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A Watershed Analysis of Long Pond South: Implications for Water Quality and Land Use Management

Colby Environmental Assessment Team, Colby College

Problems in Environmental Science course (Biology 493), Colby College

A Watershed Analysis of Long Pond South

Implications for Water Quality and Land Use Management

PROBLEMS IN ENVIRONMENTAL SCIENCE
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Authors

The analysis of the watershed of the Long Pond South Basin was conducted by the students of Biology 493: Problems in Environmental Science class at Colby College in Waterville, Maine.

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WATERSHED ASSESSMENT INTRODUCTION

EXECUTIVE SUMMARY

The water quality of the South Basin of Long Pond, located in the Belgrade Lakes region of Maine, was investigated by the Colby Environmental Assessment Team (CEAT) from May to September of 2007. The physical, chemical, and biological characteristics of water quality were analyzed to evaluate the current health of the lake. The Long Pond South watershed was examined to investigate the effect of land-use patterns, including residential and commercial development, on the lake water quality. Data were also collected from road and shoreline surveys to produce maps highlighting areas that could potentially contribute to the degradation of water quality. Data collected during the summer and fall were compared with data from previous years to study the historic water quality trends.

The water quality trends show that the lake transparency of Long Pond South has decreased by roughly one meter over the past 30 years, suggesting greater productivity. The trophic status of Long Pond South is oligotrophic, but the decreasing trend in transparency could indicate the acceleration of eutrophication. This possibility is supported by the trend of increasing pH over the past 30 years, which is linked to increased algal growth. In late summer, Long Pond South has very low oxygen levels in the temperature-defined metalimnion and near the bottom of the water column. More research is needed to determine the cause of the low-oxygen concentration in the metalimnion, but the lack of oxygen on the bottom during the summer months is likely due to stratification of the water column preventing the addition of oxygen from the surface. Existing oxygen on the bottom is then used up by the large populations of decomposers that develop because of the increased availability of sediment organic matter in aging lakes.

The amount of aquatic plant productivity in a lake is limited by the amount of phosphorus in the water. The increasing productivity trend in Long Pond South indicates increasing levels of phosphorus, and if the phosphorus levels exceed 12-15 ppm an algal bloom may result. Algal blooms can be detrimental to the health of other organisms in the lake, such as fish, can decrease the aesthetic value, and can reduce the value of shoreline homes. Although the phosphorus levels in Long Pond South are not yet high enough to cause algal blooms, the increasing trend is a cause for concern.

Following is a brief summary of findings from the study of Long Pond South and its watershed carried out by Colby Environmental Assessment Team:

- Long Pond South has a volume of 46.2 million cubic meters and a surface area of 540 hectares (MDEP 2007b). It has two deep basins, with the deepest point reaching 94 ft. 39% of Long Pond South has a depth of less than 16 ft. These areas are at risk for the colonization and establishment of invasive plants, since these species prefer shallow water.
- The total phosphorus concentration of Long Pond South was 9.1 ± 3.0 ppb, up from the Long Pond North concentration of 7.6 ± 1.7 ppb in 2006 (CEAT 2007). The largest external sources of phosphorus are agricultural land (22%), mixed forest (13%), successional land (12%) and atmospheric input (12%) based on the phosphorus budget.
- Long Pond South has a flushing rate of 3.52 flushes per year, with 79% of the water input coming from Long Pond North, 12% from runoff, 6% from Ingham Pond, and 3% from precipitation.
- Fishing is an important recreational activity in Long Pond South but the cold water fishery may be threatened by decreasing DO levels resulting from accelerating eutrophication. Fisheries should continue to be managed through fish stocking, control of invasive species, and habitat preservation.
- Land-use has undergone several changes in the period between 1966 and 2003:
    - Residential area has increased from 0.3% in 1966 to 2.3% in 2003, especially along previously developed roadways and along the shoreline. However, compared to surrounding watersheds, the Long Pond South watershed has a lower density of residential areas.
    - Agricultural land has decreased 4.3% since 1966, which is consistent with trends in surrounding watersheds and throughout southern suburban Maine.
    - There has been a 4.3% increase in successional land since 1966, an amount proportional to the amount of agricultural land that is being reverted.
    - Residential development has occurred primarily in forested areas, so forested land has decreased from 78% to 72% since 1966, even with the decrease in agricultural land.

    - High impact development, such as commercial, cleared land, and parks, has seen only a 1% increase since 1966.
- Wetland areas continue to comprise 11.2% of the Long Pond South watershed. The wetlands have important ecosystem functions for the water body by acting as nutrient sinks that filter the water and capture sediment, and by providing habitat for numerous species.
- Over 40% of the roads in the watershed are camp roads, which are more likely to contribute to water pollution because of the presence of erodible materials and less frequent maintenance than roads servicing year-round homes.
- Just under half of the camp roads are in fair (16.7%) or poor (31%) condition based on our survey and are likely contributors of phosphorus into the lake. These roads will continue to pose problems, if they are not repaired and maintained. Likewise, degradation of roads currently in good or acceptable condition could increase phosphorus loading.

Overall, roads in the Long Pond South watershed are in worse condition (16.7% good) than roads in the Long Pond North watershed (53.7% good; CEAT 2007). Many roads in poor condition in the Long Pond South watershed are in areas undergoing development with few or no residents living there to maintain the roads.

The shoreline of Long Pond South has experienced significantly less development than Long Pond North, with only 126 shoreline homes versus 239 homes in Long Pond North (CEAT 2007). Development has been limited by the amount of land suitable for building and by the recent downturn of the housing market.

Septic systems installed before 1974 may contribute more phosphorus to the lake because they are not required to meet the current strict standards. As residents improve their homes for greater intensity of use, many grandfathered septic systems will be replaced. The installation of new, more efficient septic systems will accompany new construction as the population increases over the next 20 years. Both old and new septic systems should be maintained to minimize the amount of phosphorus entering the lake and affecting water quality.

The Maine State Planning Office estimates that the population of the three towns (Belgrade, Mount Vernon, and Rome) that make up the Long Pond South watershed will increase 65% from 2000 to 2030. The Belgrade Lakes area is becoming increasingly popular as people move into the area upon retirement. CEAT established that there are approximately 50 shoreline lots that could be developed, as well as other areas of potential development within the watershed. Limits to development include mandated resource setbacks, drainage problems, availability of access roads, and the current housing market.

As development in the watershed increases so will phosphorus levels in the lake. Development around the shoreline should be limited and regulated, and development around wetlands and off shore should be done prudently. Roads and shoreline buffers should also be maintained to minimize erosion and to help prevent nutrients from entering the lake with sediment runoff. Educating the public regarding the impact of their actions on lake water quality is important. Awareness of proper maintenance and remediation techniques should also be addressed. Long Pond South is part of a chain of Belgrade Lakes. Long Pond North provides 79% of the water to Long Pond South, so water quality in Long Pond North has a large impact on Long Pond South. The water quality of upstream lakes must also be maintained to ensure good water quality in Long Pond South. CEAT recommends close collaboration with neighboring lake associations to protect the water quality of all the lakes in the region.

BACKGROUND

Lake Characteristics

Distinction Between Lakes and Ponds

Lakes and ponds are inland bodies of standing water created either naturally through geological processes or artificially through human intervention (Smith and Smith 2001). Lakes and ponds differ in their size and depth profiles: lakes have greater surface area and depth than ponds (Smith and Smith 2001), and generally develop both vertical stratification and horizontal zonation while ponds do not. Horizontal zonation divides lakes into zones based on sunlight penetration and the growth of vegetation. The littoral or shallow-water zone is the area in which sunlight can penetrate to the bottom, allowing vegetation to grow from the substrate. The deep-water area is divided into the upper limnetic and lower profundal zones where rooted plants are unable to grow. Ponds do not have this zonation and are shallow enough that vegetation can be rooted throughout (Smith and Smith 2001). The vertical stratification found in lakes depends on water density differences that occur as a result of temperature. Deep lakes will stratify with the densest (colder) water on the bottom until a threshold of 4° C and the least dense (warmer) water toward the surface. Ponds and shallow lakes do not stratify because disturbance from wind and waves causes constant mixing and temperature circulation.

General Characteristics of Maine Lakes

Lakes are a vital natural resource in Maine (Davis et al. 1978), providing fresh water for swimming, fishing, drinking, livestock, and agriculture. Lakes also serve as important habitats for wildlife, such as fish, birds and mammals. Maine lakes also draw tourists to the state throughout the year.

The majority of Maine lakes were formed during the Wisconsonian glaciation of the Pleistocene Epoch (Davis et al. 1978). Glacial activity in Maine has left most lake basins comprised of glacial till, bedrock, and glaciomarine clay-silt. These deposits and the underlying granite bedrock are infertile and as a result, most of Maine's lakes are relatively nutrient poor. The movement of glaciers in Maine was predominantly to the southeast, carving out Maine lakes in a northwest to southeast direction (Davis et al. 1978). This orientation, along with lake surface area and shape, plays a fundamental role in the effect of wind on the water body, which is an important factor for lake turnover, or the mixing of thermal layers.

Most lakes in Maine are located in lowland areas among hills (Davis et al. 1978). Many lake watersheds within the state are forested. These forests are potentially threatened by logging by timber companies. Residential development of watersheds and increased construction of lake recreation facilities may also pose a significant threat to the water quality in many lakes and ponds in Maine. In watersheds, where agricultural practices are not significant, both residential development and forestry may be the most acute sources of anthropogenic, or human-caused, nutrient loading (Davis et al. 1978).

In Maine, many factors influence lake water quality. These include proximity to the ocean, location within the state, residence time of water within the soil, wetland influences, and bedrock chemistry (Davis et al. 1978). Terrestrial and aquatic vegetation, as well as the presence of unique habitat types, may also affect the water quality, including depth and surface area can affect temperature and turnover in the lake, which will ultimately influence water quality.

Annual Lake Cycles

Water has the unique physical property of being most dense at 4° C (Smith and Smith 2001). Water decreases in density at temperatures above and below 4° C, allowing ice to float on the surface of lakes and ponds and warm water to stratify above cold water. In the summer, direct solar radiation warms the upper levels of the water column forming the epilimnion, which hosts the most abundant floral communities (Davis et al. 1978). The photosynthetic capabilities of the plants create an oxygen rich stratum. However, available nutrients in the epilimnion can be depleted by algal populations growing in the water column, and may remain depleted until the turnover of the water column in early fall (Smith and Smith 2001). The process of lake turnover is summarized in Figure 1.

Below the epilimnion is a layer of sharp temperature decline, known as the metalimnion (Smith and Smith 2001). Within this stratum is the greatest temperature gradient in the lake, called the thermocline. The thermocline separates the epilimnion from the hypolimnion, the lowest stratum of a lake. The hypolimnion, only found in deeper lakes, is beyond the depth to which sufficient light can penetrate to facilitate effective photosynthesis (Figure 1). It is in the substrate below the hypolimnion where most decomposition of organic material takes place, through both aerobic and anaerobic biological processes. While aerobic (requiring oxygen) bacteria break down organic matter more quickly than anaerobic (not requiring oxygen) bacteria, they also significantly deplete the oxygen at these depths (Figure 1; Davis et al. 1978).

As the weather becomes colder, water temperature decreases and wind facilitates thermal mixing until the vertical profile of the water column is uniform in temperature. This event, known as turnover, re-oxygenates the lower depths of the lake and mixes nutrients throughout the strata. The cold water near the surface can hold increased levels of oxygen, which is redistributed with turnover. Through this process, organisms at depth receive oxygenated water. A similar turnover event also occurs in the spring (Smith and Smith 2001). A lake that has two turnover events per year is classified as dimictic, whereas shallow lakes that may turn over at anytime of the year are known as polymictic.

In winter, lakes in Maine are covered with ice for four to five months, wherein the stratification is reversed as the coldest water and ice are on the surface and the warmest water (roughly 4° C) extends to the bottom because water is densest at 4° C. Significant snow cover on the ice may affect the photosynthetic processes under the ice by blocking some of the incoming solar radiation. Ice prevents diffusion of oxygen into the water and photosynthetic activity decreases, reducing oxygen production from phytoplankton thus decreasing the dissolved oxygen levels enough to cause significant fish kills (Smith and Smith 2001).

After the ice has melted in the spring, solar radiation warms the upper stratum of the lake. The freshly melted water sinks and this process continues until the water column is uniform in temperature and oxygen and nutrients are mixed throughout the water column. As late spring approaches, solar radiation increases, stratification occurs, and temperature profiles return to that of summer in dimictic lakes, preventing water column mixing (Smith and Smith 2001).

Trophic Status of Lakes

The biological classification of lakes by their eutrophic state is based on nutrient levels in the water (Maitland 1990). Lakes are divided into four major trophic states: oligotrophic, mesotrophic, eutrophic, and dystrophic (Table 1). The mesotrophic characterization is not included in Table 1, because it is referred to as a transitional stage between oligotrophic and eutrophic states (Chapman 1996). Oligotrophic lakes tend to be deep and oxygen rich with steep-sided basins, creating a low surface to volume ratio. They are low in suspended solids such as nitrates and more importantly phosphorus, the limiting nutrient for plant productivity in most freshwater ecosystems. The shape of a lake can also influence its productivity: steep-sided oligotrophic lakes are not conducive to extensive growth of rooted vegetation because there is little shallow margin for attachment (Table 1).

Eutrophic lakes are nutrient-rich and have a relatively high surface to volume ratio compared to oligotrophic lakes (Maitland 1990, Chapman 1996). These lakes have a large phytoplankton population that is supported by the increased availability of dissolved nutrients. Low dissolved oxygen levels at the bottom of a eutrophic lake are the result of decomposers using oxygen. Anoxic (oxygen deficient) conditions lead to the release of phosphorus and other nutrients from the bottom sediments, resulting in their eventual recycling through the water column (Chapman 1996). This phosphorus release and recirculation stimulates further growth of phytoplankton populations (Smith and Smith 2001). Eutrophic lakes tend to be shallow and bowl-shaped as a result of sediment loading, allowing for the establishment of rooted plants in shallow areas.

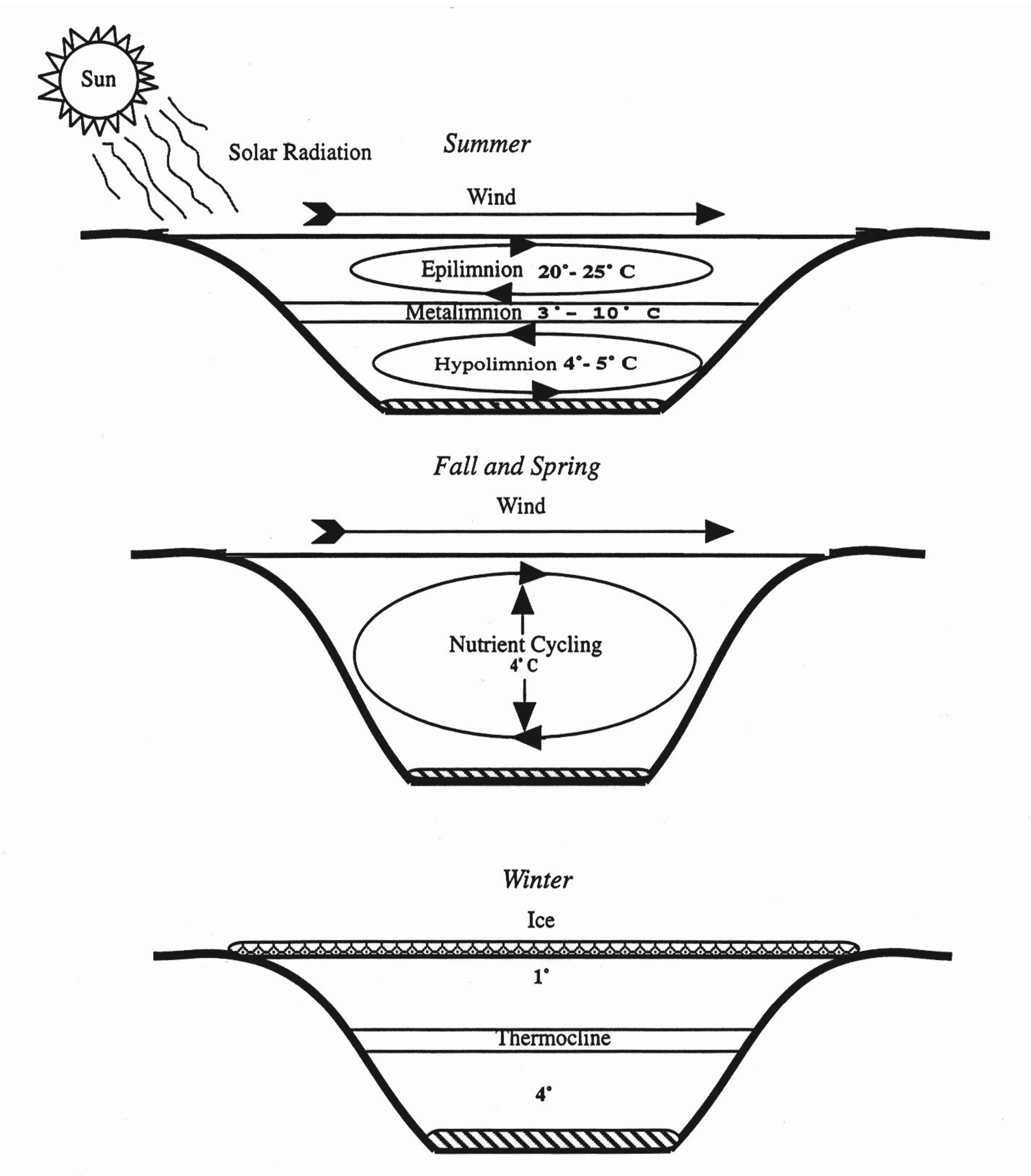

Figure 1. Mixing by means of lake turnover in dimictic lakes. During the summer, lakes are stratified into three layers (epilimnion, metalimnion, and hypolimnion). During the fall and spring, the isothermal temperature and density facilitate the lake turnover and redistribution of nutrients. In the winter, the lake is again stratified with the slightly warmer water on the bottom of the lake and the ice at the surface.

Dystrophic lakes have slightly lower water quality and receive large amounts of organic matter from the surrounding land, particularly in the form of humic (dead organic) materials (Smith and Smith 2001). The large quantity of humic materials stains the water brown. Dystrophic lakes have highly productive littoral zones, high oxygen levels, high macrophyte productivity, and low phytoplankton numbers (Table 1). Eventually, the invasion of rooted aquatic macrophytes chokes the habitat with plant growth, leading to the filling in of the basin, ultimately developing into a terrestrial ecosystem (Goldman and Home 1983).

Eutrophication is a natural process—lakes begin as oligotrophic, and after a long period of aging, eventually become terrestrial landscapes (Niering 1985). This process, which is called eutrophication, is greatly accelerated by anthropogenic activities that increase nutrient loading.

The United States Environmental Protection Agency (EPA) characterizes the process of eutrophication by the following criteria:

- Decreasing hypolimnetic dissolved oxygen concentrations.
- Increasing nutrient concentrations in the water column.
- Increasing suspended solids, especially organic material.
- Progression from a diatom population to a population dominated by cyanobacteria and/or green algae.
- Decreasing light penetration (e.g., increasing turbidity).
- Increasing phosphorus concentrations in the sediments (Henderson-Sellers and Markland 1987).

Lakes may receive mineral nutrients from streams, groundwater, runoff, and precipitation. As a lake ages, it fills with dead organic matter and sediment that settles to the bottom. The increase in nutrient availability, particularly phosphorus, promotes algal growth.

Phosphorus and Nitrogen Cycles

In freshwater lakes, phosphorus and nitrogen are the two major nutrients required for the growth of algae and macrophytes (Smith and Smith 2001). Each nutrient has its own complex chemical cycle within the lake (Overcash and Davidson 1980), and it is necessary to understand these cycles to devise better techniques to control high nutrient levels.

Table 1. Generalized characteristics of oligotrophic, eutrophic, dystrophic lakes (adapted from Maitland 1990).

Character	Oligotrophic	Eutrophic	Dystrophic
Basin shape	Narrow and deep	Broad and shallow	Small and shallow
Lake shoreline	Stony	Weedy	Stony or peaty
Water transparency	High	Low	Low
Water color	Green or blue	Green or yellow	Brown
Dissolved solids	Low, deficient in N	High, especially in N and Ca	Low, deficient in Ca
Suspended solids	Low	High	Low
Oxygen	High	High at surface, deficient under ice and thermocline	High
Phytoplankton	Many species, low numbers	Few species, high numbers	Few species, low numbers
Macrophytes	Few species rarely abundant yet found in deeper water	Many species, abundant in shallow water	Few species some species are abundant in shallow water
Zooplankton	Many species low numbers	Few species, high numbers	Few species, low numbers
Zoobenthos	Many species low numbers	Few species, high numbers	Few species, low numbers
Fish	Few species, Salmon and Trout characteristics	Many species, especially minnows	Extremely few species, often none

Phosphorus is the most important limiting nutrient for plant growth in freshwater systems (Maitland 1990). Phosphorus naturally occurs in lakes in minute quantities measured in parts per billion (ppb). However, due to the high efficiency with which plants can assimilate phosphorus, normal phosphorus concentrations are sufficient for plant growth (Maitland 1990). There are multiple external sources of phosphorus (Williams 1992), but a large quantity is also found in the lake sediments (Henderson-Sellers and Markland 1987). The cycle of phosphorus is complex, with some models including up to seven different forms of phosphorus (Figure 2; Frey 1963).

For the purposes of this study, it is necessary to understand two broad categories of phosphorus in a lake: dissolved phosphorus (DP) and particulate phosphorus (PP). DP is an inorganic form that is readily available for plant use in primary production. It is this form of phosphorus that is limiting to plant growth. PP is incorporated into organic matter such as plant and animal tissues. DP is converted to PP through the process of primary production, PP then gradually settles into the hypolimnion in the form of dead organic matter. PP can be converted to DP through aerobic and anaerobic processes. In the presence of oxygen, PP will be converted to DP through decomposition by aerobic bacteria. In anoxic conditions, less efficient anaerobic decomposition occurs, resulting in byproducts such as hydrogen sulfide, which is toxic to fish (Lerman 1978).

An important reaction occurs in oxygenated water between DP and the oxidized form of iron, Fe (III) (Chapman 1996). This form of iron can bind with DP to form an insoluble complex, ferric phosphate, which can effectively tie up large amounts of phosphorus as it settles into the bottom sediments. Fe (III) is reduced to Fe (II) in the presence of decreased oxygen levels at the sediment-water interface, resulting in the release of DP. The ferric phosphate complex, combined with the anaerobic bacterial conversion of PP to DP, can lead to a significant build-up of DP in anoxic sediments.

The sediments of a lake can have phosphorus concentrations of 50 to 500 times the concentration of phosphorus in the water (Henderson-Sellers and Markland 1987). Sediments can be an even larger source of phosphorus than external inputs. Nutrients are generally inhibited from mixing into the epilimnion by stratification during the summer, and as a result, DP concentrations accumulate in the lower hypolimnion until fall turnover. During fall turnover, water temperatures become more uniform and wind mixes the water, resulting in a large flux of nutrients moving from the bottom of the lake to the upper layers, creating the potential for algal blooms. Algal blooms can occur when phosphorus levels rise above 12 ppb to 15 ppb. If an algal bloom does occur, DP is converted to PP in the form of algal tissues. The algae die as winter approaches and the dead organic matter settles to the bottom where PP is converted back to DP and reaccumulates, allowing for another large nutrient input to surface waters during spring turnover (Bouchard, pers. comm.).

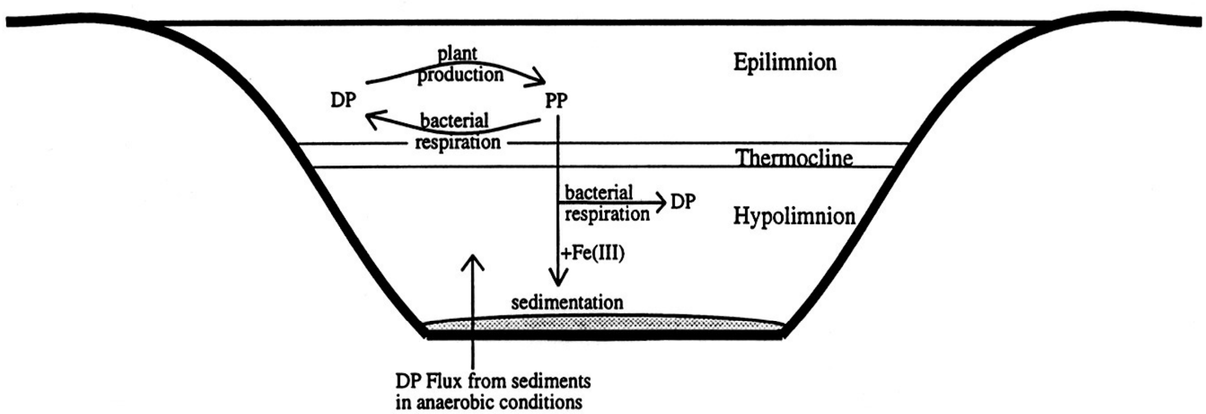

Figure 2. A model of the cycle of the major forms of phosphorus, dissolved (DP) and particulate (PP), within a lake ecosystem. The sedimentation of DP through complexation with Fe (III) contributes to the build-up of DP in the sediments. Note the production of DP in the hypolimnion due to bacterial decomposition as well as from the release of DP from the Fe complex in the sediments during anaerobic conditions. The fact that the thermocline prevents DP from mixing between the surface and bottom water is critical to the cycle because it can allow DP to accumulate in bottom waters (adapted from Lerman 1978).

Nitrogen, the other major plant nutrient, is usually not the sole limiting factor for plant growth in a lake (Chapman 1996), but it is still important to understand its cycle because high concentrations can lead to algal blooms in the presence of phosphorus. Available nitrogen exists in lakes in three major chemical forms: nitrates (NO_3^-), nitrites (NO_2^-), and ammonia (NH_3) (Figure 3). The majority of free nitrogen in a lake exists in the form of nitrates (Maitland 1990), a form that is directly available for assimilation by algae and macrophytes. In eutrophic lakes, there may be so much algae and macrophyte growth that most of the nitrates in the lake are incorporated into plant tissues (Maitland 1990). Plants, however, cannot use nitrites. In aerobic conditions, nitrate-forming bacteria convert nitrites to nitrates. Ammonia enters the lake ecosystem as a product of the decomposition of plant and animal tissues and their waste, and is processed in one of three ways. Macrophytes can assimilate ammonia directly into their tissues. Alternatively, under oxygen-rich conditions, aerobic bacteria will convert the ammonia directly to nitrates, the more usable form of nitrogen. Finally, anaerobic decomposition, characteristic of the sediments of stratified lakes, can reduce nitrates to nitrites. If these anaerobic conditions persist, the nitrites can be broken down to elemental nitrogen (N_2). This form is not available to any plants without the aid of nitrogen-fixing bacteria. Plants depend on these bacteria to convert nitrogen to nitrates through the process of nitrogen fixation (Overcash and Davidson 1980).

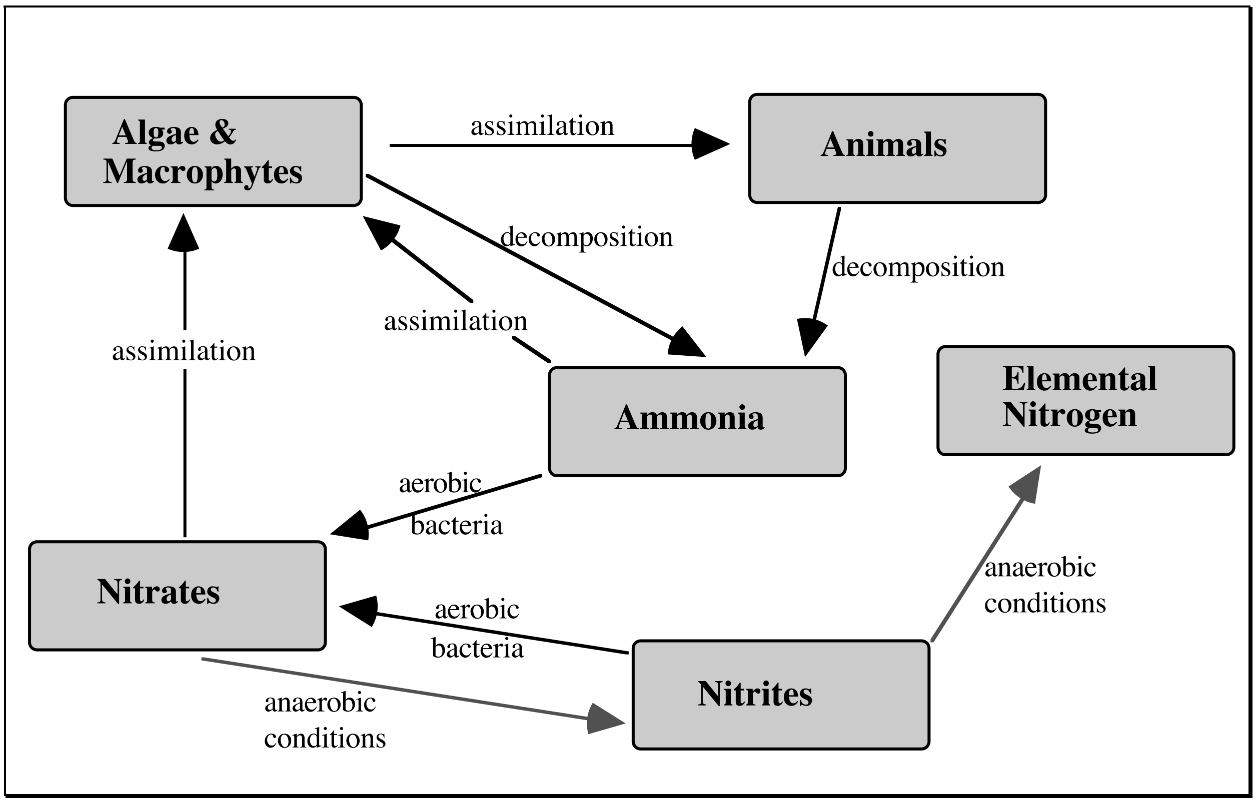

Figure 3. A diagram of the various forms of nitrogen that occur in the nitrogen cycle within a lake ecosystem. It is important to note that in aerobic conditions both ammonia and nitrites are converted to nitrates, which are available for use by plants.

The underlying pattern evident from this cycle is that all forms of nitrogen added to the lake will eventually become available for plant use. The various forms of nitrogen, as well as the oxygen concentrations (aerobic and anaerobic conditions) in the water, must be considered to understand the availability of this nutrient for plant growth. Several in-lake mitigation techniques exist to deal with the problem of excessive nutrients. (Henderson-Sellers and Markland 1987).

None of these techniques are without disadvantages, but for lakes with serious algal growth problems they may become necessary (Henderson-Sellers and Markland 1987).

Once nutrients have built up in a lake, eliminating them is a challenging task. The ideal method for controlling nutrients in a lake is to regulate and monitor the input sources before they become problematic. The natural processes of nutrient cycling and uptake by flora and fauna to compensate for nutrient inputs without further accelerating eutrophication of the lake.

Watershed Land Use

Land-Use Types

A watershed is the total land area that contributes a flow of water to a particular basin. The boundary of a watershed is defined by the highest points of land that surround a lake or pond and its tributaries. Any water introduced to a watershed will be absorbed, evaporate (including transpiration by plants), or flow into the basin of the watershed.

Nutrients naturally bind to soil particles; if eroded, nutrient-rich soil will add to the nutrient load of a lake, hastening the eutrophication process and leading to algal blooms (EPA 1990). Different types of land uses have different effects on nutrient loading in lakes because of varying influences on erosion and runoff. Assessment of land-use within a watershed is essential in the determination of factors that affect lake water quality.

A land area cleared for agricultural, residential, or commercial use contributes more nutrients than a naturally vegetated area such as forested land (Dennis 1986). The combination of vegetation removal and soil compaction involved in the clearing of land results in a significant increase in surface runoff, amplifying the erosion of sediments carrying nutrients and anthropogenic pollutants.

Naturally vegetated areas offer protection against soil erosion and surface runoff. The forest canopy reduces erosion by diminishing the force of impact of rain on soil. The root systems of trees and shrubs reduce soil erosion by decreasing the rate of runoff by holding water in place, allowing water to percolate into the soil. Roots decrease the nutrient load in runoff through direct absorption of nutrients for use in plant structure and function. As a result, a forested area acts as a buffering system by decreasing surface runoff and absorbing nutrients before they enter water bodies.

Residential areas are a significant threat to lake water quality. These areas generally contain lawns and impervious surfaces, such as driveways, parking spaces, or roof-tops that reduce percolation and increase surface runoff. Due to their proximity to lakes, shoreline residences are often direct sources of nutrients to the water body.

Forests cover much of Maine, and the development or expansion of residential areas often necessitates the clearing of wooded land. New development dramatically increases the amount of surface runoff because natural ground cover is replaced with impervious surfaces (Dennis 1986). Evidence of increased surface runoff due to development and its effects on nutrient transport is presented in a study concerning phosphorus loading in Augusta, Maine (Figure 4). The study revealed that surface runoff from a residential area contained ten times more phosphorus than runoff from an adjacent forested area. The study concluded that the surface-runoff flow rate of residential areas can be in excess of four times the rate recorded for forested land (Dennis 1986).

The use of chemicals in and around the home is potentially harmful to water quality. Products associated with cleared and residential land include fertilizers, pesticides, herbicides, and detergents that often contain nitrogen, phosphorus, other plant nutrients, and miscellaneous chemicals. These products can enter a lake by leaching directly into ground water or traveling with eroded sediments. Heavy precipitation aids the transport of these high nutrient products due to increased surface runoff near residences (Dennis 1986). Upon entering a lake, these wastes have adverse effects on water quality. It should be noted that more environmentally friendly soaps and detergents containing low phosphorus levels are now available and recommended (Figure 4; MDEP 1992a).

Septic systems associated with residential and commercial land are significant sources of nutrients when improperly designed, maintained, or used (EPA 1980). Proper treatment and disposal of nutrient-rich human waste is essential in maintaining high lake water quality.

Commercial uses of forested land can have detrimental effects on lake water quality. Activities that remove the cover of the canopy and expose the soil to direct rainfall increase erosion. Two studies by the Land Use Regulation Commission on tree harvesting sites noted that erosion and sedimentation problems occurred in 50% of active and 20% of inactive logging sites selected (MDC 1983). Skidder trails may pose a problem when they run adjacent to or through, streams. Shoreline zoning ordinances have established that a 75 ft strip of vegetation must be maintained between a skidder trail and the normal high water line of a body of water or upland edge of a wetland to alleviate the potential impact of harvesting (MDEP 1990).

Roads are a source of excessive surface runoff if they are poorly designed or maintained (Michaud 1992). Different road types have varying levels of nutrient loading potential. In general, roughly 80% of nutrient loading problems are caused by only 20% of culverts or crossings. Roads and driveways leading to shoreline areas or tributaries can cause runoff to flow directly into a lake.

Buffer Strips

Buffer strips play an important role in absorbing runoff by helping to control the amount of nutrients entering a lake (MDEP 1990). Excess amounts of nutrients, such as phosphorus and nitrogen, can promote algal growth and cause faster eutrophication (MDEP 1990). Suggested buffer strip width is dependent on, but not limited to, steepness of slope, soil type and exposure, pond watersheds, floodways, and areas designated critical for wildlife (City of Augusta 1998).

A good buffer should have several vegetation layers and a variety of plants and trees to maximize the benefit of each layer (MDEP 1990). Native vegetation forms the most effective buffer. Trees and their canopy layer provide the first defense against erosion by reducing the impact of rain and wind on the soil; their deep root systems absorb water and nutrients while maintaining the topographical structure of the land. The shallow root systems of the shrub layer also aid in absorbing water and nutrients and help to hold the soil in place. The groundcover layer, including vines, ornamental grasses, and flowers slows surface water flow and traps sediment and organic debris. The duff layer, consisting of accumulated leaves, needles, and other plant matter on the forest floor, acts like a sponge to absorb water and trap sediment. Duff also provides a habitat for many microorganisms that break down plant material and recycle nutrients (Figure 5; MDEP 1990).

An ideally buffered home should have a winding path down to the shoreline so that runoff is diverted into the woods where it can be absorbed by the forest litter rather than channeled into the lake (Figure 5). The house itself should be set back at least 100 ft from the shoreline and have a dense buffer strip composed of a combination of canopy trees, understory shrubs, and groundcover, between it and the water. To divert runoff effectively, the driveway should be curved rather than straight, and not leading directly toward the water.

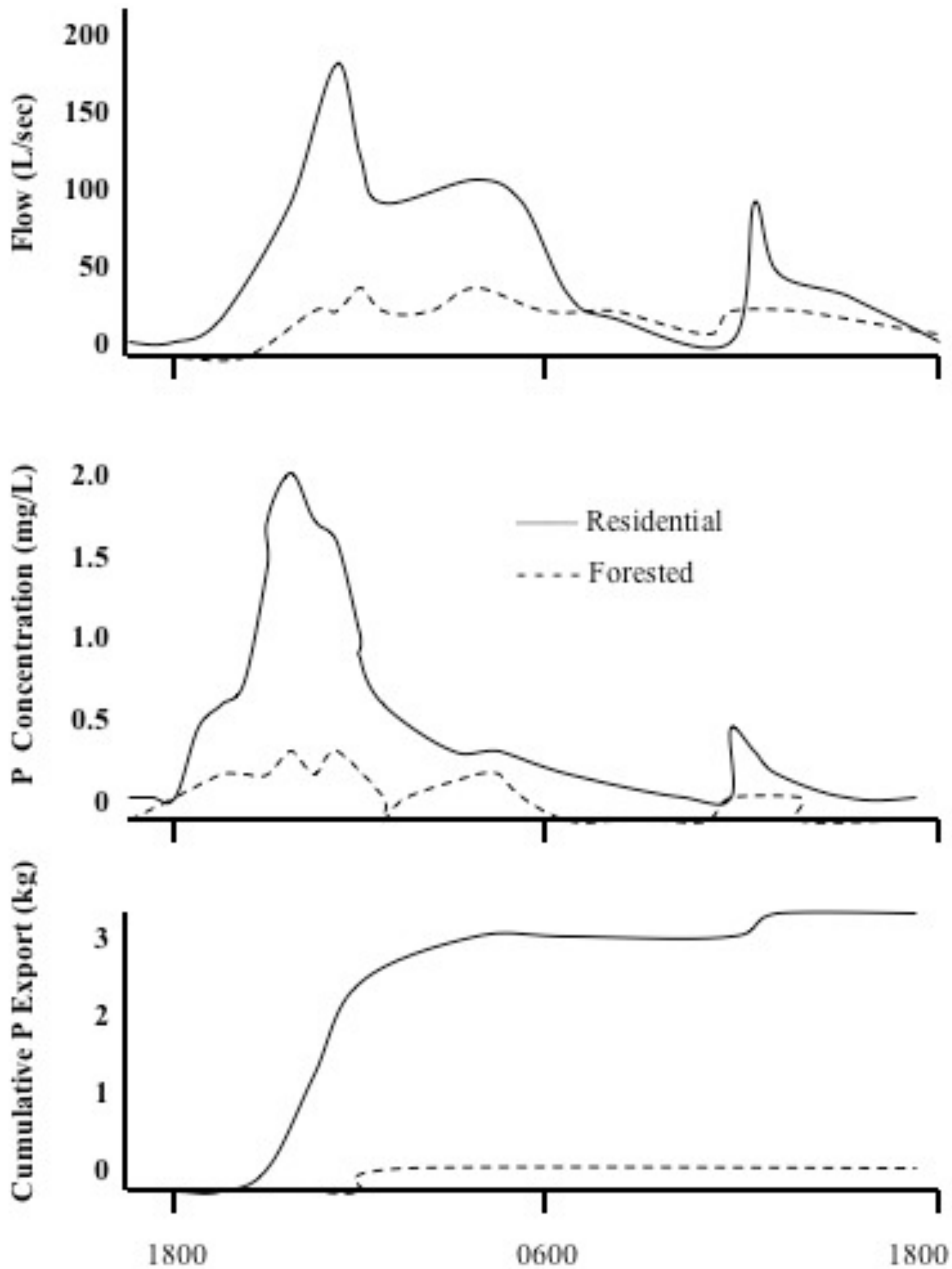

Figure 4. Comparisons of runoff after an April rainstorm in two neighboring watersheds near Augusta, ME. Top: volume of immediate runoff over a 12 hour period; Middle: phosphorus concentration in the runoff; Bottom: total amount of phosphorus exported into local streams and lakes from the storm (Dennis 1986).

Slopes within a buffer strip that are less than 2% steep are most effective at slowing down the surface flow and increasing absorption of runoff (MDEP 1998a). Steep slopes are susceptible to heavy erosion and will render buffer strips ineffective.

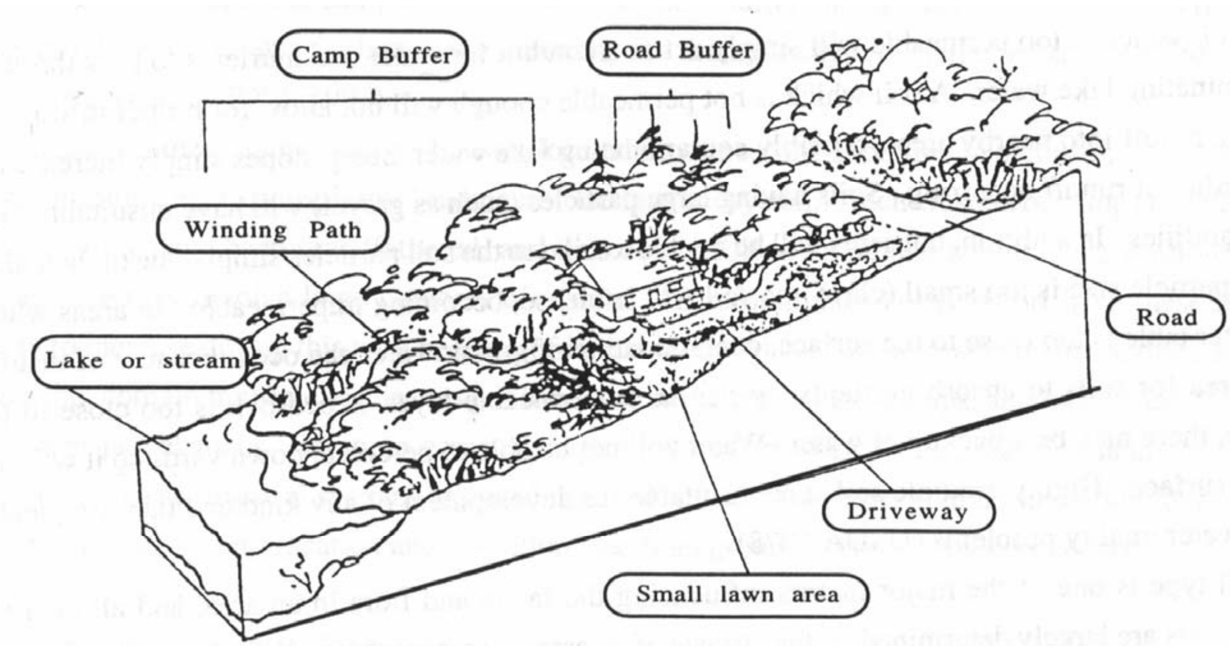

Figure 5. Diagram of an ideally buffered home.

In addition to buffer strips, riprap can be an effective method to prevent shoreline erosion by protecting the shoreline and adjacent shoreline property against heavy wave action (MDEP 1990). Riprap consists of three primary components: the stone layer, the filter layer, and the toe protection. The stone layer consists of rough, large, angular rock. The filter layer is composed of a special filter cloth that allows groundwater drainage and prevents the soil beneath the riprap from washing through the stone layer. The toe protection prevents settlement or removal of the lower edge of the riprap. Riprap depends on the soil beneath it for support, and should be built only on stable shores or bank slopes (MDEP 1990).

Nutrient Loading

Nutrient loading into a lake can be affected by natural and anthropogenic processes (Hem 1970). Human activity usually accelerates the loading of nutrients and sediments into a lake the water quality can be adversely affected in a short period of time. Clearing forests to construct roads and buildings with impervious surfaces increases runoff that carries nutrients from agricultural, residential, and industrial products (such as detergent, fertilizer, and sewage) into the lake. Since phosphorus and nitrogen are the limiting nutrients to algal growth, and algal growth affects the trophic state of a lake, increases in phosphorus and nitrogen in the water column from these sources can lead to a decrease in lake water quality and eventual eutrophication. Total phosphorus loading to a lake can be determined using a phosphorus loading model. This model takes into account the various aspects upon which the phosphorus concentration in the lake basin is dependent, such as lake size, volume, flushing rate, and land-use patterns within the watershed (Cooke et al. 1986). The model allows for the projection of the impact that various factors may have on phosphorus loading and generates predictions of lake responses to changes in land-use. The accuracy of the assumptions determines the accuracy of the predictions (EPA 1990).

Soil Types

Nutrient loading in a lake ecosystem is partially a function of the soil types and their respective characteristics. The physical characteristics of soil (permeability, depth, particle size, organic content, and the presence of an impermeable layer or “fragipan”), as well as the environmental features (slope, average depth to the water table, and depth to the bedrock) that influence them are important to consider in determining the nutrient loading functions (USDA 1978). These factors can determine appropriate land uses, such as forestry, agriculture, and residential or commercial development. The soils most capable of accommodating such disturbances by preventing extreme erosion and runoff of both dissolved and particulate nutrients are those which have medium permeability, moderate slopes, deep water tables, low rockiness and organic matter, and no impermeable layer (USDA 1992). Soils that do not meet these criteria should be considered carefully before implementing a development, forestry, or agricultural plan.

Zoning and Development

The purpose of shoreline zoning and development ordinances is to control water pollution, protect wildlife and freshwater wetlands, monitor development and land-use, conserve wilderness, and anticipate the impacts of development (MDEP 1998a). Shoreline zoning ordinances regulate development along the shore in a manner that reduces the chances for adverse impacts on lake water quality. Uncontrolled development along the shoreline can result in a severe decline in water quality that is difficult to correct. In general, these regulations have become more stringent as increased development has caused water quality to decline in many watersheds (MDEP 1992b). If no comprehensive plan or town ordinances have been enacted, the state regulations are used by default.

Shoreline Residential Areas

Shoreline residential areas are of critical importance to water quality because of their proximity to the lake. This study considered houses less than 200 ft from the shoreline to be shoreline residences. Any nutrient additives from residences (such as fertilizers) have only a short distance to travel to reach the lake. Buffer strips along the shore are essential in acting as sponges for the nutrients flowing from residential areas to the lake (Woodard 1989).

Residences that have lawns leading directly down to the shore have no barriers to slow runoff, allowing phosphorus to pass easily into the lake. Buffer strips, when used in conjunction with appropriate setback laws for house construction, can dramatically reduce the proximity effects of shoreline residences (MDEP 1992b).

Seasonal residences, especially older ones located on or near the shoreline in a cluster, can contribute disproportionately to phosphorus loading into the lake ecosystem. Such clusters of camps usually exist because they were built before shoreline zoning laws were passed and are legally non-conforming. Although seasonal, they may accommodate large numbers of people in season. Phosphorus export from these areas is likely to increase during periods of heavy use. The location and condition of septic systems also affects the nutrient loading from these plots (see Sewage Disposal Systems).

Non-shoreline Residential Areas

Non-shoreline residential areas (greater than 200 ft from the shoreline) can also have an impact on nutrient loading, but generally less than that of shoreline residential areas. Runoff, carrying fertilizers and possibly phosphorus-containing soaps and detergents, usually filters through buffer strips consisting of forested areas several acres wide, rather than a few feet wide.

In these cases, phosphorus has the opportunity to be absorbed into the soils and vegetation; the majority will not reach the lake, but will enter the forest nutrient cycle.

Residences located up to one half mile away from the lake can potentially supply the lake with phosphorus almost directly when poorly constructed roads persist. Runoff collected on roofs and driveways may travel unhindered down roads or other runoff channels (e.g., driveways) to the lake. Although non-shoreline homes are not as threatening as shoreline residences, watersheds having large residential areas with improper drainage can have a significant effect on phosphorus loading.

Tributaries can make non-buffered, non-shoreline residences as much of a nutrient loading hazard as a shoreline residence. Phosphorus washed from residential lawns without buffer strips can enter into a stream and eventually into the lake. Similar restrictions and regulations as those for shoreline residences apply to non-shoreline homes that are located along many streams.

Subsurface Wastewater Disposal Systems

Subsurface wastewater disposal systems are defined in the State of Maine Subsurface Wastewater Disposal Rules as devices and associated piping including treatment tanks, disposal areas, holding tanks, and alternative toilets which function as a unit to dispose of wastewater in the soil (MDHS 2002). These systems are generally found in areas with no municipal disposal systems, such as sewers. Examples of these subsurface disposal systems include pit privies, holding tanks and septic systems.

Pit Privy

Pit privies are also known as outhouses and are mostly found in areas with low water pressure systems. They are simple disposal systems consisting of a small, shallow pit or trench. Human excrement and paper are the only wastes that can be decomposed and treated. Little water is used with pit privies and chances of ground water contamination are reduced. Contamination due to infiltration of waste into the upper soil levels may occur if the privy is located too close to a body of water.

Holding Tank

Septic systems are the most widely used subsurface disposal system. The system includes a building sewer, treatment tank, effluent line, disposal area, distribution box, and often is connected to a pump (Figure 6). The pump enables effluent to be moved uphill from the shoreline to a more suitable leach field location (MDHS 1983). Septic systems are an efficient and economical alternative to a sewer system, provided they are properly installed, located, and maintained. Septic systems that are not installed or located properly lead to nutrient loading and groundwater contamination. The location of the systems and the soil characteristics determine the effectiveness of the system.

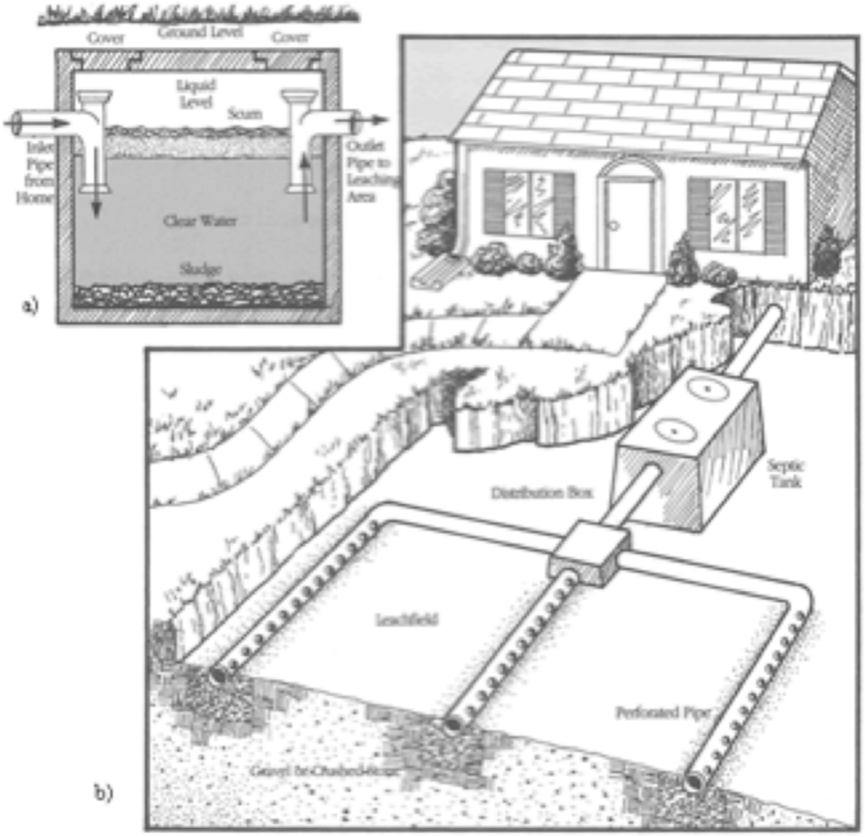

Figure 6. The cross-section of a septic treatment tank (a), showing the movement of effluent through the tank and the separation of the scum, water, and sludge. Also the layout of a typical septic system (b), with septic tank, distribution box, and leach field (Soundkeeper 2007).

The distance between a septic system and a body of water should be sufficient to prevent contamination of the water by untreated septic waste. However, many parcels of land are grandfathered, which means their septic systems were installed before the passage of current regulations. Those systems may be closer to the shore than is currently permitted; any replacement systems in these grandfathered areas must reflect the new regulations. Replacement systems can either be completely relocated, or an effluent pump installed on the outside of the existing treatment tank can be used to move the sewage uphill to an alternative disposal area further from the water body (MDHS 1983).

Human waste and gray water are transferred from a residence through the building sewer to the treatment tank. There are two kinds of treatment tanks, aerobic and septic, both of which are tight, durable, and usually made of concrete or fiberglass (MDHS 1983). The aerobic tanks rely on aerobic bacteria, which have a greater rate of respiration than anaerobic bacteria. Unfortunately, aerobic bacteria are also more susceptible to condition changes. Tanks containing aerobic bacteria also require more maintenance, more energy to pump in fresh air, and are more expensive. Septic tanks rely on anaerobic bacteria. Solids are held until they are sufficiently decomposed and suitable for discharge (MDHS 1983). As the physical, chemical, and biological breakdowns occur, scum and sludge are separated from the effluent (Figure 6). Scum is the layer of grease, fats, and other particles that are lighter than water and move to the top of the treatment tank. Baffles trap scum so that it cannot escape into the disposal area. Sludge is composed of the solids that sink to the bottom of the tank. Over time, much of the scum and sludge is broken down by anaerobic digestion. The effluent then travels through the effluent line to the disposal area.

The purpose of a disposal area is to provide additional treatment of wastewater. The disposal area can be one of three types: bed, trench, or chamber (MDHS 1983). Beds are wider than trenches, and usually require more than one distribution line; typically, beds need a distribution box. Chambers are made of pre-cast concrete. The size of the disposal area depends on the volume of water and soil characteristics. The soils in the disposal area serve to distribute and absorb effluent, provide microorganisms and oxygen for treatment of bacteria, and remove nutrients from the wastewater through chemical and cation exchange reactions (MDHS 1983). Effluent contains anaerobic bacteria as it leaves the treatment tank. Treatment is considered complete when aerobic action in the disposal field has killed the anaerobic bacteria. If the effluent is not treated completely, it can be a danger to a water body and the organisms within it, to groundwater, and to human health. Three effluent threats to lakes include organic particulates, which increase the biological oxygen demand (BOD), nutrient loading, and water contamination through the addition of viruses and bacteria (MDHS 1983).

BOD is the oxygen demanded by decomposers to break down organic waste in water. Organic matter will increase if there is contamination from human and animal wastes and as the amount of organic material increases, BOD increases. If the BOD depletes dissolved oxygen, species within a lake may begin to die. If the flushing rate is low, reduced dissolved oxygen levels and increasing organic matter could become problematic.

The three major types of wastes that travel into the septic system are garbage disposal wastes, black water, and gray water. Garbage disposal wastes can easily back up the septic system and should not be discharged to a septic system. Black water and gray water are significant contributors of phosphorus. Black water contributes nitrogen, toilet wastes, and microorganisms, while gray water brings in chemicals and nutrients. Once a system containing black or gray water is clogged or a leak develops, humans are exposed to potential bacterial and viral contamination (MDHS 1983).

Reducing the chances of clogging will allow septic systems to be most efficient. Year-round residents should have their septic tanks pumped every three to five years, or when the sludge level fills half the tank (MDEP 2003d). Seasonal residents should pump their septic tanks every five to six years to prevent clogging from occurring in the disposal field. Garbage disposals place an extra burden on a septic system (Williams 1992). Cigarette butts, sanitary napkins, and paper towels should never be disposed of in septic systems because they are not easily broken down by the microorganisms and fill the septic tank too quickly. The disposal of chemicals, such as pouring bleach or paint down the drain, may also affect septic systems by killing microorganisms. Water conservation slows the flow through the septic system and allows more time for bacteria to treat the water. By decreasing the amount of water passing through the disposal field, the septic system can work more effectively and recover after heavy use (Williams 1992). Odors, extra green grass over the disposal field, and slow drainage are symptoms of a septic system that has been subject to heavy use and is not functioning properly.

When constructing a septic system, it is important to consider soil characteristics and topography to determine the best location. An area with a gradual slope (10 to 20%) that allows for gravitational pull is often necessary for proper sewage treatment (MDHS 2002). A slope that is too gradual causes stagnation. A slope that is too steep drains the soil too quickly cutting treatment time short and preventing water from being treated properly. Adding or removing soils to change the slope is one solution to this problem.

Soil containing loam, sand, and gravel allow the proper amount of time for runoff and purification (MDHS 1983). Soils should not be too porous or water runs through them too quickly, and is not sufficiently treated. Depth of bedrock is another important consideration. If the bedrock is too shallow, waste will remain near the soil surface. Fine soils such as clay do not allow for water penetration, causing wastewater to run along the soil surface untreated. Adding loam and sand to clay containing soils can help alleviate this problem. In the opposite case, if a soil drains too quickly, loam and clay can be added to slow down the filtration of wastewater.

Federal, state, and local laws are in place to protect land and water quality. The federal government sets minimum standards for subsurface waste disposal systems. States can then choose to make their rules stricter, but not more lenient, than federal guidelines. The Maine Comprehensive Land Use Plan sets standard regulations that each city and town must follow (MLURC 1976). Individual municipalities have the ability to establish their own comprehensive land-use plan in accordance with the state regulations. However, many towns develop local ordinances that consider specific issues, such as shoreline zoning. The Maine Department of Environmental Protection (MDEP), Maine Department of Conservation (MDC), and local Code Enforcement Officers are responsible for overseeing the enforcement of these laws.

Since 1974, state mandates have prevented septic systems from being installed without a site evaluation or within 100 ft from the high water mark. Other regulations state that there must be no less than 300 ft between a septic system disposal field and a well that uses more than 2,000 gallons per day (MDHS 2002). Also, 20% is the maximum slope of the original land that can support a septic system. These regulations are in place for the safety of people living in the watershed as well as for the aquatic ecosystem.

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Roads

Roads can significantly contribute to the deterioration of water quality by adding phosphorus to runoff and creating a route to the lake for the runoff (KCSWCD 2000). Roads may allow easy access for runoff of nutrients and organic pollutants into the lake via improperly constructed culverts and ditches. Improper road construction and maintenance can increase the nutrient load entering the lake.

Proper drainage of roads is very important when trying to control phosphorus loading within a watershed. Construction materials such as pavement, dirt, or gravel, may influence the amount and rate of runoff (Woodard 1989). The inevitable erosion of these building materials due to road traffic causes deterioration of the road surface. Storms increase road deterioration by dislodging particles from the road surface; nutrients attached to these particles are transported to the lake by runoff from the roads (Michaud 1992).

Road construction should try to achieve the following long-term goals: minimize the surface area covered by the road, minimize runoff and erosion with proper drainage and the placement of catch basins (as well as culverts and ditches), and maximize the lifetime and durability of the road (MDEP 1990). A well-constructed road should divert surface waters into a vegetated area to prevent excessive amounts of surface runoff, phosphorus, and other nutrients from entering the lake. Items that should be considered before beginning construction include: road location, road area, road surface material, road cross-section, road drainage (ditches, diversions, and culverts), and road maintenance (MDEP 1992a).

Although the State of Maine has set guidelines to control the building of roads, road location is typically determined by the area in which homes are built (MDEP 1990). All roads must be set back at least 100 ft from the shoreline of a lake if they are for residential use, and 200 ft for industrial, commercial, or other non-residential uses involving one or more buildings (MDEP 1991).

Designing a road with future use in mind is very important. A road should be constructed no longer than is absolutely necessary, and a particular road should not be extended past the last structure that is to be serviced by that road. The width of a road, which is often based upon the maintenance capabilities of the area, must also be considered (Cashat 1984). Proper planning that includes maintenance concerns is an effective, practical, and economical way to develop the road area (Woodard 1989).

Road surface material is another important factor to consider in road construction. Studies have shown that phosphorus washes off paved surfaces at a higher rate than from sand and gravel surfaces (Lea et al. 1990). On the other hand, sand and gravel roads erode more quickly and have the potential for emptying more sediment and nutrients into a body of water. Consequently, pavement is chosen for roads with a high volume of traffic. Sand and gravel are typically used for roads in low traffic areas or seasonal use areas. Both types of roads need proper maintenance. Gravel road surfaces should be periodically replaced and properly graded so that a stable base may be maintained and road surface erosion minimized.

The road cross section is another important factor to consider when planning road construction. A crowned road cross section allows for proper drainage and helps in preventing deterioration of the road surface (MDOT 1986). This means that the road will slope downward from the middle, towards the outer edges. This crown should have a slope of 0.13 to 0.25 inches per foot of width for asphalt and 0.50 to 0.75 inches per foot of width for gravel roads (Michaud 1992). This slope allows the surface water to run off the road on either side as opposed to remaining on the road surface and running along its whole length. Road shoulders should also have a slightly steeper cross slope than the road itself so that runoff can flow into a ditch or buffer zone (Michaud 1992).

The drainage off a road and the land that surrounds it must also be considered during construction or maintenance projects. Ditches and culverts are used to help drain roads into buffer zones where nutrients added by the road can be absorbed by vegetation or filtered through soil. These measures are also used in situations for handling runoff that may be blocked by road construction. Ditches are necessary along wide or steep stretches of road to divert water flow to areas where it can be absorbed. They are ideally u-shaped, deep enough to gather water, and do not exceed a depth to width ratio of 2:1. The ditch should be free of debris and covered with abundant vegetation to reduce erosion (Michaud 1992). Ditches must also be constructed of riprap or soil that will not be easily eroded by the water flowing through them.

Culverts are pipes that are installed beneath roads to channel water in proper drainage patterns. The most important factor to consider when installing a culvert is size. Culverts must be large enough to handle the expected amount of water that will pass through it during the peak flow periods of the year (KCSWCD 2000). If this is not the case, water will flow over and around the culvert and wash out the road. This may increase the sediment load entering the lake. The culvert must be set in the ground at a 30° angle down slope with a pitch of 2 to 4% (Michaud 1992). A proper crown above the culvert is necessary to avoid creating a low center point and damaging the culvert. The standard criterion for covering a culvert is to have one inch of crown for every 10 ft of culvert length (Michaud 1992). The spacing of culverts is based upon the road grade.

Diversions allow water to be channeled away from the road surface into wooded or grassy areas. These are important along sloped roads, especially those leading towards a lake. By diverting runoff into wooded or grassy areas, natural buffers are used to filter sediment and decrease the volume of water by infiltration before it reaches the lake (Michaud 1992). Efficient installation and spacing of diversions can also reduce the use of culverts.

Maintenance is very important to keep a road in working condition, as well as to prevent it from causing problems for a lake. Over time, roads deteriorate, and problems will only become worse if ignored and will cost more money in the long run to repair. Roads should be periodically graded; ditches and culverts should be cleaned and regularly inspected to assess any problems that may develop. Furthermore, any buildup of sediment on the sides of the road (especially berms) that prevents water from running off into the adjacent ditches must be removed. These practices will help to preserve the water quality of a lake and improve its aesthetic value.

Agriculture and Livestock

Agriculture within a watershed can contribute to nutrient loading in a lake. Plowed fields and livestock grazing areas are potential sources of erosion (Williams 1992) and animal wastes are also sources of excess nutrients. To minimize these problems, there are ordinances that prohibit new tilling of soil and new grazing areas within 100 ft of a lake or river. Problems can still exist in areas that were utilized for agriculture prior to the enactment of these ordinances by the State of Maine in 1990. According to the Shoreline Zoning Act, these areas can be maintained as they presently exist and may result in relatively high levels of erosion and decreased water quality (MDEP 1990). Plowing with the contour lines (across as opposed to up and down a slope) and strip cropping both serve to reduce soil erosion and sediment deposition in the lake.

Another potential agricultural impact on water quality comes from livestock manure. Improper storage of manure may result in excess nutrient loading. Manure also becomes a problem when it is spread as a fertilizer, a common agricultural practice. Manure spreading can lead to nutrient loading, especially in winter when the ground is frozen and nutrients do not have a chance to filter through the soil. To help prevent these problems, the state has passed zoning ordinances, which prohibit the storage of manure within 100 ft of a lake or river (MDEP 1990). The Nutrient Management Act also prohibits the spreading of manure on agricultural fields during the winter season (Nutrient Management Act 2006). The town may provide subsidies as an incentive if the problem is large enough but these solutions do not address the problem of livestock that defecate close to bodies of water. One solution for this problem may be to put up fences to keep the animals away from the edge of the lake or pond.

Runoff containing fertilizers and pesticides may also add nutrients and other pollutants to a lake. Fertilizing only during the growing season and not before storms can minimize this problem. Pesticides may also have negative impacts on water quality. Alternative methods of pest control may be appropriate, including biological controls such as integrated pest management and intercropping, planting alternating rows of different crops in the same field.

Forestry

Forestry is another factor that can contribute to nutrient loading through erosion and runoff. The creation of logging roads and skidder trails may direct runoff into a lake. The combination of erosion, runoff, and pathways can have a large impact on the water quality of a lake (Williams 1992). There are state and municipal shoreline zoning ordinances to address these specific problems. They specify that timber harvesting equipment, such as skidders, cannot use streams as travel routes unless the streams are frozen and traveling on them causes no ground disturbance (MDEP 1990). Clear-cutting within 75 ft of the shoreline of a lake or a river running to the lake is prohibited. At distances greater than 75 ft, harvest operations cannot create clear-cut openings greater than 10,000 ft^2 in the forest canopy, and if they exceed 500 ft^2, they must be at least 100 ft apart. These regulations are intended to minimize erosion (MDEP 1990), but in order for these laws to be effective they have to be enforced. This may be a difficult task for most towns since they do not have the budgets necessary to hire staff to regulate forestry. Illegal practices may occur and negatively impact lake water quality.

Successional Land

Before any form of development occurred in the China Lake watershed, the entire area was covered primarily by forest. As population increased, much of the forest surrounding the lake was cleared for agricultural, residential, industrial, and recreational use. In recent years, agriculture has decreased and much of the land previously used for this purpose has been allowed to revert back to forested land.

Succession is the replacement of one vegetative community by another that results in a mature and stable community referred to as a climax community (Smith and Smith 2001). An open field ecosystem moves through various transitional stages before it develops into a mature forest. The earliest stages of open field succession involve the establishment of smaller trees and shrubs throughout a field. Intermediate and later successional stages involve the growth of larger, more mature tree species. The canopy becomes more developed, allowing less light to reach the forest floor. A developed canopy also slows rainfall, reducing its erosion potential. This land type, in which a forest is nearing maturity and contains over 50% tree cover, is referred to as transitional forest. Mature forest is defined as areas of closed canopy that predominantly contain climax species.

Wetlands

There are different types of wetlands that may be found in a watershed. A bog is dominated by shrubby vegetation and large quantities of sphagnum moss, and typically has a low level of productivity (Lewis 2001). Fens are open wetland systems that are nutrient rich and may include such species as sedges, sphagnum moss, and bladderwort. Marshes have variable water levels and are rich with vegetation that is rooted in the ground and grows above the surface of the water (Brennan 2005). Swamps are characterized by waterlogged soils and can either be of woody or shrub types, depending on the vegetation, and often occur near forested areas (Brennan 2005). Wetlands are important because they produce a habitat for a variety of animals, including waterfowl and invertebrates (Brennan 2005).

The type of wetland and its location in a watershed are important factors when determining whether the wetland either prevents nutrients from going into a lake or contributes nutrients to a lake, a nutrient sink or source (Washington State Department of Ecology 1998). It is important to note that one wetland may be both a source and a sink for different nutrients and may vary with the season, depending on the amount of input to the wetland. Vegetation diversity within a wetland is important because different flora absorb different nutrients. This indicates that shrub swamps are better nutrient sinks than many other types of wetlands. When nutrient sink wetlands are located closer to the lake, the buffering capacity is greater than those located further back from the water body. Wetlands that filter out nutrients are important in controlling the water quality of a lake and help moderate the impact of erosion near the lake.

Wetlands are important transitional areas between lake and terrestrial ecosystems. Wetland soil is periodically or perpetually saturated, because wetlands usually have a water table at or above the level of the land, and contains non-mineral substrates such as peat. Growing in this partially submerged habitat is hydrophytic vegetation, meaning it is adapted for life in saturated and anaerobic soils (Chiras 2001). Wetlands support a wide range of biotic species (Table 2; MLURC 1976). Wetlands also help to maintain lower nutrient levels in an aquatic ecosystem because of the efficiency in nutrient uptake by their vegetation (Niering 1985, Smith and Smith 2001). Finally, wetlands have the potential to absorb heavy metals and nutrients from various sources including mine drainage, sewage, and industrial wastes (Chiras 2001).

Although there are regulations controlling wetland use, a lack of enforcement leads to development and destruction of wetlands. Wetland areas should be protected by the Resource Protection Districts and other means, which prevent development within 250 ft of the wetland. Due to their location, wetlands along the shoreline may be prone to illegal development (Chiras 2001). A decrease in wetlands will have negative effects on the water quality of a lake due to increased runoff, erosion, and decreased natural buffering (Table 2).

Table 2. Descriptions of site characteristics and plant populations of different types of freshwater inland wetlands (Smith 1990).

Wetland Type	Site Characteristics	Plant Populations
Seasonally flooded basins or flats	Soil covered with water or waterlogged during variable periods, but well drained during much of the growing season; in upland depressions and bottomlands	Bottomland hardwoods to herbaceous growth
Freshwater meadows	Without standing water during growing season; waterlogged to within a few inches of surface	Grasses, sedges, broadleaf plants, rushes
Shallow freshwater marshes	Soil waterlogged during growing season; often covered with 15 cm or more of water	Grasses, bulrushes, spike rushes, cattails, arrowhead, pickerel weed
Deep freshwater marshes	Soil covered with 15 cm to 1 m of water	Cattails, bulrushes, reeds, spike rushes, wild rice
Open freshwater	Water less than 3 m deep	Bordered by emergent vegetation such as pondweed, wild celery, water lily
Shrub swamps	Soil waterlogged; often covered with 15 cm of water	Alder, willow, buttonbush, dogwoods
Wooded swamps	Soil waterlogged; often covered with 0.3 m of water; along sluggish streams, flat uplands, shallow lake basins	Tamarack, arbor vitae, spruce, red maple, silver maple
Bogs	Soil waterlogged; spongy covering of mosses	Heath shrubs, sphagnum moss, sedges

LONG POND CHARACTERISTICS

Watershed Description

Long Pond is located in the Belgrade Lakes region of Kennebec County, Maine, and is characterized by two major basins known as Long Pond North and Long Pond South. This study focuses on Long Pond South and its watershed. Last year Colby Environmental Action Team (CEAT 2007) studied Long Pond North. Long Pond South has a total volume of 46,191,231 m^3, a lake surface area of 1,334 acres, a mean depth of 10 m, and a maximum depth of 28 m (PEARL 2007a). Long Pond South is considered a dimictic lake. The lake is characterized by spring and autumn turnovers and summer stratification (see Background: Lake Characteristics: Annual Lake Cycles).

The Long Pond South watershed is 9,684 acres and encompasses cleared land, shoreline and non-shoreline residential lots, agricultural land, successional land, wetlands, and forested land **(**see Appendix D**)**. Relatively flat topographical features characterize the watershed. At 502 ft, an unmarked hill on the northeast side of the lake is the highest elevation in the watershed. The lowest elevation in the watershed, in the center of the lake, is 237 ft. Although no town centers are located within the watershed, the watershed includes part of the towns of Rome, Mt. Vernon, and Belgrade.

In comparison to the watersheds of Long Pond North and China Lake, the Long Pond South watershed has a large percentage of wetlands, a comparable percentage of forested land, and a smaller percentage of residential land (see Watershed Land-Use Patterns). There was a golf course in the Long Pond North watershed (CEAT 2007) and a cemetery in the China Lake watershed (CEAT 2006). The Long Pond South watershed contains neither of these land-use types. Land-use data are from digitital orthophotoquads (DOQs) in 2003 (see Watershed Land-Use Patterns).

Long Pond is the second to last lake in the chain of Belgrade Lakes. Great Pond, located to the northwest, flows into Long Pond and is a major source of water and phosphorus. Water flows from the north basin to the south basin and drains into Messalonskee Lake, to the southeast, through Belgrade Stream. Messalonskee Lake is the final lake in the chain. Messalonskee Stream then carries the water to the Kennebec River, which flows into the Atlantic Ocean. In addition to the major water input from Long Pond North, Ingham Pond, a small pond on the southeast side of Long Pond, contributes water and phosphorus to Long Pond South. Dolov Pond and Unnamed Pond are on the northeastern side of Long Pond South and water from them flows into the lake (see Water Budget). Dolov Pond, Unnamed Pond, Ingham Pond, and Long Pond North are point sources for phosphorus (see Phosphorus Budget).

The water qualities of Great Pond and, to a greater extent, Long Pond North, impact the overall health of Long Pond South as point source inputs of phosphorus. Long Pond South has been placed on the impaired lakes list (MDEP 2007b) due to a declining trend in water quality. There has been a trend in declining dissolved oxygen concentrations since the Belgrade Lakes Association first began monitoring lake water quality in 1975 (see Long Pond Water Quality Assessment). Additionally, an increased incidence of *Gloeotrichia echinulata*, an invasive blue-green bacterium, has been observed in all three lakes, but most abundantly in Great Pond (see Long Pond Characteristics).

Historical Perspective

Water Quality

<u>General Chemistry</u>

The Maine Department of Inland Fisheries and Wildlife (MDIFW), Fishery Division began comprehensive studies on various Maine lakes, including Long Pond, in 1972. Annual studies performed by MDIFW assess numerous parameters contributing to lake quality, including: depth, transparency, temperature, dissolved oxygen, conductivity, phosphorus, chlorophyll, pH, and true color. Long Pond has historically displayed consistently high water quality, but it was placed on the impaired waters list in 2006 due in part to the declining quality of water in the surrounding lakes (PEARL 2007b).

The trophic status of a lake is based on primary production. It helps to describe lakes and provides a characterization of life within the lake. The trophic status can be estimated by water transparency, which is measured with a Secchi disk. Primary production is the amount of biomass the lake produces; greater production corresponds to decreased transparency and lower Secchi disk values. It is possible to use a transparency-based Trophic State Index (TSI) to determine the lake productivity and placement on the productivity scale ranging from oligotrophic to dystrophic (see Background: Trophic Status of Lakes). The average historical TSI for Long Pond South is 37 (PEARL 2007c). This TSI places Long Pond South between the oligotrophic and mesotrophic categories (see Water Quality: Transparency).

Long Pond South has historically been less productive than the other lakes in the Belgrade region. For example, Salmon Pond has had a historical average TSI of 50 and Great Pond historically has had a mean TSI of 39 (PEARL 2007c). These trophic states are greater than the historical average of 37 for Long Pond South. Because the lakes throughout the Belgrade Lakes Region are interconnected, their declining water quality could influence the health of Long Pond South, transforming it from an oligotrophic to a mesotrophic state.

Dissolved oxygen is a parameter that is most often measured to determine the health of a lake. During the summer stratification, the bottom layers of deep lakes often become anoxic as the accumulation of organic matter increases the numbers of decomposing bacteria that consume organic matter and deplete the oxygen. In addition to low dissolved oxygen levels at the bottom of the water column during the summer, Long Pond South experiences a temporary drop in oxygen in the metalimnion, or thermocline (see Water Quality: Dissolved Oxygen). This depletion has historically occurred in the late summer since at least 1989 (PEARL 2007b). Most lakes, including Long Pond North and the other Belgrade Lakes (CEAT 2007, PEARL 2007b), however, have historically had enough oxygen in the middle layer to support the life in the lake, but the metalimnion of Long Pond South may have experienced increased oxygen consumption. This phenomenon is continuing today and requires further study (see Water Quality: Dissolved Oxygen).

Lake temperature and pH measurements of Long Pond South have corresponded with those of the surrounding lakes. Historically, as the summer progresses, the surface temperatures increase, but the temperature profiles for Long Pond South have been fairly similar each year and consistent with the surrounding lakes (PEARL 2007a). Mean pH levels in Long Pond South have slowly been becoming more basic, a trend that is consistent with the surrounding lakes (CEAT 2007). Because pH helps determine which plant and animal species can survive in the lake, these varying levels may eventually change the species concentration (MVLMP 2006a).

Conductivity and true color both measure the concentration of dissolved materials in the water. Conductivity measures the ability of water to carry a charge, which is dependent on the amount of dissolved ions, and true color provides evidence for the dissolved organic acids. Long Pond South has had a historical mean conductivity of 42 μS/cm (PEARL 2007b). Because this measurement has historically been slightly lower than that for Long Pond North (44μS/cm), it shows that the productive waters of the north basin could influence the quality of Long Pond South (CEAT 2007). The surrounding input lakes, such as Long Pond North, Great Pond, and North Pond, have not dramatically increased their amounts of dissolved organic acids. These lakes and Long Pond South have historically been non-colored, indicating that they have lower amounts of dissolved organic acids from decomposition (PEARL 2007b).

Phosphorus concentrations are effective indications of lake productivity. Historically, phosphorus levels at the surface and mid-depths of the Long Pond South have been consistent, but phosphorus in the bottom layer has been rising (PEARL 2007b). Since the 1980's, the bottom layer has almost had a 20 ppb increase in phosphorus concentration. (PEARL 2007b). Because Long Pond South has such low phosphorus concentrations, this is a dramatic increase that shows the rising effects of internal loading.

These increasing bottom phosphorus concentrations may influence algal growth, which determines the quantity of chlorophyll-*a* in the water column. Because chlorophyll-*a* is present in all photosynthetic cells, the mean chlorophyll-*a* count provides another measure for determining productivity. Long Pond South has a mean historical chlorophyll-*a* concentration of 4.8 ppb, which is consistent with the historical mean concentrations, ranging from 3.8 ppb and 7.3 ppb, of the surrounding Belgrade lakes (PEARL 2007b). Overall, however, there is a trend of rising chlorophyll-*a* concentrations throughout the Belgrade Lakes (PEARL 2007b).

Gloeotrichia

The increasing abundance of *Gloeotrichia echinulata* in Long Pond and Great Pond has been a concern for property owners, especially on Great Pond where several blooms have occurred (King, pers. comm.). *G. echinulata* is a nitrogen-fixing cyanobacteria that lives in spherical colonies and is commonly associated with eutrophication. *G. echinulata* has a dichotomous life cycle, and the first stage occurs in the benthos, where nutrients are plentiful. Internal carbon dioxide production increases buoyancy of a colony, which results in the colony rising in the water column up to the epilimnion. *G. echinulata* has the ability to store phosphorus above normal concentrations for later growth and reproduction in surface waters (King, pers.

comm.). Although, there has been concern about the potential for phosphorus movement from sediments to surface waters by *G. echinulata*, a study by Firmage and King (unpublished data) indicated that *G. echinulata* does not move significant amounts of phosphorus throughout the water column.

Regional Land-use Trends

Historically, Maine's watersheds have been managed heavily for forestry (Austin 2004). Since the 1980's, a decrease in the operation of paper mills and large-scale logging in Maine has led to the loss of more than 5,000 jobs in the forest industry (Austin 2004). Throughout Maine, shifts in forest resource use have opened the market for residential subdivisions, especially around particularly valuable lake real estate. Additionally, agricultural practices have declined as Maine land-use shifts to development in the residential and tourism sectors (Platinga et al. 1999). Large-scale point-source pollution is now relatively rare in Maine lake watersheds. However, non-point source pollution from land-use practices such as agriculture and industry contributes to phosphorus and other nutrient loading. Other factors contributing to phosphorus loading include malfunctioning septic systems from residential areas, reduction of phosphorous absorption potential by land surface due to the clear-cutting of vegetation, and the relative input and absorption of phosphorus from habitats such as forests. An understanding of the historical land-use trends in a watershed provides vital information for estimating the present non-point source nutrient loading (Davis et al. 1978).

Land-use patterns in the Belgrade Lakes Region have undergone dramatic shifts since its settlement in 1774. One of the most dramatic shifts in land-use continues to occur in the agricultural sector. During the 1800's, residents within the Long Pond South watershed relied on the farming of wheat, corn, and other grains to support a number of gristmills in the surrounding towns and to sustain their families (Austin 2004). Other major crops during this time included potatoes and apples. In the 1930's, the watershed consisted of year-round, isolated farms. With an increase in seasonal homes and an economic shift towards tourism during the 1980's, the attractiveness of farming in the Long Pond South watershed diminished (Platinga et al. 1999). In addition, greater topographical variation in the Belgrade Lakes Region watershed makes it less suitable for the larger-scaled agricultural activity seen in southern Maine and Aroostook Country. A decline in agriculture since the 1950's has reduced the majority of crop land in the

Long Pond South watershed and reverted a large portion of pasture to forested areas (Platinga et al. 1999). This trend is seen throughout the state with a loss of 713,000 acres of crop land and 174,000 acres of pasture (Platinga et al. 1999). Forest succession continues to reclaim most abandoned agricultural land.

Trends in timber harvesting have had a large impact on aquatic nutrient loading of Long Pond South watershed (Platinga et al. 1999). In 1872, timber harvesting reached its peak when forested land covered only 53.2 percent of the total land area in Maine. Today forests cover over 90 percent of land in Maine (Plantinga et al. 1999). Both diminishing agricultural practices and decreased logging interests contribute to the increase in forest area in the watershed. Although two lumber companies exist today in Belgrade, the largest town in the Long Pond South watershed, only private logging is occurring within the watershed as revealed by the ground truthing and aerial photography surveys.

A rise in industry and road construction within the Long Pond South watershed has facilitated an increase in residential development in recent years. In the 1960's, towns adjacent to the lake agreed that the construction of camp roads and the subdivision of large shoreline farm plots would benefit municipal growth (Davis et al. 1978). An increase in subdivided plots of Belgrade, the foundation of Hammond Lumber Company in 1958, and the introduction of a cement and gravel supplier in town makes land and materials for this development more accessible (Austin 2004). Impact from residential development is highest during the summer months when the population doubles due to use of summer camps by seasonal lake property owners. The sewage disposal, forest clearance, building construction, and road maintenance associated with residential development all actively contribute to phosphorus-loading into the water body.

Agriculture and residential development have the greatest impact on water quality (Davis et al. 1978). The historical shifts from agricultural activity and tree harvesting to residential subdivisions and development help explain the patterns of nutrient-loading within Long Pond South watershed. Analysis of past land-use trends provides valuable insight into the motives of town development, and sources of vulnerability for water quality maintenance. These patterns may be used to understand factors impacting lake health by targeting areas suitable for development, as well as those spaces in the watershed most sensitive to the impact of land-use.

Biological Perspective

Introduction

Comprised of wetlands, coniferous, deciduous mixed forests, small ponds and streams, the area surrounding Long Pond South provides habitat for a diverse range of flora and fauna. Wetlands or wetland-forest mixture surrounds roughly 40 percent of the lake, preventing shoreline development in these areas and helping to preserve the integrity of the lake habitat. However, non-shoreline development within the watershed also endangers the health of the lake because ecosystems within the watershed are interconnected. Due to this interconnecting relationship, human settlement in any area of the watershed may contriibute to cultural eutrophication, which is the acceleration of the natural aging process of the lake (Wade 1999). During cultural eutrpohication, phosphorus run-off associated with fertilizers, sewage, and other human activities may lead to unaesthetic algae blooms resulting in eventual oxygen depletion, habitat loss, and natural biodiversity reduction.

Native Aquatic Flora/Fauna

By providing food, shelter, and oxygen to aquatic organisms, aquatic plants are an important component of any freshwater ecosystem. In addition to directly providing these essentials to the organisms of the ecosystem, plants help maintain water quality by absorbing nutrients such as phosphorus. Macrophytes help prevent detrimental algal blooms by utilizing nutrients such as phosphorus in the water, reducing availability to algae. Alternatively, excessive growth of marcophytes can be a biological indicator of excess nutrients within a lake or pond (Lacoul and Freedman 2006).

Fish Stocking

The Maine Department of Inland Fisheries and Wildlife (MDIFW) fish-stocking program has become a common and successful practice in the State of Maine. Beginning in the mid 1800's, fish stocking introduced non-native fish species and expanded the range of several native fish species within the state to provide anglers with more recreational opportunities (Boucher 2004). The three most important recreational fisheries in the Belgrade area that involve stocking are the brown trout, brook trout, and landlocked salmon fisheries (Danner, pers. comm.). Since 1997, approximately 125,000 brown trout and 50,000 brook trout have been annually released into the waters of the Augusta region. To a lesser degree, the MDIFW stocks landlocked salmon in the Augusta region with 123,000 fish introduced from 1996-2000 (MDIFW 2007). Since 1989, Long Pond has been stocked with both landlocked salmon and brook trout (MDIFW 2007). In 2006, 1,000 landlocked salmon and 3,550 brook trout were stocked into both basins of Long Pond (MDIFW 2007). Poor spawning success created by limited nursery and spawning areas, and pressure created by fishing in Long Pond require the periodic stocking of these popular game fish (Boucher 2004).

In addition to stocked brook trout and landlocked salmon, 17 other fish species, both native and introduced, can be found within Long Pond (Table 3). Although these populations are naturally maintained, they may be threatened by invasive species, erosion, and declining water quality. Of the non-native fish in Long Pond, the northern pike poses the largest threat to indigenous species (Danner, pers. comm.). As a top predator with a fast growth rate and relatively long lifespan, northern pike can consume large quantities of smaller native fish, such as the brook trout and landlocked salmon, severely reducing their population size (Brautigam 2001). In addition to threats from introduced predators, trends of decreasing dissolved oxygen concentration in the deeper areas of a lake pose a problem not only to the popular salmonid game fish (salmon and trout), but to all deep water fishes in the lake (Table 3). Preferring relatively high levels of dissolved oxygen (above five parts per million) salmonids are the most susceptible to suffocation in areas of reduced dissolved oxygen (Bonney 2001). Erosion due to development and land clearing presents another problem for the fish populations of Long Pond.

Because erosion reduces stream water quality and vegetation through sedimentation, fishes that travel upstream to spawn or reproduce in weedy shallows may lose or encounter degraded breeding habitat (Table 3). This decline in habitat quality could require the stocking of additional species at increasing yearly stocking costs or result in the complete loss of certain species in Long Pond.

Table 3. Fish species of Long Pond South with origin, general habitat depth, and common spawning habitat. Fish more common to waters greater than seven meters were designated as deep-water fish (Higginbotham 1988, Steiner 2000, MDIFW Management Plans 2001-2005, PEARL 2007a).

Common Name	Scientific Name	Native	Habitat	Spawning Habitat
American eel	*A. rostrata*	Yes	Shallow	Catadromus
Brook trout	*S. fontinalis*	Yes	Shallow	Streams/Gravel
Brown bullhead	*A. nebulosus*	Yes	Bottom	Shallows
Chain pickerel	*E. niger*	Yes	Shallow	Shallows/Weedy
Golden shiner	*N. crysoleucas*	Yes	Shallow	Shallows/Weedy
Landlocked salmon	*S. salar sebago*	Yes	Deep	Shallows/Gravel
Pumpkinseed	*L. gibbosus*	Yes	Shallow	Shallows
Rainbow smelt	*O. mordax*	Yes	Shallow	Shallows
Redbreast sunfish	*L. gibbosus*	Yes	Shallow	Shallows
Slimy sculpin	*C. cognatus*	Yes	Deep	Streams/Rock
White perch	*M. americana*	Yes	Shallow	Deep Waters
White sucker	*C. commersoni*	Yes	Bottom	Shallows/Streams
Yellow perch	*P. flavescens*	Yes	Shallow	Shallows
Black crappie	*P. nigromaculatus*	No	Shallow	Shallows/Weedy
Brown trout	*S. trutta*	No	Shallow	Streams/Gravel
Largemouth bass	*M. salmoides*	No	Shallow	Shallows/Weedy
Northern pike	*E. lucius*	No	Shallow	Shallows/Weedy
Smallmouth bass	*M. dolomieu*	No	Deep	Streams
Walleye	*S. vitreus*	No	Deep	Shallows/Gravel

Invasive Plants

As with the introduction of any non-native species to an ecosystem, invasive macrophytes can heavily disrupt a lake ecosystem. Without the natural controls that mitigate native plant growth, uninhibited growth of invasive species allows them to displace native plants, reduce natural habitat, and dominate lake waters. This is not only detrimental to the natural ecosystem, but also negatively impacts recreation and aesthetics (MDEP 2005d). Although no occurrences of invasive macrophytes have been reported for Long Pond South, 11 species threaten Maine waters with two already established in Kennebec County (Table 4). Of the two species currently found in Kennebec County (Figure 7), Variable-leaf water milfoil poses the most substantial threat, both because it has been found in Belgrade Stream (the outlet to Long Pond South) and because of the life history tactics of the plant (Humphrey 2002). Once introduced, Variable-leaf water milfoil resists eradication through its rapid growth rate and method of reproduction (fragmentation: whole plants growing from any plant fragments) making it virtually impossible to exterminate once introduced (MDEP 2005d). Once established, the plant forms dense mats that entangle boat motors, impair fishing and swimming, reduce water quality, and potentially reduce the value of shoreline property (MDEP 2005d).

Table 4. Invasive aquatic plants threatening the inland waters of Maine, organized by county (Maine DEP 2005d). A single asterisk indicates plants found in Maine. A double asterisk indicates plants found in Kennebec County. Maine Counties and Abbreviations: Androscoggin (And); Cumberland (Cum); Franklin (Fra); Hancock (Han); Kennebec (Ken); Oxford (Ox); Penobscot (Pen); Sagadahoc (Sag); Somerset (Som); Waldo (Wal).

Common Name	Scientific Name	Infested County or Counties
Eurasian water milfoil	*Myriophyllum spicatum*	None
Parrot feather	*Myriophyllum aquaticum*	None
Water chestnut	*Trapa natans*	None
Fanwort	*Cabomba caroliniana*	None
European naiad	*Najas minor*	None
Brazilian elodea	*Egeria densa*	None
Frogbit	*Hydrocharis morsus-ranae*	None
*Hydrilla**	*Hydrilla veticillata*	York
Curly-leaf pondweed*	*Potamogeton crispus*	York
Variable-leaf water milfoil**	*Myriophyllum heterophyllum*	And, Cum, Ken, Ox, York
Yellow floating heart**	*Nymphoides peltata*	And, Cum, Fra, Han, Ken, Knox, Ox, Pen, Sag, Som, Wal, York

Geological and Hydrological Perspective

Most of the geologic features in Maine were formed by glacial scouring events during the Pleistocene Epoch from 20,000 to 25,000 years before present (ybp). The Laurentide Ice Sheet advanced in a south-southeast direction from northern Canada into southern Quebec and New England, covering Maine and reaching its terminal point near Long Island, New York, approximately 22,000 ybp (Marvinney and Thompson 2000). The motion of the ice shaped the current landscape of Maine as the ice sheet lifted and deposited rock and debris, destroyed existing waterways, and formed hundreds of new basins. The ice sheet was several thousand feet thick and its weight pushed the land downward several hundred feet. When the glacier receded, these basins were left as lakes and ponds. Many lakes in Maine, including Long Pond South, have a northwest to southeast orientation, which coincides with the path of glacial movement (see Background: Lake Characteristics: General Characteristics of Maine Lakes).

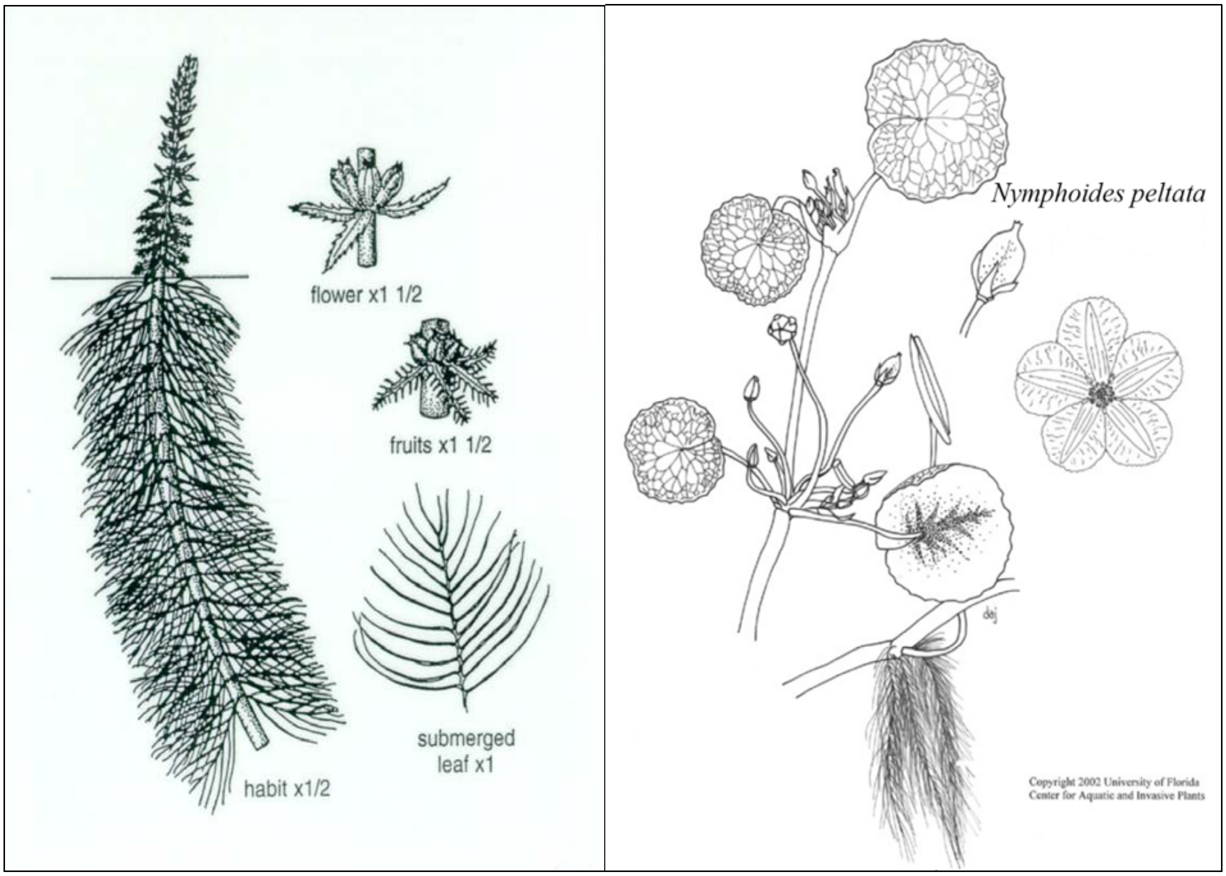

Figure 7. Two invasive, aquatic plant species present in Kennebec County: Variable-leaf water milfoil (left) and Yellow floating heart (right) (University of Florida 2002, MDIFW 2007).

Due to climatic change, the Laurentide Sheet began receding about 21,000 years ago and by 10,000 ybp had receded from Maine (Davis et al. 1978). Further deposition of rock and glacial debris produced eskers and till, which are characteristic of the Belgrade area, other areas in Maine, and throughout New England. After deglaciation, sea level rose faster than land rebound occurred and sediment-rich water inundated the land, depositing a glaciomarine silt and clay substrate known as the Presumpscott Formation, which covers the bedrock in the southern third of Maine. Eventually sea level dropped, exposing the land and leaving newly formed basins, which filled with water and became lakes. These lakes are young by geologic standards since they were formed about 10,000 ybp. Many of the lakes in Maine have the Presumpscott Formation sediment on the bottom substrate. Long Pond South has minor amounts of the Presumpscot Formation sediments which, when disturbed by anthropogenic activity, cause increased nutrient fluxes and sedimentation rates (Davis et al. 1978).

Long Pond is the second to last lake in the Belgrade Lake chain of six lakes and consists of two basins (see Long Pond Characteristics). Consecutive studies of both Long Pond basins enable CEAT to assess the overall health of Long Pond and compare the relative health of each basin. Long Pond receives water from other lakes in the Belgrade Lakes chain. Water flows from East Pond into North Pond, and then through Great Meadow Stream into Great Pond. Salmon Lake, another name for the basin that consists of McGrath Pond and Ellis Pond, also empties into Great Pond. Water from Great Pond flows into Long Pond and then moves southwest to Messalonskee Lake via Belgrade Stream (see Water Budget). Messalonskee Lake empties into the Kennebec River, which carries the water to the Atlantic Ocean.

Bathymetry

The Bathymetry Map displays the depth profile of Long Pond South (Figure 8). Greater depth is indicated by a darker color, with the deepest point at 94 ft in the northeast portion of the lake. Water sampling Site 1 was located at the deep location (see Figure 30 for site locations). Long Pond South has two major basins, one reaching a depth of 63 ft and one with the maximum depth of 94 ft, shown by the two areas of darker color located in the upper center portion of the lake, in between the islands. Areas of deep water are significant because they do not mix during the summer, and deep water may become anoxic (see Background: Lake Characteristics). Also, 39% of Long Pond South is less than sixteen deep, making these areas at risk for colonization and establishment of invasive plants (see Long Pond Characteristics: Biological Perspective), because invasive plants such as Variable-leaf water milfoil or Yellow floating heart prefer shallow water (MVLMP 2006c).

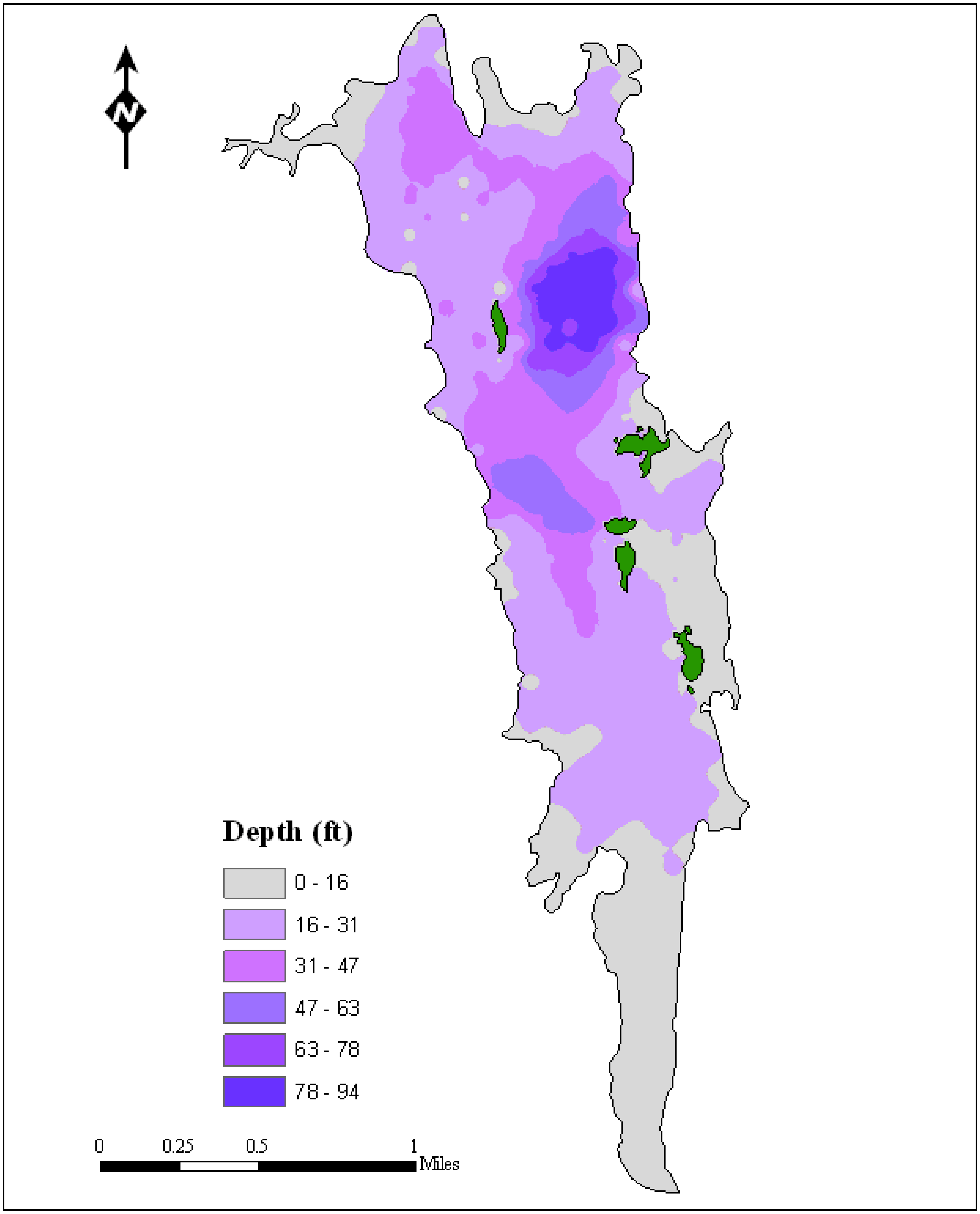

Figure 8. Bathymetry Map. The depth of Long Pond South, with the islands indicated in green. Darker purple indicates areas of greater depth. Depth point data obtained from Long Pond Map (2007).

STUDY OBJECTIVES

Introduction

This study comprehensively examined the south basin of Long Pond and its associated watershed. The Colby Environmental Assessment Team (CEAT) conducted water-quality sampling, road and house surveys, shoreline buffer surveys, and a land-use assessment in the watershed. Our goal was to identify non-point sources of phosphorus loading and to assess their impact on the water quality of Long Pond South. Sources of phosphorus loading include roads, agriculture, fields, lawns, and septic systems. This information was used to determine a phosphorus budget for the lake and make recommendations for the maintenance and improvement of the health of the lake.

Land Use Assessment

Land-use patterns in a watershed have a significant impact on the health of an associated water body. Different land-uses produce different types and amounts of anthropogenic and natural pollutants, and allow those pollutants to runoff into water bodies at different rates. For example, forested land adjacent to a water body is beneficial because it filters nutrients out of runoff and traps sediment that otherwise would have contributed to nutrient loading. A commercial property located adjacent to a water body is considered detrimental due to its typically large area of impervious surfaces as well as the pollution it adds to the environment. The impervious surfaces associated with commercial property can prevent precipitation from being absorbed into the ground. The resulting runoff can carry pollutants, sediments, and the nutrients associated with sediments (most importantly phosphorus) into the water body where they can accelerate eutrophication.

The goal of the land-use assessment was to identify and quantify the current patterns of land-use in the Long Pond South watershed using aerial photography, ArcGIS 9.2® software, and ground truthing. Establishing total areas of each land-use type were essential for the phosphorus model, as well as the erosion impact and erosion potential models. These models facilitate the future projections of watershed land-use and water quality.

Water Quality Assessment

The primary purpose of this part of the study was to determine the ecological health of Long Pond South Basin and make recommendations for improving water quality. General water quality is the best indicator of the nutrient load coming from non-point pollution sources as well as the ecological condition of the lake. Colby Environmental Analysis Center (CEAC) measured multiple chemical, physical, and biological water quality parameters. Water samples were collected in the summer and fall to determine how water quality changed in relation to seasonal changes. Findings were compared to water analysis conducted by the Maine Department of Environmental Protection (Maine DEP) in previous years to examine the long term effects of human activity on the trophic status of Long Pond South.

Future Trends

When making plans to protect a watershed it is imperative to consider the potential for future development. CEAT developed a water budget, phosphorus model, erosion potential model, and an erosion impact model to predict the effects of further land-use changes on nutrient loading in Long Pond South. This knowledge was then extrapolated to help predict future trends and how they may impact the lake.

ANALYTICAL PROCEDURES AND RESULTS

GIS

Introduction

A Geographic Information System (GIS) is a combination of computer hardware and software that uses spatially referenced and georeferenced information to create maps and models (Chang 2006). Spatially referenced information is data that are shown in the correct location in relation to other features on a map; by definition, data displayed on a map are spatially referenced. Georeferenced data are data that have been linked to the map by a location using a coordinate system such as latitude and longitude or a Universal Transverse Mercator (UTM). The UTM system divides most of the earth into 60 different zones, omitting areas that are above 84° N latitude and below 80° S latitude. The point of reference for each zone is the intersection of its central meridian with the equator. Points within a zone are located by a northing and easting coordinate pair, which refers to how far east and north a point is from the point of reference of the zone. The UTM system is often preferable to latitude and longitude when working with maps because it minimizes the distortion that occurs when a circular object such as the earth is represented on paper. Spatially referenced information is created by adding a layer on ArcGIS® 9.2 and then editing that layer to add the desired information, such as points, lines, or polygons. Common sources of georeferenced information include GPS points or a digitized pre-existing map (Chang 2006).

A GIS can accomplish up to four different tasks: data input, data storage and retrieval, data analysis and manipulation, and data display. CEAT used ArcGIS® 9.2 software, published by ESRI, to create maps and spatial models. ArcGIS® 9.2 uses two forms of data called spatial data structures: vector and raster. Vector data are comprised of points, lines, or polygons. Vector data were used to determine land-use in the watershed of Long Pond South. Satellite images were digitized into polygons, with each polygon denoting the area of a different land-use. Raster data are obtained by transforming either vector data or photographic images into uniformly sized cells. Each cell in raster format is associated with a datum. Temperature gradients are an excellent example of a use of raster data. A raster layer of temperature gradients is made up of uniformly sized cells that are assigned a color based on the datum they are associated with, in this case a numerical temperature. Images are frequently used as base layers for GIS maps because they provide familiar reference points to viewers. However, they can also be transferred into raster or vector format to increase clarity or for use in data analysis. For example, it may be easier to see the location of streams when they are colored lines instead of looking at satellite photos of a large area. Transferring image data into vector or raster format can be helpful in data analysis because these formats are required for all quantitative analysis, such as determining land-use areas and generating models.

A GIS layer contains data pertaining to the same theme, and must be of the same spatial data structure and type. Examples of layers include temperature gradients, land use classes, soil types, and roads. Each layer is associated with relevant information such as its name, location, and date sampled. The compilation of associated information contributes to the attributes of a layer, and the attributes can be viewed or edited. Most maps are a combination of several layers that are needed to present the desired information. Models are created by ranking the categories within a georeferenced layer based on the impact the categories have on what is being investigated. For example, in the erosion potential model categories of land use are ranked based on how susceptible each land-use type is to erosion. The ranked layers are then weighed and multiple layers are combined to create a new layer, which displays the output from the model. This method is analogous to finding a weighted average; the weighted average is the model. The models created on GIS include an erosion potential model, erosion impact model and a septic suitability model.

Water and watershed studies require data that are typically georeferenced, allowing for a GIS to be used. GIS is a powerful tool because it allows the user to analyze information and visually represent complex data. The maps and models created as part of this study are designed to provide a generalized view of the watershed from which future improvements can be suggested.

WATERSHED LAND-USE PATTERNS

Introduction

A comprehensive survey of watershed health, status, and trends must identify existing land-uses and quantify their effect upon water quality. Each land-use impacts the watershed to a different extent based on surface sensitivity to runoff, percentage of impervious surface, and level of nutrient-loading activity; the combination of these land-use qualities generates unique erosion properties that ultimately influence nutrient flux in the receiving water body. For example, those land-use types characterized by dense persistent vegetation (e.g., coniferous forest, deciduous forest, or mixed forest) absorb rainfall and reduce the erosion generated by runoff. The root structure of vegetation lowers the erosion potential of the underlying soil by stabilizing it. Due to the water absorption and erosion prevention provided by highly vegetated coverage, these land-uses add minimal amounts of nutrients to the associated water body. On the other hand, land-uses with minimal vegetation (e.g., commercial land, parks, pasture, or residential land) increase the impervious surface of the watershed and destabilize surrounding soil, increasing runoff potential and erosion. These land-use types contribute more nutrients to the receiving water body (Dennis 1986).

When conducted across time, land-use surveys provide valuable insight into historical land patterns, which may be used to predict future trends in land activity. The current land-use survey compares Long Pond South watershed data collected in 2003 to data from 1966. By identifying land-uses and analyzing their modification throughout time, this study elucidates historical land-use trends and facilitates future predictions of land activity in the Long Pond South watershed.

Methodology

CEAT utilized two spatially referenced aerial photographs to display, analyze, and interpret land-use patterns of the Long Pond South watershed. Images from 1966 and 2003, were scanned into digital format; CEAT evaluated each image using ArcGIS 9.2. Color Digital Orthophoto-Quadrangles (DOQ’s) obtained from the Maine Office of GIS (MEGIS) provided the primary aerial layer on which to base all digitization of Long Pond South watershed land-use for 2003. Image displacement caused by terrain relief and camera angle was removed to increase the accuracy of the 1966 satellite image (USGS 2006), making it suitable for georeferencing. ArcGIS displayed the DOQ's and provided the tools to generate a series of polygon layers representing each land-use type. The Maine Department of Environmental Protection provided a perimeter map of Long Pond South watershed and its sub-watersheds (MDEP 2007b). Digital polygons were generated to define the land-use of all areas within the watershed boundary.

The 2007 land-use survey of Long Pond North provided a model for land-use assignments of the Long Pond South watershed (CEAT 2007). CEAT used more specific definitions for land-use types for the Long Pond South watershed than those used in the Long Pond North study of 2006. To achieve a high level of continuity between the two studies, this study references the general descriptions of the Long Pond North land-use types to group more specific land-use categories, facilitating a future comparison between land use changes in both the North and South basins of Long Pond. Land-use categories in this study include cropland, pasture, non-shoreline residences, shoreline residences, parks, cleared land, commercial land, roads, regenerating forest, reverting land, coniferous forest, mixed forest, deciduous forest, wetland, and water bodies. Undertaking a polygonal digitization requires clear predefinition of land-use types (Figure 9).

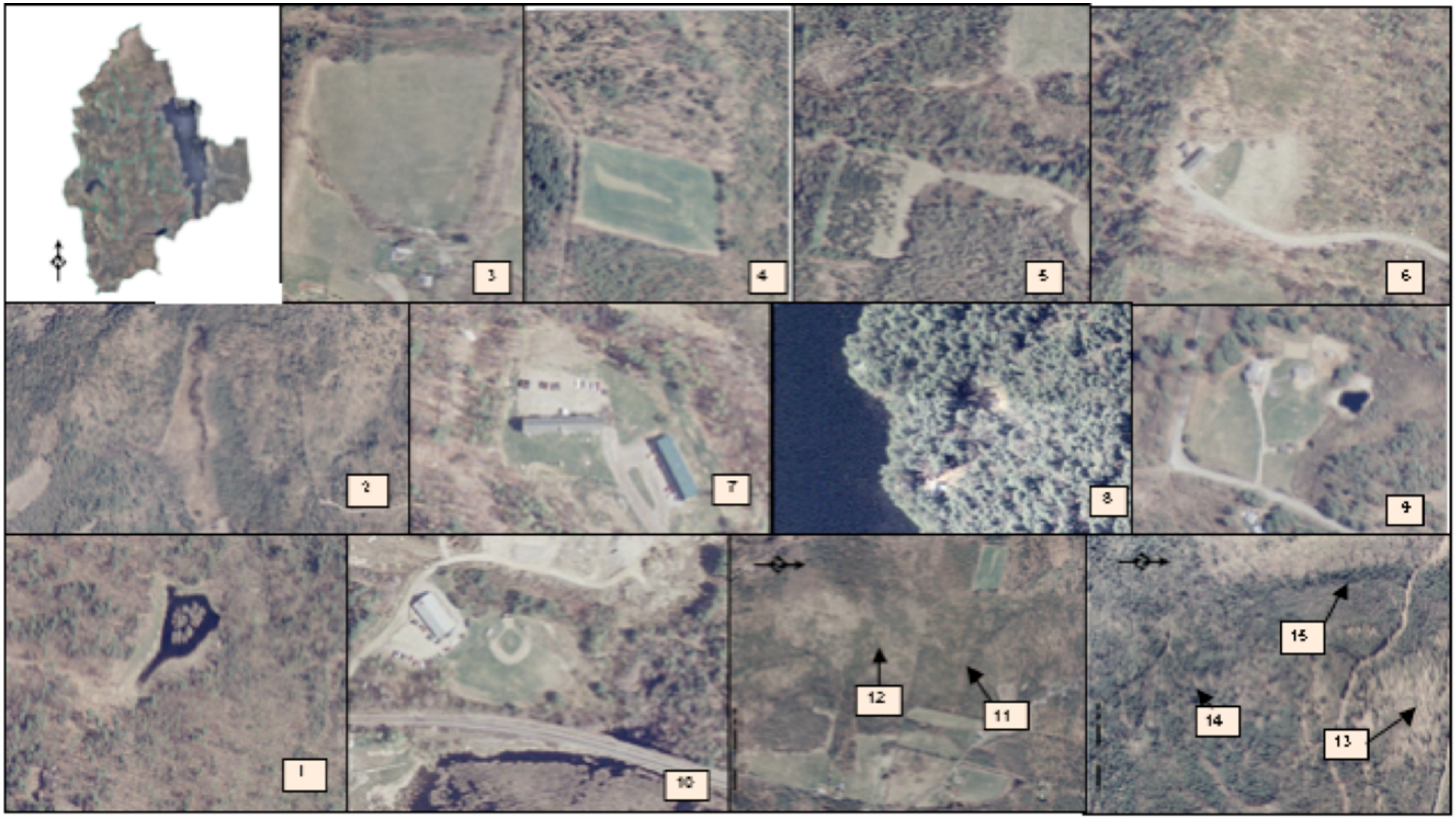

Figure 9: Images illustrating land-use definitions for Long Pond South watershed: 1. Waterbody, 2. Wetland, 3. Pasture, 4. Cropland, 5. Tree Farm, 6. Cleared Land, 7. Commercial Land, 8. Shoreline Residence, 9. Non-shoreline, Residence, 10. Park, 11. Regenerating Land, 12. Reverting Land, 13. Deciduous Forest, 14. Mixed Forest, 15. Coniferous Forest

Land categories were interpreted using the DOQ with 1 m resolution. A brief description of each land-use type is presented below:

Cleared Land: Disturbed dirt with little or no vegetation, tire tracks, and/or piles of refuse or gravel may be present.

Commercial: Land associated with high levels of impervious surfaces (parking lots, access roads), large buildings clearly not used for residential purposes, smoke stacks, or trucks.

Park: Land associated with open grass, and potential irregularities in shape. May display possible access by road, and trails running throughout, as well as distinguishing features such as sports fields, tracks, or parking areas at entrances.

Non-Shoreline Residences: Land not adjacent to the shoreline (farther than 250 ft), and associated with houses, driveways, or related residential structures (pools, sheds, fences, and/or lawns).

Shoreline Residences: Land adjacent to the lake shoreline (less than 250 feet), and associated with houses, driveways, related structures (pools, sheds, fences, and lawns, dock or boat).

Agriculture: Land that consists of crop lines or large rectangular fields with farm structures/equipment and livestock on or nearby. This category includes crop fields, pasture lands, orchards, and tree farms.

Cropland/farm: Includes land recognizable by exposed dirt with crop lines evident and defined by a rectangular or polygon-shaped perimeter (not to be confused with cleared land). Tractors may be adjacent

Pasture: An open, uniformly low-vegetation field with a defined perimeter or possibly a fence enclosing livestock. Adjacent structures may include barns, haystacks, animal shelters, and trucks.

Orchards: Relatively open field with regularly spaced or grouped trees. Trees may be immature or mature.

Tree Farms: Relatively open field with regularly spaced or grouped foliage. Trees may be immature or mature, and/or darker color because evergreen canopy dominates the area.

Successional Land: Land that is in transitional stages between a clear-cut surface to mature forest habitat, often recovering from the impact of development or agriculture. This land has been left fallow, and is in a natural progression towards reforestation.

Regenerating Land: Land with a visible perimeter of previous agricultural impact. Trees are shorter, less dense, and less green than forests, and all growing back at the same height. Regenerating land is often found on the outside edge of an open field.

Reverting Land: Land with a visible perimeter of previous agricultural impact. Unlike regenerating land, a section reverting land encompasses various stages of re-growth, therefore includes vegetation of variable height.

Coniferous Forest: Land consisting of dense coniferous forest signified by a dark green color and a closed canopy in the DOQs.

Mixed Forest: Land categorized by a heterogeneous coniferous and deciduous canopy layer, and a spotty forest of mixed coloration on the DOQ.

Deciduous Forest: Forest cover consisting of trees less dense than coniferous, oftentimes displaying spotted wooded areas if the DOQ was taken after autumn leaf loss.

Waterbody: Area in the DOQ consisting of waterbodies, streams, and/or rivers that persist annually.

Wetland: Low elevation land that transitions between aquatic and terrestrial ecosystems, often containing darkened saturated soils.

Roads: Area symbolized with lines from the official Maine Office of GIS roadlayer (Data Catalog 2007).

Once the land-use definitions were established, ArcGIS provided the tools to transform each defined area on the DOQ or aerial photo into a polygon image. Once drawn, the polygons were combined in a cohesive coverage of the watershed for analysis of their area ratios. The total area was calculated for each land-use category in the watershed using polygons generated for the 1966 and 2003 land-use maps. CEAT calculated the area of missing aerial coverage in the 1966 image, and derived 1966 land-use percentages relying only upon the data available. CEAT calculated the percent land-use areas from the photographic information provided to account for this missing data. The areas of each land-use type contributed to a pie chart comparison displaying the ratios between each category across the watershed. The land-use ratios calculated from the 1966 and 2003 provided a comparison of land-use trends over time.

While ArcGIS provided a powerful tool for analyzing non-residential land-use areas, the analysis of road areas and residential areas required supplementary data for their calculations. The Maine Office of GIS provided a polyline layer appropriate for the representation of roads on the final land-use map; however, the attributes of that layer lack the comprehensive width necessary for their area calculations. The road surveys completed in September-07 provided measurements of lengths and mean widths of every road in the watershed. CEAT used the road survey to document the current status of roads, supplementing the road quality data not included in the original polyline file. Once calculated, the total road areas were subtracted proportionately from associated land-use types to maintain a constant watershed area for quantitative analysis.

A similar method of area deduction accounted for the inaccuracy of aerially-defined residential polygons. Vegetation and canopy cover creates a challenge when defining residential land, where oftentimes tree coverage obscures distinguishing residential features such as roofs and driveways. A supplementary house survey provided the calculations necessary to determine residential area. The house survey took place during the road survey to tally and determine the location of all developed off-shore lots (> 250 ft from shore) in the watershed. The buffer survey provided a count of shoreline residences along Long Pond South. As suggested by Maine DEP, residential area was allotted 0.5 acres for each shoreline residential lot, and one acre for non-shoreline residential lots (Roy Bouchard, pers.com.). Total residential area derived from house counts was then subtracted from the mixed forest layer, as the majority of residential development takes place within the mixed forest land coverage.

A physical survey, known as ground truthing, verified those land-uses defined by aerial photography. Interpretation of some land-use patterns, such as forest, regenerating, and reverting land, offers challenges in areas of ambiguous land transitions. For example, the DOQ's were generated in the spring and displayed a lack of deciduous vegetation, making it difficult to identify these forest types. Ground truthing provided the opportunity to visit each undetermined area and visually confirm the land-use type. Because the DOQ was conducted in 2003 and the ground truthing in 2007, a temporal separation may be cause for further discrepancies in land-use identification. However, both data-generating activities occurred close enough in time to avoid large-scale changes in natural succession throughout the Long Pond South watershed. The developmental data generated through supplementary sources showed no incongruities when compared with the aerial photography data.

Each land-use type was grouped into one of six categories: residential areas, high-impact development, agricultural land, forested land, successional land, or wetlands. The following sections examine the amount and locations of each land-use type and evaluate its impact on Long Pond South. Impact of the land-use type was analyzed by investigating buffering capacity, erosion potential, runoff production and nutrient export or import, as well as additional factors that affect the overall quality of the watershed and lake. Changes in land-use were assessed by comparing the 1966 and 2003 Land-Use Maps (Figures 10 and 11). The Changes in Land-Use Map: 1966 to 2003 (Figure 12) illustrates areas of land-use change in the watershed. These land-use changes can be quantitatively visualized and compared with 1966 and 2003 pie charts (Figure 13). Table 5 lists the amount of acreage gained or lost from each land-use type.

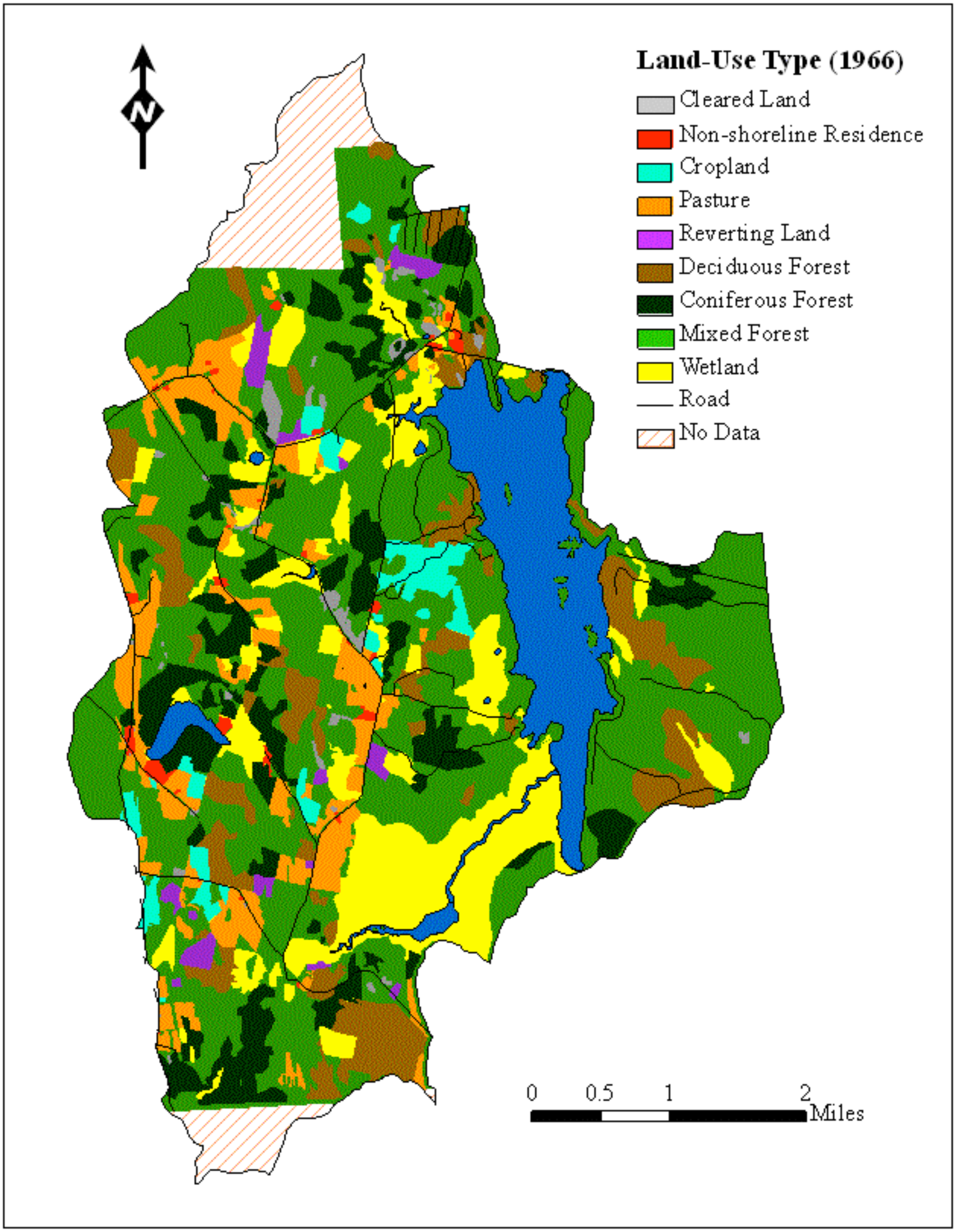

Figure 10. Land-use types in Long Pond South watershed based on 1966 aerial photograph (Data Catalog 2007).

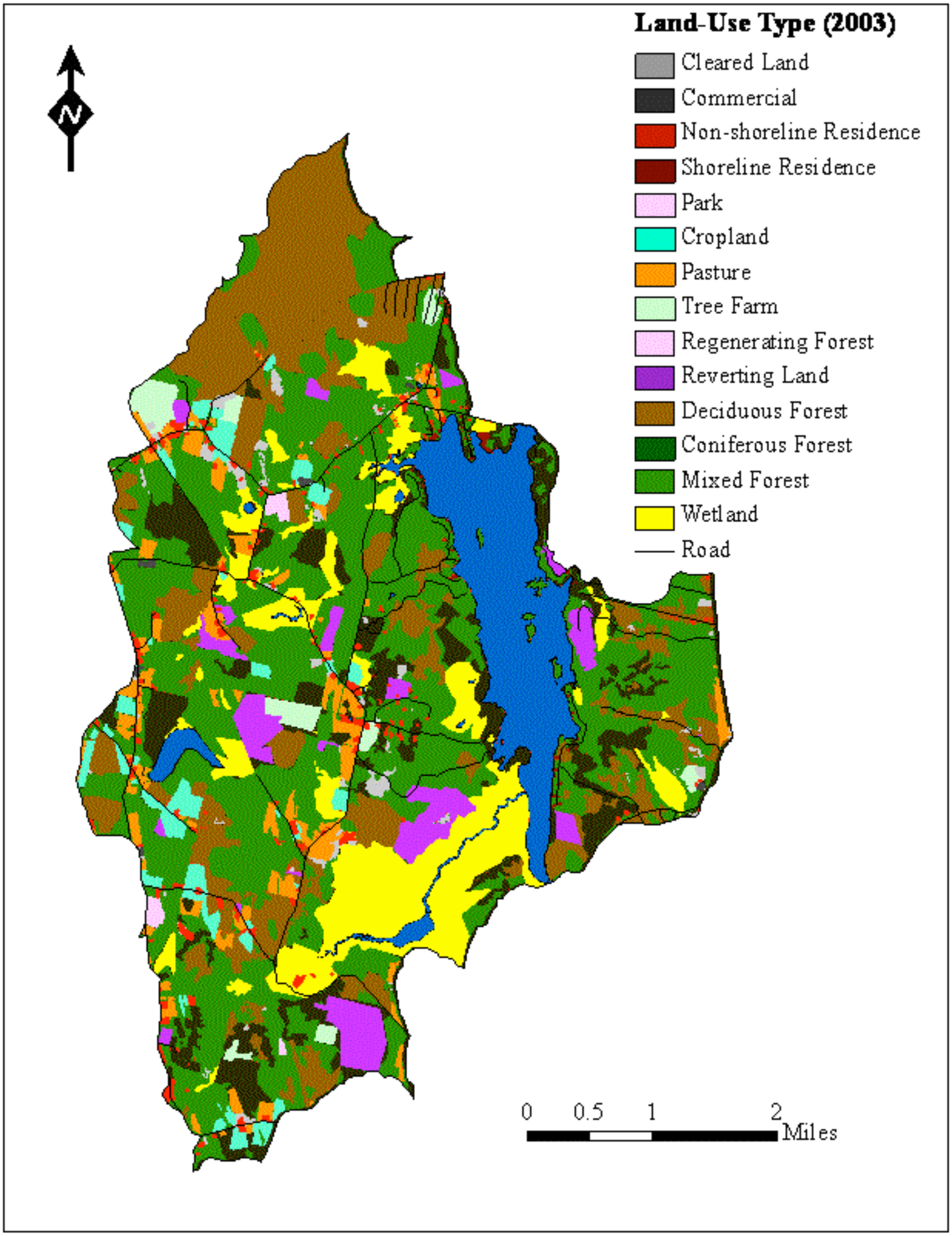

Figure 11. Land-use types in Long Pond South watershed based on 2003 digital orthophoto quads (Data Catalog 2007).

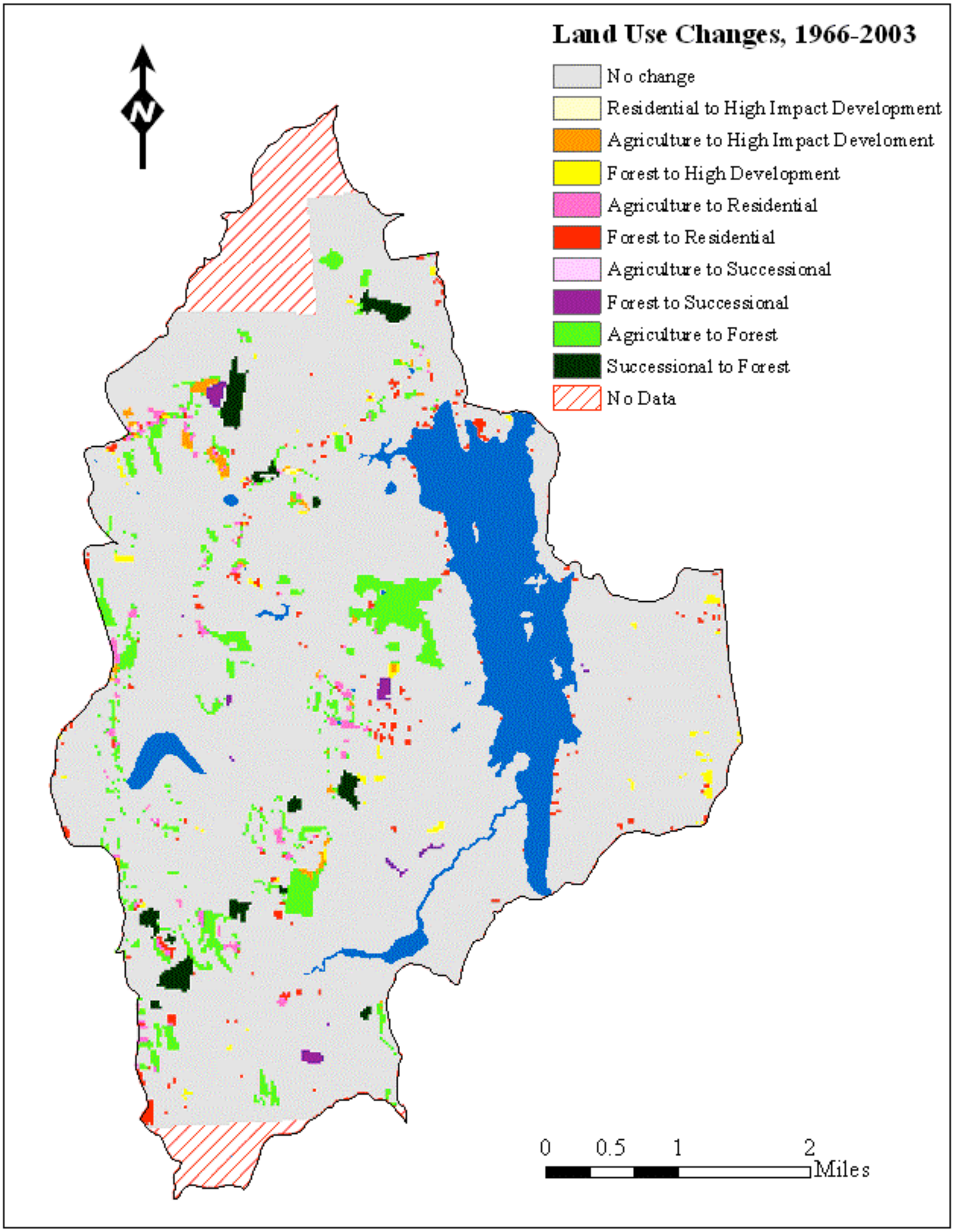

Figure 12. Land use changes from 1966-2003 based on aerial photography and ortho photography analysis (Data Catalog 2007).

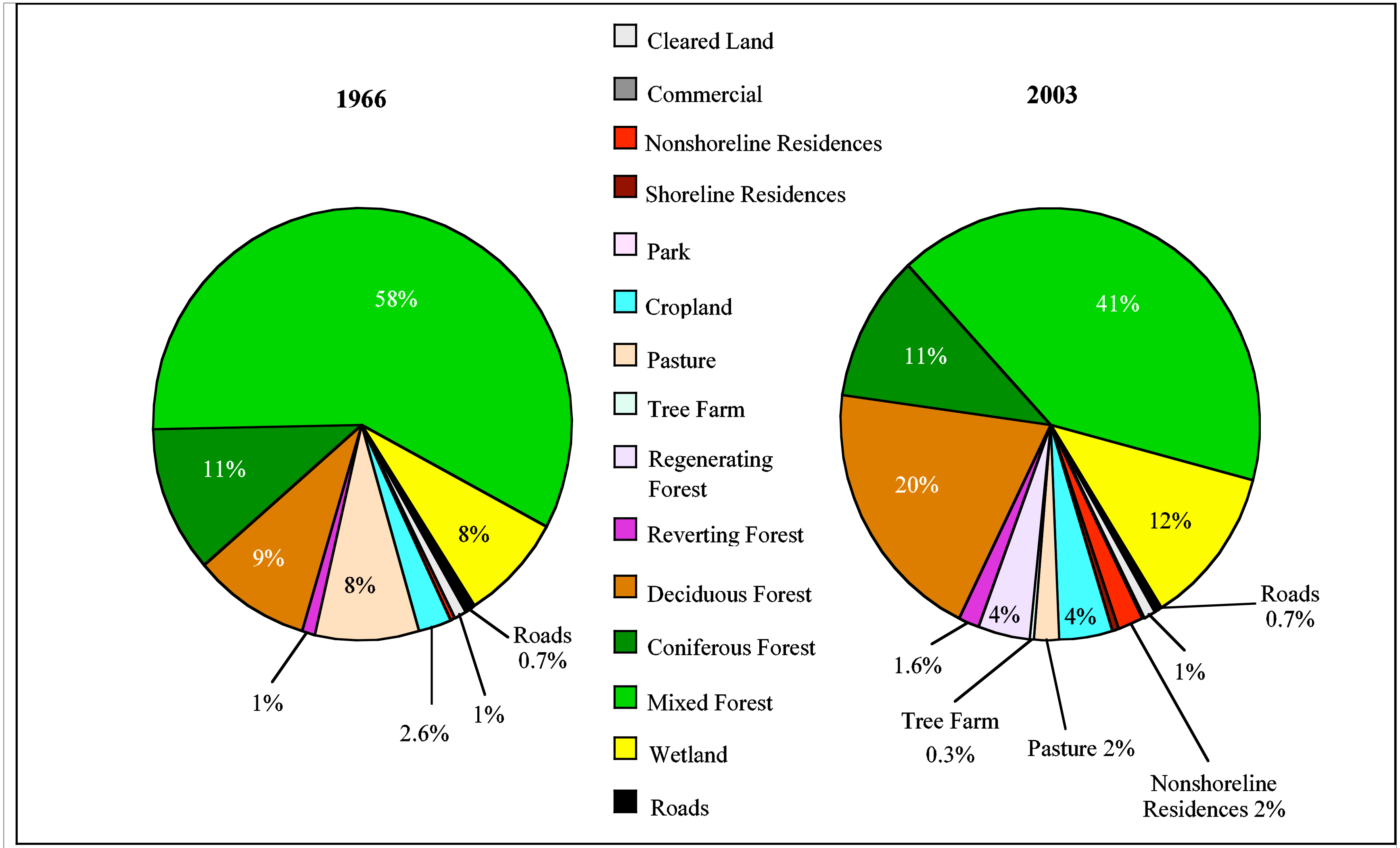

Figure 13. Percent cover of land-use types in Long Pond South watershed for 1966 and 2003.

Table 5. The percentage of each land-use type found in Long Pond South watershed for 1966 and 2003. Also shown is the change in acreage, with a loss of acres indicated by a negative sign.

Land-Use Type	Percent in 1966	Percent in 2003	Change in Acres
Residential Areas	**0.3**	**2.3**	**266.0**
Non-shoreline	0.3	1.8	203.0
Shoreline	0.0	0.5	63.0
High-Impact Development	**1.0**	**1.3**	**35.2**
Cleared Land	1.0	1.2	16.1
Commercial	0.0	0.1	18.6
Park	0.0	0.004	0.5
Agricultural Land	**10.6**	**6.3**	**-2052.0**
Cropland	2.6	2.0	-92.1
Pasture	8.0	4.0	-563.0
Tree Farm	0.0	0.3	-1396.9
Forested Land	**78.1**	**71.6**	**-1149.1**
Deciduous Forest	9.3	19.7	1330.6
Coniferous Forest	10.5	11.1	33.4
Mixed Forest	58.3	40.9	-2513.2
Successional Land	**1.3**	**5.8**	**599.1**
Regenerating Forest	0.0	4.3	566.1
Reverting Land	1.3	1.6	33.0
Wetland	**8.0**	**11.8**	**481.8**

Residential Areas

Introduction

Residential areas may impact the water quality of Long Pond South because they are inadequate in preventing erosion and runoff effectively. Such surfaces include impervious rooftops, driveways, and patios, and to a lesser extent lawns. Residences, especially those along the shoreline, produce nutrients that may run directly into the lake or enter the ground water or surface water and then travel into the lake. Septic systems contribute to residential nutrient input because they can leak nutrients to the lake through ground water contamination. A malfunctioning septic system can cause large phosphorus and nitrogen loadings into the lake. Fertilizers and pesticides used on lawns and gardens are other residential-associated phosphorus sources (Gray and Becker 2002; Pedersen et al. 2006).

Due to their proximity to the lake (within 250 ft), shoreline residences have a potentially greater impact on lake health in comparison to non-shoreline residences (see Background: Watershed Land Use, Shoreline Residential Areas). Erosion and runoff are more harmful on the shoreline since there is less of a buffer. Natural vegetation plays a key role in buffering the lake from residential associated pollutants. However, residents often degrade the buffer by removing vegetation to provide lake accessibility, added sunlight, and a better view.

CEAT counted and assessed shoreline residences during a lake buffer survey conducted on 20-September-07. Non-shoreline residences were counted and assessed during a road survey on 24-September-07. These assessments allowed for undetected, tree-hidden houses in aerial photographs to be counted and for all new residential construction since 2003 to be included. CEAT used the same area estimates used by Maine DEP, which allots one acre to non-shoreline residences and one-half acre to shoreline residences, for our standard. Different methods were used to asses residential land areas in 1966. Houses were visually identified and counted on the 1966 aerial photographs. In addition, topography maps with labeled residential units from 1956 and 1980 were used to supplement the 1966 aerial photographs.

Results and Discussion

The lake buffer and road surveys conducted by CEAT counted 365 residences (see Residential Survey). Of the total residential areas, 239 were non-shoreline and 126 were shoreline, which equated to 302 acres covered by residential areas (2.3 percent of the land in the watershed). Residential areas in Long Pond South watershed cover a smaller area than the residential areas in Long Pond North watershed, which has 5.5 percent land covered by residences (CEAT 2007). Similarly, Great Pond watershed had a higher percentage (4.5 percent) of residential land area than Long Pond South (CEAT 1999). Since 1966, there has been a change in the residential land-use patterns in Long Pond South. Based on the 1966 Land-Use Map (Figure 10), there were no shoreline residences in the watershed and non-shoreline residences covered only 0.3 percent of the land area (rather than 1.8 percent in 2003). Since shoreline residences could have been obscured by a dense canopy cover, two supplementary historical maps were used to define shoreline residential areas in 1966. Both supplementary maps, one from 1956 and another from 1980, did not show the entire basin, and so only an approximate number of shoreline residential area could be obtained. The 1956 topography map showed at least 15 shoreline residences and the 1980 topography map showed at least 42 shoreline residences. The majority of the houses in 1980 were located in the southeast area of the lake. These historical numbers indicate that there were houses along the shoreline in 1966 and their visibility in the aerial photographs was most likely obstructed by a think canopy layer. Overall, it can be concluded that there was a smaller number of shoreline residences on Long Pond South in 1966 that at present.

These data support the overall trend seen in residential land-use area in southern Maine. Kennebec County has experienced a substantial population growth between 1960 and 2003; in Maine, the year-round population has increased by 300,000 people and 80 percent of this growth has been in southern counties, where Kennebec County is located (Richert 2004). This time period also experienced a doubling in residential units and a tripling in residential land area (Richert 2004).

In 2003, Long Pond South watershed boasted a relatively small percentage of residential areas as well as a high flushing rate (see Water Budget). The combination of these two factors suggests that the health of Long Pond South is not in immanent danger from residential areas.

Yet, if southern Maine continues to witness increasing population, Long Pond South may have the land needed for the development of houses.

High-Impact Development

Introduction

This category includes cleared land, commercial land, and parks. Cleared land consists of areas where natural vegetation has been removed by humans and may be sites of planned or active construction or development. Commercial land includes businesses, schools, gravel pits, and large commercial farms. Parks are open areas used for human recreation such as baseball fields. All three land-use types exhibit surfaces with low to no permeability, increasing the potential for contaminated runoff to remain on the surface and flow into adjacent water bodies. The increased amount of runoff leads to increased erosion and decreased filtration of polluted waters. Examples of impervious surfaces are paved parking lots and rooftops. Surfaces exhibiting decreased permeability are compacted soil, manicured lawns and gravel driveways.

Results and Discussion

High impact development covers 1.3 percent of the watershed (176.1 acres or 71.3 ha). These areas often border land used by humans such as croplands, pastures, and residential areas. This land-use type suggests deforestation because a patch of cleared land was sometimes completely surrounded by dense forest. The Long Pond South watershed benefits from a small area of high-impact development because it implies that the watershed is not highly threatened by harmful impervious and semi-impervious surfaces. The majority of high-impact development found in the watershed was land stripped of its natural vegetation and not utilized in another way, such as for agriculture or residential development. Very little commercial industry exists in Long Pond South. However, CEAT observed some large commercial farms during the road survey. Relative to nearby watersheds, high-impact development also covers a small percent of the watershed for Long Pond North (2.2 percent) and Great Pond (1.9 percent) (CEAT 2007, CEAT 1999). Since 1966, Long Pond South has experienced a small increase (less than one percent) in the amount of high-impact development (Figure 13). By keeping the amount of commercial land to a minimum, the area covered with impervious surfaces is kept low. This is beneficial for the watershed because it means that this land-use type is not contributing a great amount of runoff and nutrients into the lake.

Agricultural Land

Introduction

Agricultural practices found in the Long Pond South watershed include cropland, pasturelands, and tree farms. The EPA has cited agricultural practices as the main cause of lake impairment in regards to non-point pollution (Baker 1993). Sources of non-point pollution are fertilizers, pesticides, and livestock. Fertilizers and pesticides contain nutrients that negatively impact the lake when in high concentrations (see Background: Lake Characteristics). Livestock affect the land in three ways. First, animal treading packs soil leading to higher amounts of runoff and reduced permeability. Second, livestock erode surfaces through consumption of natural vegetation. Third, manure and feed are external sources of phosphorus and nitrogen. Croplands, pasturelands and tree farms are types of agricultural practices found in the watershed.

Results and Discussion

In 2003, agricultural lands accounted for 6.3 percent of the watershed (Table 5). Although not a major percentage of the watershed, small amounts of this land-use type can have a large impact on the watershed because it is a large source of external nutrients, especially phosphorus (see Appendix D).

The 1966 Land Use Map (Figure 10) showed a very different percentage of agricultural land-use, verifying the decrease in agriculture over the past 40 years. In 1966, agricultural lands covered 10.6 percent of the watershed, or 529 acres more of the land than in 2003. The majority of agricultural land consisted of pastureland (8.0 percent), cropland made up 2.6 percent, and there were no tree farms (Table 5). The decrease in agricultural lands from 1966 to 2003 (4.3 percent) indicates that a high rate of agricultural land reversion occurred between these years. Much of this became either successional forest land or land cleared for development. This decrease in agriculture is seen in Great Pond as well. Between 1966 and 1998, Great Pond watershed saw a 3.0 percent decrease in agricultural land use (CEAT 1999). In many areas of southern Maine this land-use type has declined with the population increase and with a changing job market (see Future Projections: Populations Trends, Historic Population Trends). Historically, the amount of farms in Maine increased substantially until the 1970s, when the number leveled off (Smith 2004). Since then, both sales and the mean size of farms have decreased; Maine has seen a 50 percent decline in farmland acreage between 1964 and 1997 and this trend is reflected in the Long Pond South watershed. Even with the decline, there are still farms, crops and pasturelands in this area, and in 1997, dairy production was the largest type of agricultural practice in Kennebec County (Smith 2004). If the declining trend in agricultural lands continues, and is combined with the heightened awareness of the toxicity of pesticides and fertilizers, the resulting impact of agricultural lands on the water quality of Long Pond South should be minimal.

Forest Types

Introduction

Forests benefit the watershed by reducing erosion and absorbing nutrients. Erosion is reduced because the root systems stabilize soil and the canopy protects the ground from the erosive capabilities of rainfall. The roots absorb nutrients that could otherwise enter the lake through runoff or ground water filtration. A mature root network helps to stabilize soil and trap sediments that could potentially carry contaminated runoff into the lake. There are three types of forest cover identified in Long Pond South watershed: coniferous forest, deciduous forest, and mixed forest. One difference between the three is that conifers retain their canopy layer (needles) throughout the winter, which allows them to have a protective canopy layer for a longer time during the year in comparison to deciduous trees. This canopy layer will protect the ground from eroding raindrops. Also, the leaf litter from deciduous trees contributes a higher amount of phosphorus to the lake (see Background: Forest Types).

Lumbering affects the amount of forested area. In Maine, the replacement of small lumber companies with large, modern mills caused the size of the lumber industry to triple between 1960 and 2000 (Irland 2004). At the same time, changing opportunities in Maine and the rest of the United States caused the manufacturing industry to shrink considerably. The decrease in the manufacturing sector has resulted in an overall diminished lumber industry in the state. In contrast, a CEAT study of Great Pond watershed found less than one percent of the watershed to be logged in 1998 and there was no evidence of logging in 1966 (CEAT 1999).

Results and Discussion

Altogether, Long Pond South watershed is 71.4 percent covered by forests. Mixed forest made up the largest forest area type, as well as the largest overall land-use type. It covers 5,389 acres (2,181 ha) of the watershed, which is 40.9 percent of the total area. Deciduous forest covered more land area than coniferous forest (19.7 percent versus 11.1 percent). The percent of forest land cover has decreased by 6.5 percent since 1966 (Figure 13). This decrease was caused by a net loss in mixed forest since 1966; 2,513 acres (1,017 ha) have been deforested, but an increase in the amount of both deciduous and coniferous forest has offset some of this loss in mixed forest. Another reason for the increase in both deciduous and coniferous forest is that mixed forest was harder to identify in the 1966 aerial photographs. Area covered by forests in nearby watersheds is variable because of the subjective nature of forest type identification regarding what is mature forest and what is successional forest. In 1998, Great Pond was covered by only 34.1 percent forest, while successional land covered 42.5 percent. In Long Pond North, forests comprised 85.6 percent of the watershed, but there was very little successional land (2.2 percent).

It will be important to protect all three forest types from further deforestation to maintain lake water quality. The northern tip of the watershed is covered primarily in deciduous forest with a small amount of mixed forest (north of Castle Island Road). There are no roads running through it, but this large area of natural land may be appealing to developers.

Successional Land

Introduction

During the past forty years, agricultural practices have decreased and there has been an abandonment of farmlands and pasturelands. Natural vegetation succeeds this abandoned land, and if left untouched, this land will develop into mature forest in the future. Trees grow into the abandoned fields in two different patterns, designated as reverting and regenerating land in this study. Similar to forested land, successional land prevents erosion, reduces runoff and absorbs nutrients, yet is less effective at doing so because it is comprised of immature trees with fewer leaves and a less extensive root system. In addition, successional lands provide added wildlife habitat. The overall conversion of any human altered land-use type to one that is natural is a generally considered a positive change for lake health.

Results and Discussion

Successional land covered a total of 776.7 acres (314.3 ha), or 5.9 percent of the watershed land area. The majority of successional land is regenerating forest (4.3 percent). A large amount of this area was situated adjacent to the lake itself or to the wetlands nearby. The location of successional lands suggests that there were once farmlands and pasturelands bordering the water body. These areas are in the process of succession, which will help buffer the lake from polluted runoff, absorb excess nutrients, and stabilize soil to prevent erosion. Data obtained by comparing the 1966 and 2003 Land-Use Maps supports this observation because there has been a significant decrease in agricultural land and an increase in successional lands (Figure 13). In 1966, successional land covered only 1.31 percent of the watershed. The successional lands in Long Pond South watershed made up a relatively large percentage of the land-use types in the watershed relative to Long Pond North, which had only 2.2 percent of the watershed as successional land in 2003 (CEAT 2007). Contrastingly, successional land in Great Pond comprised 42.5 percent, but this could be due to differing forest identification techniques.

Wetlands

Introduction

All wetland ecosystems are protected in the United States under the Clean Water Act and, in Maine, by the Natural Resource Protection Act and Mandatory Shoreline Zoning Act which are part of Maine DEP (Environmental Law Institute 2005). Some common wetland plant species include cattails, rushes, sphagnum moss, spruce, and other hydrophytic plants (Nebel 1987). Wetland ecosystems are extremely beneficial to lakes in that they provide various services that improve and protect the health of the lake (see Background: Wetlands). Most importantly, they act as a sink for pollutants and nutrients, meaning that rather than contaminating the lake, pollutants and nutrients are absorbed by plant tissue and utilized by microorganisms. Wetlands boast a unique environment that is capable of hosting microbes that will use phosphorus and nitrogen in their lifecycle, preventing these nutrients from flowing into the lake. Sewage effluent and fertilizer runoff may contain large amounts of heavy metals and nutrients that have the ability to pollute the lake. Wetlands are an effective buffer to these substances, especially during the growing season. In addition to the absorption of excess nutrients, wetlands trap sediments flowing toward the lake, provide a unique wildlife habitat, and act as a natural land buffer to prevent erosion of the land by water and wave action.

There was a difference in wetland identification methods in 1966 and 2003. In the creation of the 2003 Land-Use Map (Figure 11), CEAT had the assistance of the Maine Office of GIS in determining wetland areas on colored DOQs. Wetland areas predefined by this organization were used as guidance in distinguishing wetland areas. In contrast, for the 1966 Land-Use Map (Figure 10), identification was done by CEAT on uncolored aerial photographs of a lower resolution.

Results and Discussion

The largest area of wetlands is located on the southeastern side of Long Pond South Basin surrounding Ingham Pond and Ingham Stream, but smaller areas are found throughout the watershed. In 2003, wetlands covered a total area of 1,565.2 acres (633.4 ha). This comprises 11.8 percent of the land use in the watershed, a much higher percentage than found in nearby watersheds. Wetlands accounted for only 2.8 percent of the Long Pond North watershed in 2003 (CEAT 2007) and 7.0 percent in the Great Pond watershed in 1998 (CEAT 1999). Additionally, the Great Pond watershed has experienced a 4.7 percent loss in wetland area in the years between 1966 and 1998. The large wetland land coverage is advantageous for Long Pond South, for the reasons stated above and in the Background section found in this report (see Background: Wetlands). Ingham Stream brings water from Moose Pond and Ingham Pond into Long Pond South. Surrounding Ingham Stream is extensive wetland habitat, which suggests that impaired water flowing out of Moose Pond and Ingham Pond into Long Pond South will be restored by the wetlands through which it travels

There has been no net loss in wetland land area since 1966; contrastingly, there has been a 3.8 percent increase (8.0 percent in 1966 to 11.8 percent in 2003) (Figure 13). Since wetlands are protected, they will not be expected to change in area over the years, yet data collected by CEAT suggest otherwise. The difference may have arisen in the methods of wetland identification. The identification done with uncolored aerial photographs of a lower resolution made it difficult to identify exact areas of wetland. In 2003, CEAT was able to identify wetland areas with the DOQs, Maine Office of GIS, and ground truthing, and so the 11.8 percent of wetland cover is considered to be an accurate percentage. Additionally, change in wetland area can arise from small amounts of forest receding at the perimeter. Importantly, wetland area has not changed much between 1966 and 2003, and the implications are a watershed ecosystem that is more capable in buffering, absorbing runoff, and providing a valuable habitat.

WATERSHED DEVELOPMENT PATTERNS

Residential Survey

House Count

<u>Introduction</u>

The amount of development in the watershed is a critical factor in determining the overall health of Long Pond South. Development may contribute to greater phosphorus loading through the installation of more wastewater disposal systems and the construction of roads. To quantify development in the watershed, CEAT conducted a residential survey inside the watershed boundaries, both along the shoreline and inland. Shoreline development has a potentially larger and more direct impact than inland development due to proximity to the lake. Shoreline development has historically caused the degradation of important buffer strips that protect the lake from nutrient-laden runoff. Even though shoreline zoning regulations have mandated a 250 ft setback from great ponds, many older houses were built directly on the shoreline with little to no protective buffer. Houses like these contribute greatly to phosphorus loading, not only through runoff from the lawn and impervious surfaces but also through leaching of septic systems that are too close to the high water line. Many of these older septic systems are too close to the high water line to be effective in filtering harmful nutrients from wastewater before it enters the water body.

CEAT also considered the intensity of house usage within the watershed. While many houses in the area are used only seasonally, many others have residents year-round. William

Najpauer, Code Enforcement Officer of Rome (pers. Comm.), identified the length of the summer season as approximately 90 days, with the possiblility of it becoming longer as time goes on. Seasonal houses contribute less to the phosphorus loading of the lake than year-round homesbecause the septic system is only used for part of the year.

Methods

The residential survey was conducted in two parts. The shoreline house survey was done in conjunction with the buffer strip survey on 20-September-07. On this day, houses within 250 ft of the shoreline were counted brom boats. These houses were categorized as seasonal or year-round homes. Chimneys, solid concrete foundations, and woodpiles were all considered indicators of year-round residences. The inland houses were counted during the road survey on 24-September-07. These houses were also categorized as seasonal or year-round using the same characteristics.

To measure the current rate of development, these house numbers were compared to the lot divisions on local, tax maps acquired from the town halls of Belgrade, Mount Vernon, and Rome. Tax maps illustrate every defined lot, many of which remain undeveloped, representing the future buildable land within the watershed. There are lots that are zoned for building, but have not yet been developed.

Results and Discussion

In the Long Pond South watershed, CEAT counted a total of 365 houses. One hundred twenty six (34.5 percent) of the houses counted were located on the shoreline, five of which are located on islands. The team classified 43 (34.1 percent) of these properties as permanent and 83 (65.9 percent) were classified as seasonal. Two hundred thirty nine (65.5 percent) of the houses counted were inland. Of these non-shoreline properties, the majority of houses were classified as permanent, at 229 (95.8 percent), and ten houses were classified as seasonal (4.2 percent).

Houses close to the shoreline may have a much greater impact on water quality than those located far back from the shoreline. This is because there is less distance from the house to the high water line for the ground to absorb and filter out nutrients that are potentially harmful to the water quality. This suggests that the shoreline homes may contribute more to phosphorus loading than non-shoreline homes. The phosphorus loading from shoreline homes may be lower in the Long Pond South watershed than in other watersheds within the same local area due to the lower number of homes in the Long Pond South watershed than in others (Table 6).

Shoreline residences are not spaced evenly along the shoreline of Long Pond South and there are several undeveloped areas and large parcels of natural vegetation along the perimeter of the pond. The shoreline density of Long Pond South is 9.2 houses per shoreline mile. Compared to other lakes in the region, this is a very low shoreline density (Table 6). This number is lowered because of the large amount of unbuildable land, especially wetlands and stream basins, along the shoreline of the pond.

Non-shoreline residences account for nearly two thirds of the total houses counted during the residential survey. While these houses do not pose as great a threat to the water quality of Long Pond South, they do contribute to phosphorus loading in the water. The amount of phosphorus loading that can be attributed to non-shoreline homes depends on the soil type they are built on, as well as the seasonality of the home. Currently, the minority of the homes is classified as seasonal. According to Richard Marble, Code Enforcement Officer of Mount Vernon (pers. comm.), the number of seasonal homes being converted to year-round homes is rising and the number of new year-round homes is decreasing. However, in Rome, there is little conversion of seasonal homes for year-round use, due to the resistance of many homeowners to sell off part of their land to allow for the widening and paving of roads that would be necessary for year-round use (Najpauer, pers. comm.). However, Najpauer has observed that houses in Rome are being expanded for greater intensity of use during the summer season by the building of additional bedrooms. This discrepancy may suggest that some areas of the pond are more desirable than others, potentially due to differences in local laws between the three towns.

Table 6. Shoreline house counts and shoreline residential density, shown in houses per shoreline mile, for selected Maine lake watersheds (CEAT 2004, 2005, 2006, 2007).

Lake	Shoreline Homes	Residential Density
Threemile Pond	203	20.5
Togus Pond	184	17.9
East Basin of China Lake	472	30.2
Long Pond North	267	17.5
Long Pond South	126	9.2

Buffer Strips

Introduction

Proximity of buildings to water may affect water quality; buildings that are closer to the water have a greater impact than those farther away from the shore. Cleared land, exposed soil, impervious surfaces, and non-native plantings all increase the amount of runoff into lakes. The quantity and quality of natural vegetation along the edge of lakes and streams is crucial to absorption and diversion of harmful nutrients that contribute to the eutrophication of the lake. Having a variety of plants along the shoreline increases the ways in which runoff and rainwater are diverted and slowed down. Ground cover plants interrupt and slow the quantity of water runoff, increasing the amount of absorption and decreasing the amount of nutrients flowing into the lake (see Background: Buffer Strips).

The ideal buffer is comprised of several different types of vegetation, including ground cover plants, mid-height shrubs and bushes, as well as full-sized trees (MDEP 2005c), and should cover the majority of the shoreline length of the property. An effective buffer can remove as much as 70 to 95 percent of incoming sediment and 25 to 60 percent of incoming harmful nutrients and pollutants (Dreher and Murphy 1996). Having the buffer comprised of native vegetation can cut down on maintenance for homeowners while simultaneously increasing the efficiency of the buffer itself (Figure 14).

To protect the natural resources of the state, the Maine Department of Environmental Protection implemented the Mandatory Shoreland Zoning Act in 1971 (MDEP 2003c). The Act regulates and governs development within the shoreland zone, which they define to be "250 feet from the high-water line of any great pond, river or saltwater body, within 250 feet of the upland edge of a coastal wetland, within 250 feet of the upland edge of a freshwater wetland…or within 75 feet of the high-water line of a stream" (MDEP 2003c). According to this act, municipalities containing water types outlined above must adopt zoning ordinances of equal or greater standards than the minimum guidelines outlined by the Act. The Long Pond South watershed falls under the jurisdiction of the Towns of Belgrade, Mount Vernon and Rome. All three of the towns have adopted ordinances that follow the minimum guidelines outlined by the statewide Mandatory Shoreland Zoning Act, without noticeable exception.

Setback laws within the Act mandate that all new principal or accessory buildings or expansions that would increase either volume or floor area by 30% or more must be set back from the shoreline by at least 250 ft (MDEP 2003c). Because this law was passed initially in 1971 and revised in 1974, many properties with houses built before these dates are potentially noncompliant. Part of the Act exempts these properties, and considers them to be "grandfathered" in to the system. However, if these houses were to be expanded upon or revised in any way, they would then be considered noncompliant and building or expansion permits would not be permitted by the municipality or by the state.

Methods

The buffer strip survey was conducted by CEAT on 20-September-07. The team was divided into several groups, each assessing different parts of Long Pond South to evaluate the quality of the shoreline. At points along the shoreline where there were visible homes less than 250 ft from the shore, CEAT members recorded a GPS point and evaluated the buffer on the property of that home (see Appendix I). For areas of natural vegetation, CEAT recorded beginning and end points of the vegetation and qualified the type of vegetation present, such as "wetland" or "forest." In order to evaluate the buffer, surveyors were asked to quantify certain characteristics of the shoreline: percent of vegetated buffer, buffer depth from shore, and slope rating. For each of these categories, point values were assigned according to the quality of that characteristic, with the higher values corresponding to higher quality (see Appendix I). Scores for each characteristic were summed, and divided by the highest score possible (12) to create a buffer strip index. Values between zero and 25 percent were considered "poor" buffers, those between 26 and 50 percent considered "fair," between 51 and 75 percent considered "acceptable," and those 76 percent or above considered "good." In order to make a fair comparison to the Long Pond North, the data sheets from that study were analyzed and re-scored according to the new system.

Figure 14. Examples of buffer strips along the Long Pond South shoreline. Top photo shows an effective buffer with dense and varied vegetation of an appropriate depth to help protect the lake from runoff. Bottom photo shows a degraded buffer strip without the effective depth or density of vegetation to prevent runoff.

Results and Discussion

A total of 126 properties were evaluated during the shoreline buffer survey. The results of the shoreline buffer survey indicated that 22 (17.5 percent) of the shoreline properties had a "good" rating, 56 (44.4 percent) had an "acceptable" rating, 30 (23.8 percent) had a "fair" rating, and 14 (11.1 percent) had a "poor" rating. Four properties (3.2 percent) were classified as "no data." CEAT also surveyed 36 areas of natural vegetation, including three islands, as well as one boat launch, one floating dock, and one house site under construction (Figure 15).

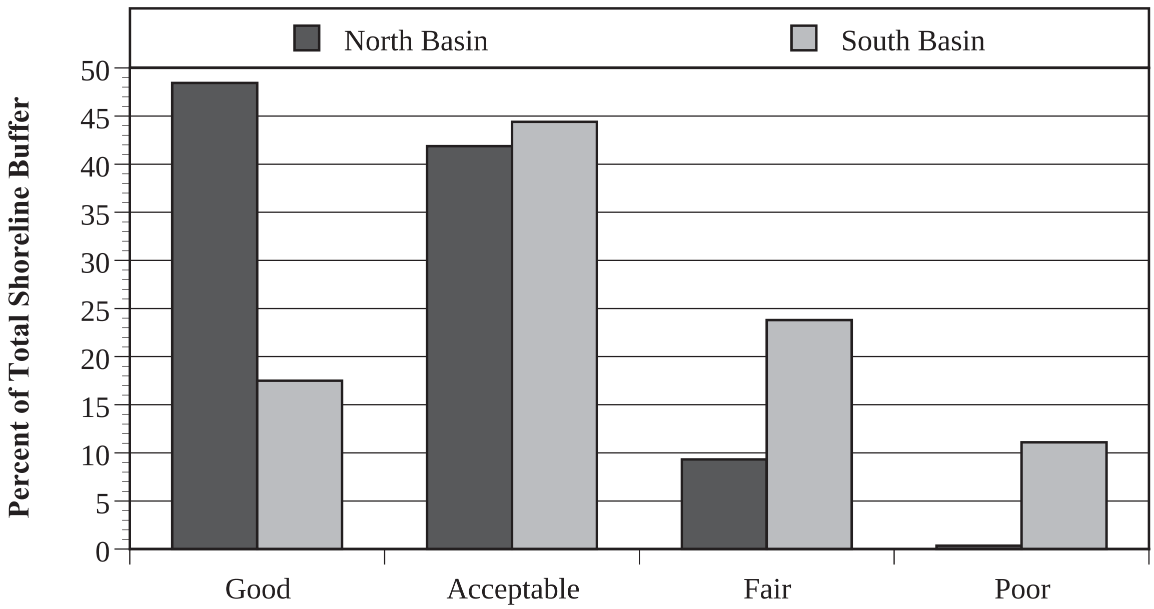

Figure 15. A comparison of shoreline buffer quality in the North and South Basins of the Long Pond Watershed. Data are displayed as a percentage of the total, and quality was determined using the buffer strip survey form (see Appendix H).

The length of the shoreline combined with the buffer rating can indicate the quantity of runoff and erosion at each property. The survey indicated that there were 25 properties with a shoreline distance of zero to 60 ft, 55 properties with a distance of 60 to 120 ft, 42 properties with a distance of 120 to 180 ft, and four properties with a distance of 180 ft or greater (Figure 16).

Mapping the collected data allowed for patterns of buffer quality to emerge. The most significant areas of fair and poor buffers exist in the northwest corner of Long Pond South

(Figure 17). The survey data indicated that this area was also highly developed. However, the results of the survey indicated that there were an equal number of houses built before and after the setback change in the Mandatory Shoreland Zoning Act 1974. Clustered areas of exceptional buffer quality occurred in the southeast corner of the lake, near Site 7 (see Figure 30 for site locations). This area was also highly developed, although these houses were generally smaller, had less shoreline distance, and were set farther back from the shoreline. The houses were also found to be a mix of both old and new houses, but the overall good quality of buffers suggests a higher degree of homeowner responsibility.

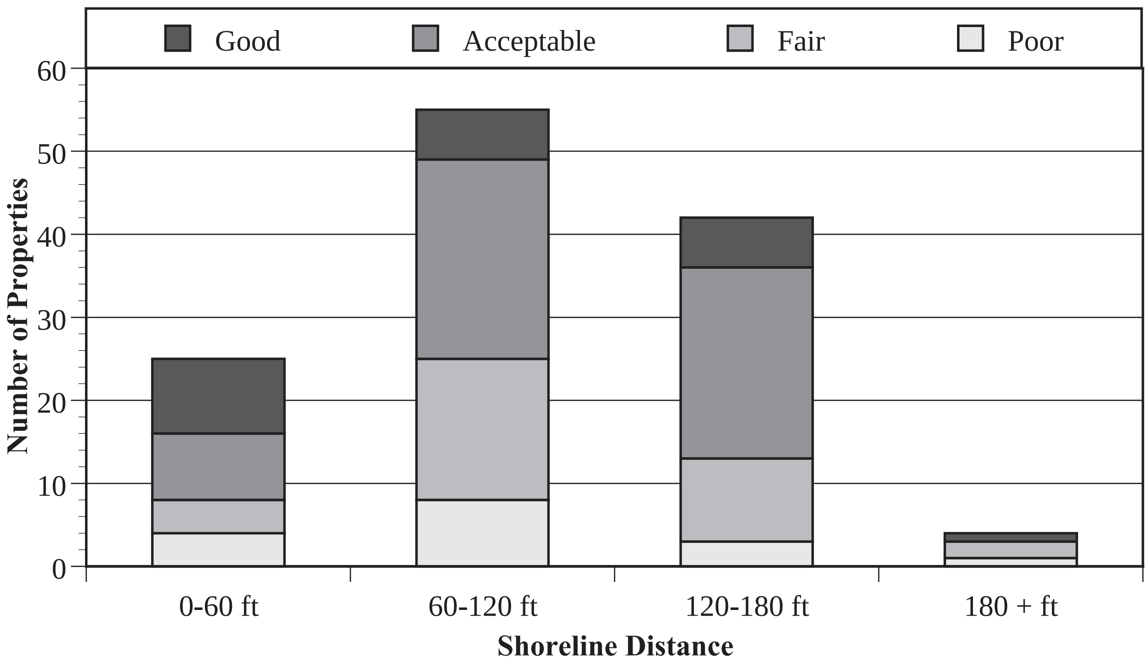

Figure 16. The distribution of properties along the shoreline of Long Pond South in buffer quality categories by size. Larger lots with more shoreline area have an increased impact on water quality.

Subsurface Disposal Systems

Introduction

In rural areas long distances may separate houses, which makes sewer systems an inefficient means of wastewater disposal. The towns surrounding Long Pond South do not use sewer lines to collect and move waste; instead other methods of subsurface wastewater disposal systems are used. Pit privies, better known as outhouses, are deep holes where human waste and paper decompose (see Background: Subsurface Wastewater Disposal Systems). Because of their low intensity of use and low water content, pit privies are not typically water-contaminating forces unless they are located very close to the water. If properly constructed and maintained, holding tanks are another safe method of wastewater disposal within the watershed because they do not leach wastewater. Holding tanks store waste in tanks for long periods of time. They must be pumped out regularly to prevent overflow (see Background: Subsurface Wastewater Disposal Systems).

The overboard discharge is a less common method of wastewater disposal that has been phased out in recent years. The overboard discharge consists of wastewater simply flowing out of an open pipe into a body of water. Even though these systems require a treatment process before wastewater is released, the likelihood of malfunction prompted the State of Maine to strictly regulate and/or replace overboard discharge systems in the mid-1970s (MDEP 2003a).

Septic systems are the most common method of subsurface wastewater disposal in the Long Pond South watershed (Cole, pers. comm.). Septic systems allow for wastewater to be slowly treated by natural processes within the soil before it seeps into the groundwater or surface water supply (see Background: Subsurface Wastewater Disposal Systems). Septic systems consist of an underground, two-compartment septic tank to which wastewater from the house can flow by gravity (Figure 18). Solid waste in the septic tank settles to the bottom, and oil and grease rise to the top, separating out the treatable effluent (Canter and Knox 1985). The effluent, which is contaminated by nitrates, phosphorus, microorganisms, heavy metals, and solvents, moves into the leach field through a system of perforated pipes. Soils treat the effluent as it leaches out of the pipe. Bacteria and viruses are filtered out of the effluent by the soil, and nutrients are absorbed by soil particles. If the septic system is installed in soils with proper permeability and depth, it can be very effective in treating wastewater on a small scale to prevent water contamination (EPA 2005).

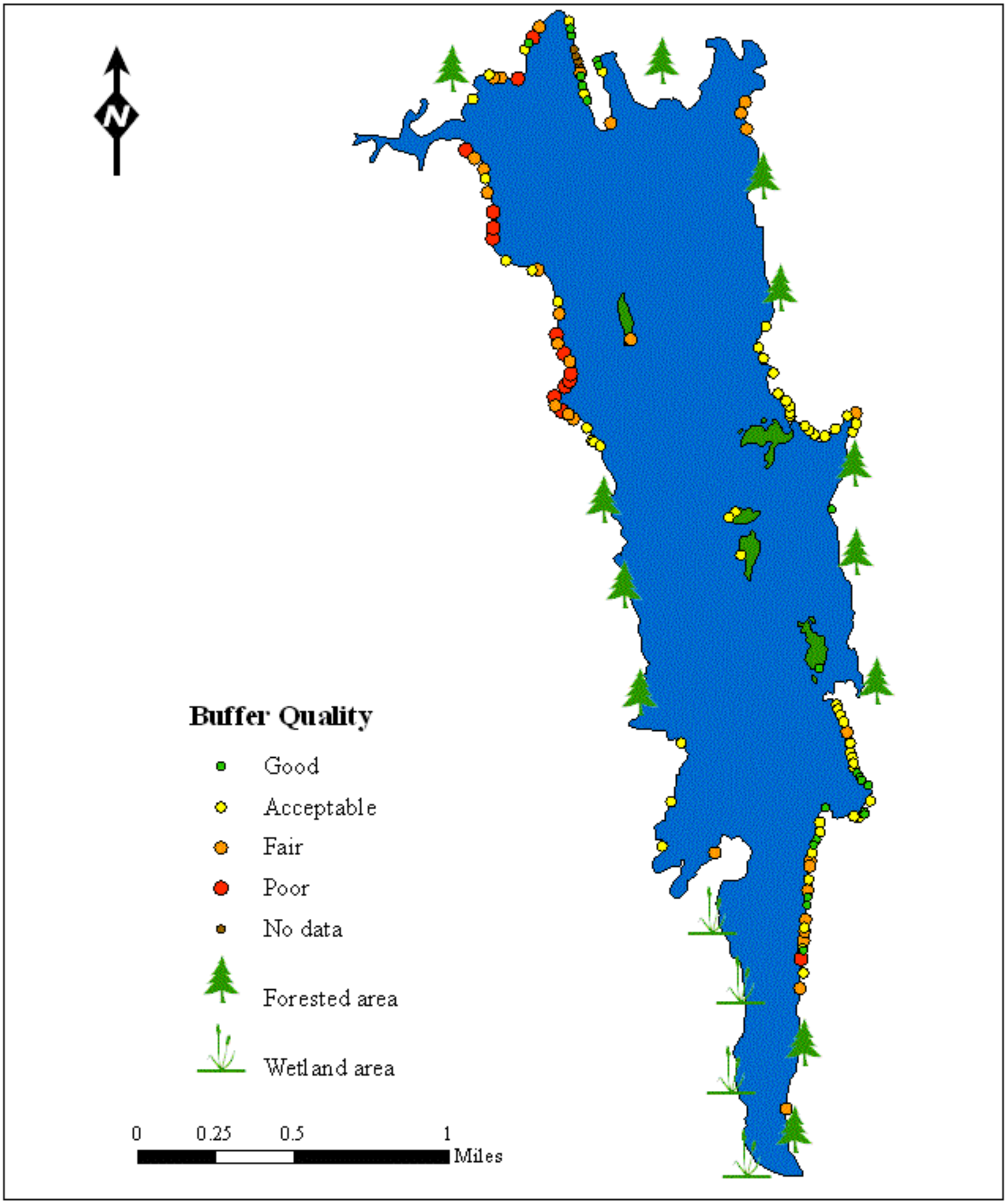

Figure 17. The location and quality of buffers for individual homes on the Long Pond South shoreline along with the natural vegetation of unpopulated areas. Buffer effectiveness was assessed by CEAT based on the 24-September-2007 shoreline survey (see Appendix H).

Like holding tanks, septic tanks must be pumped periodically to ensure proper functioning. If solid waste accumulates in the septic tank, the effluent may not completely separate from the solids and scum before entering the leach field. If the septic system is not installed at the correct depth, setback adequately from the shoreline, or in the right soils, wastewater may percolate through the soil before the nutrients can be completely absorbed by the surrounding soil. This malfunction is called phosphorus treatment failure, and it is a threat to water quality especially from systems along the shoreline where soil is typically thin and vegetation is limited by development (O'Hara no date). Unlike a complete septic system failure, phosphorus treatment failure shows no warning signs as nutrient contaminated water leaches into bodies of water; a malfunctioning septic system often goes undetected and untreated causing pollution of local lakes, ponds, and streams (O'Hara no date).

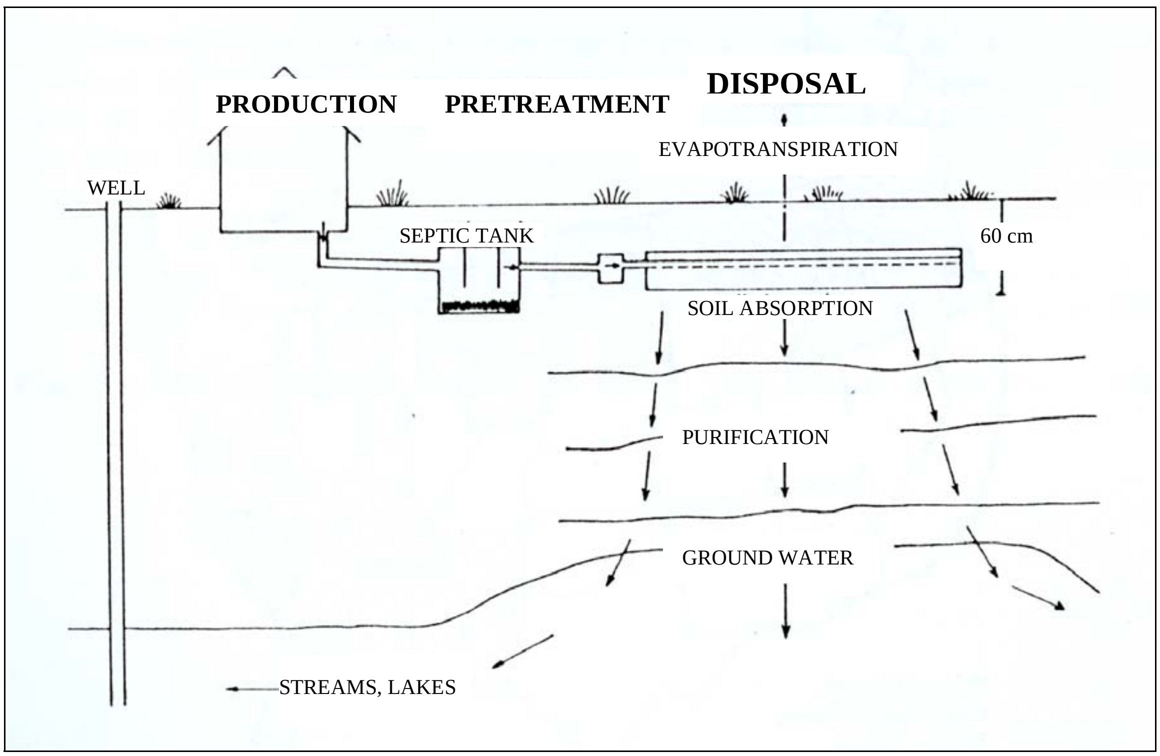

Figure 18. An illustration of effluent treatment through a standard septic system. Water is purified in the soil by physical and biological processes before it leaches into the ground water and surface water resources (adapted from Canter and Knox 1985).

To address the risk of malfunctioning septic systems to groundwater and surface water resources, the State of Maine passed a septic regulation policy in 1974 (MDEH 2003). The current mandates stipulate that septic systems may only be installed after a site evaluation. New systems cannot be placed within 100 ft of the high water mark or within 300 ft of a neighboring well (MDEH 2003). Despite these state regulations, many old properties in the Long Pond South watershed may still use grandfathered septic systems that were installed without expert guidance and may not be functioning properly. These old systems are likely to contribute to the phosphorus loading in the lake to a greater degree, especially those along the shoreline.

<u>Methods</u>

To examine the impact of wastewater disposal systems on Long Pond South, CEAT conducted house counts throughout the watershed and interviewed the Code Enforcement Officers from Mount Vernon, Rome, and Belgrade. Shoreline houses were counted from the water during the buffer strip survey (see Appendix H). Any house within 250 ft of the shore was listed as a shoreline property, which received special consideration when septic system impact was examined. Offshore houses were counted along the developed roads within the boundaries of the watershed during the road survey (see Appendix F). The Code Enforcement Officers of the three watershed towns were interviewed about the overall age and condition of septic systems within the watershed, and they were asked for their projections for development in the area over the next three decades. Additional data were collected from the Comprehensive Plan of Land Use Ordinance from the watershed towns.

<u>Results and Discussion</u>

The shoreline of Long Pond South has experienced less development than the North Basin shoreline. CEAT counted a total of 365 houses in the watershed, 121 of which are on the shoreline with an additional 5 houses on the islands. Along 11.3 miles of buildable shoreline (excluding wetland habitat) the housing density is 10.7 houses per shoreline mile. This value is relatively low as compared to the shoreline housing density of the North Basin at 17.5 houses per shoreline mile (CEAT 2007). This low density of shoreline development suggests a low contribution to external phosphorus loading from subsurface wastewater disposal. While a large amount of undeveloped land may still experience future construction, many of these lots are not suitable for development without mitigation due to drainage and soil problems or because of their proximity to wetlands and other protected natural resource areas (Najpauer, pers. comm.). In addition to the limits of buildable land, the current downturn of the housing market has also slowed the rate of development. No new roads or subdivisions are in the planning phases, and the total number of new single-family houses constructed in all three towns has decreased from 75 in 2002 to 60 in 2006 (Figure 19). Further watershed development is expected to occur only in existing subdivisions that have already been planned and partitioned (Najpauer, pers. comm.). Several of these areas in Rome and along the shoreline in Belgrade are already in the construction phase.

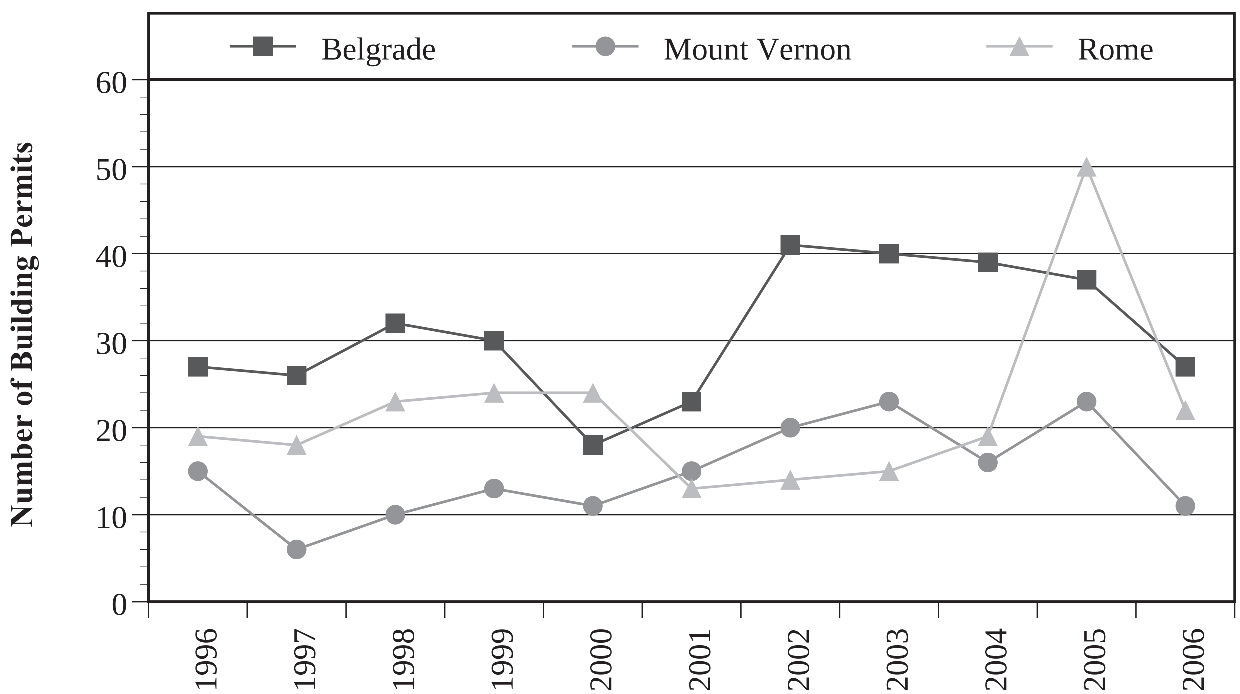

Figure 19. The number of building permits granted for new single-family house construction from 1996 to 2006 in the Towns of Belgrade, Mount Vernon, and Rome (City-Data.com 2007).

Many houses along the Long Pond South shoreline are built for seasonal use only which means that their septic systems are used only for approximately three months out of the year. Seasonal homes make up one-third of the houses in the entire town of Mount Vernon and one-half of the houses in the town of Belgrade (KVCOG 2007). The Long Pond South watershed has seen little conversion of houses from seasonal use to permanent use. Many seasonal residents, however, have lengthened their summer season or added bedrooms to their houses (Najpauer, pers. comm.). The summer season, which has historically been from Memorial Day to Labor Day, may gradually lengthen as more and more retirees move to the area for half the year. The summer season also draws more people to the area, as the average number of people per household increases from 2.6 year round to 3.8 in the summer (Najpauer, pers. comm.). Although this seasonal increase in the intensity of use will result in greater phosphorus loading, it may also lead to the replacement of old or damaged systems.

Septic systems are usually checked when properties are sold or updated for a greater intensity of use either under the requirements of a permit or because of the concern of the homeowner. As a result of these changes, individual property owners have replaced many of the grandfathered systems over the years (Najpauer, pers. comm.; Marble, pers. comm.). The Code Enforcement Officers of the three watershed towns have different estimates for the number of grandfathered septic systems, they agree that they rarely hear complaints about septic system malfunction (Najpauer, pers. comm.; Marble, pers. comm.; Fuller, pers. comm.). Even though septic systems may seem to be working properly, phosphorus-laden water can leach into the surface and ground water without warning (O'Hara no date). The water quality of Long Pond South may still be affected by phosphorus inputs from septic systems despite the lack of homeowner complaints.

The recent decline in construction will not last forever. Historical trends show that the Belgrade Lakes Region is a growing area, as demonstrated by the doubling of Mount Vernon's population in the past two decades (KVCOG 2007). Local tax maps indicate that roughly 50 lots along the shoreline, and many more within the watershed, may still be developed in the future. The Long Pond South watershed will undoubtedly see the construction of many new houses over the next few decades, even if that means the expansion of current subdivisions. Despite the 1974 regulations that govern septic system installation, the likely increase in septic systems that accompany population growth is likely to negatively affect the water quality of Long Pond South.

The towns of the Long Pond South watershed are prepared to manage population growth and future development by making clear subdivision provisions in their Land Use Ordinances. Subdivisions may only be built on soils that are adequate for wastewater disposal with proper consideration given to the effect of slope on effluent (Town of Belgrade 1995, Town of Mount Vernon 2004). Subdivisions must also provide for adequate waste disposal, and they may not adversely affect the natural beauty of the area. Concerned residents also play a significant role in managing development, because they wish to maintain the qualities and resources of the area that attracted them to it in the first place (Town of Belgrade 1998). For example, residents have managed to prevent development by refusing to sell the land needed to widen roads for year-round access (Najpauer, pers. comm.). Additionally residents who oppose further development have voting power to elect town officials, giving them a voice in major town decisions pertaining to development and town policies. The ability of residents to stave off long-term development, however, is uncertain, and town provisions are always subject to interpretation.

The Long Pond South watershed is experiencing several trends that may influence the water quality of the lake. While development has recently slowed and many old septic systems have been replaced, the intensity of use of summer properties has been gradually increasing over the years. These opposing trends have managed to control the impact of septic systems on the water quality of Long Pond South recently. The increasing intensity of use of summer properties, however, will definitely continue into in the future, and the fluctuating local real estate market is likely to improve over the next several years. Proper management and the influence of residents are essential for minimizing the negative impacts of likely long-term development. With the population projections for the three towns predicting additional watershed construction over the next thirty years, all three towns must be prudent and cooperative in their management strategies to prevent degradation of Long Pond South.

Septic Suitability Model

Introduction

The type of soil in the septic leach field determines the level of treatment of effluent. Soil can effectively filter microorganisms and absorb nutrients if the effluent leaches slowly through the soil for an adequate time and distance. Porous soils with a high percentage of sand will allow the effluent to leach through too quickly before the contaminants are completely removed. Soils can also be too fine and dense, nearly impermeable to effluent, causing it to run off into water resources before being treated (Canter and Knox 1985). Percolation tests evaluate the soil permeability at a proposed septic site. Special concern should also be given to soil depth. If the underlying bedrock is too high the soil may not be deep enough to treat the effluent, and the effluent will run off into ground and surface water resources before the contaminants are completely removed. Likewise a septic system built over a high water table could contaminate ground water when the water table rises into the leach field in the spring or during severe weather (see Background: Subsurface Wastewater Disposal System).

The slope of the site helps to control the speed at which effluent moves through the leach field. If it is too steep, water will move too quickly to be properly treated and it can cause significant erosion. As a rule of thumb the slope of a septic site should not exceed 20 percent (Canter and Knox 1985).

CEAT used slope and soil information to compile a septic suitability model. This model illustrates the areas within the Long Pond South watershed that have the most suitable land for septic system installation before remediation techniques.

Methods

The soil type map for the Long Pond South watershed was obtained from the Maine Office of GIS website (Data Catalog 2007). The resolution of this map is 10 x 10 meter and it includes 28 different soil types (Figure 20). The Togus soil category includes Vassalboro soil and the Woodbridge soil category includes Winooski soil. The soils were grouped as described by the Maine Office of GIS because they are very similar. The Kennebec County Soil and Water Conservation District has rated the suitability of different soil types for septic system construction using classifications of *not limited*, *somewhat limited*, and *very limited* (USDA 2006a). The septic suitability ratings considered permeability, mean depth to bedrock, erodibility, nutrient absorption capacity, and slope. To model septic suitability, CEAT rated soil septic suitability on a scale from 1 to 9, with 1 being *not limited*, 5 being *somewhat limited*, and 9 being *very limited*. All of the soil types in the Long Pond South watershed are rated as either *somewhat limited* or *very limited*; with the majority of soil types are rated as *very limited* (Data Catalog 2007).

Slope was obtained from a Digital Elevation Model (DEM) of the watershed from the Maine Office of GIS website (Data Catalog 2007). The DEM is a raster of 10 x 10 meter cells containing elevation data. The percent grade of the slope ranged from 0 to 114 percent, with 114 percent reflecting a cliff. The mean slope has an 8.2 percent grade. The percent grade of the slope was converted to a rating of 1 to 9: Very flat slopes are assigned a rating of 1 and very steep slopes are assigned a rating of 9. The ratings for soil type and slope were weighted equally and combined algebraically to generate the septic suitability model (see GIS: Introduction). Slope data was not available for the islands, so they were not included in this model.

Results and Discussion

The septic suitability model for the watershed of Long Pond South displays a gradient of septic suitabilities (Figure 21). In the septic suitability model, an area indicated to have a high septic suitability has a low rating, because a low rating indicates that an area is suitable for the installation of septic systems. The values for septic suitability in the Long Pond South watershed ranged from 3 to 8, on a scale form 1 to 9. It is important to note that the septic suitability model does not take mitigation into account. Although some houses are constructed on land that has a low septic suitability rating, homeowners may have taken steps to remediate the low septic suitability. When the septic suitability rating adjacent to the lake is low, and the land has already been developed, there is cause for concern. If a septic system adjacent to the lake was not working properly the excess nutrients could enter the lake. Most of the watershed is suitable for septic system construction despite the poor septic suitability of the soil because of the low percent grade of the slope. There are notable exceptions on the shoreline of Long Pond South that have been developed and require monitoring to ensure that the septic systems in those areas of low septic suitability are functioning properly. Those areas include the northwestern shore opposite the most northern island and on the southeastern shore slightly south of the most southern island (Figure 8).

Roads

Introduction

Roads within the Long Pond South watershed may pose serious threats to the health of the lake, because up to 85 percent of all erosion and sedimentation issues in watershed areas are caused by poorly constructed and maintained camp roads (KCSWCD 2000). Roads contribute to poor water quality by facilitating the flow of phosphorus and other nutrients into nearby bodies of water. Nutrients are absorbed by camp road surface materials like gravel and sand. Road use and runoff water erode surface materials, and as these particles are deposited downhill into waterbodies, the nutrients are carried with them. Sedimentation and corresponding phosphorus input often result in algal blooms, which can lead to a decline in nearby property values (KCSWCD 2000). Roads within the Long Pond South watershed were assessed by CEAT to determine their contribution to lake pollution.

Roads within the watershed fall into three categories: state roads, town roads, and camp roads. State roads and town roads are used more frequently than camp roads, but are less likely to erode because they are paved and regularly maintained by local and state governments.

Camp roads may be used on a seasonal or year-round basis, and homeowners are generally responsible for their maintenance. As a result, they often experience increased degradation and erosion compared to other road types because residents are less willing to pay for repairs. Additionally, sand and gravel, the surface materials for camp roads, erode more easily than pavement, further contributing to lake pollution.

Erosion control measures aim to slow down the movement of runoff water and to reduce the area covered by runoff (KCSWCD 2000). Examples of drainage structures designed to reduce phosphorus input are explained in detail in the Background: Roads section of the report. Proper drainage structures include ditches lined with vegetation and riprap, culverts that are properly sized and installed (Figure 22), and turnouts and channels that return water to natural pooling areas. Road construction techniques that encourage the flow of water off road surfaces include crowning and grading. An ideal road is graded to direct water from the road surface to nearby ditches, preventing runoff from pooling on the road and minimizing its contact with erodible surface materials. Rubber bars can also be installed across roads to channel water to nearby ditches (KCSWCD 2000).

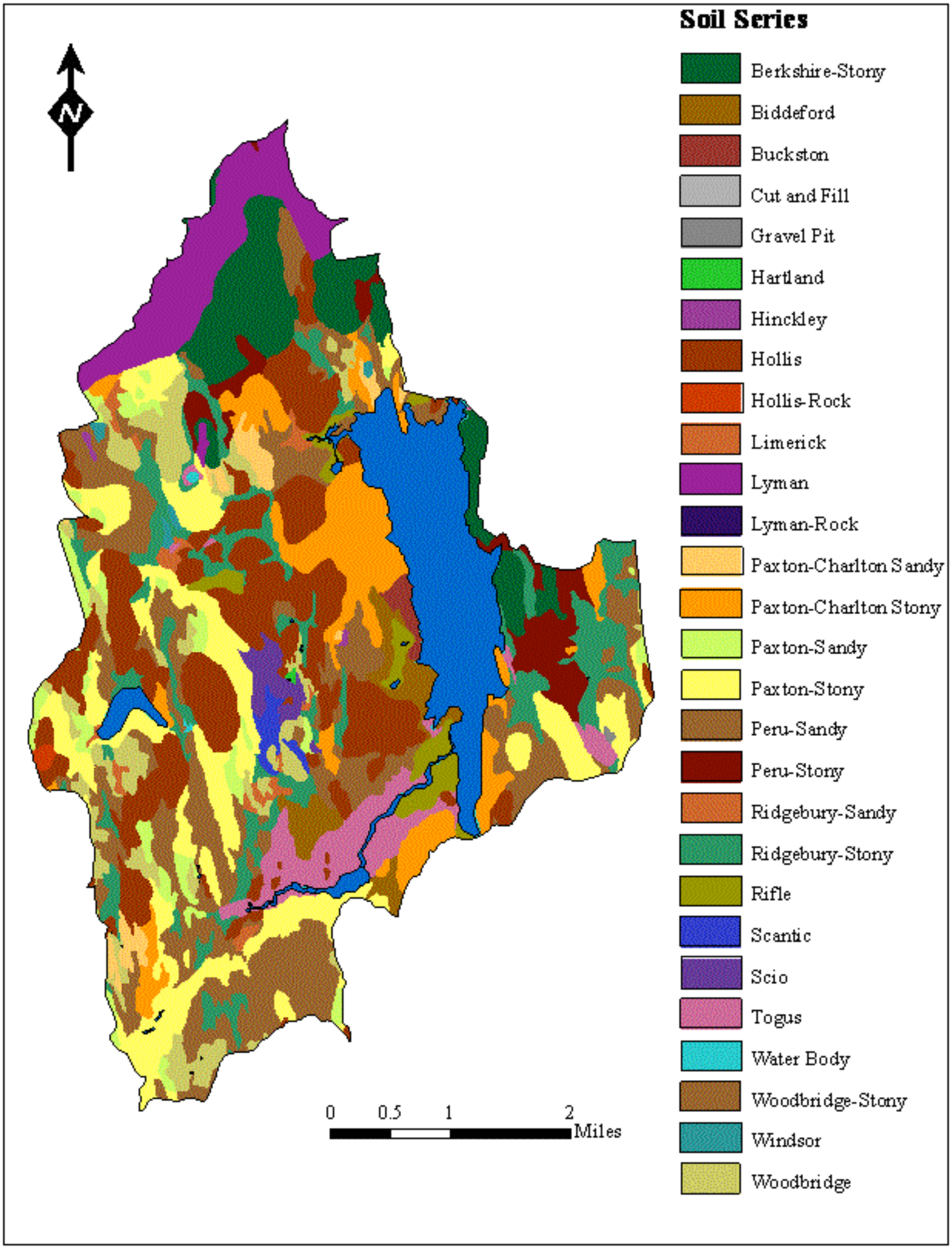

Figure 20. The types of soil found within the Long Pond South watershed. Data were obtained from the Maine Office of GIS (Data Catalog 2007).

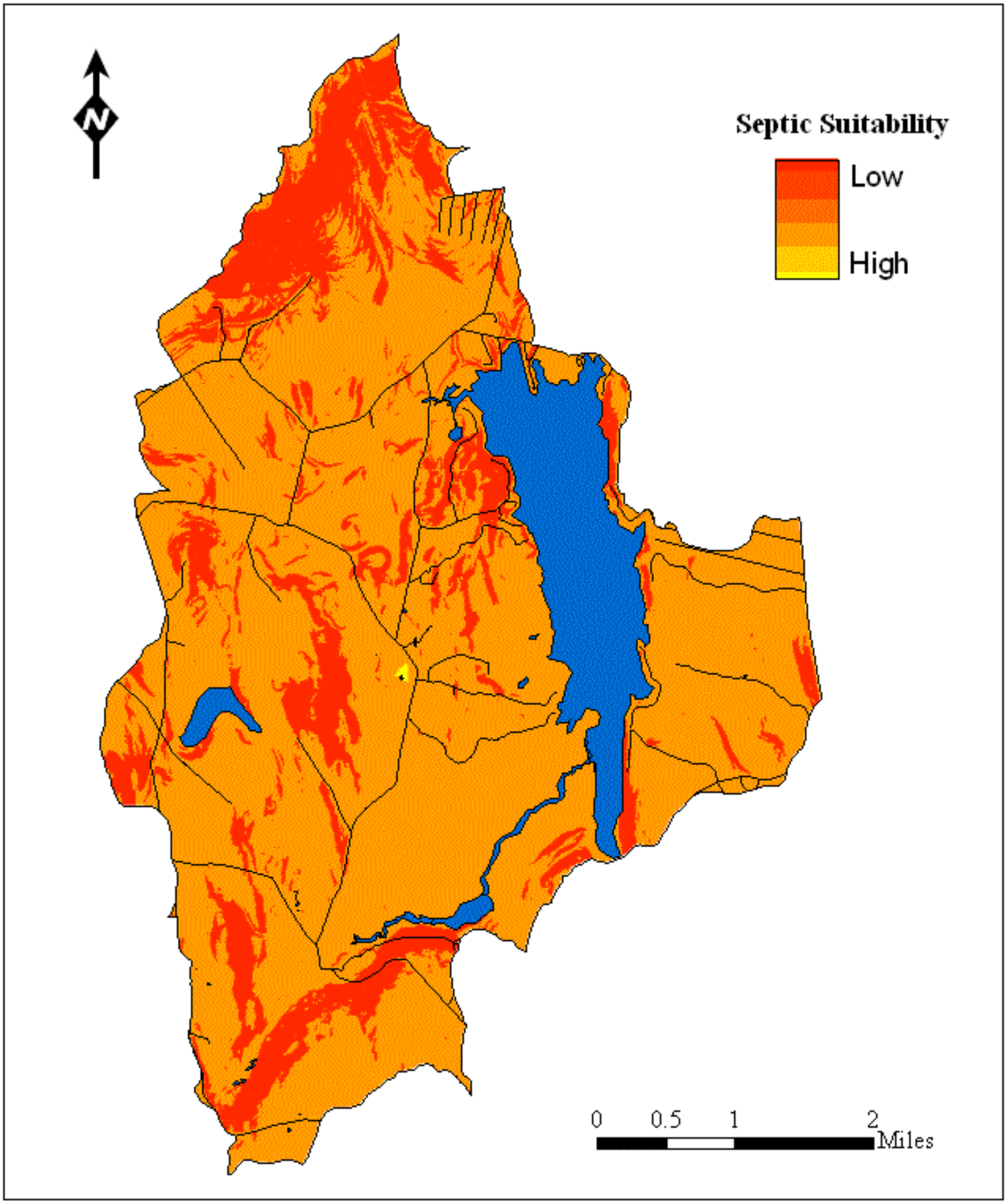

Figure 21. Septic Suitability Model. The relative suitability for septic systems in the Long Pond South watershed based on soil characteristics and slope. Darker colors indicate areas that are not suitable for septic system construction. Lighter colors indicate areas that are suitable for septic system construction.

Future development in the Long Pond South watershed could increase the number of camp roads. If not properly constructed and maintained, these new roads will also contribute to declining lake water quality. Five Maine laws currently regulate camp road construction in an effort to protect the environment. The Erosion and Sediment Control Law requires that erosion control devices be installed and maintained before and during the process of any construction that disturbs soil, and requires that existing sites eroding into nearby lakes, streams, rivers or wetlands are stabilized by 1-July-10. The Natural Resources Protection Act regulates any soil-disturbing activities within 100 ft of the shoreline by requiring permits. Similarly, the Mandatory Shoreline Zoning Act regulates development within 250 ft of the shoreline through zoning requirements, and individual towns may have additional ordinances further restricting development in this area. The construction of new camp roads may also be regulated by the Stormwater Management Law or the Site Location of Development Law depending on the size of the project (KCSWCD 2000).

Methods

Roads within the Long Pong South watershed were assessed to determine individual road contributions to lake pollution. The watershed was divided into six general areas, and CEAT teams evaluated the roads in each area on 24-September-07. Some reassessments and additional survey work were done on 1-October-07, 4-October-07, and 11-October-07. GPS points were taken at the start and end of all roads in the watershed, as well as at any potential "problem spots," such as areas with poorly-maintained ditches or places where streams crossed roads. For problem or potential problem sites, a brief description of the issue and possible remediation strategies were also noted by CEAT teams. Surveyors also counted the number of homes they found and classified them being as shoreline or non-shoreline, year-round or seasonal. Road evaluation forms were more detailed for non-paved roads than paved roads because paved surfaces generally make smaller, more predictable contributions to the flow of phosphorus into nearby water sources (see Background: Roads). These roads were not assessed for their quality; CEAT teams simply noted their width and length in addition to potential problem areas (particularly those located near streams). For camp roads, evaluation forms requested information about road slope, surface materials, road age and use, ditches, crowning,

Figure 22. Good (top) and bad (bottom) culverts. The top culvert is large enough to allow proper water flow. The bottom culvert exhibits blockage by debris and a cluttered path for water flow. Photo credit: LMNO Engineering 2007.

and overall condition, as well as width and length and problem spots. Information specific to the camp road form was scored and assessed (see Appendix F).

Surveyors answered each scored question on the evaluation form by circling an appropriate response from a set of given options. Each response was assigned a corresponding number, and numbers were totaled for each road to calculate an overall score (see Appendix F). Lower numbers were assigned to road characteristics more likely to contribute to phosphorus loading (such as steep slopes), and higher numbers were assigned to conditions or road structures less threatening to lake health (such as clear, U-shaped ditches).

Crown height was scored differently; height (in inches) was divided by road width, and this ratio was scored and assessed. Because height was quantified by a range rather than a specific number, the mean number of the selected inch range (one for the zero to two inch range, three for the two to four inch range) was divided by the road width. A good ratio of crown to road width falls between 0.25 and 0.38. Ratios occurring above this range will also facilitate the movement of runoff to roadside ditches, but roads with higher crown-to-road ratios are more difficult to use. Ratios falling below this range suggest that there is not enough of a crown to sufficiently drain runoff. Because an adequate crown plays a key role in preventing erosion from runoff, roads with crown-to-width ratios within or above the ideal range were assigned two points, and those roads with lower ratios received zero points.

Each total road score was divided by 29, which was the maximum number of points that could have been achieved. The resulting number for each road was a percentage of the total number of points that could have been earned. These percentages were grouped into quartiles: 0-25 percent, 26-50 percent, 51-75 percent, and 76-100 percent. Roads with lower overall scores contributed more phosphorus to the lake, and those with higher scores posed a lower threat to water quality. Roads receiving scores of 0-25 percent were considered to be in poor condition (Figure 23). Scores of 26-50 percent indicated fair condition, scores of 51-75 percent indicated acceptable condition, and scores above 76 percent indicated that a road was in good condition. The road survey results were based upon the judgment of surveyors, but each evaluation form was filled out by at least two CEAT members to limit discrepancies in the study. The data collected from the evaluations enabled CEAT to identify key problem areas in the watershed, and determine the total contribution roads make to the phosphorus budget of the watershed (see Phosphorus Budget).

Figure 23. Example of a poor quality road within the Long Pond South watershed. Photo shows a road in need of ditches to divert runoff. As runoff is trapped by the berm on the left, the water erodes channels and causes debris to build-up.

Results and Discussion

After surveying, CEAT calculated 52 roads in the Long Pond South watershed; two of these were state roads, eight were town roads, and 42 were camp roads**.** A total of 90.3 acres of area was covered by roads, 9.1 acres of this being state roads, 42.7 acres being town roads, and 38.4 acres being camp roads. Seven camp roads were classified as good, 15 were considered acceptable, seven were fair, and another 13 roads were considered poor (Figure 24).

State and town roads made up the majority of the total road area in the watershed (57.4 percent). While CEAT did not assess paved roads, they generally contribute less phosphorus to nearby water sources than camp roads (see Background: Roads). Camp roads make up the remaining road area, and just over half of these roads received good or acceptable classifications. These results suggest that a majority of the roads in the Long Pond South watershed do not pose a serious threat to lake health. Additionally, some of the roads considered "good" in the southwest part of the lakeshore were beneficiaries of maintenance projects carried out recently by a Conservation Corps team (Cole, pers. comm.). This demonstrates some degree of interest and commitment among local residents to improve declining road conditions.

Large portion of roads receiving fair or poor classifications are probable contributors to phosphorus in the lake, and will continue to be problematic in the future, if they are not repaired and maintained. Forty percent of the road area in the watershed is made up of camp roads, which could pose future problems for the lake because they generally are not regularly maintained. Any additional degradation to camp roads in the watershed, including those rated in good or acceptable condition now, could increase the flow of phosphorus into Long Pond.

The 2006 road survey conducted in the Long Pond North watershed indicated that the majority of camp roads in this area (53.7 percent) were considered good, 20.8 percent of roads were in acceptable condition, 20.3 percent were in fair condition, and only 5.2 percent were in poor condition (CEAT 2007). Based on these results, a larger proportion of camp roads in Long Pond South are in poor condition than in Long Pond North. This could be explained by the fact that there is more development in the North watershed than in the South watershed. Roads in the North basin are used more regularly because this area has a greater population density. Having more local residents who depend on camp roads could create both increased resources for and overall interest in regular road maintenance. Roads in the South basin may have fewer users, perhaps resulting in a reduced need and ability to maintain roads.

Some of the roads in the worst condition in Long Pond South watershed were those in areas currently being developed, such as the Wild Flower Estates. These areas have few to no houses, and the lack of residents decreases the likelihood that these roads will be properly maintained. This fact could also mean that as more houses are built in this area and residents move in, the condition of roads will improve.

Major differences between road surveys taken in the North and South watersheds could also be attributed to the fact that roads were classified differently in Long Pond North. The overall road quality as perceived by surveyors was the only factor considered in judging the condition of roads. Classification of roads in Long Pond South was based upon a more thorough, informed assessment, which could explain why fewer roads fulfilled the criteria to be considered "good." Differences in methodology may limit comparisons between roads in Long Pond North and roads in Long Pond South (Figure 25).

Problems from Road Survey

Murdock Place in Belgrade, which has a number of lots partitioned for construction, had more problems than any other road in the watershed. This information is consistent with the observation that roads in poor condition were often found in places undergoing development. Pinpointing problem areas like Murdock Place and implementing maintenance strategies to alleviate road concerns could reduce phosphorus loading in the watershed (see Appendix H).

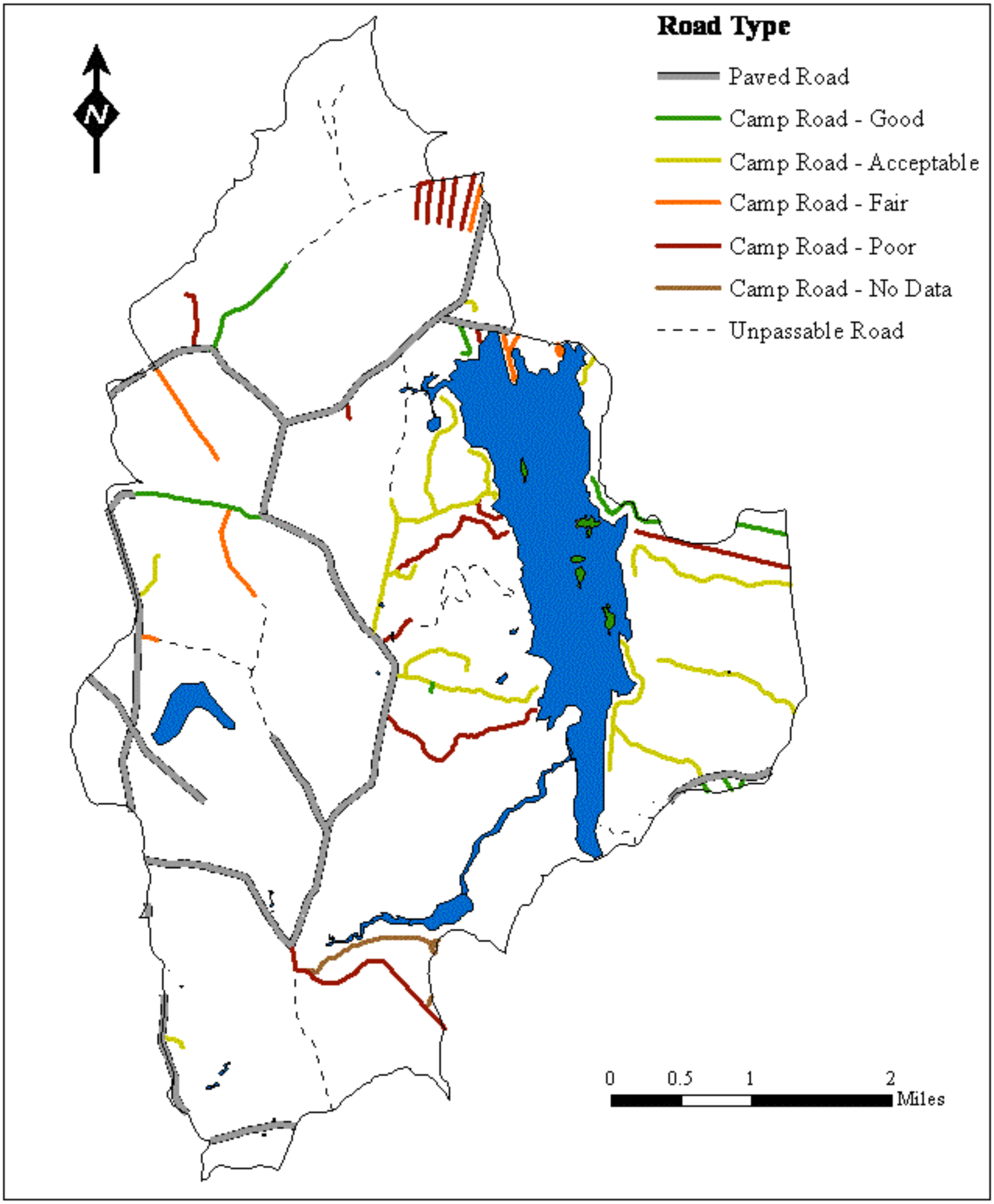

Figure 24. Road Type Map. The different road types within the Long Pond South Watershed. Camp roads are rated according to their condition, based on the amount of erosion and the condition of the road crown, ditches, culverts and runoff diversions (see Watershed Development Patterns: Roads).

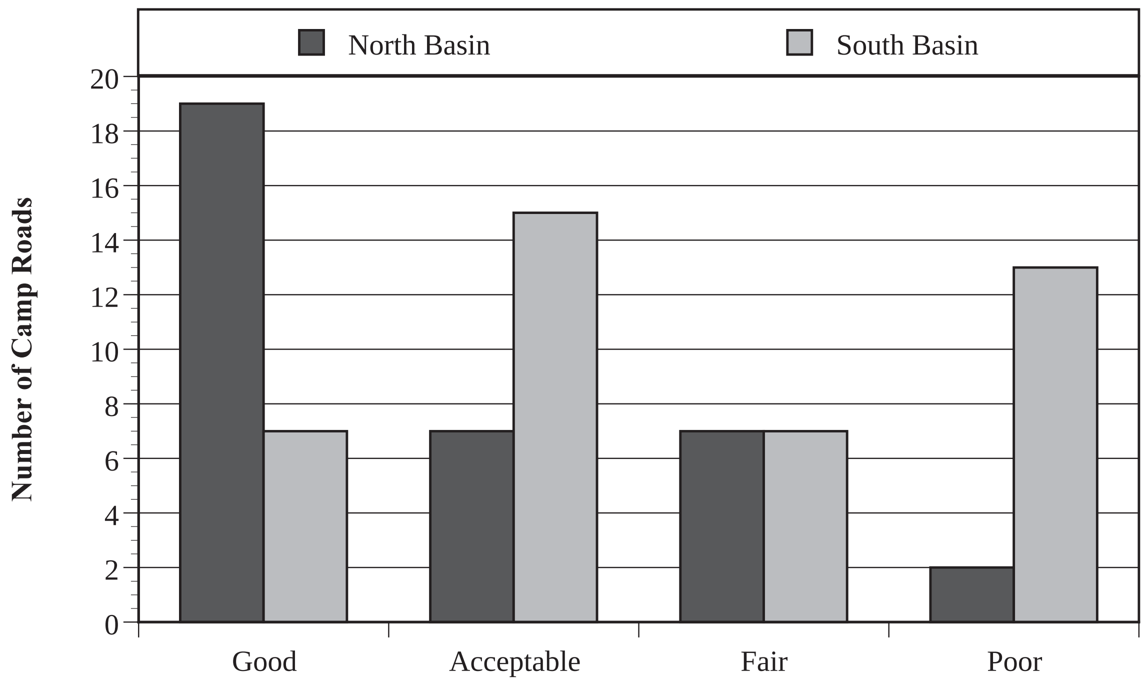

Figure 25. A comparison of camp road quality in the North and South Basins of the Long Pond Watershed. Data displayed are number of camp roads.

Erosion Potential Model

Introduction

Erosion is the transportation of soil and organic material away from its original location. The soil can then be deposited in the form of sediment in other locations, including within water bodies. Sediment naturally contains large amounts of nutrients and can also pick up excess nutrients from the application of fertilizers. Nutrients are carried with the eroded soil and add to the nutrient load of a lake (see Background: Nutrient Loading). Extra nutrients can cause algal blooms that are detrimental to lake water quality and chemicals from fertilizers and pesticides can also be harmful to wildlife. Different areas, such as recently tilled agricultural land or construction sites, can be more susceptible to erosion than other areas that are less exposed to weathering. The three main factors that contribute to risk of erosion are soil type, slope, and land use. The erosion potential of the Long Pond South watershed was modeled by examining the influence of these factors.

Soil type is the most important factor affecting erosion. The erodibility of soil is defined as the resistance of the soil to detachment and transportation. Soil properties that can affect this include texture, infiltration capacity, organic content, and aggregate stability (Morgan 2005). Large particles are more resistant to transportation because more energy is required to move them. Conversely, very fine particles are resistant because they are very cohesive to each other. The least resistant soil types are silts or sands, which are not as cohesive as clays, for instance, but are small enough to be easily transported. Loose soils that are more easily infiltrated by water are broken up quickly and easily eroded while more stable soils are more resistant to breaking down. The effect of organic material on soil depends on the type of material. Manure, for example, increases soil stability by "gluing" the particles together, while mulch or peat decreases aggregate strength, making it more erodible (Morgan 2005).

Slope has a strong affect on the rate of erosion. Steeper slopes allow water to gain more speed and erosive power because the water experiences greater gravitational pull. The high-energy water causes soils to be eroded quicker, and larger particles can be transported. In contrast, water moves more slowly over flatter ground and so has less energy to transport sediment.

The type of land-use also plays a part in erosion. Activities, such as construction or farming, that break up the ground, exposing soil to the elements and decreasing its stability, dramatically increase the rate of erosion. Forests, on the other hand, increase soil stability with tree and plant roots, and the vegetation canopy helps to protect the soil from the effects of water and wind. Vegetated areas have much lower erosion rates as a result.

The intensity and amount of rainfall can have a significant effect on erosion both because it contributes to the overall amount of runoff and because the impact of raindrops can effectively disturb the soil surface. However, the amount of rainfall is assumed to be consistent throughout the watershed and so was not included within the model. In general, areas with less rainfall would have less erosion.

Methods

The erosion potential model was created by combining soil, slope and land-use layers in ArcGIS® 9.2, according to the respective erosion potential ratings of the layers (see GIS: Introduction).

Soils

The soil layer (Figure 20) for the Long Pond South watershed was downloaded from the Maine Office of GIS (Data Catalog 2007). Each soil type has a K-factor value, which indicates the susceptibility of the soil to erosion based on the amount of silt, sand, and organic material in the soil structure (NRCS 2006). K-factor values range from 0 to 0.69, with the higher rating indicating greater susceptibility to erosion. None of the Long Pond South soils were highly erodible, with the range of K-factor values extending from 0 to 0.49 (NRCS 2006). The erosion potential ratings for the soil types were calculated by converting the K-factor values (k) obtained from the National Resources Conservation Service (NRCS) with the formula:

$$\text{Erosion potential ratings} = 11.6k + 1$$

The formula converts the K-factor values into a standard rating system that ranges from 1 to 9, and is used for all the layers involved in the erosion potential model. When converted to erosion potential ratings, the range of the soil types spanned from 1 to 6.68. The calculated erosion potential ratings were added to the attributes table of the soil layer and converted to raster form for use in the model.

Slope

The slope data for the watershed were downloaded from the Maine Office of GIS in the form of a Digital Elevation Model (DEM) in a 10x10 m grid format (Data Catalog 2007). Slope data for the islands within Long Pond South was not available, so the islands were not included in the model. Each square of the grid was tied to a specific elevation value according to the elevation of the corresponding area in the watershed. The elevation values were converted using Spatial Analyst™ software in ArcGIS® into slope values. The range of slope values in Long Pond South was from 0 to 62 percent. The slope values were then divided into 9 equal parts, with each section being equal to 1/9 of the total slope range within the watershed. The slope value sections were then assigned erosion potential ratings, with a rating of 1 indicating flat ground and a rating of 9 indicating the steepest possible slope within the watershed.

Land-Use

The land-use types for the Long Pond South watershed were obtained from the CEAT Land-Use team (see Land-Use: Methods). Each of the land-use types was given an erosion potential rating (Table 7). To be consistent with the Long Pond North models and to make comparisons easier, the same ratings for land-use types were used in this study (CEAT 2007). Ratings were determined according to the potential soil disturbance of a particular land-use type. The more the soil is disturbed, the greater the opportunity for erosion.

Table 7. Erosion potential ratings assigned to the land-use types in the Long Pond South watershed, with 0 being low and 9 being high potential erosion. Values were used to convert the land-use map into raster format so it could be included in the GIS Erosion Potential Model.

Land Use Type	Erosion Potential Rating
Wetland	0
Mature Forest	1
Commercial	2
Regenerating Land	3
Park	6
Cleared Land	7
Agriculture	8
Residential	9

Wetlands were given a rating of 0. The abundance of plants species in healthy wetlands slows water flow and captures sediment. Wetlands are often sediment sinks, or areas where sediment is deposited, not eroded, because the dense vegetation traps it (Morgan 2005).

Mature forest, which includes coniferous, deciduous, and mixed forest habitat types, was rated as 1 for erosion potential. The vegetation canopy protects the soil from the impact of raindrops, which can dislodge soil particles, and the complex root systems help hold the soil together.

Commercial land is often paved and is not easily eroded, but sediment on top of the pavement is easily carried away with runoff, which is of more concern for phosphorus modeling. It is important to differentiate that the erosion potential model is interested in the amount of disturbance contributing to erosion, not the amount of phosphorus from runoff. Commercial land has impervious surfaces which are not easily disturbed so was given a low rating of 2.

Regenerating land, made up of regenerating and reverting forest, was rated as 3. This type of land has enough vegetation to mitigate most weathering, but lacks the dense vegetation and well-developed root system of mature forests.

Parks often have exposed soil paths and open areas; these areas were assigned a rating of 6.

Cleared land was rated as 7 since the land generally has high erosion potential due to reduced soil stability from recent disturbances.

Agricultural land, which includes cropland, pasture and tree farms, was assigned a rating of 8. Pasture is often disturbed from the grazing and trampling of livestock. Cropland and tree farms require maintenance, which also disturbs the soil. The land is often exposed with only limited vegetation to protect from weathering.

Residential land was given the highest rating of 9, since residential areas are often cleared or maintained, with reduced vegetation. Dirt paths and driveways are exposed to weathering and can act as channels for runoff, also increasing potential erosion.

Weighted Overlay

The erosion potential ratings assigned to the soil, slope, and land-use layers of the watershed were combined using a weighted overlay. Soil type has the greatest effect on potential erosion (Morgan 2005) so it was weighted heavily at 40 percent, with slope and land-use each counting as 30 percent of the final model (Figure 26). The ratings were added in each 1 x 1 m grid cell of the model to get a high-resolution picture. The resulting map shows the erosion potential of the Long Pond South Watershed, with low erosion potential rated 1 and high erosion potential rated 6. The erosion potential rating scale was from 1 to 9, but none of the soil types were rated high enough for the watershed areas to reach a rating of 9 because the K-values of the soil types were too low (see Erosion Potential: Soils).

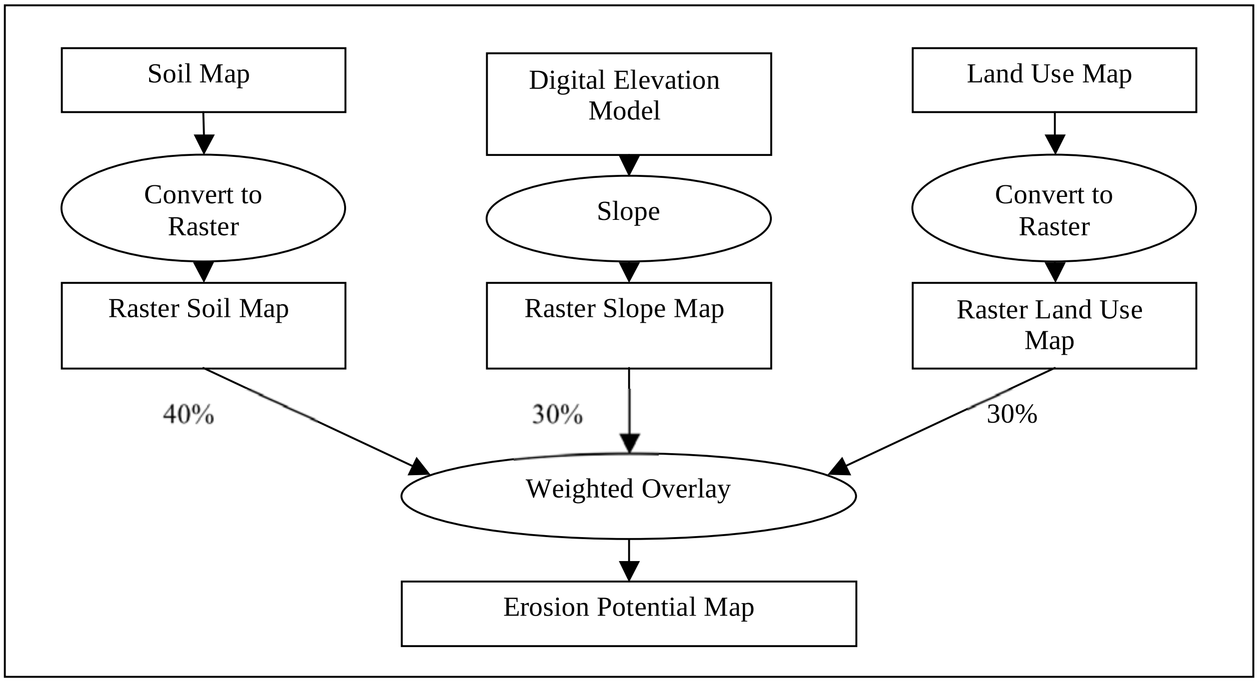

Figure 26. Components of the Erosion Potential Model and their relative weights. Soil (40%), Slope (30%) and Land-Use (30%) were all converted to raster format according to their erosion potential ratings and combined using a weighted overlay in ArcGIS® 9.2 to determine the erosion potential of the Long Pond South watershed.

Results and Discussion

The map (Figure 27) created from the erosion potential model represents the combined weighted erosion potential ratings of the soil, slope, and land-use in the Long Pond South watershed. Darker colors indicate areas of high potential erosion with lighter areas indicating low potential erosion. Most of the watershed displayed moderate erosion potential, though areas of wetland, like those around Ingham Pond, show almost no possibility of erosion. Very dark areas with high potential erosion are most likely locations used for agricultural or residential purposes. These areas could potentially have a large amount of sediment erosion that could impact the lake water quality. Areas with high erosion potential can still be developed, but they may need remediation or improvement to control erosion prior to development.

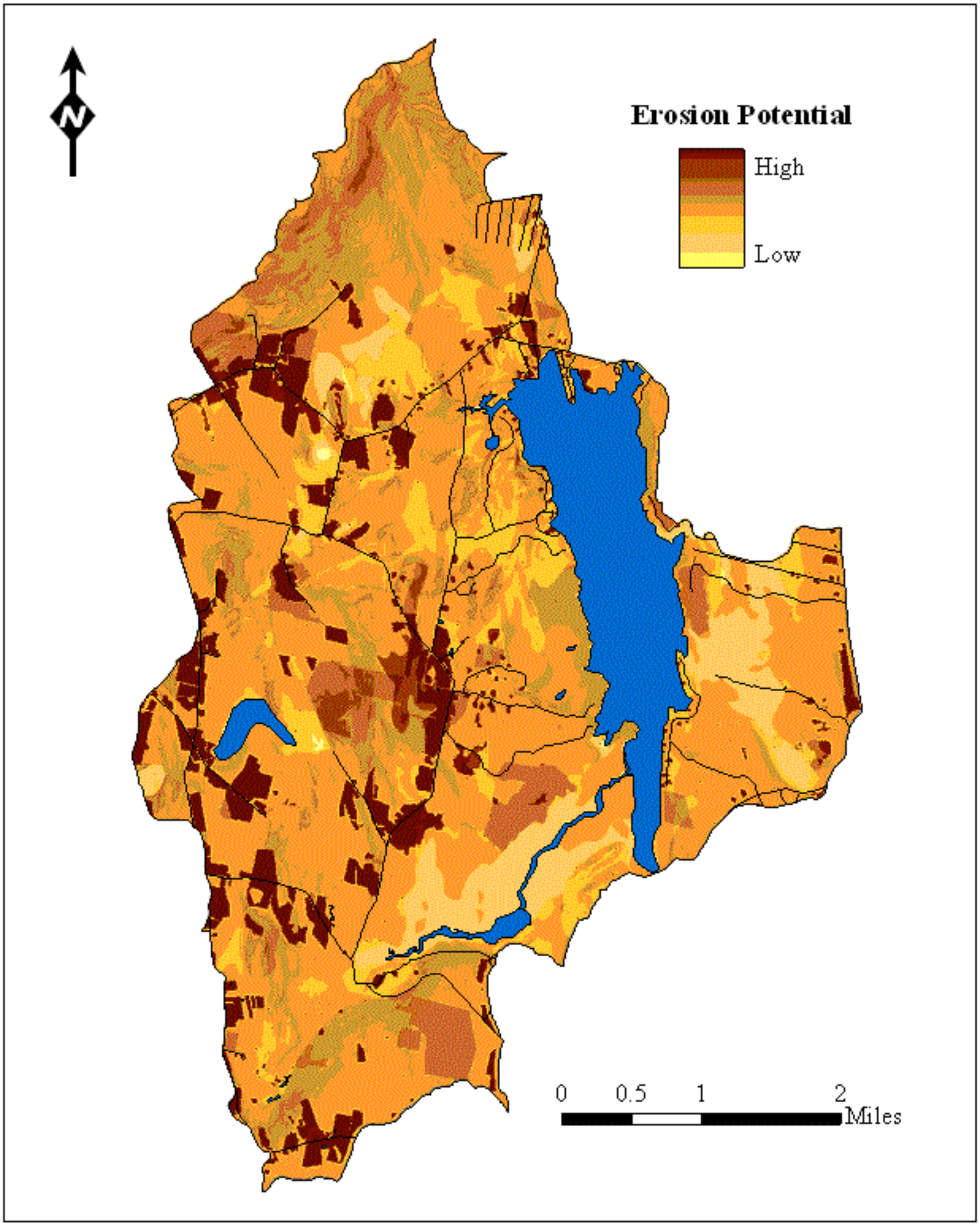

Figure 27. Erosion Potential Model. Areas of potential erosion within the Long Pond South watershed. Darker colors indicate areas of greater possible erosion. The model was calculated using weighted erosion potential ratings of soil (40%), land use (30%) and slope (30%).

Erosion Impact Model

Introduction

Different areas of erosion within a watershed result in variable impacts on the lake. For example, erosion that occurs very close to the lake affects the lake more heavily than erosion that occurs further away. This is because sediment traveling from further away has more chance for vegetation absorption or deposition before reaching the lake. Calculating the nutrient contribution of sediment to the lake must account for the distance from the lake. The Erosion Impact model does this by qualifying the Erosion Potential model according to the distance the point of erosion is from the lake or from streams that directly feed into the lake.

Methods

The Erosion Impact model combines the Erosion Potential model with lake and stream proximity layers in ArcGIS® 9.2 according to the erosion potential ratings of the layers (see GIS: Introduction).

Erosion Potential

The Erosion Potential model of the Long Pond South watershed indicates the areas at risk for high levels of erosion within the watershed (see Watershed Development Patterns: Erosion Potential). Erosion potential was rated on a scale of 1 to 6, with 6 indicating a high susceptibility of erosion. The Erosion Potential model was included in the Erosion Impact model without further alteration.

Proximity Zones

Two proximity zone layers were created to take into account the location of potential erosion. The first proximity layer indicates the distance from the lake. The watershed was divided into 14 zones, and each was assigned a rating according to a 9 point scale. The first zone was 200 ft from the lake shore and the others were 1000 ft intervals out from the first zone. The 200 ft shoreline zone was rated 9, since sediment eroded from that area would be the most likely to reach the lake and contribute nutrients (see Background: Nutrient Loading). The 1000 ft zones decreased in rating by 0.666 until the farthest zone from the shoreline, at the edge of the watershed, was rated 1.

The second proximity zone map rated the distance of erosion areas from streams that fed into Long Pond South. Areas within 200 ft on either side of a stream were rated as 8. Sediment entering the streams has a high likelihood of entering the lake so areas near streams were given a high erosion potential rating. However, there is still a chance the sediment will settle out or be captured by vegetation before reaching the lake, so the areas were not rating 9 like the shoreline proximity zone. All other areas in the watershed were rated as 0, since their locations were already accounted for by the lake proximity zone map. The model is concerned with predicting areas where erosion will result in sediment entering the lake, so the emphasis is on locations that abut water sources, like streams. Areas away from the water do not need to be rated more than once.

Both rated proximity maps were then converted into raster format.

Weighted Overlay

The Erosion Potential model was rated most heavily at 50 percent, since the erosion has to actually occur before it can affect the lake (Figure 28). Areas with high amounts of erosion will have a greater impact regardless of their location. However, even small amounts of erosion can have a large impact if it occurs right next to the shoreline, so the proximity to the lake was weighted as 40 percent. Stream proximity was weighted as 10 percent. Streams carry sediment to the lake as well, but there is more chance for the sediment to settle out or be trapped by vegetation, especially if the stream flows through one of the many wetlands in the Long Pond South watershed.

Results and Discussion

The Erosion Impact Map (Figure 29) displays the areas of erosion in the Long Pond South watershed that potentially have the greatest effect on the lake. Darker colors, like those around the shoreline, indicate areas where erosion will more likely result in sediment entering the lake, affecting water quality. Light colors mark areas with low erosion impact, as is seen in the upper portion of the watershed. These areas are mostly covered by forest. Residential and agricultural land have the greatest impact, as was seen with the Erosion Potential Model (Figure 27), though most of these areas do not directly abut the lake. Developed land has a high potential for erosion because it is often disturbed. Erosion from non-shoreline development can be carried into the lake by connected water bodies, such as Moose Pond. However, there is a strong chance the sediment will be captured by vegetation since the water travels a long distance through extensive wetlands before entering Long Pond South. Areas with high erosion impact should be maintained by planting vegetation and reducing disturbances to minimize the amount of sediment erosion.

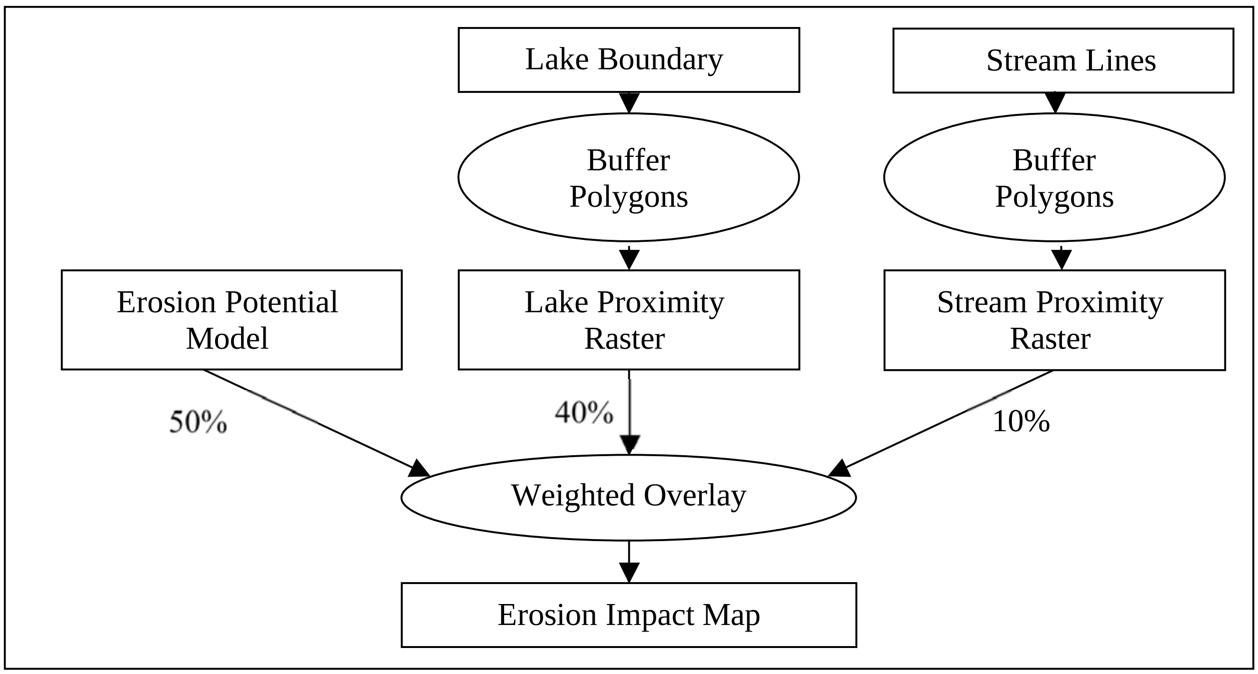

Figure 28. Components of the Erosion Impact Model and their relative weights. Lake and Stream Proximity Zone Maps were created by building buffer polygons around the lake boundary and stream lines. Each zone was assigned an erosion impact rating according to its distance from the water source and converted to raster format. The Proximity Zone Maps were combined with the Erosion Potential model using a weighted overlay in ArcGIS® 9.2 to determine the erosion impact of the Long Pond South watershed.

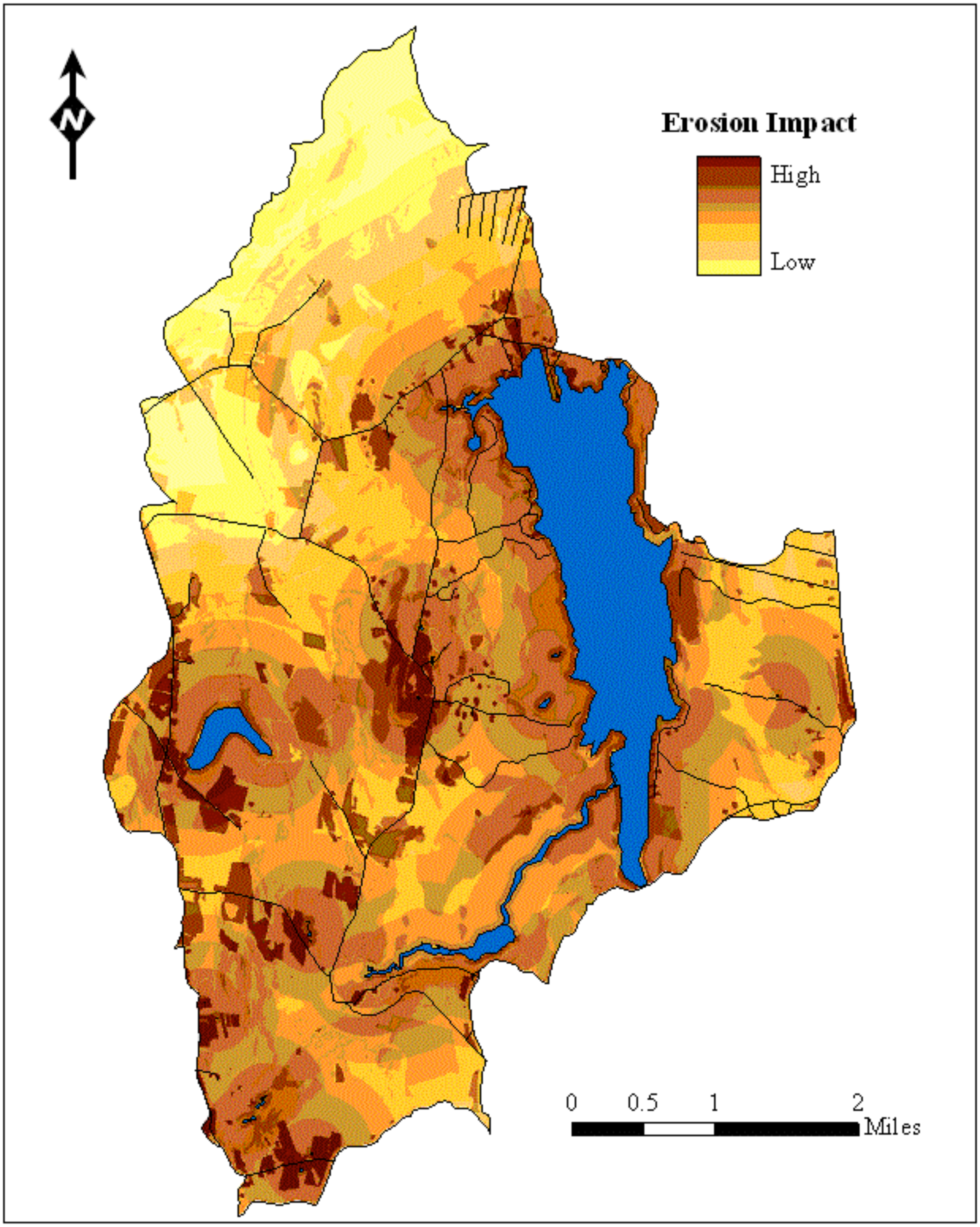

Figure 29. Erosion Impact Model. The impact of erosion in the Long Pond South watershed. Erosion impact was determined by ranking and weighing erosion potential (50%), proximity to Long Pond South (40%), and proximity to tributaries (10%). Darker colors indicate a greater impact of erosion.

WATER QUALITY

Water Quality Study Sites

Fourteen study sites were chosen for water quality testing on Long Pond South. Sites were carefully selected to either investigate the water quality of different sections of the lake, or to determine the potential phosphorus contribution of specific streams and tributaries to the lake. Four comprehensive sites were sampled throughout the study to characterize the lake. Parameters measured at the comprehensive sites included dissolved oxygen, temperature, turbidity, true color, conductivity, pH, and total phosphorus. Alkalinity was measured at Sites 1, 2, and 3. Chlorophyll-*a*, temperature, DO, and conductivity were measured using a YSI 650 MDS Sonde at all four sites. An epicore sample was performed at Sites 1 and 3. The comprehensive sites were tested weekly from 21-May-07 until 13-September-07. The spot sites and tributary Sites B, C, and D were sampled on 13-September-07. Parameters measured at the spot sites and Sites B, C, and D included dissolved oxygen, temperature, turbidity, true color, conductivity, pH, and total phosphorus. Sites E and G were sampled on 19-July-07, Site F was sampled on 03-August-07. Phosphorus was the only parameter measured at Sites E, F, and G.

Spot sites were chosen to help investigate potential differences in water quality at various locations in the lake as well as to identify potential problem areas.

Tributaries were also tested to determine what effect they may have on lake water quality. Tributary Sites E, F, and G were sampled after 0.75 inches of rain had fallen. At those sites, a 2-liter sample was taken immediately, then 100 mL samples were taken every ten minutes until an additional 2 liters of water had been obtained. The first two liters were analyzed separately from the latter 2 liters of water, referred to as single and continuous, respectively (see Appendix I).

The study site map shows the location of all sampling sites included in this study (Figure 30). The coordinates for the comprehensive sites were downloaded into the correct format for ArcGIS 9.2® from a GPS unit. The location of the spot sites and additional tributary sites are spatially referenced because they were plotted based on the map locations used by sampling teams. The Universal Transverse Mercator (UTM) 19N coordinate system was used when plotting all points. For an explanation of georeferencing, spatially referencing, and coordinate systems please refer to the GIS: Introduction.

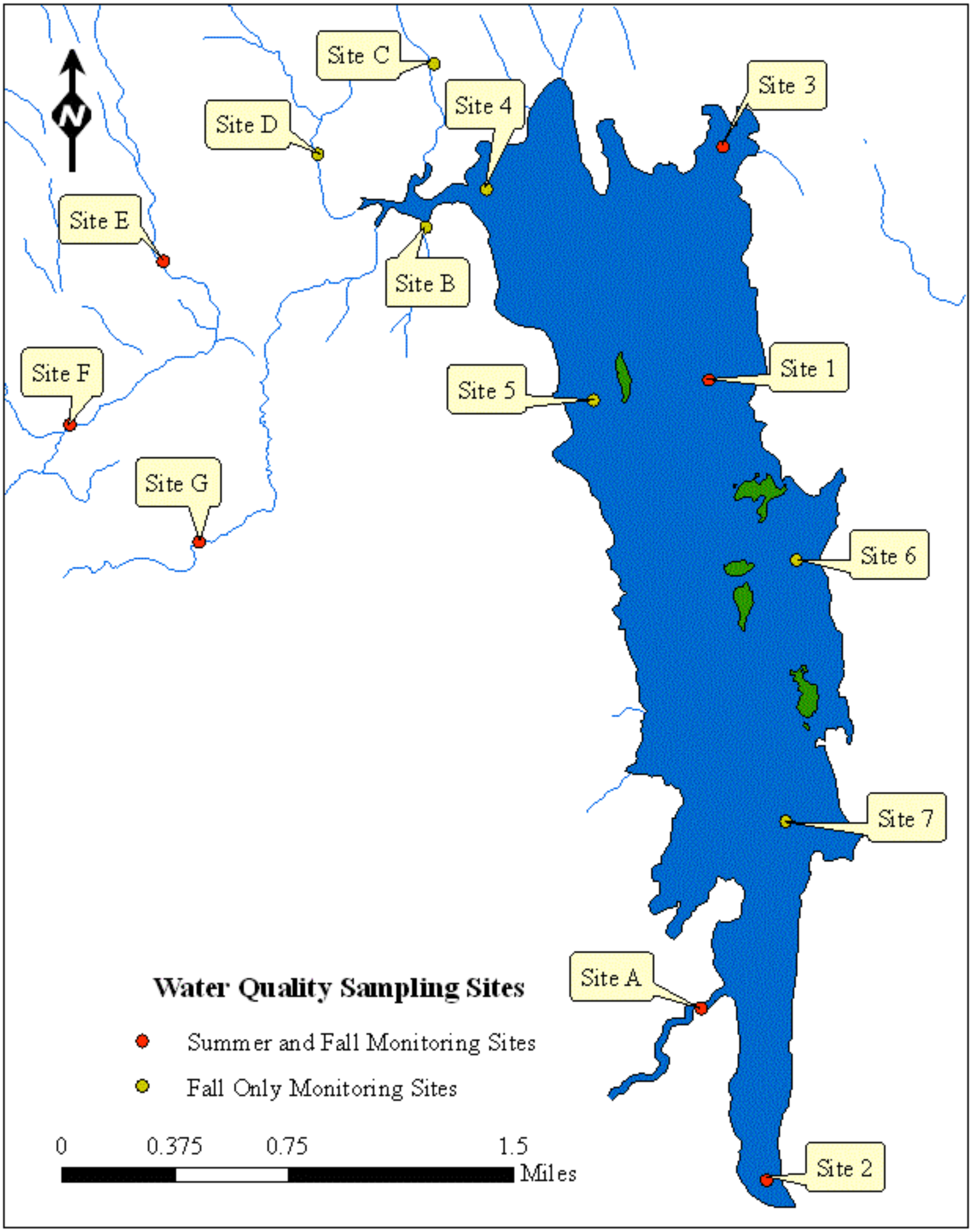

Figure 30. The location of all water chemistry sampling sites that were used in the study. These sampling sites are classified into "Summer and Fall Monitoring Sites" and "Fall Only" Monitoring Sites.

Comprehensive Sites

Site 1: Northing: 4927723 Easting: 0427523 Depth: 29.0 m
Located at the northeast part of the lake at the deep hole, approximately 290 m from the eastern shore. The Maine Department of Environmental Protection (Maine DEP) has sampled at Site 1 in the past so data from this site was useful for making historical comparisons.

Site 2: Northing: 4923457 Easting: 0427828 Depth: 1.8 m
Located approximately 130 m north of the southern tip of the lake.

Site 3: Northing: 4928963 Easting: 0427597 Depth: 6.0 m
Located at the northeastern part of the lake approximately 230 m south of where water from the North Basin of Long Pond flows into the South Basin.

Site A: Northing: 4924375 Easting: 0427479 Depth: 3.1 m
Located at the southwest part of the lake approximately 170 m inside the mouth of Ingham Stream. Samples from this site were used to determine the impact of wetlands, Ingham Stream, and Moose Pond on water quality.

Spot Sites

Site 4: Northing: 4928749 Easting: 0426905 Depth: 5.8 m
Located approximately 100 m east of the mouth of an unnamed inlet in the northwestern corner of the lake. Samples from this site were useful in determining inputs from multiple tributaries that converge in the inlet.

Site 5: Northing: 4927621 Easting: 0426905 Depth: 10.0 m
Located approximately 210 m from the western shore on the northwestern side of the lake where there are many houses with poor buffer quality.

Site 6: Northing: 4926776 Easting: 0427980 Depth: 7.0 m
Located approximately 140 m from the eastern shore in the middle of the lake where there is potential for development.

Site 7: Northing: 4925384 Easting: 0427936 Depth: 6.1 m
Located in the southeastern part of the lake approximately 340 m from the eastern shore where there are many houses

Tributary Sites

Site B: Northing: 4928546 Easting: 0426007 Depth: < 1.0 m
Located just inside the mouth of a tributary that runs into an unnamed inlet from the south. Site 4 is approximately 100 m East of the inlet. Site B was useful in determining inputs of the tributary.

Site C: Northing: 4929410 Easting: 0426042 Depth: < 1.0 m
Located on a tributary approximately 540 m north of the unnamed inlet it feeds into. Also it was useful in determining inputs of the tributary.

Site D: Northing: 4928934 Easting: 0425425 Depth: < 1.0 m
Located on a tributary approximately 380 m northwest of the unnamed inlet it

feeds into. Also it was useful in determining inputs of the tributary.

Sites E, F, and G: Located on adjacent tributaries that feed into the inlet mentioned above from the southwest. Useful in determining inputs of the tributaries into the lake. Located approximately 1, 1.9, and 2.0 km from the inlet, respectively.

Site E: Northing: 4928356 Easting: 0424612 Depth: < 1.0 m
Site F: Northing: 4927484 Easting: 0424115 Depth: < 1.0 m
Site G: Northing: 4926860 Easting: 0424804 Depth: < 1.0 m

Long Pond Water Quality Assessment

Physical Measurements

Dissolved Oxygen and Temperature

Introduction

Dissolved oxygen (DO) and temperature are important indicators of lake water quality. DO measures the amount of oxygen (O_2) dissolved in the water column (MVLMP 2006a), and temperature represents the amount of heat in the water. Nearly all aquatic organisms depend on oxygen to complete the process of respiration. DO is removed from the water when organisms respire and is added when primary producers, such as plants and algae, photosynthesize (MVLMP 2006a). Since organisms photosynthesize during the day, and decomposition occurs continuously throughout the day and night, DO levels are generally lowest before sunrise (PEARL 2007g).

Water temperature is negatively correlated with DO. High water temperatures during the summer months cause the water to stratify into three layers: the epilimnion, the metalimnion, and the hypolimnion (see Background: Annual Lake Cycles). Higher temperatures reduce the solubility of oxygen, causing DO levels to drop (MDEP unpublished report). While diffusion of O_2 between the surface water and the atmosphere helps replenish DO in the epilimnion, stratification prevents this DO from reaching water in the metalimnion and hypolimnion. Due to this stratification, anoxic conditions can occur in the lower strata of the lake before the temperature becomes isothermic and fall turnover occurs (see Background: Annual Lake Cycles). At all depths, DO levels are lowest at the end of summer due to high water temperatures and high biological activity (MDEP unpublished report).

A lake is considered anoxic once DO levels drop below 1 part per million (ppm), but cold water fish cannot survive in water with DO below 5 ppm (MDEP unpublished report). Under anoxic conditions, phosphorus trapped in sediments as part of ferric and other ionic complexes can be re-released into the water column (Mortimer 1942, Nurnburg 1987). When this phosphorus is brought to the surface during fall turnover, this increase in surface water phosphorus can lead to algal blooms. Algal blooms result in elevated respiration and decomposition rates in the lake, further reducing DO concentrations (PEARL 2007g).

Data collected by the Maine Department of Environmental Protection (Maine DEP) show a trend of decreasing levels of DO in Long Pond from 1975 through 2005 (PEARL 2007b). Since DO and temperature can greatly alter the biological composition of a lake, this trend is one of the primary reasons behind the decision of Maine DEP to list Long Pond as a “degraded” water body (Bouchard, pers. comm.).

Methods

A YSI 650 Sonde was used to make profile measurements of Sites 1, 3, and A. A Speedtech Instruments Depthmate portable sounder was used to find the depth at Sites 2, 4-7, B, and D. The dissolved oxygen and temperature were recorded at every meter using a YSI dissolved oxygen probe. Sites 1, 2, 3, and A were sampled throughout the summer, and the remaining sites were measured only on 13-September-07 (see Appendix A). Data were not collected at Sites A, C, and D. See Figure 30 for site locations.

Results and Discussion

The DO at Site 1 of Long Pond South, the deepest point in the lake, was highest during May and June (see Figure 30 for site location). Concentrations continued to decrease over the summer months, with the lowest DO profiles occurring during August and September (Figure 31, see Appendix I**)**. In all months, the DO was highest in the first 6 to 7 meters of the water column and ranged from around 8 to 13 ppm. The DO dropped quickly for the next 10 m, falling below the 5 ppm threshold in August and September. It then returned to levels similar to those at the surface. The DO began dropping again after a depth of 21 m, with the bottom depths becoming anoxic (DO concentrations less than 1 ppm) during August and September. The temporary drop in DO in the middle of the water column became increasingly pronounced over the course of the summer, reaching a low of 2.4 ppm at a depth of 11 m on 13-September-07. The mean dissolved oxygen at the remaining lake sites ranged from 6.8 to 9.1 ppm.

The temperature at Site 1 was highest in the epilimnion and ranged from about 17º C to 25º C (Figure 32). The temperatures were higher towards the end of the summer and decreased with depth until stabilizing around 6° C near 17 m in depth. Although temperature is usually negatively correlated with DO, temperatures did not rise in the middle of the lake where DO experienced a temporary drop. The mean temperature at the remaining lake sites ranged from 20.0º C to 21.5º C.

It is common for the DO in the bottom layers of a lake to decrease and even reach anoxic levels during the late summer since stratification prevents the water from mixing and replenishing the DO, despite the low temperatures at the lake bottom. It is uncertain why the DO temporarily drops in the metalimnion, although historical data from Long Pond South taken at Site 1 show that this phenomenon has been occurring since at least 1989 (PEARL 2007b).

One explanation for this temporary drop in DO could be the vertical movement of zooplankton between the epilimnion and metalimnion. Zooplankton respiration in the epilimnion is offset by DO added from photosynthesizing algae and gas exchange between surface water and the atmosphere. Since summer stratification prevents the epilimnion and metalimnion from mixing, the DO consumed by zooplankton in the metalimnion cannot be replenished. CEAT temperature and DO profiles support this hypothesis, since the drop in DO occurred at the start of the temperature-defined metalimnion (Figure 33). The return of DO at 16 m depth to epilimniotic concentrations could indicate the bottom end of the zooplankton range.

The anoxic conditions observed at the bottom of Site 1 create conditions that could lead to the release of phosphorus from the sediments, which can provide the nutrients necessary for algal blooms (see Background: Phosphorus and Nitrogen Cycles). Maine DEP data from Site 1 show that the mean depth where DO drops below 5 ppm (the threshold for cold water fish) in September has been becoming more shallow since 1975 (PEARL 2007b). In 2004 and 2006, the mean depth was 8 m (PEARL 2007b), while data collected by CEAT on 13-September-07 show this drop occurring at 9 m. Although CEAT found that the average depth where DO first drops below 5ppm was a meter deeper than in 2004 and 2006, this finding does not necessary signify a reverse in the trend since the historical data has fluctuations as great as 5 m between data points (PEARL 2007b).

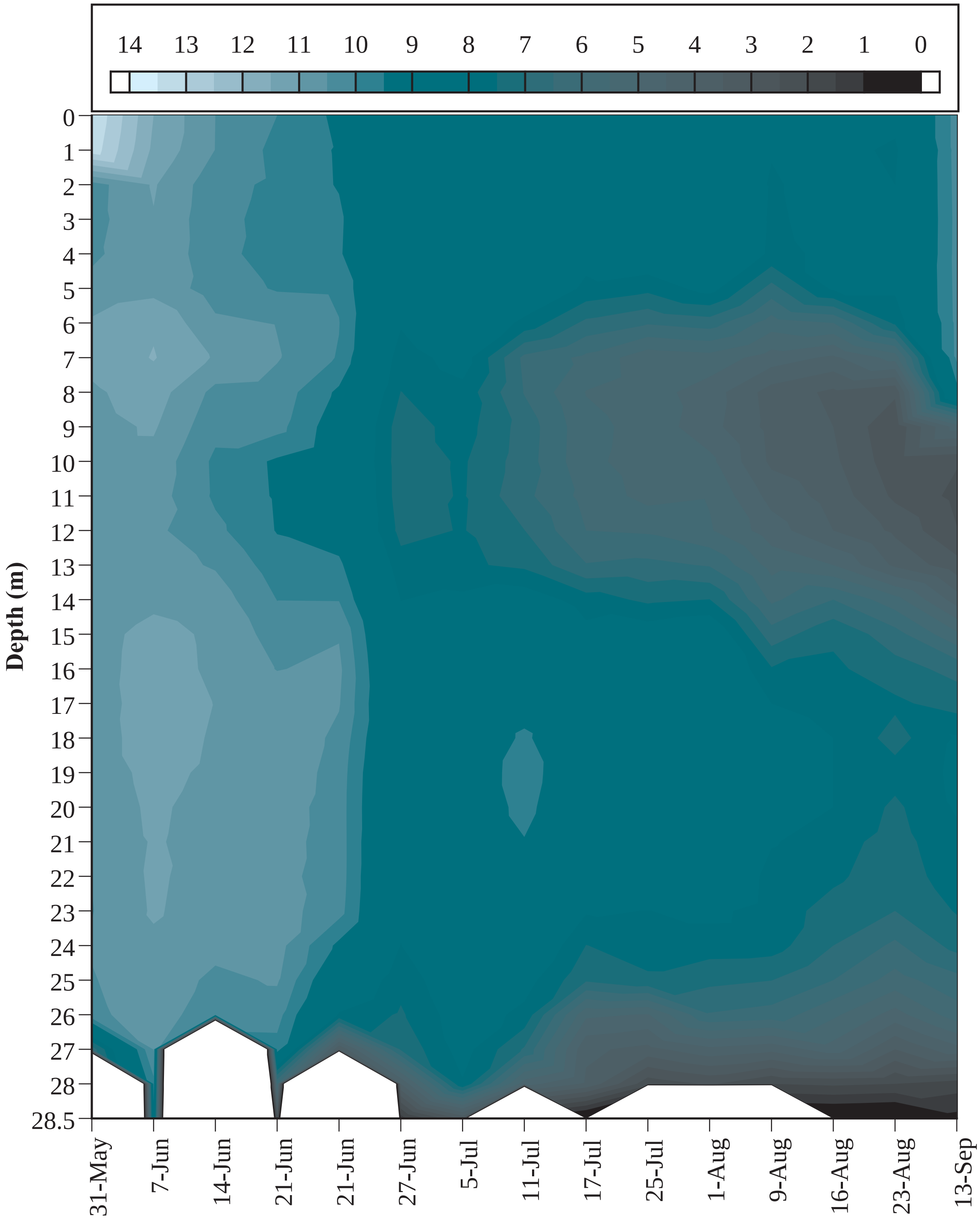

Figure 31. Dissolved Oxygen (ppm) profile of Site 1 in Long Pond South as measured by CEAT during the summer of 2007 (see Figure 30 for site locations). Wind and boat drifting prevented data collection at some depths.

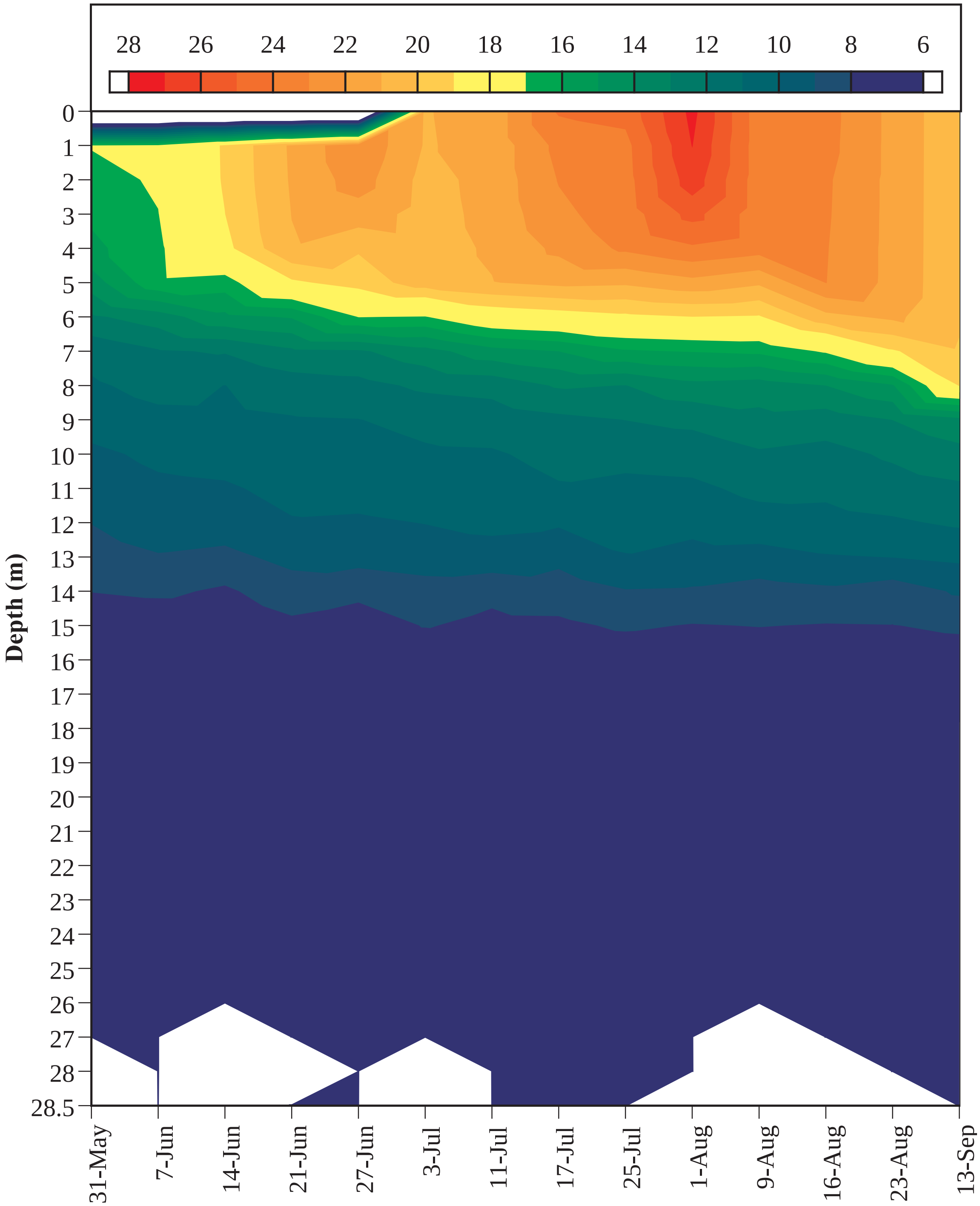

Figure 32. Temperature (ºC) profile at Site 1 of Long Pond South measured by CEAT from May to September 2007 (see Figure 30 for site locations).

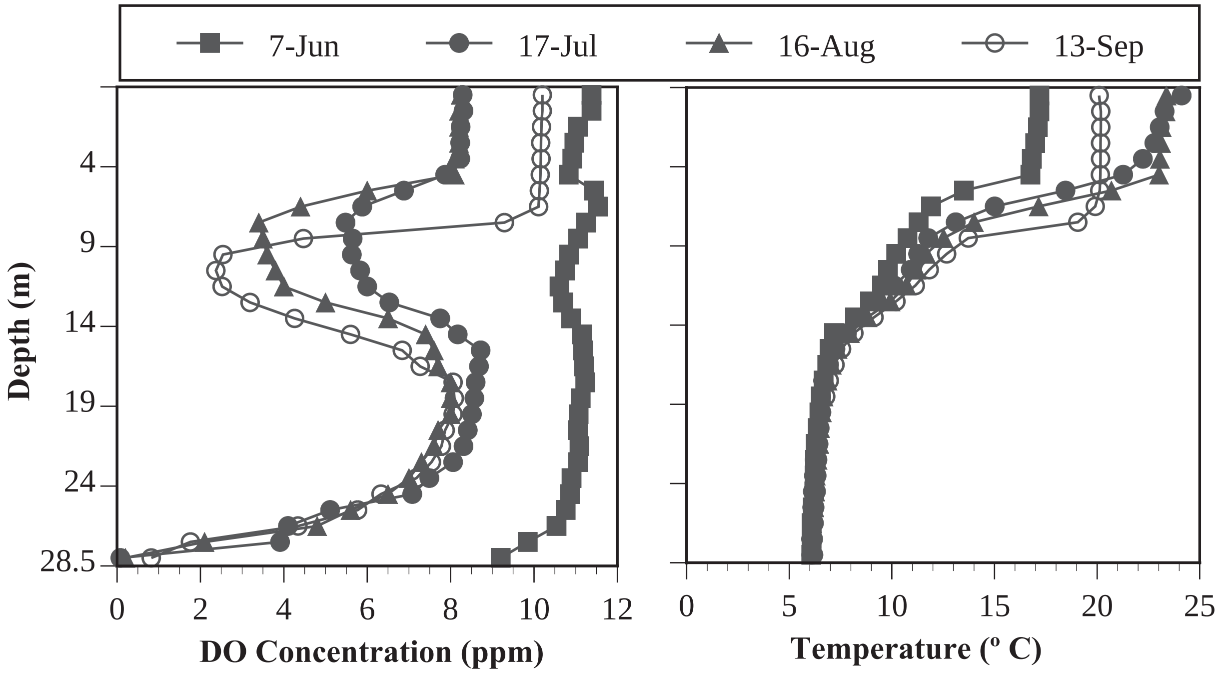

Figure 33. Dissolved oxygen (ppm) and temperature (º C) profiles taken by CEAT at Site 1 on Long Pond South from June to September 2007 (see Figure 30 for site location).

Of the remaining sites, Site 5 was the only location that had anoxic conditions (see Figure 30 for site location; see Appendix I). The DO was around 8 ppm until a depth of 9 m, where it dropped to 1 ppm and then to 0.8 ppm at a depth of 10 m.

One explanation for this anoxia could be the location of Site 5; according to CEAT erosion potential and impact models, Site 5 is located near areas with medium to high erosion potential and impact (see Watershed Development Patterns: Erosion Potential Model (Figure 27) and Erosion Impact Model (Figure 29)). The buffer quality on the shoreline closest to Site 5 is fair to poor, which may allow more phosphorus to enter the lake near this site than in other locations (see Watershed Development Patterns: Residential Survey (Figure 17)). It is possible that phosphorus from eroding soil particles and other non-point residential sources caused increased biological activity, which lowered the DO.

Transparency

Introduction

Transparency is a measure of water clarity. It is also an indirect measure of algal density because as algal density increases, clarity decreases (EPA 2007a). Algal growth, however, is not the only water quality factor that affects transparency; suspended sediments in the water column and the color of the water also play a role (Michigan Lake and Stream Associations, Inc 2007). As a result of these factors, transparency measurements should be used in conjunction with other water quality parameters to fully determine the potential for algal growth in the water body.

Transparency is measured in meters using a Secchi disk, an eight-inch diameter disk with black and white quadrants attached to a measuring tape. The disk is lowered into the water column until it disappears and then is raised until it can be seen again (see Appendix B). By recording the depth on the measuring tape when the disk disappears and reappears, it is possible to determine the clarity of the water column. Higher Secchi disk readings indicate clearer water and lower lake productivity. Unless a lake has highly colored water, the mean transparency can be used to calculate the trophic state of the lake with a Trophic State Index (TSI).

The transparency-based TSI is calculated by using the equation: $TSI = 10[6-(\ln SD)/(\ln 2)]$ (PEARL 2007c). SD represents the mean Secchi depth measured, and lakes with a Secchi measurement of one meter have a TSI of 60 and are highly productive. Lakes with TSI index values less than 40 are associated with higher transparency and lower productivity (oligotrophic). Lakes with a TSI between 40 and 50 are associated with moderate productivity (mesotrophic), and those with aTSI greater than 50 have high productivity (eutrophic) (PEARL 2007c). Nuisance algal blooms are a problem for many mesotrophic and eutrophic lakes (PEARL 2007c). A Secchi depth of two meters or less indicates that the lake may have a water quality problem that stems from nuisance algal blooms (PEARL 2007c).

The accuracy of Secchi disk readings depends on the person taking the measurement, the angle of the sun at the time of the measurement, weather conditions, and surface water conditions (EPA 2007a). For these reasons, the Maine Volunteer Lakes Monitoring Program (2006a**)** suggests practices to standardize the readings. According to these standards, measurements should be taken between 9:00 AM and 3:00 PM when the sun is most directly overhead, and the disk should be used in conjunction with an Aqua-scope which allows for more accurate Secchi readings by reducing the surface glare and wave interference (see Appendix B).

Methods

Secchi disk readings were taken at Sites 1 and 3 on a weekly basis from 31-May-07 until 23-August-07 and again at Site 1 on 13-September-07 (see Appendix A). They were also taken on a biweekly basis at Site 1 in Long Pond North to monitor for changes because this area drains into the South Basin. Site A and Site 2 were too shallow for Secchi measurements. Historical transparency readings were obtained from the Maine DEP (PEARL 2007b) for comparison with the current results. The transparency-based equation for the Trophic State Index was also used to compare the current lake productivity with the historical levels.

Results and Discussion

Over the summer of 2007, transparency at Site 1 ranged from 5.4 m to 6.3 m with a mean (±SE) of 6.0 ±0.3 m. At Site 3, it ranged between 5.3 m and 6.3 m with a mean (±SE) of 6.1 ±0.4 m. Secchi depths increased slightly over the summer and water clarity was maintained (Figure 34). The Secchi depths also never fell below two meters for either of these sites, indicating that no algal blooms occurred. According to the transparency-based TSI equation above, in the summer of 2007, Long Pond South had a TSI of 34, categorizing it as an oligotrophic water body (PEARL 2007c). This current TSI is slightly lower than the historical average TSI, indicating that 2007 was a less productive year for the lake. Despite these results, any future increase in nutrients could easily transform Long Pond South into a mesotrophic state. From 1971 to 1983, water transparency was consistent with a mean Secchi depth greater than 6.5 meters. From 1985 to 2007, however, mean transparency became more variable and began to show a decreasing trend (Figure 35). In general, Secchi depth readings have decreased by one meter total since the 1970's. This decrease is less drastic than the three-meter decrease recorded for Long Pond North in the same time period (CEAT 2007), but it is a trend that shows a decrease in visibility, implying a decline in water quality. If action is not taken to protect or improve the water quality of Long Pond South, it may continue to decline.

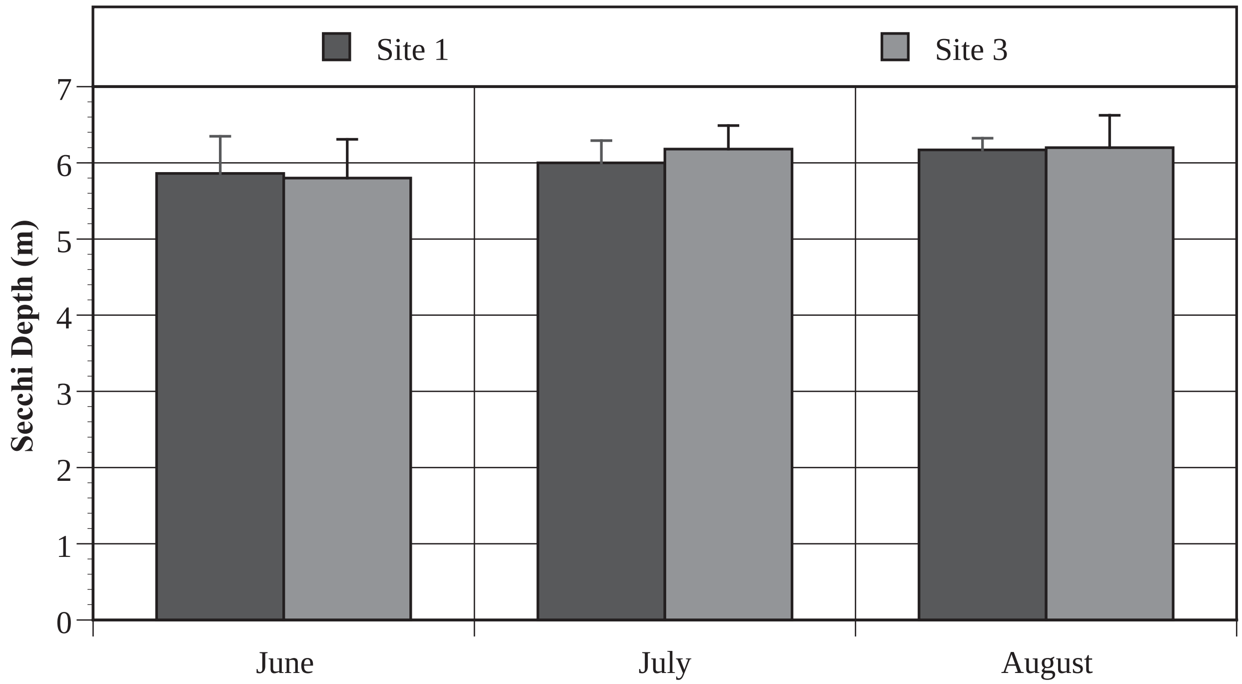

Figure 34. Mean (±SE) Secchi depth (m) for Long Pond South measured at Sites 1 and 3 by CEAT (see Figure 30 for site locations).

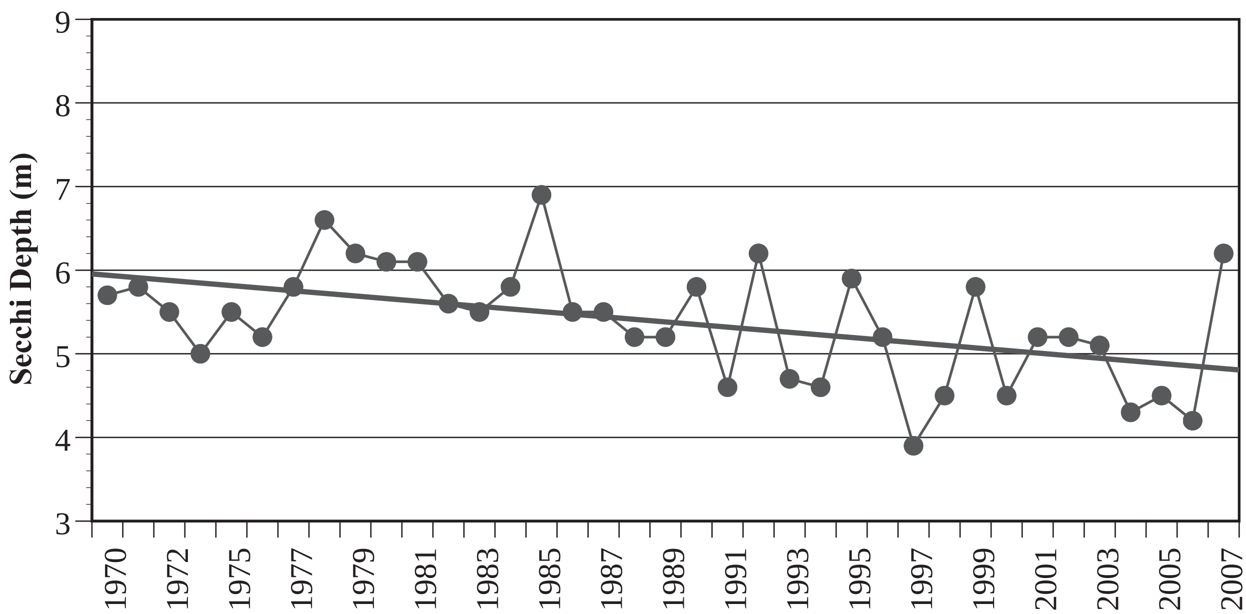

Figure 35. Water transparency represented by mean Secchi depth (m) and linear trendline from 1971 to 2007 for Long Pond South Site 1 (see Figure 30 for site locations). Data from 2007 collected by CEAT, all other data from Maine DEP (PEARL 2007b).

Turbidity

Introduction

Turbidity is another method for measuring the visibility of the water column. Instead of using a Secchi disk, turbidity, measured in Nephelometric Turbidity Units (NTU), is based on the interaction of light with suspended particles in the water. If there are many particles of sand, silt, clay, or fine organic or inorganic matter present in the water column, more of the light becomes absorbed and reradiated in different directions (MPCA 2005). A turbidimeter determines the turbidity by sending a beam of light through a sample of the water. The suspended particles in the water scatter the light energy, which is converted into an electric signal providing a turbidity reading. High NTU values coincide with increased light scattering, which indicates lower water clarity due to a greater density of suspended particles and increased turbidity (MPCA 2005).

Many factors can contribute to an increase in turbidity, including waste discharge, runoff and erosion from the watershed, algae and aquatic weeds, and humic acids or other organic compounds created from plant decay (EPA 1999). Boat action and turbulence in shallow areas of the lake can also increase turbidity. The waves from these boats raise the amount of suspended particles in the water and may cause the nutrients that had settled in the sediments, such as phosphorus, to become available for increased algal growth (Lake Access 2005). An increase in turbidity indicates a decrease in the amount of light available for photosynthesis. The low availability of light can potentially decrease productivity of algae and inhibit the invertebrate population that feeds on the algae (USGS 2004). High turbidity readings, however, can also indicate an increase in the algal population abundance in the lake (EPA 1999). Because turbidity is affected by many parameters, it is important to use these readings in conjunction with other tests to characterize the state of the lake.

Methods

Water samples from the surface, mid, and bottom depths of Sites 1 and 3 and from the surfaces at Site 2 and Site A, which were too shallow to collect at other depths, were taken every week from 31-May-07 to 23-August-07 and again on 13-September-07 (see Figure 30 for site locations). Turbidity readings for surface, mid, and bottom depths were also conducted biweekly throughout the summer of 2007 at Long Pond North Site 1 and used to compare to the 2006 data and results measured by CEAT (2007) to control for large discrepancies. A HACH™ 2100P Turbidimeter was used to measure turbidity in Nephelometric Turbidity Units (NTU).

Results and Discussion

Throughout the summer, surface turbidity readings for Site 1 ranged from 0.54 NTU to 1.07 NTU with a mean (±SE) of 0.70 ± 0.15 NTU. Bottom turbidity readings were much higher than at the surface and at the mid level, especially for dates after 17-July-07 (Figure 36). Algal populations increase throughout the summer. When these populations die, the dead organisms fall through the water column to the hypolimnion where decomposers break them down. The accumulation of organic matter is reflected in the elevated bottom turbidity reading.

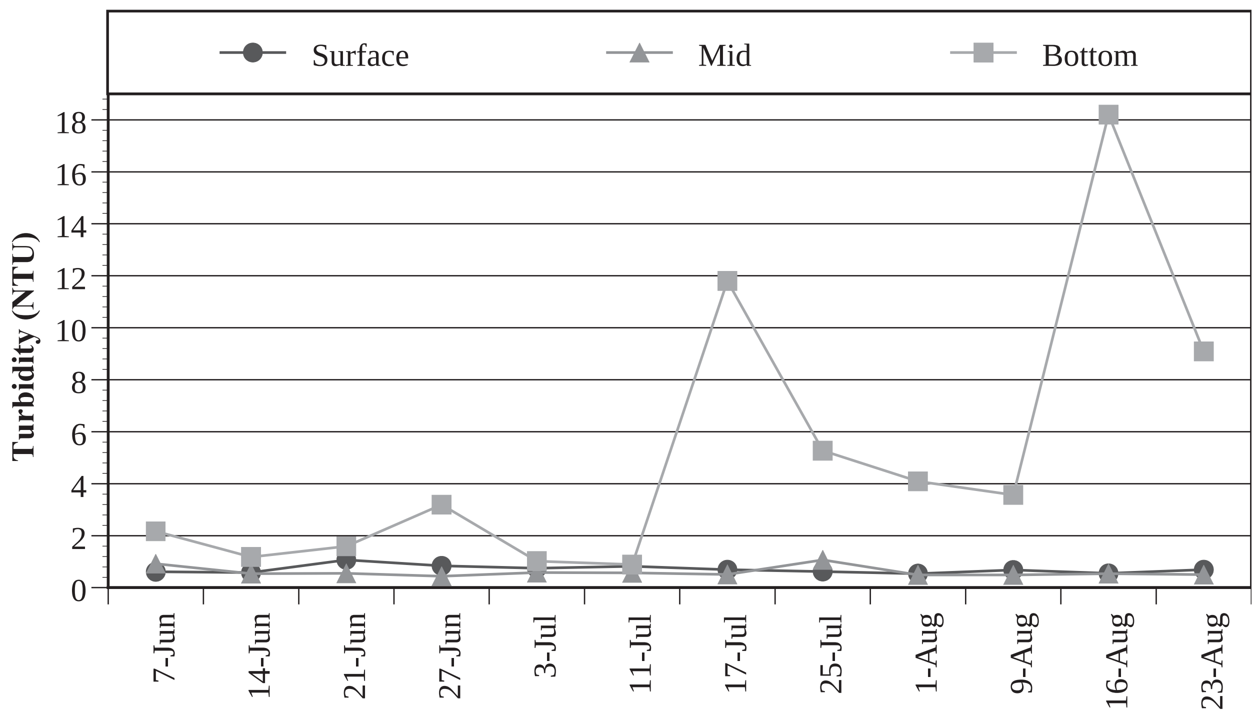

Figure 36. Surface, mid, and bottom turbidity (NTU) measurements made on selected dates in the summer of 2007 for Long Pond South Site 1 (see Figure 30 for site locations).

Sites 1, 2, and 3 had approximately equal mean surface turbidity readings throughout the summer (Figure 37). Since Sites 1 and 3 were both deep enough to limit mixing between the hypolimnion and epilimnion of the lake, their surface waters had lower amounts of suspended

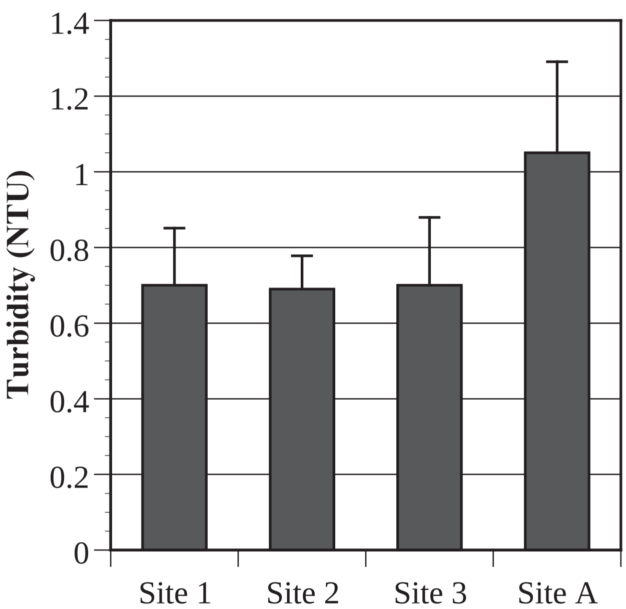

Figure 37. Mean (±SE) surface turbidity (NTU) for Long Pond South Sites 1, 2, 3, and A in the summer of 2007 (see Figure 30 for site locations).

sediments. Site 2 was located in waters approximately two meters deep where turbidity readings were expected to be higher. Instead the adjacent wetlands apparently buffered the site against erosion and large amounts of suspended sediments (see Figure 30 for site locations). The wetlands buffering capability was reflected in the lower turbidity readings seen at Site 2. Site A, which is a shallow stream site, had higher mean surface turbidity over the summer than the other sites because the flowing water mixed the bottom sediments into the water column (Figure 37). These higher mean turbidity values at Site A correlate with the increased color values at that site (see Water Quality: True Color) and they could also be due to an increased amount of dissolved organic matter from the extensive wetlands through which it flows (see Figure 30 for site locations).

<u>True Color</u>

Introduction

The color of a lake can be measured in two ways: apparent and true color. Apparent color is a measure of both dissolved and suspended particles in the water column. The true color is the value taken after the suspended particles have been filtered out of the water sample. The suspended particles can be the result of human induced soil erosion or from the natural weathering of the surrounding substrates and the decomposition of plant material (PEARL 2007h). The dissolved compounds are tannic and humic organic acids that result from the decomposition of plant material and are what gives lake water a tea color (PEARL 2007h).

Color is measured in Standard Platinum Units (SPU) and can be an indicator of productivity in a lake, but chlorophyll-*a* is the best measure (MDEP unpublished report). Long

Pond has historically been categorized as a non-colored lake with a mean of 15 SPU (PEARL 2007b). Colored lakes are categorized as having greater than 25 SPU, and the mean apparent color for lakes in Maine is 27 SPU (MVLMP 2006b). The range for apparent color in Maine lakes is 2 to 194 SPU (MVLMP 2006b). Only true color was analyzed for this study of Long Pond South.

Methods

Surface grabs were taken from all sites in 500 ml Nalgene bottles and were brought back to the Colby Environmental Analysis Center laboratory for analysis. The water was filtered using a 47 mm, 0.45 microns membrane filter, which was rinsed using deionized Epure water. The samples were placed in cells and read using a HACH 4000 DR spectrophotometer. All samples were refrigerated after returning to the laboratory and all analysis occurred within 24 hours of collection. The samples were allowed to return to room temperature before they were placed in the spectrophotometer. Samples were taken at Sites 1-3 on 14-June-07, 11-July-07, and 13-September-07. Data were collected at Sites 4-7 and A-D on 13-September-07 (see Appendix A). See Figure 30 for site locations.

Results and Discussion

All lake sites, except for Site 3, were non-colored and ranged from 15 to 25 SPU (Figure 38; see Appendix I). This range was slightly higher than the historical average of 15 SPU. Site 3 was highly colored in September, as were stream sites A, B, and C (Figure 38). Site 3 is located in the northern end of the lake near where Long Pond North connects with Long Pond South. Castle Island Road crosses this channel connecting

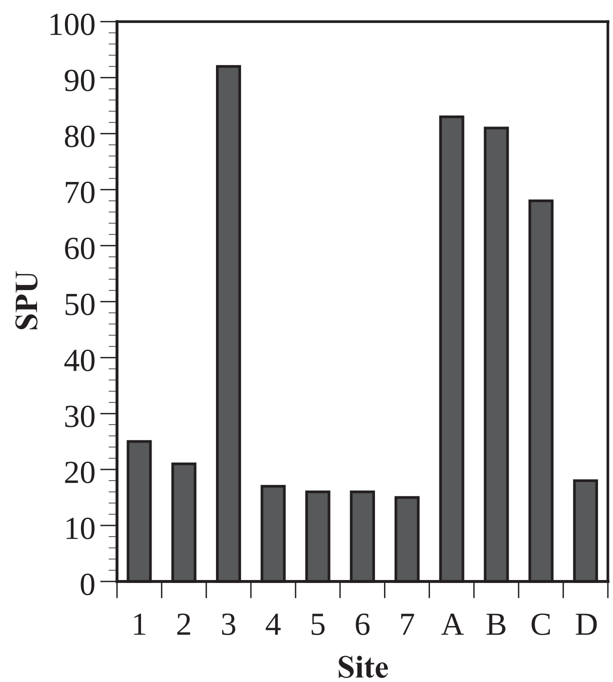

Figure 38. True color of Long Pond South on 13-September-07 at sites 1 through 7 and A through D. The data were collected and analyzed by CEAT.

the two basins (see Watershed Development Patterns: Roads Figure 24**)**. This portion of Castle Island Road has a steady flow of traffic, is narrow, and lacks a buffer. Even though Castle Island Road is paved, the lack of buffer means that dirt on the road shoulder easily disturbed by traffic can enter the lake. Development on the southern tip of Long Pond North could also be a source of phosphorus for Long Pond South because water from the north basin flows directly into Long Pond South. These potential sources of phosphorus could explain the elevated color readings at this site.

The high color readings from Sites A, B, and C were likely due to natural sources of organic acids. All three sites are surrounded by wetlands, which have a high amount of decaying organic material (see Watershed Land-Use Patterns: Introduction Figure 11).

Chemical Analyses

<u>pH</u>

Introduction

The pH is a measure of hydrogen ion (H^+) concentration, or acidity. Acidic solutions have higher concentrations of hydrogen ions. The pH of water is measured on a logarithmic scale, where pH is equal to the negative log of the H^+ concentration, and ranges from 1 to 14 (Shaw et al. 2004). A change of one on the pH scale represents a tenfold change in the concentration of hydrogen ions (MDEP unpublished report). Water with a pH higher than 7 is basic and water with a pH below 7 is acidic; water with a pH of 7 is considered neutral. The mean pH for lakes in Maine is 6.8 and the range is 4.2 to 9.5 (MVLMP 2006b). The mean pH in Long Pond between 1976 and 2006 was 7.0, with the data ranging from 6.4 to 7.5 (PEARL 2007b).

Plants use carbon dioxide during photosynthesis, which causes an uptake of hydrogen ions and reduces the acidity (PEARL 2007i). However, plants also produce carbon dioxide during respiration, which releases hydrogen ions and lowers the pH (PEARL 2007i). Since photosynthesis occurs during daylight, there is often a daily and seasonal fluctuation in pH levels. The pH may also decrease with depth since photosynthesis is limited by light penetration, whereas respiration and decomposition can continue to occur throughout the water column (PEARL 2007i).

The pH is one of the determining factors for the distribution of organisms in a lake because species have different pH tolerances (MVLMP 2006b). Low pH levels may be harmful to many fish species by impairing their reproduction (PEARL 2007i). Toxic metals, such as mercury and aluminum, are more soluble in acidic water and can bioaccumulate in the food chain, harming the many species, including humans (Shaw et al. 2004). This increased solubility of heavy metals can also cause phosphorus release from sediments since fewer metals, such as calcium and aluminum, are available to sequester the nutrient (Shaw et al. 2004, PEARL 2007i).

Methods

A YSI 650 Sonde was used to take profile measurements at Sites 1, 2, 3, and A from May through August 2007. The YSI Sonde was also used at Sites 1 and 3 on 13-September-07. Surface pH measurements were taken at Sites 2, 4-7, and A-D using an EXTECH Instrument ExStick pH meter on 13-September-07 (see Appendix A). See Figure 30 for site locations.

Results and Discussion

The mean pH at Site 1, the deep hole, on 13-September-07 was 7.0 and the range was 6.1 to 7.4 (see Appendix I). The pH was close to neutral in the epilimnion and was just below neutral in the lower levels (Figure 39). One reason the pH was higher in the epilimnion could be that the sunlight led to more photosynthetic activity, which removes carbon dioxide and hydrogen ions and consequently raises the pH. As the summer progressed, the metalimnion and hypolimnion became more acidic. This drop in pH is likely due to high levels of respiration, which reduce pH, and lake stratification preventing epilimnion water mixing with lower strata. This explanation is supported by the fact that at Site 3, where the lake is only 6.5 m deep, the pH values did not drop as low as those in Site 1 and less fluctuation in pH occurred over depth or time (Figure 39).

The mean pH at Site 1 has increased since data were first collected in 1976 (PEARL 2007b). The yearly mean pH readings between 1976 and 1985 were all under 7.0, while the mean pH readings from 2001 through 2007 were all above 7.0 (PEARL 2007b). The overall mean pH from the time period 1976-1985 was 6.9 and the overall mean from 2001-2007 was 7.2, suggesting an increase in pH over time. Only two data points were available between 1985 and 2001 (the pH was 6.4 in 1988 and 7.5 in 1991) so these years were not included in calculating the historic mean pH levels (PEARL 2007b). This trend of rising pH levels suggests that the productivity of Long Pond South has been increasing over time. This observation agrees with other trends identified by Maine DEP and CEAT, such as decreasing dissolved oxygen concentrations and lower transparency (see Dissolved Oxygen and Transparency).

The pH from all other sample sites ranged from 6.2 to 8.3, with the exception of Site C at 5.5 (see Appendix I). All pH values were near the historical mean for Long Pond of 7.0. Site C, a stream site, was the only location with a pH reading below 6. The stream at Site C travels through wetland prior to crossing Belgrade Road (see Watershed Land Use Patterns: Introduction **(**Figure 11)). Since wetlands are acidic, it is likely that the Site C stream had picked up the extra H^+ from this source. It is also possible that pollutants from the commercial land-use in the area surrounding Site C caused the drop in pH (see Watershed Land Use Patterns: Introduction **(**Figure 11)). Despite the low pH at Site C, the pH of Long Pond South is high enough so as not to impact fish health, and is unlikely to significantly affect internal phosphorus loading.

<u>Conductivity</u>

Introduction

Conductivity is the ability of water to carry a charge, which is dependent on the amount of dissolved ions in the water (MVLMP 2006b). Geology, hydrology, and pollution are important factors in determining the conductivity of a lake (PEARL 2007f). Runoff carries ions into the lake from soils and rocks in the watershed, as well as from organic pollutants, fertilizer, and road salt (PEARL 2007f). In Maine lakes, the mean level of conductivity is 45 µS/cm and the range is 10-888 µS/cm (MVLMP 2006b). The mean conductivity for Long Pond between 2001 and 2006 was 48 µS/cm (PEARL 2007b).

Methods

A YSI 650 Sonde was used to make profile measurements of Sites 1, 2, 3, and A from May through August 2007 (see Appendix A). The YSI Sonde was also used at Sites 1 and 3 on 13-September-07. Sites 2, 4-7, and A-D were sampled on 13-September-07 by taking a surface grab in a 500 ml Nalgene bottle back to the Colby Environmental Analysis Center for analysis. Samples were refrigerated after returning to the lab and all testing occurred within 24 hours of sample collection. Conductivity measurements were taken in µmhos (equivalent to µS/cm) using a Fisher Scientific Model 31A YSI Conductance Bridge (see Figure 30 for site locations).

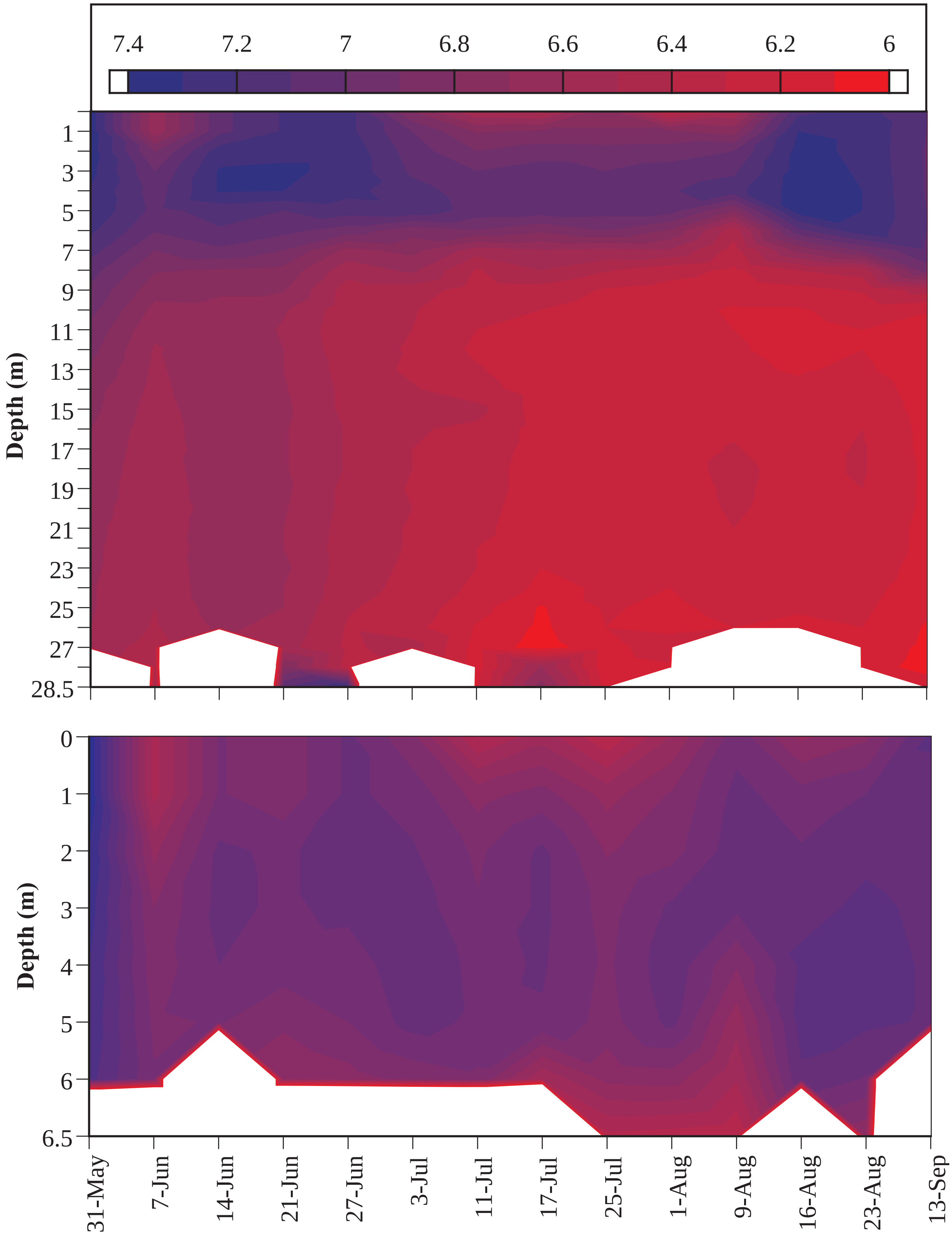

Figure 39. pH profiles as measured by CEAT in the summer of 2007 for Site 1 and Site 3 (see Figure 30 for site locations).

Results and Discussion

The conductivity at Site 1 did not vary with depth, but did increase as the summer progressed. The conductivity during May and most of June varied between 45 and 46 µS/cm (see Appendix I**)**. By August, the readings varied between 53 and 55 µS/cm, although the bottom two meters of the September profile were 58 and 69 µS/cm, respectively (see Appendix I). Despite this increase in conductivity, the values were still close to the state average (45 µS/cm) and the Long Pond historic average (48 µS/cm).

The conductivity at the other lake sample sites was 34 µS/cm, with the exception of Sites 2 and 3 (Figure 40; see Appendix I**)**. The mean conductivity at Site 3 was 50 µS/cm, with a range of 44 to 59 µS/cm. At Site 2, the mean was 48 µS/cm, although the September measurement (34 µS/cm) was lower than in the previous months, which ranged from 45 to 54 µS/cm.

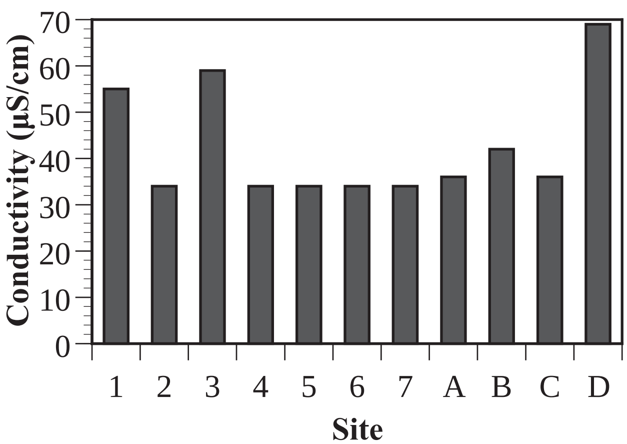

Figure 40. Conductivity (µS/cm) in Long Pond South at lake sites 1 through 7 and stream sites A through D. Data were collected by CEAT on 13-September-07.

The stream sites also had higher conductivity readings. Even though Sites C and D cross the same stretch of Belgrade Road, Site C had the lowest conductivity (36 µS/cm) and stream Site D had the highest (69 µS/cm). This variability in conductivity is likely due to a difference in water depth. There is a greater chance of disturbing bottom sediments when sampling in shallow sites than in deep sites, and disturbed sediment can increase conductivity readings. Although both sites were shallow (below a quarter meter), Site D was shallower than Site C.

Total Phosphorus

Introduction

In Maine lakes, phosphorus is the limiting nutrient for phytoplankton growth. This means that the supply of phosphorus in the water does not meet algal demand. As a result, the algae population cannot further grow in biomass until phosphorus levels increase (O'Sullivan and Reynolds 2004). Because of its ability to limit growth, a small increase in phosphorus can lead to an algal bloom and a consequent decrease in water quality.

The phosphorus in the lake comes in both organic and inorganic forms. The inorganic form is an orthophosphate ion, and the organic forms are dissolved, low concentration phosphorus compounds produced by living organisms (O'Sullivan and Reynolds 2004). As phosphorus levels increase, the trophic status of the lake can change. Oligotrophic lakes tend to have an annual mean total phosphorus level between four parts per billion (ppb) and ten ppb. Eutrophic lakes have levels between 35 ppb and 100 ppb (O'Sullivan and Reynolds 2004). Lakes with higher phosphorus levels have more nuisance algal blooms, which may include floating algal mats. As the algae die and settle to the bottom, turbidity increases and decomposers in the hypolimnion consume oxygen while aiding algal decay (O'Sullivan and Reynolds 2004). Because the deeper lakes are stratified in layers that do not mix and light for effective photosynthesis does not penetrate to the deep layers, the oxygen that is consumed by decomposing bacteria cannot be replenished during the season. In some cases, algae decomposition on the lake bottom leads to an anoxic hypolimnion where fish species cannot survive (see Background: Phosphorus and Nitrogen Cycles).

An anoxic hypolimnion can also help to increase phosphorus levels because when oxygen is present, iron exists as insoluble ferric compounds. These ferric compounds form ferric phosphate with the phosphorus and precipitate out of the water column. This renders much of the phosphorus unavailable for plant uptake (Maitland 1990). In anoxic conditions, however, the iron is reduced to its soluble ferrous state, which dissolves into the water column. The bond with phosphorus is released and phosphorus is available for plant growth once again (Maitland 1990). This phenomenon is known as internal loading because the bottom sediments release phosphorus as opposed to external phosphorus loading from the surrounding watershed (PEARL 2007d).

External loading through runoff from the watershed generally provides most of the phosphorus in the lake. Because phosphorus is typically a non-point source pollutant, many factors contribute to its levels in the lakes. The phosphorus concentration in the lake can be broken down into many small individual sources of phosphorus, such as camp roads, driveways, paths on steep slopes, lawn and garden fertilizers, septic systems, and pet waste (PEARL 2007d). The wide distribution and source variation render the prevention of phosphorus loading difficult.

Methods

CEAT collected water samples weekly between 31-May and 23-August-07, and on 13-September-07. Epicore, surface, mid, and bottom samples were taken at Site 1. Only surface, mid, and bottom samples were taken at Site 3. At Site 2 and Site A, the shallow depth of the water allowed for only the surface waters to be sampled. CEAT also sampled the surface, mid, and bottom waters of Long Pond North Site 1 bi-weekly from 14-June-07 to 23-August-07 to monitor for possible changes to the water flowing into the South basin and make comparisons to the 2006 study of the North basin (see Appendix A).

The ascorbic acid method was used to determine the total phosphorus concentration (ppb) of the water samples (see Appendix B). After the samples were collected, they were put in coolers and carried back to the Colby Environmental Analysis Center. The water was then split into two 50 ml samples and one ml of 1.75 N ammonium peroxydisulfate and one ml of 11 N sulfuric acid were added to each sample. The samples were then placed in the autoclave for 30 minutes at 15 lb/in^2 and 120º C. This digestion process converted the condensed and organic phosphorus into soluble orthophosphate that could be measured. To measure the samples after digestion, 11 N sodium hydroxide was added to readjust the pH to 6. Eight milliliters of a combined reagent (5 N Sulfuric Acid, Potassium antimonyl tartrate, Ammonium molybdate, and Ascorbic acid) were then added to react with the orthophosphate and produce a blue colorimetric reaction. The intensity of this faint shad of blue was measured with a Milton Roy Thermospectronic Aquamate Spectrophotometer using cells with a 10 cm path length. This measurement was recorded as a phosphorus concentration in parts per billion (ppb) based on a standard curve. Historical phosphorus data were obtained for comparison from the Maine Department of Environmental Protection (PEARL 2007b).

Results and Discussion

At Site 1, the mean (±SE) summer surface, mid, epicore, and bottom phosphorus levels were 8.8 ±5.6 ppb, 7.0 ± 1.3 ppb, 9.1 ± 3.0 ppb, and 35.2 ± 18.8 ppb respectively. The high variability of phosphorus in the bottom sample resulted from the low readings obtained during the middle of the summer (Figure 41**)**. The surface samples also had fairly high variability, which could be due to fluctuations in the phosphorus concentration as plants take it up and as it precipitates through the water column. The epicore sample at Site 1 was used to characterize the phosphorus concentration of the entire lake because it includes a larger proportion of the water column. Instead of using a grab sample with a small amount of water from one small portion of the water column, the epicore sample is a combination of the waters in the epilimnion. It had a phosphorus concentration of 9.1 ± 3.0 ppb. This value was used to determine the accuracy of the CEAT Phosphorus Model (see Phosphorus Budget).

The bottom samples were consistently higher than the phosphorus concentration of the surface samples at Site 1 reflecting the effects of stratification and internal loading. Mean (±SE) surface, mid, and bottom phosphorus concentrations at Site 3 were consistent with depth: 8.2 ±1.7 ppb, 8.0 ± 1.7 ppb, and 8.1 ± 1.4 ppb respectively. At Site 2, the mean (±SE) surface phosphorus concentration was 8.2 ± 3.1 ppb. Because these two sites were not as deep as Site 1 and did not experience anoxic conditions, they had no added effects from internal loading.

Monthly mean phosphorus levels from June to August at Sites 1 and 3 were fairly constant over time (Figure 41). At Site 2, the phosphorus levels decreased as the summer progressed perhaps because the higher levels created by spring turnover were absorbed throughout the summer by the wetlands surrounding the site (see Figure 30 for site locations). Also, this decrease may indicate that the wetlands become a source of phosphorus in the early spring when turnover and turbulence break and redistribute wetland plant material into the lake. The phosphorus concentrations found during this short-term study suggest that Long Pond South may be able to maintain constant phosphorus levels in the future if the wetlands continue to absorb the phosphorus out of the water column. The long-term data, however, show a difficult problem that wetland phosphorus absorption will not easily solve.

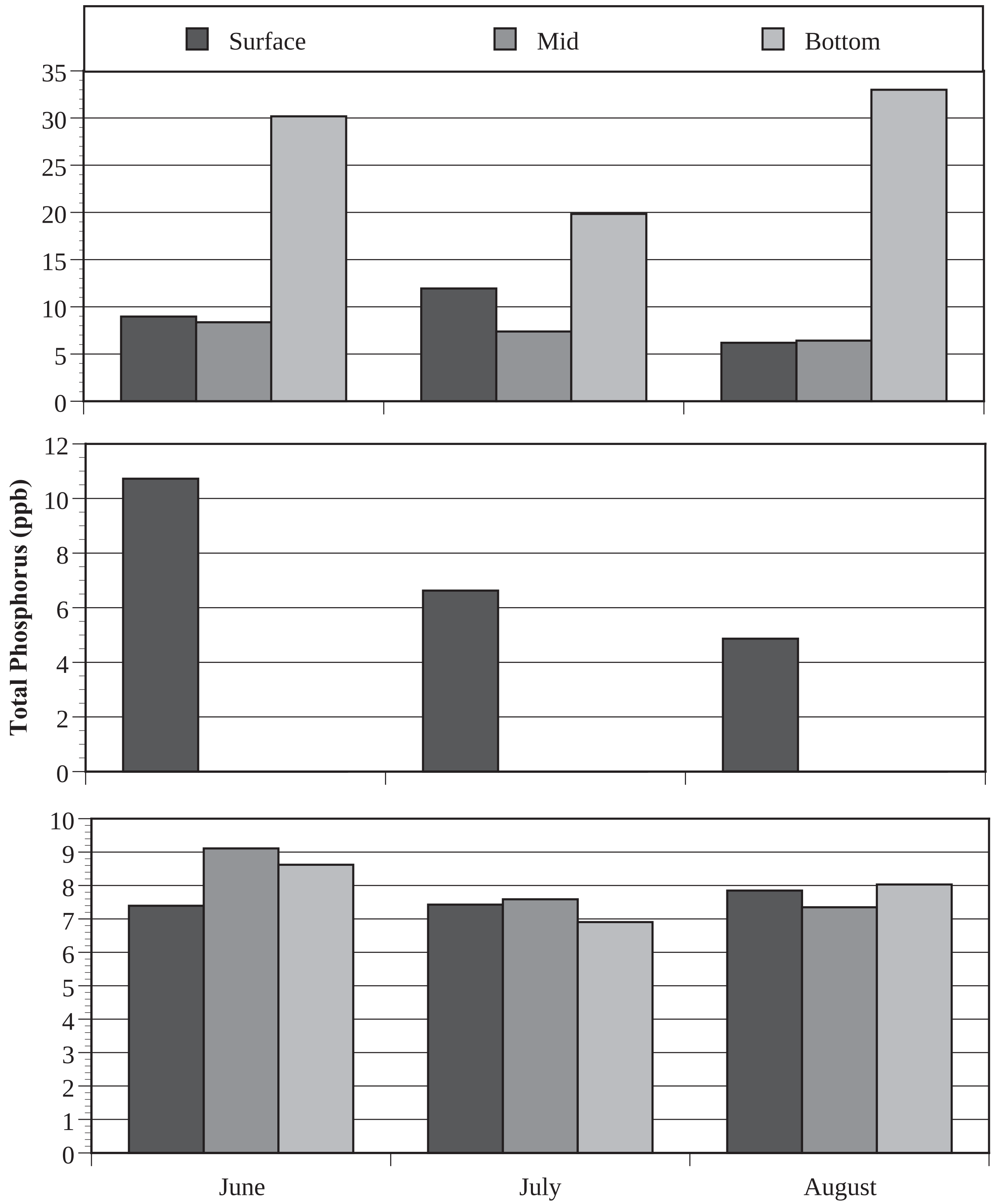

Figure 41. Mean total phosphorus at varying depths for Sites 1, 2, and 3 of Long Pond South as measured by CEAT during the summer of 2007 (see Figure 30 for site locations). Note that the y-axis scale differs for each site location and only surface measurements were taken at Site 2.

Historically, total phosphorus concentrations from surface, epicore, and mid-depth samples have maintained a level similar to the values CEAT obtained (between 5 and 12 ppb), but bottom phosphorus levels have been rising. Bottom total phosphorus concentrations maintained fairly low levels until 1992, but began to increase in the later years, peaking around 57 ppb in 2001 (Figure 42). The phosphorus levels have decreased again since 2001, but have remained higher

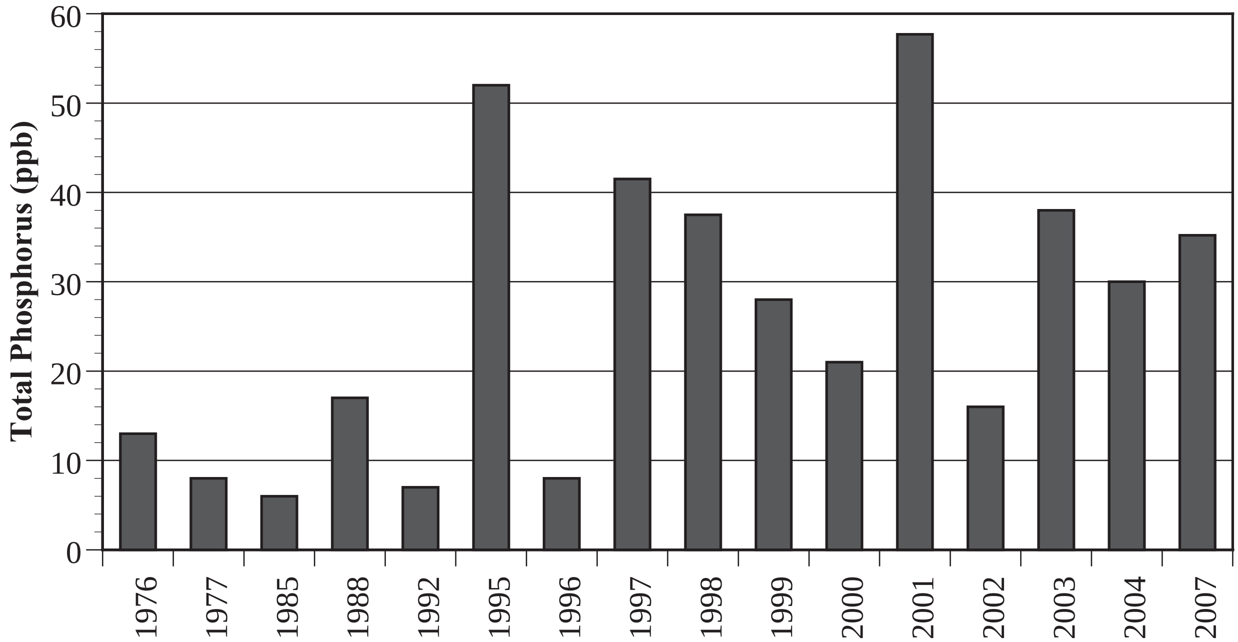

Figure 42. Mean total phosphorus concentrations (ppb) from 1976 to 2007 for the bottom depth of Long Pond South Site 1 (see Figure 30 for site location). Data from 2007 were collected by CEAT, all other data from Maine DEP (PEARL 2007b).

than the 1976 to 1992 levels. High bottom phosphorus concentrations are probably the result of internal loading, suggesting that the bottom waters become anoxic during the summer. High bottom phosphorus concentrations can cause greater eutrophication, a process that increases the amount of anoxic water over time because of the accumulation of organic matter. As phosphorus is released from the sediments, more is available for algal growth, and more oxygen is consumed by decomposers. The increasing concentrations of phosphorus in the bottom layers cause lower water quality throughout the water column.

When comparing the phosphorus samples at the sites sampled on 13-September-07, it is important to compare the site locations with respect to development along the shore (Figure 43). Site 4, located in the northwestern corner of the lake where many tributaries enter the water body (see Figure 30 for site locations), had a surface phosphorus concentration of 6.5 ppb. This concentration was exactly equal to the concentration at Site 5, which was located directly to the south. Sites 6 and 7, which were on the eastern shore of the lake, also had equal surface phosphorus concentrations (6.2 ppb) that were roughly equal to those at Sites 4 and 5 (6.5 ppb). The lack of local effects on phosphorus levels might be explained by diffusion from the high flushing rate of the lake and the fact that the shoreline with the poor buffer is located near the wetland and forested areas, which have natural shoreline vegetation (Figure 17). The phosphorus in Long Pond South is quickly distributed by the flow of water toward Messalonskee Lake (see Long Pond Characteristics: Watershed Description). As water flows toward the southern tip of the lake, the shoreline of wetlands and natural vegetation become a sink for the phosphorus. These areas of natural vegetation help to improve the water quality at the southern tip of Long Pond South.

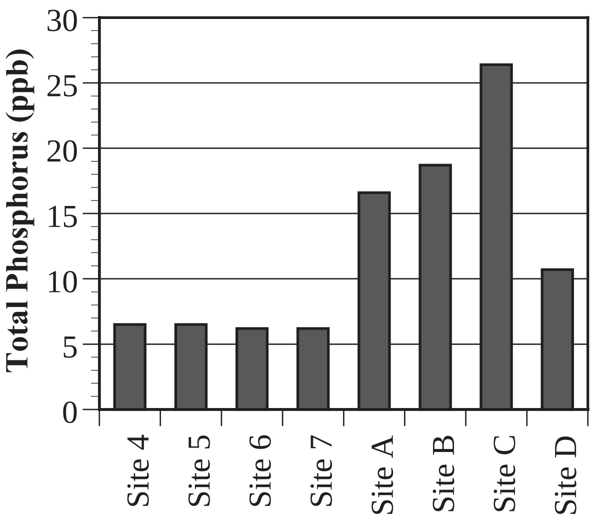

Figure 43. Total phosphorus concentration (ppb) at spot sites measured by CEAT on 13-September-07 (see Figure 30 for site locations). Note that stream sites have higher total phosphorus concentrations than lake sites.

All stream sites had higher total phosphorus concentrations than any of the lake sites (Figure 43). This demonstrates that the increased turbidity and sediments in these streams raise their phosphorus concentrations and help reduce water quality. Because these streams are point sources, they are adding more phosphorus into the lake. They should be carefully monitored and assessed for buffer quality to find methods for reducing their phosphorus impact on the lake.

Biological Parameters

<u>Chlorophyll-α</u>

Introduction

Chlorophyll-*a* is the green pigment in algae that is necessary for photosynthesis (PEARL 2007e). Because the chlorophyll-*a* content positively correlates with the concentration of phytoplankton cells, it is an effective way to estimate the algal biomass of the lake (O'Sullivan and Reynolds 2004**)**. Chlorophyll-*a* actually comprises between 0.5 and 2 percent of the dry weight of algae, and as a result, chlorophyll-*a* measurements can provide an indirect estimate of the trophic state (O'Sullivan and Reynolds 2004).

Methods

Chlorophyll-*a* readings were taken weekly at Sites 1, 2, 3, and A throughout the summer of 2007 from 31-May to 23-August as well as on 13-September-07. Readings at Sites 2 and A were taken at the surface only, but readings were taken every meter at Sites 1 and 3. Long Pond North Site 1 also had a complete chlorophyll-*a* depth profile conducted biweekly from 14-June-07 to 1-August-07. The measurements were collected with a YSI 650 MDS Sonde, which was calibrated with a zero standard of E-pure water before use (see Appendix B). This probe used fluorescence to determine the chlorophyll-*a* concentration at different sites with respect to zero parts per billion (ppb) of chlorophyll-*a*. Historical annual mean concentrations of chlorophyll-*a* at Site 1 were used for comparison (PEARL 2007b).

Results and Discussion

The profile reading at Site 1 shows that higher concentrations of chlorophyll-*a* occur from the surface down to ten meters (Figure 44). Below this level, light becomes limited, making photosynthesis difficult. Since oxygen is a byproduct of photosynthesis, the high concentrations of dissolved oxygen at the surface (Figure 31) correlate with the higher chlorophyll-*a* concentrations. The chlorophyll-*a* profile for Site 1, however, (Figure 44) does not correlate with the oxygen decrease found in the metalimnion (Figure 31**)** since the chlorophyll-*a* is present at this depth. By comparing chlorophyll-*a* and oxygen levels, it is possible to suggest that the oxygen depletion in the metalimnion of Long Pond South is not due to variation in the concentration of algae (see Water Quality: Dissolved Oxygen).

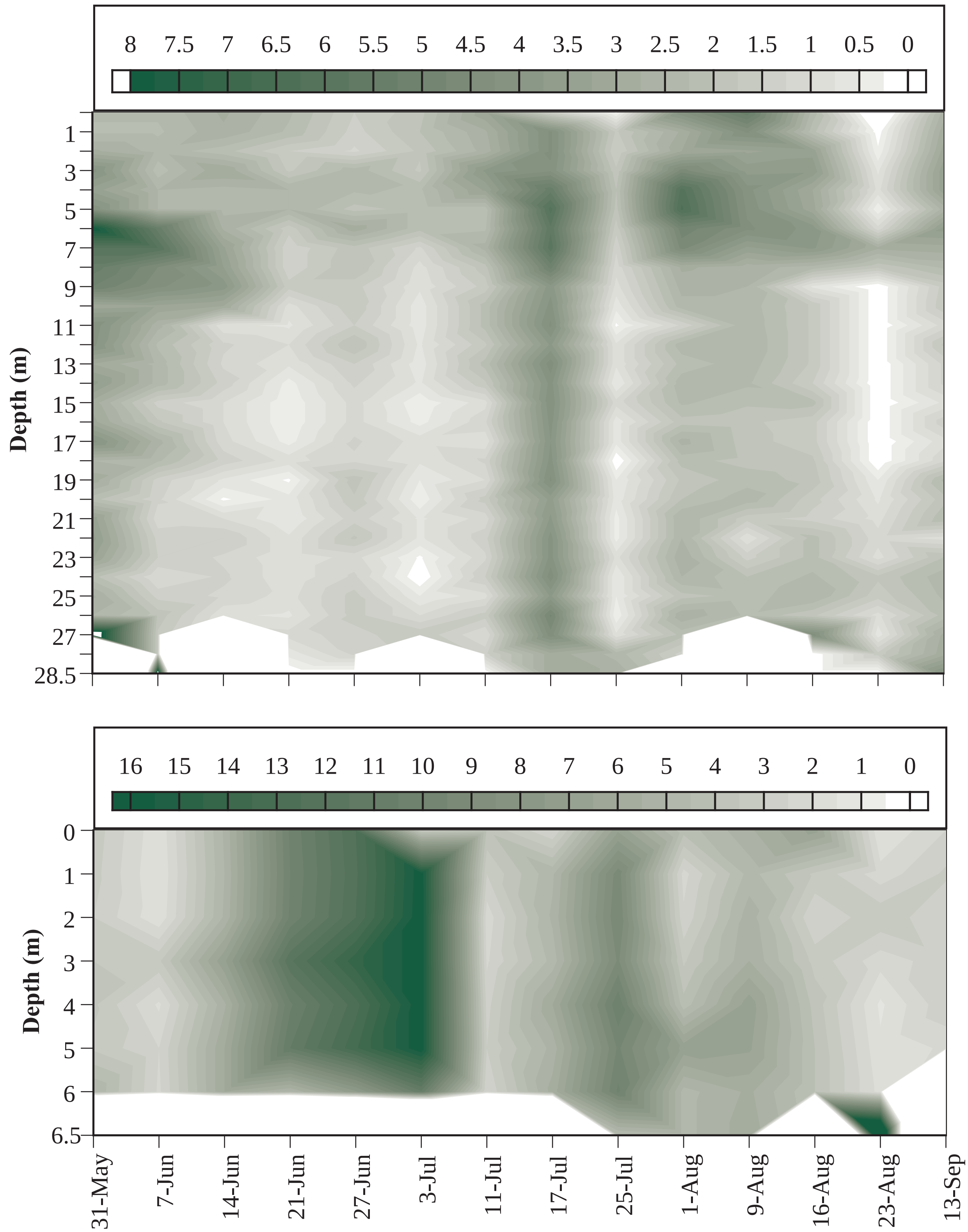

Figure 44. Chlorophyll-*a* (ppb) profile for selected dates in 2007 at Long Pond South Sites 1 and 3 (see Figure 30 for site locations).

At Site 1, the highest chlorophyll-*a* readings were found in late July and early August where warmer temperatures and more turbid bottom waters caused high productivity (Figure 32 and Figure 36). Because Site 3 was fairly shallow, light was able to penetrate to the bottom. This resulted in elevated chlorophyll-*a* concentrations throughout the water column at this site, especially during July. In late July and early August, the chlorophyll-*a* concentration began to resemble to that of Site 1 (Figure 44). This increased concentration at Site 3 could be reflected in the higher true color reading (see Water Quality: True Color). The high concentration of chlorophyll-*a* could also be due to the proximity of Site 3 to the shore and the presence of phytoplankton throughout the water column at this site.

Peak chlorophyll-*a* readings also did not occur right at the surface of the water because of damage to plant cells from ultraviolet sunrays and surface turbulence. Instead, the amount of chlorophyll-*a* peaked a few meters below the surface, where the conditions were more favorable for algal growth. At Site 1, the concentrations peaked from four meters to seven meters, but at Site 3 they remained fairly constant with the depth only being six meters.

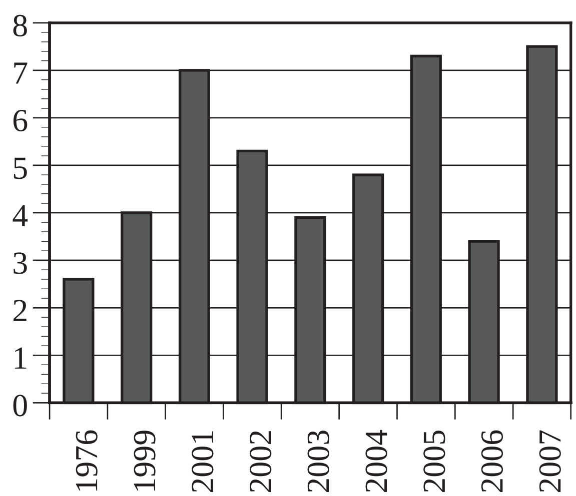

Figure 45. Mean annual chlorophyll-*a* concentrations (ppb) in all available years for Long Pond South Site 1 (see Figure 30 for site locations). Data for 2007 were collected by CEAT, all other data from Maine DEP (PEARL 2007b).

Chlorophyll-*a* concentrations for Long Pond South have been variable over time (Figure 45). In 1976, they did not surpass three ppb, despite none of the values in the 21st Century being below three ppb. It is difficult to discern if this observation represents an increasing trend due to the lack of data in the years between 1976 and 1999, but the values in 2006 were the highest that have been recorded. These data indicate that there has been more algae growth recently than in the past. The values measured by CEAT for 2007 were taken through different methods than the more standardized data taken by the Maine DEP and consequently cannot be used for an accurate comparison to the historical data.

WATER BUDGET

Introduction

A water budget is a series of calculations that account for all the inputs and outputs of water in a lake. The budget generates a flushing rate, which represents the number of times the volume of water in a lake is replaced throughout a year (Chapman 1992). This knowledge can be helpful in determining lake vulnerability to pollution and nutrient loading. Lakes with a low flushing rate tend to retain the same water through the course of the year, allowing pollutants and nutrients to accumulate. Buildup of this material could lead to algal blooms, unswimmable waters, and other problems. On the other hand, the water within a lake with a high flushing rate will have a higher turnover rate, clearing detrimental pollutants, particles and excess nutrients that may build up in a lake with a low flushing rate. This high turnover rate prevents the build up of pollutants and excess nutrients and allows an accelerated recovery from depositional events (George et al. 2007).

Another important insight gained from a lake water budget is the percent input of water that other water bodies contribute to the lake. With this information, the relative impact of major water bodies contributing to the lake can be identified and assessed. For example, Long Pond South receives water directly from Long Pond North, Ingham Pond and two smaller ponds within the Long Pond South watershed (Doloff Pond and Unnamed Pond) meaning any change in water quality of these four water bodies could influence Long Pond South.

Methods

The water budget calculation for Long Pond South includes all inputs of water entering the lake and deducts lake water loss due to evaporation to create a net input (I_{net}) of water into the lake, measured in cubic meters per year and a flushing rate measured in flushes per year. The following formulae were used to calculate I_{net} and flushing rate for Long Pond South (see Appendix C):

I_{net}= (runoff x watershed land area) + (precipitation x lake and ponds area) – (evaporation x lake and ponds area)

Flushing Rate= [(I_{net} Long Pond South) + (I_{net} Long Pond North) + (I_{net} Ingham Pond)]/ (mean depth x Long Pond South surface area)

Although lake water levels constantly change due to droughts and storm events, this study assumed that the amount of water entering the lake was equal to the amount leaving the lake at any given time over the course of the year because lake size was not increasing. I_{net} values of Long Pond North and Ingham Pond were included in the flushing rate calculation because they both flow directly into Long Pond South, making them an indirect part of the Long Pond South watershed. It is important to note that Moose Pond, Doloff Pond, and Unnamed Pond are also located within the Long Pond South but were not directly included in the flushing rate calculation for Long Pond South (see Appendix C). Moose Pond was not directly included because it flows directly into Ingham Pond and not direcly into Long Pond South. Consequently, its contribution to the I_{net} of Long Pond South was included in the I_{net} of Ingham Pond. Because Doloff Pond and Unnamed Pond are part of Long Pond South watershed their areas were added to the precipitation and evaporation portions of the I_{net} equation. By doing this, runoff and storm events adding water and evaporation subtracting water to these ponds were included in the study.

Parameters for the inputs of the Long Pond South water budget were derived from many sources. The runoff coefficient (0.508 m/yr) and mean lake depth (8.4 m) for the I_{net} calculation of Long Pond South were obtained from the Maine DEP vulnerability compilation of Long Pond South (MDEP 2007b). A study of the Lower Kennebec Basin produced an evaporation constant of 0.56 m per yr that was used in this study (Prescott 1969). Mean precipitation was measured over a 10-year period by the National Oceanic and Atmospheric Administration (NOAA 2006) from a recording station located at the Waterville Treatment Plant. Watershed land area was calculated using ArcGIS®9.2 with layers received from Steve Harmon from the Maine DEP (Harmon, pers. comm.). The flushing rates of Ingham Pond and Long Pond North were obtained from the Maine DEP (PEARL 2007b) and CEAT (2007) respectively.

Results and Discussion

Long Pond North contributes the most water to Long Pond South (79%) with land runoff (12%), Ingham Pond (6%), and storm events (3%) also contributing. In contrast, water exits Long Pond South via Belgrade Stream and evaporation. Because most of the water entering

Long Pond South begins in Long Pond North, the quality of water within Long Pond South is heavily influenced by this input. A study of Long Pond North by CEAT (2007) categorized Great Pond as one of the most important inputs to Long Pond North. The position of Long Pond South in the Belgrade Lakes chain suggests that the water quality of Long Pond South is indirectly affected by the water quality of most other Belgrade Lakes.

Although most other Belgrade Lakes have relatively low flushing rates, the flushing rate of Long Pond South was found to be approximately 3.5 flushes per year (Table 8). In an independent study the Maine DEP also found the flushing rate of Long Pond South to be 3.5 confirming the accuracy of the flushing rate (MDEP 2007a). The flushing rate of Long Pond South is much higher than the mean rate of the Belgrade Lakes and of Maine lakes in general (Table 8). Because the water in Long Pond South is replaced at this high rate, high concentrations of nutrient and pollution loading are less likely to occur in the water column and a high cleansing potential is possible. A high flushing rate may be one important reason Long Pond South is generally considered a healthy lake. Despite its recent trend in declining dissolved oxygen, Long Pond South has yet to experience algal blooms.

Table 8. Watershed areas, volumes, and flushing rates for Belgrade Lakes including Long Pond North and South.

Lake	Watershed Area (m^2)	Volume (m^3)	Flushes/year
Great Pond[c]	214,710,014	209,160,000	0.52
Messalonskee Lake[c]	125,084,285	150,249,096	1.59
Long Pond, South Basin	39,190,184	46,191,231	3.61
North Pond[d]	30,920,000	37,148,856	1.36
Long Pond, North Basin[a]	23,161,123	34,922,160	3.79
Salmon Lake[e]	23,126,300	28,410,750	0.58
East Pond[b]	10,598,777	33,848,120	0.29

[a]CEAT 2007, [b]CEAT 2000, [c]PEARL 2007, [d]CEAT 1997, [e]CEAT 1995.

PHOSPHORUS BUDGET

Introduction

This study used a phosphorus loading model to estimate the amount of phosphorus entering the south basin of Long Pond in 2007. The model helped to determine the movement of phosphorus within the Long Pond South watershed and estimate the phosphorus entering from point sources outside the watershed. Categorizing the watershed into different land-use types enabled CEAT to assign export coefficients to each land use type. Export coefficients assess the estimated impact of each land-use type (see Appendix D). Point sources such as Long Pond North and Ingham Pond were also factored into the model as sources of phosphorus. Other sources of phosphorus such as septic systems and sediment release from lake bottom sediments were also taken into account.

The model estimated the phosphorus concentration in Long Pond South and this estimate was compared to test results obtained from water chemistry (see Water Chemistry) to validate the accuracy of the model. Once the model was adjusted by changing coefficients, it was used to project the impact of trends within the watershed on phosphorus levels (see Phosphorus Projections). The phosphorus fluctuation in the lake as development and population size increase is important because anthropogenic activity can lead to cultural eutrophication (see Background: Trophic Status of Lakes).

Methods

The phosphorus model used for Long Pond South was adapted from a study by Reckhow and Chapra (1983), as well as previous studies on regional lakes (CEAT 2005, CEAT 2006, CEAT 2007). The following equation was used to estimate the yearly phosphorus influx into the Long Pond South watershed. W represents the total mass of phosphorus entering Long Pond South in kg per year. To calculate W, export coefficients, soil retention coefficients, septic system abundance and location, sediment release, and point source input were factored into the model.

$$W = (Ec_a \text{ x } Area_{ls}) + (Ec_{ag} \text{ x } Area_{ag}) + (Ec_{mf} \text{ x } Area_{mf}) + (Ec_{cf} \text{ x } Area_{cf}) + (Ec_{df} \text{ x } Area_{df}) + (Ec_w \text{ x } Area_w) + (Ec_{cc} \text{ x } Area_{cc}) + (Ec_{cm} \text{ x } Area_{cm}) + (Ec_{sl} \text{ x } Area_{sl}) + (Ec_{cr} \text{ x } Area_{cr}) + (Ec_{sr} \text{ x } Area_{sr}) + (Ec_s \text{ x } Area_s) + (Ec_{ns} \text{ x } Area_{ns}) + [(Ec_{ss} \text{ x \# capita years}_{ss} \text{ x } (1-SR_1)) + (Ec_{nss} \text{ x \# capita years}_{nss} \text{ x } (1-SR_2))] + (Sd_{lb} \text{ x } Area_{lb}) + PSI_{lpn} + PSI_{ip}$$

Export coefficients, denoted by the Ec term, were derived for various land-use types within the watershed. Each export coefficient corresponds to a different land-use type and its relative phosphorus contribution in kg per hectares per year (see Appendix D Phosphorus Model Equation). The phosphorus input sources included in the model are: atmosphere (a), agricultural land (ag), mixed forest (mf), coniferous forest (cf), deciduous forest (df), wetlands (w), cleared land (cc), commercial land (cm), successional land (sl), camp roads (cr), paved roads including state and municipal roads (sr), shoreline development (s), and non-shoreline development (ns). The export coefficient for each land-use type was multiplied by the area of the corresponding land-use type to obtain the phosphorus contribution (kg per hectare per year) into Long Pond South of each land-use type. The area of the corresponding land-use type for the atmospheric coefficient was denoted by lake surface (ls).

Point sources, soil retention values, and sediment release values were also included in the model. PSI_{lpn} and PSI_{ip} represent the point source inputs from Long Pond North and Ingham Pond, respectively. The soil retention coefficients SR_1 and SR_2 signify the ability of shoreline (SR_1) and non-shoreline (SR_2) soils to sequester phosphorus. Soil retention coefficients are based on a scale from 0 – 1.0 (Reckhow and Chapra 1983). A higher soil retention coefficient indicates that the soil retains more phosphorus and prevents more phosphorus from entering the lake than a lower coefficient, which represents a decreased phosphorus retention capacity. Soil retention coefficients are based on soil phosphorus adsorption capacity, natural drainage, permeability, and slope (Reckhow and Chapra 1983). $Area_{ls}$ represents the surface area of Long Pond South. Sd_{lb} represents the amount of phosphorus released from sediments at the bottom of Long Pond South, and $Area_{lb}$ represents the surface area of the lake bottom. The surface area of Long Pond South, the surface area of the lake bottom, and the areas for the land-use types were obtained using ArcGIS®9.2 (see Land Use Patterns).

To calculate the input of phosphorus from septic systems, the impact from shoreline and non-shoreline septic systems were each calculated separately and the resulting values were added together. The export coefficient for shoreline septic systems was multiplied by the number of capita years for shoreline residences and by one minus the coefficient value for shoreline soil retention. The same equation was used to find the phosphorus contribution value for non-shoreline septic systems.

The term “capita year” defines the number of people inhabiting a house multiplied by the number of days per year that the house is occupied. Based on a 2000 census, the estimated mean ($\pm$ SE) was 2.6 $\pm$ 1.4 people per household (pph) in Mount Vernon, Rome, and Belgrade (Najpauer, pers. comm.). Year-round homes are occupied for more days per year than seasonal homes. This longer occupation period implies that the septic systems of year-round homes generally are used more than seasonal homes. Year-round homes can have a higher per capita year value than seasonal homes. As a result, year-round homes contribute a greater amount of phosphorus to the lake than seasonal homes in general. This greater phosphorus contribution is contingent upon the proximity to the water of a certain residence, the quality of the septic system, and the actual number of residents of a particular residence. Year-round and seasonal residences were estimated to be occupied for 355 and 95 days of the year, respectively. In the Long Pond North watershed, which encompasses the towns of Belgrade and Rome, the mean number of pph was 2.54 in 2007 (Najpauer, pers. comm.). Year-round and seasonal residences were occupied for approximately 355 and 95 days of the year in Long Pond North. The year-round occupation period of Long Pond South is similar to the year-round periods of surrounding watersheds (355 days). The occupation period for seasonal residences in Long Pond South is higher than some ponds in the area (East Pond, 90 days) and similar to others (Great Pond, 95 days) (CEAT 2000, CEAT 2007).

High, low, and best estimates of export coefficients were assigned to each land-use type by assessing the ability of the land to retain phosphorus as water drained into the lake and the relative phosphorus contribution of each land-use type. High and low estimates were used to derive confidence intervals, which help compensate for possible error resulting from natural fluctuations and estimation. The best estimate coefficients were what CEAT believed to be the best representation of phosphorus contribution for each land-use type. The coefficients were based on a phosphorus loading model by Reckhow and Chapra (1983), past studies on local watersheds (CEAT 1995, CEAT 2003, CEAT 2005, CEAT 2006, CEAT 2007), and the Total

Maximum Daily Load Reports for Long Lake (MDEP 2005a), Togus Pond (MDEP 2005b), and Wilson Pond (MDEP 2007a).

The following formulae, from Reckhow and Chapra (1983), facilitated the calculation of atmospheric and land-use phosphorus input into Long Pond South (P):

$$q_s = Q_{total} / A_s$$

$$L = W/A_s$$

$$P = L/(11.6+1.2q_s)$$

Annual atmospheric loading (q_s) in m per yr was calculated by dividing the total volume of inflow (Q_{total}) in m^3 per year by the lake surface area (A_s) in m^2 (see Water Budget; Appendix D). L is the annual areal phosphorus loading in kg per hectare per year and is calculated by dividing the high, low, and best phosphorus loading values (W) by (A_s) lake surface area. Dividing L by the settling velocity of phosphorus ($11.6+1.2q_s$) gives total phosphorus concentration (P) in parts per billion (ppb).

Results and Discussion

The phosphorus loading model predicted a phosphorus range of 1,637 kg per year to 3,222 kg per year entering Long Pond South from external sources and non-point sources within the watershed, with a best estimate of 2,039 kg per year. When sediment release (internal phosphorus loading) was considered, the model predicted a range of 1,691 to 3,762 kg per year of phosphorus entering the lake from internal sources, external sources, and non-point sources within the watershed, with a best estimate of 2,363 kg per year. According to the model, the best estimate for total phosphorus concentration was 8.9 ppb, with a range of 6.4 to 14.1 parts per billion (ppb). The best estimate of the total phosphorus concentration from the model corresponds with the mean phosphorus concentration determined for epicore samples collected by CEAT from 31-May-07 to 13-September-07 at Site 1 (mean $\pm$ SE; 9.1 $\pm$ 3.0 ppb, n= 11).

The phosphorus released into Long Pond South came from runoff, point-source inputs, and sediment release. Runoff from land within the watershed is defined as non-point source loading within the watershed. Point-source inputs are considered external phosphorus loading and sediment release is a form of internal phosphorus loading. External loading contributed 54 percent (1,280 kg), non-point source loading within the watershed contributed 32 percent (759 kg), and internal loading (sediment release) contributed 14 percent (324 kg) of the phosphorus entering Long Pond South.

Two point-source inputs, Long Pond North and Ingham Pond, contribute 54 percent (1,280 kg per year) of the total phosphorus entering Long Pond South. Long Pond North contributes 90 percent (1157 kg) of the phosphorus entering Long Pond South from point sources and 49 percent of the total phosphorus entering Long Pond South from all sources. Ingham Pond, influences Long Pond South in a similar manner to Long Pond North, but to a lesser extent since Ingham Pond is much smaller than Long Pond North. Ingham Pond is located in the south end of Long Pond South near where the water flows into Belgrade Stream. Water coming from Ingham Pond does not remain in Long Pond South for a long period of time before it is flushed out of the lake.

Runoff contributed 32 percent of the total phosphorus entering Long Pond South. Of all of the sources of runoff, agricultural land, atmospheric input, successional land, and mixed forest contributed the greatest amounts of phosphorus (Table 9).

Agricultural land, including cropland, pasture, and tree farms, contributed the largest quantity of phosphorus to Long Pond South via runoff (126 kg). Agricultural land represents 7.6 percent of the total watershed area. Agricultural land contributes phosphorus because crop fertilizers contain phosphorus to foster growth, not all of which can be used by the crops. Agricultural land is traditionally planted in rows with spaces between that lack plants. This lack plants and their root systems in most agricultural lands prevents runoff water from slowing. Since the runoff is not slowed by vegetation and nutrients are not adsorbed by roots, relatively high amounts of phosphorus can flow into the lake from this agricultural land, as the high export coefficient (0.45 kg per hectare per year) indicates (Table 9).

Atmospheric input accounted for 12 percent (88 kg) of phosphorus loading from runoff because although the coefficient value is relatively low (0.17 kg per hectare per year), the water body comprises 9.6 percent of the watershed. The combined area of Dolhov Pond and Unnamed Pond was added to the watershed area. Dolhov and Unnamed Pond are located in the northwest corner of the lake (see Watershed Description). Phosphorus can be deposited into the lake by precipitation once it is released into the atmosphere (Reckhow and Chapra 1983). Woodstoves and industrial production are two of the many processes that release phosphorus into the air

(Reckhow and Chapra 1983). Due to these processes of phosphorus accumulation from the atmosphere, the total amount of phosphorus deposited into Long Pond South is high (Table 9).

Successional land contributes 12 percent (94 kg) of phosphorus entering the lake via runoff. Successional land has a relatively high export coefficient (best 0.3 kg per hectare per year) and it represents 6 percent of the Long Pond South watershed area. Successional land encompasses reverting land and regenerating land. Both of these land-use types do not have much undergrowth to slow runoff and prevent sediment from moving into lake water, so in a similar manner to agricultural land, successional land can contribute phosphorus into the lake (Table 9).

Table 9. Low, best, and high estimates of percent contribution of phosphorus for all land-use types within the Long Pond South watershed based on the Phosphorus Model (see Phosphorus Budget: Results and Discussion). Land-use types are rated from highest to lowest contribution. Calculations omit phosphorus loading from point sources. Values reflect the amount of phosphorus input for each land use type relative to the total phosphorus load.

Land Use Type	Low Estimate (%)	Best Estimate (%)	High Estimate (%)
Agriculture	25.9	21.9	21.9
Atmospheric	17.4	11.6	11.6
Regenerating land	13.2	12.4	14.6
Mixed Forest	12.3	13.0	13.0
Deciduous Forest	5.9	6.9	4.9
Non-shoreline Development	5.4	5.1	8.0
Cleared Land	5.3	5.0	5.2
Shoreline Septic Systems	3.6	5.1	6.9
Shoreline Development	2.9	3.7	3.5
Non-shoreline Septic Systems	2.2	1.9	2.5
Camp roads	2.0	5.9	5.1
Coniferous Forest	1.7	3.1	2.1
Paved Roads	1.5	2.1	3.9
Commercial Land	0.8	0.4	0.4
Wetlands	0.0	1.7	1.6

Mixed forest contribution accounted for 13 percent (99 kg) of the phosphorus contained in runoff. Mixed forest has a low export coefficient (0.045 kg per hectare per year) but represents 40.9 percent (5, 389 acres) of the watershed area (see Watershed Land-Use Patterns). Mixed forest has significant root structures to slow runoff and adsorb nutrients and sediment from the water. Each hectare of mixed forest contributes a small amount of phosphorus relative to other land-use types per hectare contribution. Since mixed forest comprises such a large area of the watershed, its total phosphorus contribution is high because the small amounts of phosphorus per hectare accumulate (Table 9).

Sediment release was calculated using similar export coefficients as used in Long Pond North (CEAT 2007). Since the north and south basins of Long Pond are the same lake, the sediment composition and the sediment release should be similar. The sediment coefficient ranged from 0.1 to 1.0 kg per hectare per year, with a best estimate of 0.6 kg per hectare per year. These values are low relative to previous studies performed on various anoxic lake sediments, but the calculated total phosphorus concentration estimates of Long Pond South are significantly lower than the lakes in previous studies (Nurnberg 1988, Mattson and Isaac 1999).

Depending on the time of year, wetlands can be a "phosphorus sink" and contribute to the maintenance of water quality. Wetland ecosystems have intrinsic abilities to modify or trap a wide spectrum of water-borne substances commonly considered pollutants or contaminants (Hammer 1993). Wetlands comprise much of the land directly adjacent to Long Pond South (11.9 percent of the watershed) and may prevent phosphorus from different land use types from entering the lake. The export coefficient is the lowest of all coefficients assigned to land-use types within the watershed. With a best estimate of zero kg per hectare per year contribution, wetlands retain phosphorus. Wetlands sequester phosphorus in the myriad of root systems provided by dense grass, shrubs, and other vegetation (see Watershed Land-Use Patterns: Wetlands). Long Pond South has more wetlands than Long Pond North (3,867 acres and 251 acres, respectively), which may help prevent lake water quality from declining due to phosphorus increase. These wetlands should be protected and preserved to maintain lake water quality.

Long Pond is the second to last lake in the Belgrade Lakes chain, and previous studies have shown that the phosphorus concentration in Long Pond North is influenced by phosphorus loading from Great Pond because the two lakes are connected (CEAT 2007). Additionally, East Pond, North Pond, and Salmon Pond flow into Great Pond and these are all lakes on the impaired waters list (MDEP 1996). These lakes have experienced algal blooms and have higher phosphorus levels than Long Pond South (9.1 ppb) or Long Pond North (7.8 ppb) (CEAT 2007). As a result of phosphorus loading from point sources, Great Pond has experienced a decline in lake health as characterized by *Gloeotrichia echinulata* blooms and an increased phosphorus concentration (see Long Pond Characteristics: *Gloeotrichia*). Long Pond South may experience a similar increasing trend in phosphorus concentration if the water quality of Long Pond North continues to decline. Monitoring the water quality of Long Pond North, Great Pond, and the other lakes in the Belgrade Chain is critical in maintaining the health of Long Pond South, since the six lakes in the chain are connected.

FUTURE PROJECTIONS

POPULATION TRENDS

Historic Population Trends

Census data from the University of Maine (2001) indicate that the Towns of Belgrade, Mount Vernon, and Rome have all experienced population growth from the beginning of the 20th century to today, particularly since 1930 (Figure 46). The population fluctuated between 1930 and 1970 in both Mount Vernon and Rome. Over this period the population varied between highs of 755 in Mount Vernon and 420 in Rome to lows of 596 and 362 respectively (University of Maine 2001). On the other hand, Belgrade experienced continuous population growth throughout this time, though not at a constant rate. All three towns experienced rapid population growth in the period between 1970 and 1980 (Figure 46). In Belgrade alone, the population of young adults (22 to 34 years old) increased by 141 percent during the 1970s (Town of Belgrade 1998). This surge in population size can be partly explained by a national trend of Americans moving out of cities to live in suburban and rural areas. People moved to Belgrade in particular to enjoy low taxes, beautiful scenery, and abundant land in close proximity to Augusta and Waterville (Town of Belgrade 1998). Currently, a growing number of individuals and couples approaching retirement are converting seasonal homes into year-round homes in Mount Vernon (Marble, pers. comm.). Conversion does not increase the number of houses in the watershed, but it does add to the number of year-round residents. Population growth in turn leads to an increase in activities that are potentially harmful to the lake, such as septic system use, and continued growth will pose threats to Long Pond South in the future.

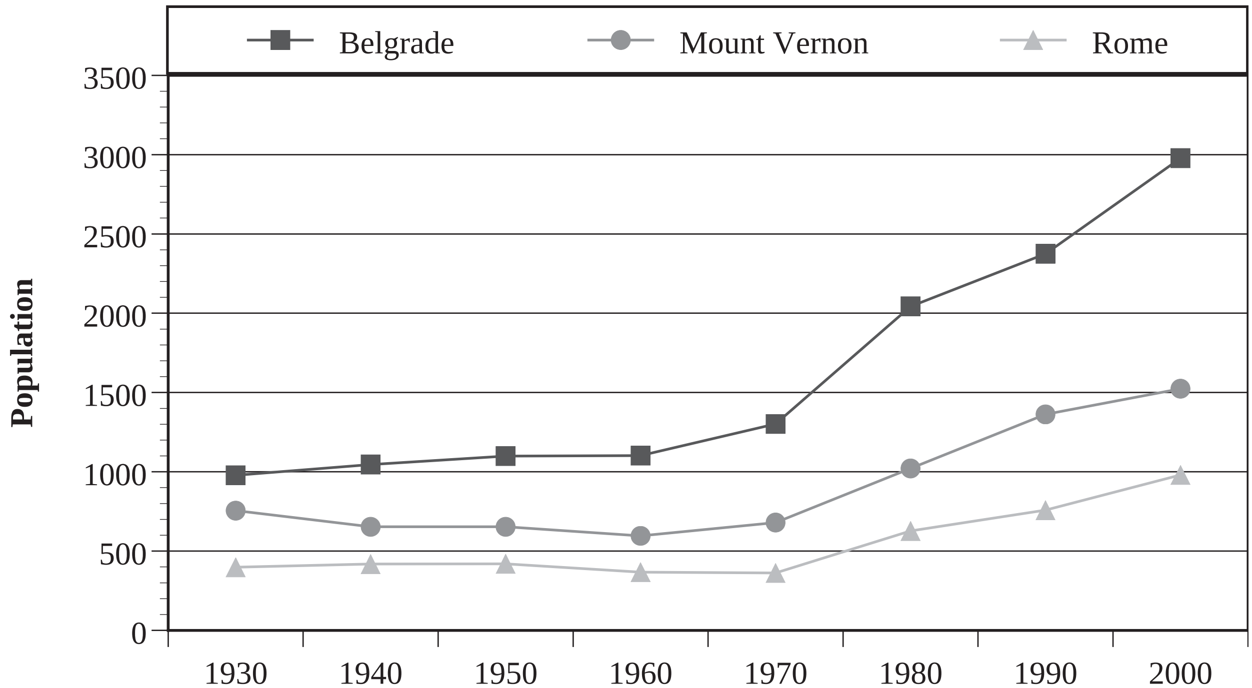

Figure 46. Population counts from the Census Bureau of the United States Department of Commerce for the Towns of Belgrade, Mount Vernon, and Rome, Maine for the years 1930-2000 (University of Maine 2001).

Future Population Projections

The same qualities that attracted residents to the Belgrade Lakes area in the past 40 years continue to draw new people to the area. As people search for shoreline land in Maine for second homes or a place for retirement living, they often begin looking in the Sebago Lakes Region in southern Maine and continue their search moving northward if property is unavailable or too expensive (Najpauer, pers. comm.). The number of available lots in the Long Pond South watershed will almost certainly decrease in the next few decades as more people move to the area. Generally, shoreline lots are the first to be developed, and development then continues away from the lakefront (Cole, pers. comm.). Some residents fear that these quiet lakeside towns will resemble a bustling suburb of Augusta by 2050 (Marble, pers. comm.). Data from the State of Maine Planning Office (Najpauer, pers. comm.) predict a 65 percent increase in the population from 5482 to 8460 for the Towns of Belgrade, Mount Vernon, and Rome between 2000 and 2030 (Figure 47). The three watershed towns will undoubtedly grow in population numbers, necessitating construction of new homes on undeveloped land.

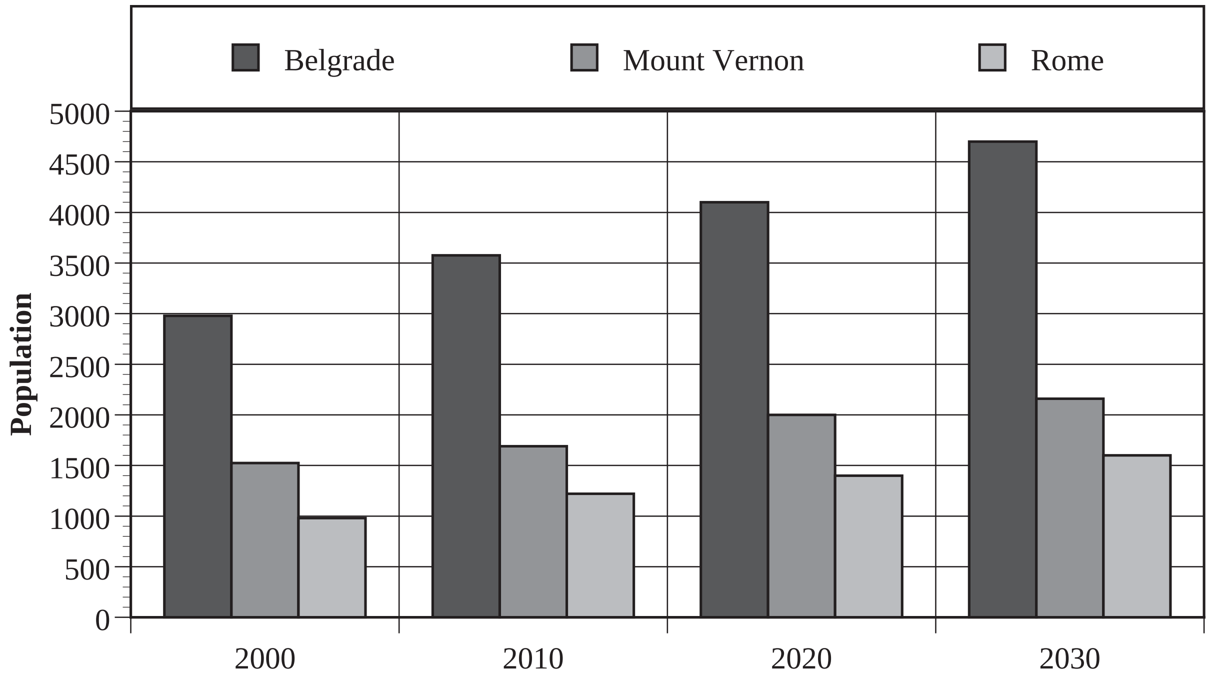

Figure 47. Population predictions for Belgrade, Mount Vernon, and Rome (Najpauer, pers. comm.).

GENERAL DEVELOPMENT TRENDS

New home and road construction will be necessary to facilitate growing populations in Belgrade, Rome, and Mount Vernon. The development that has occurred on Long Pond in the North Basin is likely to be continued in the South Basin. Additionally, the number of camps converted to year-round homes is likely to increase, as more homeowners reach retirement age.

There are roughly 50 shoreline lots available for development in the watershed. An estimate of the number of available shoreline lots was obtained by subtracting the total number of lakefront houses in the watershed from the total number of lakefront lots as indicated by tax maps of Belgrade, Mount Vernon, and Rome. Of the property available for development, there are approximately 16 shoreline lots are available in Belgrade on the eastern shore opposite Site 6 and approximately 31 shoreline lots are available in Mount Vernon on the western shore south of

Site 5 (Figure 30). It is possible that some of the available lots could be subdivided and developed into areas with multiple houses, because several of the shoreline lots are large. In Belgrade, there are at least four lots along the northeast corner of Long Pond South and at least two lots further south along the shore that could potentially be subdivided. There are also larger lots on the non-shoreline side of Timber Point Road with a lakefront common access point in this area. The lots could be subdivided and new residents may be inclined to build in this area because of the proximity to the lakeshore. Development along the lakeshore in Mount Vernon may be more limited because much of this land is wetland as indicated by the current tax maps.

Additional development is also likely within the Belgrade watershed. In the period between 1988 and 1998, the growth rate of Belgrade was twice that of the entire State of Maine (Town of Belgrade 1998). The 1998 Comprehensive Plan explains that development in the town during that time was scattered, and no open space was conserved to compensate for the loss of undeveloped land. The Plan expressed concern that this type of development would eventually change the town from a rural to a suburban community, and that population growth would create environmental problems such as reduced water quality (Town of Belgrade 1998). Ten years later, the town continues to experience population growth and past concerns related to this pattern still apply today. Within Belgrade, there are a number of non-shoreline areas where development is likely or has already begun. CEAT road surveyors found cleared lots and/or construction vehicles along Murdock Place and Rockwood Drive. Holly Hill Drive appears to be an established subdivision on the Belgrade tax maps; however, CEAT surveyors found construction vehicles and cleared land in this area, indicating that this area will soon be developed.

In Mount Vernon, the number of new homes constructed per year has been declining (Marble, pers. comm.), but the value of new homes is increasing (Figure 48). There are a number of large lots throughout Mount Vernon that could potentially be subdivided and further developed. In some areas, development may be limited by steep elevation changes, the presence of wetlands, and the absence of adequate roads. Also, there are no current plans for new subdivisions or road construction, but rising home values have led to an increase in the conversion of seasonal residencies to year-round residences (Marble, pers. comm.).

In Rome, there is an abundance of available, non-shoreline property; however, it is likely that many of these lots cannot be developed without mitigation because they contain wetlands and/or steep slopes, and have drainage issues. Any available lots without these issues will likely be developed over time, including properties in the Wild Flower Estates subdivision, which falls in the Long Pond South watershed (Najpauer, pers. comm.). There are 255 lots in Wild Flower Estates. CEAT counted only 14 homes in this area, suggesting that more construction is possible. However, development in Rome may be limited as a result of public opinion. Many Rome residents have protested new home construction by refusing to sell land for necessary road widening projects (Najpauer, pers. comm.). State legislation and town ordinances may regulate construction and housing conversion, but they will not eliminate environmental degradation caused by these activities altogether. As long as development continues in the watershed, phosphorus loading in Long Pond South will persist as well.

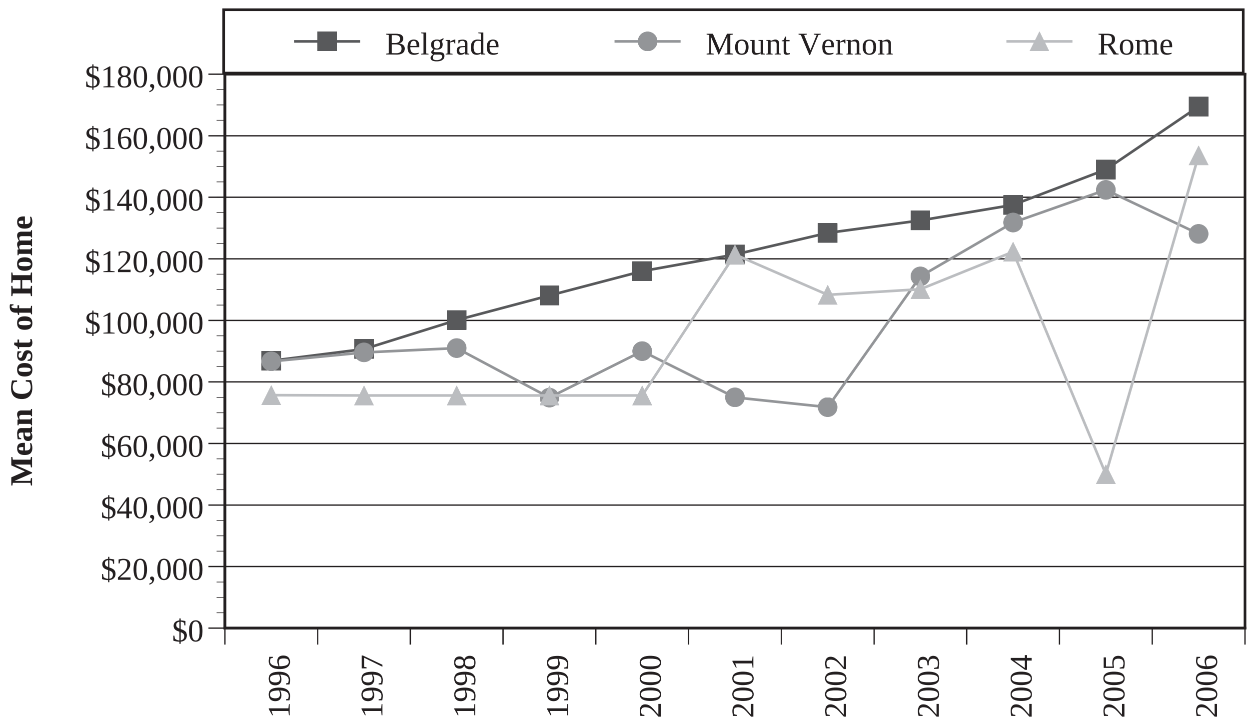

Figure 48. The mean cost of a newly constructed single-family home in the Towns of Belgrade, Mount Vernon, and Rome (City-Data.com 2007).

PHOSPHORUS MODEL PREDICTIONS

Introduction

The CEAT phosphorus model was validated by comparing its total phosphorus concentration value with the actual total phosphorus concentration found through field-testing. With this validation, it is possible to use this model to approximate future phosphorus level through the manipulation of variables within the model.

Methods

Projected land use and population changes based on information gathered by CEAT in Rome, Belgrade, and Mount Vernon were used in conjunction with the 2007 phosphorus model of Long Pond South to forecast future phosphorus levels within the lake. Trends in land development were created first by digitizing 1966 satellite photos of the Long Pond South watershed and then comparing them to a 2003 land use map of the watershed using ArcGIS®9.2. Patterns of development for specific areas and land-use types of the watershed were then extrapolated to create projected land-use changes. Population projections of Rome, Belgrade, and Mount Vernon were obtained from the State Planning Office of Maine (Najpauer, pers. comm.). The population growth model predicted changes in population size after each decade. The change in population from each decade was divided by mean number of people per household (# capita years) to obtain number of houses that would be constructed. A mean ($\pm$ SE) per capita number of 2.6 $\pm$ 1.4 people per household was estimated from 2010 to 2020 and 2020 to 2030, respectively (see Development: Subsurface Disposal Systems). The total number of houses was divided into shoreline and non-shoreline houses based on the current proportion of the watershed. The land area of new lots replaced area that was formerly mixed forest. Land that had been regenerating was labeled as mixed forest due to succession over 10 and 20 years.

Results and Discussion

Land-Use and Development

Using 2010 projections as current population (6,487 people), overall growth between 2010 and 2030 was estimated to be 30 percent (1,973 people) (Maine State Planning Office 2007). Growth from 2010 (6,487 people) to 2020 (7500 people) was 15.6 percent, while growth from 2020 to 2030 showed a 12.8 percent increase (960 people). Based on per capita numbers, this growth will produce 390 new houses by 2020 and 320 additional houses by 2030 for a total of 710 houses. Using the current proportions of 34.5 percent shoreline and 65.5 percent non-shoreline, 135 shoreline units and 255 non-shoreline units would be constructed by 2020. However, 50 shoreline lots are currently available for construction (see Future Predictions: Future Population Trends), limiting the projected 135 shoreline units to 50 units and increasing the 255 non-shoreline units to 340 units. Using these same limitations and proportions for 2030, 320 non-shoreline additional units could be constructed. These numbers may change if lots are subdivided or if lots are bought and designated as conservation sites.

Regardless of the number of subdivisions land would have to be cleared for the construction of new homes. For the purposes of this study it was assumed that the land cleared would be from the dominant land-use type of mixed forest. Based on the number of houses being built and the acreage required to build each house, it was estimated that 132 ha of mixed forest would be converted to residential area by 2020 and an additional 114 ha by 2030. In contrast to mixed forest loss to residential development, some regenerating land will become mixed forest by 2020 and 2030. To account for this the satellite photos of 1966 were compared to the current land-use map of the watershed to determine approximate succession rates (Figure 11). With this comparison it was determined that five percent (16 ha) and ten percent (31 ha) of current regenerating land would become mixed forest by 2020 and 2030, respectively. Shifting land-use trends indicate a net conversion of 116 ha from mixed forest to residential lots by 2020 and an additional 83 ha by 2030.

Phosphorus Budget Projections

The current trend of increasing residential population in the Long Pond South watershed indicates a rise in phosphorus within Long Pond South by both 2020 and 2030. When entered into the Phosphorus Model, the land-use projections produced a low estimate of 6.59 ppb, a high estimate of 15.88 ppb and a best estimate of 9.36 ppb of total phosphorus concentration within Long Pond South by 2020. The model projected a low estimate of 6.79 ppb, a high estimate of 17.34 ppb and a best estimate of 9.74 ppb phosphorus concentration by 2030. These numbers suggest a best estimate increase in phosphorus concentration of five percent by 2020 and ten percent by 2030.

The projected population enlargement implicates increased construction of residential buildings within the watershed, more impervious surfaces, additional septic systems, increasing road area, a net loss of mixed forest, and a constant wetlands area. Each house needs a driveway and access road, which is often gravel, and other impervious surfaces (see Watershed Land-Use Patterns: Residential Areas). Impervious surfaces do not absorb water and increase runoff into the lake that may contribute phosphorus to the lake. Septic systems contribute phosphorus to the lake by leaching of effluent into ground or surface water resources (see Watershed Development Patterns: Subsurface Disposal Systems). Converting mixed forest, which has a low export coefficient (Ec_{mf} = 0.045 kg/ha/yr), to residential lots, which have a higher relative export coefficient (Ec_{sd} = 1.1 kg/ha/yr and Ec_{n} = 0.4 kg/ha/yr), increases overall external land-use phosphorus contribution (see Appendix D). Wetlands are protected by the Wetlands Protection Act (EPA 2007b)**,** which limits development to greater than 250 ft away from wetlands (see Watershed Land-Use Patterns: Wetlands). The export coefficient for wetlands is very low (Ec_{w} = 0 kg/ha/yr) and wetlands retain phosphorus and other nutrients (Hammer 1993). Existing wetlands will continue to trap phosphorus, but will not prevent total phosphorus concentration increase if more land-use types contribute greater amounts of nutrients to the lake.

RECOMMENDATIONS

The water quality of Long Pond South is currently in good condition, but future development within the watershed and especially along the shoreline could result in degradation. Future changes in shoreline development, road construction, recreational activity, and land-use could damage to the water quality of Long Pond South. The Colby Environmental Assessment Team (CEAT) suggests that the following actions be done to help maintain the healthy condition of Long Pond South and prevent future damage to the lake water quality.

WATERSHED MANAGEMENT

Buffer strips/Erosion

The maintenance of buffer strips along the shoreline is crucial to the preservation of water quality in Long Pond South. Approximately 62 percent of shoreline houses have good or acceptable buffers, but additional steps can be taken to improve the remaining buffer strips that are in fair or poor condition. Some of the shoreline houses were built before the Mandatory Shoreland Zoning Act was implemented in 1971, 1974 and as a result, they may not have suitable buffers to protect the lake from nutrient-laden runoff.

- CEAT recommends that homeowners replant native shrubs along the shoreline to restore the natural buffer.
- Homeowners should replant areas of exposed soil and visible erosion.
- Homeowners should be advised to avoid the use of fertilizers especially along the shoreline or use phosphorus-free fertilizer.

Roads

Many camp roads within the watershed have erosion problems that contribute to additional phosphorus entering Long Pond South. These problems should be corrected in a timely matter. To help prevent future erosion and potential phosphorus loading, camp road maintenance is essential.

- Proper maintenance includes periodic re-grading of the road surface, removing berms, filling rutted areas, and clearing debris from ditches and culverts.
- Regular maintenance of camp roads will benefit camp-owners as well as help prevent phosphorus loading due to erosion.
- Development should be planned in ways that minimizes the number of new roads that are required in Belgrade, Mount Vernon, and Rome.
- New roads should be constructed with proper drainage structures to minimize phosphorus inputs from erosion.

Septic Systems

CEAT recommends that current homeowners continue to monitor and maintain their septic systems. Many of the grandfathered septic systems in the watershed have been replaced because of the concern of responsible homeowners, which has reduced the potentially damaging effects of malfunctioning systems.

- Belgrade, Mount Vernon, and Rome should set a goal for upgrading all remaining grandfathered septic systems in the watershed, giving priority to the replacement of those along the shoreline.
- Old septic systems should be phased out as soon as possible before new development increases the potential nutrient loading in the lake.

Land-Use

Increased development in the Long Pond South watershed is highly likely given the historic population trends and future projections for the Belgrade Lakes region. As development in the watershed increases, phosphorus levels within the lake will increase if growth is not properly managed. Mount Vernon, Belgrade, and Rome should consider water quality and phosphorus loading when developing new regulations.

- Builders and planners should continue to consider phosphorus mitigation strategies for new construction.
- Builders should continue to use effective silt barriers during construction to reduce phosphorus inputs due to erosion.
- Builders should be especially prudent near wetlands and close to the shoreline because construction in these areas can increase phosphorus loading.
- The natural beauty and quiet, rural character of the towns are highly valuable. Residents should strive to protect these unique traits from the negative consequences of development.

IN-LAKE MANAGEMENT

Recreation

Recreation is an important factor in the protection of Long Pond South because it draws seasonal visitors to the area and reminds people about the value of good water quality. Fishing is a popular recreational activity, but the local fisheries may be threatened by declining water quality, especially dissolved oxygen levels. The Long Pond public boat ramp near Castle Island is a prime site of accidental introduction of invasive plant species and erosion. The Belgrade Regional Conservation Alliance (BRCA) has been crucial to the invasive species prevention effort in Long Pond South by conducting frequent surveys, lake inspections, and public education.

- The watershed towns should preserve Long Pond South as a recreational resource with managed fish stocking, invasive species control, and habitat preservation.
- The Belgrade Regional Conservation Alliance should continue their good work of educating boaters about invasive species. BRCA should continue to check outboard motors and boats for invasive plant species that can potentially damage the Long Pond South ecosystem.
- Continue to raise public awareness of the issue, both at the boat ramp and in the surrounding communities.

Water Quality

The declining water quality of other lakes in the Belgrade Lakes Region indicates the potential for similar degradation of Long Pond South. As Long Pond South approaches mesotrophic status, there is concern about maintaining the current condition of the lake and preventing additional nutrient influx. Approximately 79% of the water in Long Pond South comes from Long Pond North, which creates a strong link between these two lakes.

- To maintain the water quality of Long Pond South, Long Pond North must continue to be monitored periodically and maintained at the same standards.
- This recommendation also applies to Great Pond and lakes in the upper chain because the low levels of dissolved oxygen and increased presence of *Gloeotrichia echinulata* in recent years may threaten water quality in Long Pond North and South.
- Environmental professionals and volunteer lake monitors should continue to watch the dissolved oxygen levels in the Long Pond South metalimnion to gain an understanding of the cause of this problem.
- Phosphorus loading should continue to be monitored, especially in the hypolimnion, to be sure that changes in the Long Pond South watershed are not negatively impacting the water quality of the lake.

COMMUNITY AWARENESS AND EDUCATION

The Belgrade Lakes Association has already made significant strides in protecting Long Pond South. Because all of the lakes are connected, coordination among lake associations is essential to improve the water quality of every lake in the Belgrade Lakes region. CEAT encourages the Belgrade Lakes Association to continue making strong alliances with the other lake associations to help improve lake water quality.

- The Belgrade Lakes Association should continue to work with the Conservation Corps in hiring high school students and summer employees in their work mitigating phosphorus loading into the lake, as well as continue to hold community awareness demonstrations.

- Watershed community members should be encouraged to join in the Belgrade Lakes Association and expand discussion regarding the prevention of future impairments to the water quality of Long Pond South.
- The Belgrade Regional Conservation Alliance should continue their work to unify efforts by area towns and lake alliances to protect local watersheds.

APPENDIX I. WATER QUALITY TESTS FOR LONG POND SOUTH

Physical Tests: Temperature (º C) and dissolved oxygen (ppm) at Site 1. Data were collected by CEAT May – September 2007.

	31-May-07		7-Jun-07		14-Jun-07		21-Jun-07		27-Jun-07		3-Jul-07		11-Jul-07	
Depth (m)	**Temp.**	**DO**	**Temp.**	**DO**	**Temp.**	**DO**	**Temp.**	**DO**	**Temp.**	**DO**	**Temp.**	**DO**	**Temp.**	**DO**
0	-	-	-	-	-	-	-	9.4	-	-	21.0	9.0	21.4	8.3
1	13.3	17.1	17.1	11.4	19.2	10.5	21.2	9.9	22.9	8.1	21.0	9.1	21.3	8.3
2	10.3	16.7	17.1	11.1	19.1	10.2	21.1	9.9	225	8.2	20.7	9.2	21.3	8.2
3	10.3	16.2	17.0	11.0	19.0	10.2	21.0	9.8	21.6	8.2	20.6	9.2	21.3	8.2
4	10.4	15.7	16.8	11.0	18.7	10.2	20.9	9.8	20.1	8.2	20.6	9.2	21.1	8.2
5	10.7	14.5	16.8	10.8	16.5	10.3	18.8	10.0	19.4	8.2	20.5	9.2	21.0	7.9
6	11.1	12.8	13.5	11.4	14.8	10.6	15.1	10.5	17.0	8.1	17.0	8.9	18.2	6.9
7	11.2	11.3	11.9	11.5	12.1	11.0	12.8	10.5	12.7	7.7	13.6	8.3	14.6	5.9
8	11.0	10.9	11.3	11.3	11.0	10.4	11.5	10.3	11.7	7.5	12.2	7.8	12.4	5.5
9	10.9	10.5	10.8	11.1	10.8	10.2	10.9	10.2	11.0	7.2	11.3	7.7	11.5	5.7
10	10.8	9.8	10.2	10.8	10.3	9.9	10.5	9.4	10.6	7.2	10.9	7.6	10.9	5.6
11	10.7	9.4	9.8	10.7	9.9	9.9	10.2	9.4	10.3	7.2	10.5	7.6	10.6	5.8
12	10.6	9.0	9.5	10.6	9.4	10.1	9.9	9.5	9.9	7.3	10.0	7.5	10.2	6.0
13	10.6	8.6	8.9	10.7	8.8	10.5	9.3	9.8	9.4	7.7	9.6	7.6	9.7	6.5
14	10.6	8.0	8.2	10.9	7.8	10.8	8.6	10.0	8.3	8.0	8.5	8.1	8.2	7.8
15	10.8	7.1	7.2	11.2	7.2	10.9	7.8	10.3	7.5	8.2	8.1	8.5	7.8	8.2
16	10.8	6.9	7.0	11.2	7.1	10.9	7.2	10.5	7.2	8.3	7.2	8.7	7.4	8.7
17	10.8	6.7	6.9	11.2	6.8	11.0	6.8	10.8	7.0	8.4	7.0	8.7	7.1	8.7
18	10.8	6.6	6.7	11.2	6.7	10.9	6.7	11.0	6.9	8.4	6.7	8.7	6.9	8.6
19	10.8	6.6	6.5	11.1	6.6	10.9	6.6	11.0	6.7	8.3	6.7	8.8	6.7	8.6
20	10.8	6.5	6.5	11.1	6.5	10.8	6.5	10.8	6.5	8.3	6.5	8.8	6.5	8.5
21	10.5	6.4	6.4	11.1	6.5	10.8	6.4	10.7	6.4	8.2	6.4	8.8	6.5	8.4
22	10.5	6.4	6.3	11.1	6.3	10.8	6.4	10.7	6.4	8.1	6.3	8.7	6.4	8.3
23	10.5	6.3	6.3	11.1	6.3	10.7	6.3	10.7	6.3	8.1	6.3	8.6	6.3	8.1
24	10.6	6.2	6.2	11.0	6.2	10.7	6.3	10.7	6.3	8.0	6.3	8.6	6.3	7.5
25	10.5	6.2	6.2	10.9	6.2	10.4	6.2	10.6	6.2	7.7	6.2	8.5	6.2	7.1
26	10.4	6.2	6.2	10.8	6.2	10.2	6.2	10.2	6.2	7.4	6.2	8.3	6.2	5.1
27	6.7	6.1	6.1	10.5	-	-	6.1	9.8	6.1	7.1	6.1	8.2	6.1	4.1
28	-	-	6.1	9.9	-	-	-		6.1	6.4	-	8.0	6.1	3.9
28.5	-	-	6.1	9.2	-	-	6.3	2.6	6.1	1.2	-	3.1*	6.1	0.1

APPENDIX I (continued)
Temperature and DO at Site 1 17-July-07 through 13-September-2007.

	17-Jul-07*		25-Jul-07*		1-Aug-07*		9-Aug-07*		16-Aug-07*		23-Aug-07*		13-Sept-07	
Depth (m)	**Temp.**	**DO**	**Temp.**	**DO**	**Temp.**	**DO**	**Temp.**	**DO**	**Temp.**	**DO**	**Temp.**	**DO**	**Temp.**	**DO**
0	24.1	8.3	24.4	8.8	27.3	8.1	23.4	8.1	23.4	8.2	21.7	8.2	20.2	10.2
1	23.3	8.3	23.7	8.7	27.0	8.3	-	-	23.3	8.2	21.7	7.9	20.2	10.2
2	23.1	8.2	23.6	8.6	26.6	8.6	23.5	8.0	23.2	8.2	21.7	8.0	20.2	10.2
3	22.8	8.2	23.5	8.6	25.4	9.0	-	-	23.1	8.2	21.7	8.0	20.2	10.2
4	22.2	8.2	23.2	8.5	23.9	9.0	23.4	7.9	23.1	8.1	21.7	8.0	20.2	10.2
5	21.3	7.9	21.2	7.6	21.7	8.2	-	-	23.0	8.1	21.7	8.1	20.2	10.2
6	18.5	6.9	18.8	6.6	19.0	6.7	18.9	5.8	20.7	6.0	21.2	7.6	20.1	10.1
7	15.0	5.9	15.9	5.2	16.1	5.3		-	17.2	4.4	18.9	5.2	19.9	10.1
8	13.1	5.5	13.0	5.2	13.7	4.8	13.5	3.8	14.0	3.4	14.9	3.1	19.1	9.3
9	11.8	5.7	12.0	5.3	12.2	4.7	-	-	12.5	3.5	13.0	2.6	13.7	4.7
10	11.3	5.6	11.4	5.3	11.4	5.1	11.9	3.9	11.7	3.6	12.2	2.7	12.7	2.5
11	10.9	5.8	10.7	5.3	10.8	5.5	-	-	11.2	3.8	11.6	2.9	11.8	2.4
12	10.1	6.0	10.2	5.9	10.3	5.6	10.6	4.7	10.7	4.0	10.9	3.4	11.1	2.5
13	9.3	6.5	10.0	6.6	9.7	6.5	-	-	9.9	5.0	10.0	3.9	10.2	3.2
14	8.5	7.8	8.9	7.4	8.9	7.5	8.6	5.9	8.8	6.5	8.5	5.7	9.1	4.3
15	7.8	8.2	8.1	8.4	8.0	8.6	-	-	8.0	7.4	8.0	6.7	8.2	5.6
16	7.3	8.7	7.3	8.7	7.3	8.9	7.4	7.5	7.4	7.6	7.5	7.2	7.6	6.8
17	6.9	8.7	6.9	8.9	7.0	8.8	-	-	7.1	7.7	7.1	7.6	7.2	7.3
18	6.7	8.6	6.8	8.9	6.8	8.8	6.7	8.5	6.9	8.0	6.8	7.3	7.0	8.1
19	6.6	8.6	6.6	8.9	6.5	8.8	-	-	6.7	8.0	6.7	7.7	6.8	8.1
20	6.5	8.5	6.5	8.8	6.5	8.7	6.6	8.3	6.6	8.0	6.6	7.4	6.6	8.1
21	6.4	8.4	6.4	9.1	6.4	8.7		-	6.5	7.7	6.5	7.3	6.5	7.9
22	6.3	8.3	6.4	8.8	6.4	8.9	6.5	7.8	6.5	7.6	6.5	7.2	6.4	7.8
23	6.2	8.1	6.3	8.0	6.3	8.2	-	-	6.4	7.3	6.4	7.0	6.4	7.5
24	6.2	7.5	6.3	7.7	6.2	7.7	6.3	7.7	6.3	7.0	6.3	6.4	6.3	7.2
25	6.2	7.1	6.3	7.4	6.2	7.1	-	-	6.3	6.5	6.3	5.8	6.3	6.3
26	6.1	5.1	6.2	5.0	6.1	6.5	6.2	6.3	6.2	5.6	6.3	4.8	6.2	5.8
27	6.1	4.1	6.1	4.0	6.1	4.4	-	-	6.1	4.8	6.2	3.5	6.2	4.3
28	6.1	3.9	6.1	2.2	6.1	2.6	-	2.0	-	2.1	6.2	2.0	6.2	1.8
28.5	6.1	0.1	6.2	-	-	-	-	-	-	0.2	-	0.1	6.2	0.1

*readings from separate DO meter

APPENDIX I (continued)

Physical Parameters: Temperature (º C) and dissolved oxygen (ppm) at Sites 2, 3, and A. Data were collected by CEAT May – September 2007.

	31-May-07		7-Jun-07		14-Jun-07		21-Jun-07		27-Jun-07		3-Jul-07		11-Jul-07	
Depth (m)	**Temp.**	**DO**	**Temp.**	**DO**	**Temp.**	**DO**	**Temp.**	**DO**	**Temp.**	**DO**	**Temp.**	**DO**	**Temp.**	**DO**
Site 2														
0	18.3	9.2	17.4	10.9	19.4	9.7	20.3	9.0	24.2	8.6	20.7	-	20.9	-
Site 3														
0	-	-	-	-	-	-	-	-	-	-	20.9	8.6	21.9	8.7
1	16.5	11.1	17.1	10.4	19.2	10.0	21.3	9.7	22.4	8.4	20.9	7.9	21.9	8.7
2	16.0	11.1	16.9	10.3	18.1	10.3	20.9	9.7	22.1	8.3	20.6	7.7	21.9	8.7
3	15.4	11.1	16.9	10.2	17.5	10.4	20.4	9.7	21.0	8.3	20.5	7.6	21.9	8.8
4	14.5	11.4	16.8	10.1	16.7	10.4	18.8	9.9	19.5	8.2	20.5	7.8	21.9	8.7
5	13.5	11.6	16.7	10.1	15.4	10.5	16.1	10.1	19.0	8.2	20.3	7.5	21.8	8.7
6	12.6	11.8	15.8	10.3	-	-	-	-	-	-	16.5	6.0	20.7	8.4
6.5	-	-	-	-	-	-	-	-	-	-	20.9	8.5	21.9	5.9
Site A														
0	17.2	10.8	-	-	19.2	10.6	20.7	8.6	-	8.2	20.8	-	21.0	7.2

APPENDIX I (continued)

Physical Parameters: Temperature (º C) and dissolved oxygen (ppm) at Sites 4-6 and Site B. Data were collected by CEAT 13-September-07.

Depth (m)	Temp.	DO
Site 4*		
0	20.6	6.8
1	20.1	7.2
2	19.8	6.8
3	19.7	6.8
4	19.7	6.8
Site 5		
0	20.8	8.3
1	20.7	8.3
2	20.5	8.3
3	20.3	8.3
4	20.1	8.3
5	20.0	8.3
6	19.9	8.2
7	19.9	8.1
8	19.2	6.2
9	16.2	1.1
10	14.0	0.8

Depth (m)	Temp.	DO
Site 6		
0	20.4	8.4
1	20.3	8.4
2	20.3	8.4
3	20.2	8.5
4	19.8	8.3
5	19.6	8.3
6	19.4	8.2
Site B*		
0	18.0	4.7
0.5	16.7	4.7

*DO converted from % saturation to ppm according to Water Action Volunteers (2006).

APPENDIX I (continued)
Physical Parameters: Turbidity (NTU) and Transparency (Secchi depth (m)) readings at Sites 1, 2, 3, and A on selected dates throughout the summer of 2007 as measured by CEAT (see Figure 30 for site locations).

	31-May	7-Jun	14-Jun	21-Jun	27-Jul	3-Jul	11-Jul	17-Jul	25-Jul	1-Aug	9-Aug	16-Aug	23-Aug	13-Sept
Site 1														
Turbidity														
Surface	-	0.61	0.58	1.07	0.84	0.75	0.82	0.69	0.62	0.54	0.68	0.55	0.69	0.93
Mid	0.89	0.92	0.54	0.55	0.44	0.58	0.57	0.51	1.07	0.49	0.49	0.54	0.50	0.72
Bottom	9.46	2.17	1.18	1.59	3.19	1.02	0.89	11.80	5.27	4.09	3.57	18.20	9.09	11.30
Secchi	6.20	5.70	5.80	5.40	6.55	6.25	5.70	5.80	6.25	6.00	6.30	6.20	-	5.90
Site 2														
Turbidity														
Surface	0.82	-	0.70	0.64	-	0.68	0.73	0.79	0.60	0.61	0.66	0.78	0.54	0.67
Site 3														
Turbidity														
Surface	-	0.57	0.69	1.23	0.77	0.70	0.73	0.67	0.56	0.63	0.64	0.59	0.61	0.55
Mid	0.70	0.68	0.82	0.95	0.79	0.69	0.79	0.78	0.60	0.68	0.80	0.71	0.85	0.66
Bottom	-	1.60	0.77	0.91	0.93	0.89	0.76	0.90	0.71	0.72	0.71	0.72	0.73	0.67
Secchi	6.05	5.90	5.25	-	6.25	5.90	6.00	6.20	6.60	6.50	5.90	-	-	-
Site A														
Turbidity														
Surface	-	-	-	0.76	0.96	1.49	1.41	1.01	1.00	0.89	0.96	0.92	-	1.27

APPENDIX I (continued)

Physical Parameters: Turbidity readings for lake Sites 4-7 and stream Sites B-D as measured by CEAT on 13-September-07 (see Figure 30 for site locations).

	Site 4	Site 5	Site 6	Site 7	Site B	Site C	Site D
Surface	0.89	0.52	0.57	0.47	0.89	1.97	0.75
Mid	-	-	0.59	0.59	-	-	-
Bottom	-	-	1.29	0.65	-	-	-

Physical Parameters: True color (SPU) at sites 1-7 and A-D June through September 2007. Data were collected by CEAT.

Site	14-Jun-07	27-Jun-07	11-Jul-07	1-Aug-07	13-Sept-07
1	1	-	25	-	25
2	28	-	17	-	21
3	19	-	19	-	92
4	-	-	-	-	17
5	-	-	-	-	16
6	-	-	-	-	16
7	-	-	-	-	15
A	29	78	55	27	83
B	-	-	-	-	81
C	-	-	-	-	68
D	-	-	-	-	18

APPENDIX I (continued)

Chemical Parameters: pH at Long Pond South Site 1 May-September 2007. Data were collected by CEAT.

Depth (m)	31-May	7-Jun	14-Jun	21-Jun	27-Jun	3-Jul	11-Jul	17-Jul	25-Jul	1-Aug	9-Aug	16-Aug	23- Aug	13-Sept
0	-	-	-	-	-	6.8	6.5	6.5	6.8	6.3	6.5	7.2	7.2	7.1
1	7.4	6.6	7.1	7.2	7.2	7.0	6.8	6.8	6.8	6.8	6.8	7.3	7.3	7.1
2	7.4	6.9	7.3	7.3	7.3	7.1	6.9	7.0	6.9	7.0	7.0	7.3	7.3	7.1
3	7.3	7.0	7.3	7.3	7.3	7.1	7.0	7.1	7.0	7.0	7.1	7.3	7.3	7.1
4	7.3	7.1	7.3	7.3	7.2	7.1	7.1	7.1	7.1	7.1	7.2	7.4	7.3	7.1
5	7.3	7.1	7.1	7.1	7.2	7.2	7.1	7.1	7.0	7.0	6.8	7.4	7.3	7.1
6	7.2	7.0	7.1	7.0	7.0	6.8	6.9	6.8	6.9	6.8	6.4	7.1	7.3	7.1
7	7.1	6.9	7.0	6.9	6.7	6.7	6.6	6.6	6.6	6.6	6.4	6.7	6.9	7.1
8	7.0	6.8	6.8	6.8	6.5	6.6	6.4	6.5	6.4	6.3	6.3	6.4	6.5	7.0
9	7.0	6.7	6.7	6.7	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.3	6.3	6.5
10	6.9	6.7	6.7	6.6	6.4	6.4	6.3	6.3	6.3	6.2	6.2	6.2	6.2	6.2
11	6.9	6.6	6.7	6.6	6.4	6.4	6.3	6.3	6.2	6.2	6.2	6.2	6.2	6.1
12	6.8	6.6	6.7	6.6	6.4	6.4	6.3	6.2	6.2	6.2	6.2	6.2	6.2	6.1
13	6.8	6.6	6.7	6.6	6.5	6.4	6.3	6.2	6.2	6.2	6.2	6.2	6.2	6.1
14	6.7	6.6	6.7	6.6	6.5	6.4	6.3	6.3	6.2	6.2	6.2	6.2	6.3	6.1
15	6.7	6.6	6.7	6.6	6.5	6.4	6.4	6.3	6.3	6.3	6.3	6.2	6.3	6.2
16	6.7	6.5	6.7	6.6	6.5	6.4	6.4	6.3	6.3	6.3	6.3	6.3	6.3	6.2
17	6.7	6.5	6.7	6.6	6.5	6.4	6.4	6.3	6.3	6.3	6.3	6.3	6.3	6.2
18	6.7	6.5	6.7	6.6	6.5	6.4	6.4	6.3	6.3	6.3	6.3	6.3	6.3	6.2
19	6.7	6.5	6.7	6.6	6.5	6.4	6.4	6.3	6.3	6.3	6.3	6.3	6.3	6.2
20	6.7	6.5	6.7	6.6	6.5	6.4	6.3	6.2	6.3	6.3	6.3	6.3	6.3	6.2
21	6.6	6.5	6.7	6.6	6.5	6.4	6.3	6.2	6.3	6.2	6.3	6.3	6.3	6.2
22	6.6	6.5	6.7	6.6	6.5	6.4	6.3	6.2	6.2	6.2	6.3	6.3	6.3	6.2
23	6.6	6.5	6.7	6.6	6.5	6.4	6.3	6.2	6.2	6.2	6.3	6.2	6.3	6.2
24	6.6	6.5	6.7	6.6	6.4	6.4	6.3	6.2	6.2	6.2	6.3	6.2	6.2	6.1
25	6.6	6.5	6.7	6.6	6.4	6.4	6.2	6.1	6.2	6.2	6.2	6.2	6.2	6.1
26	6.6	6.5	6.6	6.6	6.4	6.3	6.2	6.1	6.2	6.2	6.2	6.2	6.2	6.1
27	6.6	6.5	-	6.5	6.4	6.5	6.2	6.1	6.2	6.3	-	-	6.2	6.1
28	-	6.4	-	-	6.4	-	6.2	6.6	6.1	6.2	-	-	6.1	6.1
28.5	-	6.5	-	7.1	7.3	-	6.2	6.8	6.2		-	-	-	6.2

APPENDIX I (continued)

Chemical Parameters: pH at Sites 2, 3, and A from May–September 2007. All data were collected by CEAT.

Depth (m)	31-May	7-Jun	14-Jun	21-Jun	27-Jun	3-Jul	11-Jul	17-Jul	25-Jul	1-Aug	9-Aug	16-Aug	23-Aug	13-Sept
Site 2														
0	7.2	6.9	6.7	7.0	6.9	6.8	6.7	6.7	6.8	6.7	6.6	6.8	-	7.6
Site 3														
0	-	-	-	-	-	6.9	6.5	6.7	6.4	6.7	7.1	6.8	6.9	7.2
1	7.6	6.7	7.0	6.9	7.1	7.1	6.9	6.9	6.8	6.9	7.1	7.0	7.1	7.1
2	7.5	6.8	7.1	7.1	7.2	7.1	7.0	7.1	6.9	7.0	7.2	7.1	7.2	7.2
3	7.5	6.9	7.1	7.1	7.1	7.2	7.0	7.1	7.0	7.1	7.1	7.2	7.2	7.2
4	7.4	6.9	7.1	7.1	7.0	7.2	7.1	7.1	7.0	7.2	6.9	7.2	7.2	7.2
5	7.4	7.0	7.0	6.9	7.0	7.1	7.1	7.1	7.0	7.1	6.7	7.2	7.2	7.2
6	7.3	7.0	-	6.8	6.9	6.9	7.0	6.6	6.8	6.9	6.6	7.2	7.1	-
6.5	-	-	-	-	-	-	-	-	6.5	6.5	6.4	-	6.8	-
Site A														
0	6.5	6.6	6.7	6.9	6.6	6.4	6.5	6.4	6.5	6.6	6.5	-	-	7.9

Chemical Parameters: Surface pH at Sites 4-7 and B-D on 13-September-07. Data were collected by CEAT.

Site 4	Site 5	Site 6	Site 7	Site B	Site C	Site D
6.2	7.4	7.3	8.3	6.5	5.5	7.1

APPENDIX I (continued)

Chemical Parameters: Conductivity (µS/cm) at Site 1 May-September 2007. Data were collected by CEAT.

Depth (m)	31-May	7-Jun	14-Jun	21-Jun	27-Jun	3-Jul	11-Jul	17-Jul	25-Jul	1-Aug	9-Aug	16-Aug	23-Aug	13-Sept
0	-	-	-	-	-	48	49	49	49	52	53	54	53	55
1	46	46	45	46	48	48	49	48	49	52	53	53	53	55
2	46	46	45	46	48	48	49	48	49	52	53	53	53	55
3	46	46	45	46	48	48	49	48	49	51	52	53	53	55
4	46	46	45	46	48	48	49	48	49	51	52	53	53	55
5	46	45	45	46	48	48	49	48	49	51	52	53	53	55
6	46	46	45	45	48	47	49	48	49	51	52	53	53	55
7	45	45	45	46	47	47	49	47	49	51	52	53	53	54
8	45	45	45	46	47	47	48	47	48	51	52	53	53	55
9	45	45	45	46	47	47	48	47	48	51	52	53	53	56
10	45	45	45	46	47	47	49	47	48	50	52	53	53	55
11	45	45	45	45	47	47	48	47	48	50	51	52	53	55
12	45	45	45	46	47	47	48	47	48	50	51	52	52	55
13	45	45	45	46	47	47	48	47	48	50	51	52	52	54
14	45	45	45	45	47	47	48	47	48	50	51	52	52	53
15	45	45	45	45	47	47	48	47	48	50	51	52	52	53
16	45	45	45	45	47	47	48	47	48	50	51	52	52	53
17	45	45	45	46	47	47	48	47	48	50	51	52	52	53
18	45	45	45	46	47	47	48	47	48	50	50	52	52	53
19	45	45	45	46	47	47	48	47	48	50	50	52	52	54
20	45	45	45	46	47	47	48	47	48	50	51	52	52	54
21	45	45	45	46	47	47	48	47	48	50	51	52	52	54
22	45	45	45	46	47	47	49	47	48	50	51	52	52	54
23	45	45	45	46	48	47	49	47	48	50	51	52	52	54
24	45	45	45	46	48	47	48	47	48	50	51	52	53	54
25	45	45	46	46	48	47	49	48	48	51	51	53	53	55
26	45	45	46	46	48	48	49	49	49	52	52	53	53	56
27	45	46	-	47	49	57	50	49	50	53	-	56	54	57
28	-	46	-	-	50	-	51	81	56	55	-	-	56	58
28.5	-	51	-	106	67	-	63	87	58	-	-	-	-	69

APPENDIX I (continued)

Chemical Parameters: Conductivity (µS/cm) at Sites 2, 3, and A from May to September 2007. Data were collected by CEAT.

Depth (m)	31-May	7-Jun	13-Jun	21-Jun	27-Jun	3-Jul	11-Jul	17-Jul	25-Jul	1-Aug	9-Aug	16-Aug	23-Aug	13-Sep
Site 2														
0	45	45	46	47	49	48	50	48	49	52	53	54	-	34
Site 3														
0	-	-	-	-	-	48	49	49	49	52	53	55	56	59
1	45	47	45	46	48	48	49	49	49	52	53	54	55	57
2	45	47	45	46	48	48	49	49	49	52	53	54	55	56
3	45	47	45	46	48	48	49	49	49	51	53	54	55	56
4	45	47	45	46	48	48	49	48	49	51	53	54	54	55
5	44	47	45	46	48	48	49	48	49	51	53	54	54	55
6	44	47	-	46	48	47	49	48	49	51	53	54	54	-
6.5	-	-	-	-	-	-	-	-	48	51	53	-	56	-
Site A														
0	47	-	46	48	49	49	50	50	50	53	54	-	-	36

Chemical Parameters: Surface conductivity (µS/cm) on 13-September-07 at lake sites 4-7 and stream sites B-D. Data were collected by CEAT.

Site 4	Site 5	Site 6	Site 7	Site B	Site C	Site D
34	34	34	34	42	36	69

APPENDIX I (continued)

Chemical Parameters: Total Phosphorus (ppb) for Sites 1, 2, and 3 on selected dates during the summer of 2007 as measured by CEAT (see Figure 30 for site locations).

	31-May	7-Jun	14-Jun	21-Jun	27-Jun	3-Jul	11-Jul	17-Jul	25-Jul	1-Aug	9-Aug	16-Aug	23-Aug	13-Sep
Site 1														
Surface	5.8	6.1	8.5	10.9	10.5	6.5	8.7	5.9	26.6	--	7.1	9.0	7.2	8.6
Epicore	10.5	11.5	14.0	10.9	13.9	6.0	10.3	8.7	5.3	6.0	6.5	-	5.8	9.2
Mid	8.3	9.0	8.7	8.1	7.7	6.6	12.9	5.3	4.7	7.1	6.2	6.4	6.0	7.2
Bottom	34.5	32.0	20.7	25.3	42.6	10.4*	7.3*	54.4	7.2	23.3	22.1	-	53.6	71.8
Site 2														
Surface	8.9	12.2	14.6	8.0	8.1	8.3	9.7	7.0	-	3.3	3.8	7.5	-	7.1
Site 3														
Surface	9.2	5.7	10.1	7.7	6.1	10.3	10.1	7.6	5.0	7.3	5.9	8.4	9.8	7.8
Mid	6.3	10.6	7.3	9.6	9.0	8.7	10.4	5.6	5.7	9.0	7.0	6.9	6.5	6.6
Bottom	11.0	9.2	8.3	8.8	8.2	6.5	6.6	7.4	7.2	8.0	-	10.1	6.0	8.3

*Bottom may not have been reached due to boat movement

APPENDIX I (continued)

Chemical Parameters: Total phosphorus (ppb) for all lake sites and stream sites sampled on September 13, 2007 by CEAT (see Figure 30 for site locations).

Site:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**A**	**B**	**C**	**D**
Surface	8.6	7.1	7.8	6.5	6.5	6.2	6.2	16.6	18.7	26.4	10.7
Mid	7.2	-	6.6	-	-	23.7	5.9	-	-	-	-
Bottom	71.8	-	8.3	-	-	18.6	7.6	-	-	-	-
Epicore	9.2	-	-	-	-	-	-	-	-	-	-

Chemical Parameters: Total phosphorus (ppb) concentrations for stream Sites E, F, and G as measured by CEAT after rainstorms in the summer of 2007 (see Figure 30 for site locations).

Site:	**E**	**F**	**G**
Single	26.8	70.0	30.0
Continuous	26.9	36.8	20.4

APPENDIX I (continued)
Biological Parameters: Chlorophyll-*a* profile (ppb) for Long Pond South Site 1 as measured on selected dates by CEAT during the summer of 2007.

Depth	31-May	7-Jun	14-Jun	21-Jun	27-Jun	3-Jul	11-Jul	17-Jul	25-Jul	1-Aug	16-	23-	13-Sep
0	2.2	2.2	2.7	2.2	1.4	1.9	3.2	1.5	0.2	4.2	2.4	-0.6	2.6
1	2.8	2.4	2.1	1.5	1.2	2.0	2.7	4.3	1.7	2.8	2.1	0.1	2.9
2	4.1	2.1	3.0	1.7	2.4	1.8	2.6	4.3	1.5	3.0	3.4	0.3	3.1
3	3.4	2.5	2.4	2.5	2.3	1.7	3.8	4.2	1.8	4.6	3.7	0.7	3.4
4	4.2	2.5	2.4	2.5	1.9	2.2	3.3	5.4	2.0	6.1	3	0.9	3.4
5	9.1	5.4	2.7	1.6	2.9	2.1	2.1	6.1	1.9	6.3	3.1	0.3	2.6
6	6.0	6.0	3.3	1.3	1.9	2.1	2.2	5.7	1.6	4.9	3.9	1.1	3.6
7	5.4	4.5	3.5	1.3	2.0	1.2	2.6	5.9	1.3	4.6	3.8	2.8	2.9
8	5.0	4.3	3.9	1.6	1.6	0.9	1.9	5.1	1.1	2.8	2.4	1.8	2.3
9	3.1	3.2	3.0	0.9	1.7	0.8	1.6	3.9	0.9	2.6	0.7	0.0	1.6
10	4.2	2.6	0.8	0.7	1.5	0.6	2.1	4.1	0.6	2.4	1.7	0.0	1.7
11	4.1	2.2	1.3	1.0	2.0	0.6	2.1	4.3	0.2	1.3	1.7	0.0	1.1
12	3.0	2.4	1.2	0.8	1.5	0.7	1.7	3.8	0.8	2.4	1.7	0.0	1.8
13	3.6	2.4	1.4	0.4	1.3	0.6	2.1	4.4	0.8	2.1	1.7	0.0	1.3
14	2.9	1.4	1.0	0.3	1.1	0.7	1.7	4.1	0.5	2.4	1.5	0.0	1.3
15	3.1	1.8	1.0	0.3	1.1	0.3	0.9	4.2	1.1	2.3	2.1	0.0	0.8
16	4.1	2.6	1.1	0.4	1.3	0.4	1.2	4.1	0.6	1.9	1.6	0.0	1.4
17	2.5	2.3	1.4	0.9	1.2	0.9	0.8	4.0	0.6	2.6	1.6	0.0	0.9
18	2.9	1.4	0.7	0.2	1.9	0.8	1.3	4.1	0.0	2.1	1.8	0.0	1.2
19	2.1	1.3	0.2	0.6	1.7	0.5	1.0	4.3	0.5	1.8	1.9	0.5	2.3
20	3.4	1.1	1.0	0.5	1.4	0.3	1.6	3.6	0.6	2.0	1.6	0.7	1.9
21	3.6	1.4	1.5	0.8	1.8	0.7	1.1	3.8	0.4	2.5	1.4	0.9	2.2
22	3.3	1.5	1.2	0.8	1.1	0.7	1.4	4.1	0.4	2.5	2.1	1.1	0.9
23	2.1	1.0	1.3	0.8	1.3	0.2	1.2	4.1	0.9	2.7	2.1	0.9	2.0
24	2.8	1.4	1.2	0.9	1.6	0.0	1.5	4.4	0.5	2.5	2.3	1.8	2.4
25	2.5	1.9	0.8	0.7	1.6	0.5	0.9	3.8	0.5	1.9	2.5	1.6	2.3
26	28.4	1.7	-	1.1	1.4	1.0	1.6	4.8	0.3	2.7	1.8	0.9	2.1
27	-	1.7	-	1.0	1.3	1.7	1.0	4.4	0.8	2.1	4.4	0.6	2.8
28	-	11.4	-	0.0	0.0	-	1.4	2.9	2.4	1.4	-	1.6	2.9
28.5	-	-	-	-	-	-	0.0	2.9	2.7	-	-	-	4.1

APPENDIX I (continued)

Biological Parameters: Chlorophyll–*a* (ppb) profile for Long Pond South Site 3 as measured on selected dates by CEAT during the summer of 2007.

Depth	31-May	7-Jun	14-Jun	21-Jun	27-Jun	3-Jul	11-Jul	17-Jul	25-Jul	1-Aug	9-Aug	16-Aug	23-Aug	13-Sep
0	-	-	-	-	-	2.0	3.9	2.5	2.4	4.2	5.4	6.7	1.5	2.5
1	3.2	1.5	2.3	1.1	1.2	1.4	3.0	4.9	0.4	2.3	4.7	3.4	2.2	3.1
2	3.0	1.6	4.3	2.1	1.6	1.6	2.2	5.1	1.2	2.6	5.3	2.5	3.4	2.5
3	3.5	3.4	4.1	1.8	2.0	1.4	2.4	4.7	1.2	3.4	5.5	3.3	2.2	2.8
4	3.6	1.9	4.7	2.4	1.1	1.8	2.8	6.0	1.1	4.2	6.8	3.8	1.4	2.9
5	3.4	2.5	3.6	2.0	2.6	2.0	3.0	5.2	1.9	6.8	6.6	4.0	1.6	2.1
6	5.0	2.4	-	1.4	2.3	2.3	2.5	5.7	1.4	4.8	5.6	4.0	1.8	-
6.5	-	-	-	-	-	-	3.9	2.5	5.8	4.8	5.8	-	28.5	-