.06 - 0.75	36	21	7%
Sub-totals	**360**	**7%**			**145**	**94**	**30%**
Actively Managed Forest							
Light-Cut Forest	236	5%	0.08	0.01 - 0.2	96	8	2%
Sub-totals	**236**	**5%**			**96**	**8**	**2%**
Shoreline Development							
Low Impact residential	12	0.2%	0.5	0.25 - 1.75	5	2	0.8%
Medium Impact residential	3	0.1%	1.0	0.4 - 2.2	1	1	0.4%
High Impact residential	14	0.3%	1.4	0.4 - 2.2	6	8	3%
Shoreline Septic Systems	seasonal	N/A				9	3%
Shoreline Septic Systems	year-round	N/A				19	6%
Unimproved Roads	10	0.2%	2	0.60 - 10.0	4	8	3%
Sub-totals	**39**	**1%**			**16**	**49**	**16%**
Non-Shoreline Development							
Low Impact Residential	88	2%	0.5	0.25 - 1.75	36	18	6%
Medium Impact Residential	8	0.2%	1	0.25 - 1.75	3	3	1%
Commercial	7	0.1%	1.92	0.8 - 4.20	3	5	2%
Institutional	11	0.2%	1.92	0.8 - 4.20	4	8	3%
Town and State Roads	38	0.8%	1.5	0.60 - 10.0	16	23	7%
Unimproved Roads	7	0.2%	2	0.60 - 10.0	3	6	2%
Parks, Cemeteries	2	0.04%	0.8	0.25 - 0.98	0.8	0.6	0.2%
Sub-totals	**161**	**3%**			**65**	**65**	**20%**
Total: DEVELOPED LAND	**796**	**16%**			**322**	**215**	**68%**
Non-Developed Land							
Inactive/Passively managed Forest	3,273	67%	0.04	0.01 - 0.2	1,324	53	17%
Scrub-Shrub	7	0.1%	0.15	0.01 - 0.2	3	0.4	0.1%
Grassland/Reverting Fields	158	3%	0.15	0.01 - 0.2	64	10	3%
Wetlands	58	1%	0.01	0.02 - 0.83	24	0.2	0.1%
Total: NON-DEVELOPED LAND	**3,496**	**72%**			**1,415**	**63**	**21%**
Total: Surface Water (Atmospheric)	**562**	**12%**	0.16		**228**	**36**	**11%**
Totals: DIRECT WATERSHED	**4,855**	**100%**			**1,965**	**314**	**100%**

Key for Columns in Table 3

Land Use Class: The land use category that was analyzed for this report.

Land Area in Acres: The area of each land use as determined by GIS mapping, and aerial photography.

Land Area %: The percentage of the watershed covered by the land use.

TP Coeff. Range kg/ha: The range of the total phosphorus coefficient values listed in the literature associated with the corresponding land use.

TP Coeff. Value kg/ha: The selected coefficient for each land use category. The total phosphorus coefficient is determined from previous research – usually the median value, if listed by the author.

Land Area in Hectares: Conversion, 1.0 acre = 0.404 hectares.

TP Export Load kg TP : Land area in hectares x TP coefficient value for the land use category.

TP Export Total %: The percentage of estimated phosphorus exported by the land use.

Total Phosphorus Land Use Loads

Estimates of total phosphorus export from different land uses found in the Wilson Pond watershed as presented on the previous page in Table 3. This table represents the extent of the current direct watershed phosphorus loading to the lake (314 kg/yr). Total phosphorus loading from Wilson Pond's indirect watershed (Berry Pond and Dexter Pond –132 kg/yr), was determined on the basis of *flushing rate (9.52 times/yr) x volume (1.23 x* 10^6 m^3*) x TP concentration (13ppb),* representing typical area gauged stream flow calculations.

Total phosphorus loading measures are provided as a range of values to reflect the degree of uncertainty generally associated with such relative estimates (Walker 2000). The watershed total phosphorus loading values were primarily determined using literature and locally-derived export coefficients as found in Schroeder (1979), Reckhow et al. (1980), Dennis (1986), Dennis et al. (1992), and Bouchard et al. (1995) for residential properties, roadways, agriculture and other types of land uses.

Agriculture: Phosphorus loading coefficients as applied to agricultural land uses were adopted from: Dennis and Sage (1981): non-manured hayland (0.64 kg/ha/yr), and Reckhow et al. (1980): row crops/ tillage/cultivation (2.24 kg TP/ha/yr).

Actively Managed Forest Land: The phosphorus loading coefficient applied to actively managed forest land (0.08 kg/ha/yr) was changed beginning with the Long Lake PCAP-TMDL report (2005) following consultation with Lakes Environment Association and Maine Forest Service staff. The rationale for this change was based on the fact that properly managed harvest areas will generally act as phosphorus sinks during periods of regeneration. According to the Maine Forest Service, of the nearly 3,500 water quality inspections conducted throughout the state in 2003, approximately 7% of the harvested sites posed “unacceptable” risks to water quality.

PCAP-TMDL reports prior to the Long Lake report identified a “worst case” upper limit phosphorus loading coefficient of 0.6 kg/ha/yr for operated forestland. Therefore, for any given watershed in Maine we determined that applying this “worst case” coefficient to 7% of operated forest land while applying the “best case” coefficient (0.04 kg/ha/yr) to the remaining operated forest land would provide a relatively accurate estimate of total phosphorus loading from operated forest land. Combining worst case and best case coefficients yields the new phosphorus loading coefficient for operated forest land of 0.08 kg/ha/yr [(0.07 x 0.6) + (0.93 x 0.04)].

Residential Development: The phosphorus loading coefficients for residential land uses, including; low density residential (0.5 kg/ha/yr), medium density residential (1.0 kg TP/ha/yr), and high density residential (1.4 kg TP/ha/yr) were developed from information on residential lot stormwater export of phosphorus as derived from Dennis et al (1992), and first implemented in the 1995 Cobbossee Lake TMDL.

Private and Public Roads: The total phosphorus loading coefficient for private and public roads (2.0 kg/ha/yr for shoreline roads and 1.5 kg/ha/yr for non-shoreline roads) was chosen, in part, from previous studies of rural Maine highways (Dudley et al. 1997) and phosphorus research by Jeff Dennis (Maine DEP).

Parks/Cemeteries: The phosphorus loading coefficient for parks and cemeteries (0.80 kg TP/ha/yr) is based on unpublished research from Wagner-Mitchell-Monagle (BEC 1989).

Total Developed Lands Phosphorus Loading: A total of 68% (215 kg) of the phosphorus loading to Wilson Pond is estimated to have been derived from the cumulative effect of the preceding cultural land use classes: agriculture (30% - 94 kg); forestry (2% - 8 kg); shoreline development 15% - 49 kg); and non-shoreline development (20% - 64 kg) as depicted in Table 3.

Non-Developed Lands Phosphorus Loading: The phosphorus export coefficient for inactive/ passively managed forest land (0.04 kg/ha/yr) is based on a New England regional study (Likens et al 1977) and phosphorus availability recommendation by Jeff Dennis (Maine DEP). The phosphorus export coefficient for grassland/reverting fields and scrub/shrub (0.15 kg/ha/yr) is based on research for the Annabessacook Lake TMDL in 2004, and by Bouchard in 1995. The export coefficient for wetlands is based on research by Bouchard 1995 and Monagle 1995 (0.01 kg/ha/yr). The phosphorus loading coefficient chosen for surface waters (atmospheric deposition - 0.16 kg/ha/yr), was originally used in the China Lake TMDL (Kennebec County), and subsequent PCAP-TMDL lake studies in Maine.

Shoreline Erosion: Undeveloped areas of the lake shoreline that may be eroding due to natural causes (i.e., wind, wave and ice action) are not included as a source of phosphorus due to the difficulty in quantifying impact area and assigning suitable phosphorus loading coefficients.

Phosphorus Load Summary

It is our professional opinion that the selected export coefficients are appropriate for the Wilson Pond watershed. Results of the land use analysis indicate that a best estimate of the present total phosphorus loading from external (direct and indirect drainages) nonpoint source nutrient pollution for Wilson Pond approximates 446 (314 +132) kg/yr.

LINKING WATER QUALITY and POLLUTANT SOURCES

Annual/Daily Load Capacity: Total Phosphorus (TP) serves as a surrogate measure of Maine's narrative water quality standards for lake trophic status. The phosphorus-based TMDL is originally calculated as an annual load (kg TP/yr), which is based on an in-lake numeric water quality target (ppb or ug/l TP) and the annual flushing rate of the lake, using generally accepted response models for lakes. It is appropriate and justifiable to express the Wilson Pond TMDL as an annual load because the lake basin has an annual flushing rate of 1.8 (see discussion of seasonal variation on page 33). The annual flushing rate, or the theoretical rate at which water in a lake is replaced on an annual basis, is calculated as:

 # *Flushes/year* = (Watershed area * Runoff/year) / Lake volume

This TMDL also presents daily pollutant loads of TP in addition to the annual load. Daily flushing rates were determined by first calculating the monthly discharge from Dudley (2004). A number of parameters were required for input into these formulas including: Drainage area; % of significant sand and gravel aquifers; distance from the watershed to a predetermined line off the Maine coast; and mean annual precipitation. These parameters were determined using GIS (ArcMap 8.3).

Once the monthly discharge was determined, this information was used to ascertain the following:

% Total Monthly Discharge = (Total monthly discharge/ Total annual discharge) *100

 # *Flushes/month* = (Total # of flushes/year * % of total monthly discharge)

 # *Flushes/day* = (Flushes/month)/(Days/month)

The majority of the parameters used for calculating the annual loading capacity (kg TP/yr) on page 34 (Dillon and Rigler 1974, where L= (Azp)/(1-R)), remain unchanged for use in calculating the daily loading capacity. The exception is p, where p now equals flushes/month. Thus, the monthly loading capacity is expressed as a proportion of the annual loading capacity, based on the discharge expected for that month. The daily loading capacity was then calculated as follows:

Daily Load Capacity (kg/day) = (Monthly Load Capacity)/(Days/month)

The daily loads for Wilson Pond are presented on page 35.

Assimilative Loading Capacity: The Wilson Pond basin lake assimilative capacity is capped at 638 kg TP/yr, as derived from the empirical phosphorus retention model based on a target goal of 13 ppb. This value reflects the modeled annual phosphorus loading responsible for current trophic state conditions, based on a long term goal of maintaining average phosphorus concentrations at or below 13 ppb. This TMDL target concentration is expected to be met at all times (daily, monthly, seasonally, and annually). However, because the annual load of TP as a TMDL target is more easily aligned with the design of best management practices used to implement nonpoint source and stormwater TMDLs for lakes than daily loads of specific pollutants, this TMDL report recommends that the annual load target in the TMDL be used to guide implementation efforts. Ultimate compliance with water quality standards for the TMDL will be determined by measuring in-lake water quality to determine when standards are attained.

Future Development: In order to effectively meet the stated goal of decreasing the current trophic state conditions, further reductions in the existing watershed loading is necessary. Although very little development has occurred in the watershed over the past several years, the region is expected to be a relatively high growth area in the near future. The unmitigated rate of increase in Wilson Pond's annual phosphorus load due to new development approximates 37 kg TP/yr (Dennis et al. 1992 application).

The Maine DEP water quality goal of a decreasing trophic state includes a reduction of current P-loading which accounts for both current P-loading as well as potential future development in the watershed. The methods used by the Maine DEP to estimate future growth (Dennis et al. 1992) are inherently conservative, as they provide for relatively high-end regional growth estimates and largely non-mitigated P-export from new development. This provides an additional non-quantified margin of safety to ensure the attainment of state water quality goals.

Anticipated P-loading from future development in the Wilson Pond watershed is 37 kg (1 ppb change in trophic state = 49 kg x 0.75). Hence, existing phosphorus load sources must be reduced by an additional 37 kg/yr to allow for anticipated new sources of phosphorus loading to the pond.

Internal Lake Sediment Phosphorus Mass: The relative contribution of internal sources of total phosphorus within Wilson Pond – in terms of internal recycling of sediment-based phosphorus – were analyzed (using lake volume-weighted mass differences between late spring and late summer/early fall) and estimated on the basis of water column TP data from 2006. During the summer of 2006, in-lake total phosphorus increased from a low of 141 (June 12) to 231 kg (September 12). It is assumed that this increase (90 kg/yr) is attributed primarily to internal recycling of phosphorus from phosphorus-rich sediments.

Linking Pollutant Loading to a Numeric Target: The basin loading assimilative capacity for non-colored Wilson Pond was set at 638 kg/yr of total phosphorus to meet the numeric water quality target of 13 ppb of total phosphorus. A phosphorus retention model, calibrated to in-lake phosphorus data, was used to link phosphorus loading to numeric target.

Supporting Documentation for the Wilson Pond TMDL Analysis includes the following: CWD water quality monitoring data; watershed land use maps; literature derived phosphorus export coefficients; and specification of a phosphorus retention model - including both empirical models and retention coefficients.

Wilson Pond Total Phosphorus Retention Model

(after Dillon and Rigler 1974 and others)

L = P (A z p) / (1-R) where, **1 ppb change = 49 kg**

638 = **L** = total phosphorus load capacity (kg TP/year)
13 = **P** = total phosphorus concentration (ppb) = Target Goal = **13 ppb**
2.23 = **A** = lake basin surface area (km^2) = 36 ha or 90 acres
7.0 = **z** = mean depth of lake basin (m) **A z p = 28.10**
1.8 = **p** = annual flushing rate (flushes/year)
0.57 = **1- R** = phosphorus retention coefficient, where:
0.43 = **R = 1 / (1+ sq. rt. p)** (Larsen and Mercier 1976)

Previous use of the Vollenweider (Dillon and Rigler 1974) type empirical model for Maine lakes, e.g., Cobbossee, Madawaska, Sebasticook, East, China, Mousam, Highland (Falmouth), Webber, Threemile, Threecornered, Annabessacook, Pleasant, Sabattus, Toothaker, Unity, Upper Narrows, Highland (Bridgton), Little Cobbossee, Long (Bridgton), Togus, Duckpuddle, Lovejoy, Lilly, Sewall, Cross, Daigle, Trafton, Monson, Echo, and Arnold Brook Lake PCAP-TMDL reports (Maine DEP 2000-2006) have all shown this approach to be effective in linking watershed total phosphorus (external) loadings to existing in-lake total phosphorus concentrations.

Strengths and Weaknesses in the Overall TMDL Analytical Process: The Wilson Pond TMDL was developed using existing water quality monitoring data, collected and compiled by CWD; derived watershed phosphorus export coefficients (Reckhow et al. 1980, Maine DEP 1981 and 1989, Dennis 1986, Dennis and McPhedran 1991, Dennis et al. 1992, Bouchard et al. 1995, and Monagle 1995); and a phosphorus retention model which incorporates both empirically derived and observed retention coefficients (Vollenweider 1969, Dillon 1974, Dillon and Rigler 1974 a and b, and 1975, Kirchner and Dillon 1975). Use of the Larsen and Mercier (1976) total phosphorus retention term, based on localized data (northeast and north-central U.S.) from 20 lakes in the US-EPA National Eutrophication Survey (US-EPA-NES) provides a more accurate model for northeastern regional lakes.

Strengths:

- Approach is commonly accepted practice in lake management.
- Makes best use of available water quality monitoring data.
- Export coefficients were derived from extensive databases, and were determined to be appropriate for the application lake.
- Based upon experience with other lakes in the northeastern U.S. region, the empirical phosphorus retention model was determined to be appropriate for the application lake.

Weaknesses:

- Inherent uncertainty of TP load estimates (Reckhow 1979, Walker 2000) and associated variability and generality of TP loading coefficients.
- Absence of TP loading coefficients for shoreline erosion contribution.

Critical Conditions occur in Wilson Pond during the late summer and early autumn, when the potential (both occurrence and frequency) of nuisance algae blooms are greatest. The loading capacity of 13 ppb of total phosphorus was set to achieve desired water quality standards during this critical time period, and will also provide adequate protection throughout the year (see Seasonal Variation).

LOAD ALLOCATIONS (LA's) - The load allocation for Wilson Pond equals 638 kg TP on an annual basis and represents, in part, that portion of the lake's assimilative capacity allocated to non-point (overland) sources of phosphorus (from Table 3). Direct external TP sources (totaling 314 kg annually) have been identified and accounted for in the land-use breakdown portrayed in Table 3 (corrected GIS). Further reductions in nonpoint source phosphorus loadings necessary to satisfy the load allocation will need to be produced from implementation of NPS best management practices for the road networks in the watershed and improved overall " environmental housekeeping" practices by all watershed residents, and for the, agricultural land uses (see summary, pages 20-23). As previously mentioned, it was not possible to separate natural background from non-point pollution sources in this watershed because of the limited and general nature of the available information. As in other Maine TMDL lakes (see Sebasticook Lake, East Pond, China Lake, and subsequent TMDLs), in-lake nutrient loadings in Wilson Pond originate from a combination of direct and indirect (watershed + Dexter Pond) external and internal (lake sediment) sources of total phosphorus.

WASTE LOAD ALLOCATIONS (WLA's): Since there are no existing point source discharges subject to NPDES permit requirements in the Wilson Pond watershed, the WLA is set at 0 (zero), and all of the loading capacity is allocated as a gross allotment to the "load allocation".

MARGIN OF SAFETY (MOS): The TMDL expressed in terms of annual and daily loads includes an implicit MOS through the relatively conservative selection of the numeric water quality target (based on a state-wide database for lakes, supported by in-lake data). Based on both the Wilson Pond historical records and a summary of statewide Maine lakes water quality data for non-colored (< 30 SPU) lakes - the target of 13 ppb (638 kg/yr in Wilson Pond) represents a highly conservative goal to assure future attainment of Maine DEP water quality goals of non-sustained and non-repeated blue-green summer-time algae blooms due to NPS pollution or cultural eutrophication and stable or decreasing trophic state.

SEASONAL VARIATION: The Wilson Pond TMDL is protective of all seasons, as the allowable annual load was developed to be protective of the most sensitive time of year – during the summer, when conditions most favor the growth of algae and aquatic macrophytes. With an average flushing rate of 1.8 flushes/year, the average annual phosphorus loading is most critical to the water quality in Wilson Pond. Maine DEP lake biologists, as a general rule, use more than six flushes annually (bi-monthly) as the cutoff for considering seasonal variation as a major factor (to distinguish lakes vs. rivers) in the evaluation of total phosphorus loadings in aquatic environments in Maine. Furthermore, non-point source best management practices (BMPs) proposed for the Wilson Pond watershed have been designed to address total phosphorus loading during all seasons.

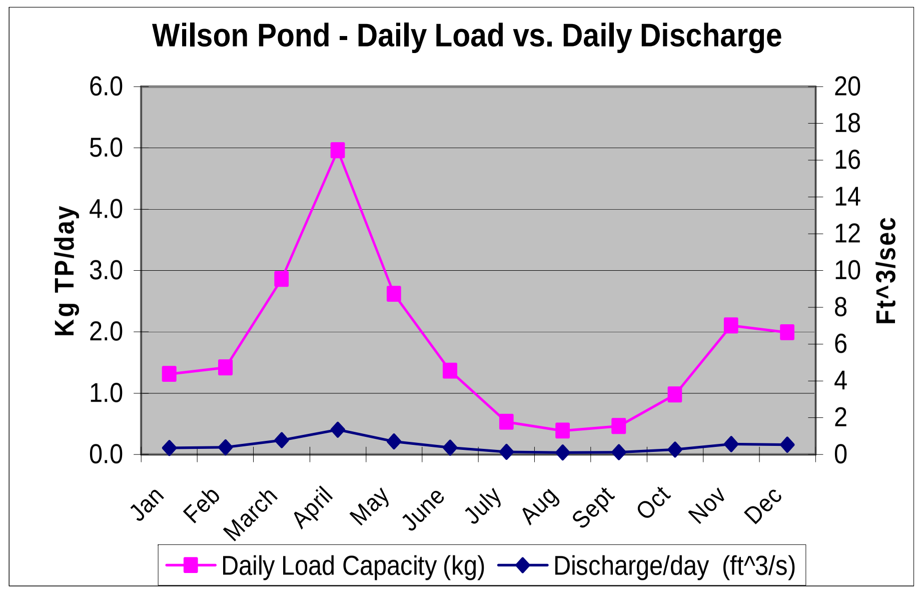
This variation is further accounted for in calculations of seasonal (May-October, November– April), monthly, and daily TP load calculations (p. 35). These numbers are derived from formulas developed by Dudley (2004) for ungaged rivers in Maine, and are based on several physical and geographic parameters including: 1) drainage area of the waterbody, 2) percent of sand and gravel aquifers in the drainage area, 3) distance from a stationary line along the Maine coast, and 4) mean annual precipitation. Daily loading rates are then determined using variables from Dillon and Rigler (1974 - p. 33) for calculating the external total phosphorus load capacity (pp. 28-31) for the lake.

Daily TP Pollutant Loads for Wilson Pond

Month	Discharge (ft^3/s)	% of Total	Flushes/month	Monthly Load Capacity (kg)	Discharge/day (ft^3/s)	Flushes/day	Daily Load Capacity (kg)
Jan	11.01	6%	0.11	40.7	0.092	0.004	1.31
Feb	10.75	6%	0.11	39.8	0.095	0.004	1.42
March	24.00	14%	0.25	88.8	0.20	0.008	2.86
April	40.23	23%	0.42	148.8	0.59	0.014	4.96
May	21.91	13%	0.23	81.1	0.58	0.007	2.62
June	11.06	6%	0.12	40.9	0.19	0.004	1.36
July	4.43	3%	0.05	16.4	0.070	0.001	0.53
Aug	3.23	2%	0.03	11.9	0.051	0.001	0.39
Sept	3.77	2%	0.04	13.9	0.062	0.001	0.46
Oct	8.19	5%	0.09	30.3	0.14	0.003	0.98
Nov	17.05	10%	0.18	63.1	0.31	0.006	2.10
Dec	16.69	10%	0.17	61.7	0.19	0.006	1.99

Season	% of Total	# Flushes
May -October	31%	0.5
November-April	69%	1.3

Vollenweider: L = P (Azp) / (1-R)	
L = external P load capacity (kg TP	638
P = total P concentration (ppb)	13
A = lake basin surface area (km2)	2.23
z = mean depth of lake basin (m)	7
p = annual flushing rate	1.8
1-R = P retention coefficient	0.57
R = 1 / (1 + sq. rt. p)	0.43



Regression Equations Used for Calculating Daily Loads for Wilson Pond (from Dudley, 2004)

16 **Estimating Monthly, Annual, and Low 7-Day, 10-Year Streamflows for Ungaged Rivers in Maine**

Table 7. Regression equations and their accuracy for estimating mean monthly streamflows for ungaged, unregulated streams in rural drainage basins in Maine

[ASEP, average standard error of prediction; PRESS, prediction error sum of squares; EYR, equivalent years of record; n, number of data points used in regression]

Regression equation	ASEP (in percent)	$(PRESS/n)^{1/2}$ (in percent)	Average EYR
$Q_{jan\ mean} = 36.36\ (A)^{1.007}\ (DIST)^{-0.771}$	-10.2 to 11.4	-11.1 to 12.5	29.9
$Q_{feb\ mean} = 46.79\ (A)^{0.991}\ (DIST)^{-0.829}$	-9.79 to 10.8	-12.0 to 13.7	41.2
$Q_{mar\ mean} = 109.10\ (A)^{0.924}\ (DIST)^{-0.807}$	-21.0 to 26.6	-22.4 to 28.8	7.27
$Q_{apr\ mean} = 1.362\ (A)^{1.006}\ 10^{0.013(pptA)}$	-15.6 to 18.4	-16.7 to 20.0	4.94
$Q_{may\ mean} = 0.350\ (A)^{1.035}\ (DIST)^{0.486}$	-15.8 to 18.8	-16.8 to 20.2	6.96
$Q_{jun\ mean} = 1.372\ (A)^{1.030}$	-14.6 to 17.1	-15.2 to 17.9	13.1
$Q_{jul\ mean} = 0.475\ (A)^{1.089}\ 10^{0.631(SG)}$	-19.3 to 24.0	-21.4 to 27.2	8.38
$Q_{aug\ mean} = 0.353\ (A)^{1.075}\ 10^{0.822(SG)}$	-22.0 to 28.2	-22.9 to 29.6	8.60
$Q_{sep\ mean} = 0.434\ (A)^{1.049}\ 10^{0.834(SG)}$	-19.9 to 24.9	-23.2 to 30.2	13.9
$Q_{oct\ mean} = 1.084\ (A)^{0.989}\ 10^{0.399(SG)}$	-19.3 to 24.0	-22.5 to 29.1	17.0
$Q_{nov\ mean} = 2.497\ (A)^{0.948}$	-18.6 to 22.9	-20.7 to 26.0	11.9
$Q_{dec\ mean} = 16.92\ (A)^{0.979}\ (DIST)^{-0.476}$	-12.4 to 14.1	-13.6 to 15.7	28.9

where,

Q — streamflow statistic of interest.

A — contributing drainage area, in square miles.

SG — fraction of the drainage basin that is underlain by significant sand and gravel aquifers, on a planar area basis, expressed as a decimal. For example, if 15 percent of the drainage area of a basin has significant sand and gravel aquifers, then *SG* = 0.15. Based on the significant sand and gravel aquifer maps produced by the Maine Geological Survey and maintained as GIS data sets by the Maine Office of GIS.

pptA — mean annual precipitation, in inches, computed as the spatially averaged precipitation in the contributing basin drainage area. Based on non-proprietary PRISM precipitation data spanning the 30-year period 1961-1990. Data maintained as GIS data sets by the Natural Resources Conservation Service (1998).

DIST —distance from the coast, in miles, measured as the shortest distance from a line in the Gulf of Maine to the contributing drainage basin centroid. The line in the Gulf of Maine is defined by end points 71.0W, 42.75N and 65.5W, 45.0N, referenced to North American Datum of 1983.

See the Regression Analyses section of this report for more details.

PUBLIC PARTICIPATION: Adequate ('full and meaningful') public participation in the Wilson Pond PCAP-TMDL development process was ensured - during which land use and phosphorus load reductions were discussed - through the following avenues:

1. **February 15, 2007:** FB Environmental staff met with Maine DEP and CWD to discuss the Wilson Pond TMDL process.

2. **April 2, 2007:** CWD Project Manager Bill Monagle met with the Winthrop Town Council to explain local lake conditions in general, and the decline in Wilson Pond water quality and the TMDL process.

3. **April 3, 2007:** CWD Project Manager Bill Monagle explained the Wilson Pond TMDL to the Town of Wayne Board of Selectmen.

4. **April 11, 2007:** CWD Project Manager Bill Monagle addressed the Town of Monmouth Board of Selectmen to provide an update on local lake water quality, including the apparent decline in Wilson Pond water quality and the TMDL process.

5. **April 2007:** Mr. Monagle submitted an annual summary to the Berry, Dexter, and Wilson Watershed Association outlining the Wilson Pond TMDL for inclusion in the BDWWA's spring newsletter.

6. **May 22, 2007:** CWD Project Manager Bill Monagle provided an overview of local lake conditions at the CWD's annual meeting. The meeting was publicly noticed and open to all residents of the eight member towns of the CWD.

7. **May 30, 2007:** FB Environmental staff Tricia Rouleau met with CWD Project Manager, Bill Monagle to collect Wilson Pond water quality and historical information.

STAKEHOLDER AND PUBLIC REVIEW PROCESS

A two-week stakeholder review was distributed electronically on July 11, 2007 to the following individuals who expressed a specific interest, participated in the field work or helped develop the draft Wilson Pond PCAP-TMDL report: Cobbossee Watershed District (Bill Monagle, Wendy Dennis, Robert Clunie, Heinz Walbaum, Jane Andrews, and Andrew Bosworth); Town of Winthrop (Cornell Knight); Town of Wayne (Greg Davis); Town of Monmouth (Paul Bird); Berry, Dexter, Wilson Watershed Association (Phil Thorp and Marcia Jackson); KC-SWCD (John Blais); *Friends of Cobbossee Watershed* (Bob Moore); Maine Forest Service (Chris Martin); Maine Department of Inland Fisheries and Wildlife (Bill Woodward); and David Rocque (Maine Department of Agriculture).

The following statement was advertised in the *Community Advertiser* over the week of August 11 - 17, 2007, and the *Kennebec Journal* over the weekend of August 18 -19, 2007:

WILSON POND - Monmouth, Wayne and Winthrop, Maine

In accordance with Section 303(d) of the Clean Water Act, and implementation regulations in 40 CFR Part 130 - the Maine Department of Environmental Protection has prepared a combined Phosphorus Control Action Plan (PCAP) and Total Maximum Daily Load (TMDL) nutrient report (DEPLW– 0849) for the **WILSON POND WATERSHED**, located within the Towns of Monmouth, Wayne and Winthrop. This PCAP-TMDL report identifies and provides best estimates of non-point source phosphorus loads for all representative land use classes in the **WILSON POND** direct watershed and the total phosphorus reductions required to restore and maintain acceptable water quality conditions. A Public Review draft of this report may be viewed at Central Maine DEP offices in Augusta (Ray Building, Hospital Street - Route 9, Land & Water Bureau) or on-line: http://www.maine.gov/dep/blwq/comment.htm. Please send all comments, in writing by August 27, 2007 to Dave Halliwell, Lakes TMDL Program Manager, Maine DEP, State House Station #17, Augusta, ME 04333 or e-mail: david.halliwell@maine.gov.

PUBLIC REVIEW Comments Received

Susan Hawkins (shoreline resident, Wilson Pond) reviewed the document and noted the omission of a small public beach in the Wilson Pond public access information (p. 9). Additionally, Ms. Hawkins expressed concern regarding the increased presence of a milfoil species on the north-east end of Wilson Pond.

RESPONSE - from David Halliwell, Maine DEP
Thank you for your interest and comprehensive review of the Wilson Pond public review draft. Your concerns, particularly the public beach omission, will be further addressed in the final submittal to EPA. In regard to possible "milfoil" infestations, I checked with John McPhedran (Maine DEP Invasive Aquatic Species Program) and he was only aware of the presence of fairly dense native milfoil species in Wilson Pond. To date, only native milfoil plant species have been seen. If you send in a plant sample to IAS staff, they would be happy to confirm its identity.

All received public review comments were incorporated into this final EPA draft submittal.

LITERATURE

Lake Specific References

Cobbossee Watershed District. Wilson Pond Watershed Survey Project (in progress) (#ME-2005R-02). *Cobbossee Watershed District*, Winthrop, ME.

Dennis, W.K. and K.J. Sage. 1981. Phosphorus loading from agricultural runoff in Jock Stream, tributary to Cobbossee Lake, Maine: 1977-1980. *Cobbossee Watershed District*, Wayne, ME.

Maine Department of Environmental Protection. 1999. Cobbossee Lake (Kennebec County, Maine) Final TMDL Addendum (to Monagle 1995). *Maine Department of Environmental Protection*, Augusta, ME.

Monagle, W.J. 1995. Cobbossee Lake Total Maximum Daily Load (TMDL): Restoration of Cobbossee Lake Through Reduction of Nonpoint Sources of Phosphorus. Final report to U.S EPA (TMDL minigrant program). Cobbossee Watershed District, Winthrop, ME.

General References

Barko, J.W., W.F. James, and W.D. Taylor. 1990. Effects of alum treatment on phosphorus and phytoplankton dynamics in a north-temperate reservoir: a synopsis. *Lake and Reservoir Management* 6:1-8.

Basile, A.A. and M.J. Vorhees. 1999. A practical approach for lake phosphorus Total Maximum Daily Load (TMDL) development. *US-EPA Region I*, Office of Ecosystem Protection, Boston, MA (July 1999).

Bostrom, B., G. Persson, and B. Broberg. 1988. Bioavailability of different phosphorus forms in freshwater systems. *Hydrobiologia* 170:133-155.

Bouchard, R., M. Higgins, and C. Rock. 1995. Using constructed wetland-pond systems to treat agricultural runoff: a watershed perspective. *Lake and Reservoir Management* 11(1):29-36.

Butkus, S.R., E.B. Welch, R.R. Horner, and D.E. Spyridakis. 1988. Lake response modeling using biologically available phosphorus. *Journal of the Water Pollution Control Federation* 60:1663-69.

Carlton, R.G. and R.G. Wetzel. 1988. Phosphorus flux from lake sediments: effect of epipelic algal oxygen production. *Limnology and Oceanography* 33(4):562-570.

Chapra, S.C. 1997. Surface Water-Quality Modeling. McGraw-Hill Companies, Inc.

Correll, D.L., T.L. Wu, E.S. Friebele, and J. Miklas. 1978. Nutrient discharge from Rhode Island watersheds and their relationships to land use patterns. In: *Watershed Research in Eastern North America: A workshop to compare results*. Volume 1, February 28 - March 3, 1977. (mixed pine/ hardwoods).

Cooke, G.D., E.B Welch, S.A. Peterson, and P.R. Newroth. 1986. Lake and Reservoir Restoration. Buttersworth, Boston, MA.

Dennis, J. 1986. Phosphorus export from a low-density residential watershed and an adjacent forested watershed. *Lake and Reservoir Management* 2:401-407.

Dennis, J., J. Noel, D. Miller, C. Elliot, M.E. Dennis, and C. Kuhns. 1992. Phosphorus Control in Lake Watersheds: A Technical Guide to Evaluating New Development. *Maine Department of Environmental Protection*, Augusta, Maine.

Dillon, P.J. 1974. A critical review of Vollenweider's nutrient budget model and other related models. *Water Resources Bulletin* 10:969-989.

Dillon, P.J. and F.H. Rigler. 1974a. The phosphorus-chlorophyll relationship for lakes. *Limnology and Oceanography* 19:767-773.

Dillon, P.J. and F.H. Rigler. 1974b. A test of a simple nutrient budget model predicting the phosphorus concentration in lake water. *Journal of the Fisheries Research Board of Canada* 31:1771-1778.

Dillon, P.J. and F.H. Rigler. 1975. A simple method for predicting the capacity of a lake for development based on lake trophic status. *Journal of the Fisheries Research Board of Canada* 32:1519-1531.

Dudley, R.W. 2004. Estimating Monthly, Annual, and Low 7-Day, 10-Year Streamflows for Ungaged Rivers in Maine. U.S. Geological Survey, Scientific Investigations Report 2004-5026, Augusta, Maine.

Dudley, R.W., S.A. Olson, and M. Handley. 1997. A preliminary study of runoff of selected contaminants from rural Maine highways. U.S. Geological Survey, Water-Resources Investigations Report 97-4041 (DOT, DEP, WRI), 18 pages.

Ferwerda, J.A., K.J., LaFlamme, N.R. Kalloch, and R.V. Rourke. 1997. The soils of Maine. Maine Agricultural and Forest Experiment Station, University of Maine.

Gasith, Avital and Sarig Gafny. 1990. Effects of water level fluctuation on the structure and function of the littoral zone. Pages 156-171 (Chapter 8) in: M.M. Tilzer and C. Serruya (eds.), *Large Lakes: Ecological Structure and Function*, Springer-Verlag, NY.

Heidtke, T.M. and M.T. Auer. 1992. Partitioning phosphorus loads: implications for lake restoration. *Journal of Water Resources Plan. Mgt.* 118(5):562-579.

James, W.F., R.H. Kennedy, and R.F. Gaubush. 1990. Effects of large-scale metalimnetic migrations on phosphorus dynamics in a north-temperate reservoir. *Canadian Journal of Fisheries and Aquatic Sciences* 47:156-162.

James, W.F. and J.W. Barko. 1991. Estimation of phosphorus exchange between littoral and pelagic zones during nighttime convective circulation. *Limnology and Oceanography* 36(1):179-187.

Jemison, J.M. Jr., M.H. Wiedenhoeft, E.B. Mallory, A. Hartke, and T. Timms. 1997. A Survey of Best Management Practices on Maine Potato and Dairy Farms: Final Report. University of Maine Agricultural and Forest Experiment Station, Misc. Publ. 737, Orono, Maine.

Kallqvist, T.and D. Berge. 1990. Biological availability of phosphorus in agricultural runoff compared to other phosphorus sources. *Verh. Internat. Verein. Limnol.* 24:214-217.

Kirchner, W.B. and P.J. Dillon. 1975. An empirical method of estimating the retention of phosphorus in lakes. *Water Resources Research* 11:182-183.

Larsen, D.P. and H.T. Mercier. 1976. Phosphorus retention capacity of lakes. *Journal of the Fisheries Research Board of Canada* 33:1742-1750.

Lee, G.F., R.A. Jones, and W. Rast. 1980. Availability of phosphorus to phytoplankton and its implications for phosphorus management strategies. Pages 259-308 (Ch.11) in: *Phosphorus Management Strategies for Lakes*, Ann Arbor Science Publishers, Inc.

Likens, G.E., F.H. Bormann, R.S. Pierce, J.S. Eaton, and N.M. Johnson. 1977. Bio-Geochemistry of a Forested Ecosystem. Springer-Verlag, Inc. New York, 146 pages.

Marsden, Martin, W. 1989. Lake restoration by reducing external phosphorus loading: the influence of sediment phosphorus release (Special Review). *Freshwater Biology* 21(2):139-162.

Martin, T.A., N.A. Johnson, M.R. Penn, and S.W. Effler. 1993. Measurement and verification of rates of sediment phosphorus release for a hypereutrophic urban lake. *Hydrobiologia* 253:301-309.

Mattson, M.D. and R.A. Isaac. 1999. Calibration of phosphorus export coefficients for total maximum daily loads of Massachusetts lakes. *Journal of Lake and Reservoir Management* 15(3):209-219.

Michigan Department of Environmental Quality. 1999. Pollutant Controlled Calculation and Documentation for Section 319 Watersheds *Training Manual*. Michigan DEQ, Surface Water Quality Division, Nonpoint Source Unit.

Nurnberg, G.K. 1984. The prediction of internal phosphorus load in lakes with anoxic hypolimnia. *Limnology and Oceanography* 29:111-124.

Nurnberg, G.K. 1987. A comparison of internal phosphorus loads in-lakes with anoxic hypolimnia: Laboratory incubation versus in situ hypolimnetic phosphorus accumulation. *Limnology and Oceanography* 32(5):1160-1164.

Nurnberg, G.K. 1988. Prediction of phosphorus release rates from total and reductant-soluble phosphorus in anoxic lake sediments. *Canadian Journal of Fisheries and Aquatic Sciences* 45:453-462.

Nurnberg, G.K. 1995. Quantifying anoxia in lakes. *Limnology and Oceanography* 40(6):1100-1111.

Reckhow, K.H. 1979. Uncertainty analysis applied to Vollenweider's phosphorus loading criteria. *Journal of the Water Pollution Control Federation* 51(8):2123-2128.

Reckhow, K.H., M.N. Beaulac, and J.T. Simpson. 1980. Modeling phosphorus loading and lake response under uncertainty: a manual and compilation of export coefficients. EPA 440/5-80-011, *US-EPA*, Washington, D.C.

Reckhow, K.H., J.T. Clemens, and R.C. Dodd. 1990. Statistical evaluation of mechanistic water-quality models. *Journal Environmental Engineering* 116:250-265.

Riley, E.T. and E.E. Prepas. 1985. Comparison of phosphorus-chlorophyll relationships in mixed and stratified lakes. *Canadian Journal of Fisheries and Aquatic Sciences* 42:831-835.

Rippey, B., N.J. Anderson, and R.H. Foy. 1997. Accuracy of diatom-inferred total phosphorus concentrations and the accelerated eutrophication of a lake due to reduced flushing and increased internal loading. *Canadian Journal of Fisheries and Aquatic Sciences* 54:2637-2646.

Schroeder, D.C. 1979. Phosphorus Export From Rural Maine Watersheds. *Land and Water Resources Center, University of Maine*, Orono, Completion Report.

Singer, M.J. and R.H. Rust. 1975. Phosphorus in surface runoff from a (northeastern United States) deciduous forest. *Journal of Environmental Quality* 4(3):307-311.

Sonzogni, W.C., S.C. Chapra, D.E. Armstrong, and T.J. Logan. 1982. Bioavailability of phosphorus inputs to lakes. *Journal of Environmental Quality* 11(4):555-562.

Soranno, P.A., S.L. Hubler, S.R. Carpenter, and R.C. Lathrop. 1996. Phosphorus loads to surface waters: a simple model to account for spatial pattern. *Ecological Applications* 6(3):865-878.

Sparks, C.J. 1990. Lawn care chemical programs for phosphorus: information, education, and regulation. U.S. Environmental Protection Agency, Enhancing States' Lake Management Programs, pages 43-54. [Golf course application]

Stefan, H.G., G.M. Horsch, and J.W. Barko. 1989. A model for the estimation of convective exchange in the littoral region of a shallow lake during cooling. *Hydrobiologia* 174:225-234.

Tietjen, Elaine. 1986. Avoiding the China Lake Syndrome. Reprinted from *Habitat* - Journal of the Maine Audubon Society, 4 pages.

U.S. Environmental Protection Agency. 1999. Regional Guidance on Submittal Requirements for Lake and Reservoir Nutrient TMDLs. *US-EPA Office of Ecosystem Protection*, New England Region, Boston, MA.

U.S. Environmental Protection Agency. 2000a. **Cobbossee (Cobbosseecontee) Lake** TMDL Final Approval Documentation **#1**. US-EPA/NES, January 26, 2000.

U.S. Environmental Protection Agency. 2000b. **Madawaska Lake** TMDL Final Approval Documentation **#2**. US-EPA/NES, July 24, 2000.

U.S. Environmental Protection Agency. 2001a. **Sebasticook Lake** TMDL Final Approval Documentation **#3**. US-EPA/NES, March 8, 2001.

U.S. Environmental Protection Agency. 2001b. **East Pond (Belgrade Lakes)** TMDL Final Approval Documentation **#4**. US-EPA/NES, October 9, 2001.

U.S. Environmental Protection Agency. 2001c. **China Lake** TMDL Final Approval Documentation **#5**. US-EPA/NES, November 5, 2001.

U.S. Environmental Protection Agency. 2003a. **Highland (Duck) Lake** PCAP-TMDL Final Approval Documentation **#6**. US-EPA/NES, June 18, 2003.

U.S. Environmental Protection Agency. 2003b. **Webber Pond** PCAP-TMDL Final Approval Documentation **#7**. US-EPA/NES, September 10, 2003.

U.S. Environmental Protection Agency. 2003c. **Threemile Pond** PCAP-TMDL Final Approval Documentation **#8**. US-EPA/NES, September 10, 2003.

U.S. Environmental Protection Agency. 2003d. **Threecornered Pond** PCAP-TMDL Final Approval Documentation **#9**. US-EPA/NES, September 10, 2003.

U.S. Environmental Protection Agency. 2003e. **Mousam Lake** PCAP-TMDL Final Approval Documentation **#10**. US-EPA/NES, September 29, 2003.

U.S. Environmental Protection Agency. 2004a. **Annabessacook Lake** PCAP-TMDL Final Approval Documentation **#11**. US-EPA/NES, May 18, 2004.

U.S. Environmental Protection Agency. 2004b-c. **Pleasant (Mud) Pond** PCAP-TMDL Final Approval Documentation **#12-13**. US-EPA/NES, May 20, 2004 (also **Cobbossee Stream**).

U.S. Environmental Protection Agency. 2004d. **Sabattus Pond** PCAP-TMDL Final Approval Documentation **#14**. US-EPA/NES, August 12, 2004.

U.S. Environmental Protection Agency. 2004e. **Highland Lake (Bridgton)** PCAP-TMDL Final Approval Documentation **#15**. US-EPA/NES, August 12, 2004.

U.S. Environmental Protection Agency. 2004f. **Toothaker Pond (Phillipston)** PCAP-TMDL Final Approval Documentation **#16**. US-EPA/NES, September 16, 2004.

U.S. Environmental Protection Agency. 2004g. **Unity (Winnecook) Pond** PCAP-TMDL Approval Documentation **#17**. US-EPA/NES, September 16, 2004.

U.S. Environmental Protection Agency. 2005a. **Upper Narrows Pond** PCAP-TMDL Final Approval Documentation **#18**. US-EPA/NES, January 10, 2005.

U.S. Environmental Protection Agency. 2005b. **Little Cobbossee Lake** PCAP-TMDL Final Approval Documentation **#19**. US-EPA/NES, March 16, 2005.

U.S. Environmental Protection Agency. 2005c. **Long Lake (Bridgton)** PCAP-TMDL Final Approval Documentation **#20**. US-EPA/NES, May 23, 2005.

U.S. Environmental Protection Agency. 2005d. **Togus (Worrontogus) Pond** PCAP-TMDL Final Approval Documentation **#21**. US-EPA/NES, September 1, 2005.

U.S. Environmental Protection Agency. 2005e. **Duckpuddle Pond** PCAP-TMDL Final Approval Documentation **#22**. US-EPA/NES, September 1, 2005.

U.S. Environmental Protection Agency. 2005f. **Lovejoy Pond** PCAP-TMDL Final Approval Documentation **#23**. US-EPA/NES, September 21, 2005.

U.S. Environmental Protection Agency. 2006a. **Lilly Pond** PCAP-TMDL Final Approval Documentation **#24**. US-EPA/NES, December 29, 2005.

U.S. Environmental Protection Agency. 2006b. **Sewall Pond** PCAP-TMDL Final Approval Documentation **#25**. US-EPA/NES, March 10, 2006.

U.S. Environmental Protection Agency. 2006c-d. **Daigle Pond** PCAP-TMDL Final Approval Documentation **#26-27**. US-EPA/NES, September 28, 2006 (also **Daigle Brook**).

U.S. Environmental Protection Agency. 2006e-f. **Cross Lake** PCAP-TMDL Final Approval Documentation **#28-29**. US-EPA/NES, September 28, 2006 (also **Dickey Brook**).

U.S. Environmental Protection Agency. 2007a. **Trafton Lake** PCAP-TMDL Final Approval Documentation #**30**. US-EPA/NES, October 26, 2006.

U.S. Environmental Protection Agency. 2007b. **Monson Pond** PCAP-TMDL Final Approval Documentation #**31**. US-EPA/NES, November 28, 2006.

U.S. Environmental Protection Agency. 2007c. **Echo Lake** PCAP-TMDL Final Approval Documentation #**32**. US-EPA/NES, February 5, 2007.

U.S. Environmental Protection Agency. 2007d. **Arnold Brook Lake** PCAP-TMDL Final Approval Documentation #**33**. US-EPA/NES, February 5, 2007.

Vollenweider, R.A. 1969. Possibility and limits of elementary models concerning the budget of substances in lakes. *Arch. Hydrobiol.* 66:1-36.

Walker, W.W., Jr. 2000. Quantifying Uncertainty in Phosphorus TMDL's for Lakes. March 8, 2001 *Draft* Prepared for NEIWPCC and EPA Region.