PHOSPHORUS CONTROL ACTION PLAN

and Total Maximum Daily (Annual Phosphorus) Load Report

Cross Lake

Cross Lake and Square Lake Twp.

Aroostook County, Maine

Cross Lake PCAP-TMDL Report

Maine DEPLW - 0790

Maine Department of Environmental Protection

and Maine Association of Conservation Districts

EPA Final Review Document - September 25, 2006

CROSS LAKE - Cross Lake and Square Lake Twp.

Phosphorus Control Action Plan (PCAP)

Table of Contents

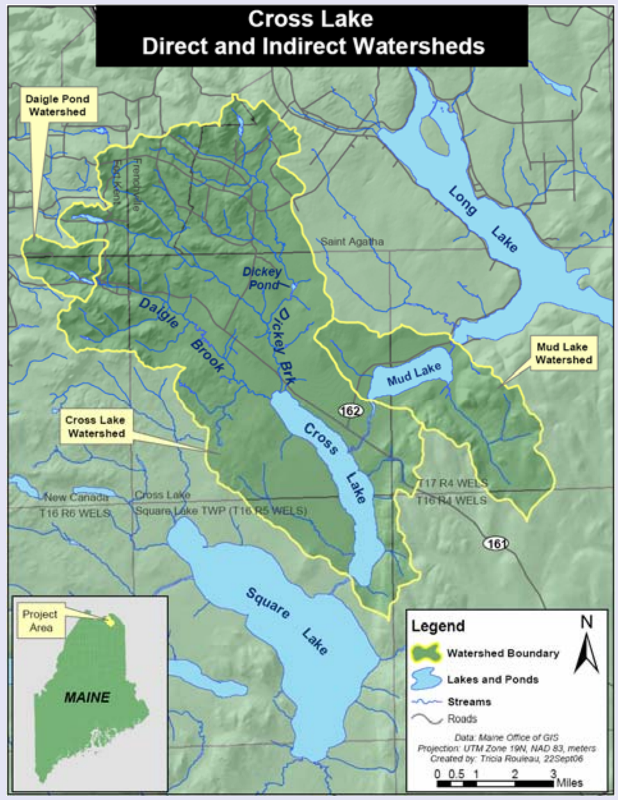
CROSS LAKE (Cross Lake & Square Lake Twp.)

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 Presque Isle) and U.S. EPA New England Region I staff, the following individuals, groups and agencies were instrumental in the preparation of this Cross Lake combined Phosphorus Control Action Plan and Total Maximum Daily Load report: MACD staff (Forrest Bell, Fred Dillon, Jennifer Jespersen, and Tricia Rouleau); Maine Department of Agriculture (David Rocque); Maine Forest Service (Chris Martin); Maine Department of Inland Fisheries and Wildlife (Dave Basley); the Saint John Valley Soil and Water Conservation District (Heidi Royal), and Maine Volunteer Lake Monitoring Program Volunteer Reynold Martin (1996-2006).

CROSS LAKE -
CROSS LAKE & SQUARE LAKE TWP., MAINE
PHOSPHORUS CONTROL ACTION PLAN

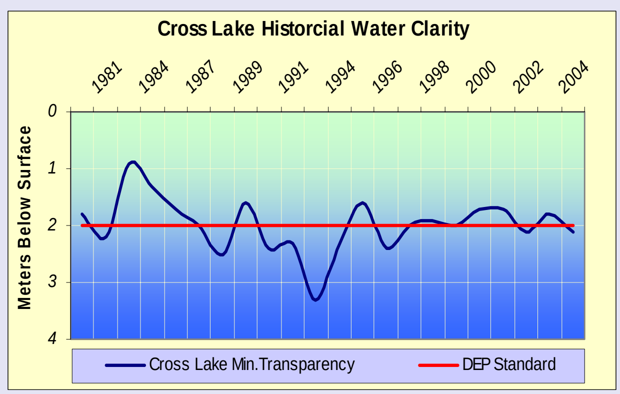


Background

CROSS LAKE (Midas No. <u>1674</u>) is a large, 2,537 acre moderately **colored lake** located in the unorganized townships of Cross Lake and Square Lake (T16 R5 WELS) in Aroostook County, Maine. Cross Lake has a <u>direct</u> drainage area (see map to right and on pg. 8) of approximately 60 square miles; a maximum depth of 46 feet (14 meters), a mean depth of 20 feet (6 meters); and a **flushing rate** of 3.3 times/year. The <u>total</u> Cross Lake watershed drainage area, inclusive of associated sub-watersheds (Daigle Pond and Mud Lake) is approximately 75 square miles.

Historical Information

Cross Lake has displayed impacts from non-point source pollution, due largely to loading from cropland, roads, and pollution delivered by upstream **watersheds** (Bouchard et al. 1995). Substantial organic and nutrient loading was recorded in both Cross Lake, and its northern neighbor, Long Lake in the 1950's when discharges from municipal sewage, a starch factory, and potato waste disposal were prevalent (Bouchard et al. 1995). These activities resulted in high **phosphorus** loading (external load) and low dissolved oxygen concentration in past decades.



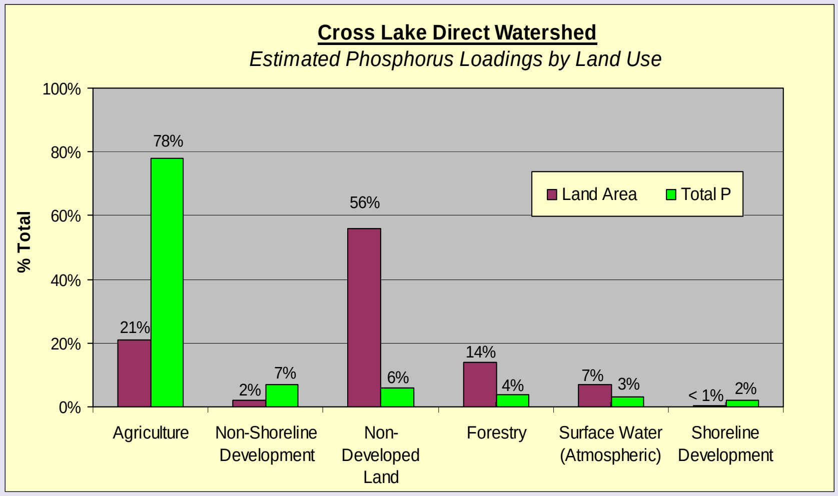
Water clarity improved in Cross Lake during the early 1990's, but does not meet DEP minimum standards today.

High wind events on Cross Lake cause sediment resuspension and turbidity of previously deposited sediment, which contributes to the high rate of internal phosphorus cycling (internal load). New sources of phosphorus (sediments from land uses in the watershed) also contribute to Cross Lake's declining water clarity. In the past 15 years there has been a substantial effort to reduce agricultural sediment and phosphorus loading in the watershed (NEIRTT 2001). This work helped reduce loading, and improved water clarity into the mid 1990's (see figure to right). Yet phosphorus levels rebounded in the late 1990's and are high enough to affect water quality, and promote substantial algae growth. Cross Lake is on the state's303(d) list of impaired water bodies, as well as the state's Non-point Source Priority Watershed List.

- ***<u>Colored</u>*** *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.*
- ***<u>Flushing rate</u>*** *refers to how often the water in the entire lake is replaced on an annual basis.*
- ***<u>Watershed</u>*** *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.*
- ***<u>Phosphorus</u>****: 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.*

What We Learned

The land use assessment conducted for the Cross Lake watershed helped to determine the potential sources of phosphorus that may run off from land areas during storm events and spring-time snow melting. This assessment utilized many resources, including generating and interpreting maps, inspecting and verifying aerial photos using local knowledge, and visiting the watershed. A land-use model (p.7) estimated that approximately 5,946 kg of phosphorus is exported annually (external load) to Cross Lake from the direct watershed (p. 27). The bar chart (right) illustrates the land area representative land uses as compared to the phosphorus export load for each land use. During recent years, the average amount of **total phosphorus (TP)** being recycled internally (internal load - 2,971 kg/year) from Cross Lake bottom sediments during the summer-time (1989-92, 2003) is more than half of the lake's natural capacity (5,050 kg/year) for in-lake phosphorus assimilation (assuming a target goal water concentration of 16 ppb).



Agricultural land-uses in the watershed make up a large proportion of the total phosphorus exported to Cross Lake.

Phosphorus Reduction Needed

Cross Lake's average summertime TP concentration (originating from a combination of external and internal loading) approximates 20 ppb (6,320 kg) - equal to an additional 1,264 kg more than the lake's natural capacity. Including a 158 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 16 ppb or less) in Cross Lake approximates 1,422 kg (see In-Lake Concentration Method p. 17).

What You Can Do To Help!

As a watershed resident, there are many things you can do to protect the water quality of Cross Lake. Lakeshore owners can use phosphorus-free fertilizers and maintain natural vegetation adjacent to the lake. Agricultural and commercial land users can consult the St. John Valley Soil and Water Conservation District or Maine Department of Environmental Protection for information regarding Best Management Practices (BMPs) for reducing phosphorus loads. Watershed residents can become involved by volunteering to join the Fish River Lakes Water Quality Association and by participating in events sponsored by State agencies and local organizations. The estimated phosphorus loading to Cross Lake originates from both shoreline and non-shoreline areas, so all watershed residents must take ownership of maintaining suitable water quality.

Prolific algae blooms like this one in Cross Lake during the fall of 2001, may be prevented by reducing NPS pollution.

Lake stakeholders and watershed residents can learn more about their lake and the many resources available, including review of the Cross Lake Phosphorus Control Action Plan and **TMDL** report. Following final EPA approval, copies of this detailed report, with recommendations for future NPS/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 Maine DEP offices in Presque Isle (1235 Central Drive, Skyway Park) or Augusta (Bureau of Land and Water Quality, Ray Building, AMHI Campus).

Key Terms

- ***Total Phosphorus (TP)*** *- the total concentration of phosphorus found in the water including organic and inorganic forms.*
- ***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 lakes 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 the Maine Association of Conservation Districts (MACD), from 2005 to 2006.

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 Cross Lake watershed (see study methodology, p. 7). Simply stated, a TMDL is the total amount of phosphorus that a lake can receive without harming water quality. Maine DEP, with assistance from the MACD, 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 at David.Halliwell@maine.gov*).

Secondly, watershed assessment work was conducted for Cross Lake by the Maine DEP-MACD project team to help assess total phosphorus reduction techniques that would be beneficial for the Cross Lake Watershed. The results of this assessment report include recommendations for future conservation work in the watershed to help citizens, organizations, and agencies restore and protect Cross Lake. A shoreline survey and septic evaluation was previously conducted for Cross Lake (NMRPC 1988) **Note:** *To protect the confidentiality of landowners in the Cross Lake watershed, site-specific information has not generally been provided as part of this PCAP-TMDL report.*

This Phosphorus Control Action Plan (PCAP) report compiles and refines land use data derived from various sources, including the Maine Office of Geographic Information Systems, the St. John Valley Soil & Water Conservation District (SJV-SWCD), the Maine Department of Environmental Protection (DEP), the USDA/Natural Resources Conservation Service (NRCS), the USDA/Farm Service Agency (FSA) and the Maine Forest Service (MFS). Local citizens, active watershed organizations such as the Fish River Chain of Lakes Water Quality Association, and other 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 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.

> ***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.*

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

Study Limitations

Land use data gathered for the Cross Lake 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. Land uses in the Cross Lake watershed have changed since the 1995 land use data was developed. Field observations made by MACD staff during the TMDL process has helped provide a more accurate summary of watershed land uses.

Study Methodology

Background information for Cross Lake was obtained using several methods, including a review of previous studies of the lake and associated watersheds, numerous phone conversations and personal interviews with regional organizations and state agencies, and two field tours of the watershed.

Land use data were determined using several methods, including (1) **Geographic Information System (GIS)** map analysis, (2) analysis of topographic maps, (3) analysis of aerial photographs, and (4) **ground-truthing.** Much of the non-developed land use area (i.e., forest, wetland, grassland) was determined using a GIS layer which is a combination of Maine Gap Analysis (GAP) landcover and USGS Multi Resolution Landcover Characterization (MRLC) landcover layers. It was created at the request of Maine DEP Bureau of Land and Water Quality (BLWQ) staff. It includes those classes in each layer which are best suited to calculating impermeability of watersheds. Both MRLC and GAP (and so Maine COMBO) are based on 1995 Landsat imagery. The developed land use areas were obtained using the best possible information available through analysis of methods 1 through 4 listed above.

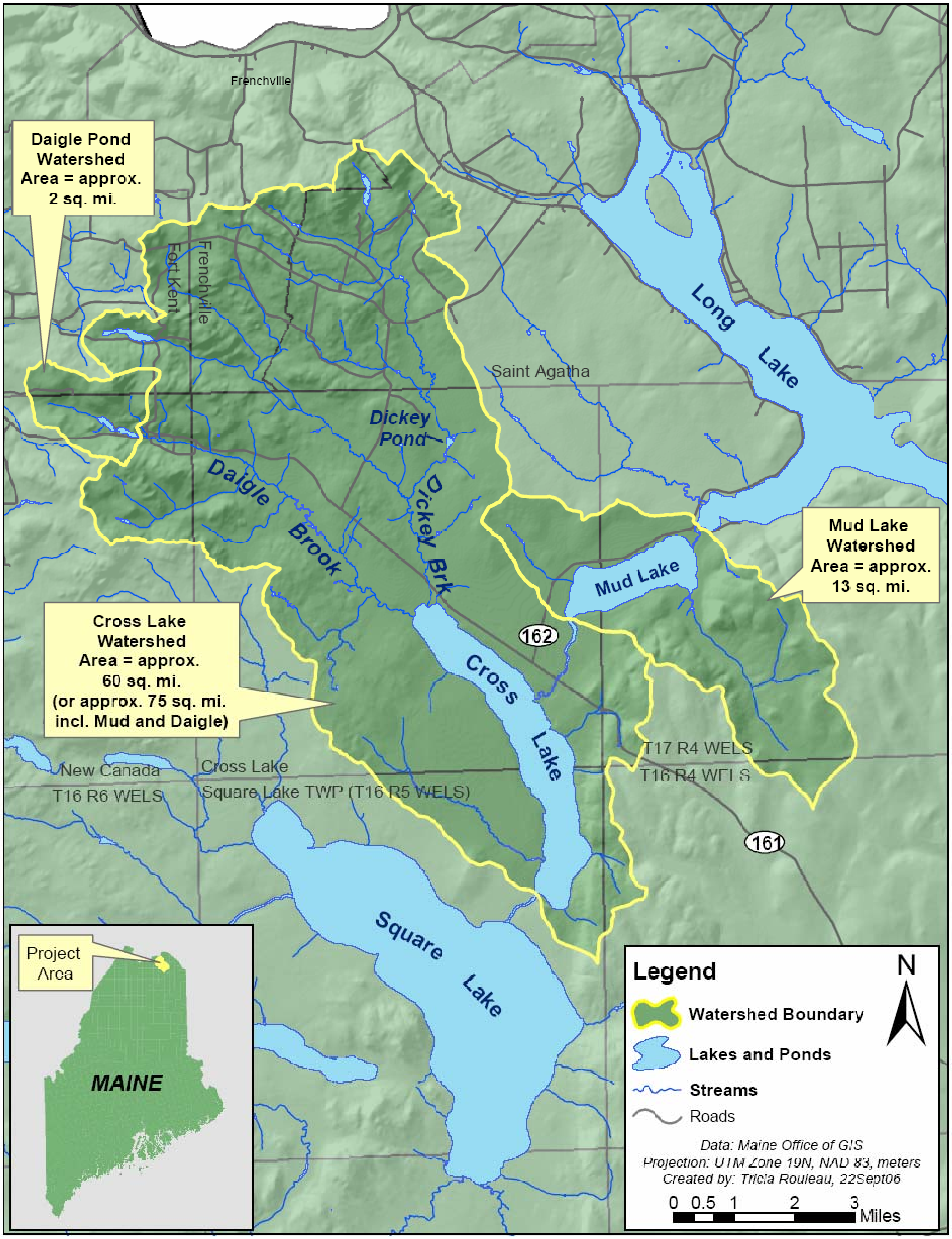
Final adjusted phosphorus loading numbers (see Table 3, page 27) were modeled using overlays of soils, and slope. All of the land use coverage data for agricultural areas were re-configured using aerial overlays, FSA maps, ground-truthing, and review by the SJV-SWCD in conjunction with the USDA/NRCS. Information regarding forest harvest operations were reviewed by the Maine Forest Service, Department of Conservation.

Roadway widths were estimated from previous PCAP reports where actual measurements were made for the various road types and from actual on-screen measurements using GIS. In State owned roads were found to be 22 meters wide; town-owned roads were found to be 16 meters wide; and privately-owned roads were found to be 6 meters wide. GIS was used to calculate total road surface area.

***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.*

Figure 1. Map of Cross Lake Direct and Indirect Watersheds



CROSS LAKE Phosphorus Control Action Plan

DESCRIPTION of WATERBODY (MIDAS Number 1674) and WATERSHED

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

CROSS LAKE is a large 2,537 acre (1,027 hectares) single-basin, moderately-colored waterbody situated in the unorganized townships of Cross Lake and Square Lake (T16 R5 WELS) (DeLorme Atlas, Map 68), within Aroostook County, Maine. Cross Lake has a **direct watershed** area (see Figure 1, previous page) of approximately 35,800 acres (56 square miles) exclusive of lake surface area (MEGIS 2006), or approximately 60 square miles including lake surface area. The Cross Lake direct watershed is located within several towns or townships, including Cross Lake (51%), St. Agatha (16%), Square Lake (T16 R5 WELS) (10%), Frenchville (8%), Fort Kent (5%), New Canada (5%), T17 R4 WELS (3%), and T16 R4 WELS (2%). Cross Lake has a maximum depth of 46 feet (14 meters), overall mean depth of 20 feet (6 m), and a flushing rate of 3.3 times/year.

Drainage System: Cross Lake is the third lake in the east branch of the Fish River Chain. Water enters Cross Lake from the north-east through a thoroughfare that connects Mud Lake to Cross Lake. Two major tributaries flow into Cross Lake on the north-west side including water quality impaired 303 (d) listed Daigle and Dickey Brooks. Daigle Brook originates from 303(d) listed (Total Phosphorus) Daigle Pond. The poor water quality of both Daigle and Dickey Brooks is caused by excessive pollutants (total phosphorus) from their direct watersheds which results in low dissolved oxygen concentrations. Cross Lake outlets into Square Lake to the south, potentially impacting the water quality of Square Lake (NEIRTT 2001).

Water Quality Information

Cross Lake is listed on the Maine DEP's 2004 303(d) list of lakes that do not meet State water quality standards as well as the State's Nonpoint Source Priority Watersheds list. Daigle and Dickey Brooks are both listed on the Maine DEP's Non-Point Source (NPS) Priority Watersheds list. Therefore, a combined Phosphorus Control Action Plan and TMDL report was prepared, during the spring/summer of 2006.

Based on **Secchi disk transparencies,** and current measures of both TP and **chlorophyll-a**, the water quality of Cross Lake is considered to be below average and the potential for nuisance algae blooms is high (Maine VLMP 2005). Together, these water quality data document a trend of increasing **trophic state,** in direct violation of the Maine DEP Class GPA water quality criteria requiring a stable or decreasing trophic state.

Historically, poor water quality in Cross Lake is attributed to high nutrient loads associated with discharges from municipal sewage, a starch factory and potato waste disposal into upstream tributaries and waterbodies in the 1950's (Bouchard et al. 1995).

***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.*

***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.*

***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 be used to assess trophic state.*

Additionally, nonpoint sources of pollution such as erosion from land uses such as agriculture, roads, and development in the watershed all contribute to the declining water quality in Cross Lake.

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 bottom sediments. 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 algae blooms, which can damage the ecology/aesthetics of a lake, as well as the economic well-being of the entire lake watershed.

Principle Uses & Human Development: The prevalent human uses of the Cross Lake shoreline are primarily residential (Figure 2). A 1988 survey of shoreline residents revealed that two-thirds of Cross Lakes shoreline is developed by 250 residential units, with a majority of this land being leased from Irving Paper Company (NMRPC 1988). Approximately 10% of these camps are used year round, with the remainder being used, on average, 100 days/year. The public can access Cross Lake via the boat launch on the south-east side of the Lake.

The remainder of the developed areas of the watershed outside of the immediate shoreline are dominated by agricultural land-uses such as row crops, and hayland, and operated forestland. An extensive road network (both paved and upaved) provides access to the many agricultural fields spread across the watershed. NPS pollution is a significant concern for the watershed. Consequently, Cross Lake is on the State's **Nonpoint Source Priority Watersheds** list due primarily to excessive phosphorus, lake enrichment and the prevalence of late summer and early fall nuisance algal blooms.

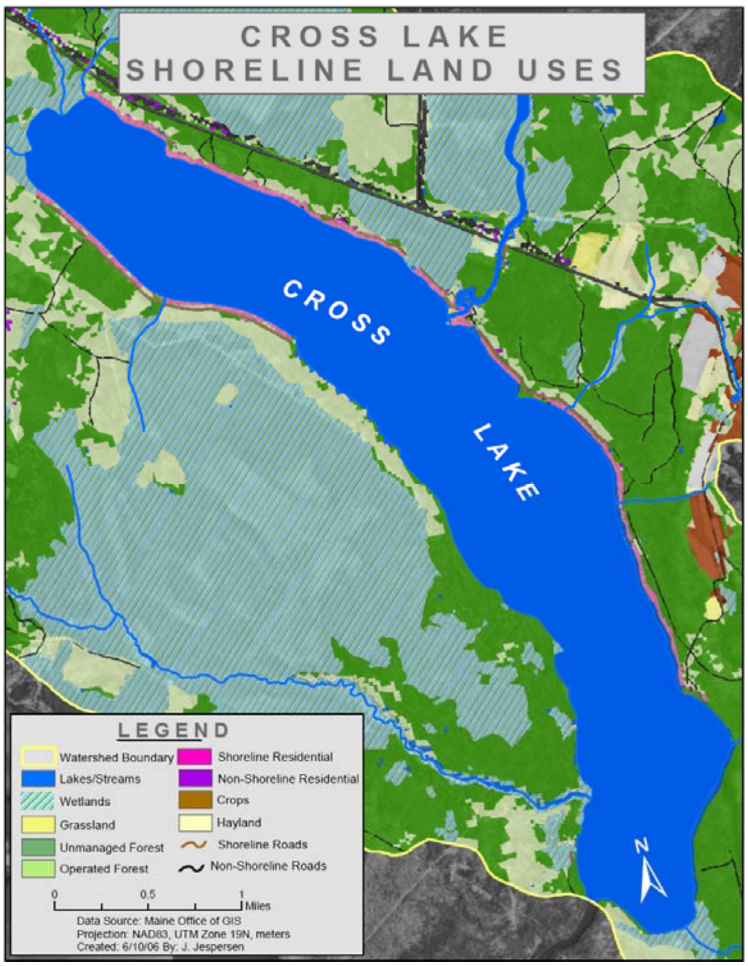


Figure 2. *The northern and eastern shoreline of Cross Lake is heavily developed by approximately 250 residential dwellings. Forests and wetlands border the lake to the south and west.*

Non Point Source Priority Watersheds

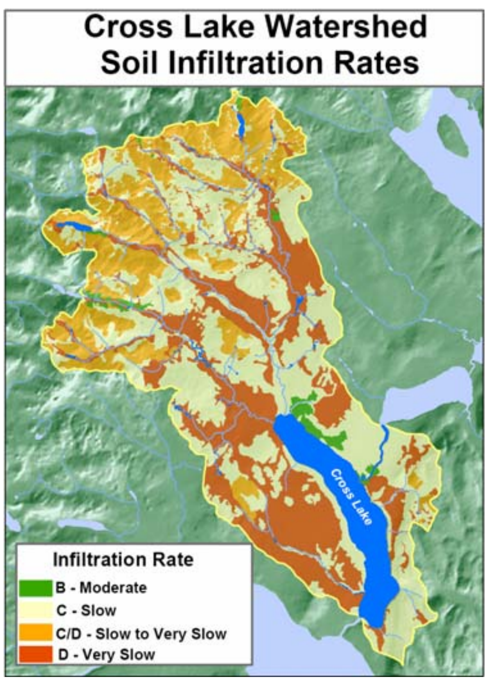
*Waterbodies within designated **NPS priority watersheds** have significant value from a regional or statewide perspective and have water quality that is either impaired or threatened due to NPS water pollution. This list identifies watersheds where state and federal agency resources for NPS water pollution prevention or restoration should be targeted.*

General Soils Description

The Cross Lake Watershed is characterized by three general soil associations consisting primarily of loamy soils formed in dense glacial till, and organic soils located in wetlands (Ferwerda et al. 1997). The first group of soils is the Aurelie-Daigle-Perham-Burnham Association, which is a loamy soil formed in loamy dense glacial till. These soils encompass a large portion of the Cross Lake watershed, including the immediate shoreline. The principal soils in this association are the poorly drained Aurelie, somewhat poorly drained Daigle, moderately well-drained Perham, and the very poorly drained Burnham. The basil till at 20" in these soils restricts water flow and leads to a high seasonal water table. A majority of soils in this association are located on slopes less than 8%, but can be as steep as 45%.

The second association is the Plaisted-Penquis-Thorndike-Howland Association which includes loamy soils underlain by either dense glacial till or bedrock. These soils make up a large portion of the northwestern portion of the watershed where agriculture is more prevalent. The principal soils in this association are the well-drained Plaisted, well drained Penquis, somewhat excessively drained Thorndike, and the moderately well-drained Howland. The Howland soil is the only soil reported to have a seasonal high water table between 18 and 30". The basil till between 25 and 28" in the Plaisted and Howland slows water movement in the lower part of the profile. Soils in this association are located on slopes from 3-45%, yet a majority of these slopes are less than 25%.

The final soil association is the Vassalboro-Sebago-Wonsqueak Association which are very poorly drained organic soils found in primarily in bogs. These soils are located within the wetlands on the southwestern side of Cross Lake. The principal soils in this association are the very poorly drained, slightly decomposed Vassalboro, the very poorly drained, moderately decomposed Sebago, and the very poorly drained, highly decomposed Wonsqueak soils. Water movement through these soils is moderate. Slopes within this association are negligible, ranging between 0 and 2%.



Majority of Soils Slow to Very Slow Infiltration- *Slow infiltration leads to overland flow of sediment and nutrients.*

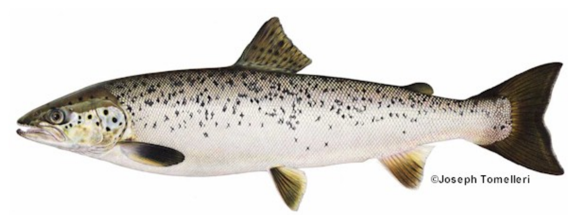
Majority of Slopes 0-8% – *Cross Lake's upper watershed is dominated by steeper slopes.*

Even though the loamy surface soils of the two major soil associations in the Cross Lake watershed allow for high water holding capacity, which helps limit excessive runoff, 57% of cropland in the Cross Lake watershed is classified as highly erodible (St. John Valley SWCD 1989). As such, particular attention should be paid to land uses on soils with steep slopes, and on land with exposed surface soils.

Cross Lake Fish Assemblage & Fisheries Status

Based on records provided by the Maine Department of Inland Fisheries and Wildlife (Maine DIF&W) and recent communication with fisheries biologist Dave Basley (Region G, Ashland DIF&W office), 2,515-acre (maximum depth 46 feet) Cross Lake (T16 R5, T17 R5, Fish River drainage system) is currently managed as a coldwater (brook trout and landlocked Atlantic salmon) fishery. Cross Lake was originally surveyed by Maine DIF&W in 1953, while their lake fisheries report was previously revised in 1976 and 1990. A total of **17** fish species are found to occur, including: **12** native indigenous fish species (brook trout, longnose and white suckers, burbot/cusk, slimy sculpin, and threespine and ninespine sticklebacks, in association with 5 northern minnows - lake and creek chubs, fallfish, common shiner, and blacknose dace); and **5** introduced non-indigenous fish species (landlocked Atlantic salmon, rainbow smelt, brown bullhead, yellow perch, and golden shiner). Maine DIF&W notes (1990) that water quality enhancement projects are being implemented throughout the entire Cross Lake watershed drainage to help correct and control nonpoint source phosphorus loading problems.

Brook trout



Landlocked Atlantic salmon

Generally, increases in trophic state as a result of nonpoint source phosphorus loading increases water temperature and reduces dissolved oxygen concentrations. Improvements in water quality will serve to enhance existing coldwater fisheries conditions in Cross Lake. Given that the trophic state of Cross Lake has been degraded by cumulative watershed impacts over the past several decades - then a significant reduction in the total phosphorus loading from the Cross Lake drainage may lead to maintaining in-lake nutrient levels within the natural assimilative capacity of this lake to effectively process total phosphorus - and enhance existing coldwater salmonid fisheries.

.

Land Use Inventory

The results of the Cross Lake watershed land use inventory are depicted in Table 1 (below). The various land uses are categorized by developed land vs. non-developed land. The developed land area comprises approximately 36% of the watershed, and the undeveloped land, including the water surface area of Cross Lake, comprises the remaining 64% of the watershed. These numbers may be used to help make future planning and conservation decisions relating to the Cross Lake watershed. The information in Table 1 was also used as a basis for preparing the Total Maximum Daily (Annual Phosphorus) Load report (see Appendices).

Table 1. Cross Lake Direct Watershed—Land Use Inventory and External Phosphorus Loads

LAND USE CLASS	Land Area Acres	Land Area %	TP Export Load kg TP	TP Export Total %
Agricultural Land				
Hayland (non-manured)	1,339	3%	417	7%
CRP/EQIP	2,647	7%	383	6%
Row Crops	3,569	9%	3,530	59%
Animal Feedlot/Barnyard	20	<1%	194	3%
Pasture (Grazed Meadows)	441	1%	174	3%
Sub-Totals	**8,016**	**21%**	**4,698**	**78%**
Actively Managed Forest	5,255	14%	207	4%
Sub-Totals	**5,255**	**14%**	**207**	**2%**
Shoreline Development				
Shoreline Septic Systems			62	1%
Low Density Residential	113	<1%	24	<1%
Shoreline Roads	17	<1%	15	<1%
Sub-Totals	**130**	**<1%**	**101**	**2%**
Non-Shoreline Development				
Roads	531	1%	375	6%
Low Density Residential	110	<1%	25	<1%
Commercial/Industrial	8	<1%	7	<1%
Sub-Totals	**648**	**2%**	**408**	**7%**
Total: DEVELOPED LAND	**14,049**	**36%**	**5,414**	**91%**
Non-Developed Land				
Inactive/Passively Managed Forest	12,881	33%	253	4%
Grassland/Reverting Fields	504	1%	37	<1%
Scrub-Shrub	202	1%	15	<1%
Wetlands	8,167	21%	41	1%
Total: NON-DEVELOPED LAND	**21,754**	**56%**	**346**	**6%**
Total: Surface Water (Atmospheric)	**2,820**	**7%**	**186**	**3%**
TOTAL: DIRECT WATERSHED	**38,622**	**100%**	**5,946**	**100%**

Descriptive Land Use and Phosphorus Export Estimates

Agriculture: Agricultural land is estimated to comprise 8,016 acres (21%) of the Cross Lake watershed area and contributes an estimated 4,698 kg (78%) of the total phosphorus loading to Cross Lake. Land planted in row crops lies fallow for as long as 7-8 months of the year (Bouchard et al. 1995), making soils under this land use particularly vulnerable to erosion. With an average cropland soil loss of approximately 3-5 tons/acre/yr (St. John Valley SWCD 1990), row crops have the potential contribute large amounts of phosphorus to Cross Lake. Data mapped using GIS software and verified using aerial photography estimated that row crops contribute 59% of the total phosphorus load to Cross Lake. Combined, non-manured hayland and land set aside in the Conservation Reserve Program (CRP) account for 13% of the total phosphorus load. Land converted to CRP has led to a large reduction in soil loss and P loading to Cross Lake. Pasture and animal feedlots make up the remaining 6% of agricultural NPS inputs to Cross Lake.

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

Actively Managed Forest Land: The estimated operated forest land for the Cross Lake direct watershed consists of 5,255 acres. This estimate is based on a GIS analysis of land uses and represents 14% of the total land area and 4% of the total phosphorus load to Cross Lake. While poorly managed forestry operations have the potential to negatively impact a waterbody through erosion and sedimentation from logging sites, properly managed forestry operations generally do not. Sustainable forest management can enhance water quality through sequestering excess nutrients, particularly in forested riparian areas. Harvested forest acres in Maine typically regenerate as forest, whether or not they are under any type of planned forest management or under the supervision of a Licensed Forester.

Shoreline Development consists of all lands within the immediate shoreland area (250 feet) of Cross Lake. This type of land use can have a large total phosphorus loading impact to lakes in comparison to their relatively small percentage of total land are in the watershed. The following section describes only those land uses (or parts of land uses) that are within 250 feet of Cross Lake. A sanitary survey was conducted in 1988 by the by the Northern Maine Regional Planning Commission (NMRPC 1988). The survey addressed not only sanitary issues, but also runoff potential, buffer areas, and camp use. Although the survey does not quantitatively evaluate the nonpoint source pollution impact for each lot in regard to phosphorus loading, the data can be used to approximate loading using tested phosphorus coefficients. This information may not accurately reflect current shoreline practices, however, it is the most comprehensive information available.

A total of 180 of the 250 lots on Cross Lake's shoreline were accounted for in the survey. On average, residences on Cross Lake are less than 1/2 acre, and structure setbacks average 51 feet from the high water level of the lake. Most of the 180 lots surveyed showed potential to contribute non-point source pollution to Cross Lake (NMRPC 1988). Vegetative buffers help to decrease the amount and flow of run-off from the sites, yet many shoreline areas around Cross Lake lack vegetative plantings, with 53% of camp owners reporting only grass in the buffer area. Additional impacts and phosphorus inputs to Cross Lake from shoreline development include fertilizing lawns, and improper or poorly operating septic systems. The impact of residential shoreline development on Cross Lake appears to be substantial, yet, compared to other land uses, the impact remains relatively small, contributing 1% of the total phosphorus load to Cross Lake.

Shoreline Septic Systems: The state of Maine requires a minimum of 20,000 square feet (0.46 acres) and 100 feet of frontage for dwellings that use a septic system for sewage disposal. With an average lot size of 0.42, and a average frontage of 51 feet, many of the camps on Cross Lake do not have adequate land to install a septic system (NMRPC 1988). A number of shoreland properties rely on cesspools or other substandard sanitary systems averaging 24 m or less from the lake (FRLWQA 1991, St. John Valley SWCD 1989). Based on the results from the sanitary survey (Table 2), a simple model was used to approximate total phosphorus export loading from residential sewage systems. This model estimated that 62 kg of phosphorus is potentially exported to Cross Lake from these systems (Bouchard 1991).

Table 2. Sanitary Survey
(Adapted from NMRPC 1988)

Septic	*90*
Outhouses	*49*
Holding Tanks	*22*
Cesspools	*9*
Other	*2*

Based on these numbers, shoreline sewage systems represent a relatively small contribution (less than 1%) of the total phosphorus loading to Cross Lake. Potential sewering of camp lots is thought to be cost prohibitive, and may have deleterious effects as a result of pollution that can be generated during construction (Bouchard 1991).

Unpaved and poorly maintained roads throughout the watershed contribute more than 6% of the total phosphorus to Cross Lake.

Private/Camp Roads: NPS pollution associated with shoreline roads can vary widely, depending upon road type, slope and proximity to a surface water resource. Routine maintenance of unimproved roads and associated drainage structures is often inadequate. The average road width for private roads on Cross Lake's shoreline approximates 6 meters, while town roads approximate 16 meters (based on findings from previous PCAP TMDL reports and measurements using GIS). Total phosphorus loading was estimated by calculating the surface area for the shoreline section of the roads with GIS. Based on these factors, shoreline roads contribute an estimated 15 kg/year (< 1%) of the total phosphorus load to Cross Lake's direct watershed.

Overall, shoreline development comprises less than 1% of the total watershed area and contributes approximately 101 kg of total phosphorus annually, which is 2% of the estimated phosphorus load.

Non-Shoreline Development and Land Uses

Non-Shoreline Development consists of all lands outside of the immediate shoreline (>250') of Cross Lake- including roads, and low density residential areas. The total area occupied by these land uses was determined using GIS.

Roads: Both private and local road widths were estimated from GIS analysis, as well as previous PCAP reports at 6 meters and 16 meters, respectively. State road widths were estimated at 22 meters. These road widths were used to determine the amount of total phosphorus loading from this land use category. Based on these factors, non-shoreline roads contribute an estimated 375 kg/year (6%) of the total phosphorus load to Cross Lake's direct watershed. Although the phosphorus export estimate is low for roads, considerable lengths of private gravel roads remain unmapped and may contribute significant loading (NMRPC 1988).

Low Density Residential: Low density residential land use consists of approximately 110 acres and contributes an estimated 25 kg/year (<1%) of the total phosphorus loading to the Cross Lake direct watershed.

Commercial/Industrial: Commercial/Industrial land uses in the Cross Lake watershed are limited to approximately 8 acres and contribute < 1% of the total phosphorus load to the Lake.

Phosphorus Loading from Non-Developed Lands and Water

Inactive/Passively Managed Forests: Of the total land area within the Cross Lake watershed, 12,881 acres are forested, characterized by privately-owned non-managed deciduous and mixed forest plots. This is the largest land use category, comprising 33% of the watershed land area. Approximately 4% of the phosphorus load (253 kg/year) is estimated to be derived from non-commercial forested areas within Cross Lake's direct drainage area.

Other Non-Developed Land Areas: The combination of wetlands, grasslands/reverting fields and scrub shrub account for the remaining 23% of the land area in the Cross Lake watershed and 2% of the total phosphorus export load.

Atmospheric Deposition (Open Water): Surface waters for Cross Lake's direct watershed comprise nearly 7% of the total land area (2,820 acres) and account for an estimated 186 kg of total phosphorus per year, representing 3% of the total direct watershed load entering Cross Lake. 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.

Particulates in the air contribute phosphorus to Cross Lake, and are factored into the GIS land-use model.

PHOSPHORUS LOADS - Watershed, Sediment and In-Lake Capacity

Supporting documentation for the phosphorus loading analysis includes water quality monitoring data from Maine DEP and the Volunteer Lake Monitoring Program, and the development of a phosphorus retention model (see <u>Appendices,</u> p.31, 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 GIS-based model 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 Cross Lake 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.

GIS-based Land Use and Indirect Load Method

<u>Watershed Land Uses:</u> Total phosphorus loadings to Cross Lake originate from a combination of external watershed and internal lake sediment sources. Watershed total phosphorus sources, totaling approximately <u>5,946</u> kg annually (corrected GIS) have been identified and accounted for by land use in the direct watershed (See Table 3 - page 27), while the average annual internal lake sediment P-loading of 2,971 kg was estimated from five years of data (1989-92, 2003).

<u>Loading from the Indirect Watershed:</u> Total phosphorus loading from two associated upstream sources including Mud Lake (1,755 kg) and Daigle Pond (235 kg) accounts for an estimated indirect watershed average load of <u>1,990</u> kg annually, determined on the basis of *flushing rate x volume x TP concentration* (see page 28 for more information).

The sum of these two potential sources of TP indicates that an estimated <u>7,936</u> kg/yr may be contributing to the current in-lake phosphorus levels of Cross Lake. However, these models do not take into account many of the complex factors that affect lake water quality. Instead, these figures provide stakeholders with estimates that should assist with targeting implementation measures in the watershed.

2. In-Lake Concentration Method (TMDL)

<u>Lake Capacity:</u> The assimilative capacity for all existing and future non-point pollution sources for Cross Lake is <u>5,050</u> kg of total phosphorus per year, based on a target goal of <u>16</u> ppb (see Phosphorus Retention Model - page 31).

<u>Target Goal:</u> A change in 1 ppb in phosphorus concentration in Cross Lake is equivalent to <u>316</u> kg. The difference between the target goal of 16 ppb and the measured average summertime total phosphorus epilimnion concentrations (1982-2004 = <u>20</u> ppb) is 4 ppb or <u>1,264</u> kg (4 ppb x 316 kg).

<u>Future Development:</u> The annual total phosphorus contribution to account for future development for Cross Lake is <u>158</u> kg (0.50 x 316 kg) (see Future Development page 30 for more information).

<u>Reduction Needed:</u> Given the target goal and a 158 kg allocation for future development, the total amount of phosphorus needed to be reduced, on an annual basis, to eventually restore water quality standards in Cross Lake approximates <u>1,422</u> kg (1,264 kg + 158 kg).

PHOSPHORUS CONTROL ACTION PLAN

Recent and Current NPS/BMP Efforts

The St. John Valley SWCD has recognized the need for reducing the NPS pollution to streams and lakes in the Cross Lake watershed. In 1982 the District set a goal of reducing soil erosion by more than 60% in the Dickey Brook watershed (a tributary of Cross Lake) corresponding to an annual sediment load reduction of almost 4200 metric tons (St. John Valley SWCD 1982). In 1990, the District developed a more ambitious plan to apply additional conservation measures to the entire Long-Cross Lakes drainage basins (St. John Valley SWCD, 1990). Innovative nutrient-sediment control systems (NSCS) have been proposed on as many as 25-30 sites serving watersheds of 8-61 hectares each with a projected total cost of over $800,000 (Bouchard et al. 1995).

As of 2001, a total of 1,438 water quality projects have been approved for installation, 918 have completed, and 520 are active (NEIRTT 2001). Notes from a 2001 public outreach meeting reported that livestock farmers are involved in nutrient management planning, and grazing land management, livestock operations are doing conservation work under EQIP, and applying practices such as animal fencing to keep animals out of streams, stream crossings, and solar pumps. In addition, potato growers are buying fertilizer custom blended based on soil tests. Incentive program's like CRP, that reduce the number of potato acres by paying farmers to take land out of production, and the State program that paid 100% of the cost for installing sediment nutrient control structures, have helped get BMPs on the ground (NEIRTT 2001).

Continued efforts for installing BMPs and reducing NPS pollution in the Cross Lake watershed are imperative given the current water quality conditions. Many of the action items listed below have been suggested by residents and professionals that live in the Cross Lake watershed (NEIRTT 2001).

Recommendations for Future NPS/BMP Work

Cross Lake has impaired water quality as a result of nonpoint source (NPS) pollution, and resultant internal lake sediment recycling of phosphorus. This PCAP-TMDL report will serve as a compilation of existing information about past and present projects undertaken in order to adequately assess future NPS BMP needs in the watershed. 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 Cross Lake are as follows:

Watershed Management: Several agencies (e.g. Maine DEP, SJV-SWCD, USDA-NRCS, Fish River Lakes Water Quality Association (FRLWQA)) have shown interest in continuing efforts to educate landowners and operators about the importance of good land use management practices and to encourage installation of BMPs to reduce NPS pollution in Cross Lake. There is a general concern about costs of construction for installing BMPs on agricultural land, especially the sediment and nutrient control basins which cost between $25 -$30,000 (NEIRTT 2001). However, without full public funding, the cost of these structures may not make them a viable option for the watershed (Roy Bouchard, Personal Communication).

Action Item # 1: Coordinate existing watershed management efforts		
Activity	**Participants**	**Schedule & Cost**
Initiate efforts to develop a Cross Lake Restoration and Protection Fund	FRLWQA, SJV-SWCD, NRCS, Maine DEP, interested watershed citizens - stakeholders	Search for funding and write proposals - beginning in Fall 2006 - minimal cost

Agriculture: Agricultural activities are among the most dominant land uses in the watershed and combined contribute the greatest proportion of phosphorus loading to Cross Lake. BMP recommendations for agricultural land uses include continued education on conservation practices and planning assistance. The Natural Resources Conservation Service provides technical assistance for using proper agricultural BMPs. For more information contact the NRCS office in Aroostook County (834-3311).

Action Item # 2: Educate and assist agricultural landowners		
Activity	**Participants**	**Schedule & Cost**
• Conduct workshops encouraging the use of phosphorus control measures within the Cross Lake watershed • Set up a demonstration area showing the use of sediment and nutrient control structures • Apply for funding that would provide cost-sharing for installing nutrient/sediment control basins • Design sediment basins to allow easy and periodic sediment removal • Provide education and incentives for maintenance and upkeep of existing BMPs • Investigate the use of cull potato storage areas • Provide education and assistance for practicing rotational cropping • Consider conservation tillage (Chisel plowing) over conventional methods • Plant a winter cover crop to reduce soil erosion during the off season and consider yearly crop rotations	SJV-SWCD, NRCS, agricultural landowners and watershed municipalities	Annually beginning in 2006 Variable cost depending on type of activities

Shoreline Residential: Densely developed residential dwellings have the potential to negatively effect water quality. The 1988 shoreline survey reported 250 shoreline dwellings located within the buffer zone, with inadequate shoreline buffers and lots with 60% of the trees and bushes cleared. 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 follow Land Use Regulation Commission (LURC) standards for maintaining adequate and effective vegetated shoreline buffers. 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 SJV-SWCD at 834-6435.

Action Item # 3: Educate watershed citizens about shoreline buffers		
Activity	**Participants**	**Schedule & Cost**
Develop a Buffer Awareness Campaign for Watershed Citizens	Maine DEP, SJV-SWCD, interested watershed citizens	Begin immediately— **$2,500/year**

Septic Systems: Older, poorly designed and installed septic systems within the shoreland zone may contribute significantly to water quality problems, adding to the cumulative phosphorus load to Cross-Lake. While Cross Lake septic systems – when properly sited, constructed, maintained, and set back from the water – should not affect water quality, many septic systems do not meet all of these criteria and thus have the potential to contribute phosphorus and other contaminants to lake water. Septic systems around Cross Lake which are sited in coarse, sandy or gravelly soils with minimal filtering capacity (patches on the northeast shoreline) and older septic systems which pre-date Maine's 1974 Plumbing Code are especially likely to contribute nutrients to lake waters.

Lakeshore residents who believe they may have problems with their septic systems are encouraged to contact the local Maine-DEP office for possible technical and/or financial assistance.

Action Item # 4: Develop septic/sewage system inspection program		
Activity	**Participants**	**Schedule & Cost**
Conduct septic/sewage system inspections to identify any potential malfunctions and promote regular pumping to ensure proper operation	Maine DEP, SJV-SWCD, FRLQA, and watershed citizens	Annually beginning in 2006 $1,500/yr

Roadways: A common cause of NPS pollution in lake watersheds is often related to roads, which if not properly designed and maintained can be a major source of erosion and sedimentation into ponds, lakes and streams. This PCAP report estimates that public and private roads combined contribute more than 6% of the total phosphorus load per year to Cross Lake. Considerable lengths of private gravel roads remain unmapped and unaccounted for, and may contribute significant loading to the Cross Lake Watershed (NMRPC 1988). As such, efforts should be undertaken to identify pollution sources from the both mapped and unmapped roads so that appropriate BMPs can be designed and installed to remediate problem areas.

Action Item # 5: Implement roadway Best Management Practices		
Activity	**Participants**	**Schedule & Cost**
Conduct survey of public and private roads in watershed to determine NPS pollution sources and establish/ implement roadway BMPs	Maine DEP, SJV-SWCD, Towns in watershed, interested watershed citizens	Annually beginning in 2006 **$10,000**

Forestry: Forestry activities are more limited from a phosphorus loading perspective, compared to agricultural land uses in the Cross Lake watershed. However, existing voluntary state guidelines for simplified pre-harvest plans, filter areas and proper erosion control as described in *Best Management Practices for Forestry: Protecting Maine's Water Quality* would minimize erosion and sedimentation during harvesting. Watershed municipalities should adopt new Statewide Standards for Timber Harvesting and Related Activities in Shoreland Areas. For more information contact the Maine Forest Service (1-800-367-0223).

Action Item # 6: Promote sound forest management in shoreland areas		
Activity	**Participants**	**Schedule & Cost**
• Promote use of voluntary forestry BMPs • Adopt statewide Standards for Timber Harvesting and Related Activities in Shoreland Areas • Encourage landowner participation in Be Woods Wise, MFS's education, technical and financial assistance program for forest landowners	Watershed municipalities, forest landowners, logging professionals, local land trusts, Maine Forest Service	Beginning 2006 (**Cost dependent on activities**) Financial cost-share assistance available to develop long-term forest management plans and implement sustainable forestry projects including NPS corrective action

Non-Shoreline Development: Combined, these types of land uses are estimated to contribute nearly 7% of the total phosphorus load to Cross Lake. Particular attention should be given to properties adjacent to watershed brooks and streams.

Action Item # 7: Develop stewardship initiatives for Cross Lake tributaries		
Activity	**Participants**	**Schedule & Cost**
"Adopt" local streams to promote stewardship efforts including education and water quality monitoring.	Maine DEP, SJV-SWCD, FRLWQA, Stream Team, local schools and watershed citizens.	Annually beginning in 2007 **$2,500/yr**

Individual Action: All watershed residents should be encouraged through continued education and outreach efforts, including: retention or planting of natural vegetation of buffer strips, use of non-phosphate cleaning detergents, elimination of phosphorus-containing fertilizers, and adequate maintenance of septic systems.

Action Item # 8: Expand homeowner education & technical assistance programs		
Activity	**Participants**	**Schedule & Cost**
Increase outreach and education efforts to watershed citizens including technical assistance to landowners	SJV-SWCD, Maine DEP, FRLWQA	Annually beginning in 2006 **$2,500/yr includes printing of educational materials**

WATER QUALITY MONITORING PLAN

Historically, the water quality of Cross Lake has been monitored via measures of Secchi disk transparencies during the open water months since 1981 (Maine DEP and VLMP). Continued long-term water quality monitoring of Cross Lake will be conducted monthly, from May to October, through the continued efforts of Maine DEP and VLMP. Under this planned, post-TMDL water quality-monitoring plan, sufficient data will be acquired to adequately track seasonal and inter-annual variation and long-term trends in water quality in Cross Lake. A post-TMDL adaptive management status report will be prepared five to ten years following EPA approval.

PCAP CLOSING STATEMENT

The Maine Association of Conservation Districts and St. John Valley Soil and Water Conservation District (SJV-SWCD) along with the Fish River Lakes Water Quality Association (FRLWQA), in cooperation with lake stakeholders, have initiated the process of addressing nonpoint source pollution in the Cross Lake watershed. Technical assistance by SJV-SWCD is available to watershed residents (see list of towns, page 9) to mitigate phosphorus export from existing NPS pollution sources and to prevent excess loading from future sources. It is critical that watershed residents recognize the inherent value of Cross Lake and its vital link to the community by providing strong support for restoration efforts. The municipalities in the watershed should cooperate with the SJV-SWCD and NRCS in the pursuit of local and regional lake protection and improvement strategies. This teamwork approach should result in an eventual overall improvement in Cross Lake through NPS-BMP implementation and increased public involvement and awareness.

APPENDICES

CROSS LAKE –Cross Lake & Square Lake Twp.

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 both daily and annual total 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 8 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, and Sewall Pond. PCAP-TMDLs are presently being prepared by Maine DEP, with assistance from the Maine Association of Conservation Districts (MACD) and County Soil and Water Conservation Districts (SWCD’s) - for Hermon and Hammond Ponds and Daigle Pond. PCAP-TMDL studies have also been initiated for Trafton Lake and Monson Pond, as well as several other 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.

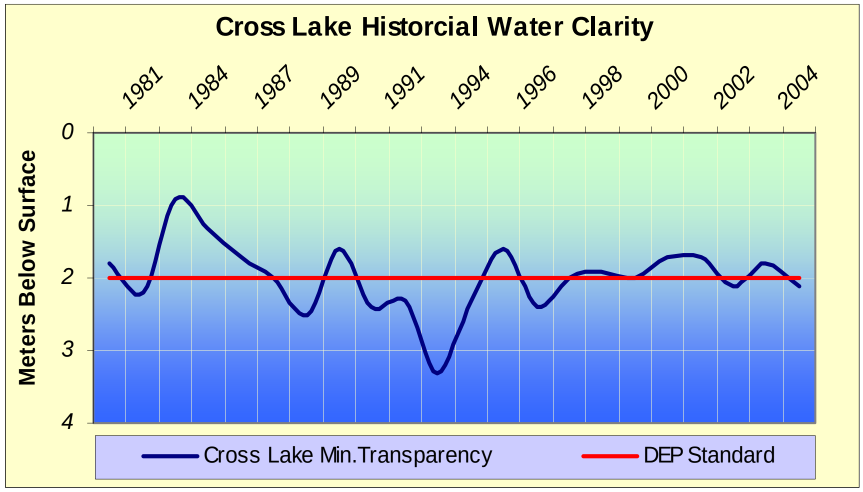
PCAP-TMDLs are important tools for maintaining and protecting acceptable lake water quality and are designed to 'get a handle' on the magnitude of the NPS pollution problem and to develop plans for implementing Best Management Practices (BMPs) to effectively address the lake’s water pollution problem. 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: Maine DEP and VLMP 2005) Water quality monitoring data for *Cross Lake* (station 1, deep hole) has been collected annually since 1981(with the exception of 1985 and 1993), and is based on 22 years of Secchi disk transparency (SDT) measures, combined with 12 years of epilimnion core total phosphorus (TP) data, 11 years of water chemistry and 17 years of chlorophyll-a monitoring data.

Water Quality Measures: (Source: Maine DEP and VLMP, 2005) Historically, *Cross Lake* has had a range of SDT measures from 0.9 to 4.4 meters, with an average of 2.6 m; an epilimnion core TP range of 12 to 23 with an average of 17 parts per billion (ppb), and chlorophyll-a measures ranging from 2.3 to 53.4, with an average of 10.8 ppb. Recent dissolved oxygen (DO) profiles show minimal DO depletion in deep areas of the lake prior to the 2000 sampling season, yet the three subsequent years that DO data are available (2000, 2003-05) show that DO is low (< 5 ppm) in the bottom 4-6 meters making this region of the lake unsuitable for cold water fish. The potential for total phosphorus to leave the bottom sediments and become available to algae in the water column (internal loading) is low, except during high wind events when the lake experiences turbidity from sediment resuspension (VLMP, 2005).



Minimum annual water clarity for Cross Lake appeared to be increasing from 1984 through 1994, but then began declining through the late 90's into the present.

Priority Ranking, Pollutant of Concern and Algae Bloom History: Cross Lakes is listed on the State's 2004 303(d) list of waters in non-attainment of Maine State water quality standards, and was moved up in the priority development order due to the need to complete an accelerated approach to lakes TMDL development. This Cross Lake TMDL has been developed for total phosphorus, the major limiting nutrient to algae growth in freshwater lakes in Maine.

As indicated by water clarity, the water quality of *Cross Lake* appeared to improve during the early 1990's. However, since 1995 water clarity has been declining and minimum transparencies have averaged at or below 2 meters in 13 of the 22 sampling years. Total phosphorus (18 ppb-based on recent summertime data 1997 to 2004) and chlorophyll-a (mean 12.3 ppb-based on recent summertime data from 1997 to 2005) do not meet State minimum standards for acceptable water quality.

Natural Environmental Background levels for Cross Lake was 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 non-point source loading, it is very difficult to separate natural background from the total non-point source load (US-EPA 1999). There are no known point sources of pollutants to Cross Lake.

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 (SDT's) < 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. *Cross Lake* is a moderately colored lake (average color 38 CPUs), with relatively low late summer SDT readings (annual average of 2.6 meters), in association with moderate/high chlorophyll-a levels (15 ppb late summertime average-1981 to 2005).

Currently, Cross Lake does not meet water quality standards due to low water transparency trends over time, combined with a monitored annual summertime hypolimnetic dissolved oxygen trending toward deficiencies. This water quality assessment uses historic documented conditions as the primary basis for comparison.

Designated Uses and Antidegradation Policy: Cross Lake is designated as 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 Cross Lake is set at 16 ppb total phosphorus (5,050 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 attain the narrative water quality standard. Spring-time (late May - June) total phosphorus levels in *Cross Lake* approximate 9 - 25 ppb and average 17 ppb, while summertime levels range from 12-32 ppb and average 21 ppb (algal bloom conditions).

In summary, the numeric water quality target goal of 16 ppb for total phosphorus in Cross Lake was based on hypothetical late spring - early summer pre-water column stratification estimates, generally corresponding to non-bloom conditions, as reflected in suitable (water quality attainment) measures of both Secchi disk transparency (> 2.0 meters) and chlorophyll-a (< 8.0 ppb).

Notably, the development of the Cross Lake TMDL (DEPLW 0790) and selection of a numeric water quality target of 16 ppb total phosphorus is protective of upstream uses in both Daigle Brook (downstream of Daigle Pond), and Dickey Brook which are both water quality impaired and 303(d) listed. The water quality impairment of both Daigle and Dickey Brooks is due to dissolved oxygen loss related to primary productivity caused by excessive pollutants (total phosphorus) from Daigle Pond (for Daigle Brook) and the brooks’ direct watersheds (Daigle and Dickey Brooks) within the Cross Lake drainage system. The planned reduction of total phosphorus loading to both Daigle and Dickey Brooks (contributing nutrient sources for downstream Cross Lake) coupled with the attainment of the in-lake target of 16 ppb in Cross Lake will provide for attainment and maintenance of water quality standards in Daigle and Dickey Brooks. Following final EPA approval of the Cross Lake TMDL (DEPLW 0790) and the Daigle Pond TMDL (DEPLW 0789), both Daigle and Dickey Brooks will be re-designated from the 303(d) list to category 4A (TMDL approved).

ESTIMATED PHOSPHORUS EXPORT BY LAND USE CLASS

Table 3 details the numerical data used to determine external phosphorus loading for the Cross Lake watershed. The key below Table 3 explains the columns and the narrative that follows (pages 28-29) relative to each of the representative land use classes.

Table 3. Cross Lake Direct Watershed - Estimated Phosphorus Export by Land Use Class

LAND USE CLASS	Land Area Acres	Land Area %	TP Coeff. Range kg TP/ha	TP Coeff. Value kg TP/ha	Land Area Hectares	TP Export Load kg TP	GIS Adjusted kg TP	TP Export Total %
Agricultural Land								
Hayland - Non-Manured	1,339	3%	0.35 - 1.34	0.64	542	347	417	7%
CRP/EQIP	2,647	7%	0.2 - 0.4	0.30	1,071	321	383	6%
Row Crops/Tillage	3,569	9%	0.26 - 18.6	3.68	1,444	2,949	3,530	59%
Animal Feedlot/Barnyard	20	0.1%	21 - 795	21	8	169	194	3%
Pasture (grazed Meadows)	441	1%	0.14 - 4.9	0.81	178	145	174	3%
Sub-Totals	**8,016**	**21%**			**3,244**	**3,930**	**4,698**	**78%**
Actively Managed Forest								
Actively Managed Forest	5,255	14%	0.04 - 0.6	0.08	2,127	170	207	4%
Sub-Totals	**5,255**	**14%**			**2,127**	**170**	**207**	**4%**
Shoreline Development								
Shoreline Septic Systems						62	62	1%
Shoreline Low Density Residential	113	0.3%	0.25- 1.75	0.5	46	23	24	0.4%
Shoreline Roads	17	0.04%	0.60 - 10.0	1.5	7	10	15	0.3%
Sub-Totals	**130**	**0.3%**			**52**	**95**	**101**	**2%**
Non-Shoreline Development								
Roads	531	1.4%	0.60 - 10.0	1.5	215	322	375	6%
Low Density Residential	110	0.3%	0.25- 1.75	0.5	44	22	25	0.4%
Commercial/Industrial	8	0.02%	0.77 - 4.18	1.5	3	5	7	0.1%
Sub-Totals	**648**	**2%**			**262**	**349**	**408**	**7%**
Total: DEVELOPED LAND	**14,049**	**36%**			**5,685**	**4,544**	**5,414**	**91%**
Non-Developed Land								
Inactive/Passively Managed Forest	12,881	33%	0.01 - 0.08	0.04	5,213	209	253	4%
Grassland/Reverting Fields	504	1%	0.1 - 0.2	0.2	204	41	37	0.6%
Scrub-Shrub	202	1%	0.1 - 0.2	0.15	82	12	15	0.3%
Wetlands	8,167	21%	0.0 - 0.05	0.01	3,305	33	41	1%
Total: NON-DEVELOPED LAND	**21,754**	**56%**			**8,804**	**295**	**346**	**6%**
Total: Surface Water (Atmospheric)	**2,820**	**7%**		**0.16**	**1,141**	**183**	**186**	**3%**
TOTAL: DIRECT WATERSHED	**38,622**	**100%**			**15,630**	**5,022**	**5,946**	**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 coeff. 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. The coefficient is often adjusted using best professional judgment based on conditions including soil type, slope, and best management practices (BMPs) installed.

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

TP Export Load kg P: Total hectares x applicable total phosphorus coefficient

GIS Adjusted kg TP: Uses GIS to incorporate soils and slopes into the final phosphorus loading number.

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 Cross Lake watershed are presented on the previous page in Table 3. These tables represent the extent of the current direct watershed phosphorus loading to the Lake (5,946 kg/yr). Total phosphorus loading from *Cross Lake's* indirect watersheds (Mud Lake-1,755 kg/yr, and Daigle Pond-235 kg/yr), was determined on the basis of *flushing rate x volume x TP concentration (Mud Lake = 10.8 flushes/yr x 12.5 x 13ppb), Daigle Pond = 21.3 flushes/yr x 0.22 x 50 ppb)* 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 (e.g., commercial/industrial).

Agriculture: Phosphorus loading coefficients as applied to agricultural land uses were adopted from: Reckhow et al. (1980): animal feedlot/barnyard (21 kg TP/ha/yr), pasture/grazed meadow (0.81 kg TP/ha/yr), and row crops/tillage/cultivation (2.24 kg TP/ha/yr). Row crops were further broken down to account for crops under two-year rotation (1.44 kg/ha/yr) based on a 1:1 grass: row crop rotation. and The coefficient used for non-manured hayland (0.64 kg/ha/yr) was based on research by Dennis and Sage (1981) which may actually underestimate its impact since some hayland receives manure, commercial fertilizer, or wood ash. The coefficient for land under USDA CRP/EQIP (0.30 kg TP/ha/yr) from Bouchard (1995) was first used for the Long Lake TMDL. The land use coefficient used for animal feedlot/barnyard (21 kg TP/ha/yr) is the lowest value in a range of coefficients (21 -795 kg TP/ha/yr) which was chosen based on the distance from Cross Lake and its contributing tributaries, and the continued work of landowners to install BMPs over the past two decades.

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 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 range of phosphorus loading coefficients used (0.25 – 2.70 kg/ha/yr) was developed from information on residential lot stormwater export of phosphorus as derived from Dennis et al. (1992). Phosphorus loading coefficients for low density residential development was estimated to be 0.50 kg/ha/yr.

Private and Public Roads: The total phosphorus loading coefficient for private/camp and public roads (2.0 kg/ha/yr for private/camp roads and 1.50 kg/ha/yr for public roads) was chosen, in part, from previous studies of rural Maine highways (Dudley et al. 1997) and phosphorus research by Jeff Dennis (Maine DEP).

Total Developed Lands Phosphorus Loading: A total of 91% (5,414 kg) of the phosphorus loading to *Cross Lake* is estimated to have been derived from the cumulative effect of the preceding cultural land use classes: agriculture (78% - 4,698 kg) and forestry (4% - 207 kg); shoreline development (2% - 101 kg), including septic systems (1% - 62 kg) and non-shoreline development (7% - 408 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 (0.20 kg/ha/yr) and scrub/shrub (0.10 kg/ha/yr) is based on research by Bouchard et al. (1995) (0.20 kg/ha/yr). The export coefficient for wetlands is based on research by Bouchard et al. (1995), and Monagle (1995) (0.01 kg/ha/yr). The phosphorus loading coefficient chosen for surface waters (atmospheric deposition) was (0.16 kg/ha/yr), as 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 Cross Lake 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 *Cross Lake* approximates 7,936 (5,946 + 1,990) 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 TP 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 Cross Lake TMDL as an annual load because the lake basin has an annual flushing rate of 3.3 (see discussion of seasonal variation on page 32). 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 31 (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 Cross Lake are presented on page 33.

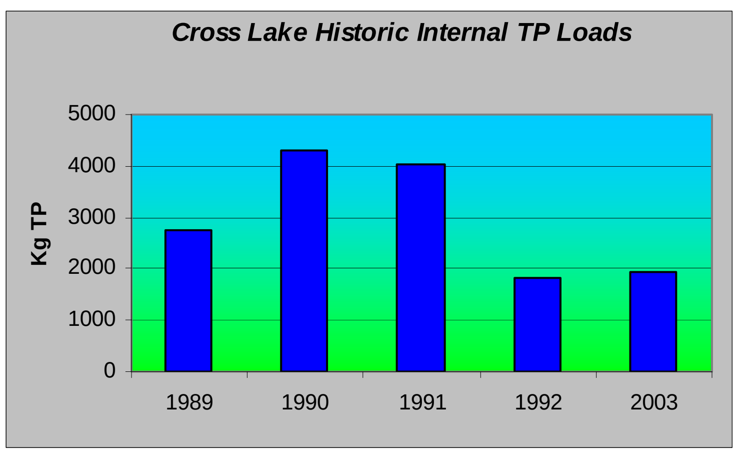
Assimilative Loading Capacity: The Cross Lake basin lake assimilative capacity is capped at 5,050 kg TP/yr as derived from the empirical phosphorus retention model based on a target goal of 16 ppb. This value reflects the modeled phosphorus loading responsible for current trophic state conditions, based on a long term goal of maintaining average phosphorus concentrations at or below 16 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: The Maine DEP water quality goal of maintaining a stable trophic state includes a reduction of current P-loading which accounts for both recent P-loading as well as potential future development in the watershed. The methods used by 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. Previously unaccounted P-loading from anticipated future development on Cross Lake watershed approximates 158 kg annually (0.5 x 1 ppb change in trophic state or 316 kg).

Human growth will continue to occur in the Cross Lake watershed, contributing new sources of phosphorus to the lake. Hence, existing phosphorus source loads must be reduced by at least 158 kg in order to allow for anticipated new sources of phosphorus to Cross Lake.

Overall, the presence of nuisance algae blooms in Cross Lake may be reduced, along with halting the trend of increasing trophic state, if the existing combined phosphorus loading is reduced by approximately 1,422 kg TP/yr.

Internal Lake Sediment Phosphorus Mass: The relative contribution of internal sources of total phosphorus within Cross Lake - in terms of sediment TP recycling - were analyzed (using lake volume-weighted mass differences between early and late summer) and estimated on the basis of water column TP data. The only years for which adequate lake profile TP concentration measures were available to derive reliable estimates of internal lake mass for Cross Lake were 1989-1992 and 2003. Average TP for the period 1989 to 1992 was 5,190 kg, while data from 2003 show internal TP concentration of 1,951 kg.



Linking Pollutant Loading to a Numeric Target: The basin loading assimilative capacity for moderately-colored Cross Lake was set at 5,050 kg/yr of total phosphorus to meet the numeric water quality target of 16 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 Cross Lake TMDL Analysis includes the following: Maine DEP and VLMP water quality monitoring data, development of a GIS land-use model, and specification of a phosphorus retention model – including both empirical models and retention coefficients.

Cross Lake Total Phosphorus Retention Model

(after Dillon and Rigler 1974 and others)

L = P (A z p) / (1-R) where, **1 ppb change = 316 kg**

5,050 = **L** = external total phosphorus load capacity (kg TP/year)
16 = **P** = total phosphorus concentration (ppb) = **Target Goal = 16 ppb**
10.27= **A** = lake basin surface area (km^2)
6.0 = **z** = mean depth of lake basin (m) **A z p = 202**
3.28 = **p** = annual flushing rate (flushes/year)
0.64 = **1- R** = phosphorus retention coefficient, where:
0.36 = **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, and Sewall 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 Cross Lake TMDL was developed using existing lake water quality monitoring data, derived watershed export coefficients (Reckhow et al. 1980, Maine DEP 1981 and 1989, Dennis 1986, Dennis et al. 1992, Bouchard et al. 1995, Soranno et al. 1996, and Mattson and Isaac 1999) and a phosphorus retention model which incorporates both empirically derived and observed retention coefficients (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 1972 National Eutrophication Survey (US-EPA-New England) 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.
- 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.

Critical Conditions occur in Cross Lake during the summertime, when the potential (both occurrence and frequency) of nuisance algae blooms are greatest. The loading capacity of 16 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 Cross Lake equals 5,050 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 5,946 kg annually) have been identified and accounted for in the land-use breakdown portrayed in Table 3 (corrected GIS). Further reductions in non-point source phosphorus loadings are expected from the continued implementation of NPS best management practices (see summary, pages 18-22). 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 Cross Lake originate from a combination of direct and indirect (watershed + Mud Lake + Daigle Pond) external and internal (lake sediment) sources of total phosphorus.

WASTE LOAD ALLOCATIONS (WLA's): Since there are no known existing point sources of pollution (including regulated storm-water sources) in the Cross Lake watershed, the waste load allocation (WLA) is set at 0 (zero) and all of the loading capacity is allocated as a gross allotment to the "load allocation".

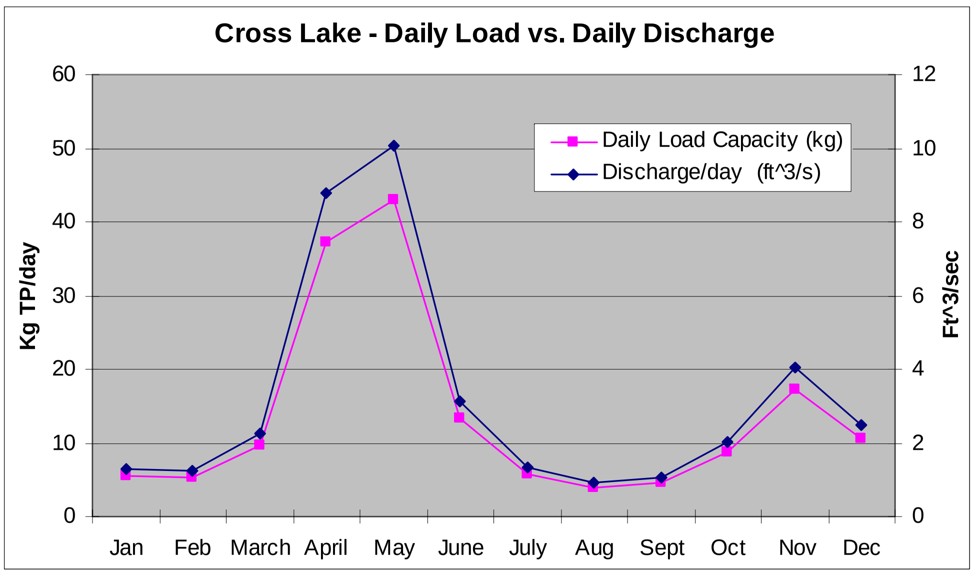
MARGIN OF SAFETY (MOS): The TMDL expressed in terms of annual and daily loads includes an implicit MOS through the relatively conservative selection of the numeric water quality target (based on a state-side database for lakes, supported by in-lake data). Based on both the Cross Lake historical records and a summary of statewide Maine lakes water quality data for colored (> 30 SPU) lakes - the target of 16 ppb (5,050 kg/yr in Cross Lake) 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. The statewide data base for colored Maine lakes indicate that summer nuisance algae blooms (growth of algae which causes water transparency to be less than 2 meters) are more likely to occur at 18 ppb or above.

SEASONAL VARIATION: The Cross Lake 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 3.3 flushes/year, the average annual phosphorus loading is most critical to the water quality. 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, nonpoint source best management practices (BMPs) proposed for the Cross Lake 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 (see page 33). 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) for calculating the external total phosphorus load capacity (page 29-30) for the lake.

Cross Lake Daily Load Calculations

Month	Discharge/Month (ft^3/s)	% of Total	Flushes/month	Monthly Load Capacity (kg)	Discharge/day (ft^3/s)	Flushes/Day	Daily Load Capacity (kg)
Jan	39.58	3%	0.11	168.46	1.28	0.004	5.43
Feb	35.18	3%	0.10	149.75	1.26	0.003	5.35
March	69.94	6%	0.19	297.73	2.26	0.006	9.60
April	263.10	22%	0.73	1119.94	8.77	0.024	37.33
May	312.71	27%	0.87	1331.11	10.09	0.028	42.94
June	93.77	8%	0.26	399.14	3.13	0.009	13.30
July	41.48	4%	0.12	176.58	1.34	0.004	5.70
August	29.14	2%	0.08	124.02	0.94	0.003	4.00
September	32.20	3%	0.09	137.07	1.07	0.003	4.57
October	62.98	5%	0.18	268.07	2.03	0.006	8.65
November	121.91	10%	0.34	518.95	4.06	0.011	17.30
December	77.19	7%	0.21	328.58	2.49	0.007	10.60



Vollenweider: L = P (Azp) / (1-R)	
L = external P load capacity (kg TP/yr)	**5050**
P = total P concentration (ppb)	16
A = lake basin surface area (km2)	10.27
z = mean depth of lake basin (m)	6
p = annual flushing rate	3.28
1-R = P retention coefficient	0.64
R = 1 / (1 + sq. rt. p)	0.36

Season	% of Total	# Flushes
May -October	49%	1.6
November-April	51%	1.7

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

1. **September 26, 2005:** MACD staff traveled to Aroostook County to meet with staff from Maine DEP and the SJV-SWCD to gather information and discuss the water quality of Cross Lake.

2. **September 27, 2005:** MACD staff met with Maine DEP and SJV-SWCD staff in the field and were given a tour of the Cross Lake watershed.

3. **February 7, 2006:** MACD staff member Jennifer Jespersen contacted Heidi Royal at SJV-SWCD to gather historical information about the watershed.

4. **February 17, 2006:** MACD staff member Tricia Rouleau created and sent GIS land use maps to Heidi Royal at the SJV-SWCD for review.

5. **June 8, 2006:** SJV-SWCD staff Heidi Royal sent updated land use maps and lists of feedlot BMPs to MACD staff Jennifer Jespersen for incorporation into the TMDL.

6. **June 29, 2006:** MACD and SJV-SWCD sponsored a public meeting at the New Canada Community Center to discuss the Cross Lake TMDL and to receive stakeholder feedback.

7. **June 30, 2006:** MACD staff spent the morning reviewing land use maps at the SJV-SWCD office in Fort Kent to incorporate CRP land into the TMDL. MACD staff spent the remainder of the day driving the Cross Lake watershed to "ground-truth" the agricultural land uses, particularly to verify the location of CRP land in the watershed.

STAKEHOLDER AND PUBLIC REVIEW PROCESS

A two-week stakeholder review was distributed electronically on July 18, 2006 to the following individuals who expressed a specific interest, participated in the field work or helped develop the draft Cross Lake PCAP-TMDL report: Maine DEP (Kathy Hoppe and Bill Sheehan); Saint John Valley SWCD (Heidi Royal and Board of Directors); USDA/NRCS (Dave Tingley); Maine Forest Service (Chris Martin); Maine Department of Inland Fisheries and Wildlife (Dave Basley); and Maine Department of Agriculture (David Rocque).

The following statement was advertised in the Bangor Daily News over a month long (2-weekend) period (August 12-13 and August 19-20, 2006), and in the St. John Valley Times over a four-week period beginning the week of August 7, 2006:

CROSS LAKE
Cross Lake & Square Lake TWP (T16 R5 WELS)

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 for the **CROSS LAKE** (DEPLW 2006-0790) watershed, located in the Townships of CROSS LAKE and SQUARE LAKE (T16 R5 WELS). This PCAP-TMDL report identifies and provides best estimates of non-point source phosphorus loads for all representative land use classes in the **CROSS LAKE** 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 Maine DEP Northern Maine Regional offices in Presque Isle (1235 Central Drive, Skyway Park) or at the 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 September 1, 2006 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

An internal review by Maine-DEP requested the inclusion of 303(d) listed Daigle Brook (outlet stream from Daigle Pond which flows into Cross Lake) into the lake PCAP-TMDL report. The following Addendum was added to the report and released for Public Review during the 2-week period (August 28th - September 8, 2006), as advertised in the Bangor Daily News and posted on the Maine DEP website. No comments were received during this review.

DAIGLE Brook, Aroostook County - Total Maximum Daily Load (TMDL) Report Addendum (change notification)

*The development of the Daigle Pond TMDL (DEPLW 2006-0789) and selection of a numeric water quality target of 16 ppb total phosphorus is protective of downstream uses in Daigle Brook, which is also water quality impaired and 303(d) listed. The water quality impairment of Daigle Brook is due to dissolved oxygen loss related to primary productivity caused by excessive pollutants (total phosphorus) from Daigle Pond and the brooks' direct watershed within the Cross Lake drainage system. The planned reduction of total phosphorus loading to Daigle Brook (a primary nutrient source for downstream Cross Lake) coupled with the attainment of the in-lake target of 16 ppb in Daigle Pond will provide for attainment and maintenance of water quality standards in the brook. Following final EPA approval of the Daigle Pond and the Cross Lake TMDL (DEPLW 2006-0790), Daigle Brook will be re-designated from the 303(d) list to category 4A (TMDL approved). Please send any public comments, in writing by **September 8, 2006** to Dave Halliwell, Lakes TMDL Program Manager, Maine DEP, State House Station #17, Augusta , ME 04333, or e-mail: David Halliwell.*

A further internal review by Maine-DEP, including the northern Maine regional office (Kathy Hoppe), requested the inclusion of 303(d) listed Dickey Brook into the report. Changes were made in the 'Drainage System' section (p. 9) to acknowledge that both Daigle and Dickey Brooks are 303(d) listed, and a part of the Cross Lake watershed. Changes were also made to the 'Water Quality' section (p. 9) to acknowledge that these two brooks are on the State's Non Point Source Priority Watershed List. The 'Numeric Water Quality Target' section (p. 26) was revised to include both Daigle and Dickey Brooks as follows:

Notably, the development of the Cross Lake TMDL (DEPLW 0790) and selection of a numeric water quality target of 16 ppb total phosphorus is protective of upstream uses in both Daigle Brook (downstream of Daigle Pond), and Dickey Brook which are both water quality impaired and 303(d) listed. The water quality impairment of both Daigle and Dickey Brooks is due to dissolved oxygen loss related to primary productivity caused by excessive pollutants (total phosphorus) from Daigle Pond (for Daigle Brook) and the brooks' direct watersheds (Daigle and Dickey Brooks) within the Cross Lake drainage system. The planned reduction of total phosphorus loading to both Daigle and Dickey Brooks (contributing nutrient sources for downstream Cross Lake) coupled with the attainment of the in-lake target of 16 ppb in Cross Lake will provide for attainment and maintenance of water quality standards in Daigle and Dickey Brooks. Following final EPA approval of the Cross Lake TMDL (DEPLW 0790) and the Daigle Pond TMDL (DEPLW 0789), both Daigle and Dickey Brooks will be re-designated from the 303(d) list to category 4A (TMDL approved).

DEP internal review asked for clarification regarding direct drainage area calculations and sources, and that the direct drainage area be reported exclusive of the lake surface area. Changes were made to the 'Description of Waterbody and Watershed' section (p. 9) to cite the source of the information. This reference was added to the 'Lake Specific References' list (p. 37).

Further agency review (US-EPA) comments requested additional justification of the link between the annual load and the annual flushing rate of Cross Lake. Changes were made to the 'Annual/Daily Load Capacity' section (page 29).

LITERATURE

Lake Specific References

Bouchard, R., 1991. Maine Department of Environmental Protection Memorandum. Sewering Cross Lake Shorefront: Water Quality Issues. July 31, 1991.

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

FRLWQA. 1991. Fish River Lakes Sanitary Survey Data. Fish River Lakes Water Quality Association, July, 1991.

Hebert, L.J., 1993. Fish River Chain of Lakes Watershed Management Plan. St. John Aroostook RC&D.

MEGIS. 2006. Maine Office of Geographic Information Systems . http://megis.maine.gov/catalog. WBDME6_A, Subwatersheds for Maine.

Maine VLMP. 2005. Maine Volunteer Lake Monitoring Program. Water Quality Summary: Cross Lake, T17 R5 WELS, Aroostook County, Midas 1674. Maine DEP, Augusta Maine.

NEIRTT. 2001. Long-Cross Lakes Watershed Project Report: Summary of Findings. New England Interdisciplinary Resources Technical Team. June, 2001 (Draft).

NMRPC. 1988. East Fish River Chain of Lakes Restoration Project - Evaluation of Selected Activities Affecting Water Quality in Cross Lake. Northern Maine Regional Planning Commission, Caribou, ME (December 1988).

St. John Valley SWCD. 1982. Environmental Impact Appraisal: Dickey Brook Watershed Project.

St. John Valley SWCD. 1989. Long Lake and Cross Lake Watersheds Sanitary Data. St. John Valley SWCD, 1989.

St. John Valley SWCD. 1990. Watershed Plan: Long-Cross Lakes. July, 1990.

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)

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*, Winthrop.

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 '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.

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, Torsten and Dag 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.

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

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.

Monagle, W.J. 1995. Cobbossee Lake Total Maximum Daily Load (TMDL): Restoration of Cobbossee Lake through reduction of non-point sources of phosphorus. *Prepared for ME-DEP by Cobbossee Watershed District.*

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 '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. **Pleasant (Mud) Pond** PCAP-TMDL Final Approval Documentation #**12**. US-EPA/NES, May 20, 2004. (Also Cobbossee Stream)

U.S. Environmental Protection Agency. 2004c. **Sabattus Pond** PCAP-TMDL Final Approval Documentation #**13**. US-EPA/NES, August 12, 2004.

U.S. Environmental Protection Agency. 2004d. **Highland Lake (Bridgton)** PCAP-TMDL Final Approval Documentation #**14**. US-EPA/NES, August 12, 2004.

U.S. Environmental Protection Agency. 2004e. **Toothaker Pond (Phillipston)** PCAP-TMDL Final Approval Documentation #**15**. US-EPA/NES, September 16, 2004.

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

U.S. Environmental Protection Agency. 2005a. **Upper Narrows Pond** PCAP-TMDL Final Approval Documentation #**17**. US-EPA/NES, January 10, 2005.

U.S. Environmental Protection Agency. 2005b. **Little Cobbossee Lake** PCAP-TMDL Final Approval Documentation #**18**. US-EPA/NES, March 16, 2005.

U.S. Environmental Protection Agency. 2005c. **Long Lake (Bridgton)** PCAP-TMDL Final Approval Documentation #**19**. US-EPA/NES, May 23, 2005.

U.S. Environmental Protection Agency. 2005d. **Togus (Worrontogus) Pond** PCAP-TMDL Final Approval Documentation #**20**. US-EPA/NES, September 1, 2005.

U.S. Environmental Protection Agency. 2005e. **Duckpuddle Pond** PCAP-TMDL Final Approval Documentation #**21**. US-EPA/NES, September 1, 2005.

U.S. Environmental Protection Agency. 2005f. **Lovejoy Pond** PCAP-TMDL Final Approval Documentation #**22**. US-EPA/NES, September 21, 2005.

U.S. Environmental Protection Agency. 2006a. **Lilly Pond** PCAP-TMDL Final Approval Documentation #**23**. US-EPA/NES, December 29, 2005.

U.S. Environmental Protection Agency. 2006b. **Sewall Pond** PCAP-TMDL Final Approval Documentation #**24**. US-EPA/NES, March 10, 2006.

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.