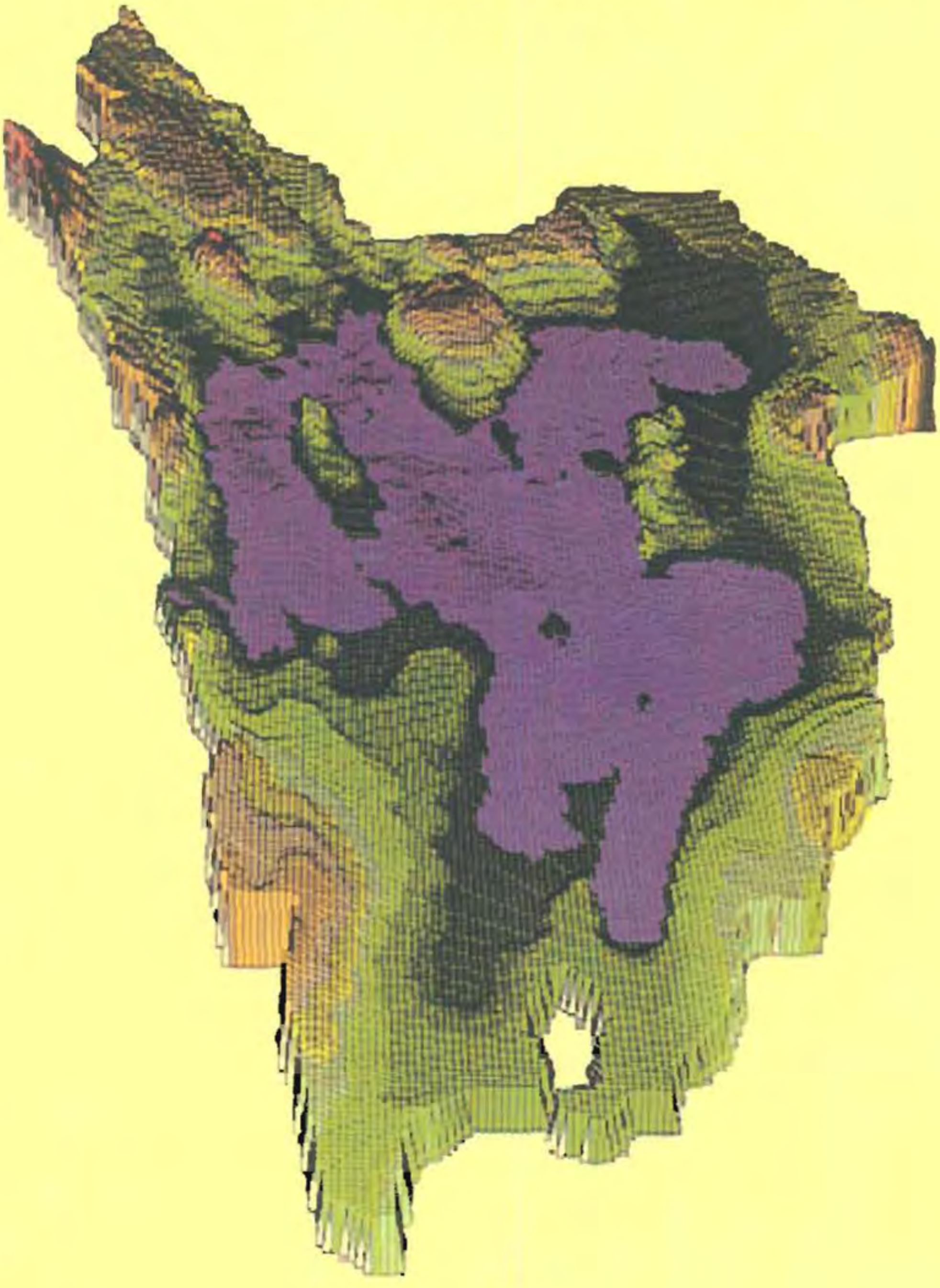
Land Use Patterns In Relation To Lake Water Quality In The Great Pond Watershed

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

Colby Environmental Assessment Team, Colby College

LAND USE PATTERNS IN RELATION TO LAKE WATER QUALITY IN THE GREAT POND WATERSHED



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Problems in Environmental Science
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DATE: May15, 1999

TO: **Report recipients**

FROM: **Professors David Firmage and Russell Cole**

RE: **Class report on Great Pond and its watershed**

We make this report available in the hope that the work contained herein may be of interest or help to others interested in the problem addressed. We realize that some areas of the study could and perhaps should be expanded. We feel confident of the quality of the work done and only wish the time had been available so that the students could fulfill their desire to conduct a more comprehensive study.

This report is the work of students enrolled in the Problems in Environmental Science course (Biology 493) taught at Colby College during the fall semester of 1998. The course is taken by seniors who are majoring in Biology with a concentration in Environmental Science. The students work as though they were an environmental consulting firm. The object of the course is to teach the students how to approach a problem, how to develop a workplan, and what is necessary to implement the plan successfully. As part of this learning process the students use methods and tools they have learned in other courses and they are also introduced to new methodology as needed. Standard methods of analysis are used as well as state of the art instrumentation for any of the original analysis done. The methods used were those approved by EPA and the DEP. However, there are time constraints involved in the study since all requirements for the course must be completed within the fall semester. These constraints mean that much of the new data can only be gathered during the months of September through early November and, typically, that extensive analysis can not be done. Some of the water quality data were gathered during the previous summer and made available to the class for analysis in addition to their fall sampling. Also, in order to teach various techniques and to have the students consider a problem from a number of angles, the project is expanded to more areas than a group might normally take on for a short term project. This means that in some areas we sacrifice some depth for more breadth.

While the class was constrained by time, they have managed to accomplish an amazing amount of work during that period and we are very pleased with the quality of that work! We hope that you find it useful.

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INTRODUCTION

GENERAL NATURE OF THE STUDY

Lakes are natural resources, which have many effects on the land surrounding them. They support adjacent communities by providing water and regulating temperatures, helping to define the surrounding ecosystem, and serving as sources of drinking water as well as recreation. The prolonged presence of human activity in a watershed can disturb the physical and chemical cycles of the lake and its surrounding ecosystems (Henderson-Sellers and Markland 1987).

Over time, lakes undergo a process called eutrophication, a natural aging process during which the nutrient levels increase and dissolved oxygen levels decrease (Smith and Smith 1998). As the lake ages or becomes more eutrophic, organic material gradually collects in the lake basin. For a period of time, the increased organic matter raises the nutrient level in the lake and causes higher productivity. As the lake becomes more eutrophic, dissolved oxygen (DO) levels fall because of the high levels of organic material decomposing in the water. Organisms that cannot live under low dissolved oxygen levels begin to die. Over time, as DO levels continue to drop the diversity and overall health of the lake decrease until only a few highly tolerant species remain (Henderson-Sellers and Markland 1987).

Human activity within the watershed can greatly accelerate the eutrophication process by increasing the rate at which nutrients such as phosphorus and nitrogen enter the lake (Fernandez, Kahl, Nieratko 1992). Increased nutrient loading causes dramatic increases in algal populations resulting in algal blooms. Many New England lakes develop a greenish tint because of algal blooms during early summer or early fall (Smith and Smith 1998). Populations of bacteria, which feed on organic material, rise because of increased food supply. Bacterial activity decreases the level of dissolved oxygen in the lake (Henderson-Seller and Markland 1987). A sharp decrease in dissolved oxygen levels can cause massive death of many lake fauna especially fish, a process known as fish kill. While this process is not yet occurring in Great Pond it could occur in the future depending on the activity of local residents. The Great Pond Watershed includes the communities of Belgrade, Smithfield,

Rome, Mercer, and Oakland as shown on United States Geological Survey topographical maps for the quadrangles of Belgrade, Belgrade Lakes, Readfield, and Rome, Maine. The watershed is located in the Belgrade Lakes region of south central Maine.

Great Pond receives nutrient inputs from many different sources both natural and anthropogenic. Natural input sources such as Great Meadow Stream, Bog Brook, Salmon Brook and Rome Trout Brook carry nutrients from their drainage basins to the lake attached to suspended particles and dissolved in the water. Activities and developments such as roads, residential and industrial construction, logging, and human waste disposal (in subsurface waste disposal systems) have negative effects on water quality. These anthropogenic inputs contribute unnaturally high levels of nutrients and suspended particles into the lake through its tributaries.

Historically Great Pond has not suffered from algal blooms like neighboring East Pond which experiences seasonal algal blooms because of high nutrient levels (BI493 1991). However, if human activity is not monitored and development not carefully controlled, the nutrient cycle of Great Pond could be accelerated resulting in algal blooms, poor water quality, and fish kills.

The main purpose of this study is to assess the current land use patterns and their influences on the water quality of Great Pond, including the biotic and abiotic parameters which are involved. More specifically, four main objectives were established. First, was to calculate the water budget and flushing rate for Great Pond. Second, was to determine the influence of current and historical land use patterns on lake water quality. Third, was to utilize gathered information, including the assessment of current water quality, to construct a phosphorus model, which will enable future water quality predictions to be made. Our fourth and final objective was to make recommendations to the Great Pond Lake Association and the towns of Belgrade, Mercer, Oakland, Rome, and Smithfield based on our findings.

The water quality and land use assessment of the Great Pond Watershed was conducted by the Colby Environmental Assessment Team (CEAT) during the fall of 1998.

BACKGROUND

Lake Characteristics

Difference Between a Lake and a Pond

Lakes and ponds are natural or man-made inland bodies of water (Niering 1985). Environmental conditions may vary from lake to pond, but there are certain characteristics that are shared between the two (Smith and Smith 1998).

The amount of light that is able to penetrate the surface water in a pond or lake is an important feature of both. It is primarily surface area and depth that distinguishes between the two types of water bodies (Niering 1985). Ponds tend to be smaller and have larger littoral zones (shallow area of the water body where light reaches the bottom) than lakes.

Temperature, which changes with the seasons and depth, is an important factor in both pond and lake ecosystems (Smith and Smith 1998). Because water is most dense at approximately 4° C, many species are able to survive in an aquatic environment throughout the year, since ice remains on the surface and prevents most lakes from freezing solid. During the summer, lake water stratifies, establishing an upper, warm water layer called the epilimnion, and a lower, cold water layer called the hypolimnion. Between the epilimnion and the hypolimnion is an area of rapid temperature change called the metalimnion. Thermal stratification prevents mixing of oxygen and nutrients within a lake. Ponds, due to their shallow waters, typically do not thermally stratify during the summer months. In some lakes, the shallow depth prevents stratification, and therefore the lake does not experience changes in dissolved oxygen (DO) associated with depth. Variations in oxygen and temperature strongly influence the adaptations for life and the buffering capabilities for pollutants in ponds and lakes (Smith and Smith 1998).

General Characteristics of Maine Lakes

Lakes are a vital natural resource in Maine (Davis et al. 1978). They provide fresh water for swimming, fishing, drinking, livestock, and agriculture. The aesthetic beauty of Maine's lakes draws many tourists throughout the year and lakes are important habitats for

wildlife. Nine percent of Maine's approximately 5700 lakes have areas greater than 5.6 mi^2, and there has been relatively little research conducted to examine their watersheds, ecosystems and potential for development, and or recreational utilization (Davis et al. 1978).

The majority of Maine lakes were formed during the most recent glaciation (Wisconsin) of the Pleistocene period (about 10,000 years ago) (Davis et al. 1978). As a result of glacial activity in Maine, most lake substrates are dominated by glacial till, bedrock, and glaciomarine clay-silt. Generally these deposits and the underlying bedrock (typically granitic) are of an "infertile" nature. This characteristic helps account for the fact that few lakes in Maine are naturally eutrophic (old and nutrient saturated), or even mesotrophic (middle-aged and nutrient rich). Many lakes in this region are oligotrophic (recently formed and nutrient poor).

The movement of the glaciers in Maine was predominantly southeasterly explaining the orientation of many of the lakes in Maine. They are often long and relatively narrow in the southeastern direction (Davis et al. 1978). This feature of a lake is important to consider, particularly with reference to the seasonal changes which take place in the water body. Surface area and shape play a fundamental role, for instance, in the effect of wind on the water body, a critical function of its turnover effectiveness.

With few exceptions, lakes in Maine are located in lowland areas among hills (Davis et al. 1978). They are generally frozen on the surface four to five months out of the year. While Davis et al. (1978) noted that much of the lake watersheds within the state were forested, these stands have recently come under increasing pressure from the timber industry. Residential development of watersheds and increased construction of lake recreation facilities have also posed a significant threat to the water quality in many of lakes and ponds in Maine. In watersheds where agricultural practices have been less significant, both residential development and forestry practices may be the most acute causes of anthropogenic, or human caused, nutrient loading.

The level of dissolved matter (including sodium ions, potassium ions, phosphorus and organic matter) in lakes act as a standard measure of lake water quality. In Maine, several factors exist which serve as a function of water quality: proximity to the ocean, location within the state, residence time of water within the soil, wetland influences, and bedrock

chemistry (Davis et al. 1978). Physical factors also play a critical role in the water quality. Particular terrestrial and aquatic vegetation, as well as unique habitat types, will also affect the water quality. Also, lake morphometry, as mentioned above, (e.g., depth and surface area) can function to change lake temperature, nutrient cycles, and effective turnover.

Lake Basin Characteristics

The physical properties of the lake basin drastically affect the biological and chemical processes of the lake. The morphometry, hydrologic cycles, and sediments of a basin contribute to the processes which affect the nutrient cycling and seasonal changes in the lake ecosystem. Most temperate lakes illustrate a degree of turnover, and lakes that turnover completely in both the spring and fall are referred to as dimictic (Smith and Smith 1998).

Stratification is such a vital component in lake ecosystem functioning that its implications should be understood. Water has the unique property of a maximum density at 4° C. Whereas the density of all other substances increase with a decrease in temperatures. Therefore ice, which freezes at 0° C, actually floats in water which is above the freezing point. The process of stratification is created by the different densities in lake water due to differences in temperature. This stratification follows a seasonal epilimnion (Fig. 1). While usually no deeper than about 7 m to 8 m in northeastern lakes, the pattern in conjunction with the changes in solar radiation received by the lake water. Direct radiation of the upper levels of the water column warms that layer of water forming the epilimnion hosts the most abundant floral communities (Davis et al. 1978). This creates an oxygen rich stratum due to the photosynthetic capacities of these communities. Nutrients in the epilimnion, however, get depleted by algal populations growing in the water column (Cole, pers. comm.), and may remain depleted until the turnover of early fall (Smith and Smith 1998).

Below the epilimnion is a layer of sharp temperature decline, known as the metalimnion (Smith and Smith 1998). Within this stratum is the greatest temperature gradient in the lake, called the thermocline, which tends to decrease approximately 1° C per meter depth (Smith and Smith 1998). This thermocline separates the epilimnion from the hypolimnion, the lowest layer of a lake. The hypolimnion is beyond the depth to which sufficient light can penetrate in order to facilitate effective photosynthesis. It is an area in

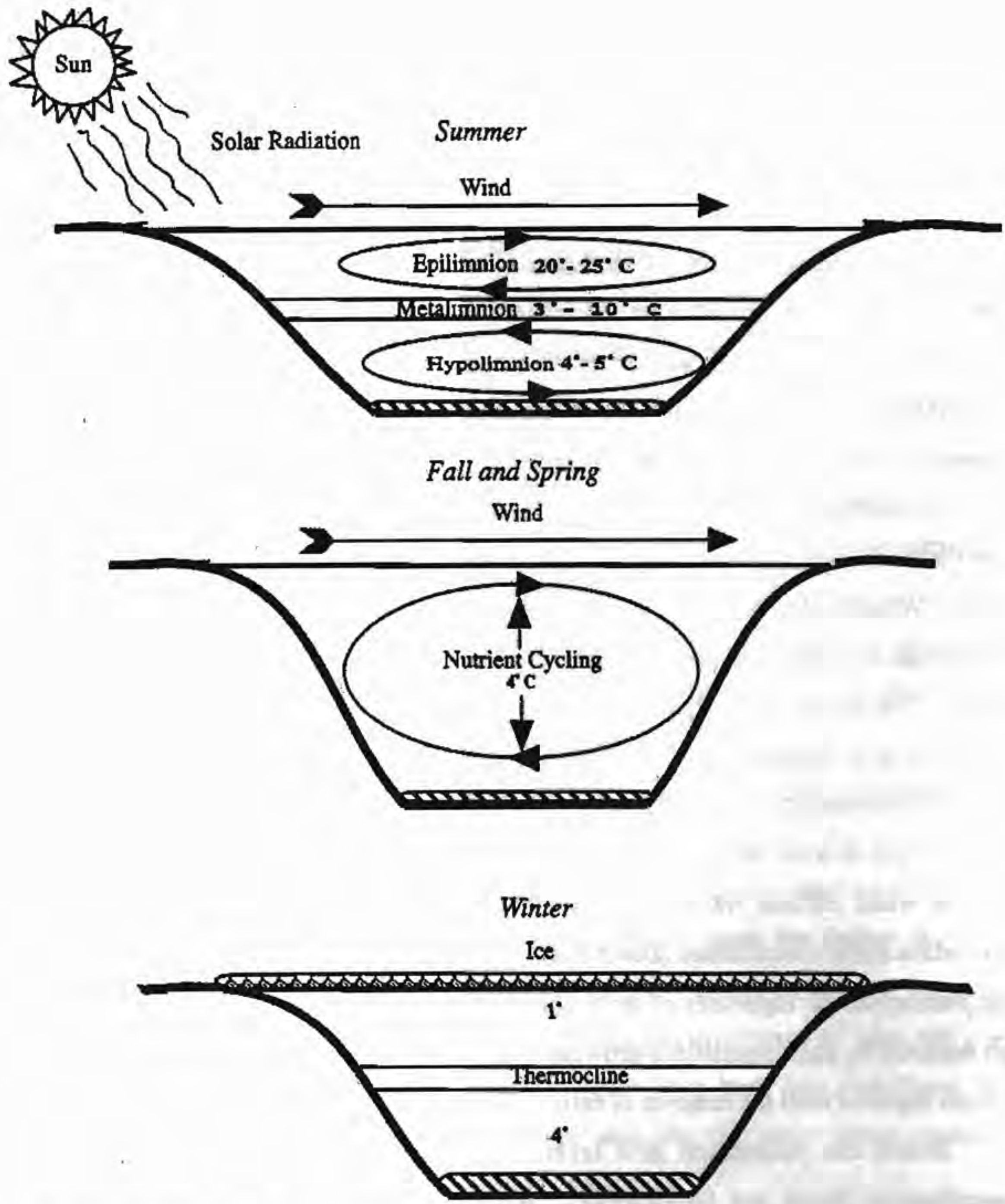

Figure 1. Mixing by means of lake turnover in dimictic lakes. During the summer, lakes are stratified into three layers (epilimnion, metalimnion, and hypolimnion). During the fall and spring, the isothermal temperature and density facilitate the lake turnover and redistribution of nutrients. In the winter,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

which 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, they also significantly deplete the oxygen at these depths (Davis et al. 1978).

Both the spring and fall turnovers serve to reoxygenate the lower depths and mix the nutrients throughout the upper strata. These turnovers are a function of several factors which include the geographic position and shape of the lake, seasonal changes in temperatures, the interaction of the wind on the waters' surface, and the depth of the lake (Davis et al. 1978). The cold water near the surface can hold high levels of oxygen and since the demand for oxygen is considerably less due to decreased activities of aquatic organisms at these temperatures, it is crucial for deep water organisms that seasonal turnovers occur (Smith and Smith 1998). A snow cover, however, will affect the photosynthetic processes during the winter months by blocking solar radiation. In the later winter months, oxygen levels may become so depleted as to cause substantial fish kills (Cole, pers. comm.). As the winter passes, and the ice layer melts, the upper layers of the lake begin to warm once more and wind begins to mix the lake. Oxygen may be carried down the water column while nutrients pervade the epilimnion. As late spring approaches, solar radiation increases and stratification will again become evident, and the temperature profiles return to that of the summer (Smith and Smith 1998).

Trophic Status of Lakes

There are many ways of characterizing a lake, and each way has its limitations. One of the most useful biological classifications was originally proposed by Thienemann and later elaborated by others (Maitland 1990). Thienemann's characterization is based primarily on the nutrient levels within a lake. Lakes are generally divided into four major categories: oligotrophic, mesotrophic, eutrophic, and dystrophic (Table 1). It is important to note, that the mesotrophic characterization is not included in Table 1, because it is generally referred to as a transitional stage between oligotrophic and eutrophic states (Chapman 1996). Young or oligotrophic lakes are usually lacking in nutrients, while eutrophic lakes are nutrient rich (Niering 1985). Oligotrophic lakes tend to be deep and oxygen rich with steep-sided basins.

There is a low surface to volume ratio. They are characterized as nutrient deficient, even though they may be high in nitrate levels. They are primarily deficient in phosphorus, which is the limiting nutrient for plant productivity in most freshwater ecosystems. The shape of a lake can also determine its productivity. Steep-sided oligotrophic lakes are not conducive to extensive growth of rooted vegetation; there is no shallow margin for attachment. Eutrophic lakes, partially due to sediment loading over years, tend to be relatively shallow and bowl shaped, which allows for the productivity of rooted plants (Table 1).

Table 1. Generalized characteristics of oligotrophic, eutrophic, and 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	High	Low	Low
Water color	Green or blue	Green or yellow	Brown
Dissolved solids	Low, deficient in N	High, especially in Ca, N	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 characteristic	Many species, especially minnows	Extremely few species, often none

Eutrophic lakes are nutrient enriched (Chapman 1996) and typically have a relatively high surface to volume ratio (Maitland 1990). These lakes are generally rich in phytoplankton, which is supported by the increased availability of dissolved nutrients (Table

1). A eutrophic lake supports a tremendous amount of planktonic algae and is usually low in dissolved oxygen. Low dissolved oxygen levels at the bottom of the lake 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 stimulates even further growth of phytoplankton (Smith and Smith 1998). There is relatively little biotic diversity in a highly eutrophic lake, except for the phytoplankton and the decomposers that maintain the low levels of oxygen.

Lakes that receive large amounts of organic matter from the surrounding land, particularly in the form of humic (dead organic) materials, are termed dystrophic lakes (Smith and Smith 1998). The large quantity of humic materials stains the water brown. Dystrophic lakes generally have highly productive littoral zones (shallow area along the lake basin where light penetrates to the bottom). The littoral zone allows submergent, floating, and emergent vegetative growth.

High oxygen levels, high macrophyte productivity, and low phytoplankton amounts are characteristic of dystrophic lakes (Table 1). Eventually the invasion of rooted aquatic macrophytes chokes the aquatic habitat with plant growth, and the lake basin is filled in, resulting in the development of a terrestrial ecosystem (Goldman and Home 1983).

Over time, lakes tend to be enriched by introduced nutrients and eventually become eutrophic (Niering 1985). No matter how a lake basin originated, the lake will undergo succession (Goldman and Home 1983). Nutrient enrichment and the filling in of lakes are a natural phenomena. These processes, however, can be greatly affected by anthropogenic activities which increase the rate at which nutrient loading occurs. The United States Environmental Protection Agency (USEPA) characterizes the process of eutrophication by the following criteria:

1) Decreasing hypolimnetic dissolved oxygen concentrations;
2) Increasing nutrient concentrations in the water column;
3) Increasing suspended solids, especially organic material;
4) Progression from a diatom population to a population dominated by blue-green algae and/or green algae;
5) Decreasing light penetration (e.g., increasing turbidity);

6) Increasing phosphorus concentrations in the sediments (Henderson-Sellers and Markland 1987).

As a lake ages, it continues to fill up through the deposition of dead organic matter and sediment from various inputs. Lakes may also receive mineral nutrients from streams, groundwater, and runoff. As nutrient availability increases, so does primary productivity. Increased productivity leads to more dead organic material which accumulates in lentic ecosystems (pertaining to standing water, as lakes and ponds). Lakes are created and destroyed by biological and geological processes. In time, lakes will fill in, decrease in size, and may finally be replaced by a terrestrial community (Smith and Smith 1998).

Phosphorus and Nitrogen

In a freshwater lake, phosphorus and nitrogen are the two major nutrients that are important for the growth of algae and macrophytes. Each nutrient has its own complex chemical cycle within the lake (Overcash and Davidson 1980). It is necessary that we understand these cycles so that better techniques to control high levels of these nutrients may be devised.

Phosphorus is generally considered the most important nutrient in lakes because it is the limiting nutrient for plant growth in freshwater systems (Maitland 1990). Phosphorus naturally occurs in lakes in minute quantities (measured in ppb), however this is all that is needed for plant growth due to the high efficiency with which plants can assimilate phosphorus (Maitland 1990). There are multiple external sources that contribute phosphorus to a lake (Williams 1992), but a large source is also within the lake itself (Henderson-Sellers and Markland 1987). The cycle of phosphorus in a lake is extremely complex, with some models including up to seven different forms of phosphorus (Frey 1963). For the purposes of this study, it is only necessary to understand that there are two broad categories of phosphorus in a lake: dissolved phosphorus (DP), and particulate phosphorus (PP). The basic cycle that these forms of phosphorus follow in a stratified lake is summarized in Fig. 2. DP is an inorganic form of phosphorus which is readily available for plant use in primary production; it is this form of phosphorus which is limiting to plant growth. PP is phosphorus which is incorporated into organic matter such as plant and animal tissues. DP is converted

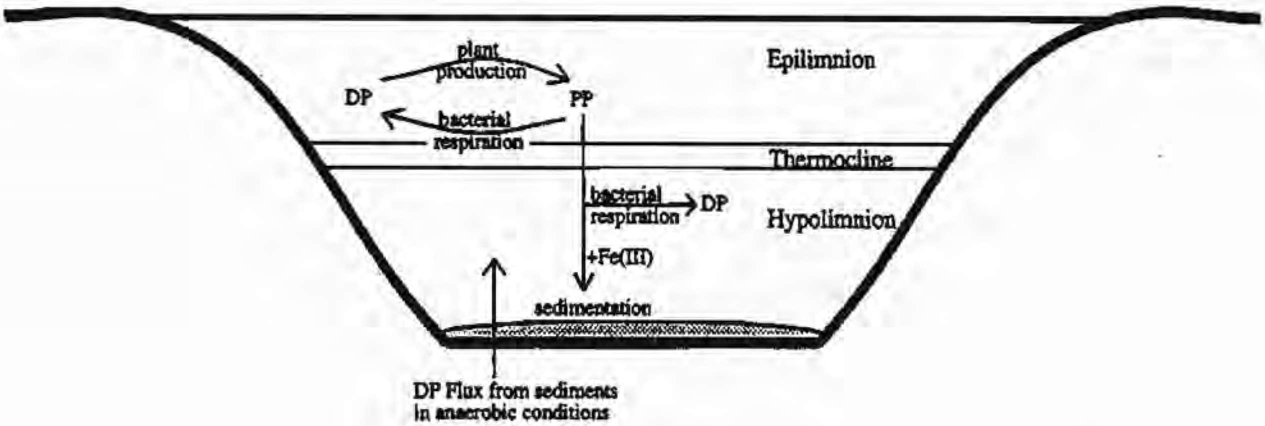

Figure 2. A model of the cycle of the major forms of phosphorus, dissolved (DP) and particulate (PP), within a lake ecosystem. The sedimentation of DP through complexation with Fe (III) contributes to the build-up of DP in the sediments. Note the production of DP in the hypolimnion due to bacterial decomposition 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 for build up of DP in bottom waters (adapted from Lerman 1978).

into PP through the process of primary production, which occurs in the epilimnion. Much of this PP then gradually settles into the hypolimnion in the form of dead organic matter. If there is oxygen present, PP will be converted to DP through decomposition by aerobic bacteria. When there is little or no oxygen present, which is often the case in the sediments of a stratified lake, anaerobic bacterial decomposition will result in the conversion of PP to DP (Lerman 1978).

In oxygenated water, an important reaction occurs which involves 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. Upon decreasing the oxygen levels at the sediment-water interface, such as after extended periods of stratification, the Fe(III) will be reduced to Fe(II) which results 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, or oxygen devoid, sediments. In fact, the sediments of a lake can

have phosphorus concentrations of 50-500 times the phosphorus concentration of the water (Henderson-Sellers and Markland 1987). This allows a lake's sediment to be an even larger source of phosphorus than external inputs. Because nutrients are inhibited from mixing into the epilimnion during the summer by stratification processes, DP concentrations that are formed in the sediments and lower hypolimnion waters can build up until fall turnover.

The fall turnover results in a large flux of nutrients to the region of the lake where plant growth can occur, creating the potential for algal blooms. If an algal bloom does occur, DP will be converted to PP in the form of algal tissues. The algae will die as winter approaches and the dead organic matter will settle to the bottom where PP will be converted back to DP and build up again, allowing for another large nutrient input to surface waters during spring overturn (Chapman 1996).

The other major plant nutrient, nitrogen, is not usually the limiting factor for plant growth in a lake (Chapman 1996). However, it is still important to understand its cycle because high concentrations can lead to algal blooms in the presence of phosphorus. Also, levels greater than 10 ppm can lead to the development of the condition in infants known as methemoglobinemia, if the water is used as a source of drinking water (Greenberg, Clesceri, and Eaton 1992). Available nitrogen exists in lakes in three major chemical forms: nitrates (NO_3^-), nitrites (NO_2^-), and ammonia (NH_3). Their relative positions in the nitrogen cycle are summarized in Fig. 3.

The majority of free nitrogen in a lake exists in the form of nitrates (Maitland 1990). This form of nitrogen is directly available for assimilation by algae and macrophytes (Fig. 3). In eutrophic lakes, there may be so much algae and macrophyte growth that most of the nitrates of the lake are incorporated into their tissues (Maitland 1990). Nitrites, however, cannot be used by plants. Nitrate-forming bacteria in aerobic conditions convert nitrites to nitrates. Ammonia enters the lake ecosystem as a product of the decomposition of plant and animal tissues and their waste products. It can follow one of three paths. First, many macrophytes can assimilate ammonia directly into their tissues. Alternatively, in aerobic conditions, certain bacteria will convert the ammonia directly to the more usable form of nitrogen, nitrates. Finally, in the case of anaerobic decomposition, which commonly occurs in the sediments of stratified lakes, nitrates can be reduced to nitrites. If these anaerobic

conditions persist, the nitrites can be entirely broken down to elemental nitrogen (N_2). This form is not available to any plants without the aid of nitrogen-fixing bacteria, as only bacteria have the capability to convert nitrogen to nitrates through nitrogen fixation (Overcash and Davidson 1980). The underlying pattern that is evident from this cycle is that whatever form of nitrogen is added to the lake it will eventually become available for plant use. In order

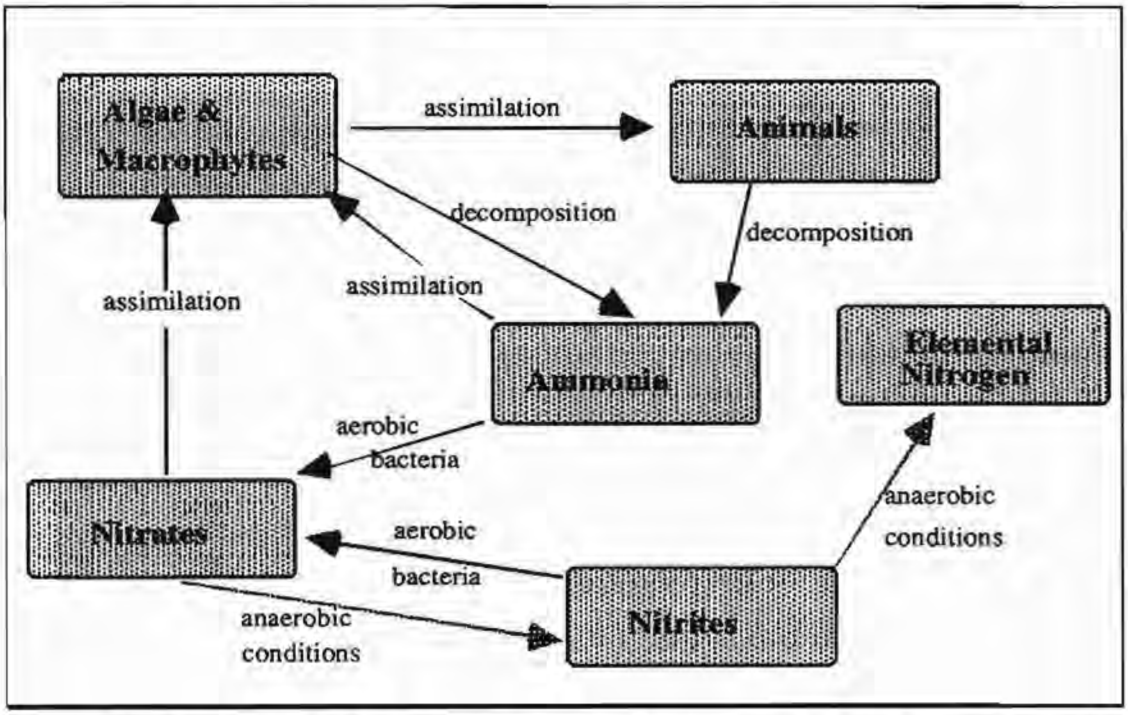

Figure 3. A diagram of the various forms of nitrogen that can occur in the nitrogen cycle within a lake ecosystem. It is important to note that in aerobic conditions both ammonia and nitrites are converted to nitrates which are available for use by plants.

to understand the amount of this nutrient available for plant growth, one must take into account not only the various forms of nitrogen, but also the oxygen concentrations (aerobic and anaerobic conditions) of the water.

Several in-lake mitigation techniques exist to deal with the problem of excessive nutrients once they are present in the lake (Henderson-Sellers and Markland 1987). All of these techniques take advantage of the information we have explaining how phosphorus cycles in a lake. None of these techniques are without disadvantages, but for lakes with serious algal growth problems they may be necessary (Henderson-Sellers and Markland 1987).

One of the easiest methods used to eliminate excessive nutrients is to decrease the lake water level rapidly (Henderson-Sellers and Markland 1987). For example, if dams are used to control the outflow of the lake, opening these widely, so that the lake loses a large volume of water in a short period of time, may cause many of the nutrients located in the epilimnion to be flushed from the lake. This is a relatively simple technique, however in cases where the lake drains into another lake or significant water body, the problem of an overload of nutrients may not be eliminated, but simply shifted to another site. Additionally this may only be a temporal solution because the source of nutrients from the hypolimnion will not be *affected; thus it will continue to supply nutrients to the rest of the lake.Another approach of* nutrient reduction involves removing the nutrient rich hypolimnetic water. By inserting a large pipe into the hypolimnion and pumping the water out in such a way that it would not go directly back into the lake, the nutrient levels in the water would be reduced (Henderson-Sellers and Markland 1987).

Chemical precipitation is a relatively simple technique which requires some expensive equipment. It is based on the natural process of iron complexing with phosphorus. Adding salt to the water will complex the DP to form an insoluble compound that will immobilize the P (Henderson-Sellers and Markland 1987). This is an effective technique but, due to the cost, is not practical for very large lakes. Furthermore, the P will eventually be released from this complex, requiring reapplication after several years.

Aeration of the hypolimnion is a process that requires some expensive machinery to perform. It operates on the principle that an increase in the oxygen levels in the lower strata of the hypolimnion will reduce the amount of DP released from the sediments. If there is oxygen present where the sediment and water interface, there will be no conversion of iron to its reduced form, so there will be no DP released from the ferric phosphate complex (Henderson-Sellers and Markland 1987).

Another approach, in lakes with large macrophyte production, is to harvest the plants. This method can be expensive due to the cost of equipment used and the frequency with which the harvesting must be performed. This procedure removes all the nutrients that are tied up in the plants at the time of the harvest and prevents them from re-entering the lake cycle (as long as the harvested plants are not stored on shore, allowing the nutrient rich water

in the plants to flow back into the lake). There is some debate over the effectiveness of this method, because plants also act as a sink for nutrients. At the time of removal, the nutrients that would normally have been taken up by the plants will be available to algae, perhaps resulting in an algal bloom (Chapman 1996). On the other hand, if only the foliage of the plants is harvested, then the plants will still be able to fulfill their role of taking up nutrients from the water.

One final management option is to dredge, which removes the nutrients from the sediments by removing the sediments themselves. Although dredging is effective it is extremely expensive due to the large cost of the equipment needed (Henderson-Sellers and Markland 1987). Also, there is some question as to ecologically disruptive effects that actions such as this may have on the lake ecosystem.

In terms of eliminating nutrients once they have built up in a lake, it is evident from these less-than-ideal techniques that it is a very challenging task especially due to the complexity of the cycling within the lake. The ideal method for controlling nutrients in a lake is to regulate and monitor the input sources, so that the natural processes of nutrient cycling and nutrient uptake by flora and fauna will be able to compensate without progressive eutrophication of the lake.

Freshwater Wetlands

Wetlands are important transitional areas between aquatic and terrestrial ecosystems. They support a wide range of biotic species (MLURC 1976). Table 2 gives descriptions of fresh inland wetlands. More importantly, they are useful for the balance of an aquatic ecosystem because of their efficiency in nutrient uptake by vegetation. Wetlands have the potential to reduce heavy metals and nutrients from various sources including mine drainage, sewage, and industrial wastes (Smith and Smith 1998). Agricultural runoff adds excess nitrogen and phosphorus, the primary limiting agents in a lake ecosystem, into the lake. Wetlands are able to absorb some of these nutrients, thereby improving the overall water quality, and store the nutrients in sediment which can later be used by the surrounding plant life (Niering 1985). Usually, wetlands have a water table near, at, or above the level of the land. Wetland soil is periodically or perpetually saturated, and contains non-mineral

Table 2. Descriptions of site characteristics and plant populations of different types of fresh inland wetlands (Smith and Smith 1998).

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
Fresh meadows	Without standing water during growing season; waterlogged to within a few inches of surface	Grasses, sedges, broadleaf plants, rushes
Shallow fresh marshes	Soil waterlogged during growing season; often covered with 15 cm or more of water	Grasses, bulrushes, spike rushes, cattails, arrowhead, pickerel weed
Deep fresh 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

substrates such as peat. Wetlands also contain hydrophytic vegetation which is adapted for

life in saturated and anaerobic soils (Chiras 1994). In the Great Pond Watershed, there are several wetlands located around various water sources, such as Austin Bog at the mouth of Bog Brook (see Development Implications of Land Characteristics: Development Suitability).

Watershed Land Use

Land Use Types

A watershed is defined by the total land area that contributes a flow of water to a particular body of water. The watershed is bounded by the highest points surrounding the body of water and its tributaries. The assessment of land use within this area is essential in determining factors that may affect the lake water quality. Different types of land use have varying effects on nutrient loading to lakes. Nutrients can bind to soil, and if eroded, this soil can add to the nutrient load. Nutrients from anthropogenic sources have had a substantial effect on water quality in numerous Maine lakes (MDEP 1992a).

Areas that have been cleared for agricultural, residential, or urban uses can contribute to nutrient loading. The combination of removing vegetation and compacting soil may result in a significant increase in surface runoff. Surface runoff can increase erosion of sediments and various wastes of human origin. Products such as fertilizers, pesticides, and herbicides associated with human activity can contain nitrogen, phosphorus, other plant nutrients, and miscellaneous chemicals (MDEP 1992a). These sediments can have adverse effects on water quality.

Natural areas, such as forested land, offer better protection against soil erosion and surface runoff. The canopy provides a cover over the soil, lessening the impact rain, and reducing soil erosion. The root systems of the trees further reduce soil erosion and slow the rate of runoff, allowing water to percolate into the soil. Forested areas act as buffering systems by absorbing the nutrients when they are located between sources of nutrients and water bodies. Forests cover much of Maine, therefore expansion of residential areas usually results in forest clearing. By clearing forested areas that serve as natural buffer strips, nutrient loading due to erosion, can increase with subsequent decline in lake water quality.

Also, the resulting development provides impervious surfaces that increase the amount of surface runoff. A study concerning phosphorus loading in Augusta, Maine revealed that a residential area produced ten times more phosphorus than an adjacent forested area (Dennis 1986; Fig. 4).

Residential areas are separated into shoreline and nonshoreline homes that can be either permanent or seasonal residences. Residential areas in a watershed generally contain lawns, driveways, parking areas, rooftops, and other impervious surfaces that reduce percolation, thereby causing increased runoff. Since year-round homes produce more phosphorus through extended use of septic systems, they may pose more of a threat to nutrient loading than seasonal homes.

The use of household products in and around the home is also potentially harmful to water quality. Due to their proximity to the lakes, shoreline homes can provide direct sources of nutrients to the lake. Products used in the household (e.g., detergents and soaps) often contain phosphorus. Lawns and gardens are maintained with fertilizers that are high in phosphorus. These products used around the home can leak into the groundwater and subsequently enter the lake. Storms can also carry away these high nutrient products due to increased surface runoff near residences. The nutrients enter the water column and lead to lake eutrophication. In addition, when improperly designed or used, septic systems found at year-round or seasonal homes can potentially be large sources of nutrients (USEPA 1980).

Commercial uses of forested land, such as logging and tree harvesting, remove the cover of the canopy, thereby exposing the soil to direct rainfall, which facilitates erosion. Skid trails may pose a problem when they run adjacent to or through streams (Hahnel, pers. comm.). Shoreline zoning ordinances have established that a 75 ft strip of vegetation be maintained between a skidder trail and the normal high water line of a water body or upland edge of a wetland to alleviate the potential impact harvesting may have on a water body (MDEP 1990). Two studies by the Land Use Regulation Commission on tree harvesting sites noted that erosion and sedimentation problems occurred on 50% of the active and 20% of the inactive logging sites selected (MDC 1983). Roads can also provide excessive surface runoff if poorly designed or maintained. Their contribution also depends on regulations enforced by local governments. Roads are divided into four main types (state, municipal,

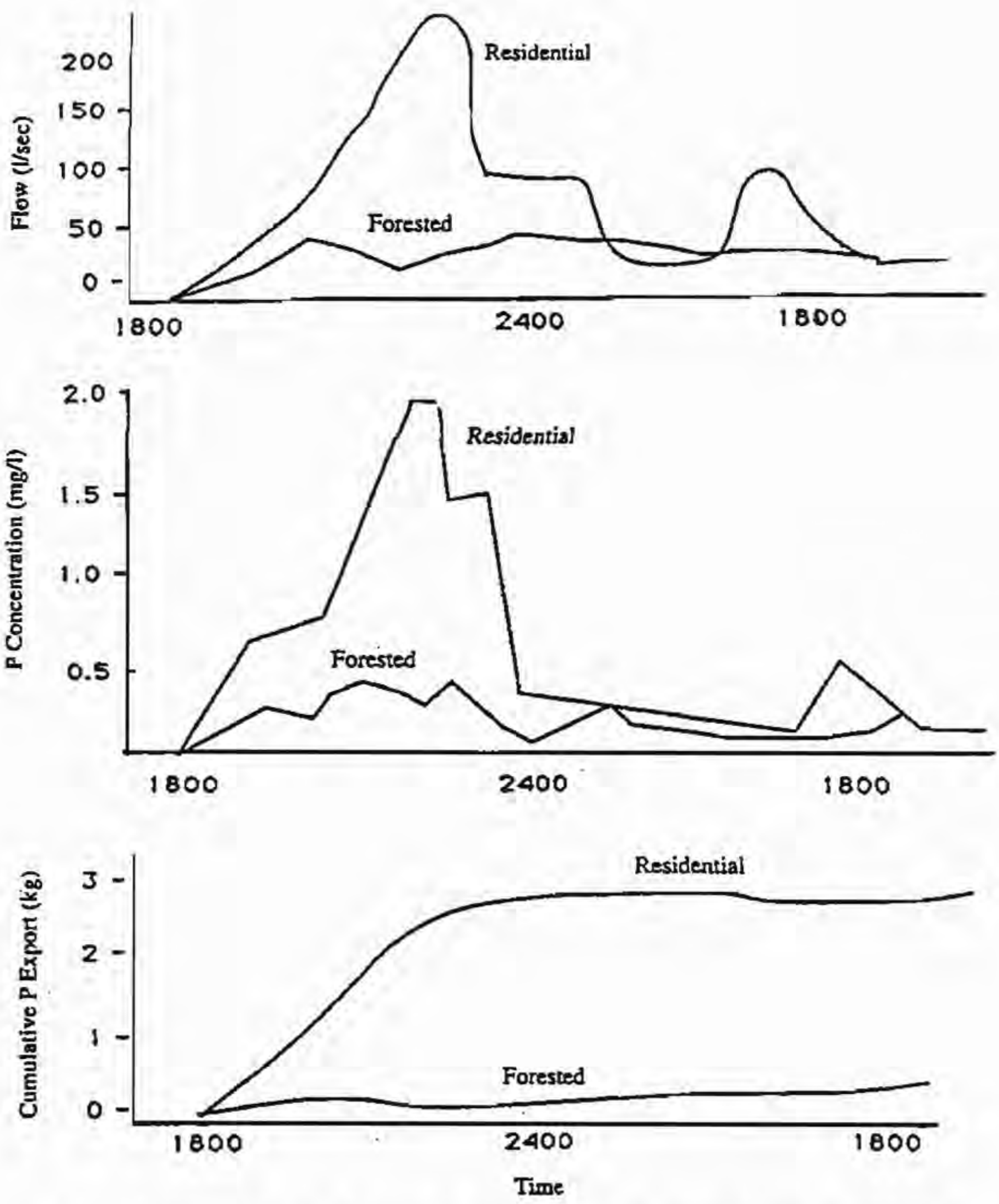

Figure 4. Comparisons of runoff after an April rain storm in two neighboring watersheds near Augusta, ME. Top: volume of immediate runoff over a 12 hour period; Middle: phosphorus concentration in the runoff; Bottom: total amount of phosphorus exported into local streams and lakes from the storm (Dennis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

dirt, and camp fire roads) and can have varying degrees of nutrient loading potential. Roads and driveways leading down to shoreline areas or streams provide easy access to the lake for runoff. This can cause the movement of large amounts of nutrients if the roads and driveways are not well constructed or maintained (Michaud 1992). Land use is an important determinant of lake water quality. Before new development can occur it is important to identify particular considerations such as soil type or the phosphorus loading potential. These considerations need to be taken into account and shared with developers as guidelines to minimize impact on the lake. To maintain water quality there must be state and local regulations in place that moderate nutrient loading from various land uses. Investigation of impacts from land use practices and possible future development will help preserve a healthy lake ecosystem.

Buffer Strips

Buffer strips are important for control of nutrients entering the lake (MDEP 1990). Increased levels of nutrients can promote algal growth and increase the lake's eutrophication rate. According to the Belgrade Shoreline Zoning Ordinance, one should have "a strip of land extending 75 ft, horizontal distance, inland from the normal high-water line of a great pond or a river flowing to a great pond, and 75 ft, horizontal distance, from any other water body, tributary stream, or the upland edge of a wetland" as a buffer strip (Belgrade 1991). An example of an ideally buffered home is shown in Fig. 5. This home has a winding path down to the water. Runoff is diverted into the woods where nutrients will be absorbed by the forest litter. The house is set back from the water 100 ft, and has a buffer strip between it and the water consisting of a large canopy which can absorb nutrients and break the impact of precipitation hitting the ground (MDEP 1990). The driveway curves down to the house.

This curving allows the water to be diverted into the woods and then filtered by the forest litter. The runoff is allowed time to be naturally filtered by the surrounding forest rather than running directly into the lake. Some buffer strips on Great Pond are not in accordance with the above shoreline zoning ordinance and may provide insufficient nutrient absorption. Some houses surrounding the lake have natural woodland buffer strips, but there are many houses on Great Pond which are surrounded by large green lawns. Such lawns do not provide adequate nutrient uptake before runoff enters the lake.

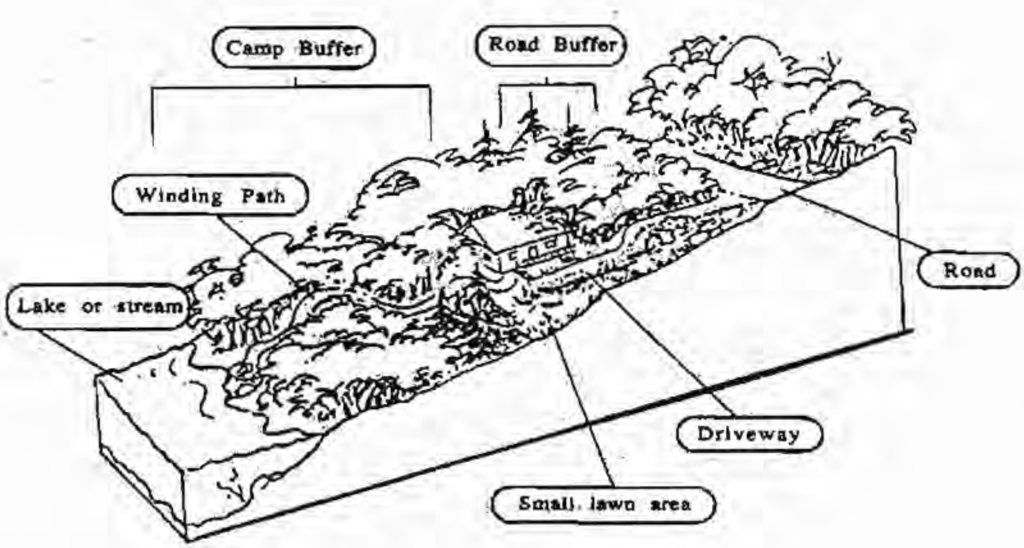

Figure 5. Diagram of an ideally buffered home.

Nutrient Loading

Nutrient loading into a lake can be affected by both 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 away forests and constructing roads and buildings with impervious surfaces increase runoff, carrying nutrients from agricultural, residential, and industrial products and uses (such as detergent, fertilizer, and sewage) into the lake. Since phosphorus and nitrogen are the limiting nutrients in algal growth, and algal growth affects the trophic state of a lake, increases of phosphorus and nitrogen from these sources can lead to a decrease in lake water quality and eventually eutrophication.

Total phosphorus loading to a lake can be determined using a phosphorus loading model (see Analytical Procedures and Findings: Phosphorus Loading). This model takes into account the factors that influence the phosphorus concentration in the lake basin, such as lake size, volume, flushing rate, and land use patterns within the watershed (Cooke et al. 1986). This model is useful because it allows for the projection of the impacts that various factors may have on phosphorus loading. It enables predictions of lake responses to changes in land

use. The accuracy of the predictions is based on the accuracy of the assumptions (USEPA 1990).

Soil Types

Nutrient loading in lake ecosystems is a function of the soil types and their respective characteristics. Both the physical characteristics of soil, such as permeability, depth, particle size, organic content, and the presence of an impermeable layer (fragipan), as well as the environmental features (slope, average depth of the water table, and depth to the bedrock) which influence them, are important to consider in deciphering 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 all of these criteria must be considered carefully before implementing a development, forestry, or agricultural plan.

Zoning and Development

The purpose of zoning and development ordinances are to maintain safe, healthy conditions, control water pollution, protect wildlife and freshwater wetlands, control building and placement of structures as well as other types of land use, conserve rural nature, and anticipate the impacts of development (Belgrade 1991). Shoreline zoning ordinances regulate development along the shoreline in a manner that reduces the deterioration of lake water quality. Uncontrolled development along the shoreline within sensitive areas can result in a severe drop in water quality that is not easily corrected. 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 due to their proximity to the lake. Any nutrient additives from residences (such as detergents) have only short distances to travel to reach the lake. Buffer strips along the shore are essential in acting as a sponge for the nutrients flowing from residential areas to the lake (Woodard 1989). These buffer strips consist of an area of natural vegetation growing between a structure and the body of water in question. Town ordinances in Belgrade regulate buffer strip widths, thereby influencing phosphorus loading to the lake (see Background, Watershed Land Use: Buffer Strips).

Residences that have lawns leading directly down to the shore have no obstacles to slow runoff, thus causing 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 the shoreline residences (MDEP 1992b).

Maine seasonal residences, 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 have been grandfathered, and thus do not follow shoreline zoning laws. Although seasonal, they may involve large numbers of people. Therefore, phosphorus export from these areas is likely to increase during periods of heavy use. The effects of these plots on nutrient loading depend on factors such as septic system location and condition (see Background, Watershed Land Use: Sewage Disposal Systems).

Non-Shoreline Residential Areas

Although not as important in phosphorus loading as shoreline areas, non-shoreline residential areas can also have an impact on nutrient loading. Runoff, carrying the phosphorus from soaps, detergents, and fertilizers usually filters through buffer strips consisting of forested areas several acres wide, rather than a few feet wide (as with shoreline buffers). In these cases, phosphorus has the opportunity to be absorbed into the soils and vegetation. The majority will not reach the lake directly, but will simply enter the forest's nutrient cycle.

However, residences located up to one half mile away from the lake can supply the lake with phosphorus almost directly when badly constructed roads persist. Runoff collected on roofs and driveways may travel unhindered down roads 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 every bit as much of a nutrient loading hazard as a shoreline residence with a large lawn. Phosphorus washed from residential lawns without buffer strips can enter into a stream and eventually into the lake. Even when far from the shoreline, a residence can have a significant impact, especially if it is near a stream which leads into the lake. Therefore, similar restrictions and regulations as those for shoreline residences apply to non-shoreline homes that are located along streams.

Sewage Disposal Systems

Subsurface wastewater disposal systems are defined in the State of Maine Subsurface Wastewater Disposal Rules as: "a collection of treatment tank(s), disposal area(s), holding tank(s), alternative toilet(s), or other devices and associated piping designed to function as a unit for the purpose of disposing of wastewater in the soil" (MDHS 1988). These systems are generally found in areas with no municipal disposal systems such as sewers. Examples of these subsurface disposal systems include pit privies and septic systems, both of which are found in the Great Pond Watershed.

Pit Privy

Pit privies are also known as outhouses. Most privies are 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 are decomposed and treated. Little water is used with pit privies. Therefore, chances of contamination of ground water are reduced. Contamination may occur if the privy is located too close to a body of water and there is infiltration of waste into the upper soil levels.

Holding Tank

Holding tanks are watertight, airtight chambers, usually with an alarm, that store waste for periods of time. The tanks are durable and made of either concrete or fiberglass (MDHS 1988). The minimum capacity for a holding tank is 1500 gallons. These must be pumped or else they could back up into the structure or may leak into the ground, causing contamination. According to Bob Martin (pers. comm.), the plumbing inspector for Belgrade, holding tanks are, "the system of last resort." The reason for his opinion may be that although purchasing a holding tank is inexpensive, the owner is then required to continually pay to have that holding tank pumped.

Septic System

Septic systems are the most widely used subsurface disposal system. They are also the most complex system for wastewater disposal. The system includes a building sewer, treatment tank, effluent line, disposal area, distribution box, and occasionally, a pump. The pump enables the effluent to be moved to a more suitable location if the location of the treatment tank is unsuitable for a leaching field (MDHS 1983). Fig. 6 shows the basic layout of the components of a typical septic system. They are an efficient and economical alternative to a sewer system, provided they are properly installed. Unfortunately, many septic systems that are not installed properly may lead to nutrient loading and groundwater contamination. The location of the systems and the soil characteristics determine the effectiveness of the system.

The distance between a septic system and a body of water should be sufficient so that there is no contamination of the water. The shoreline regulations in Belgrade state that septic systems need to be at least 100 ft away from a lake and 75 ft away from streams (Belgrade 1991). Unfortunately, many parcels of land are grandfathered, which means their septic systems were installed before the passage of current regulations. Therefore, those systems may be closer to the shore than is currently permitted. However, 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

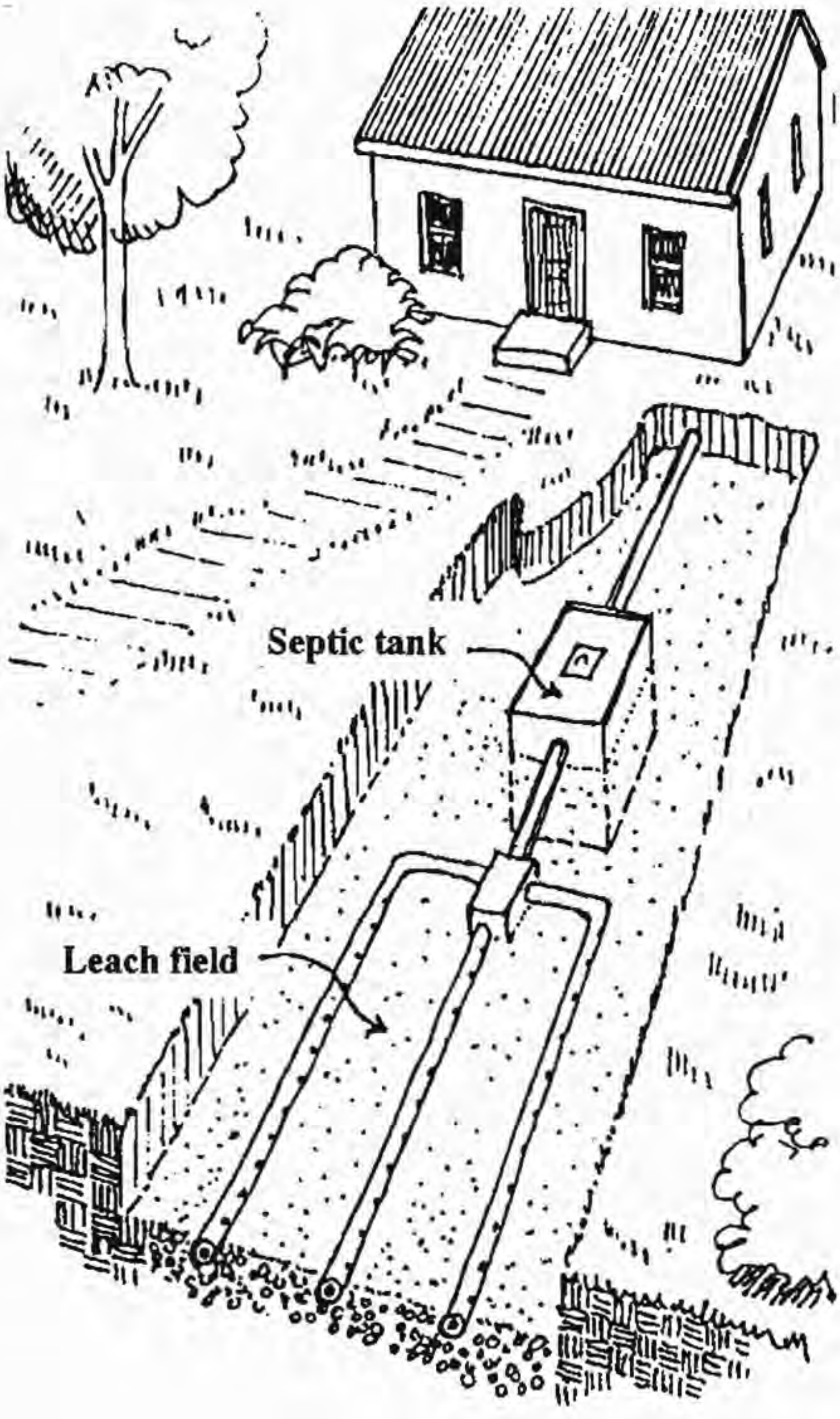

Figure 6. The layout of a typical septic system (Williams 1992).

tank can be used to move the sewage uphill to a new disposal area that is away from the pond (MDHS 1983). Human waste and gray water can be transferred from the house through the

building sewer to the treatment tank. There are two kinds of treatment tanks, aerobic and septic (MDHS 1983). The aerobic tanks rely on aerobic bacteria, which are more active. Unfortunately, they are also more susceptible to condition changes. These tanks also require energy to pump in fresh air, more maintenance, and are more expensive. For these reasons, the septic tank is preferable. Septic tanks rely on anaerobic bacteria. Both tanks are water-tight, durable, and usually made of concrete or fiberglass. Raw materials are held until they are more suitable for discharge (MDHS 1983). As the physical, chemical, and biological breakdowns occur, scum and sludge are separated from the effluent. Fig. 7 shows the cross section of a typical treatment tank.

Scum is the layer of grease, fats, and other particles that are lighter than water and move to the top of the treatment tank. Scum is caught in the baffles 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, which has received a primary treatment, then travels through the effluent line to the disposal area. The purpose of a disposal area is to provide additional treatment of the waste water. 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 is anaerobic as it leaves the treatment tank, therefore will need to be treated aerobically in the disposal field to kill the anaerobic bacteria before treatment is considered complete. If the effluent is not treated completely, it can be a danger to the water body and the organisms within it, as well as to human health. Three threats to lakes include organic particulates which increase 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. As the amount of organic material increases, BOD increases. If the BOD exceeds dissolved oxygen,

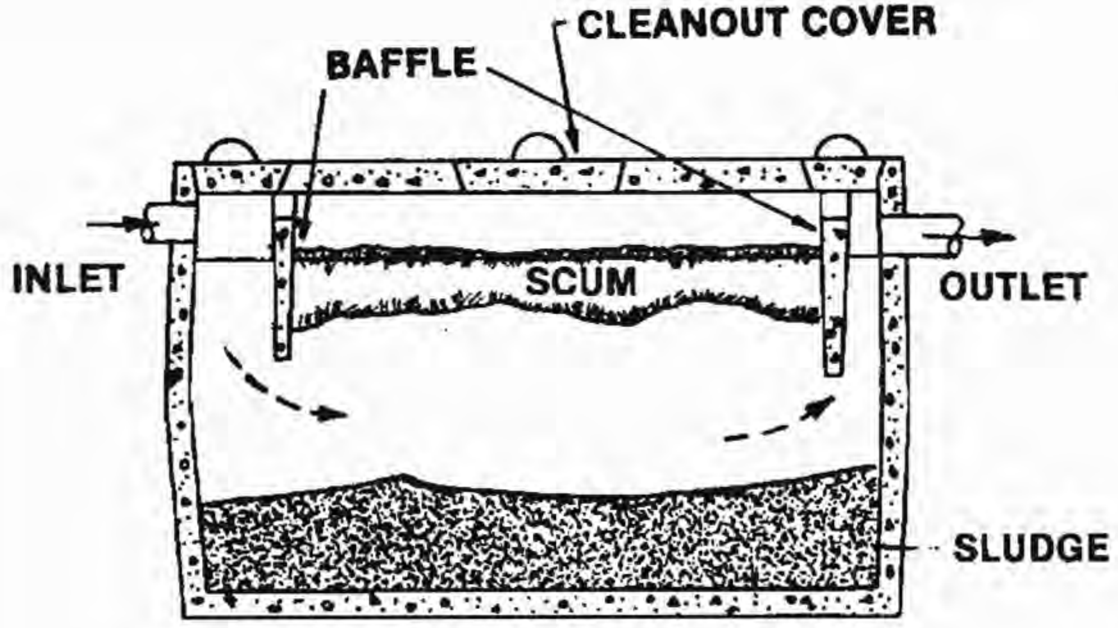

Figure 7. The cross-section of a typical treatment tank showing the movement of effluent through the tank as well as the separation of the scum and sludge (MDHS 1983).

species within the lake may begin to die. If the flushing rate is low, dissolved oxygen content and increasing organic matter could become problematic.

The three major types of wastes that travel into the septic system include garbage disposal wastes, black water, and gray water. The garbage disposal wastes can easily back up the septic system and therefore should not be added to the septic system. Black water and gray water are significant contributors of phosphorus. Black water also contributes nitrogen, toilet wastes, and microorganisms. Gray water brings in chemicals and nutrients. Once a system 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 the most efficient. Year-round residents should have their septic tanks pumped every two to three years, or when the sludge level fills half the tank (Williams 1992). 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 are not easily broken down by the microorganisms and end up filling 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 around the septic cover, and slow drainage are symptoms of a septic system that has been used heavily, and is now having problems.

When constructing a septic system, it is important to determine the best place on the lot for the system based on soil characteristics and topography. An area with a gradual slope (10 to 20%) that allows for gravitational pull is necessary for proper sewage treatment (MDHS 1988). Too little a slope causes stagnation, while too steep a slope drains the soil too quickly. Time for treatment is cut short and water is not treated properly. Adding or removing soils to decrease or increase the slope can solve this problem.

Soil containing loam, sand, and gravel allows the proper amount of time for runoff and purification (MDHS 1983). Soil cannot be too porous, otherwise water runs through too quickly and is not sufficiently treated. Depth of bedrock is another important consideration. If the bedrock is too shallow, the waste will not be able to sink and will rise back up to the surface of the soil. Clays and thin (fine) soils do not allow for water penetration and again water will run along the surface untreated. A solution to this would be to add loam and sand to improve the permeability. If a soil drains too quickly, loam and clay can be added to slow the movement down.

Federal, state, and local laws are established to protect the land and water quality. The federal government sets the minimum standards for subsurface waste disposal systems. The states then can make these rules more strict. The states set new minimums according to the federal laws. Examples include minimum setback for septic systems and no new septic systems on a flood plain (MDHS 1983). Maine's Comprehensive Land Use Plan sets the standard regulations that each city and town must follow. Each town can set up their own land use plan, according to the state regulations, but many just develop local ordinances that

consider specific things. 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 2000 gallons per day and no systems can be built less than 100 ft away from any well when the septic system uses less than 2000 gallons per day (MDHS 1988). 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 the people living in the Great Pond Watershed as well as for the ecosystem within the lake. By following these mandates, safe and efficient septic systems can be installed and used.

Roads

Roads can greatly contribute to water quality deterioration by adding to phosphorus loading within the watershed. They do this by creating an easy access route for runoff from the land into the lake. This is especially prevalent for roads that lead directly down to the water. Besides adding phosphorus, they may allow easy access for runoff of other nutrients and organic pollutants into the lake via improperly constructed culverts and ditches. Improper construction and maintenance can increase the nutrient input caused by roads.

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 help to deteriorate the road even more rapidly by dislodging particles from the road surface and carrying them away. These particles may then runoff as sediment into the lake, carrying a large amount of phosphorus with them. Roads may therefore be a large source of phosphorus loading to a lake if poor construction, maintenance, and/or erosion control practices occur (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). Thus, a well constructed road should allow surface

water to run off away from the road and divert road surface waters to prevent excessive amounts of surface runoff, phosphorus, and other nutrients from entering the lake. This may be done by considering the following items before road construction begins: road location, road area, road surface material, road cross section, road drainage (ditches, diversions, and culverts), and road maintenance (MDEP 1992a).

The location of a road is typically determined by the area in which homes are built, although the State of Maine has set guidelines to control the location of roads (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). Along with this limit, a new road in Belgrade should not be built with a grade of more than 10%, except for short segments of less than 200 ft (Belgrade 1991).

The surface area that a road occupies can also lead to an increased potential for erosion and runoff, and therefore must be limited. Thus, it is very important to design a road with its future use in mind. For instance, a road should be constructed no longer than is absolutely necessary. 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). If a group is not able to maintain the proposed road because of maintenance costs, it should build a road that is not as wide so that maintenance costs will be lower. Proper planning for maintenance is typically a more effective, practical, and less expensive way to develop the road area (Woodard 1989).

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

The road cross section is another important factor to consider when planning to build a road. A crowned road cross section allows for proper drainage to take place and helps in preventing deterioration of the road surface (MDOT 1986). This means that if the road is pictured in cross section, it will slope downward from the middle, towards the outer edges. The crown should have a slope of 1/8 to 1/4 inches per foot of width for asphalt and 1/2 inches to 3/4 inches per foot of width for dirt roads (Michaud 1992). This slope allows the surface water to run off down either side of the road as opposed to running over 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 of a road must also be considered when constructing it. Both ditches and culverts are used to help drain roads into buffer zones so that runoff will not enter the lake directly and buffer strips will absorb some of the nutrients from the road. 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 off the road and away from a body of water. They are ideally parabolic in shape with a rounded bottom and are of a sufficient depth, not exceeding a depth to width ratio of 2:1. The ditch should also be clean and free of debris, and covered with abundant vegetation to reduce erosion (Michaud 1992). These ditches must also be constructed of proper soil that will not erode easily from the velocity of waters passing through them.

Culverts are hollow pipes that are installed beneath roads to channel water in proper drainage patterns. The most important factor to consider when installing a culvert is its size. It must be large enough to handle the expected amount of water which will pass through it. If this is not the case, water will tend to flow over and around the culvert and wash out the road. This may increase the amount of erosion that is occurring on the road and thus increase the sediment load that may enter 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 pitch greater than 4% can lead to rapid velocity of water flowing through. An increase in velocity can cause erosion to fill the culvert and result in washout on the low side below the road. It is also important to have a proper crown above the culvert to avoid creating a low center point in the culvert.

The standard criteria for crowning above culverts is 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 the water into wooded or grassy areas, natural buffers are used to filter sediment and decrease volume through infiltration before the water reaches the lake, along with preventing the water from gaining velocity (Michaud 1992). Efficient installation and spacing of diversions can also eliminate the use of culverts (Michaud 1992).

Maintenance is very important to keep a road in good working condition as well as to prevent it from causing problems for the lake. Over time, extensive use and wear will cause a road to deteriorate. These problems will only become worse if ignored and will therefore cost more money in the long run to repair. Roads should be periodically graded, ditches and culverts cleaned and regularly inspected to assess any problems that may develop. These practices will help to preserve the water quality of the lake and will add to its aesthetic value.

Agriculture and Livestock

Agriculture can cause many problems within the watershed of a lake. Plowed fields and livestock grazing areas are potential sources of erosion, which could carry sediments and nutrients to the lake and have an adverse effect on the water quality (Williams 1992). 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, however, with areas that were in use before these ordinances were passed by the State of Maine in 1990. According to the Shoreline Zoning Act, these areas can be maintained as they presently exist and therefore may result in decreased water quality and increased erosion (MDEP 1990). Additional solutions to the problems related to tilling of soil are to plow with the contour lines (across as opposed to up and down a slope) and to strip crop.

Another potential agricultural impact on water quality is manure from livestock. Manure becomes a problem when it is spread as a fertilizer, which is a common agricultural practice. Manure spreading can lead to nutrient loading, especially in the winter when the ground is frozen and the nutrients do not have a chance to filter into the soil. These problems

become worse with the tendency to over fertilize. 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). Another solution may be to avoid spreading manure in the winter. The town may provide subsidies as an incentive if the problem is large enough. These solutions, though, do not address the problem of livestock that defecate close to water bodies that they may be drinking near. One solution for this may be to put up fences to keep the cattle away from the water. Runoff from the use of artificial fertilizers and pesticides is another way in which nutrients and other pollutants may end up in the lake. These problems can be minimized by only fertilizing during the growing season and not before storms. Pesticides can also lead to negative impacts on water quality. Alternative methods of pest control are available however, including biological controls like integrated pest management and inter-cropping, which is a planting alternating rows of different crops in the same field.

Forestry

Forestry is another type of development that can contribute to nutrient loading through erosion and runoff. The creation of logging roads and skidder trails may direct runoff into the lake. The combination of erosion, runoff, and pathways can therefore have a large impact on the water quality of a lake (Williams 1992). Again, there are state shoreline zoning ordinances which relate to these specific problems to minimize the damage done to a lake. For example, timber harvesting equipment, such as skidders, cannot use streams as travel routes unless the streams are frozen and traveling on them causes no ground movement (MDEP 1990). There is also a local ordinance which prohibits clear-cutting within 75 ft of the shoreline of the lake or river running to the lake. 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 have to be at least 100 ft apart. These regulations are intended to minimize erosion (MDEP 1990). 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 regulate these areas. Therefore, illegal forestry techniques may occur and negatively impact lake water quality.

Tree farms are also a component of many watersheds, including the Great Pond Watershed. These farms can be managed privately or federally. A problem may occur here depending on the purposes of the farm. For example, a tree farm may have been purchased to conserve the area, in which case, there would be limited runoff. This is because forests have the ability to act as a natural buffer for the nutrients going into a lake, if left undisturbed. On the other hand, most tree farms are raised for economic reasons, namely to harvest the trees. This use may be a problem if the farmer does not consider the value of the forest, other than timber production, before clear-cutting the area (Clawson 1975). Pesticides and fertilizers are sometimes used on tree farms, therefore, logging practices and tree harvesting are important issues in considering water quality. There are a few areas which have been logged recently and several tree farms located in the Great Pond Watershed.

Cleared Land

Cleared land also presents problems of erosion and nutrient runoff due to the large areas that have been cleared of trees and other vegetation which act as natural filters. Sediments from these cleared areas could create a problem because they carry large amounts of nitrogen, phosphorus, other plant nutrients, and chemicals to the lake. Without vegetation acting as a buffer these problems are made even worse. Since pasture land is created by the replacement of natural vegetation with forage crops, it is included in this category. Also included in this category are large grassy areas, such as lawns and parks.

The MDEP (1990) has established some guidelines for cleared land. For example, there can be no cleared openings greater than 250 ft^2 in the forest canopy within 100 ft of a lake or river. Where there are cleared lands, some solutions to minimize erosion may be to build terraces, which would decrease the flow of storm water down a slope allowing the nutrients to settle out before they get to the lake. Plowing parallel to the contour lines, as suggested for agricultural uses, will decrease the flow of storm water. These two solutions may prevent erosion by breaking up large areas of tilled soil.

Transitional Land

Before any form of development occurred in the Great Pond Watershed, the entire watershed was covered primarily in forest. As a result of population increases in the 1920s and 1930s, much of the forest surrounding the lake was cleared for multiple purposes such as agricultural, residential, industrial, and recreational. In recent years, much of the land in the Great Pond watershed has entered one of the stages of succession (see Lake Characteristics).

Succession is the replacement of one vegetative community by another with the end result a mature and stable community referred to as a climax community (Smith and Smith 1998). An open field ecosystem moves through various successional 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, fuller tree species. The canopy of this forest is more developed, and as a result, less light reaches the forest floor.

Wetlands

There are different types of wetlands that may be found in a watershed. A bog, which is dominated by sphagnum moss, sedges and spruce, has a high water table (Nebel 1987). 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 may include cattails and arrowheads (Nebel 1987). Swamps are waterlogged soils and can either be of woody or shrub types. Shrub swamps consist of alder, willow, and dogwoods while woody swamps are dominated by hemlock, red maple, and eastern white cedar (Nebel 1987). Wetlands are important because they contain a variety of animals, such as waterfowl and invertebrates (Nebel 1987).

The type of wetland and its location in a watershed are important factors when determining whether the wetland is a nutrient sink or source, that is, whether it prevents nutrients from going into the lake or contributes nutrients to the lake. It is also important to note that one wetland may be both a source and a sink for different nutrients. This characteristic may vary with the season as well, depending on the amount of input to the wetland. Vegetation is important because different flora take up different nutrients. For

example, willow and birch store more nitrogen and phosphorus than sedges and leatherleaf (Nebel 1987). This indicates that shrub swamps are a better nutrient sink than the other types of wetlands. Also, if nutrient sink wetlands are located closer to the lake, they will act more as a buffer, as opposed to ones further back in the watershed. Wetlands that do filter out nutrients are an important factor in controlling the water quality of a lake. These wetlands also help moderate the impact of erosion near the lake. Unfortunately, there are not enough incentives or regulations to protect these areas (SFI 1991). Without these regulations, water quality in some areas may decrease.

Although there are some regulations controlling wetland use, a lack of enforcement leads to development in, and therefore destruction of, wetlands. These areas should be protected by the Resource Protection Districts, which limit development to 250 ft away from the wetland. Wetlands, however, may be found in desirable areas, such as near a lake, which increases the likelihood of development even though these regulations exist (Nebel 1987). Therefore, the decrease of wetlands caused by development will most likely have negative effects on the water quality of a lake due to runoff, erosion, and a decrease of natural buffering.

Great Pond Characteristics

Geological and Hydrological Perspectives

Maine began its most recent glacial episode approximately 25,000 years before present (B.P.), when New England was enveloped by the Laurentide ice sheet (Marvinney and Thompson 1996). This ice sheet was several thousand feet thick and was centered over eastern Canada. It flowed east to southeast across Maine, until it reached its terminal position on Long Island, NY. The ice sheet began to recede as early as 21,000 B.P. By 13,800 B.P., the ice margin withdrew from the continental shelf east of Long Island, NY, and reached the current position of the Maine coast. As the ice sheet retreated to the northwest across southern Maine between 13,500 and 12,000 B.P., the late Pleistocene sea followed the ice margin, invading central Maine as far inland as East Millinocket and Bingham (Kehoe 1982). This marine submergence was due to the depression of the earth's crust by the weight

of the ice sheet, even though sea level was much lower in late-glacial times than the present, since more water was locked up as glacial ice than in the oceans.

The melting of glacial ice deposited tremendous amounts of sediment into the sea, which was in contact with the receding glacial margin. Sands and gravels discharged from streams along the ice front accumulated as deltas and submarine fans, while fine silt and clay sediments blanketed the ocean floor. Marine invertebrates found in this glacial-marine clay (known as the Presumpscot Formation) have been radiocarbon dated and indicate that marine submergence lasted until 11,000 B.P., when the depressed crust began to uplift due to isostatic rebound (Marvinney and Thompson 1996). Isostatic rebound is the uplift of the crust due to the release of a restraining factor, such as the tremendous weight of the glacial ice.

Meltwater streams in tunnels within stagnant glacial ice deposited coarse glacial sand and gravel. The melting of the surrounding ice left these deposits behind as ridges called eskers. Eskers are often well sorted, but only a few show any stratification due to their formation mechanisms. Whatever stratification was present in eskers was often disrupted and slumped as the supporting ice walls melted. There is an extensive Esker/Delta complex of note in the Belgrade Lakes Region.

Kames are irregular deposits of sand and gravel formed adjacent to, or along the ends of eskers. Any existing stratification in kames was disrupted as bodies of ice melted or toppled over, causing the layers of sand and gravel to become mixed. Other sands and gravels were deposited as outwash in valleys in front of the ice margin. These deposits are often well stratified. Unsorted, unstratified boulders and sediments that were released from "dirty" ice are known as till. These sediments do not undergo further reworking by the glacier. Ridges consisting of till or washed sediments are known as moraines, and were deposited parallel to an active ice margin, where rock debris still flowed to its terminus. Moraines are abundant in former marine submergence zones, and are useful indicators of the pattern of ice retreat (Marvinney and Thompson 1996). Moraines and glacial till are a common soil substrate found in the Belgrade Lakes Region.

In the waning period of glaciation in Maine, wind deposited outwash sands accumulated as large sand dunes on the east sides of river valleys (e.g., Androscoggin and

Saco valleys). Modern stream drainage patterns became established, and peat bogs, marshes and swamps began to deposit organic sediments. Successional forests soon replaced the tundra vegetation that had bordered the ice sheet, as the climate approached the stages of today.

One of the major drainage patterns established by glacial meltwaters and southeast glacial movement is the Messalonskee Stream drainage of which the Belgrade Lakes area a part. The Belgrade Lakes are a chain of seven lakes that connect to one another. The water in the Belgrade Lakes flows from East Pond to North Pond; then into Great Pond; into Long Pond, North Basin; then into Long Pond, South Basin; and finally into Messalonskee Lake (BI493 1998).

The lakes of the Belgrade Region vary in shape, depth and location of inputs and outputs (Table 3). These factors combine to influence the flushing rate and trophic state of the lakes and cause the variations that can be found between the lakes (see Lake Characteristics: Trophic Status of Lakes). The flushing rate of a lake is the number of times that the total volume of water in the lake is replaced in a year. A flushing rate less than 1.00 flushes per year means that it will take more than a year for the water volume to be completely replaced, while a flushing rate greater than 1.00 means that the total volume of water in a lake will be replaced in less than a year. Many lakes are completely flushed multiple times in a year while others take years to flush completely. The low flushing rate and shape of East Pond have contributed to its eutrophication and algal blooms. Long Pond, South Basin has the highest flushing rate of any of the Belgrade Lakes. This may be due to the morphology of its basin and its location towards the bottom of the Belgrade Lakes chain, as it receives water that flows through all the lakes that are higher in the chain. Great Pond has rather low flushing rate in comparison to other Belgrade Lakes. This may be due to its basin shape and that it only has one significant outlet.

Great Pond is a deep lake which is distinctively stratified during the summer months. Great Pond is classified as a dimictic lake meaning it has two turnovers, which occur in the early spring and fall (Chapman 1996). After the spring turnover, the warmer temperatures heat the upper layers of the lake and eventually cause stratification. This is when there is a difference in temperature between the upper epilimnion and the lower hypolimnion. The

Table 3. Hydrological characteristics of the lakes in the Belgrade Lakes region listed in chronological order of water flow. Data obtained from Biology 493 studies in 1991, 1994, 1995, 1997, 1998.

Lake	Orientation	Basin Shape	Surface Area (hectares)	Mean Depth (m)	Inputs	Outputs	Flushing Rate (flushes/ year)
East Pond	Northwest - Southeast	Broad, Shallow	698.0	5.0	none	Serpentine Stream	0.25
North Pond	Northwest - Southeast	Broad, Shallow	911.0	4.0	Serpentine Stream, Little Pond	Great Meadow Stream	1.00
Great Pond	North - South	Broad, Shallow	3313.0	6.0	Great Meadow Stream, Salmon Brook, Trout Brook, Robbins Mill Stream	Long Pond, North Basin	0.52
Salmon Lake	Northeast – Southwest	Narrow, Shallow	270.0	4.0	3 unnamed streams	Salmon Brook	0.54
Long Pond-North Basin	North - South	Narrow, Deep	540.0	11.0	Kidder Pond, Watson Pond, Whittier Pond, McIntire Pond	Long Pond, South Basin	2.99
Long Pond-South Basin	North – South	Narrow, Deep,	540.0	11.0	Ingham Pond, Moose Pond, Long Pond, North Basin	Belgrade Stream	3.55
Messalonskee Lake	Northeast - Southwest	Long, Narrow, Deep	1419.0	10.0	Belgrade Stream	Messalonskee Stream	1.54

transition zone between these layers is called the thermocline and it acts as a physical barrier to mixing. Increased algal growth in the epilimnion die and eventually settle out on the bottom of the lake. This increases aerobic decomposition of the organic matter lowering dissolved oxygen. Historical data from the DEP shows that by late August, Great Pond is distinctly stratified. The Belgrade Lakes Region is a part of the Messalonskee Stream drainage, one of the major drainage patterns established by glacial meltwaters and southeast glacial movement. There are seven Belgrade Lakes which flow from East Pond to North Pond, then into Great Pond (into which Salmon Lake flows), into Long Pond-North Basin, then into Long Pond-South Basin, and finally into Messalonskee Lake (Fig. 8).

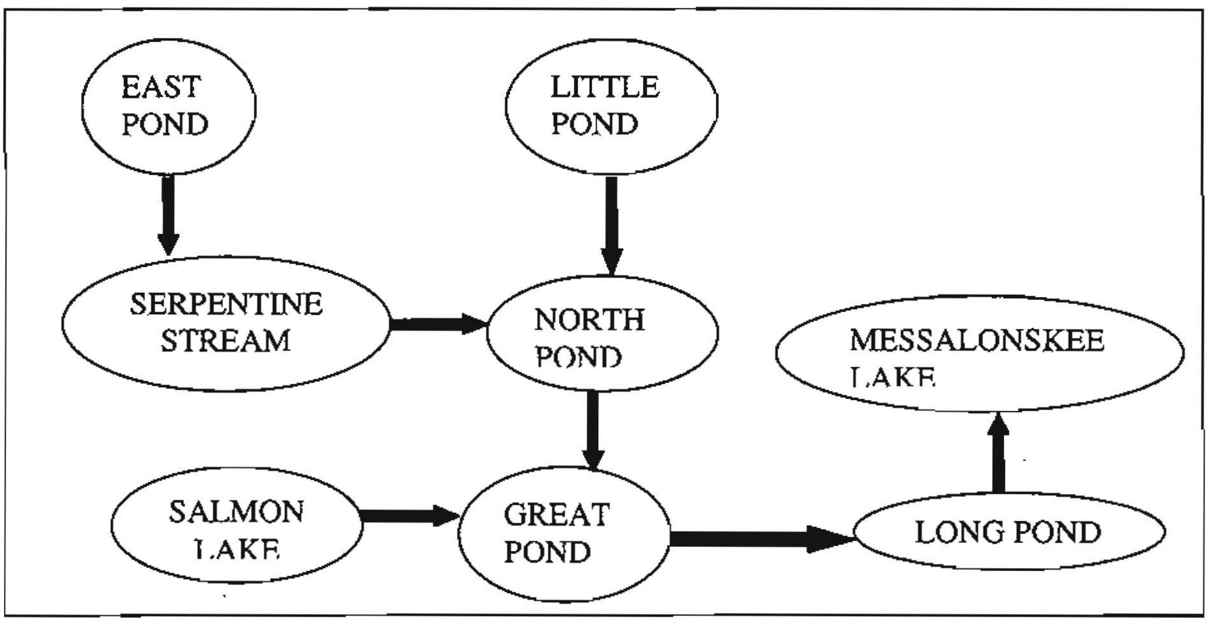

Figure 8. Schematic representation of the inflow and outflow of Great Pond. Arrows represent flow of water through the Belgrade Lakes chain. Kidder, Watson, Whittier, McIntire, Ingham, and Moose Ponds also flow into Long Pond and Ward Pond flows into Messalonskee Lake. See hydrological characteristics of the Belgrade Lakes (Table 5).

The lakes of the Belgrade region vary in shape, depth, and location of inputs and outputs (Table 3). These factors combine to influence the flushing rate and trophic state of the lakes and cause the variations that can be found among the lakes (see Lake Characteristics: Trophic Status of Lakes). The flushing rate of a lake is the number of times that the total volume of water in the lake is replaced in a year. A flushing rate of less than

1.0 flushes per year means that it will take more than a year for the water volume to be completely replaced, while a flushing rate greater than 1.0 means that the total volume of water in a lake will be replaced in less than a year. Many lakes are completely flushed multiple times in a year while others take years to completely replace the volume of water. Water will flow through a lake faster, increasing the flushing rate and rate of turnover, if a lake basin is straight, as opposed to having bays in which water may become trapped for a period of time. A flat, narrow lake basin also helps to increase these rates. The flow of water in a lake is aided by winds, especially when the orientation of the lake is the same as the prevailing winds. The prevailing winds in the Belgrade Lakes Region are south to southwest (Koons, pers. comm.), which is the direction in which some of the Belgrade Lakes are oriented (Table 3). The low flushing rate and shape of East Pond have contributed to its accelerated rate of eutrophication and algal blooms. Long Pond-South Basin has the highest flushing rate of any of the Belgrade Lakes. This may be due to the morphology of its basin and its location towards the southern end of the Belgrade Lakes chain; it receives water that flows through all the lakes that are further north in the chain.

Water flowing into Great Pond takes longer to flow through the lake in comparison to other Belgrade Lakes (Table 3). This is due to its volume in relation to the inputs and the size of its watershed. It has only one significant outlet. It also has many bays which may trap water and slow down the rate of water flow. The orientation of the long part of the lake is north to south, opposite the direction of the prevailing winds, which may also hinder the flow of water through the lake.

Great Pond is a deep lake that is distinctively stratified during the summer months (MDEP 1998). When classifying it based on its thermal characteristics that are a result of climatic conditions, Great Pond can be classified as a dimictic lake, since it is located in the cool temperature latitudes (Chapman 1996). A dimictic lake has two turnovers that occur in the early spring and fall. After the spring turnover, the warmer air temperatures heat the upper layers of the lake and eventually cause stratification. Thus, there is a difference in temperature between the upper layer (epilimnion) and the lower layer (hypolimnion). The transition zone between these layers is called the thermocline. The density of the water at the different layers inhibits mixing between layers. Algae growing in the epilimnion eventually

die and settle out in the bottom of the lake. The resulting aerobic decomposition of the organic matter lowers dissolved oxygen in the hypolimnion. Historical data from the DEP show that by late August, Great Pond has stratified to the point of oxygen depletion (MDEP 1998).

Historical Perspectives

Land use patterns in the Belgrade Lake Region have changed dramatically over the last 60 years. The land surrounding the Belgrade Lakes has experienced three distinct land use eras. In the 1930s, year-round residents of Belgrade were isolated and self-sufficient. To meet water needs for irrigation purposes, a majority of farmlands were located on lake shorelines. However, during World War II (WWII) many of the young men left the farms to join the depleted labor force that was created by the large populations that left to fight in the war. These men learned many new trades and skills in the workplace. A predictable wage and less time on the job gave the men different ideas of how to make a living when they returned home after the war (BI493 1998). Increased development and expanding job opportunities reduced the amount of land used for agriculture and grazing. Much of the land was left fallow and allowed to undergo succession.

In the 1960s, the second era of land use trends began. The Belgrade Lakes Region was greatly influenced by the occupational changes of the regional residents at the end of WWII. Many of the shoreline farms that had been left fallow after the war were subdivided so more residences could be built on the shoreline (BI493 1998). Farmed land moved farther from the shore. Also, the development of land for municipal and industrial use increased. To keep all the newly developed land linked together, many new roads were built, greatly increasing the area of roads in the watershed.

Changing development trends characterize the third era. There is no definite boundary between the second and third eras. Most of the development in recent years has been for year-round residences whereas the second era is characterized by growing industrial development. The increase in residential development is a result of people moving away from Augusta and Waterville to the Belgrade Lakes Region. Development of land for municipal and industrial use has continued to increase, but the rate of development has

slowed. As this report documents, natural land has decreased as the amount of developed land has increased over the past 60 years.

Biological Perspectives

Background

The Belgrade Lakes Region is a part of the 177 square mile Messalonskee Stream drainage which is a tributary of the Kennebec River. The seven major bodies of water making up the Belgrade Lakes Region (Great Pond, Messalonskee Lake, Long Pond South Basin, Long Pond North Basin, North Pond, Salmon Pond, and East Pond) have a total surface area of 20,311 acres (Belgrade Region, Inc. 1995). Great Pond is the largest of these lakes at 8,239 acres and has the most variation in biological and geographical features. The lake supports a dynamic ecosystem and its survival is important to the environment and economy of the Belgrade Lakes Region. Natural events and anthropogenic influences can affect the watershed environment, resulting in physical and chemical changes (Chapman 1996).

Trophic Level

The Belgrade Lakes are classified as mesotrophic (see Lake Characteristics: Trophic Status of Lakes). Historically Great Pond has been classified as oligotrophic, with some mesotrophic qualities by Davis et. al (1978). The trophic state of a lake reflects the rate of supply of nutrients supporting primary production within the water column. The biomass productivity of a lake can be determined by examining transparency, chlorophyll-*a*, and total phosphorus concentrations. An evaluation of transparency can be made with a Secchi disk. Transparency is the depth at which the Secchi disc disappears from visibility, and is influenced strongly by the amount of dissolved particulate matter suspended in the water column (Wetzel and Likens 1991). A low transparency reading suggests high amounts of dissolved organic material and could result from increased primary production.

Chlorophyll-*a* and phosphorus measurements can be used to estimate the biomass of primary producers in a lake. Chlorophyll-*a* is the dominant pigment found in aquatic plants

and is responsible for absorbing light energy for the photosynthetic process of primary producers (Wetzel and Likens 1991). Phosphorus is an essential nutrient for primary production. Lakes typically receive less phosphorus than other nutrients, and it becomes a limiting factor for plant growth as long as the amount of phosphorus is not increased artificially through anthropogenic activity (Lampert and Summer 1997). Water that has a high concentration of phosphorus, a prerequisite of chlorophyll-*a*, indicates the potential for high algal production, and accelerated eutrophication.

Great Pond Flora

Great Pond has diverse flora, including macrophytes, algae, mosses, and phytoplankton (Davis et al. 1978). The most dominant phytoplankton, based on the abundance of cell number, is Cyanobacteria, followed by Chrysophyta and then Chlorophyta. Chrysophytes, however, have larger cell bodies and make up the bulk of the phytoplankton biomass in Great Pond. Larger cells have a greater total storage of material, while smaller cells have greater metabolic rates and greater exchange of substances with the environment per unit of biomass (Davis et al. 1978). It is uncertain whether biomass or cell number has greater significance in the importance of phytoplankton.

Macrophytic plants, the most significant primary producers in the lake, make up a large part of the aquatic biomass and play a key structural role in the ecology of the lake. Macrophytes influence other autotrophic components, nutrient dynamics, dissolved organic and inorganic carbon, oxygen, and pH (Jeppesen et al. 1998). Macrophytes also regulate the structure of pelagic and benthic food webs (see Lake Characteristics), affecting the interactions between predacious, planktivorous, and benthivorous fish, and other organisms, such as large zooplankton and snails (Jeppesen et al. 1998).

Many factors can affect the macrophyte population. Higher nutrient input results in a reduction of available light, limiting the macrophytes photosynthetic abilities. A change in light intensity changes the conditions of the lake and alters the dominance of macrophytes (Jeppesen et al. 1998). Macrophyte populations can also be altered by a change in piscivore (fish eaters) density. As primary carnivores alter hunting pressure on the primary grazers, different grazing pressures are formed. These changes cascade down to the primary

producers, macrophytes, and phytoplankton. The activity of grazing birds affects macrophytes, directly by consumption, and indirectly by selective grazing, damage to surrounding plants, and distribution of nutrient cycling (Jeppesen et al. 1998).

Great Pond Fish Community

The Great Pond Watershed supports a variety of fish common in Maine. The Belgrade Lakes Region is a popular summer vacation spot, with many seasonal homes in the region, and is popular for recreational boating and fishing. Each lake has boat landing sites accessible from major roadways, and Great Pond has an active marina. Historically Messalonskee Lake, North Pond, and East Pond are known for largemouth bass (*Micropterus salmoide*) and smallmouth bass (*Micropterus dolomieui*), white perch (*Morone americana*), and chain pickerel (*Exos niger*) fishing. Long Pond has an active landlocked salmon fishery (*Salmo salar*), while Salmon Lake has yellow perch (*Perca flavescens*), brown trout (*Salmo trutta*), and black crappie (*Pomoxis nigromaculatus*) (Belgrade Region, Inc. 1995). Great Pond has the most diverse species composition of the Belgrade Lakes Region (see Appendix A).

The most popular native game fish found in the Belgrade Lakes are eastern brook trout (*Salvelinus fontinalis*) and landlocked salmon. New species have been illegally introduced to the region from outside sources and now make up the majority of the successful fish populations. Largemouth bass, smallmouth bass, northern pike (*Exos lucius*), and brown trout (*Salmo trutta*) for example have become an established and integral part of the ecosystem (Belgrade Region, Inc. 1995).

The Department of Inland Fisheries and Wildlife (IF&W) has stocked the Belgrade Lakes Region for many years. In the past, the focus has been on stocking brook trout and landlocked salmon, but recently these species have been less successful, and the IF&W has been forced to alter its stocking program. Salmon have been stocked in Great Pond since the 1930s and brook trout was introduced unsuccessfully in 1987. In 1996 the IF&W switched to stocking brown trout. The salmon stocking program has had difficulty in Messalonskee Lake as well. Splake, a hybrid between brook trout and lake trout, are stocked there instead (McNeish, pers. comm.).

The success of brown trout and splake has yet to be determined because most fish species are initially successful in a new environment (McNeish, pers. comm.). There are many reasons to believe the new species will be more successful than the predecessors, salmon and brook trout. Brook trout, for example, fail easily under heavy competition or predation. With the current predatory conditions in Great Pond, pressures on brook trout are high. They can only survive if individual sizes surpass the predation point (9 inches to 10 inches in length) and are too large to be threatened. Both brown trout and splake can better withstand the pressure of a changing predatory environment.

Brown trout and splake should be more successful than the salmon as well. Salmon is highly dependent on rainbow smelt (*Osmerus moradax*), a small fish found in the thermocline, as its primary food source. The brown trout and splake food base is much broader (McNeish, pers. comm.). Brown trout and splake will eat white and yellow perch and shiners. Despite similar predatory pressures, they are able to capture more available resources (McNeish, pers. comm.).

One possible reason why salmon fisheries fail is low amounts of dissolved oxygen (DO) found in the hypolimnion due to accelerated eutrophication (see Lake Characteristics). Salmon is typically a cold-water fish, and depends on high oxygen levels. If DO levels fall below 5 parts per million (ppm), cold water fisheries become stressed and unhealthy (Pearsall 1993).

Great Pond is experiencing an increased rate of DO depletion (see Lake Water Quality: Dissolved Oxygen and Temperature), but there are other more likely reasons for the failure of the salmon fishery. One possibility is the introduction of the northern pike, which first appeared in the lake in the 1970s (MDIFW 1996). Thousands of pike can be stocked illegally and easily as fry (very small fish). Despite a 90 percent to 95 percent death rate, those that survive grow 10 inches to 11 inches after one summer (McNeish, pers. comm.). A piscivorous species, their success is destructive to the native salmon populations. In a 1992 species composition survey of Great Pond, pike comprised 5.6 percent of the total fish population, while salmon made up only 3.5 percent, despite heavy stocking of salmon that year (MDEP, unpublished data). The survey probably underestimates the number of pike in

the lake today (McNeish, pers. comm.). The impact of the successful establishment of pike in Great Pond is uncertain and the IF&W has adopted a "wait and see" policy.

Another species recently introduced to Great Pond is the walleye pike (*Stizostedion vitreum*). A member of the perch family, they were originally stocked in the 1920s and then became extinct in the lake during the 1930s. Their sudden reoccurrence is most likely a result of illegal stocking (McNeish, pers. comm.). One indication of this possibility is their uniform size, varying between 17 inches and 18 inches in length the first year discovered. Walleye pike are very piscivorous and have further increased pressure on salmon and smelt. The presence of walleye pike is a source of considerable concern, but its future in Great Pond is not yet determinable.

Two species that have an adverse effect on salmon fisheries through inter-specific competition for smelt are the black crappie (*Pomoxis nigromaculatus*) and land-locked alewife (*Pomolobus pseudo-harengus*). Black crappie is a type of sunfish with adults ranging from 12 inches to 14 inches in size, but it is not abundant in Great Pond. However, the land-locked alewife, a type of river herring, is quickly becoming abundant in Great Pond. The impact of its increased presence is uncertain.

Not all of the Belgrade Lakes salmon fisheries are facing the same decline. Long Pond has maintained a thriving fishery, despite having a very similar species composition to Great Pond. In a 1992 species composition survey of legal fish of Long Pond (MDEP, unpublished data 1992), northern pike was not represented in the total fish population, while salmon were 13.7 percent of total population. However, a lake inventory conducted in 1996 shows northern pike as a principle fish population in Long Pond (MDIFW 1996). These data may suggest that the fate of Long Pond salmon will eventually be the same as that of Great Pond and Messalonskee Lake.

Wildlife in Great Pond Watershed

Great Pond supports a variety of other animals, both in the aquatic environment and in the surrounding watershed. There are two important wetland habitats found in North Bay and Austin Bog, that support numerous wading birds and waterfowl (see Watershed Land:

Wetlands). The Department of Inland Fishery and Wildlife uses a general protection policy to assure a stable environment for the resident species (Kemper, pers. comm.).

Some species merit additional protection and special preservation attempts are made when they inhabit the Belgrade region. The bald eagle, a nationally threatened species, occasionally inhabits the area. Great Pond hosted a bald eagle nest on Oak Island in 1974 and Messalonskee Lake had a bald eagle nest in 1995. The black tern is a threatened species in Maine with only four major colonies in the state (Wilson, pers. comm.). Belgrade Bog hosts the largest black tern population in the east coast and they are dependent on the Great Pond wetlands for foraging (Maine Department of Inland Fisheries and Wildlife - Biological and Conservation Data Base, unpublished data). This demonstrates the interdependence and importance in maintaining the quality of all the lakes in the Belgrade region (Kemper, pers. comm.).

Many other terrestrial organisms are dependent on the water quality of Great Pond. Some birds, such as the hooded merganser (*Lophodytes cucullatus*), common loon (*Gavia immer*) and the great blue heron (*Ardea herodias*), are piscivorous and depend on a healthy fishery (Kemper, pers. comm.). Other birds are dependent on macrophytic and plankton growth as their main source of food. Most ducks, for example, feed primarily on aquatic vegetation, particularly pickerel weed. Species such as the river otter (*Lutra canadensis*), muskrat (*Ondatra zibethica*), and beaver (*Castor canadensis*) rely on the lake as a source of food and protection. The watershed is also important to other mammals and birds as a stable habitat. Deer yards, found in soft wood forests, such as hemlock stands, provide a dense canopy that keep the snow depth low and are important wintering sites for white-tailed deer (*Odocoileus virginianus*) and moose (*Alces alces*) (Kemper, pers. comm.). In order to assure that Great Pond will maintain a diverse ecosystem in the future, it is imperative to protect the lake and its greater watershed area.

Regional Land Use Trends

Similarities can be found in the land use patterns of the different watersheds in the Belgrade Lakes region. Most of the land in the watersheds of the region is covered in mature forest (69.9 %) (Fig. 9). Smaller amounts of land are devoted to other land use types, with the next largest land use type in the region being transitional land (8.8 %), which includes regenerating and reverting land. The amount of land devoted to different land use types varies by watershed (Table 4). While some lakes have higher percentages of their watersheds devoted to one land use type than others, they all have similar trends of land use in their watersheds. It is difficult to compare the percentage of land in the watersheds that is transitional or mature forest, since regenerating land was included with mature forest in the East Pond and Salmon Lake Watershed studies. Mature forest covers the majority of each individual watershed. The Long Pond-South Basin Watershed has a much higher percentage of land in a transitional state than the other watersheds in the Belgrade Lakes Region. This may have resulted from a decrease in recent years in the amount of logging or agriculture in the Long Pond South Basin Watershed (BI493 1996). The Messalonskee Lake Watershed has a much higher percentage of wetlands than others. The East Pond Watershed is the most developed, while Salmon Lake is the most rural. The land use trends reported by the Colby Environmental Assessment Team for the Great Pond Watershed are similar to the regional

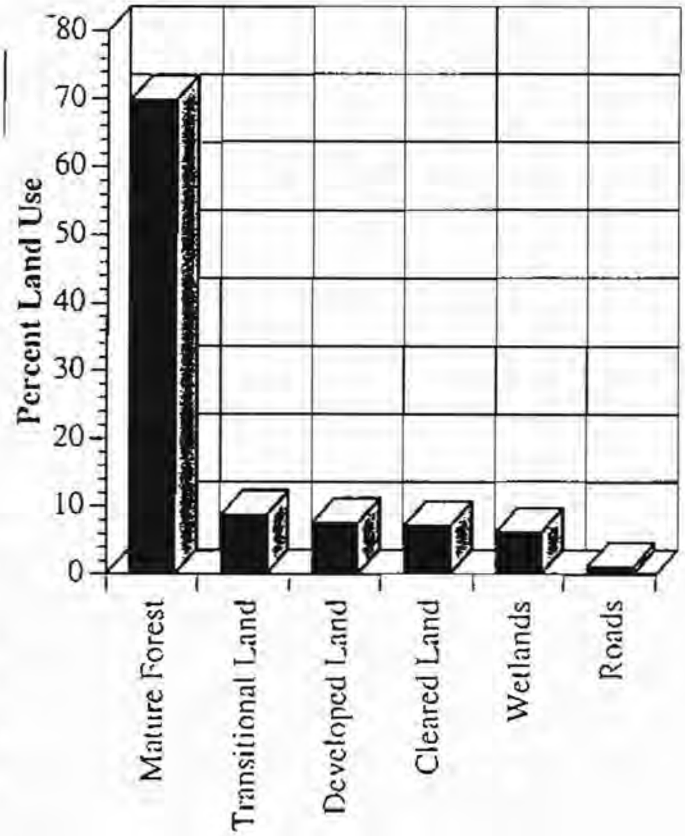

Figure 9. Mean percent land use in the Great Pond, Messalonskee Lake, Long Pond-South Basin, North Pond, Long Pond-North Basin, Salmon Lake, and East Pond Watersheds (BI493 1991, 1994, 1995, 1996, 1997, 1998).

Table 4. Percent of land use types in the watersheds of Messalonskee Lake, Long Pond-South Basin, North Pond, Long Pond-North Basin, Salmon Lake, and East Pond. Transitional land includes reverting and regenerating land. Cleared land includes agricultural and municipal land. Developed land includes industrial, commercial, and residential land. Mature forest for East Pond and Salmon Lake includes regenerating land. Data obtained from Biology 493 studies in 1991, 1994, 1995, 1996, 1997, 1998.

	Messalonskee Lake	Long Pond-S. Basin	Long Pond-N. Basin	North Pond	Salmon Lake	East Pond
Wetlands	13.5	8.3	4.2	7.0	1.0	3.0
Mature Forest	58.5	58.0	68.0	75.0	83.0	77.0
Transitional Land	4.0	27.0	14.5	2.0	3.0	2.0
Cleared Land	13.9	4.8	3.0	10.0	9.0	2.0
Developed Land	8.8	6.7	9.0	4.0	3.0	14.0
Roads	1.3	0.5	1.0	1.0	1.0	2.0

trends found previously throughout the Belgrade Lakes Watersheds (see Land Use: General Land Use Trends Overview).

Resource Protection and Nesting Areas

Great Pond holds countless valuable resources for the residents as well as for the fish and other wildlife living in its vicinity. This study aims to consider all of the resources of Great Pond in order to accurately make recommendations for the development and land use of the region to protect its future.

The prominent anthropological use of the Great Pond is tourism. People come from all over the United States to enjoy the Belgrade Lakes Region during the summer and autumn months. This is demonstrated by the sharp contrast between the winter and summer populations of the region. Private camps located around the shoreline of the lake accommodate people who enjoy fishing, boating, hunting, and the pure scenic beauty of the

area. However, all of these activities become threatened when the water quality of the lake deteriorates.

One of the most important resources found in the Great Pond Watershed is the wetland areas. There are two large wetland areas in Great Pond, North Bay and Austin Bog (Fig. 10). These sheltered wildlife habitats are classified as sensitive nesting areas for birds (MDC 1976). Wetlands act as a buffer between the land and open water ecosystems (see Watershed Land: Wetlands). The extensive vegetative root systems of wetlands are extremely efficient in the uptake of nutrients from runoff (Etherington 1983). The roots take up nutrients before they have a chance to enter the lake and enhance eutrophication.

The wetland is more vulnerable to human actions than any other habitat (Etherington 1983). Disturbances such as development on upland areas can increase erosion and add extra nutrients to the runoff, potentially overloading the wetland. If the plants cannot assimilate all of the nutrients which it encounters, the unassimilated nutrients are washed directly into the lake water. Development on the wetland reduces its buffering capacity (National Research Council 1995). Damage to the wetland can also release stored nutrients into the lake (Weller 1994).

As wetland plants take up nutrients, nutrient cycling creates an extremely fertile base upon which a diverse and highly productive collection of plants may grow. This dense growth of hydrophytes (water tolerant, rooted, soft-stemmed plants) slows the movement of runoff and induces the settling of particulate matter (Weller 1994). The hydrophytes help to protect the neighboring shoreline from erosion by breaking the force of wind and wave action, halting a significant source of nutrient loading and saving shoreline property from damage.

Because of their high primary productivity, freshwater wetlands are significant sources of biodiversity (National Research Council 1995). Below the surface of the substrate, massive decomposition by bacteria leads to anoxic conditions. Anoxic conditions harbor a unique set of microorganisms, which are integral to the workings of the wetland (Etherington 1983). Anoxia in the body of the lake is considered detrimental because it may result in the release of phosphate into the water column; however, in wetlands, anoxic conditions promote biodiversity.

Figure 10. Map of Great Pond Watershed.
Approximate scale : 1 inch = 1 mile.

Countless species reside within the wetland or use the area as a nursery, laying their eggs or bearing their young in the protected, productive area. Endangered species, such as bog orchids and bald eagles, depend on the wetland for their survival.

Great Pond has a popular recreational fishery (see Great Pond Characteristics: Biological Perspectives). This is a valuable resource, bringing tourist dollars to the surrounding towns and providing income to many people of the area. The fishery is dependent on healthy water quality. Decreasing oxygen levels caused by cultural eutrophication will lead to a decline in fish populations. This will dramatically change the fishery, as well as throw off the delicate balance of the food chain in the lake.

Also important to the tourism income of the area is the boating, swimming, and aesthetic quality of Great Pond. With nutrient loading and enhanced eutrophication of the lake ecosystem, algal blooms lead to decreased water quality. Boating and swimming become unappealing.

A third tourism resource is the hunting in areas surrounding lakes and wetlands. Numerous hunters are attracted to the ducks, deer, and small furbearers associated with the lake ecosystem (Bureau of Land and Water Quality 1998a). These animals all rely on the maintenance of water quality to support the food chain upon which they depend.

The Maine Department of Environmental Protection upholds the standards set by the Clean Water Act of 1977 to protect Great Pond. This act regulates activity on or around wetlands by requiring a permit for drainage, soil removal or construction in, on, or over a wetland or near a wetland with the threat of material in the runoff (Bureau of Land and Water Quality 1998b).

In the comprehensive plan for Maine, the Maine Department of Conservation set up a number of subdistricts in order to effectively protect the natural resources of the state (MDC 1976). Each subdistrict applies to a specific ecosystem which is found commonly in Maine. The subdistricts that apply to Great Pond are the great pond, fish and wildlife, and wetlands subdistricts. Within great pond subdistricts, development is regulated so that it will not interfere with waters, recreation, fisheries, or scenery. Commercial and campground development is restricted to permit-bearing operations and foresters must have a permit before legally harvesting trees. The wetlands protection subdistricts prohibit sanitary

landfills, mineral extraction, and other construction on wetlands and conditional permits are granted for filling, draining and dredging. The construction of transportation and utility structures is allowed on wetlands. Any land uses that have a detrimental effect on protected species are regulated within the fish and wildlife protection subdistricts. Agriculture, land management, road construction, and timber harvesting are permitted after each project has been reviewed and approved by the MDEP.

The Inland Fish and Wildlife Service (IFWS) also protects the wildlife resources of Great Pond. The policy of the IFWS is to maintain the populations of the wildlife that are naturally found in the ecosystem, by restocking and establishing protective regulations around the lake (Kemper, pers. comm.).

Belgrade has approved a more intensive comprehensive plan for the town for the next five years. In the strategies for natural resource protection, the town outlines plans to adopt and apply the DEP's standards for erosion and sedimentation control (Belgrade 1998). Code enforcement inspection will be required to ensure compliance. The town will inventory the roads of the town and take on the remediation of the worst roads. Storm drains will be cleaned regularly. The town will support the Conservation Corps in an application to the DEP for the establishment of a Priority Watershed Project. This Project will provide local towns with federal funding for the reduction of lake contamination in Great Pond and other nearby lakes. An education program will be implemented to increase awareness about the flora, fauna, and habitats of the region. The town will work towards purchasing land for public land conservation. Finally, Belgrade hopes to improve monitoring of the sensitive ecosystems and devote more money and effort to code enforcement within the town.

STUDY OBJECTIVES

Water Quality Assessment

Lake Body

The purpose of this study is to gain a general perspective on the health of Great Pond, and to identify possible problem areas. Water quality tests were performed on Great Pond to

determine both physical and chemical parameters. The physical measurements taken were dissolved oxygen, temperature, transparency, turbidity, conductivity, and color, while the chemical tests performed were total phosphorus, nitrate, hardness, pH, and alkalinity. Accurate measurements, quality sampling techniques, and detailed chemical analyses are necessary to recognize and quantify changes in the water quality. Historically, the information gained from water quality assessment has been used for corrective rather than preventative measures. Today, it can be used to identify the effects of anthropogenic activities, and find possible solutions before problems develop (Stednick 1991).

Preliminary water quality tests and camp road identification began in the summer of 1998. During the fall of 1998 the Colby Environmental Assessment Team (CEAT) performed a reconnaissance of Great Pond to gain a general overview of the terrain of the lake, shoreline residence counts, and buffer strip characteristics. CEAT then carried out detailed water quality measurements and tests. Site locations for the tests were determined by CEAT in conjunction with test sites predetermined by the Maine Department of Environmental Protection (Fig. 11).

The water quality assessment also included the relative effects of local industry, development, agriculture, and recreation within the watershed. Great Pond has seasonal homes, summer camps, horse farms, logging companies, electric utility companies, and local commerce within its watershed. Any land use and development activities have the potential to affect the quality of the water. It is therefore essential to assess these elements to assure that watershed management practices minimize pollution in the lake. Results from the Great Pond Watershed assessment were compared to the Maine Department of Environmental Protection studies.

Tributaries

Physical measurements were taken on Great Pond's tributaries to determined flow rate, dissolved oxygen, color, conductivity, temperature, and turbidity, while chemical tests determined phosphorus, and pH. Tributaries are defined as direct water flow from the watershed into the lake. The characteristics of a tributary are highly dependent on the geological structure and land-use patterns within the watershed (Wetzel and Likens 1991). Great Pond has many tributaries, but some are difficult to detect, or flow only during high

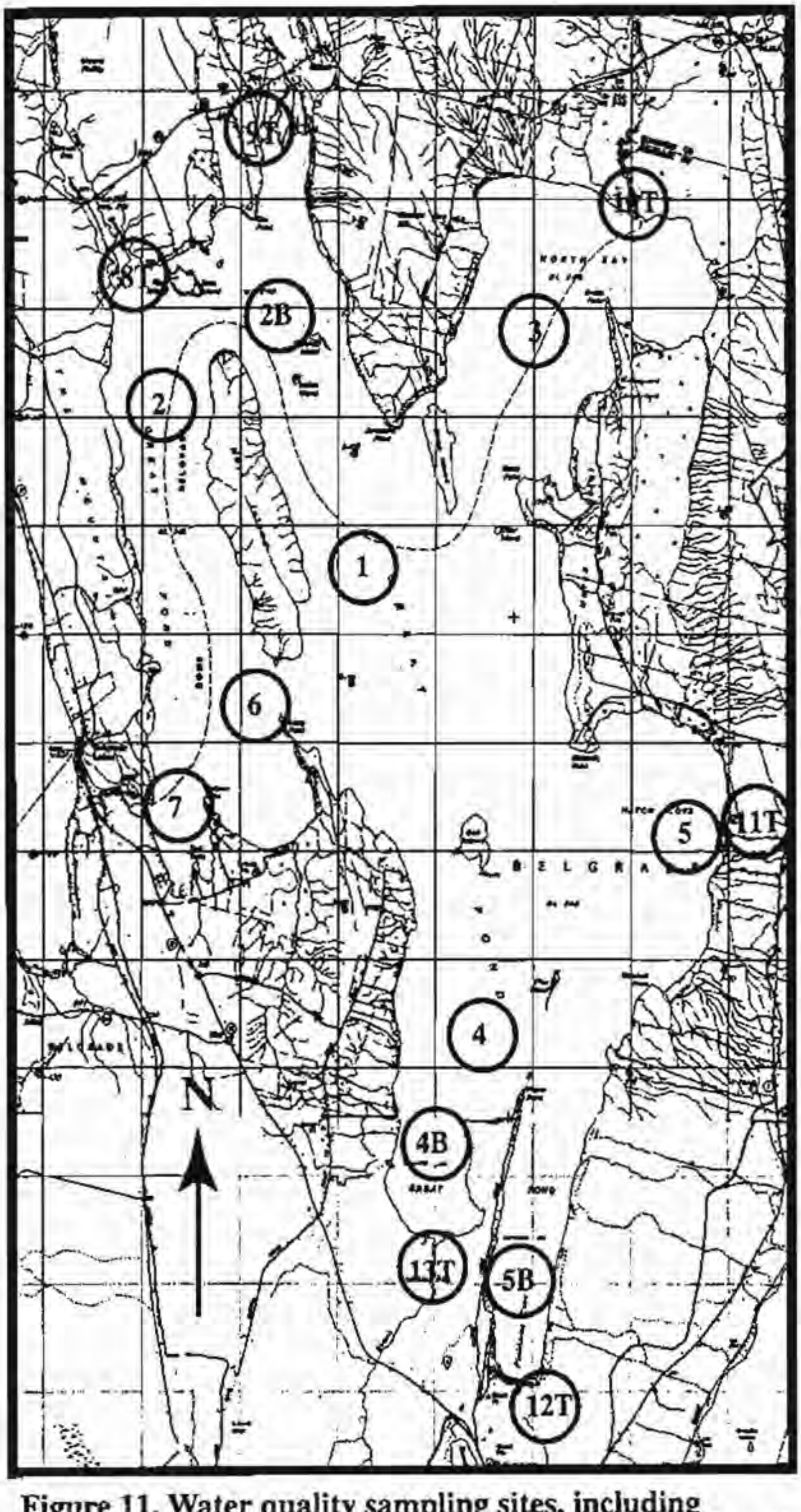

Figure 11. Water quality sampling sites, including Characterization Sites 1 - 5, Spot Sites 2B, 4B, 5B, 6 and 7, and Tributary Sites 8T - 11T in the Great Pond Watershed. Approximate Scale : 1 inch = 2 miles.

precipitation periods, such as spring snowmelt and after a storm. This report concentrates on tributaries with large year-round flow rates. Six major tributaries were identified as significant input sources by the (Fig. 11). Water carried by tributaries is potentially very nutrient-rich, and improper land use and development activities can increase these concentrations to unnatural levels and translocate toxic pollutants.

Land Use Assessment

Effect of Land Use Patterns on Water Quality of Great Pond

The Great Pond Watershed drains into tributaries leading to Great Pond and sends runoff directly into Great Pond. This water carries nutrients and other pollutants into the lake from a range of land-use sources. These different types of land use have various effects on water quality. There are two broad categories of pollution sources. The first is point sources, which are traceable sources such as an industrial outfall pipe. The second, non-point sources, are less easily defined and come from the combined contributions of a variety of sources, such as gardening, pesticide and fertilizer application, septic system leakage, building construction, and boating. The objective of CEAT was to examine the different types of land use, including cleared land, forested land, logged land, municipal land, residential land, and roads within the Great Pond Watershed in order to estimate future trends in the water quality of Great Pond.

The greatest contamination of Maine's waters comes from non-point sources, such as highway deicing chemicals, petroleum leakage from underground storage tanks, and waste disposal from septic systems (USGS 1986a). Another significant source of water pollution in Maine is the application of insecticides and herbicides. When fertilizers and pesticides are added to lawns and gardens, they are often washed with the runoff into the lake. The highest potential for changes in water quality is in high population growth and resort areas, such as the Belgrade Lakes Region. As the population grows in this region, the amount of development will increase. Roads will be built to accommodate travel, creating hard surfaces which funnel nutrients into the lake water. The number of septic systems will increase and

more nutrients from sewage effluent will leach into the lake. Nutrients from septic systems, road deicing chemicals, and lawn and garden chemicals together contribute the highest levels of inorganic constituents such as phosphorus, nitrogen, calcium, chloride, magnesium, and dissolved solids (Grady and Weaver 1988). The United States Geological Survey (1986b) did a study in Barnstable County, MA., an area undergoing similar population growth, and found a positive correlation between housing density and nitrate concentrations. Similarly, development can increase concentrations of phosphorus in runoff by up to ten times the natural concentration (COLA 1992). Both phosphates and nitrates may contribute to intense algal blooms and the accelerated eutrophication of a lake such as Great Pond.

Agricultural lands also contribute to the pollution of the lake. Fertilizers and lime contribute the highest concentrations of magnesium, organic nitrogen, and phosphorus (a major constituent in the eutrophication of a lake) (Grady and Weaver 1988).

Gravel pits at various intervals along the southeastern border of the lake have the potential to contribute mineral particles and nutrients to the lake through runoff. The destruction of vegetation along the border of the lake (due to development, landscaping, and forestry practices) reduces valuable buffer zones and vegetative nutrient sinks. This study explores the effect of these activities on the water quality trends of Great Pond.

ANALYTICAL PROCEDURES AND FINDINGS

QUANTITATIVE WATER MEASUREMENTS AND CALCULATIONS

Water Budget

Water quality within a lake is determined by chemical testing, physical measurements and by calculating the water budget. The water budget is used to determine the inputs and outputs of the lake, the flushing rate of a lake, and can be used in developing lake level management strategies. The flushing rate of the lake is a measure of how many times in a year the volume of the lake is theoretically replaced (see Great Pond Characteristics: Geological and Hydrological Perspectives). A high flushing rate slows eutrophication because it flushes nutrients through the lake ecosystem. A low flushing rate will speed the eutrophication process because nutrients accumulate in the lake.

Methods

The water budget was calculated to determine values for the I_{net} and flushing rate for Great Pond (see Appendix B). The I_{net} for Great Pond is the net volume of water entering the lake. Specifically, it is the amount of water contributed to the lake from precipitation, runoff, and upstream bodies of water minus the amount of water lost to evaporation in a year (Foster 1948, Black 1996).

The land and lake areas were determined using United States Geological Survey (USGS) 7.5 minute topographic maps of the watershed (Belgrade, Belgrade Lakes, Mercer, Rome, and Readfield quadrangles) and digitizing equipment (see Land Use: Land Use Methodology). Land area includes the land surrounding the lake within watershed boundaries as well as the area of islands in the lake. The land area used for these calculations

was 84.38 square kilometers. This value differs 1.62 square kilometers from the value of 82.76 square kilometers published by the Maine Department of Environmental Protection (MDEP). However, the MDEP does not appear to have included the area of the islands in their total land area since the difference between the CEAT value and MDEP value is very close to the area of the islands.

Precipitation was calculated as a 10-year mean of data for Augusta and Waterville. These data were obtained from the National Oceanic Atmospheric Administration (NOAA 1987-1997). The yearly amounts of precipitation were averaged over the last 10 years for both Waterville and Augusta. A mean was then taken for the two towns combined. The precipitation data for Waterville were recorded at the Kennebec Sanitary Plant and the Augusta data were recorded at the Augusta Airport. The runoff value used in the I_{net} calculation was obtained from a 10-year mean of runoff in the Kennebec River Basin from 1958 to 1967 (North Kennebec Regional Planning Commission, unpublished data). The evaporation value was obtained from a previous study of the Lower Kennebec River Basin (Prescott 1969).

The flushing rate was calculated by adding the I_{net} of Great Pond to the I_{net} values for all of the upstream lakes, ponds, and tributaries flowing into Great Pond and dividing this value by the volume of Great Pond (see Appendix B). Volume was calculated by multiplying the lake area times the average depth of the lake. The mean depth was obtained from MDEP (MDEP 1994a).

$$\textbf{Flushing Rate} = \frac{I_{nets} \text{ of contributing ponds and lakes} + I_{net} \text{ of Great Pond}}{\text{Mean depth Great Pond x Lake Area}}$$

Results and Discussion

The flushing rate is affected by three main factors, two of which come directly from the equation for the flushing rate: the total inputs from contributing lakes and ponds and volume of the lake. The watershed area is the third factor influencing the flushing rate.

The larger the total volume of inputs from upstream sources (first factor), the higher the flushing rate will be. Several inputs with low volumes or a few inputs with high volumes will lead to a high total volume of inputs to the lake. The higher volume of water entering the lake will lead to a higher flushing rate. The second factor, volume of the lake, is inversely proportional to the flushing rate. The greater the volume of the lake, the lower the flushing rate. Small lakes with less volume will have a higher flushing rate because the water will be cycled through quicker. Deep lakes with a given amount of input and a high surface area will have large volumes and low flushing rates, whereas shallow lakes with low surface area will have high flushing rates. The third factor is watershed area. A large watershed area will increase the area over which precipitation and runoff can enter the watershed. This increases the volume of water entering the lake and leads to a faster flushing rate.

Great Pond has a flushing rate of 0.52 flushes per year (see Appendix B). There are two major inputs to Great Pond from outside the watershed (North Pond and Salmon Lake) (Fig. 8) and some smaller tributaries that contribute less significant amounts to the lake. Great Pond has the largest volume of water of the lakes in the Belgrade Lakes Chain, but only the second largest watershed area (Table 5). The total inputs to Great Pond are also relatively low in relation to its volume (see Appendix B). These factors contribute to the low flushing rate of Great Pond.

Table 5. Watershed areas, volumes, and flushing rates for the Belgrade Lakes based on data from BI493 classes in 1991 and from 1994 to 1999.

Lakes	Watershed Area (acres)	Volume (m^3)	Flushing Rate (flushes/year)
Great Pond	20,540.4	209,160,000	0.52
Messalonskee Lake	30,909.3	150,249,096	1.59
Long Pond-South Basin	9,617.3	47,032,200	3.55
Long Pond-North Basin	5,971.2	46,276,529	2.80
North Pond	7,640.5	37,148,856	1.36
Salmon Lake	5,714.6	28,410,750	0.59
East Pond	2,775.0	33,848,120	0.25

There are other factors that influence how quickly water moves through lakes (Firmage, pers. comm.). If the prevailing winds blow in the same direction that the lake flows, they can help move water through the lake more quickly. The shape of the lake can also affect the movement of water through the lake. A very straight lake will make it easier for the water to flow through and increase the actual flushing rate. If the contour of the lake bottom is smooth and uniform in depth, it can decrease the amount of time it takes for water to flow through the lake.

Great Pond is not oriented in a way that wind can help push the water through the lake (Fig. 10). The outlet is between the northwest and southeast basins of the lake on the west side. The water in the northwest basin has to flow around Hoyt Island and Chute Island southwest to the outlet while the water in the southeast basin has to flow north and make a sharp turn to the west around Long Point before it can get to the outlet. The water in the two basins is flowing in different directions so the wind cannot travel in the direction of the flow of water in both basins at the same time. No matter which direction the wind is blowing, it will likely be against the flow in one basin and with the flow in another basin. Great Pond

also has several large bays such as North Bay, Hatch Cove and Pinkhams Cove in which the water can essentially become trapped and not easily mix with the water in the rest of the lake.

The two major inputs of Great Pond empty into two of these bays. North Pond flows into Great Meadow Stream which flows into North Bay and Salmon Lake flows into Salmon Brook which then flows into Hatch Cove. Great Pond also has a few deep holes that can trap water. The depths are not uniform between the northwest and southeast basins which implies that the water does not flow at the same rate in the two basins. The northwest basin depths generally range from 10 m to 15 m while the depths in the southeast basins are only 4 m to 10 m deep. The deep holes, large bays, and water flow pattern of Great Pond act together to cause some of the water in the lake to remain trapped much longer than other water.

Messalonskee Lake has a much higher flushing rate than Great Pond (Table 5). Messalonskee Lake has a smaller volume, larger watershed area, and is much narrower than Great Pond. The prevailing wind also blows in roughly the same direction that the lake flows (Koons, pers. comm.). The smaller volume and large watershed area lead to a high flushing rate and explain why the flushing rate of Messalonskee Lake is greater than that of Great Pond. The direction of the prevailing winds aids in the movement and mixing of water in the lake. In comparison, East Pond has a small input volume from natural springs and only a few tributaries. Consequently, it has a very low flushing rate.

Movement of Water into the Lake

Tributaries

There are many different ways for water to enter a lake. One source of water is tributary input. There were several tributaries flowing into Great Pond on 21-Sep-98 including Trout Brook, Robbins Mill Stream, Great Meadow Stream, Salmon Brook,

Pinkhams Cove Tributary, and Bog Brook (Fig. 10). There were other tributaries found that do not flow year round and are therefore unlikely to contribute a large volume to Great Pond. Data was not collected at these sites, though they might contribute significant amounts of phosphorus to the lake when flowing. All tributaries are likely to contribute more significant amounts of water to the lake in the spring due to the melting of snow. Tributaries are very important to consider because they carry nutrients as well as water into a lake. Runoff from lawns and roads will carry phosphorus into the tributaries. Tributaries tend to be shallow and narrow, creating turbulence that erodes sediment with its associated phosphorus from the stream banks and the streambed. The low flow rate of tributaries allows nutrients to build up in tributary water. During a storm event or in the spring, when there is high runoff due to snowmelt, the accumulated nutrients are suddenly flushed into the lake in high concentrations. CEAT measured flow rates at the five tributary sites previously mentioned (see Tributary Water Quality: Flow Rate).

Precipitation

Precipitation is a major source of water for lakes. It can enter the lake as direct input from rain, overland runoff, underground flow and through upstream tributaries. Not all precipitation makes it to the lake, however. Precipitation falling over land is subject to evaporation and infiltration processes (Foster 1948, Caswell 1987).

Precipitation = Evaporation + Infiltration + Runoff

Water lost to evaporation is returned to the atmosphere in the vapor state, whereas water lost due to infiltration soaks into the soil (Winter 1995). It has been estimated that in Maine an average of 50 percent of precipitation runs off into streams, 30 percent to 40

percent is returned to the atmosphere by evaporation processes, and 10 percent to 20 percent infiltrates the soil and recharges ground water (Caswell 1987).

The force and duration of precipitation can have different effects on the soil and amount of runoff that occurs. A hard rain that lasts a long time will tend to cause more soil erosion because of the force of the rain hitting the ground (Gregory and Walling 1973). A hard rain will lead to less infiltration into the soil and more runoff because the rain falls so fast that it does not have time to seep into the soil. Ground covered with vegetation will have less runoff than bare soil in these instances because vegetation slows runoff and protects the soil from eroding due to the force of the rain (Black 1996). If the ground is bare soil, the runoff will carry a lot of sediment and nutrients because of greater soil erosion (Cooke et al. 1986). This in turn will increase the amount of phosphorus entering the lake. A light rain will not cause as much soil erosion. The rain will have more time to seep into the soil and less runoff will occur. Any runoff still occurring during a light rain will be moving slowly enough that it may be able to seep into the soil before hitting the lake. Runoff reaching the lake after a light rain will be less harmful than runoff reaching the lake after a heavy rainfall.

Groundwater

Groundwater is water that infiltrates the sediment and occupies the spaces within the soil and rock beneath the surface of the earth (Caswell 1987). Groundwater movement depends on the soil and rock type through which it flows. This type of water can flow easily through porous soils such as gravel or sand, but it is very difficult for groundwater to move through clay soils because the small particles pack tightly. It is also easier for groundwater to move through a large soil particle layer in which the particles are of similar size than in a large soil particle layer in which the particles are of different sizes (Caswell 1987). However, a homogenous small soil particle layer such as clay is difficult for groundwater to

move through. Ideal conditions of a homogenous large soil particle layer can allow groundwater to flow at a rate of up to several feet per day (Caswell 1987).

Lakes can receive groundwater inputs along the shore and bottom of the lake (Caswell 1987, Winter 1995). However, the contribution of groundwater to lakes is normally very small (Winter 1995). Groundwater inputs are not thought of as a large contributor of phosphorus because the phosphorus is typically taken up by the soil particles as the groundwater filters up through the soil.

Runoff

Runoff is water that drains into the lake from the surrounding watershed area by overland or subterranean flow after evaporation and infiltration have occurred (Foster 1948). After the maximum amount of water has infiltrated the soil, the remaining water will travel over the land being pulled downward by the force of gravity. Any depression in the surface of the land will become filled with the runoff water. Once the depressions at higher elevations are filled, the water left over will continue to flow to lower elevations.

There are three main types of runoff that occur (Foster 1948). The first is due to leftover water from rainfall, the water that is not evaporated or does not seep into the soil. This type of runoff is not constant, but only occurs when the rain is plentiful. The second type of runoff comes from melting snow. Again this runoff typically only occurs for a short time in the spring. The third type of runoff is subsurface runoff. Runoff of this type is the most constant and can occur throughout the year unless the winter freeze is deep enough to stop water flow. The volume of water entering the lake from runoff will be greater in steeper parts of the watershed such as Horse Point, Mosher Hill, and Mount Phillip (Fig. 10).

In an undisturbed watershed it is usually difficult to see evidence of runoff (Black 1996). This is because the infiltration rate of water entering the soil is normally greater than

the rate at which rain is hitting the surface. However, very steep slopes or very intense rains can create exceptions to this generalization by decreasing the rate at which water can soak into the soil. Overland runoff usually is not seen in an undisturbed watershed. When runoff is seen occurring on parking lots, roadways, and lawns, it is not a natural occurrence, but an effect of human interference with the watershed.

Runoff occurring on roads, lawns, and paved surfaces picks up nutrients like phosphorus that attach to sediments (Cooke et al. 1986). If the sediments reach the lake, they can make areas of the lake shallower and increase the amount of nutrients in the lake.

Roads, or ditches along the roads, that lead directly down to lake waters are especially problematic because they provide an avenue by which runoff can travel directly into the lake (Cole, pers. comm.). Buffer strips are one way to prevent runoff from reaching the lake (Fact Sheet # 5 published by the Cumberland County Soil and Water Conservation District). A vegetated buffer strip positioned between a road or lawn and the lake will slow the overland flow of water and give the water a chance to infiltrate the soil. However, the type of soil ultimately determines whether infiltration occurs. Small-particle soil layers do not allow as much infiltration to occur as large-particle soil layers (see Movement of Water into the Lake: Groundwater). Less infiltration means more runoff will occur.

Vegetation types in the watershed can affect the rate of water runoff into the lake. Vegetation will slow the water and facilitate soaking into the soil, thereby decreasing runoff. Forested areas are especially good at decreasing runoff (Gregory and Walling 1973). The forest canopy intercepts some of the rain on its way down so that it never hits the ground directly (some runs down the trunk or drips onto ground), reducing erosion potential. The vegetation and organic matter that is on the forest floor will also act to slow any runoff. Lawns do not reduce runoff significantly (Firmage, pers. comm.). The grass roots are so dense on most lawns that little water can infiltrate through the mat to the soil layer,

particularly in a hard rain. Lawns may slow runoff and allow some of the sediments being carried by the water to be deposited, but they do not greatly decrease the amount of runoff. As water moves across a lawn it can also pick up nutrients from fertilizers used on the lawn. The runoff will then carry these additional nutrients from the lawn into the lake.

Heavy rains will cause more erosion on bare soils than on soils covered with vegetation. Bare soils allow more runoff to occur because there is no vegetation to slow the water and allow it to percolate into the soil. Lawns may slow runoff and allow sediments to settle out of the water, but they typically do not allow much water to seep into the soil.

Lake Level Management

Great Pond has one outlet into the North Basin of Long Pond. There is a modern dam between the two lakes that is used to control the level of water in Great Pond. The dam used to be part of an old mill before it was modernized many years ago (MacKenzie, pers. comm.). The dam has had many different owners over the past years, but is now jointly owned by the Towns of Rome, Belgrade, and Oakland. The towns share responsibility for any maintenance the dam requires and for all costs associated with the maintenance.

The dam is used primarily to keep the water at a level that is suitable for recreation such as boating and to prevent flooding in the spring (MacKenzie, pers. comm.). The level of water in Great Pond is lowered about 1 ft in the fall to help prevent ice damage from occurring along the shore in the winter. The snowmelt in the spring increases the water coming in from the watershed and increases the amount of water entering Great Pond from North Pond, Salmon Lake and other smaller tributaries. The increased volume of inputs will bring the level of water in Great Pond back to normal without causing flooding. Ideally, the increase in the water level in the spring will not exceed the level of the previous fall.

Lowering the level of water in the fall is spread out over a period of time starting in late October. This prevents drastic changes in the water level.

Great Pond is fairly resistant to flooding so the level of water in Great Pond is dropped only 1 ft in the fall (MacKenzie, pers. comm.). It takes a significant amount of rain or snowmelt to fill the lake back to its original level. In contrast, the water level of neighboring Long Pond is dropped about 18 inches in the fall by opening the Wings Mill Dam. The Wings Mill Dam is on Belgrade Stream, the outlet at the southern end of Long Pond. Even though the Long Pond water level is dropped 18 inches, it has to be monitored more closely. This is because for Long Pond, about 1 inch of rain will equal a 3-inch rise in the level of water in the lake.

The opening of these dams is coordinated so that lakes further down in the chain do not experience an increase in water level when the level of the other lakes is lowered. If the levels of Great Pond and Long Pond are lowered in the spring, then the water could build up in the next lake in the chain, Messalonskee Lake (Fig. 8). The dam at the outlet of Messalonskee Lake is controlled by Central Maine Power (CMP). The opening of the Wings Mill Dam at the outlet of Long Pond is coordinated with CMP so the water level of Messalonskee Lake is kept fairly constant (Cole, pers. comm.).

There are many positive and negative benefits that come from managing the water level in the lake. Economic benefits can be realized from water level control (MacKenzie, pers. comm.). The federal government defines flood zones along bodies of water. Residences in these areas are required to purchase expensive flood insurance. By controlling flooding with the dam, most residences in the Great Pond watershed are not required to purchase this insurance. Reducing the probability of a flood reduces the probability of property damage due to flooding. Lowering the level of the lake also allows repairs to be performed on docks, rip-rap to be placed on banks, and dam maintenance to occur (Cooke et

al. 1986). When the level of the lake is lowered, nutrients can be flushed out along with the water.

Negative effects can also occur when the water in the lake is drawn down. Many aquatic plants are killed along the shore during draw down and these plants are homes for many invertebrates (Cooke et al. 1986). The invertebrate populations often suffer major declines. When the level of water is restored in the spring, it can stir up bottom sediments that will release more nutrients into the water. This can lead to algal blooms in the lake. There is always a danger that the lake will not fill back up to its original level or that it will fill to a higher level. The higher level might cause erosion of sediments from the banks of the lake, which would add more nutrients to the water (MacKenzie, pers. comm.; Cooke et al. 1986). The dam could also decrease the flushing rate of the lake by not allowing water to flow freely as it would without the dam in place (BI493 1996). The lower flushing rate allows nutrients to build up and can lead to an increase in algal blooms as well.

GREAT POND WATER QUALITY

Study Sites

Sixteen different sites were sampled for water quality analysis in Great Pond (Fig. 11). Three different types of sites were chosen; Characterization Sites, Spot Sites, and Tributary Sites. The Characterization Sites that CEAT used are locations that were sampled in the past by the MDEP and are being used for historical context. They provide a general overview of the water quality in Great Pond. Spot Sites were chosen to determine water quality in specific areas that may indicate sources of nutrient input. An example of a Spot Site is a location near a tributary, where sampling is done to determine the effects of the tributary on the water quality of the lake in that area. Year-round tributaries of Great Pond were sampled as Tributary Sites to determine the amounts and quality of water flowing into Great Pond.

Characterization Sites

Site 1: MDEP Site 1 Latitude: 44° 32′ 3355″ N
Longitude: 69° 51′ 0164″ W

Site 1 was located in the center basin of Great Pond at a 19.2 m (63 ft) deep hole. Site 1 was chosen because it is one of the deepest regions of Great Pond and also because it has been sampled in the past by the MDEP.

Site 2: MDEP Site 2 Latitude: 44° 33′ 3357″ N
Longitude: 69° 52′ 4041″ W

Site 2 was located at a 19.2 m (63 ft) deep hole, west of Hoyt Island and north of Finger Reef. The site is located between a red house to the east on Hoyt Island and a red house on the western shoreline. Site 2 was chosen because it is the other deep hole in Great Pond and has also been sampled by the MDEP in the past.

Site 3: CEAT Site Latitude: 44° 33′ 5557″ N
Longitude: 69° 49′ 4434″ W

Site 3 was located in the middle of North Bay, just north of a cluster of boat hazard areas. Site 3 was chosen to investigate the overall water quality of the North Bay region.

Site 4: CEAT Site Latitude: 44° 30′ 2063″ N
Longitude: 69° 50′ 1927″ W

Site 4 was located west of Pine Island and south of Oak Island, in the middle of the southern basin of Great Pond. This site was chosen to determine the overall water quality of the southern region of Great Pond.

Site 5: CEAT Site Latitude: 44° 31′ 2092″ N
Longitude: 69° 48′ 3717″ W

Site 5 was located south of Hatch Cove, directly west of a house with a blue metal roof. This site was chosen to investigate the effects of shoreline development in the Hatch Cove area and the effects of Salmon Brook, Tributary 11T.

Spot Sites

Site 2B: CEAT Site Latitude: 44° 34′ 1064″ N
Longitude: 69° 51′ 4000″ W

Site 2B was located at a 18.3 m (60 ft) deep hole in the northern end of Great Pond, halfway between a three story brown house, on the eastern shoreline, and Joyce Island. The site was north of Crooked Island, and south of Robbins Mill Stream one fourth of the distance closer to Crooked Island. Site 2B was chosen to examine the effects of Robbins Mill Stream on the partially isolated northwest deep basin.

Site 4B: CEAT Site Latitude: 44° 29′ 4612″ N
Longitude: 69° 50′ 3766″ W

Site 4B was located roughly 275 m (900 ft) west of the north east shoreline of Foster Point, 200 m (655 ft) east of a small red house, and 200 m (655 ft) north of Austin Bog. Site 4B was chosen to examine the effect of Austin Bog on lake water quality.

Site 5B: CEAT Site Latitude: 44° 29′ 0266″ N
Longitude: 69° 49′ 5236″ W

Site 5B was located approximately 370 m (1211 ft) north of the end of Pinkhams Cove, an equal distance from both shorelines. It was also directly west of a yellow house with a

green roof. Site 5B was chosen to determine the effects of development in Pinkhams Cove on the water quality in the lake.

Site 6: CEAT Site Latitude: 44° 31′ 5280″ N
Longitude: 69° 52′ 1725″ W

Site 6 was located halfway between the south end of Hoyt Island and the first white house from the northern end of Abena Point. It was roughly 500 m (1637 ft) west of the northern tip of Long Point, and the same distance east of a yellow house with a green roof on one side. Site 6 was sampled to investigate the effects of the Marina on water quality.

Site 7: CEAT Site

Site 7 was located in Great Pond's only outlet, which is found in the southwest region of the lake close to the Great Pond marina. The sample site was by the dam. Site 7 was sampled to determine the quality of water leaving Great Pond.

Tributary Sites

Site 8T: CEAT Site

Rome Trout Brook was located northwest of Joyce Island. The sample was take below the beaver dam. Rome Trout Brook drains the area east of the northwest Great Pond Watershed boundary and west of Mount Phillip.

Site 9T: CEAT Site

Robbins Mill Stream was located in the northern most end of Great Pond, west of Jamaica Point. This tributary includes the Rome drainage basin, east of Mount Phillip and west of Foss Hill.

Site 10T: CEAT Site Latitude: 44° 34′ 3691″ N
Longitude: 69° 49′ 0465″ W

Great Meadow Stream was located in the northern end of North Bay. The sample was taken approximately 200 m (655 ft) upstream from the input into the lake. The input from Great Meadow Stream is North Pond.

Site 11T: CEAT Site

Salmon Brook was located south of Hatch Cove and north of Pinkhams Cove. The sample was taken 11.3 m (37 ft) from the bridge. The input for Salmon Brook is Salmon Lake and the tributary runs through the town of North Belgrade.

Site 12T: CEAT Site

The Pinkhams Cove Tributary was located in the southern most end of Pinkhams Cove. This tributary drains the southern developed area in Pinkhams Cove.

Site 13T: CEAT Site

Bog Brook runs into Austin Bog in the southern most point. Samples were taken up and downstream from the Rt 27 bridge. The drainage area of Bog Brook includes the southwest portion of the Great Pond Watershed.

Water Quality Methodology

Assessing water quality involves two major methods: field measurements of specific water attributes are taken using specific instruments; and samples are collected for laboratory analysis. Water quality field measurements and water sampling for Great Pond were conducted by the Colby College Biology Department on 25-Jun-98, 17-Jul-98, and 14-Aug-98 and by the Colby Environmental Assessment Team on 21-Sept-98, and 5-Oct-98. Physical and chemical field and laboratory tests were conducted (see Appendix C). The team tested lake-water sites and some tributaries by boat. Other tributaries were tested by car, walking and wading into sample sites from the nearest road access point (see Appendix D).

Physical measurements conducted in the field included depth, transparency, temperature, and tributary flow rate. A Depth Finder-Honder PS-7 (LCD Digital Sounder) or a Humminbird Depth Finder was used at each site, and the mean of three measurements was

recorded. A Secchi Disk and Aqua Scope (reduces reflection off water surface) were used to determine transparency. The mean of three recordings was used, to ensure accuracy. A calibrated Flo-Mate flow meter was used to determine water velocity and depth of water in Great Pond's tributaries with measurable flow rates. The width of each stream was divided into five equal sections, and the flow rate of each section was measured in order to determine the mean flow rate for the stream (see Appendix D).

The chemical tests conducted in the field were pH and dissolved oxygen (DO). A HORIBA twin pH meter was used for pH tests. The meter was calibrated before each sampling day. Dissolved oxygen was measured with an ORION DO/Oxygen Meter, which was calibrated in the lab before field testing. Three random repeats were conducted for every ten measurements to test accuracy.

Physical measurements performed in the lab included turbidity, conductivity, and true and apparent color. Chemical tests included alkalinity, hardness, nitrates and total phosphorus. These analyses were conducted according to the protocols outlined in the corresponding sections of the Lake Water Quality Measurements and Analysis section of this report. An appropriately sized and labeled sampling bottle was brought into the field for each physical and chemical test that would later be conducted in the laboratory. All bottles and epicore collection tubing used for phosphorus testing were rinsed three times with 1:1 hydrochloric acid and E-pure water, and equipment for other tests was washed with micro cleansing solution and rinsed repeatedly with Ro_w pure water (see Appendix D).

Surface grabs were taken at all sites, while epicore, mid-depth, and bottom samples were taken only where depth was substantial (see Appendix C). Epicore samples were taken from the water surface to 1 m below the thermocline, using flexible clear plastic sample tubing and a 1 liter bottle for mixing the three epicore samples collected at each site. Both bottom and mid-depth samples were taken with a Wildco water sampler. Bottom samples were taken at approximately 1 m above the bottom of the lake.

Samples were kept on ice from the time they were taken until they could be transferred to the lab refrigerator. Samples to be used for hardness testing were adjusted to a pH of less than two by adding concentrated nitric acid in a drop-by-drop manner. The samples to be used for nitrate testing were brought to a pH of less than two by adding concentrated sulfuric acid in a drop by drop manner. All samples were analyzed within the appropriate time limit for each test. Care was taken to avoid sample contamination and maintain safety in the lab (see Appendix D).

To ensure accuracy, a split sample and a duplicate sample were taken for every ten samples. To make a split, one sample bottle was used for water collection and this water was split into two bottles, which were kept cold until testing. A duplicate involves taking two separate samples for a given test at a given sampling site. Standards of known concentration were run with every set of samples for every test, to ensure that the methods and equipment were working properly (see Appendix D). All data are reported as mean ± standard error, unless otherwise specified.

Lake Water Quality Measurements and Analysis

Physical Measurements

Introduction

The water quality of any body of water depends on a variety of water characteristics. Physical parameters affect the presence and health of aquatic organisms and indicate the overall health of a lake. In this study of Great Pond, seven specific physical measurements were performed in order to assess the quality of this water with accuracy. These parameters

included dissolved oxygen, temperature, transparency, turbidity, conductivity, and color. The complete results are found in Appendix E.

Dissolved Oxygen and Temperature

Measuring dissolved oxygen (DO) levels and temperatures at various depths is important in determining the health and trophic state of a water body. DO is a measure of the concentration of oxygen in the water. Organisms require oxygen, and some organisms are better adapted to cope with low levels of dissolved oxygen than others. Anaerobic bacteria are an exception, as they are not dependent on oxygen (Stednick 1991). Low levels of oxygen can result in the success of such organisms, and organisms that cannot cope with less oxygen are out-competed as a result. In general, low oxygen concentrations result in stress on organisms (Chapman 1996). Environmental stress can cause lower reproductive rates, lower growth, and lower survivorship of organisms. Anoxic conditions also cause phosphorus accumulated in sediments to be released into the water column (see Lake Water Quality: Total Phosphorus).

The rate of cultural eutrophication may be increasing if, over the years, oxygen depletion begins earlier in the year or if more depletion occurs by the end of the summer (Pearsall 1993). Thus, it is useful to observe DO trends throughout the year and over a time continuum to assess the lake condition.

Methods

Data were collected throughout the summer by members of the Colby Environmental Assessment Team (CEAT). Additional data from previous years were made available by the Maine Department of Environmental Protection (MDEP 1994a). Dissolved oxygen and temperature were measured using an Orion Model 840 DO Meter. Readings were taken at 1 m intervals at all Characterization and Spot Sites on 21-Sep-98, and at Sites 2B and 4B on 5-Oct-98.

Results and Discussion

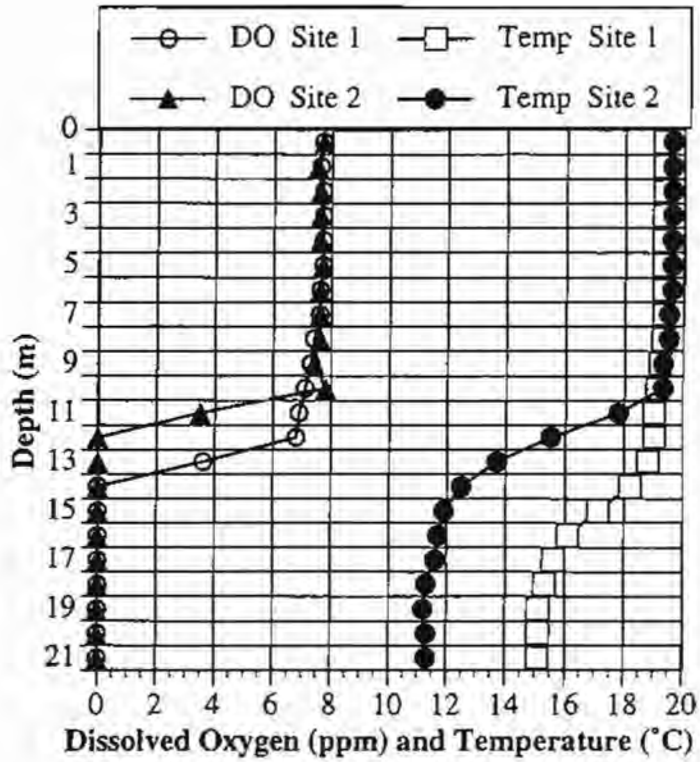

Figure 12. The dissolved oxygen (ppm) and temperature (°C) profiles at Characterization Sites 1 and 2 in Great Pond, measured on 21-Sep-98. See site map for site locations (Fig. 11).

On 21-Sep-98, the water column at Characterization Sites 1 and 2 was found to be clearly stratified (Fig. 12). The epilimnion extends to a depth of 12 m at Site 1 and to a depth of 10 m at Site 2, below which there is a noticeable decline in both the temperature and the dissolved oxygen. This drop in temperature represents the thermocline. The temperature and DO readings are relatively uniform from a depth of 14 m extending to the bottom of the lake. It is a matter of concern that much of the lake, at depths greater than 11 m to 14 m, had anoxic conditions at both sites. With a lake as deep and large as Great Pond, the extensive hypolimnion results in a large volume of anoxic water.

The area of Great Pond which could be anoxic in the late summer, based upon the summer data, occurs below 11 m. The area of the lake which is over 11 m deep is 495,274 m^2 and represents 24.7 percent of the total area (Fig. 13). This is a fairly large area and occurs mainly within the two deepest basins of Great Pond- to the West and the Southeast of Hoyt Island. These two sites correspond with Characterization Sites 1 and 2 (Fig. 11). There is also a small area that could become anoxic in North Bay.

The seasonal stratification of Great Pond becomes apparent when the DO and

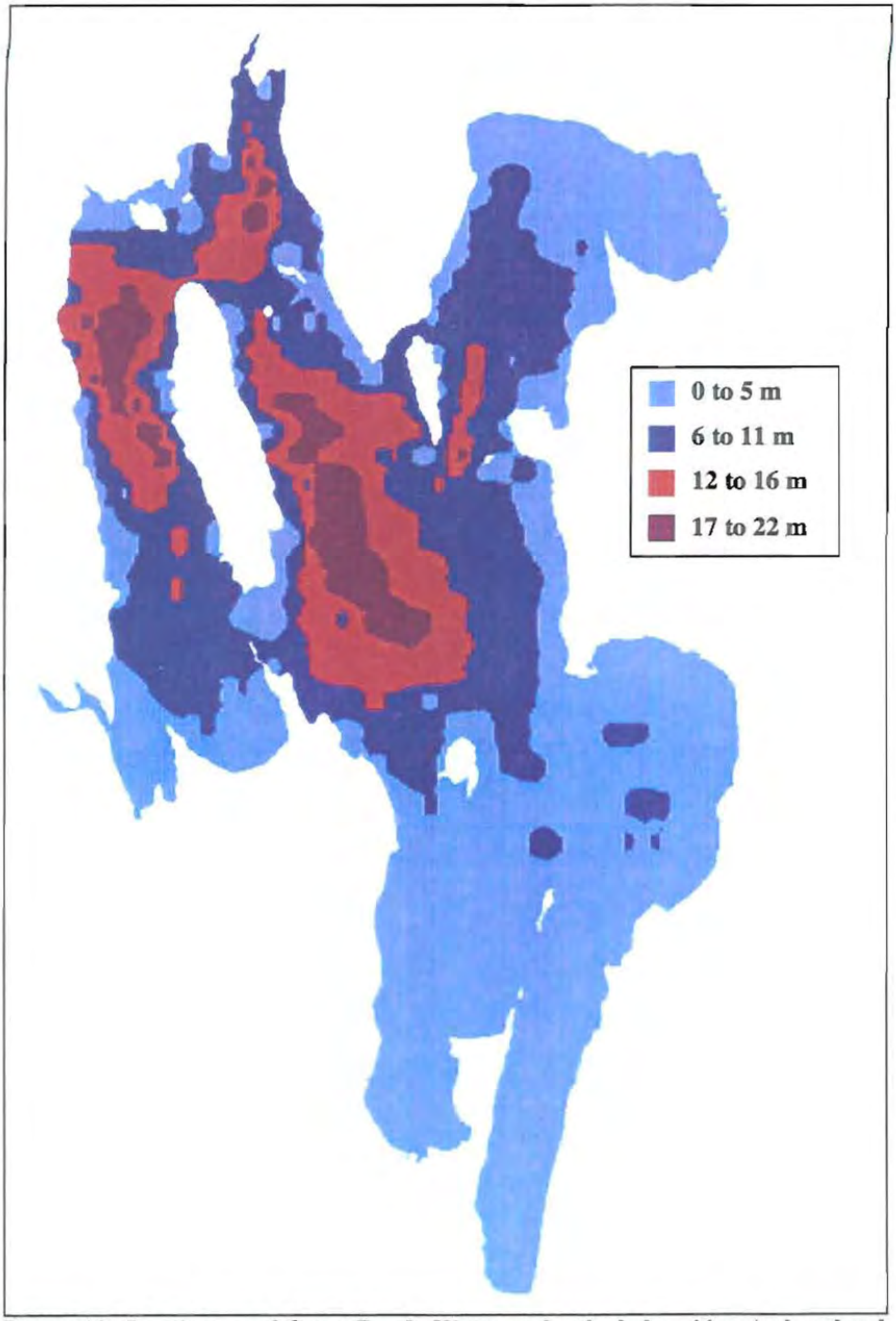

Figure 13. Depth map of Great Pond. Water at depths below 11 m (colored red or purple) can become anoxic in the summer, facilitating internal loading of phosphorus. Lake depths from the Maine Department of Conservation (1998). Approximate scale: 1 inch = 0.9 miles.

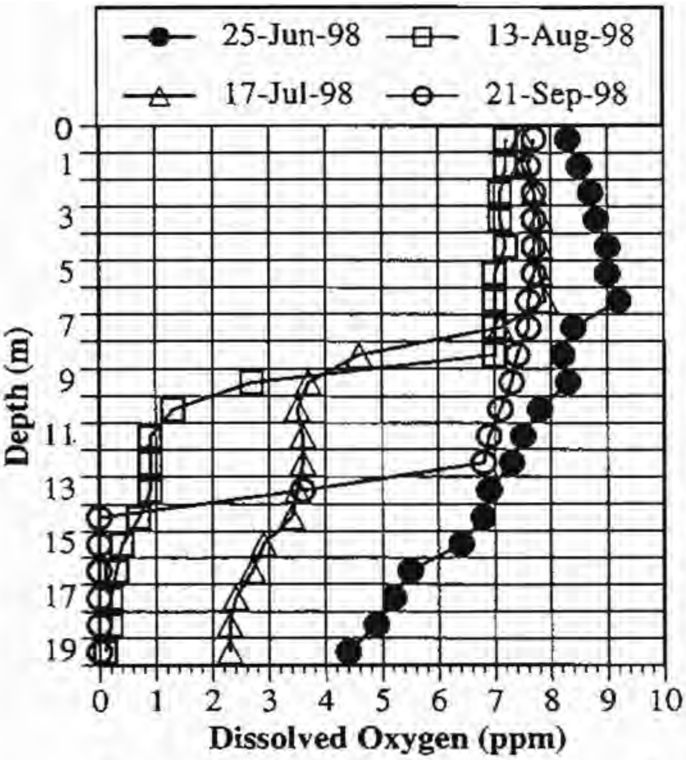

Figure 14. The dissolved oxygen (DO) profiles recorded at Characterization Site 1 in Great Pond during the summer of 1998. See site map for site locations (Fig. 11).

temperature profiles throughout the summer are compared (Fig. 14). On 25-Jun-98, the water had a less drastic drop in DO than later dates, while the profiles on 13-Aug-98 and 21-Sep-98 showed very drastic changes in DO below 8 m to 12 m depths. The decrease in DO concentration in the early fall is a result of bacteria respiring and consuming oxygen as they decompose dead organic matter on the bottom of the lake.

It is necessary to compare DO profiles over the years in order to determine changes over time and to predict future trends in water quality. When comparing annual DO profiles, it is important to look at data taken at similar times of the year, because stratification varies from season to season (see Lake Characteristics: Phosphorus and Nitrogen Cycles). In Great Pond, it appears that there may have been a slight drop in DO levels over the years (Fig. 15). Specifically, the DO levels at the end of August 1992 and August 1990 are lower than the levels in 1977 and 1989. While these differences are not drastic, it should be noted that oxygen is depleted earlier in the summer as time goes on. It is useful to note the DO profiles of 11-Aug-97 and 25-Aug 89 (Fig. 15). While the 1997 profile was recorded two weeks earlier in the summer, the low oxygen levels occur at the same depths as in the 1989 profile. These data may indicate that as years go by, the oxygen levels in the hypolimnion are becoming depleted more quickly in the summer. If, in the future, the

oxygen levels continue to be depleted earlier and earlier in the summer, the threat of accelerated cultural eutrophication may become more serious.

Data collected by the MDEP and CEAT from Characterization Sites 1 and 2 over a 22 year period also show that there is a decrease in the depth at which Great Pond turns anoxic during September and early October (Fig. 16). The slope of the line is statistically significant ($P< 0.0001$) indicating a decrease of depth of the anoxic region over time. The r^2 value of 0.235 means that the trend line can explain 23.5 percent of the variability in the data. The decrease in depth from 16 m on 11-Sep-98 to 12 m on 21-Sep-98 suggests a large increase in the volume of anoxic water present in Great Pond. The increase of the volume of anoxic water can result in the increase of total phosphorus concentrations through internal recycling and is a sign of increased productivity of a lake (Chapman 1996).

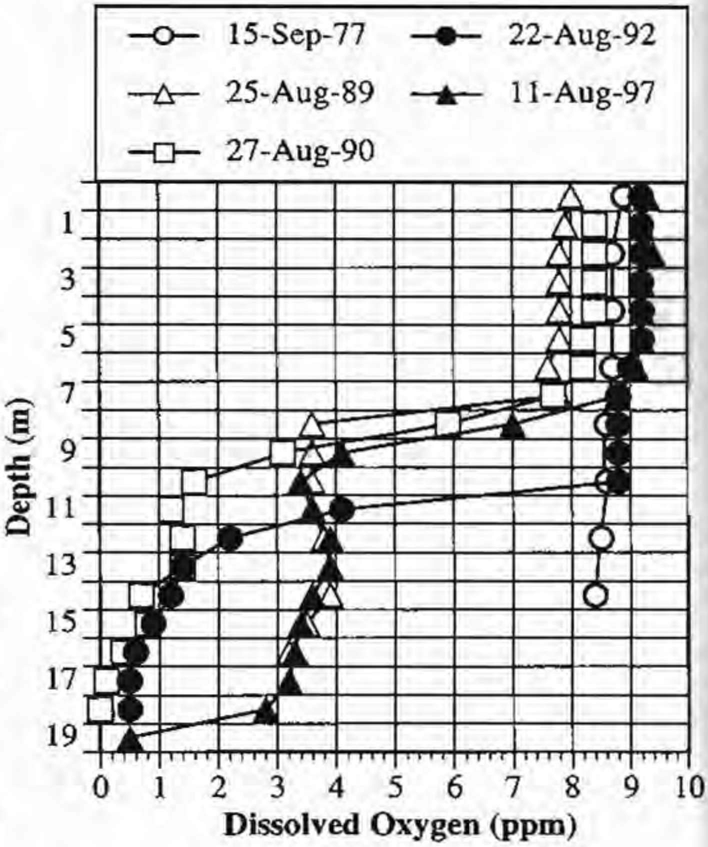

Figure 15. The dissolved oxygen (DO) profiles recorded in late summer at Characterization Site 1 in Great Pond over a 20-year period. Data obtained from Maine Department of Environmental Protection. See site map for site locations (Fig. 11).

The apparent depletion of DO earlier in the summer and the increase in volume of anoxic water both show that increased productivity and decreased aerobic activity are taking place in Great Pond. Depth profiles should be taken at the same date each year, and the

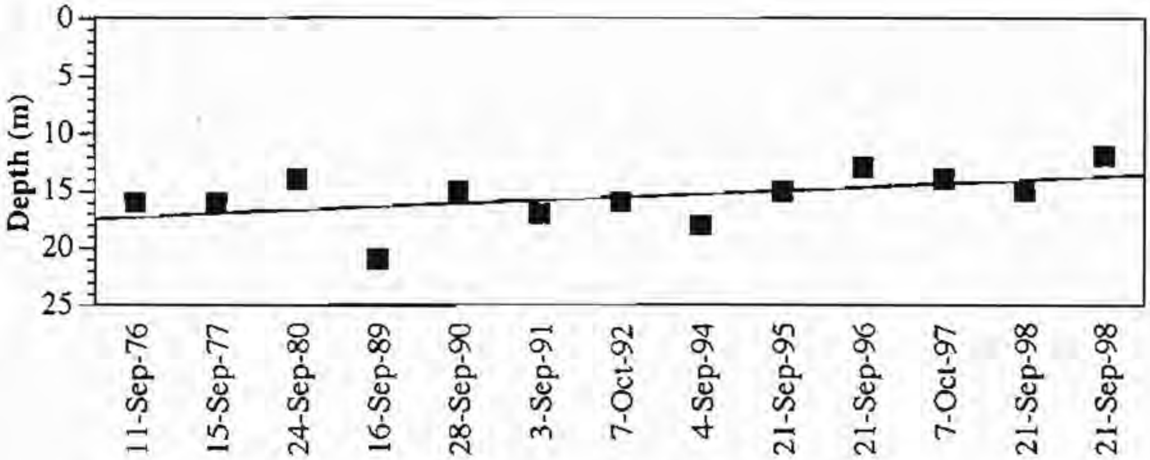

Figure 16. The depth at which Great Pond turns anoxic during September and early October from 1976 to 1998. All samples were taken at Sites 1 and 2. From 11-Sep-76 to 7-Oct-97 samples taken by the Maine Department of Environental Protection. Samples from 21-Sep-98 were taken by Colby Environmental Assesment Team. There is a trend of decreasing depth over time (P-value<.0001, r^2=.235).

monitoring of DO levels should be continued in order to accurately document any changes in DO concentrations.

Transparency

Transparency is a measurement of water clarity, which may be reduced by clay, silt, fine particulates of organic and inorganic matter, soluble organic compounds and microscopic organisms suspended within the water column (Pearsall 1993, Chapman 1996). Transparency is also an indirect measure of total phosphorus and color, making it an important indicator of algal growth and lake eutrophication (Davis et al. 1978).

Transparency readings may be used to classify lakes as oligotrophic, mesotrophic, eutrophic, or dystrophic (Chapman 1996; see Lake Characteristics: Trophic Status of Lakes). Oligotrophic lakes are clear, showing low nutrient concentrations and primary production able to support fisheries and other aquatic life. Mesotrophic lakes are transitional lakes in between the oligotrophic and eutrophic stages. They display moderate nutrient concentrations and primary productivity. Eutrophic lakes suffer from algal blooms, reduced transparency, and increased total phosphorus levels as a result of nutrient-rich conditions.

Oligotrophic lakes have Secchi disk readings greater than 8 m (MDEP 1996). Mesotrophic lakes display Secchi disk readings from 4 m to 8 m. Eutrophic lakes display Secchi readings of less than 4 m (MDEP 1996).

Trophic status is indelibly tied to transparency. The Trophic State Index (TSI) is a measurement of the nutrient supply available to support the primary production within a lake on a continuum from 0 to 100 based upon Secchi disk values, total phosphorus levels, or chlorophyll-*a* concentrations (Davis et al. 1978). The TSI for this study was based upon Secchi disk readings and is denoted as TSI_{sd}.

Methods

Transparency readings were measured using a Secchi disk and an aquascope to avoid surface glare at Characterization Sites 1 and 2 and Spot Sites 2B, 3, and 6. Data were collected monthly from 25-Jun-98 to 21-Sep-98. The mean of these values were used to determine the TSI_{sd} for Great Pond using the following formula (Pearsall

$$\mathbf{TSI_{sd}} = 70 \log [105 / (\text{mean Secchi disk reading}^2 + 0.7)]$$

Results and Discussion

The mean Secchi disk transparency reading for Great Pond Characterization Sites 1, 2, and 3 and Spot Sites 2B and 6 from 25-Jun-98 to 21-Sep-98 was 5.91 ± 0.2 m (n=13). The mean Secchi disk transparency reading for samples taken from Characterization Sites 1, 2, and 3 and Spot sites 2B and 6 on 21-Sep-98 was 5.36 ± 0.24 m (n=5; Fig. 17). In 1978, Maine lakes were reported to have a transparency range of 3.0 m to 7.0 m with a mean of 5.6 ± 0.2 m (n=17; Davis et al. 1978). Historically, from 1970 to 1994, the mean transparency of

Great Pond has been 6.6 ± 0.1 m (n=23; Fig. 18). This compares favorably with the historical mean of Long Pond, 6.8 ± 0.1 m (n=24), Salmon Lake, 5.1 ± 0.2 m (n=20), Messalonskee Lake, 5.0 ± 0.3 m (n=3), East Pond, 4.6 ± 0.1 m (n=20), and North Pond, 4.0 ± 0.1 m (n=15; MDEP 1994a). Great Pond did exhibit a mean transparency below that of the mean of Maine lakes for samples acquired on 21-Sep-98 (5.4 m versus 5.6 m). This may be indicative of greater productivity in Great Pond during the late summer and early fall months. Trends from 25-Jun-98 to 21-Sep-98 indicate that the mean transparency of Great Pond is below that of the mean calculated over a span of three decades (5.9 m versus 6.6 m).

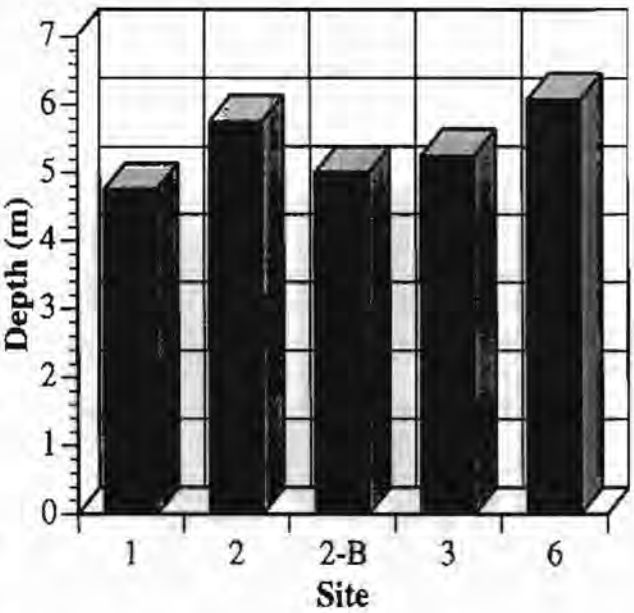

Figure 17. Secchi disk transparency readings for Great Pond Characterization Sites 1, 2, and 3 and Spot Sites 2B and 6 on 21-Sep-98. See Site Map for site locations (Fig. 11).

Great Pond, with a mean Secchi disk reading of 5.9 m, is classified as mesotrophic and moderately productive (Chapman 1996). One common attribute of temperate mesotrophic lakes is that they support perch as the dominant fish species (Chapman 1996). This is the case with Great Pond where the white perch (*Morone americana*) accounts for more than 40 percent of the fish population of the lake (MDEP, Unpublished Data). Comparing CEAT transparency readings to past analyses of Great Pond suggests an overall decreasing transparency in Great Pond over recent years. Using the mean transparency of 5.9 m and the Trophic State Index formula, CEAT calculated a Trophic State Index of 33 TSI_{sd} for Great Pond. Lakes with TSI_{sd} values greater than 60 TSI_{sd} may support algal blooms

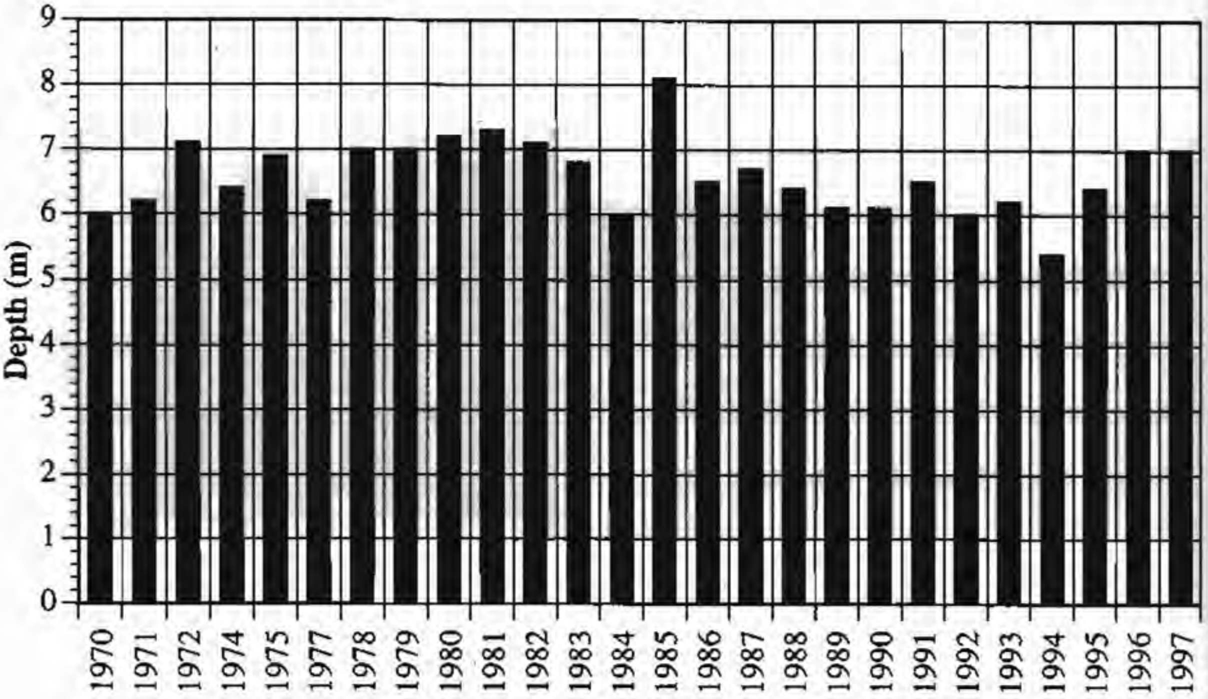

Figure 18. Mean Secchi disk transparency readings for Great Pond from 1970 to 1997 (MDEP 1994a).

(Pearsall 1993). However, productive lakes with stable water quality may support TSI_{sd} 119 TSI_{sd} (MDEP 1991; Fig. 19). The TSI_{sd} value of 39 TSI_{sd} for Great Pond falls within the 30 TSI_{sd} to 40 TSI_{sd} range, in which more than 60 of the 239 Maine lakes fell.

The reported TSI_{sd} value of 33 TSI_{sd} indicates that Great Pond is a mesotrophic lake with moderate transparency. This value is lower than all of the Belgrade Lakes with the exception of Long Pond (25 TSI_{sd}). Salmon Lake, with a mean Secchi disk reading of 2.88 m (BI493 1994), has the highest Trophic State Index among the Belgrade Lakes (75 TSI_{sd}). The trend of decreasing Secchi disk transparency of Great Pond may be an indicator of rising phosphorus or nutrient levels in the lake, which may potentially lead to algal blooms. However, Great Pond is a productive lake with stable water quality. Therefore, the lake may support a TSI_{sd} value of 70 TSI_{sd} or greater without resulting algal blooms.

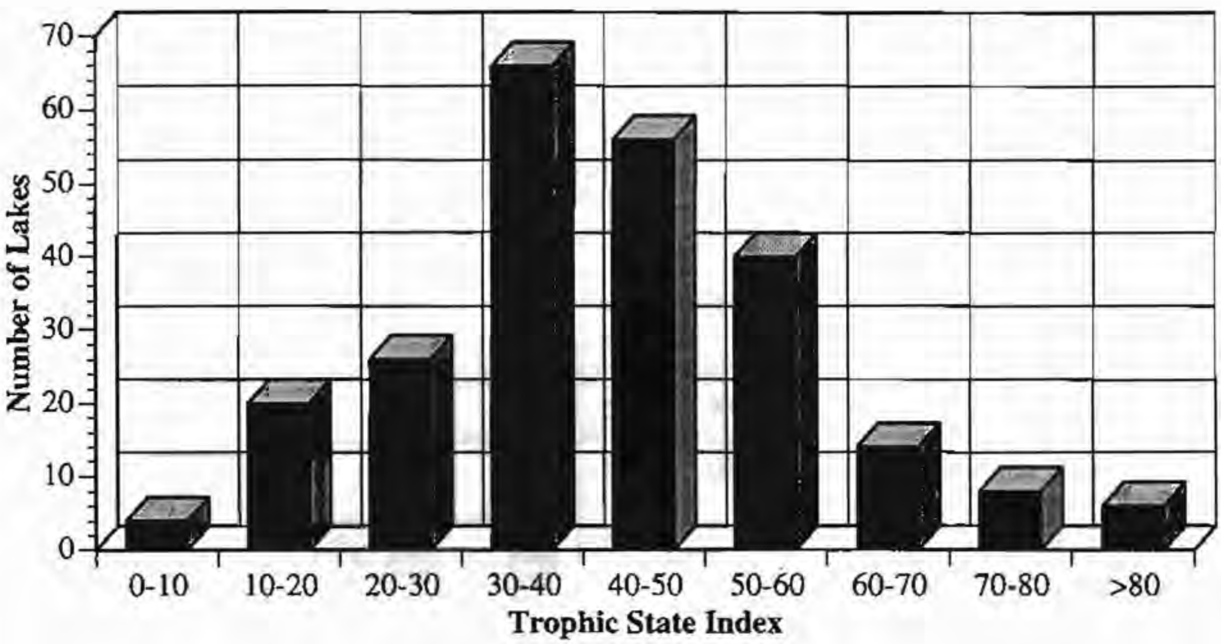

Figure 19. Distribution of Maine lakes among Trophic State Index (TSI) categories based on Secchi disk readings in 239 lakes as reported by the Maine Department of Environmental Protection (MDEP) in 1991. The reported mean was 42 TSI with a range from 8 TSI to 119 TSI.

Turbidity

Turbidity can be defined as the cloudiness of water. A turbidity test measures the presence of suspended matter such as silt, organic and inorganic particles, plankton, and other microorganisms (Chapman 1996). Turbidity, like transparency, is an important indicator of the total phosphorus levels within a water source and the possibility of cultural eutrophication of a lake system. Phosphorus can enter a lake is attached to eroded soil particles (Chapman 1996). If turbidity levels are high, they may correlate with high phosphorus loading. High turbidity also signals increased cultural eutrophication; in a eutrophic lake, high turbidity limits light penetration, and biological productivity is only permitted within a limited layer of surface water. The United States Geological Survey (USGS) study of Maine Lakes conducted in 1993 found turbidity levels between 0.3 FTU to 5.3 FTU (Formazin Turbidity Units), with most of the lakes falling between 1 FTU and 3 FTU (USGS 1993).

Methods

Surface samples were collected from all lake sites on 21-Sep-98 and tested with the HACH 2100P Turbidimeter within 24 hours of their collection (HACH 1997).

Results and Discussion

The turbidity levels of the lake sites ranged from 1.26 FTU to 20.70 FTU with a mean of 4.34 ± 1.84 FTU (n=10). All of the results except those of Characterization Site 3 fell between 1.26 and 3.87 FTU (Fig. 20). Characterization Site 3 was an extreme outlier, with a turbidity reading of 20.70 FTU; this reading was not included in Figure 20. The high turbidity at Characterization Site 3 may have been caused by material that was stirred up from the bottom of the lake. A more likely possibility is that an error was made while collecting the sample in the field or measuring the sample in the laboratory. If the data from Characterization Site 3 are excluded, the recalculated mean is 2.52 ± 0.30 FTU (n=9). These low turbidity levels do not indicate potential for excessive phosphorus loading or alarming amounts of suspended matter, however the results at Characterization Site 3 merit further investigation.

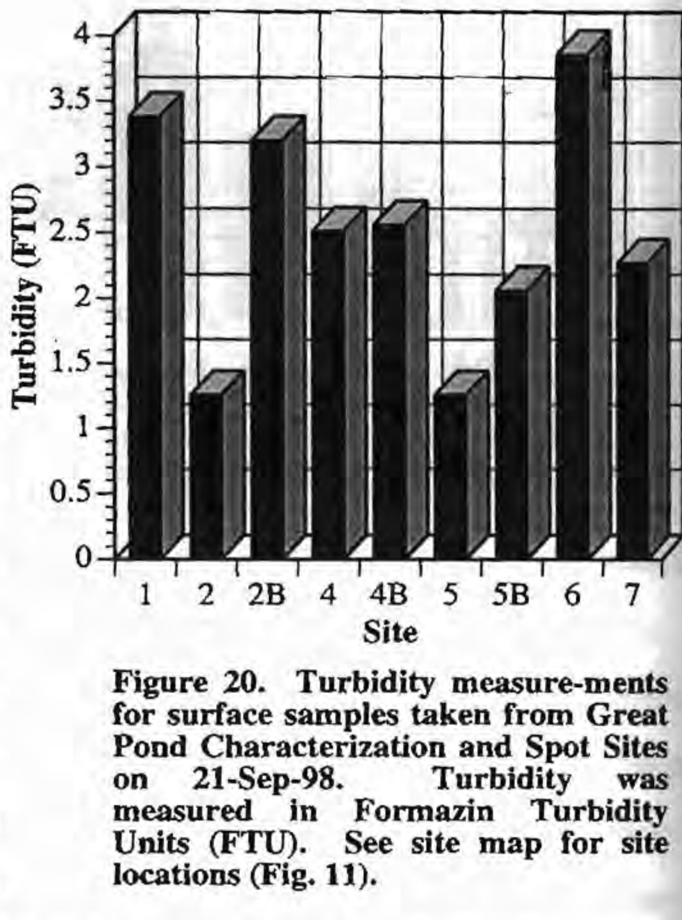

Figure 20. Turbidity measure-ments for surface samples taken from Great Pond Characterization and Spot Sites on 21-Sep-98. Turbidity was measured in Formazin Turbidity Units (FTU). See site map for site locations (Fig. 11).

The turbidity results obtained from Great Pond lake Characterization and Spot Sites are similar to results of the six other Belgrade Lakes (BI 493 1991, BI 493 1993, BI 493 1994,

BI 493 1995, BI 493 1996, BI 493 1997, BI 493 1998). The other Belgrade Lakes had a mean turbidity value of 3.41 ± 0.49 FTU (n=6). Messalonskee Lake was found to have the highest overall turbidity (5.00 FTU), while Salmon Lake was found to have the lowest turbidity (2.23 FTU). Each of the remaining Belgrade Lakes falls within this range of 2.23 FTU to 5.00 FTU. Great Pond is at the lower end of the range with a value of 2.52 FTU. Because Great Pond has turbidity levels that correlate closely with the surrounding lakes, there is no evidence that problem spots due to turbidity exist.

Conductivity

Conductivity, or specific conductance, is a measure of the ability of water to conduct an electric current. Conductivity is indicative of the amount of solutes present in the water and its sensitivity to changes in the concentrations of salts and other ions (Chapman 1996). Specific conductance and dissolved solid concentrations are roughly proportional in most natural fresh waters. Therefore, specific conductance values are often used to estimate the concentration of dissolved solids in the water (Chapman 1996). Increases in conductivity may occur due to increased amounts of sediment, nutrients, or algae, all of which are indicators of lake eutrophication.

Conductivity measurements are expressed in micromhos per centimeter (μMHOs/cm). The freshwater range of conductivity is from 10 μMHOs/cm to 1000 μMHOs/cm, often exceeding 1000 μMHOs/cm in areas of high runoff (Chapman 1996). Historically, Maine lakes have shown low conductivity values, ranging from 20 μMHOs/cm to 40 μMHOs/cm (Pearsall 1993).

Methods

CEAT collected surface samples from all Characterization and Spot Sites on 21-Sep-98. Collected samples were kept on ice until they were refrigerated in the lab. All samples were analyzed using a Model 31A YSI Conductance Bridge within 24 hours of collection.

Results and Discussion

Conductivity values for Great Pond ranged from 30 μMHOs/cm to 40 μMHOs/cm, with a mean of 32.2 ± 1.0 (n = 10). Characterization Site 5, with the greatest conductivity (40 μMHOs/cm), receives the plumb of water entering via Salmon Brook. Salmon Lake drains into Great Pond via Salmon Brook. According to past CEAT analyses, Salmon Lake has shown the greatest conductivity of the Belgrade Lakes, 69.8 ± 11.9 (BI493 1994). Salmon Lake has a volume of 28,410,750 m^3 and a flushing rate of 0.59 flushes/year (Table 5), indicating that a considerable volume of water laden with solutes is entering Great Pond via Salmon Brook each year. This may explain the high conductivity value measured at Characterization Site 5.

According to a 1978 study, the mean conductance value of the lake was 28 μMHOs/cm (Davis et al. 1978). Over twenty years, the mean conductivity of Great Pond has gradually increased to 32 μMHOs/cm, a possible result of cultural eutrophication (Fig. 21). Other lakes within the Belgrade chain have shown similar conductivity values (Table 6), with the exception of Salmon Lake. Despite the increase in conductivity values over the past two decades, the conductivity values for Great Pond are within the observed range for Maine lakes (20 μMHOs/cm to 40 μMHOs/cm; Pearsall 1993).

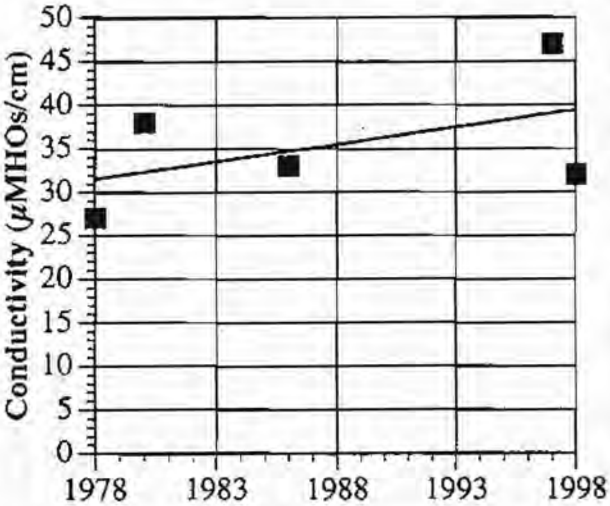

Figure 21. Conductivity measurements over time for Characterization Site 1 on Great Pond (Davis et al. 1978, MIDAS MDEP 1997, BI 493 1999). See Site Map for site location (Fig. 11).

Color

The true color of water is derived from dissolved minerals, such as ferric hydroxide, and organic substances, such as humic acids (Chapman 1996). The

primary source of these materials is decaying vegetation. Consequently, areas of high vegetative inputs will likely have the highest color measurements (Pearsall 1993). These measurements can range from less than 5 Standard Platinum Units (SPU) in a clear, clean lake to 300 SPU in dark peat-filled water. For example, a bog that experiences a lot of decomposition would have a very high color value. This true color is sometimes tainted by the presence of phytoplankton and zooplankton, which reflect light greatly and impart what is known as an apparent color to the water. The water must be filtered prior to analysis in order to remove these contaminants from the sample and get a "true color" value. This color value along with the turbidity determines the depth to which light can penetrate the water column and controls the depth of phytoplankton growth, which is an important factor in limiting primary production (Chapman 1996).

Methods

Surface color samples were taken on two separate occasions. On 21-Sep-98, samples were taken at Characterization Sites 1, 2, 3, 4, and 5 and at Spot Sites 6 and 7. On 5-Oct-98, water samples were taken at Characterization Site 1 and at Spot Sites 2B, 4B, 6, and 7. These water samples were kept on ice in the field and refrigerated in lab. They were then analyzed within 24 hours of their collection using the HACH DR/4000 spectrophotometer and the Platinum-Cobalt standard method for measuring true color (HACH 1997). This test gives the values in Standard Platinum Units (SPU), which is equivalent to parts per million (ppm).

Results and Discussion

The color measurements for Sites 1 through 7 on 21-Sep-98 yielded a mean color value of 11.8± 2.8 SPU ($n = 7$), which is much lower than the mean for Sites 1, 2B, 4B, 6, and 7 on 5-Oct-98 (16.2± 3.2 SPU, $n = 5$). The difference can be attributed to the high winds on the second day of sampling, which aided in the mixing of the lake, thereby bringing up water

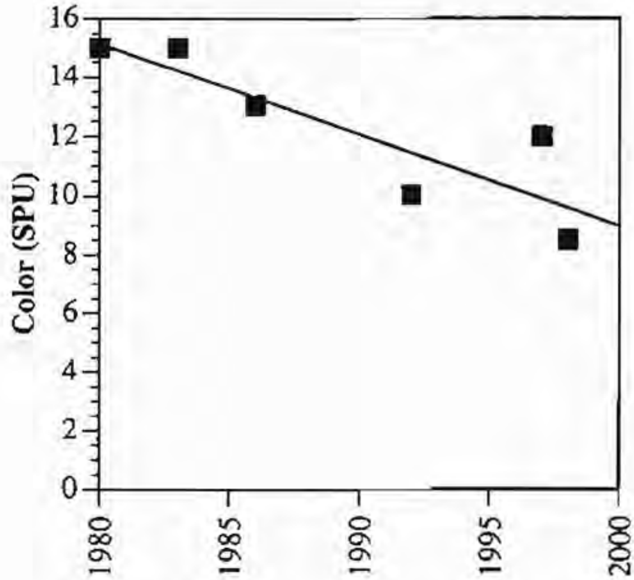

Figure 22. Regression analysis for color values in Standard Platinum Units (SPU) for Great Pond Characterization Site 1 over the past 18 years (r2=0.87, df=4, p<0.05). Historical data provided by the Maine Department of Environmental Protection.

thereby bringing up water rich in humic acids from lake depths (see Lake Water Quality: Dissolved Oxygen and Temperature). These color measurements are a bit lower than the mean color level of the other Belgrade Lakes (20 ± 7.6 SPU) as previously measured by CEAT.

In 1978 Davis et al. measured the color values for the northwest and southeast portions of Great Pond as 26 SPU (n = 3) and 20 SPU (n =3), respectively. These measurements are much higher than the values collected by CEAT in 1998. In the 1980s and 1990s further color data was collected by the Maine Department of Environmental Protection (MDEP). The MDEP data for Characterization Site 1 shows a significant decrease in color measurements over the past 18 years (R=0.871, df=4, p<0.05, n=5) (MDEP 1998; Fig. 22). This trend is possibly due to the use of different measuring instruments over the years; in particular, Nessler tubes and color wheels, instead of a spectrophotometer. These tests, which were the standard means of measuring color in the 1980s, had approximate reliabilities of ± 5 SPU and ± 10 SPU respectively (Bouchard pers. comm.). Variations in the data for water color as large as this can account for the observed trend, however this decrease in color may still be due to a unique natural proces. One possible explanation for this change in water color is that much of the forest along the water's edge has been developed for residential use (see Watershed Land: Shoreline Residential Areas). These developed areas, most of which

have grass lawns, would input fewer humic acids than the original forest floor, thereby lowering the color of the water over the past 20 years.

Chemical Measurements

Introduction

The Colby Environmental Assessment Team measured five chemical factors in Great Pond. The limiting nutrients, nitrogen and phosphorus, were measured to determine the current trophic status of the lake. Hardness, pH, and alkalinity were measured in order to examine other aspects of the overall water quality of Great Pond. All results in this section are expressed as a mean ± standard error (SE) unless otherwise stated.

Total Phosphorus

The standard critical limit for total phosphorus concentrations in a lake, with an average depth of 6 m is 15 parts per billion (ppb) (Mason 1996). To better understand how small this value is, 15 ppb phosphorus in a lake is comparable to 15 seconds in 32 years (Pearsall 1993). The minute amount of phosphorus involved in determining a critical limit is so small and difficult to pinpoint that it is subject to debate (Bouchard, pers. comm.). Since phosphorus is typically the limiting nutrient in aquatic ecosystems, the critical limit is based on the amount of phosphorus necessary to induce algal blooms in a lake. One study showed that blue-green algae could grow in water with 7 ppb phosphorus (Toy and Walsh 1987). Clair N. Sawyer, an authority on critical phosphorus levels, reported that with 10 ppb there can be undesirable algal growth (Toy and Walsh 1987). The Maine Department of Environmental Protection (MDEP) classifies lakes with less than 4.5 ppb total phosphorus as oligotrophic; lakes with total phosphorus concentrations between 4.5 ppb and 20 ppb as mesotrophic; and lakes with over 20 ppb eutrophic (State of Maine Water Quality Assessment 1996). In Understanding Maine's Lakes and Ponds, Webster Pearsall classifies a productive lake as one with over 13 ppb total phosphorus, a moderately productive lake with total phosphorus concentrations between 6 ppb and 13 ppb, and an unproductive lake with less than 6 ppb total phosphorus (Pearsall 1993). The Colby Environmental Assessment

Team (CEAT) used 15 ppb as the critical limit for algal blooms, as suggested by Mason (1996). Areas with surface samples of total phosphorus concentrations above 15 ppb were considered susceptible to algal blooms.

Methods

The Colby Environmental Assessment Team (CEAT) sampled nine sites on Great Pond. These sites were sampled to determine if the phosphorus concentration within each of the five main basins of the lake were close to 15 ppb, the concentration at which algal blooms are likely. Characterization Sites 1 and 2 had been monitored by CEAT during the summer months of 1998 and have also been historically monitored by the Maine Department of Environmental Protection (MDEP). Water samples from these sites were collected by CEAT from the surface, md-depth, and bottom (Fig. 11). Epicore samples were also taken at these two sites. An epicore sample was taken with a length of PVC tubing which was dropped into the water and extended from the surface to approximately one meter below the thermocline. This allows for the collection of a sample of the entire water column to the specified depth. Extensive testing was conducted on Sites 1 and 2 to ensure that a full profile of the water quality was obtained from representative sites. Fewer tests were conducted on the remaining Characterization Sites (Sites 3, 4, and 5). Samples for Site 3 were taken at the same depths as Sites 1 and 2. Surface, mid-depth, and epicore samples were taken at Sites 4 and 5. In addition to summer sampling, samples were also taken on 21-Sep-98 and 5-Oct-98

Samples were taken from five other sites (Spot Sites) around Great Pond (Fig. 11). They were analyzed to determine the effects of certain residential areas, tributaries and bogs on the total phosphorus concentration of the lake. Samples from sites 2B , 4B, 5B, 6, and 7 were collected on 21-Sep-98 and 5-Oct-98.

Once all samples had been collected, they were taken to the laboratory for analysis. As with other chemical tests, splits and duplicates (10 percent of all samples) were analyzed

with all samples to ensure the accuracy of the analyses. Standards with a known concentration of phosphorus were also included in each analysis. First, the samples were digested within 24 hours of collection. This process converted the particulate phosphorus into dissolved phosphorus. The digestion process consisted of adding 1 ml of 11 Normal (N) sulfuric acid and 1 ml of 1.75N ammonium peroxydisulfate to each of the samples. They were then placed in an autoclave at 15 pounds per square inch (psi) for 30 minutes. Once digested, samples were stored at 4°C and analyzed within 28 days. Samples were analyzed using the ascorbic acid total phosphorus method and a Milton Roy Spectronic 1001+ Spectrophotometer.

Results and Discussion: Characterization Sites

Characterization Site History

Data collected since the 1970s by the MDEP from Characterization Sites 1 and 2 were used to determine a trend in total phosphorus concentrations within Great Pond. A mean was established for each decade, using samples taken above 11 m. This depth was chosen because it ensures that the samples come from thoroughly mixed waters above the thermocline.

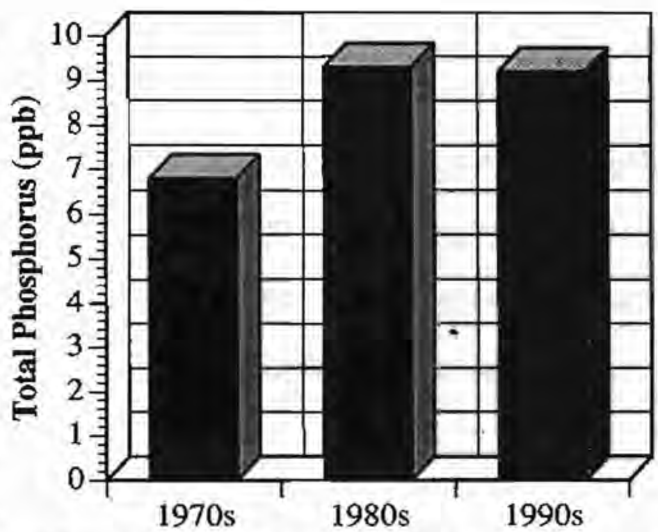

Figure 23. The mean total phosphorus concentrations (ppb) from grab and surface samples above 11m, collected by the Maine Department of Environmental Protection at Characterization Sites 1 and 2 on Great Pond. There were five dates used for the 1970s, three dates during the 1980s and 32 dates for the 1990s.

The mean for the 1970s was 6.8 ppb (Fig. 23). This level is well below the critical limit of 15 ppb. However, there was a substantial increase in the 1980s to 9.3 ppb. Then in the 1990s the mean fell slightly to 9.2

ppb. These data suggest that Great Pond has seen an increase in phosphorus since the 1970s, but that concentrations have stabilized below the critical limit of 15 ppb.

Summer Characterization Data

Surface, mid-depth, bottom, and epicore samples were taken at Characterization Sites 1, 2, 3, 4, and 5 on three dates during the summer (25-Jun-98, 17-Jul-98, and 13-Aug-98) and on 21-Sep-98. All of these samples were taken between the spring and fall overturns. At this time, the lake is stratified, and a thermocline exists. Bottom samples at both Characterization Sites 1 and 2 exceed the 15 ppb total phosphorus (Fig. 24). Site 1 bottom samples were taken

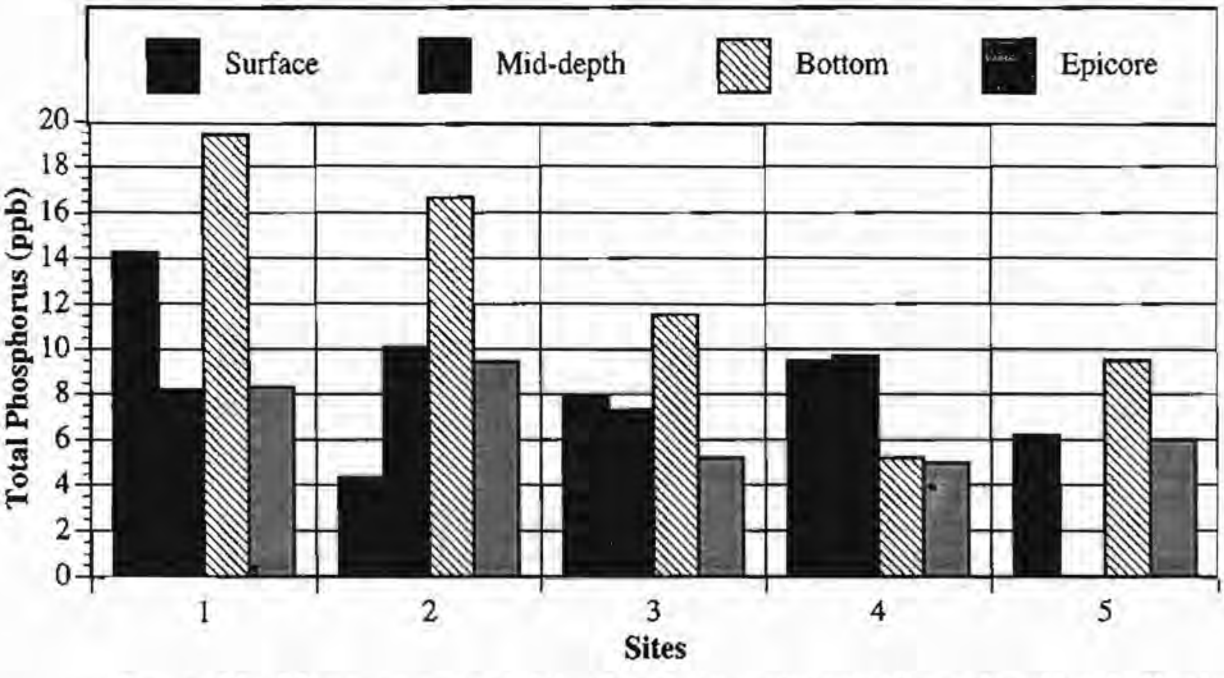

Figure 24. Mean summer total phosphorus concentrations for Great Pond Characterization Sites 1, 2, 3, 4, and 5; samples taken: 25-Jun-98, 17-Jul-98, and 13-Aug-98 at the surface, mid-depth, bottom, and by epicore. See site map for site locations (Fig 11).

at 18 m and Site 2 samples were taken at 19 m. These depths are below the upper limit (11 m) of the potentially anoxic region for the lake (see Lake Water Quality: Dissolved Oxygen and Temperature). However, during the first two sample dates, dissolved oxygen readings show that oxygen was present. On 13-Aug-98, dissolved oxygen was below 1 ppm at 11 m.

Sampling done on this date represents the highest concentration of total phosphorus throughout the summer. The bottom total phosphorus concentration for Characterization Site 1 was 24.9 ppb, 2.6 times higher than the surface samples. The concentration at Characterization Site 2, was 25.6 ppb, 4.9 times higher than the surface sample. These concentrations are believed to be attributed to the internal loading of phosphorus that occurs in anoxic waters.

The bottom samples from Characterization Sites 3 and 5 have greater total phosphorus concentrations than other samples taken from different depths at these sites. Due to shallow waters and the absence of anoxic regions, the bottom total phosphorus concentrations at Characterization Sites 3 and 5 are not as great as those from Characterization Sites 1 and 2. The proximity of Characterization Sites 3 and 5 to streams with total phosphorus concentrations above 14 ppb, is perhaps responsible for the observed total phosphorus concentrations. The higher bottom samples may also be a result of the settling out of particulate matter, that contains phosphorus. Even though the concentrations are below the critical limit of 15 ppb, phosphorus from the bottom will rise during fall overturn, increasing surface concentrations. Phosphorus concentrations at Characterization Site 4 are all below 10 ppb.

Fall Characterization Data

The results from samples taken by the Colby Environmental Assessment Team (CEAT) on 21-Sep-98 show that there are no areas in Great Pond above the critical limit of 15 ppb (Fig. 25). Results from the dissolved oxygen profile suggest that the lake was stratified, and that there was an anoxic region below 11 m at Characterization Sites 1 and 2 on 21-Sep-98 (Fig. 12). However, the bottom sample from Characterization Site 2 showed a total phosphorus concentration of 14.4 ppb, below the 25.6 ppb concentration that was measured on 13-Aug-98. This result was unexpected because, with anoxic conditions still

present, it would be expected that more phosphorus would be released into the lake, increasing total phosphorus concentrations. This suggests, that the effects of internal loading do not contribute as much as expected to the total phosphorus concentrations in Great Pond. Characterization Site 3 had the highest mean total phosphorus concentration from all depths taken (10.2 ppb). This may be attributed to external phosphorus from Great Meadow Stream (Tributary Site 10T). There were no phosphorus samples taken from the Characterization Sites that exceeded the critical limit of 15 ppb.

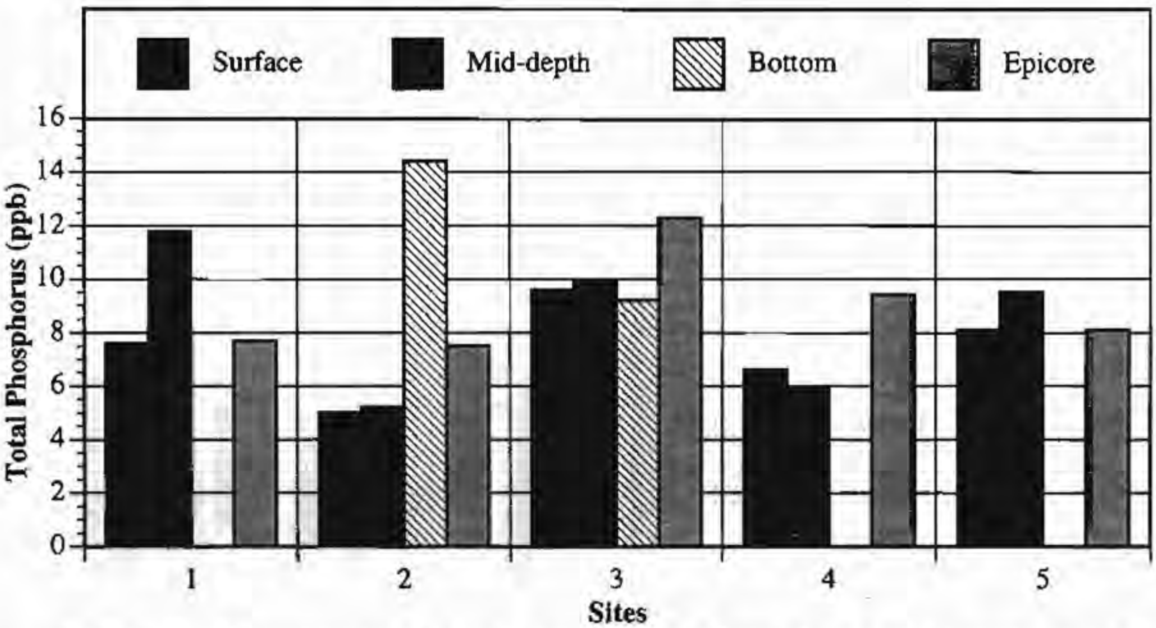

Figure 25. Concentration of total phosphorus at Great Pond for selected depths at Characterization Sites 1, 2, 3, 4, and 5 taken on 21-Sep-98. Samples were taken from the surface, mid-depth, bottom and by epicore. The bottom sample for Site 1 was omitted due to sampling error. See site map for site locations (Fig. 11).

Sampling throughout the summer and on 21-Sept-98 depicts Great Pond as a mesotrophic lake. Total phosphorus concentrations only exceeded the critical limit of 15 ppb in the deep anoxic holes present at Characterization Sites 1 and 2. If concentrations regularly exceed critical limits right before fall overturn, as they have in the past, there may be an overall increase in total phosphorus concentrations in Great Pond. Historical data suggest a slight increase in total phosphorus concentrations at Characterization Sites 1 and 2. Because

no past data exist for the other Characterization Sites, it is difficult to determine if there is a general increase of total phosphorus throughout the entire Great Pond, however there is no reason to believe that these sites are not experiencing the same trend. The increases in total phosphorus concentrations at Characterization Sites 1 and 2 may be a result of internal loading. This probably does not occur at Characterization Sites 3, 4, and 5 because there are no anoxic regions at these sites. Instead, increases of total phosphorus at these areas will most likely be linked to external loading and increased development around the lake. Our results show Great Pond as a moderately productive mesotrophic lake in no immediate danger of algal blooms. However, future increases in total phosphorus from internal or external sources could result in algal blooms. Continual monitoring of total phosphorus concentrations is recommended.

Internal Loading

Since 1972, the Maine Department of Environmental Protection (MDEP) has performed periodic phosphorus testing at Great Pond Characterization Sites 1 and 2. These sites are located at the two deepest basins of the pond (Fig. 11). This data shows trends of internal loading, the process of phosphorus being released from the sediment of the lake under anoxic conditions.

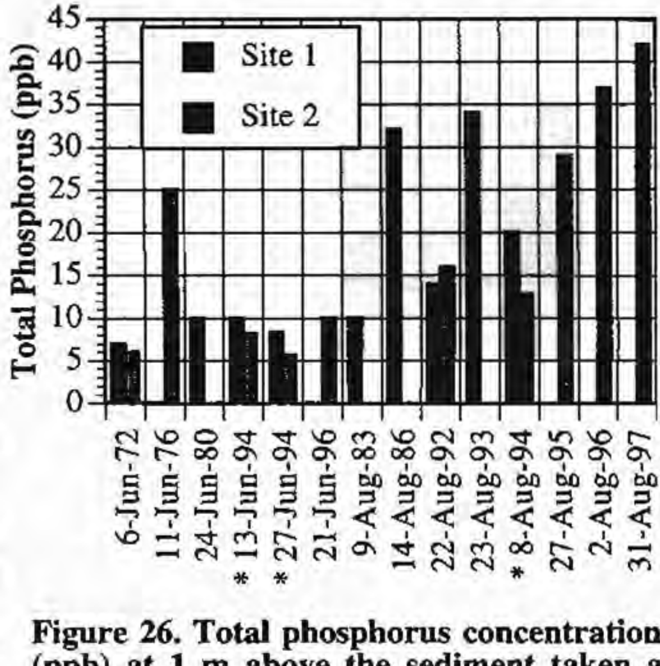

Figure 26. Total phosphorus concentrations (ppb) at 1 m above the sediment taken at Characterization Sites 1 and 2 by the Maine Department of Environmental Protection and Colby Environmental Assesment Team (CEAT). Asterisk indicates data taken by CEAT.

Historically, during the month of June, phosphorus levels near the bottom of Characterization Sites 1 and 2 were low (6 ppb

to 25 ppb) (Fig. 26). Except for Characterization Site 2 on 11-Jun-76, total phosphorus concentrations were below 10 ppb. These relatively low concentrations are the result of the spring turnover, which mixes the layers of the lake.

During late August, after the lake has been stratified for the summer, data from MDEP and CEAT show relatively higher concentrations of total phosphorous near the sediment at Characteristization Sites 1 and 2. Five dates, representing half of the August samples, show bottom concentrations at Characterization Sites 1 and 2 greater than 30 ppb and on 31-Aug-97 Characterization Site 2 had 43 ppb (Fig. 26). These high, late summer concentrations were probably due to the formation of anoxic conditions and subsequent internal loading over the summer months in the hypolimnion (see Lake Characteristics).

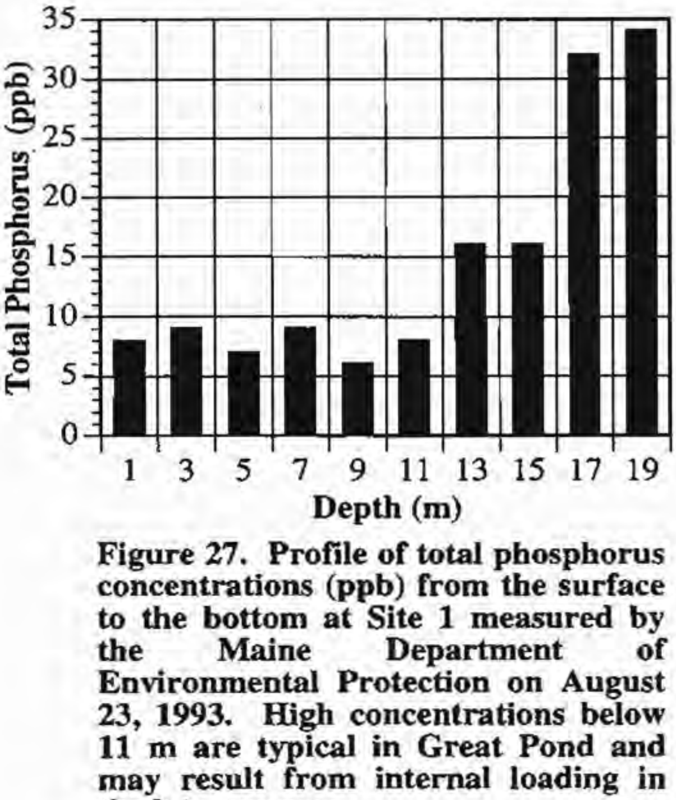

Figure 27. Profile of total phosphorus concentrations (ppb) from the surface to the bottom at Site 1 measured by the Maine Department of Environmental Protection on August 23, 1993. High concentrations below 11 m are typical in Great Pond and may result from internal loading in the late summer.

A profile of total phosphorus concentrations for 23-Aug-93 shows further evidence of significant internal loading below 11 m (Fig. 27). In the epilimnion, the concentrations are relatively low, between 5 ppb and 9 ppb. However, just below the thermocline, at 11 m, the total phosphorus levels increase and continue rising as depth increases; concentrations are nearly 35 ppb at the bottom. This profile of total phosphorus concentrations during late August and September has occurred repeatedly on dates provided by the MDEP in the 1970s and 1980s.

Data from CEAT and MDEP show this trend has continued during the 1990s.

In order to calculate the possible effects of internal loading on the total phosphorus concentrations in the entire lake, we assumed that anoxic conditions occur within the deepest 2 m of the 24.6 percent area of the lake that could be anoxic (see Lake Water Quality: Dissolved Oxygen and Temperature). Using the historical data provided from the MDEP, it was determined that the deepest 2 m at Characterization Sites 1 and 2 had a mean total phosphorus concentration of 34.3 ppb between 14-Aug and 31-Aug. The volume of water in the potential anoxic area (see Lake Water Quality: Dissolved Oxygen and Temperature) and the mean concentration of phosphorus within this volume were used to determine the total amount of phosphorus present. If this hypothetical amount of dissolved phosphorus was mixed with the rest of the lake, as would occur at turnover, the concentration of total phosphorus in the lake would rise by 0.6 ppb. This increase would be directly related to increased phosphorus due to internal loading. With a critical limit of total phosphorus concentrations in the lake set at 15 ppb, this is not a relatively high increase. However, it is still important to consider several factors of internal loading. First, phosphorus from internal loading is not included in the phosphorus budget for the Great Pond Watershed (see Water Budget). Second, there is an abundant supply of phosphorus in the sediment, and internal loading could occur independently of terrestrial and atmospheric inputs (Fig. 2). Most important is the trend of anoxia occurring at increasingly shallower depths since the 1970s (Fig. 16). A larger anoxic area could significantly increase the amount of phosphorus released from the sediment due to internal loading.

Results and Discussion: Spot Sites

Water surface samples were taken for all spot sites on 21-Sep-98. While none of the surface samples were above 15 parts per billion (ppb), some are quite close to that threshold value, ranging from a low of 5.1 to a high of 11.9 ppb (Fig. 28.).

Surface samples were taken from all spot sites, while samples from other depths were taken only at specific spot sites (Fig. 29). The surface sample at Site 2B is 10.3 ppb. Though this value is below the MDEP's critical limit, some studies have shown that an undesirable amount of algal growth can occur in the presence of as little as 10 ppb of total phosphorus (Toy and Walsh 1987). The reading obtained from site 2B could be a result of the influence of Robbins Mill Stream (Tributary 9T) located just above the sample site.

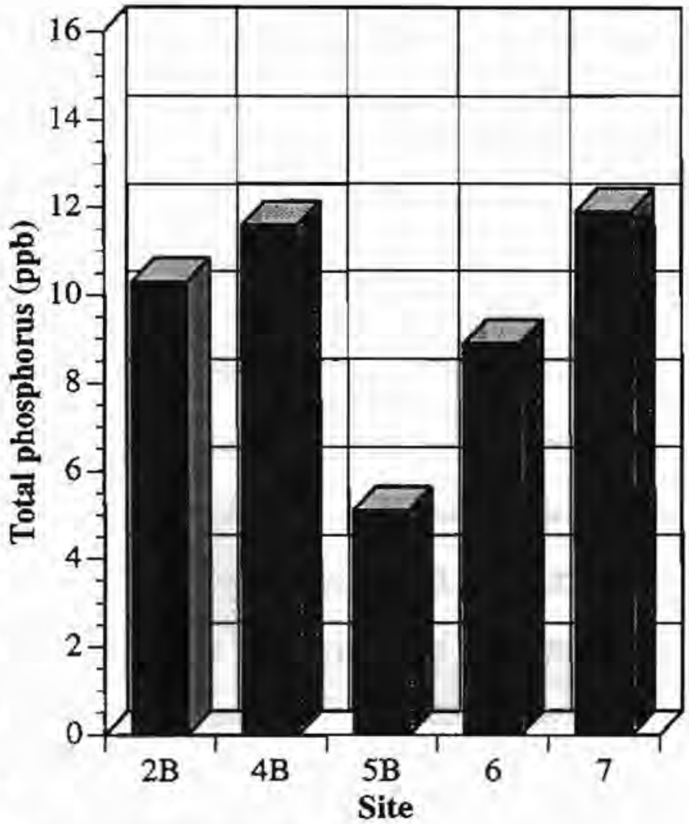

Figure 28. Total phosphorus concentrations, obtained from surface samples at all Spot Sites in Great Pond on 21-Sep-98. See site map for site locations (Fig. 11).

The total phosphorus concentration in this tributary is 26.0 ppb and could have added to the overall concentration already present at Spot Site 2B. This site was also shown to have a very high phosphorus concentration at the mid-depth level while the bottom sample had a lower concentration.

Site 4B is too shallow to stratify, indicating that not much of a difference would be seen between the phosphorus concentrations of the mid-depth and that of the bottom samples. Epicore, surface, and mid-depth samples were taken at this site. The surface and mid-depth samples taken here were very similar to each other in their values (11.6 ppb and 11.4 ppb, respectively). Wave action and the fall turnover could aid in the mixing of the water, especially near the shore. The total phosphorus readings for Spot Site 4B were taken near

Austin Bog. Wetlands, such as Austin Bog, can act as buffer strips (National Research Council 1996). Bogs are able to store nutrients and toxins and prevent the flow of these to downstream ecosystems. Bogs trap nutrients including phosphorus, offering protection from the threat of accelerated eutrophication. This is true most of the time, however, at certain times of the year, such as spring and fall, bogs can release nutrients rather than absorb them (Weller 1994). In the fall, when the rate of decay is most likely greater than plant growth, the source component of the bog might be greater than the sink component. Given that the samples were taken in September, Austin Bog may have been releasing nutrients into the lake at this time, thus affecting the total phosphorus concentration of the water at Spot Site 4B, resulting in a high reading of 11.6 ppb.

Development can cause runoff high in phosphorus to enter the lake. Pinkhams Cove (Site 5B) is lined with a high number of residences located very close to the water's edge. Our buffer strip survey indicated that the buffer strips here are poorly maintained or non-existent in some cases (see Watershed Land: Buffer Strips). Some of the septic systems in the area are quite old, and possibly contribute phosphorus to the lake in the form of runoff or effluent seeping into the lake (see Watershed Land: Sewage Disposal Systems). It was expected that the phosphorus concentration at Site 5B would be relatively high. However, it was only 5.1 ppb, the lowest value of all spot sites. While this result is different from what was expected, the reasons for it are unclear. There may be other factors influencing this area of the lake of which we are unaware.

Site 6 is near the Great Pond Marina, and experiences heavy boat traffic from early spring to fall. The waters of the marina are also affected by the currents and wave action of Great Pond. This can cause an accumulation of nutrients and organic matter at Spot Site 6, because water can bring nutrients and deposit them in this area as the waters move on to other parts of the lake.

This is also an area where water must pass to exitthe lake, thus resulting in additional nutrient accumulation. The phosphorus concentration, however, was not extremely high (8.9 ppb). Spot Site 6 also shows total phosphorus concentrations to be relatively constant in all four samples taken. The concentrations for mid-depth, bottom, and epicore are 7.4, 6.1, and 6.3 ppb, respectively (Fig. 29).

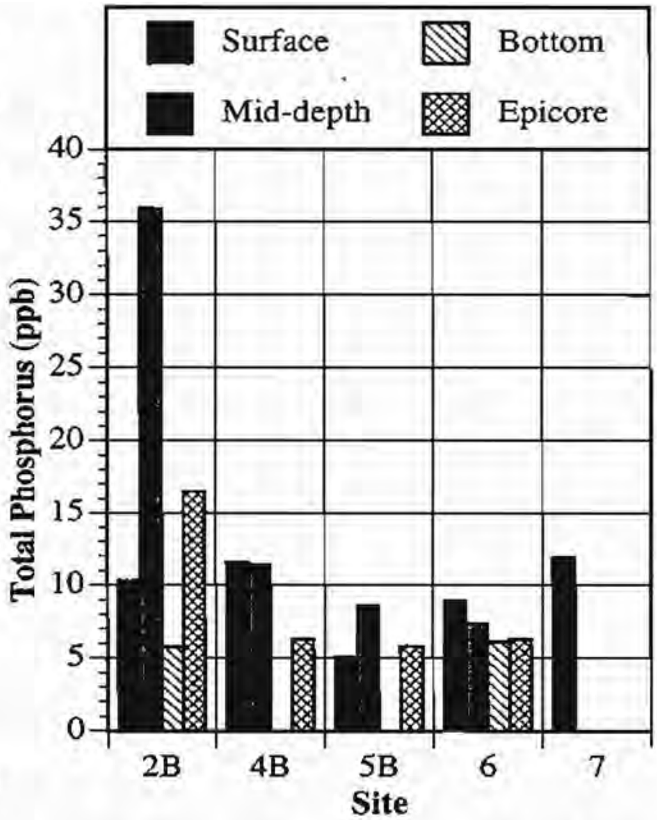

Figure 29. Total phosphorus concentrations (ppb) at Spot Sites from selected surface, mid-depth, bottom, or epicore samples from Great Pond collected on 21-Sep-98. See site map for locations (Fig. 11).

Spot Site 7 is the only outlet on the lake and is also affected by the water currents and the accumulation of nutrients from the rest of the lake. However, unlike Spot Site 6, Spot Site 7 shows the highest surface phosphorus concentration at 11.9 ppb. A greater amount of accumulation occurs here than at any other spot in the lake. As the current moves toward the dam, sediments are stirred up. This occurrence would increase the total phosphorus readings found at Spot Site 7.

The MDEP categorizes lakes on the basis of their phosphorus concentrations as well as other chemical tests (MDEP 1992a). The mean total phosphorus concentration is calculated using the surface and epicore samples only. This value for Great Pond was calculated to be 8.8 ppb ± 0.8 (n=19), from samples collected on 21-Sep-98. According to the MDEP classification system, Great Pond falls under the Good Quality Category, which indicates that

the lake is in no immediate danger of algal blooms or other effects of cultural eutrophication. Lakes that fall under this category have an mean total phosphorus concentration ranging from 5 ppb to 10 ppb. This is a typical classification for larger lakes such as Great Pond which have low total phosphorus concentrations. The Trophic Status Index (TSI) was also calculated using the total phosphorus results. The following equation was used to calculate the TSI_P:

$$\mathbf{TSI_P} = 70\,[\log(0.33 \cdot \text{phosphorus mean} + \text{S.E.})]$$

The value was calculated to be 39 TSI which corresponds to the value obtained through the use of the results from the transparency tests (see Lake Water Quality: Transparency).

The phosphorus concentrations for Messalonskee Lake, Long Pond-South Basin, Long Pond-North Basin and Salmon Lake (BI493 1994, BI493 1995, BI493 1996, BI493 1997, BI493 1998), were also calculated using surface and epicore samples. East Pond only used surface samples (Fig. 30). The phosphorus concentration of Great Pond, (8.8 ppb ± 0.8 (n=19)), falls between the values of the other lakes.

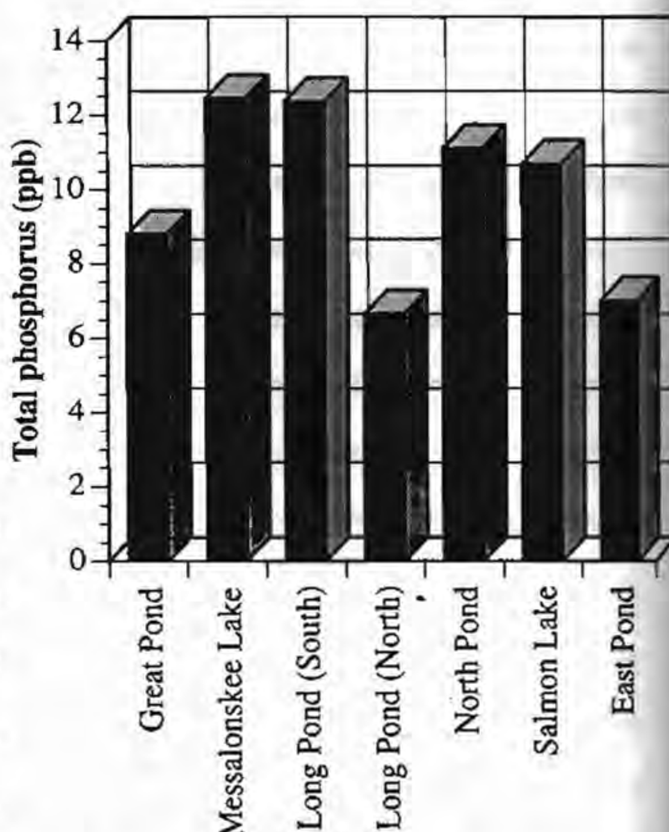

Figure 30. Mean total phosphorus concentrations (ppb surface and epicore samples) for all Belgrade Lakes taken from past Biology 493 studies conducted in 1991, 1993 and 1994-99.

Nitrates

Nitrogen is an essential element in protein synthesis, especially for the replication of genetic information (Chapman 1996). Although nitrogen has many natural avenues of input into a lake, the unnatural ones pose the greatest cause for concern. In urban areas, the primary input sources are domestic sewage, industrial wastes, and storm drainage; whereas in a rural setting the majority of nitrogen comes from agriculture, forest management practices, and rural dwellings (Mason 1996). Two essential elements for algal growth are nitrogen and phosphorus, the latter being the limiting element in Maine lakes. This means that high nitrate and nitrite levels are not a problem on their own and that there must be an excess of phosphorus, in the presence of adequate nitrogen, to begin the process of eutrophication (Pearsall 1993). Worldwide, unpolluted lakes seldom exceed 0.1 ppm of nitrate in the water, and a lake is not considered polluted until its nitrate levels exceed 5.0 ppm (Chapman 1996).

Methods

The combined levels of nitrate and nitrite for Great Pond were measured on 21-Sep-98 at Characterization Sites 1, 2, 3, and 4 and the Spot Sites 5B and 7. At each of these sites, an epicore sample was taken to measure the nitrate/nitrite level throughout the water column. Once collected, the sample was adjusted to a pH of less than 2 with H_2SO_4, placed on ice, and analyzed within 24 hours. The HACH DR/4000 spectrophotometer and the low range cadmium reduction nitrate test was used to determine nitrogen concentrations in Great Pond (HACH 1997).

Results and Discussion

The combined nitrate/nitrite levels of all the water samples analyzed were too low to detect (less than 0.02 ppm) using the HACH DR/4000 spectrophotometer. The water of Great Pond appears to be unaffected by excess external nitrogen loading. Historical data

show the mean nitrate level in Great Pond in the 1970s to have been 0.029 ppm (n = 20) with a range of 0 ppm to 0.280 ppm, and the mean nitrite level to be 0 (n = 13) (Davis et al. 1978). These very low means concurs with the data collected in 1998 by CEAT. These continuously low nitrogen values indicate a stable and healthy level of nitrogen input in to Great Pond over time, which does not pose a threat to the overall health of the lake. Although this data is valid and useful, it would benefit future researchers to measure nitrate/nitrite levels with methods capable of measuring lower range values to obtain accurate values.

In comparison to the rest of the Belgrade Lakes, Great Pond has an extremely low combined nitrate/nitrite level. The mean nitrate/nitrite level of the other Belgrade Lakes was found to be 0.049 ± 0.010 ppm (n=6), with none of the other lakes having nitrate/nitrite levels below 0.02 ppm. Although different analytical tests were performed on past samples, some not as accurate as the low range cadmium reduction method, the average still lies well below the level of a polluted water body. Therefore little cause for concern is raised about the health of the Belgrade Lakes with respect to nitrogen enrichment.

Hardness

Hardness is a measure of the concentration of dissolved calcium (Ca^{+2}) and magnesium (Mg^{+2}) salts in the water. Calcium ions and magnesium ions form an insoluble precipitate with soap and prevent the formation of a lather, making harder water less able to form suds (Mays 1996). Hardness is affected by numerous factors. Mineral deposits of bedrock in the lake contribute Ca^{+2} and Mg^{+2} to the water, and large amounts of sediments from runoff result in harder water. Hardness may also be a sign of industrial pollution because it indicates the addition of dissolved chemicals. Also, increased hardness can indicate chemical contamination caused by the presence of herbicides or pesticides (Hill et al. 1994).

The classification of water hardness ranges from soft to very hard. The United States Geological Survey (USGS) provides a general hardness scale which labels water with 0 ppm to 60 ppm calcium carbonate ($CaCO_3$) as soft, 61 ppm to 120 ppm as moderately hard, 121 ppm to 180 ppm as hard, and water with more than 180 ppm as very hard (USGS 1989). Soft water is beneficial for the growth of fish but renders fish more vulnerable to toxins and pollutants than hard water (McKee and Wolf 1963).

The American Water Works Association claims that ideal hardness levels are less than 80 ppm $CaCO_3$ (USGS 1989). If hardness is greater than 100 ppm $CaCO_3$, the USGS classifies the water as hazardous for ordinary domestic use.

Methods

Hardness was tested at Characterization Sites 1 and 2 on 21-Sept-98. The samples from these sites were acidified with nitric acid to a pH less than 2 and kept on ice until analyzed. The water was analyzed within 48 hours of collection using the calmagite colormetric method for detecting Ca^{+2} and Mg^{+2} and the HACH DR/4000 Spectrophotometer (HACH 1997).

Results and Discussion

Characterization Sites 1 and 2 had hardness values of 2.97 ppm $CaCO_3$ and 3.03 ppm $CaCO_3$, respectively. Great Pond can be characterized as having soft water by USGS standards.

Previous research determined that the hardness levels in the six other Belgrade lakes range from 3.4 ppm $CaCO_3$ in the South Basin of Long Pond to 25.4 ppm $CaCO_3$ in Salmon Pond (BI 493 1991, BI 493 1993, BI 493 1994, BI 493 1995, BI 493 1996, BI 493 1997, BI 493 1998). The mean of these six other lakes is 13.3 ± 3.5 ppm $CaCO_3$ (n=6). Great Pond has a very low hardness level in comparison with the other lakes, which may be the result of limited areas of exposed bedrock at the lake bottom and low industrial pollution.

pH

The pH of a solution at a given temperature indicates the intensity of its acidic or basic character by measuring the instantaneous concentration of the free hydrogen ion in solution (Chapman 1996). This concentration is measured on a logarithmic scale of 1 to 14. A pH of 7 is neutral, and the sample becomes increasingly more acidic as its pH value approaches zero (Pearsall 1993). Pearsall (1993) claimed that the pH in most of the lakes in Maine lies between 6.1 and 6.8, although lower values are common for waters with a high organic content; higher values are often seen in eutrophic lakes (Chapman 1996). In unpolluted areas, concentrations of carbon dioxide and the carbonate and bicarbonate ions dissolved in the water are primarily responsible for the regulation of the pH in a lake. However, organic acids from decomposition and the rate of both photosynthesis and respiration also play a role in determining the natural pH of the lake (Davis et al. 1978, Chapman 1996). Industrial effluents and atmospheric deposition of acid forming substances can affect this acid-base equilibrium as well. Changes in pH play a major role in influencing the composition and survivorship of organisms in the lake (Pearsall 1993).

Methods

The surface pH of Great Pond was measured at all of the Characterization and Spot Sites on site by CEAT team on 21-Sep-98 using a calibrated HORIBA Twin pH meter.

Results and Discussion

The mean pH of the sites measured on 21-Sep-98 was 6.98 ± 0.09 (n=10). This mean falls within the range of a healthy lake (6.0 to 8.5; Chapman 1996), however it is slightly more basic than the values found for most Maine lakes (6.1 to 6.8; Pearsall 1993). This small difference would only have minimal impact on the flora and fauna of the lake and is not a cause for concern.

Historical data has shown a mean pH of 6.85 for Great Pond (Davis et al. 1978). Additional pH data were also collected by CEAT over the summer of 1998, spanning the months of June through August. These data gave a mean pH of 7.02 ± 0.11 (n=15). Both of these values are similar to the pH measured by CEAT in the fall of 1998, indicating very low fluctuations in the pH of the lake over time. More historical data for pH, obtained from the Maine DEP (1998) for 1982 to 1997 at Characterization Site 1, presented a mean of 6.69 ± 0.20 (n = 8). The value for this site on 21-Sep-98 was 7.47, and would seem to indicate a rise in the pH of the lake. Although the pH at this one particular site appears to be rising with time, the overall pH of the lake, as expressed by the mean from all sample sites, shows little variance.

The mean pH of Great Pond is similar to the other major water bodies in the Belgrade Lakes Region is very similar. The mean pH for all of the Belgrade Lakes is 7.04 ± 0.14, indicative of a chain of lakes that has a healthy pH level. Although lakes in Maine are often a bit more acidic, this number still falls well within the normal range for lakes around the world. Even though acidification of lakes and streams is currently a common problem, it appears as if the Belgrade Lakes are, as of yet, unaffected by cultural acidification.

Alkalinity

Alkalinity is an important determinant of levels of acid-neutralizing substances dissolved in water (Chapman 1996). Measuring this buffering capacity provides information regarding levels of dissolved ions in the water, including carbonate, bicarbonate, and hydroxide. Carbonate and bicarbonate ions form when carbon dioxide or carbonate rock dissolves in water. High alkalinity values indicate that the lake is well buffered against sudden decreases in pH.

A lake becomes susceptible to the effects of acid rain and other acidifying inputs when its alkalinity level drops below 4 ppm (Pearsall 1993). Alkalinity levels will change before

pH levels fluctuate in lakes subject to acidification, making alkalinity an indicator of potential problems regarding acidity. Alkalinity is also a measurement of the inorganic carbon reservoir of the lake, a determinant of the ability of the lake to support algal growth and aquatic life (Pearsall 1993). Trends among Maine lakes indicate a range of alkalinity values between 4 ppm and 20 ppm calcium carbonate ($CaCO_3$) with a mean of 10 ppm $CaCO_3$ (Davis et al. 1978, Pearsall 1993). Levels above 10 ppm $CaCO_3$ indicate that the lake will be able to withstand the detrimental effects of acid rain longer than lakes with low alkalinity (less than 4 ppm).

Methods

Colby Environmental Assessment Team (CEAT) collected epicore samples from Characterization Sites 1 and 2 on 21-Sep-98 as well as surface samples from Spot Sites 6 and 7. Samples were kept on ice and were analyzed within 24 hours of acquisition. A simple titration was performed on each sample using 0.02N H_2SO_4. The amount of acid used in each titration was the essential component in determining the total alkalinity, expressed as ppm $CaCO_3$, using the potentiometric method (Eaton, Clesceri, and Greenberg 1995).

Results and Discussion

The mean alkalinity for 21-Sep-98 of the Characterization Sites was 8.5 ± 0.5 ppm ($n = 2$). The mean alkalinity for the Spot Sites was 9.5 ± 0.5 ppm ($n=2$).

These levels are consistent with past analyses of lakes in the region. In a 1978 study of Great Pond, the alkalinity was determined to be 10 ppm, with a range from 6 ppm to 12 ppm (Davis et al. 1978). Studies of the Belgrade lakes conducted in the 1990s found alkalinity levels ranging from 7 ppm to 18 ppm $CaCO_3$ (Table 6). Great Pond has alkalinity levels comparable to those of other lakes in the region, and is well buffered against sudden changes in pH due to acid input.

Table 6. Comparison of mean lake water quality values (±SE) for physical and chemical tests at Characterization and Spot Sites in the Belgrade Lakes. Data obtained from lake watershed studies by Biology 493 in 1991, 1994-98.

Test Conducted	Great Pond	Messalonskee Lake	North Pond	East Pond	North Basin Long Pond	South Basin Long Pond	Salmon Lake
Transparency (m)	5.91±0.21	4.60±0.40	3.50±0.20	4.00	6.90	6.50±0.003	2.88±0.38
Turbidity (FTU)	4.34±1.84	5.00±2.00	2.79±0.28	4.70	3.40	2.31±0.35	2.23±0.17
Color (SPU)	14±2	50±12	17±2	-	12	8±1	13±2
Conductivity (μMHOs/cm)	32.2±1.0	36.0±3.0	27.3±1.8	29.0	31.7	34.5±0.2	69.8±11.9
Hardness (ppm)	3.00±0.03	14.79±0.30	10.11±0.40	-	13.00	3.42±0.21	25.38±0.77
Nitrates (ppm)	*	0.10±0.00	0.05±0.01	0.03	0.04	0.04±0.003	*
pH	6.98±0.09	6.98±0.11	7.07±0.05	7.10	6.80	6.59±0.01	7.78±0.13
Alkalinity (ppm)	9±1	18±1	12±0.2	-	9	9±0.3	-

*below the limit of detection

Tributary Water Quality

Physical Measurements

Introduction

The physical attributes measured at Great Pond Tributary Sites were flow rate, turbidity, color, and conductivity. These measurements reflect the quantity and quality of water entering the lake through these inputs and contributed to the overall assessment of the health of Great Pond. All data are presented as mean ± SE unless otherwise stated.

Flow Rate

Velocity (flow rate) of a water body is a measure of the amount of water flowing past a given point for an established time period. The flow rate of a tributary enables the prediction of the amount of water, nutrients, pollutants, and other compounds which flow into the lake from the tributary (Chapman 1996). Flow rate is affected by such factors as the drainage area, slope, and basin configuration of the tributary.

Methods

Colby Environmental Assessment Team (CEAT) measured the flow rates at Rome Trout Brook (8T), Salmon Brook (11T), and Bog Brook (13T) on 21-Sep-98. Pinkhams Cove Tributary (12T) was measured on 5-Oct-98. The flow rates were determined using a Marsh-McBirney, Inc., Flow Mate flow meter. A transect, placed perpendicular to the flow of the water, was used to divide each tributary into sections. These sections, or cells, corresponded to one-fifth of the width of the tributary. The width of each tributary was recorded and flow in each cell was calculated using the following formula:

Flow Rate per cell (cfs) = [length of cell (ft)] x [mean depth of cell (ft)] x [mean cell velocity (ft/s)]

The flow rates for all cells along the transect were combined to calculate the overall flow rate of the tributary in cubic feet per second (cfs).

Results and Discussion

Although Great Meadow Stream (10T) had a velocity below the limit of detection at the time of sampling, it is the greatest source of discharge into Great Pond. In addition to runoff from the stream watershed, North Pond, with a volume of 28,410,750 m^3 and a flushing rate of 0.56 flushes/year, flows into Great Pond via Great Meadow Stream. Based upon analysis of topographical maps of the Great Pond Watershed, Great Meadow Stream (10T) has the largest drainage area of the tributaries. Salmon Brook (11T) has the next largest drainage area, followed by Rome Trout Brook (8T), Bog Brook (13T), and Pinkhams Cove Tributary (12T). From the flow rate data, Bog Brook (13T; see Appendix F), had the greatest measured flow rate. The data for Bog Brook (13T) indicates a flow rate of 6.57 cfs. The next greatest flow rate was registered at Salmon Brook (11T). Salmon Brook (11T) drains Salmon Lake into Great Pond and had a flow rate of 1.39 cfs. Rome Trout Brook (8T) displayed a flow rate of 0.94 cfs and the flow rate of Pinkhams Cove (12T) was 0.0 cfs.

Flow rate results indicated low flow rates for most of the tributaries sampled. Sampling after a storm event would provide a better indication of the potential flow rates of the tributaries as would sampling after the spring melt.

Turbidity

Turbidity measures the amount of suspended matter in water (see Lake Water Quality: Turbidity). This test accounts for cloudiness due to silt, organic and inorganic particles, plankton, and other microorganisms.

Methods

On 21-Sep-98, water samples were taken to test for turbidity at Trout Brook (8T), Robbins Mill Stream (9T), Salmon Brook (11T), Pinkhams Cove Tributary (12T), and Bog

Brook (13T). Additional samples were taken from all Tributary Sites on 5-Oct-98. All samples were preserved on ice in the field and then refridgerated until analysis. Turbidity measurements were performed within 48 hours of collection using the 2100P HACH Turbidimeter (HACH 1997). Results are presented in Formazin Turbidity Units (FTU).

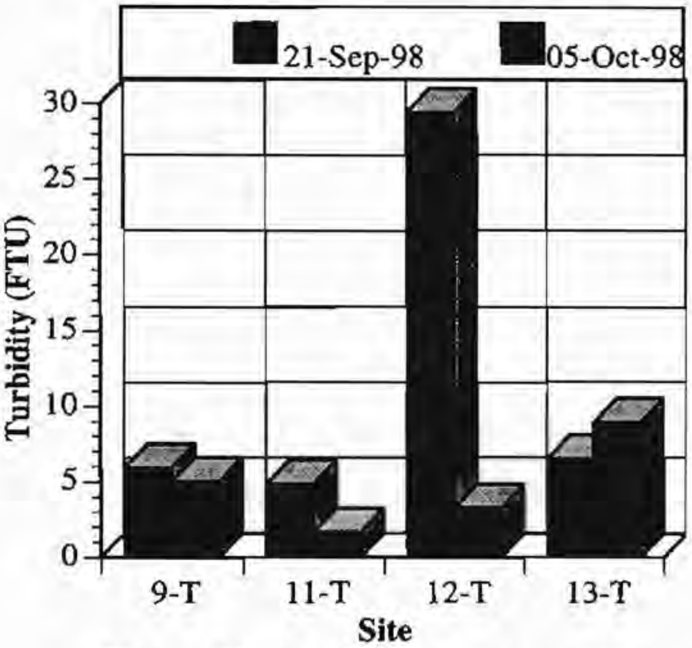

Figure 31. Turbidity measure-ments from surface grabs at Tributary Sites on 21-Sep-98 and 05-Oct-98. Turbidity was measured in Formazin Turbidity Units (FTU). See site map for site locations (Fig. 11).

Results and Discussion

On 21-Sept-98, the mean turbidity level for Tributary Sites was found to be 11.77 ± 4.58 FTU (n=5). On 5-Oct-98, the mean turbidity was 4.79 ± 0.99 FTU (n=5). Except for a difference of 26.12 FTU from the first sample date to the next at Pinkhams Cove Tributary (12T), the turbidity levels on 21-Sep-98 and 5-Oct-98 were comparable (Fig. 31). It is possible that Site 12T had a particularly high amount of runoff on 21-Sep-98 or that an error was made in the collection or analysis of the sample. The flow rate of this site, Pinkhams Cove Tributary, was not measured on 21-Sep-98, so it is difficult to determine the relationshipbetween flow rate and turbidity at this site.

Turbidity levels at the Tributary Sites were greater than the levels in the lake (see Lake Water Quality: Turbidity) because there is an increased amount of run-off particles in the tributaries. Sediments from erosion and pollution enter the lake through the tributaries, resulting in greater cloudiness in tributary samples. Turbulence serves to suspend material in

the water column. The suspended matter then settles out in the lake, and turbidity levels are lower in the still, open water.

Color

Lake water color is primarily due to dissolved minerals and organic substances that come from the decomposition of vegetation (Pearsall 1991, Chapman 1996). The levels of color in a natural water body can range from around 5 Standard Platinum Units (SPU) up to 300 SPU (Pearsall 1993). The color of tributaries, which is primarily responsible for the color of the whole lake, depends upon the source of the stream, and the areas through which it travels. The color of water restricts the depth to which light can penetrate into the water column and hence the depth of primary production (Chapman 1996). Although a fairly high color level of water can slow eutrophication, a very high color measurement is often indicative of a high rate of nutrient loading. This is due to the high concentration of organic particles often associated with highly stained water, to which nitrates and phosphates are chemically bonded (Mason 1996).

Methods

The color was measured in the laboratory from water samples taken on 21-Sep-98 and 5-Oct-98. On both of these dates, all of the tributaries flowing into Great Pond were sampled, and the water was kept on ice until it reached the laboratory where refrigerated until analyzed. The samples were analyzed within 24 hours of collection by using the HACH DR/4000 spectrophotometer and the Platinum-Cobalt standard method for measuring true color (HACH 1997). The results of this analysis are presented in SPU, which is equivalent to parts per million (ppm).

Results and Discussion

The color values for the tributaries on 21-Sep-98 had a mean of 43.14 ± 15.41 SPU (n=6). As these data show, the color values for the tributaries were quite variable. Trout

Brook (8T), Great Meadow Stream (10T), Salmon Brook (11T) and Bog Brook (13T) each had color measurements below 30, which are reasonable levels of input into Great Pond. Robbins Mill Stream (9T) and the Pinkhams Cove Tributary (12T) had color values of 57 SPU and 130 SPU respectively, which are very high. The measurements from 5-Oct-98 had a mean of 48.5 ± 11.7 SPU (n = 6). These results also show the high variability of the color in these tributaries. In this case, only Great Meadow Stream (10T) and Salmon Brook (11T) had color values below 30 SPU. The four tributaries greater than 30 SPU all had values higher than the measured levels on 21-Sep-98, except the Pinkhams Cove Tributary (12T) which experienced a drop of 40 SPU between the two sample periods. The above data clearly point to the highly independent and variable nature of the tributaries flowing into Great Pond. Their color is inconsistent from sample period to sample period, and the streams act very independently with respect to changes in their respective color levels.

There are two streams which stand out as potential problems: Robbins Mill Stream (9T) and the Pinkhams Cove Tributary (12T). These two tributaries had the highest color levels for both of the two sample dates. These high measurements may be due to the low volume of water that was flowing in these streams on 21-Sep-98. This period of low water probably served to concentrate the organic acids from their associated wetlands. These acids, which then get flushed into the tributaries during times of high water, raise the color values for both the tributaries and the lake. Although these high levels of color can actually inhibit primary production, they also may indicate a high influx of organic particles into the water body. There may be high levels of nutrients attached to these particles, especially nitrates and phosphates (see Tributary Water Quality: Total Phosphorus), which need to be controlled if cultural eutrophication is to be stopped.

Conductivity

Conductivity measures the ability of water to conduct an electric current. This physical test measures the influence of run-off waters on Great Pond (Chapman 1996). Tributaries exhibiting high conductivity values may indicate that the tributaries are receiving large amounts of run-off (Chapman 1996). This run-off can increase nutrient levels around an effluent discharge, leading to pollution zones in the lake (Chapman 1996).

Methods

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Results and Discussion

Conductivity values of Great Pond tributaries ranged from 9.1 μMHOs/cm to 36.0 μMHOs/cm with a mean of 20.2 ± 4.3 μMHOs/cm (n=6; Fig. 32). These values are lower than the mean conductivity of Great Pond (32.2 ± 1.0 μMHOs/cm; n=10). The tributaries exhibited low flow rates ranging from 0 cfs to 6.57 cfs, possibly explaining the low amounts of dissolved solutes in the

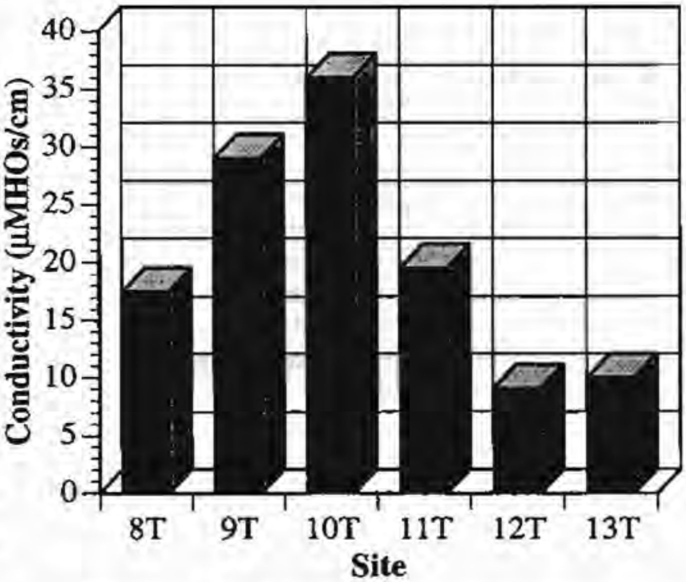

Figure 32. Conductivity measurements for surface samples taken from Great Pond tributaries 5-Oct-98. See Figure 11 for site locations.

water. This may explain the low conductivity levels of the tributaries as compared to Great Pond.

Compared with tributaries of other Belgrade Lakes, Great Pond's tributaries exhibited low conductivity values. The tributaries of Salmon Lake, to the east of Great Pond, had a mean conductivity of 180.0 ± 46.6 μMHOs/cm (n=10; BI493 1994), while the tributaries of North Pond displayed a mean conductivity of 31.4 ± 4.2 μMHOs/cm (n=10; BI493 1997). The conductivity values of Great Pond tributaries as measured on 5-Oct-98 are low and do not pose a threat to the lake.

Chemical Measurements

Introduction

The chemical tests conducted on tributary water samples were measured for total phosphorus and pH. Given that the tributaries empty into the lake, contributing their chemicals and organic material to the water body, these chemical parameters can have a significant impact on the water quality of the lake. Tests conducted on tributary waters, in addition to those conducted on the lake water, will aid in the determination of the effect of the tributaries on the water quality of the lake.

Six tributaries that empty into Great Pond were sampled and tested; Trout Brook (8T), Robbins Mill Stream (9T), Great Meadow Stream (10T), Salmon Brook (11T), Pinkhams Cove Tributary (12T), and Bog Brook (13T). Because tributary water quality varies with weather conditions (especially precipitation), all samples were taken on 21-Sep-98 to maintain consistency.

Total Phosphorus

Examination of the major tributaries to Great Pond helps to assess the amount of phosphorus loading from within the watershed and from neighboring water bodies. Tributary phosphorus levels vary depending on the volume of water flow at any given time. After a storm when the volume of water flow is high, tributaries carry a large quantity of phosphorus into the lake. Storm runoff accumulates phosphorus as it crosses soil, manure, roads, parking lots and various other nutrient sources. If this phosphorus is not absorbed into buffered areas, it is deposited in the lake either directly or through tributaries (see Watershed Land: Buffer Strips). When the volume of water flow in a tributary is low, the quantity of total phosphorus entering the lake is low, however the total phosphorus concentrations may be high because the water accumulates nutrients from decomposing organic matter as it sits (Firmage, pers. comm.). More total phosphorus enters the lake when flow volume is high than when flow volume is low, even though phosphorus concentrations may be higher with lower flow volumes.

Methods

Colby Environmental Assessment Team (CEAT) identified the following six Tributary Sites around Great Pond to examine: Rome Trout Brook (Site 8T), Robbins Mill Stream (Site 9T), Great Meadow Stream (Site 10T), Salmon Brook (Site 11T), the Pinkhams Cove Tributary (Site 12T), and Bog Brook (Site 13T) (Fig. 11). Water samples for phosphorus testing were collected and placed on ice until they could be chemically digested (see Water Quality Methodology). The samples were then carefully analyzed for total phosphorus, using the ascorbic acid method (see Lake Water Quality) and a Milton Roy Spectrophotometer.

Results and Discussion

CEAT found the mean concentration of total phosphorus in tributaries flowing into Great Pond to be 24.8 ± 12.8 (n=6) parts per billion (ppb). Although the concentration of

phosphorus entering the lake is higher than the critical limit, this alone is not cause for concern. Tributaries usually have higher concentrations of total phosphorus than the lakes they flow into, because their solutes and suspended particles are not yet diluted by the large volume of water in the lake. In addition, turbulence from tributary movement stirs up sediments and dirt from the tributary bottom (Firmage, pers. comm.).

Rome Trout Brook (Site 8T) has a value of 14.9 ppb (Fig. 33), which may be the result of several gravel pits and logging operations near the brook. The total phosphorus concentration of Robbins Mill Stream (Site 9T) is 26.0 ppb, and could be due to the fact that this tributary drains runoff from a large area of the watershed.

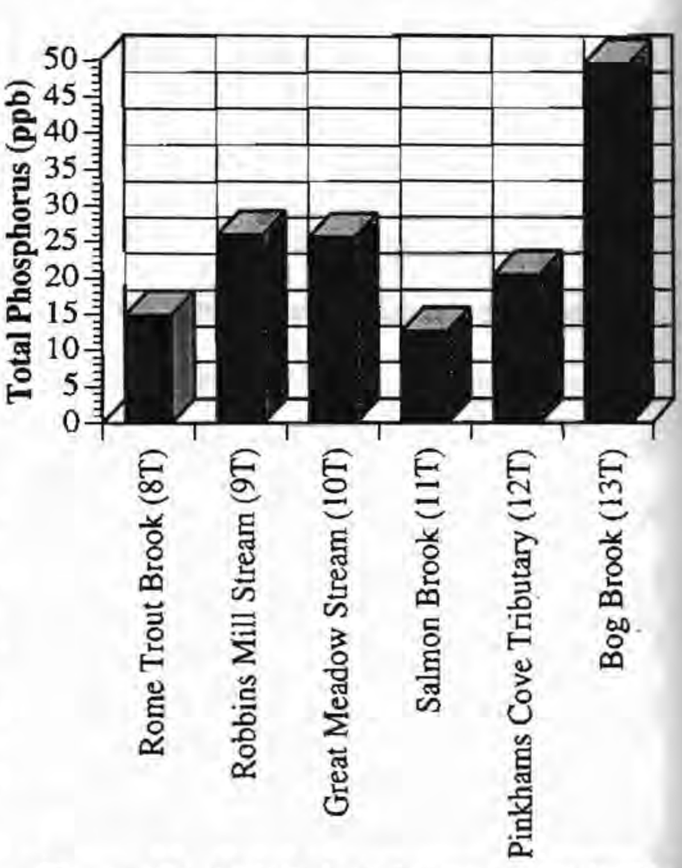

Figure 33. Total phosphorus concentration (ppb) of water entering Great Pond at selected Tributary Sites. See site map for site locations (Fig. 11).

With a value of 25.6 ppb, Great Meadow Stream (Site 10T) also has high total phosphorus concentrations. This tributary drains from North Pond, which is fed by East Pond, and both of these lakes have had high total phosphorus concentrations historically and exhibited algal blooms in the past (BI493 1991, 1997). The total phosphorus concentration value of 12.6 ppb in Salmon Brook (Site 11T) was the lowest of all the tributaries. It drains from Salmon Lake, which historically had high phosphorus concentrations with algal blooms. Clean-up efforts for point sources of pollution have

greatly improved the water quality of Salmon Lake (Nichols, Sowles, and Lobars 1984). In addition, Salmon Brook only extends for half a mile between Salmon Lake and Great Pond, which limits the area for nutrient rich runoff to accumulate.

At the tributary entering Pinkhams Cove (Site 12T), the total phosphorus concentration of 20.4 ppb could be due to the tributary's passage under several major roads. Bog Brook (Site 13T) had alarmingly high total phosphorus concentrations, with a value of 49.4 ppb. The three samples taken at this site were all high, ranging from 31.0 ppb to 68.0 ppb. Because the consistency of the total phosphorus concentrations reduces suspicion of sampling error, there must be some other explanation for the high levels of total phosphorus present. The high concentrations could be attributed to the particularly low flow rate (0.08 cfs) of Bog Brook (13T), and its proximity to Austin Bog (see Lake Characteristics: Freshwater Wetlands). Perhaps Austin Bog was releasing nutrients at the time of sampling, and because the flow rate was so low, some nutrient rich water was flowing back into Bog Brook (Site 13T).

When compared to the mean total phosphorus concentrations of tributaries entering the six other Belgrade Lakes, the mean value for Great Pond is quite high. East Pond, with a mean tributary concentration of 35.3 ppb, is the only lake in the area with a higher mean concentration of phosphorus in its tributaries than Great Pond. Although East Pond did not have severe algal blooms at the time of the study in 1991 (BI493 1991), it has since declined in water quality, and experienced a major algal bloom this past summer.

Messalonskee Lake, with a mean tributary concentration of total phosphorus of 16 ppb, Long Pond-South Basin (12 ppb), Long Pond- North Basin (10 ppb), North Pond (21 ppb), and Salmon Lake (15 ppb) all had lower mean total phosphorus concentrations in the tributaries measured than the mean for Great Pond (BI493 1991, 1993, 1994, 1996, 1997, 1998). Because tributary flow is highly variable and influenced by rainfall, snowmelt, and

other factors, and because CEAT is comparing data taken over a number of different years, no definitive conclusions about the future of Great Pond can be based on these comparisons alone. It is not promising for the future water quality of Great Pond, however, that the mean total phosphorus concentrations of the tributaries entering Great Pond are greater than any other Belgrade Lake besides East Pond. This is especially true for Great Meadow Stream (Site 10T), which is the leading single contributor of water into Great Pond. Over the summer of 1995, the Colby College Biology Department conducted total phosphorus measurements in several places, and found that the mean total phosphorus concentrations in Great Meadow Stream were 19.2 ppb (n=8).

pH

The pH of water is important in determining its ability to sustain life (see Lake Water Quality: pH). Lakes in the state of Maine are naturally slightly acidic (6.1 to 6.8 Pearsall 1991). However, the pH can be changed by industrial effluents and by atmospheric deposition of acidic compounds (Chapman 1996). The nature of the water in the tributaries of Great Pond merits investigation because of its ability to affect the overall pH of the lake as it flows into the water body.

Methods

The pH of all of the major tributaries of Great Pond was measured on 21-Sep-98. Surface pH was measured using a properly calibrated HORIBA Twin pH meter.

Results and Discussion

The pH data collected on 21-Sep-98 for all six of the tributaries to Great Pond yielded a mean value of 6.95 ± 0.30 with a pH range of 5.70 to 7.80 ($n = 6$). The lower limit of the range is the pH value for Great Meadow Stream (10T), which is the major outflow from North Pond and the major input to Great Pond. This stream has a pH that is over 100 times

more acidic than the normal pH of Maine lakes, and undoubtedly has an effect on the overall pH of the lake. This increased acidity might be caused by shoreline runoff or illegal and legal effluent dumping. It is, however, much more likely the result of the high level of vegetation and its decomposition in the stream and on its banks (Chapman 1996). This relatively low pH entering the lake puts unnatural stresses on lake flora and fauna, however, only a small portion of the lake is actually affected by this acidification. The large size of the lake serves to efficiently dilute this excess acidity and keep the rest of the lake near normal ranges (see Lake Water Quality: pH).

The rest of the streams pose little problem because their mean pH actually falls fairly close to the natural range of lakes in Maine of 6.1 to 6.8 (Pearsall 1993). This indicates that the lake is currently in no danger of becoming too acidic or basic due to the inputs of these tributaries.

WATERSHED LAND USE PATTERNS

Introduction

Lakes provide water for a multitude of uses ranging from recreation and fisheries to power generation, industry, and waste disposal (Chapman 1996). In order to preserve freshwater resources, the effects of land use patterns within the watershed must be monitored, since the surrounding lands have significant influence on water quality.

Land use patterns in the Great Pond Watershed were examined in an effort to identify sources of nutrient loading. Concern for water quality arises when land use types including cleared, residential, roads, and municipal/industrial contribute phosphorus and other nutrients to lakes. Mature forests and transitional forests posed less problems for the watershed because their extensive root systems filter out extraneous particles before runoff enters the lake. Quantifying land use patterns throughout the watershed helped determine important water quality and ecological implications for the Great Pond ecosystem. Examination of the impact of septic systems as well as zoning and town ordinances provided evidence of the level of compliance to healthy ecosystem standards in the Great Pond Watershed. Soil types and erodibility, with respect to land use, were determined using Geographic Information Systems (GIS). A phosphorus loading estimate for the watershed was determined by taking all of these factors into consideration. Understanding pollution sources related to land use for Great Pond will help in making future predictions and recommendations for this watershed.

Watershed Residential Areas Zoning

Shoreline

In 1990, the United States Census Bureau estimated that 4.5 percent of Maine residents were directly employed in the natural resources industry (US Bureau of Census 1990). This industry includes fishing, agriculture, and timber harvesting, which dominates the economy of Maine. Conservation of these resources is an investment in the future economy and

overall competitiveness of the state. Consequently, Maine has established many laws governing these natural resources and assets.

Maine has developed particularly comprehensive regulations governing state water quality. These regulations aim to protect the economic productivity, recreational, and aesthetic values of Maine's lakes, rivers, streams, and coastal regions. Aside from maintaining safe and healthy lake conditions, the ordinances prevent or control water pollution, protect critical wildlife habitats (including fisheries), and maintain areas of cultural significance (MDEP 1994b). These regulations are not all inclusive, but they are an integral component in assuring good water quality for present and future generations.

Water quality in the Great Pond Watershed is currently governed by the following four principle ordinances: Erosion and Sedimentation Control and Storm Water Management Statute, Sub-Surface Waste-Water Disposal Act, Natural Resources Protection Act, and the State of Maine Guidelines for Municipal Shoreland Zoning. Each ordinance is approved and partially enforced by the Maine Department of Environmental Protection (MDEP). Non-compliance is monitored by local municipalities but sanctions are levied by state courts per MDEP recommendation (Baker, pers. comm.). Local governments also have the jurisdiction to make these regulations more, but not less, stringent than state regulations.

<u>The Erosion and Sedimentation Control and Storm Water Management Statute</u> (1997) functions to limit nutrification and sedimentation of Maine lakes by holding individual communities accountable for addressing their own erosion problems (Hahnel, pers. comm.). As previously mentioned, increased sedimentation and nutrient loading may result in an accelerated rate of eutrophication and algal blooms in the lake. Eutrophication could have profoundly deleterious effects upon fisheries and lake aesthetics and result in decreased property values and recreational use (Belgrade 1998).

<u>The Erosion and Sedimentation Control Act</u> (1997) requires commercial and residential developers to minimize sedimentation and runoff. While specific abatement measures are not outlined in the act, developers are still required to integrate erosion control methods such as rip-rap, hay-bale barriers, buffer strips, bio-degradable silt fencing, and water diversions into development and construction plans (MDEP 1997a). Ultimately, the specific abatement measure selected is determined by the developer.

The Sub-Surface Waste Water Disposal Act (1974) also addresses lake nutrification by regulating municipal septic disposal. Poor or inadequate septic systems have the potential to contaminate the lake with bacteria and other micro-organisms. In addition, poorly designed systems can also contribute phosphorus, the primary nutrient responsible for promoting algal blooms (see Lake Water Quality: Total Phosphorus).

The enforcement of this regulation is especially important in communities like Belgrade. Most of Belgrade is underlain by sensitive soils with severe limitations for sub-surface waste disposal systems (Belgrade 1998). Despite soil constraints, Belgrade is almost entirely dependent upon sub-surface waste water disposal systems (Belgrade 1998).

In addition to regulating actual containment and disposal of septic waste, the act also mandates necessary septic system changes when converting a house from seasonal to year-round usage. This is accomplished by requiring home owners to obtain a Seasonal Conversion Permit from the Local Plumbing Inspector (LPI) before conversion. In accordance with state law, the LPI and the Code Enforcement Officer (CEO) are responsible for ensuring the proper design, installation and future maintenance of converted septic systems. This component of the act is important because year-round houses contribute more phosphorus to the lake with heightened usage and disposal needs than seasonal residences (MDHS 1988).

The Natural Resources Protection Act (1997) recognizes the scenic, recreational, cultural, historical, and environmental value of the rivers, streams, ponds and wetland areas of the state. The act requires a permit for any activities that would involve: dredging, bulldozing, removing or displacing of soil, sand, vegetation, and other materials, draining or dewatering, construction, repair, or alteration of any permanent structures such as boat moors, retaining walls, causeways, and buildings (MDEP 1997b).

The act also creates a funding mechanism to maintain lake water quality. Known as the Lake Restoration and Protection Fund, the fund may be used to pay 50 percent to 100 percent of the costs associated with lake restoration and protection. Expenses covered by the fund include educational/research efforts and technical assistance with large-scale waterfront development projects.

Under the act, great ponds or "inland bodies of water in excess of ten acres" may be

eligible for this funding (MDEP 1997b). Consequently, Great Pond, which is in excess of 8000 acres (MDEP 1994a), maybe eligible for a restoration grant. This grant could be used to implement management strategies recommended in this report. Unfortunately, the specific application procedure for this grant is not outlined in the Natural Resources Protection Act. Further information can be obtained by contacting a local MDEP office. The closest MDEP office in the Belgrade Lakes Region is in Augusta. This office is open normal business hours, Monday through Friday.

The final and most comprehensive regulation applicable to Great Pond water quality is the State of Maine Guidelines for Municipal Shoreland Zoning (1994). This ordinance is a compilation of the four previous regulations. These regulations encompass lot size, frontage, vegetation clearing, residential and commercial building construction or expansion, installation of septic systems, erosion, and road or driveway construction in shoreland areas. Shoreland zoning applies "to all land areas which are within 250 ft, horizontal distance, of the normal high-water line of any great pond, river, freshwater wetland or within 75 ft of a stream". (Belgrade 1998).

The Shoreland Zoning Ordinance mandates that all new houses must be situated at least 100 horizontal ft from the high-water line of a great pond (as defined in the Natural Resources Protection Act) or from a river that flows into a great pond, and 75 ft from the normal high-water line of a stream. Minimum lot area for all residential, recreational, and public shoreland property is 40,000 ft^2 (approximately one acre), whereas commercial facilities have a minimum lot area of 60,000 ft^2 (MDEP 1994b).

In addition, minimum uninterrupted lot frontage for residential and recreational buildings is 150 ft in Mercer, Rome and Smithfield and 200 ft in Belgrade. The 150 ft stipulation is a state guideline whereas the 200 ft limit is unique to Belgrade. Commercial properties are required to have 300 ft of uninterrupted shoreline frontage. These regulations help to ensure adequate separation of water supplies and sub-surface waste disposal systems (MDEP 1994b).

Nutrient loading is further minimized by shoreline ordinances which regulate vegetation clearing. Specifically, shoreland ordinances state that ground cover and vegetation less than three feet tall should be removed only for the creation of footpaths.

Footpaths should not exceed 25 percent (20 percent in Belgrade) or 10,000 ft^2 (state and Belgrade regulations) of the total lot area. In addition, no vegetation should be cut in the strip of land extending 75 ft (horizontal distance) from the high-water line, except to remove safety hazards. The ordinance essentially mandates that all shoreline residences have a buffer strip. Ideally, this buffer strip would be greater than 75 ft in width and composed of a mixture of native trees and shrubs (see Land Use: Shoreline Buffer Strips). Well maintained buffer strips may decrease phosphorus loading by slowing runoff and aiding in the absorption of sediments and nutrients. A decrease in buffer strip quality or quantity increases the possibility of cultural eutrophication.

Eutrophication is also accelerated when cleared land is paved for roads and driveways (MDEP 1994b). Roads and driveways can be direct point sources of phosphorus loading if runoff flows directly into the lake. Consequently, all shoreland roads or driveways must be designed in such a way as to drain into a buffer strip. The Shoreland Act requires that roads and driveways should be set back a minimum of 100 ft from the highwater line of the lake and 75 ft from wetlands, rivers, and tributaries (MDEP 1994b).

Overall, the Shoreland Zoning Act strives to mitigate lake nutrification by regulating point and non-point sources of phosphorus resulting from shoreline development. The act also governs water quality by prohibiting the construction of auto washing facilities, chemical, bacteriological and photographic labs, chemical or petroleum storage plants, commercial wood painting, stripping and preserving plants, dry cleaning and laundromat facilities, electronic circuit assembly plants, metal plating and finishing plants or printing plants in the shoreline zone (MDEP 1994b).

Although commercial regulations are inflexible, exemptions may be granted for residential structures. Non–conforming structures or buildings erected prior to 1-Jan-70, are "grandfathered" from all zoning regulations except with regard to expansion. This exemption was created because houses existing before the law was created in 1974 cannot be bound by the Shoreland Zoning Ordinance (Baker, pers. comm.). Expansion of "grandfathered structures" must occur in compliance with the same regulations imposed upon conforming structures. In addition, expansion of "grandfathered structures" can not exceed 30 percent of the total floor area or volume (MDEP 1994b).

As was the case with the Erosion and Sedimentation Act, compliance is enforced by the local code enforcement officer. Consistent enforcement of these regulations is necessary to maintain lake water quality. Although rarely utilized, Code Enforcement Officers and the MDEP have the authority to levy fines and take legal action against those violating shoreland ordinances.

A potential caveat for code enforcement officers is the creation of a new 30 percent ruling. This amendment of the Shoreland Zoning Act gives code enforcement officers (CEO) the ability to enable residential expansion within the 100 ft restricted zone while also placing deed specific regulations on buffer strips and rip-rap. If a CEO permits additional expansion, the CEO would also have the authority to stipulate buffer strip or rip-rap installation. Installation of new buffer strips or rip-rap would have to meet MDEP standards. These changes would be permanent as the stipulation is added to the property deed. If the house is sold, the new owners would be required to uphold the buffer strip or rip-rap stipulation.

Unlike the old zoning ordinance, the new ordinance only considers total floor area and building height rather than total volume. This change should facilitate record keeping in that new code enforcement officers only need to look at the total floor area to determine if a house can be expanded or not. Total area can not exceed 1200 sq ft. Previously, poor records often resulted in homeowners augmenting their houses by 30.0 percent and then being able to repeat this process later (even though this is prohibited under the Shoreline Zoning Ordinance). Although this mechanism has yet to be adopted by any town in the Belgrade Lakes Region, it could be a very good way to protect lake water quality in the future.

Septic Systems

Residential

Methods

Several methods were used to collect data on septic systems in Belgrade, Rome, and Smithfield. Mercer had no residences in the watershed. Shoreline and non-shoreline

residences were considered, as well as non-residential buildings and summer camps. Plumbing inspectors were interviewed to provide general information on the overall quality of septic systems in each town. This included comment on common problems, recent improvements or changes in regulations, relative age of septic systems, standards for design and assessment, and the permitting process.

The number of shoreline lots for each town was obtained by examining municipal tax maps. Random property card surveys were then conducted for approximately 30 percent (n= 130) of the shoreline map-lots in Belgrade and Rome. Smithfield had no shoreline lots. Feet of frontage, percent composition of septic systems, utilities, and lot acreage were recorded for each property surveyed. The percentage of shoreline residences with septic systems was then estimated using the property card survey data. Properties were also categorized by percent composition of septic systems. Percent composition is an index of how well a property is conforming to specifications for septic systems. Though data was not available for percent composition for all towns in the Great Pond Watershed, Belgrade did have percentages recorded. These were used as an indicator of overall quality of septic systems in Belgrade. Data on the quality of residential and non-residential septic systems in the watershed were used in the phosphorus-loading model to project phosphorus loading caused by septic systems.

Results and Discussion

Interviews with Plumbing Inspectors

All the plumbing inspectors interviewed were optimistic about the conditions of septic systems in Belgrade, Rome, and Smithfield. High rates of replacement, restrictions on shoreline septic systems, and improvements in system design and construction have contributed to the overall quality of subsurface disposal systems in the Great Pond Watershed.

According to Bob Martin, the Plumbing Inspector in Belgrade, two large conversions have taken place on Great Pond in the last 10 to 15 years. The first is conversion from American style camps to European Style camps. American style camps are characterized by

central dining facilities with bathrooms and cabins around them. European style camps are self-contained units with separate cooking and bath facilities (Martin, pers. comm.). The renovations required to accomplish this have resulted in substantial improvements in the septic systems of these camps. Hoyt Island Camps now have new septic systems with at least one septic tank and a plastic infiltration system set back from the lake. Abenakis Fishing Camps are no longer functioning, but the cabins have been replaced by condominiums with new septic systems (Martin, pers. comm.).

The second major transition taking place on Great Pond is the conversion of seasonal camps to year-round residences. In the past, the laws regulating seasonal conversions required only that a design for a new system with year-round capacity be filed with the deed to the property. The system did not need to be installed until or unless the old one failed. The law now requires that a year-round system be installed before a permit is issued for year-round use (Martin, pers. comm.). In Rome, a design for a year-round system must be filed when a property is sold (Buzzell, pers. comm.).

A seasonal conversion can be a switch from a pit privy to a septic system, or the upgrade of an existing system to handle year-round capacities. A permit from the MDEP is required for seasonal conversion. The system must be greater than 250 ft from shore or in an accepted zoning area. Seasonal conversion permits may be denied if the septic suitability of the soil is poor (see Development Implications of Land Characteristics: Septic Suitability) and the property is not grandfathered. A property is grandfathered if people were already living year-round in the structure when the law was passed. Septic systems can be updated with the use of holding tanks but this is generally a last resort. In Belgrade, most of the septic systems installed as part of seasonal conversions before the new mandates have been replaced. Only a few of the old septic systems remain because they have not yet malfunctioned. They are not considered major contributors to phosphorus loading (Martin, pers. comm.). Dale Buzzell (Rome) and Mike Zarcone (Smithfield) agree that most seasonal conversions were conducted according to regulations with little or no decrease in the overall quality of septic systems in Rome and Smithfield.

One of the areas most affected by seasonal conversions is Pinkhams Cove, in the southeast corner of Great Pond. Several factors make this area of Great Pond a potential

trouble spot. The south end of Pinkhams Cove was originally a peat bog, filled with gravel to allow development. Consequently, these areas have low to very low septic suitability (see Development Implications of Land Characteristics: Septic Suitability). Old systems in Pinkhams Cove pose a threat to water quality not only because of poor soil suitability, but also because early designs of septic system components were more likely to leak. In recent years, neighborhood surveying has identified problems with septic systems on many individual properties. In these cases, the Plumbing Inspector was notified and the system required replacement (Martin, pers. comm.). In Pinkhams Cove, however, the soil does not meet the requirements of current regulations and two options exist: a holding tank can be installed with appropriate capacities or the system can be moved and upgraded.

Four camps in Pinkhams Cove connected to a collector system have had to install new septic systems because of poor soils. Septic tanks for these systems were installed with pumping stations to transport waste to better soils for disposal areas. In some cases, such as Pinkhams Cove, exceptions to the Plumbing Code can be made if a residence remains seasonal, or with only a grey water system (Martin, pers. comm.).

The seasonal switch is becoming less of a concern for water quality because of high replacement rates in the last decade and because of recent changes in the plumbing code. All new systems under the present code are now designed for year-round capacities (minimum two bedrooms for residential units, though soils and leach beds may not be acceptable for year-round use). The critical focus of the present code is still on septic systems within 250 ft of the shoreline. Soil regulations have been relaxed slightly for non-shoreline septic systems, but not for shoreline systems (Martin, pers. comm.).

High replacement rates indicate that the condition of septic systems on Great Pond is improving. The most common systems used for replacements are septic tanks with one of three disposal areas: infiltration systems with plastic chambers, concrete chambers, or stone leach beds (Martin, pers. comm., Buzzell, pers. comm., Zarcone, pers. comm.). No holding tanks are currently used in Rome (Buzzell, pers. comm.). They are used as last resort in Belgrade and Smithfield (Zarcone, pers. comm., Martin, pers. comm.).

New septic systems pose less of a threat to Great Pond water quality due to better site design and component construction. The State Plumbing Code for new systems requires a

100 ft setback from the shoreline for all parts of the system. New systems often include monolithic tanks. Monolithic tanks are one piece and have no top or bottom sections (most existing tanks have two parts which are then sealed for water tightness). These tanks are more water tight and less likely to leak and contaminate (Martin, pers. comm.).

Two sources of financial aid exist for property owners wishing to replace old or substandard systems. Grant money is available from the Maine Department of Environmental Protection (MDEP) for low-income households (Zarcone, pers. comm.). Qualified applicants submit information to the Code Enforcement Officer of the town, who then submits the application to the state (Buzzell, pers. comm.). Rome recently applied for and received grant money from the MDEP for the replacement of a septic system. Belgrade and Smithfield have not participated in the program in recent years. The other source of aid for property owners is through the Kennebec Valley Action Program (KVAP). KVAP has a program that provides low interest loans to replace septic systems. It is open to all qualified applicants (Martin, pers. comm.)

Design capacities for systems are based on the number of bedrooms in the household, and a permit is required for the installation of any subsurface wastewater disposal system. Mike Zarcone suggested that the most common problem with septic systems is the annihilation of bacteria in the septic tank by grease from kitchen sinks and washing machines. This prevents the breakdown of solid material and allows untreated material to flow into the leach field and clog the soil. This condition increases the risk of soil and water contamination. If a malfunction in the system occurs, it must be replaced within a specified time (Zarcone, pers. comm.).

Soil engineers are responsible for designing each septic system for review by the Plumbing Inspector in each town. They set guidelines for monitoring schedules and tank capacities (Zarcone, pers. comm.). The Plumbing Inspector ensures the plans are in compliance with codes and looks for inconsistencies within the plan. Basic permitting fees are set by the state, and each town can decide to raise the fee. Twenty-five percent of the fee is given to the state, and the town retains 75 percent (Martin, pers. comm.). Plumbing Inspectors do not regularly inspect existing systems unless requested by individual property owners, or unless an obvious problem comes to the attention of the inspectors, usually by a

neighborhood complaint (Zarcone, pers. comm.).

Property Card Surveys

Eighty-six percent of the shoreline properties surveyed in Belgrade had septic systems (n=130). Of the properties with septic systems, 44 percent were in full compliance with suggested standards for septic systems. Eight percent were between 75 and 100 percent in compliance. Forty-four percent of the properties were within 50 to 75 percent in compliance. Only four percent of the properties were less than 50 percent in compliance. There was no apparent concentration of poor septic systems in any given area. Septic systems in the Pinkhams Cove area appear older than in other areas of Great Pond (Bouchard, pers. comm.) and might be a cause for concern. No dates were listed for the installation or upgrade of any of the systems on the property cards to confirm or refute this. Pinkhams Cove does, however, have low septic suitability and warrants special consideration (Martin, pers. comm).

In addition to septic systems, Lake Water and Drilled Wells were the major utilities listed on the property cards for Belgrade. Proper subsurface disposal is critical on properties with water supplies from or close to the lake. Household water supplies on these properties are drawn from the areas most vulnerable to contamination by septic systems. The same utilities were common in Rome. Seventy-six percent of the shoreline properties surveyed (n=79) had septic systems, but no data was available for the percentage of septic systems in complete or partial compliance.

Many of the property cards in both Belgrade and Rome listed two or more houses for each map lot. While the acreage of some lots may be sufficient to support the area required for leach fields, it is possible that smaller lots with more than one house are stretching the capacity of the land available for leach fields and soil infiltration. Smaller properties reduce area that can be used for soil infiltration, increasing the potential for contamination of the lake. Small lots with more than one house exaggerate this problem.

Youth Camps

Methods

Youth camps were defined as seasonal buildings occupied by a limited number of participants and staff for a specified portion of the year. Youth camps were primarily for children providing a range of outdoor activities using both shoreline and non-shoreline areas. The names of youth camps were listed on the tax maps and recorded on buffer strip and road surveys. Some of the youth camps were also identified through phone book searches and communication with town offices. Town officials and web sites provided names of contact people for each camp. The following information was obtained from these individuals: season length, number of campers, number of counselors and support staff, and number and age of bathrooms and septic systems. Non-residential buildings were recorded on Detailed and Non-detailed road surveys, then categorized by expected septic capacities and intensity of use. The data was then used in the phosphorus loading model.

Results and Discussion

Three youth camps and one campground were identified in the Great Pond Watershed. Camp Runoia is located at the southern end of Great Pond on Wentworth Point in Belgrade (85 acres). Approximately 100 people are in residence from the middle of June to the middle of August. Camp Runoia is a youth camp for girls, and activities include canoeing, swimming, kayaking, and sailing along its one mile of shoreline. Eleven septic systems are in use during the season. All were installed after 1974 and receive regular maintenance each fall (Cobb, pers. comm.).

Pine Island Camp, a youth camp for boys is located on Pine Island. Its season runs from 26-Jun to 9-Aug (Swan, pers. comm.). The 85 campers and 22 staff live in tents with no utilities. Not all campers and staff remain on the island for the entire seven-week season. Over 40 trips leave the island for three days to one week. Ben Swan, the camp director, estimates that on average, 80 people are present on the island each day of the season (Swan, pers. comm.). Only the kitchen on the island is equipped with running water, and its greywater waste is treated in a leach field. At present, two types of toilets exist on the island:

summer camps minimal.

Land Use

Land Use Methodology

Land use trends in the Great Pond Watershed were determined by analyzing aerial photographs of the watershed from 1965/66 and 1998. The 1965/66 set of aerial photographs was obtained from the United States Department of Agriculture High Altitude Photography Program. The 1998 aerial photographs were acquired from the James W. Sewall Co. in Old Town, Maine. The data from 1965/66 spanned two years because the entire watershed was not photographed in 1965. The photographs from 1965/66 were in black and white and taken at a scale of 1:20,000. The photographs from 1998 were in color and taken at a scale of 1:15,000. Other pictorial representations of the watershed including 7.5 minute topographic maps from 1980 and 1975 (Norridgewock Quadrangle), a 15 minute culture and drainage map from 1965 (Norridgewock Quadrangle), a 7.5 minute culture and drainage map from 1982 (Rome Quadrangle), infrared photographs from 1985, and current township maps were obtained from the Colby College Biology and Geology Departments. Infrared photographs aided in the identification of wetlands by identifying them as brown-colored areas. New tax maps for 1998 were acquired from the town offices of Belgrade, Mercer, Smithfield, and Rome. The tax maps aided in distinguishing between shoreline and non-shoreline residences.

The aerial photographs were covered with mylar. In this way, markers could be used to delineate land use boundaries on the photographs without damaging the images. In order to gain a complete view of the watershed, the photographs were assembled into a mosaic. One mosaic was assembled for each set of photographs. A small portion of the watershed was not photographed in 1998. For this area, which was composed exclusively of the northwest portion of the watershed, black and white aerial photographs from 1991 were used. The watershed boundary was transferred onto both mosaics by using an overhead projector and a transparency. The transparency depicted the lake boundary, surrounding town lines and watershed boundaries. This transparency was based on a topographic map from 1980 that included the watershed boundaries as determined by MDEP. Tracing the watershed

boundary was accomplished by matching the lake boundary from the transparency with the lake boundary on the photograph mosaics. The transparency also showed the division of the mosaics into four quadrants (Fig. 34). The quadrants served to facilitate comparisons within the watershed during the data analysis portion of the study. These quadrants were transferred to both mosaics with the watershed boundaries.

All the land area included within the watershed boundary on both mosaics was identified as one of seven land use types: wetlands, mature forest, transitional forest, logged land, cropped land, grazed land, industrial/municipal land, roads and residential land. The land use types for 1998 are shown in Figure 35. For final analysis and comparison to the other watersheds in the Belgrade Lakes Region, some land types were grouped together. Logged land was included with transitional land. Developed land was a new category formed that combined residential land and municipal/industrial land. Cleared land combined cropped and grazed land. Identification was completed with the use of stereoscopes, illuminated desk magnifiers, field reconnaissance, and topographic maps. A plane flight on 03-Oct-98 was used to check land areas that were difficult to identify on the aerial photographs. Once identified, the areas were outlined with a colored, fine tip, transparency marker in order to facilitate area measurement.

The photographs were calibrated by measuring a distance in the field selected from the aerial photographs. This distance was straight, relatively flat, and easily visible on the aerial photographs. A total of seven calibration distances were taken. Calibration distances were the same for the 1965/66 and 1998 photographs.

Land area was calculated with the use of a digitizing pad and a data analysis program created by computer specialist, John Kuehn. The calibration distances, as measured in the field, for each photograph were entered into the digitizing program. The corresponding distance on the photograph was measured with the digitizer, thereby calibrating the distance measured in the field with the same distance on the aerial photographs. The procedure was conducted multiple times until a standard below eight km was achieved. A standard deviation of eight km was chosen since it was relatively small compared to the total watershed area and it seemed to be the lowest achievable.

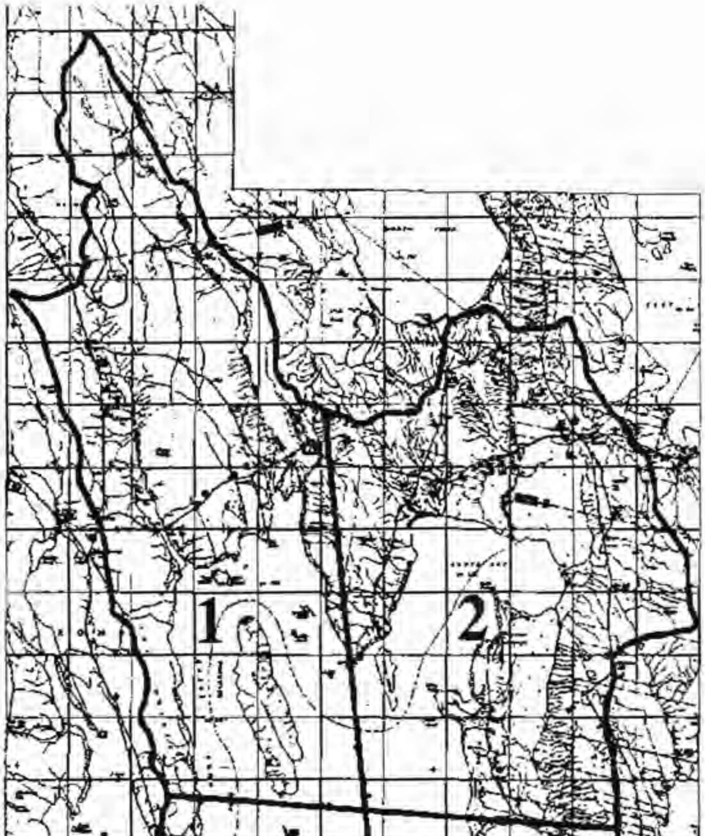

Figure 34 Map of the Great Pond Watershed divided into four quadrants used for land use analysis. Approx. scale: 1 inch = 1 mile.

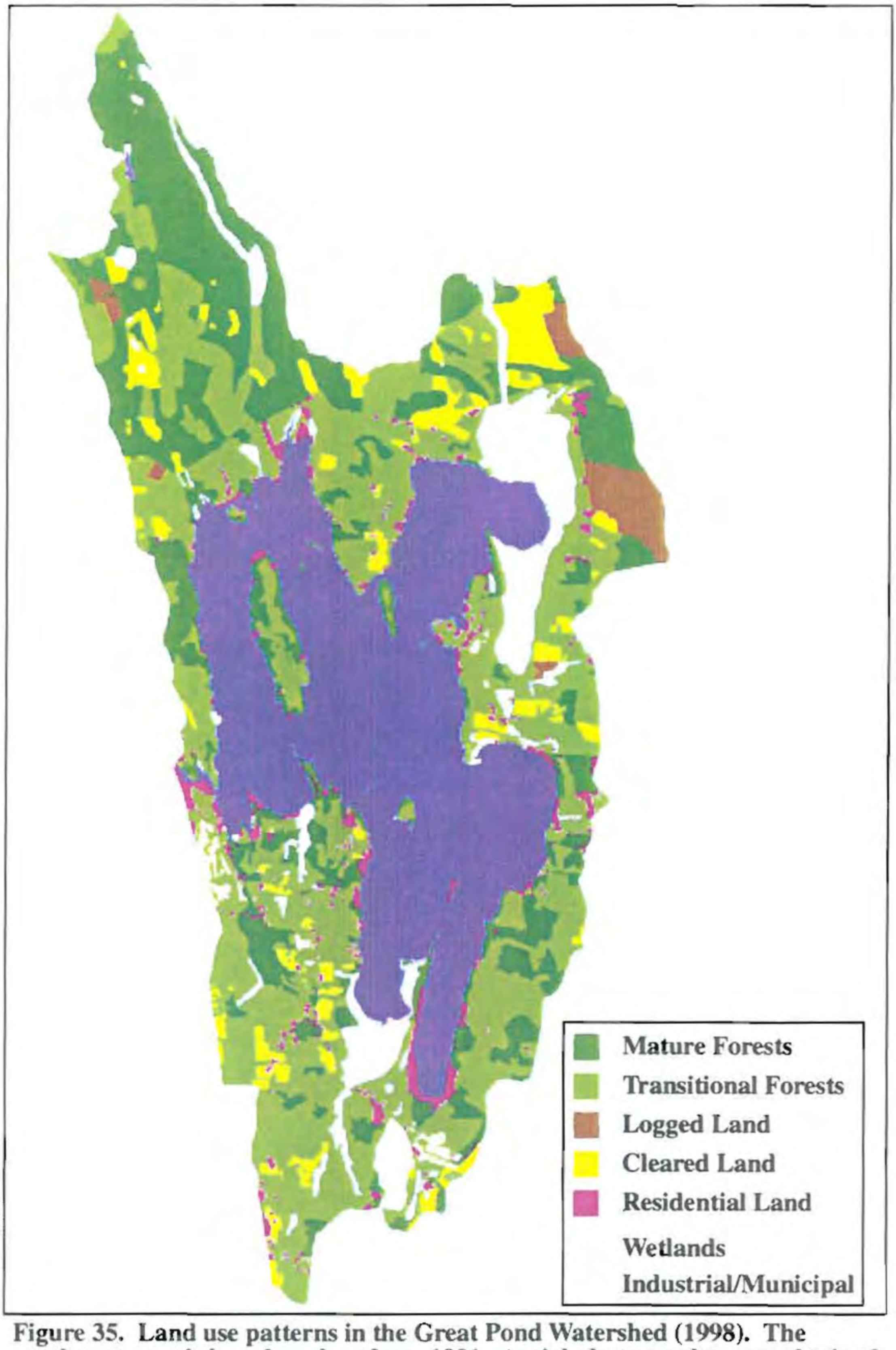

Figure 35. Land use patterns in the Great Pond Watershed (1998). The northwest area is based on data from 1991. Aerial photographs were obtained from James W. Sewall Company. Approximate scale: 1 inch = 1.5 miles.

Each land area for 1965/66 and 1998 were measured using the digitizing pad. After the program was properly calibrated for scale, the digitizer mouse was traced along the perimeter of each area. For both sets of aerial photographs, all land within the watershed was measured and totals were calculated in km^2. Total areas for the land use types were also calculated for each quadrant. Total land use areas for 1998 were used by the GIS team to create the land use map for the Great Pond Watershed.

Road and residential areas were not calculated with the use of the digitizing program. Residential area was calculated by multiplying the total number of houses (shoreline and non-shoreline) by a standard lot size derived empirically by the MDEP. A different lot size was for each category. The number of shoreline homes was multiplied by 0.5 acres. The number of nonshoreline homes was multiplied by 1.0 acres. The total number of shoreline and nonshoreline residences was determined for 1965/66 by counting houses marked on the culture and drainage map of the Norridgewock Quadrangle from 1965. The total number of shoreline and non-shoreline houses in 1998 was supplied by the watershed survey. These totals were acquired by on site surveys (see Land Use: Residential Land).

The total road area for 1998 was calculated by multiplying the total distance of roads in the watershed by the average road width of 12 ft. These figures were determined by field reconnaissance (see Land Use: Roads). The road area for 1965/66 was calculated by setting up a proportion between total residential area in 1998 and road area in 1998. This proportion is based on the assumption that residential area and road area are directly related, since an increase in residential area is usually paired with an increase in roads. The residential area for 1965/66, calculated by the method stated above, was multiplied by this proportion. The resulting number was the total road area in 1965/66.

Total watershed, total drainage area, total lake area and town area for the watershed were determined using a culture and drainage map (scale = 1:24,000) of the watershed obtained from USGS. This map was calibrated in a similar fashion to the methodology as for the aerial photographs. The results from this culture and drainage map served as comparison with the results calculated from the aerial photographs.

Industrial Land

Municipal and industrial land was identified as open areas of earth, such as gravel pits, or large municipal buildings, such as schools, town highway departments, and other non-residential buildings. Municipal parking lots and a golf course were also included. The gravel pits appeared on the aerial photos as gray areas with defined boundaries and evidence of excavation. The municipal buildings appeared as large structures. Field spot checks as well as topographic and town maps were used to further categorize the municipal areas. Furthermore, during an aerial reconnaissance over the watershed, gravel pits and municipal buildings were identified and recorded.

Results and Discussion

The results from the 1965/66 photos indicate that 75 acres were used as industrial and municipal land. Results from 1998 indicate that the industrial and municipal land had increased to 284 acres (Fig. 36). The greatest increase occurred in Quadrant 4 and included

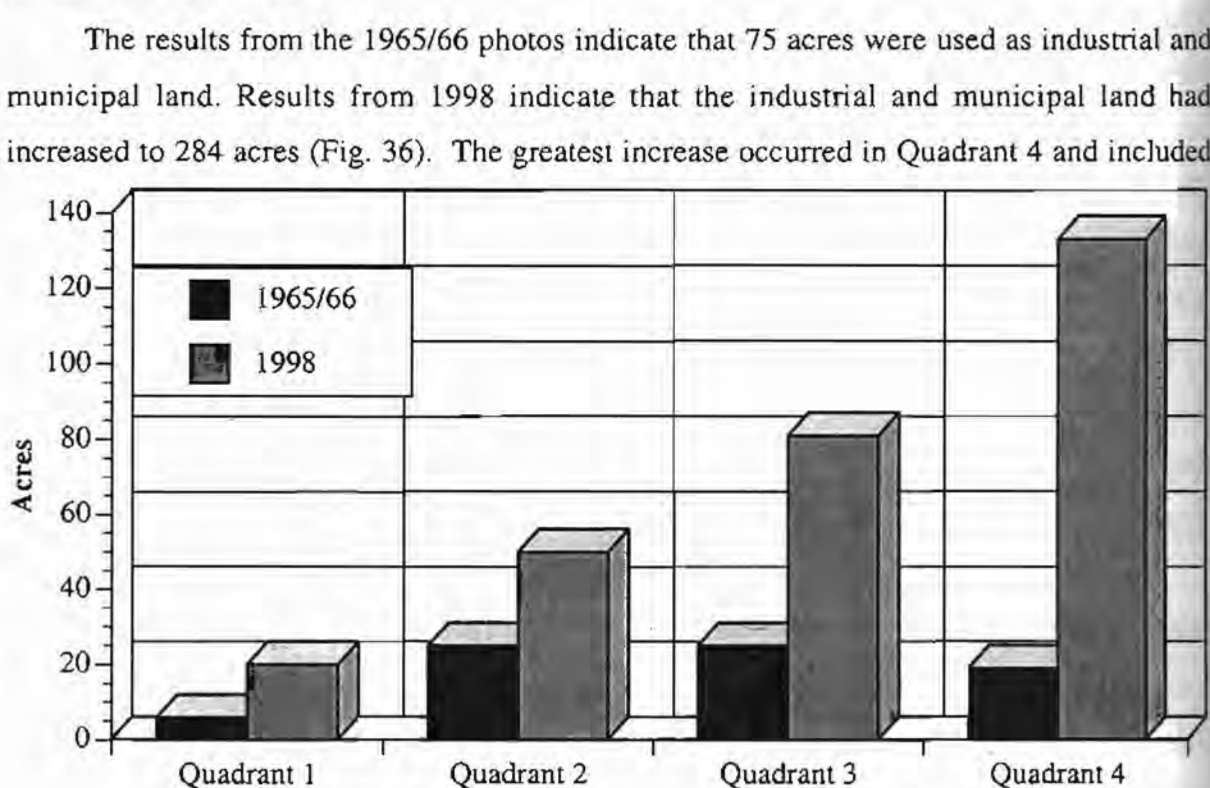

Figure 36. The number of acres of Industrial and Municipal land in each of the quadrants in the Great Pond Watershed for the years 1965/66 and 1998. 1991 photos supplemented 1998 photos in the northernmost tip of the watershed.

the development of new gravel pits and a new golf course. This increase in municipal and

industrial land corresponds with growing residential development in the Great Pond Watershed. Gravel pits can have a significant impact on water quality since these open excavations expose a large amount of sediment to runoff. The new golf course could also have a great impact on nutrient loading in the Great Pond Watershed. The course is in close proximity to Great Pond and the amount of fertilizers and herbicides used could have a harmful effect on the lake.

The non-residential buildings were mostly small businesses, particularly along Rt 27 in Belgrade and Rt 225 in Smithfield and Rome. Churches and community facilities comprised the next largest group of non-residential buildings. Vehicle services and storage areas along Rt 27 were also common, as well as construction companies, contractors, a shopping plaza and other facilities.

Cleared Land

Cleared land in the Great Pond Watershed was divided into two subcategories: cropped land and grazed land. Cropped land was distinguished as cleared fields with visible crop rows. Grazed land was classified as grassy areas fenced off as feeding grounds for livestock. Non-fenced pasture land was identified as large grassy areas with no visible crop rows. On 2-Oct-98, aerial reconnaissance of the watershed facilitated the identification of cleared land that was indistinguishable on the aerial photographs.

Results and Discussion

Changes in the location and type of cleared land provide evidence for land use patterns over time. The area of cleared land in the Great Pond Watershed significantly decreased from 1965/66 to 1998. Cleared land made up 11.0 percent of the total watershed area in 1965/66 and 7.7 percent in 1998, with cropped land being the predominant form of cleared land since 1965. The total area of cropped land decreased by 18.0 percent and the total area of grazed land decreased by 62.0 percent. Clearly, loss of both cropped and grazed land have contributed to the decreasing trend in cleared land over time.

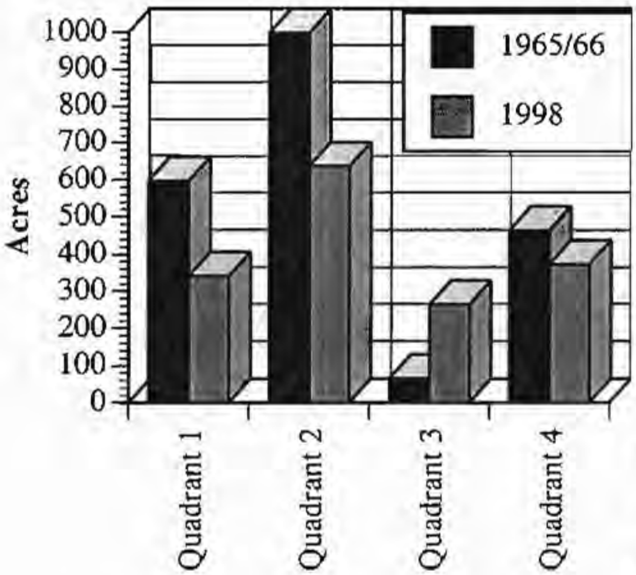

Figure 37. Total number of acres of cleared land in each of the quadrants in the Great Pond Watershed for the years 1965/66 and 1998 with 1991 photos supplementing 1998 photos in the north west tip of the watershed.

The total amount of cleared land was calculated within each quadrant of the Great Pond Watershed (Fig. 37). Quadrant 2 demonstrated the most significant change in cleared land, decreasing from 1,087 acres in 1965/66 to 637 acres in 1998. Quadrant 4 experienced the least amount of change in cleared land, decreasing from 301 acres in 1965/66 to 284 acres in 1998. The total amount of cropped and grazed land decreased 37.6 percent from 1965/66 to 1998. In 1965/66, cleared land comprised 2215 acres, decreasing to 1,372 acres by 1998. These data suggest a 38.1 percent decrease in the total area of land used for agriculture over the past 32 years.

Aerial photographs from 1965/66 and 1998 were compared to determine the fate of cleared land in the Great Pond Watershed. Changes in the area of cleared land were calculated for each quadrant. Quadrant 2 demonstrated the largest decrease in area of cleared land. Comparisons of aerial photographs from 1965/66 and 1998 suggest that a large amount of cleared land in Quadrant 2 was converted into transitional land and a smaller portion into industrial/municipal land. Transitional land results when cleared land is no longer used for agricultural purposes, allowing old fields return to forested land through succession. Aerial photographs of Quadrant 1 show a decrease in cleared land due to an increase in transitional land as well as the addition of two new gravel pits. Quadrant 4 demonstrated the smallest decrease in area of cleared land. From Aerial photographs, CEAT attributes this decrease mainly to the golf course constructed in Quadrant 4. Cleared land in Quadrant 3 was converted to industrial/municipal land to accommodate the increasing size of the Pine Grove Cemetery. The development of roads and residential areas could have contributed to the

decreasing trend of cleared land; however, this assumption could not be confirmed using aerial photographs.

Although the amount of cleared land is decreasing, the preservation of water quality remains threatened. Results suggest that cleared land has been converted to other types of land use, such as residential, roads, and municipal/industrial purposes. Unfortunately, these alternative land use types also contribute phosphorus to the lake, potentially decreasing the water quality of Great Pond through cultural eutrophication.

Logged Land

Land areas were classified as logged land using several characteristics. Logged land contained cleared patches of forest with skidder trails, loading areas, logging roads, and areas of selective harvesting. Selective harvesting areas were classified as fragmented or small patches of forest which had skidder trails and loading areas throughout. Further evidence of logging operations included a row of clear definition, such as a property line, between the area of harvest and the surrounding forest.

Results and Discussion

The results from 1965/66 indicated there was no evident large scale logging in the Great Pond Watershed. In contrast, the results from the 1998 photos indicate that 527 acres of land were logged. The area of logged land is restricted to Quadrant 1 and Quadrant 2, which are located in the northern half of the Great Pond Watershed. Quadrant 1 has 69 acres of logged land and Quadrant 2 has 458 acres of logged land. Most of the logged land in Quadrant 2 is located in the northeastern portion of the quadrant. This increase from 1965/66 illustrates the continuing trend of development in the Great Pond Watershed.

Logging can have a detrimental effect on water quality if sediment-laden runoff is allowed to flow directly into streams and lakes. However, the logged land in Quadrant 1 does not contain any major streams and is not close to Great Pond. The area of logged land in Quadrant 2 is closer to Great Pond, but a wide strip of mature forest and a wide strip of wetlands, which help absorb nutrient laden runoff by acting as a buffer zone, are located between this logged land and the lake.

Transitional Land

Transitional forest is defined as land that was at one time cleared or logged and then left alone to undergo succession to mature forest. In past years, both regenerating land and reverting land were examined as two different land use types. This year, however, they were combined to create the transitional forest category. Transitional forest is characterized in aerial photographs as a mixture of bushes and young and old trees, creating a patchy and uneven canopy. Transitional forests have a positive impact on water quality, by acting as buffers for other land use types such as roads, cleared land, and industrial land. The bushes and trees reduce erosion and slow down runoff, allowing sediments and nutrients to be absorbed before it enters the lake (BI493 1998).

Results and Discussion

In 1965/66, transitional forest comprised 33.3 percent (6,857 acres) of the total land area in the Great Pond Watershed. Of this area, 31.8 percent was found in Quadrant 1, 19.0 percent in Quadrant 2, 16.1 percent in Quadrant 3, and 34.1 percent in Quadrant 4. From 1965/66 to 1998, the total amount of transitional forest in the Great Pond Watershed increased by 2,011 acres to a new total of 8,868 acres. Transitional forest now comprises 42.5 percent of the land in the watershed (Fig. 38). The amount of transitional forest increased in Quadrants 1, 2, and 4. Quadrant 3 had a decrease in transitional forest, from 1,114 acres in 1965/66 to 134 acres in 1998. This occurred because of the large amount of development, especially for municipal and industrial purposes, in this part of the watershed.

The increase in transitional forest is the result of two major factors. First, there was a decrease in land used for agriculture and grazing. Land left fallow underwent succession. Bushes and trees overtook the once cleared land. The second reason for increased transitional forest is an increase in selective logging over the time period, converting mature forest to transitional. The increase in transitional forest is both positive and negative, because it represents a decrease in cleared land, but it also represents a decrease in mature forest. This has important implications for the phosphorus loading of the lake. Cleared land contributes 2.7 times the amount of phosphorus per acre of land to the lake than transitional

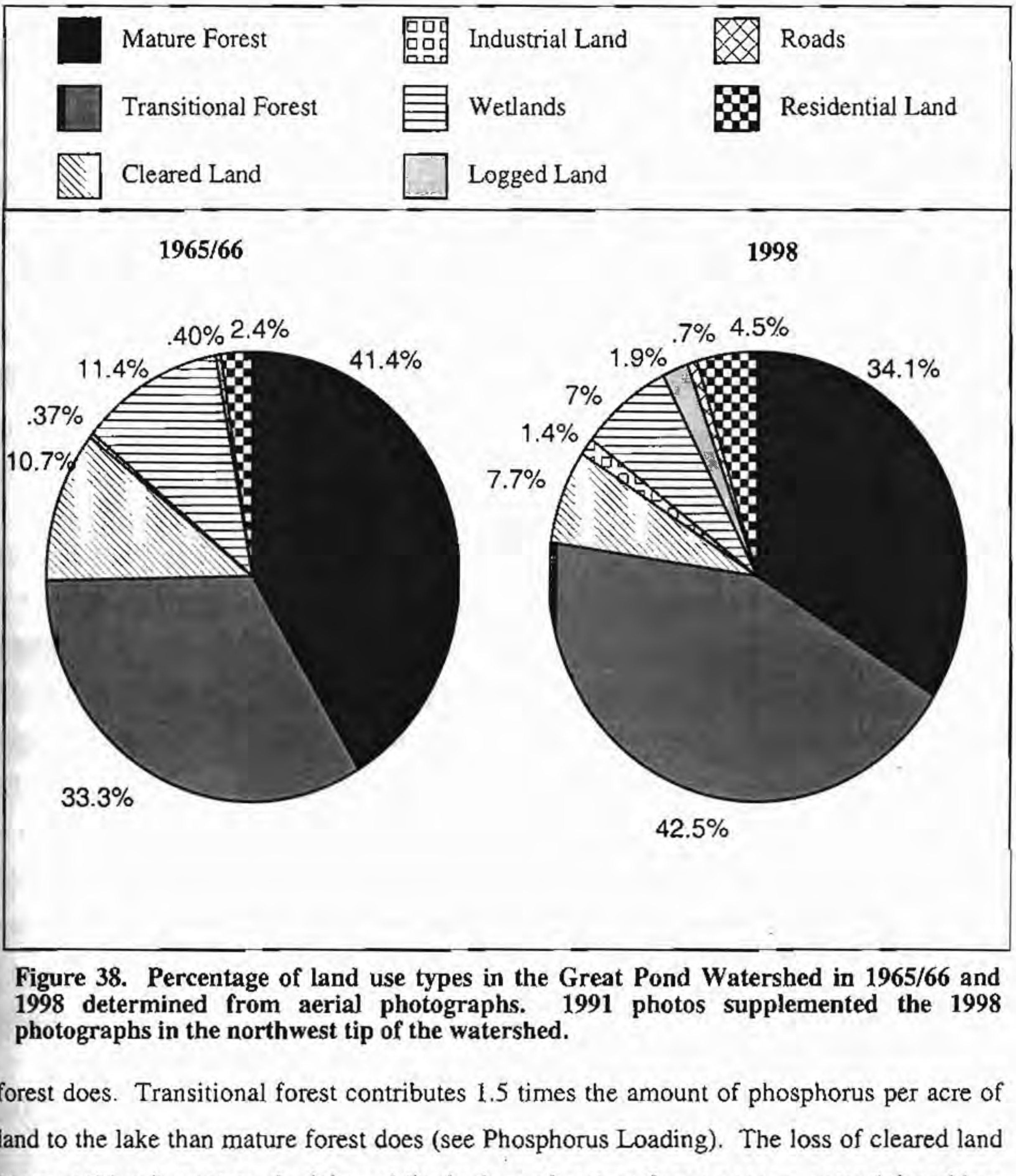

Figure 38. Percentage of land use types in the Great Pond Watershed in 1965/66 and 1998 determined from aerial photographs. 1991 photos supplemented the 1998 photographs in the northwest tip of the watershed.

forest does. Transitional forest contributes 1.5 times the amount of phosphorus per acre of land to the lake than mature forest does (see Phosphorus Loading). The loss of cleared land has a positive impact on the lake, while the loss of mature forest poses a potential problem for the water quality of Great Pond.

Mature Forest

Mature forest is identified on the aerial photographs as land that has a distinct closed canopy with no patches. Mature forest is an important land use type because the closed canopy of mature forest reduces erosion by preventing rainwater from hitting the ground directly and breaking up soil particles. Mature forest also acts as a buffer, absorbing runoff from other land use types such as roads, cleared land, and industrial land (BI493 1998). However, areas of mature forest are threatened because they have the potential to become logging sites in the future.

Results and Discussion

In 1965/66, mature forest made up 41.4 percent (8,535 acres) of the total land area in the Great Pond Watershed. Of this area, 42.1 percent was found in Quadrant 1, 27.3 percent in Quadrant 2, 12.9 percent in Quadrant 3, and 17.7 percent in Quadrant 4. Between 1965/66 and 1998, the total area of mature forest decreased to 7,114 acres, a loss of 1,421 acres. Mature forest now compromises 34.1 percent of the land in the watershed (Fig. 38). In the 1998 aerial photographs, it was observed that mature forest increased slightly (17 acres) in Quadrant 1, but decreased in all of the other quadrants. In 1998, Quadrant 1 contained 52.0 percent of the mature forest in the watershed. This increase is due to the increase of mature forest in Quadrant 1 and the decrease of mature forest in the other quadrants. Quadrant 1 contained a larger amount of mature forest because there is more land in Quadrant 1 than the other quadrants. This is because the watershed extends farther north in Quadrant 1.

One reason for the decrease in mature forest is that in 1965/66 there was no logging, while in the 1998 photos, logging is evident. There has also been a large increase in residential development. Many new roads have been constructed where mature forest once stood. There has also been a dramatic increase in industrial and municipal development. There has been an increase in the number of gravel pits in the Great Pond Watershed from 1965/66 to 1998. It should be noted, however, that buffer zones of mature forest surround a majority of these gravel pits. In 1997, a golf course was constructed in Belgrade that

accounts for some of the mature forest lost in Quadrant 4. The overall loss of mature forest may have negative implications for the water quality of Great Pond in the future.

Wetlands

Wetlands are defined as transitional areas between terrestrial and aquatic ecosystems (Weller 1994). Bogs, fens, marshes and swamps fall into this land use category. Wetlands considered in this study were identified on the aerial 1965/66 and 1998 photographs as areas of short, dense vegetation usually near a water body or as brown colored areas on infrared photographs from 1985.

Results and Discussion

Total area of wetlands decreased between 1965/66 and 1998. The total amount of wetlands found in 1965/1966 was 11.7 percent of the total watershed (2,305 acres). The total amount of wetlands found in 1998 was 7.0 percent of the total watershed (1,464 acres). The amount of wetlands in the Great Pond Watershed showed a decrease of 842 acres (4.7 percent) between 1965/66 and 1998.

The change in wetland area is seen in the amount found per quadrant in 1965/66 and 1998. In 1965/66, Quadrant 2 had the most wetlands (1117.4 acres), followed by Quadrant 4 (936 acres), Quadrant 1 (235 acres) and Quadrant 3 (16.9 acres). In 1998 Quadrant 2 had the greatest amount of wetlands (1032 acres), followed by Quadrant 1 (282 acres), Quadrant 3 (106.3 acres) and Quadrant 4 (43.0 acres).

Quadrants 2 and 4 showed a decrease in wetlands. Wetland loss was most prominent in Quadrant 4. This loss of wetlands was may be due to an increase of transitional land. The edges of wetlands succeeded naturally causing a general decrease in wetland area and corresponding increase in transitional land (Weller 1994; Fig. 38 and Fig. 39). Wetland area in Quadrants 1 and 3 did not show a decreasing trend. This could be due to a number of reasons.

Errors in calculations of wetland areas could have been due to a few factors. Incorrect calibration of the sets of photographs could have caused data to be misrepresented. Also,

since the 1998 photographs were on a larger scale, land use identification could have been more precise. The larger scale could have caused identification to be more specific than in the smaller scaled 1965/66 photographs. The increase in precision could have caused areas that had been labeled as transitional or mature forest area in 1965/66 to be identified as wetland area in 1998.

It might be expected that since residential areas increased there would be a corresponding decrease in natural areas such as wetlands. However, wetlands are difficult and expensive to develop since they must be filled in first with soil or sand. Correspondingly, since forested areas are easier to develop, they will most likely be developed instead of wetlands. This was probably the case with the wetlands in the Great Pond Watershed. Although wetland area decreased between 1965/66 and 1998 the loss in forested (transitional and mature) areas was greater (Fig. 39). This shows that development infringed on forested areas more than wetland areas. The development of wetlands is illegal without producing an equal amount in another location (Firmage, pers. comm.). This fact implies that loss of wetlands was most likely due to natural succession or error in analysis. However, some development of wetlands could have occurred in the late 1960's, before regulation of wetland development was enforced (Firmage, pers. comm.).

The amount of wetlands found within a watershed is important since wetlands serve as a nutrient source or sink for the organisms in the aquatic habitat. The unique hydrological and biological composition of these areas allows foreign and possibly toxic substances to be absorbed before entering the lake (Weller 1994). However, wetlands could also act as a source of nutrient loading (see Great Pond Characteristics: Biological Perspectives). Since the loss of wetlands has the potential to act as a nutrient sink and nutrient sink, and change in wetland composition within a watershed should be monitored closely.

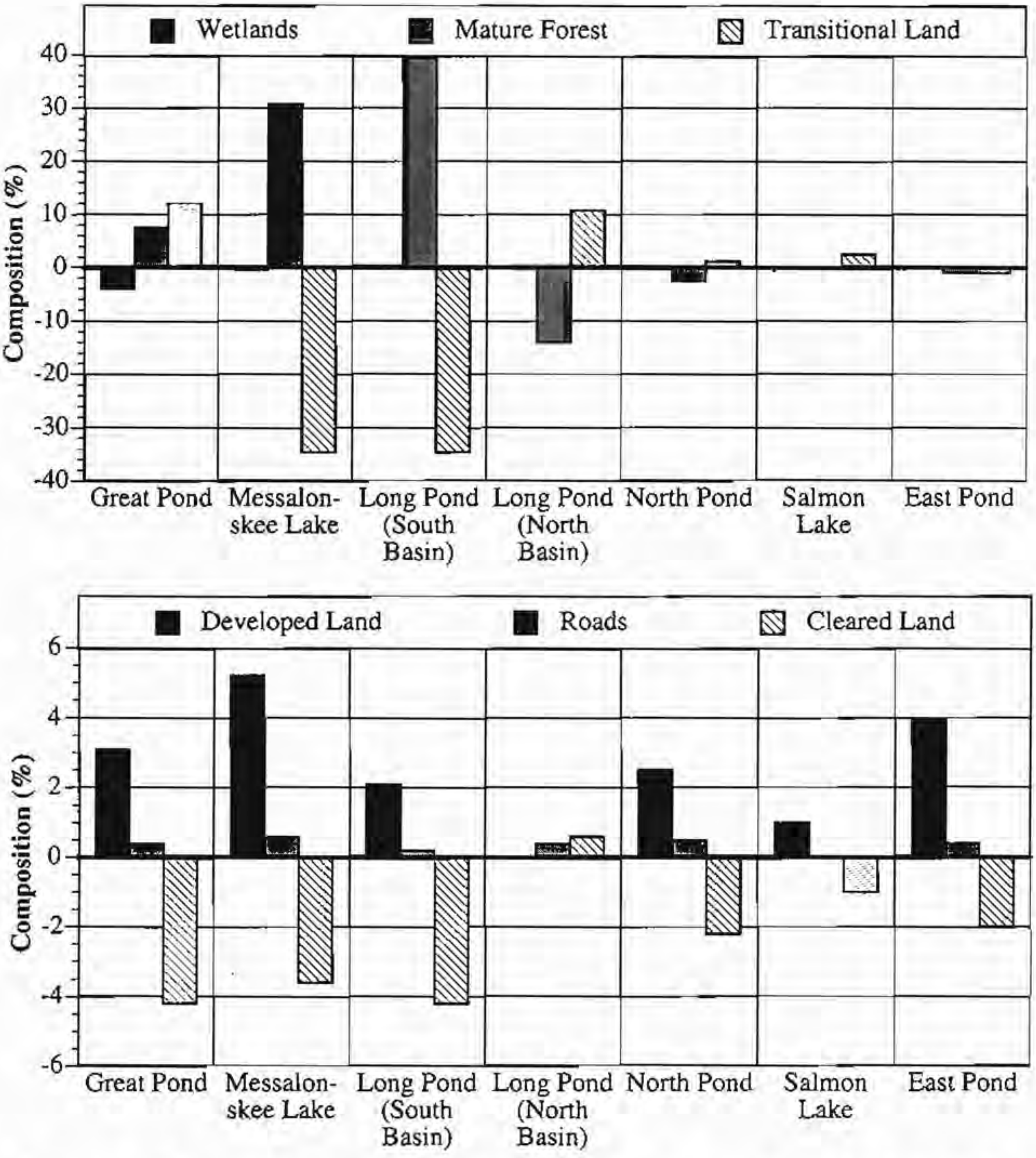

Figure 39 Percent change of wetlands, mature forest, transitional land (including logging, regenerating and reverting lands), developed land (including residential, municipal/industrial, and commercial), roads and cleared lands (including agricultural, crop and grazing) in the Belgrade Lake Watersheds between 1965/66 and a later collection date (Great Pond-1998, North Pond-1991, East Pond-1991, Salmon Lake-1991, Long Pond (South Basin)-1991, Long Pond (North Basin)-1991, and Messalonskee Lake 1991/92). Data from 1991 was used in the northwest portion of the Great Pond Watershed (1998 only). Data compiled from BI 493 courses 1991-1999.

Residential Land

Residence Count

Methods

A residence count for the Great Pond Watershed was performed by the Colby Environmental Assessment Team (CEAT). Shoreline residences were tallied by boat on 14-Sep-98 and non-shoreline residences were tallied by car on 9-Sep-98, 5-Oct-98, and 31-Oct-98. The driving survey was conducted along all roads within the watershed with the use of the Residential Survey Form (see Appendix G). Residences were classified as shoreline or non-shoreline and seasonal or year-round. Shoreline residences were situated within 200 ft of the lakeshore and non-shoreline residences were positioned greater than 200 ft from the lake shoreline. Seasonal residences often have open foundations and storm windows. They may also lack an external oil tank and chimney. Year-round residences may have an external oil tank or an oil tank in the basement, a chimney, snow removal equipment, and a large firewood supply.

Watershed boundary lines were drawn on the appropriate town maps in order to exclude residences outside of the watershed. Only residences along roads inside these boundaries were counted. Roads inside the watershed boundary lines were categorized by town in order to determine the number of residences in each town. Acreage of developed land in each of the four quadrants of the watershed was determined by adding the acreages of developed land (industrial, logging, residential land, and roads) in each quadrant. Percentages of shoreline or non-shoreline and seasonal or year-round residences were calculated.

Shoreline Results

There are a total of 1,227 residences in the Great Pond Watershed. Shoreline residences comprise 49.3 percent of these residences. Belgrade contains 43.8 percent, Rome 56.2 percent, and Smithfield and Mercer contain 0.0 percent of the total shoreline residences (Fig. 40). Rome contains 57.4 percent of the seasonal shoreline residences and Belgrade contains 42.6 percent of the seasonal shoreline residences. Rome has 51.2 percent of the

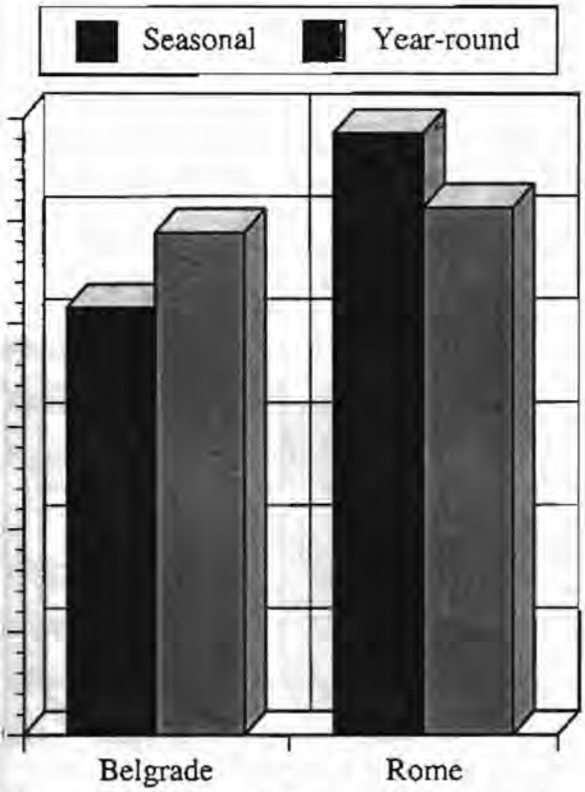

Figure 40. Percent of seasonal and year-round shoreline residences in the Great Pond Watershed. The percentages were calculated from the results of the Residential Survey (see Appendix G).

year-round shoreline residences and Belgrade has 48.8 percent of the year-round shoreline residences. Total seasonal residences comprise 80.0 percent of the shoreline while total year-round residences make up only 20.0 percent of the shoreline.

Non-shoreline Results

The non-shoreline area of the Great Pond Watershed contains 622 residences. There are 371 residences in Belgrade. Rome and Smithfield contain 170 and 81 residences, respectively. Of these 622 non-shoreline residences, 144 (23.2 percent) are seasonal and 478 (76.8 percent) are year round. Of the seasonal non-shoreline homes, 94 (65.3 percent) are located in Belgrade, 25 (17.4 percent) are located in Rome, and 25 (17.4 percent) are located in Smithfield. Of the year-round residences, 277 (57.9 percent) are located in Belgrade, 145 (30.3 percent) are located in Rome, and 56 (11.7 percent) are located in Smithfield (Fig. 41).

Discussion of Residences

The Great Pond Watershed is a delicately balanced ecosystem. Due to the low flushing rate of Great Pond (0.52 flushes per year), nutrient levels can build up, and any changes along the shoreline produce a lasting effect on the water quality.

Residential areas have a strong impact on a lake, particularly when they are built close to the shore. Since runoff from shoreline houses does not travel far to reach the water, the water can be easily contaminated with trace chemicals, fertilizers, insecticides, sewage effluent sediments, or household water. In addition to erosion and nutrient loading into the lake, shoreline development destroys the habitats of numerous species, threatening existing

flora and fauna. Development also decreases the scenic nature, and results in greater traffic and noise levels around the lake. Although one home alone will not destroy an entire watershed, the cumulative effect of many houses may cause irreversible damage to the lake.

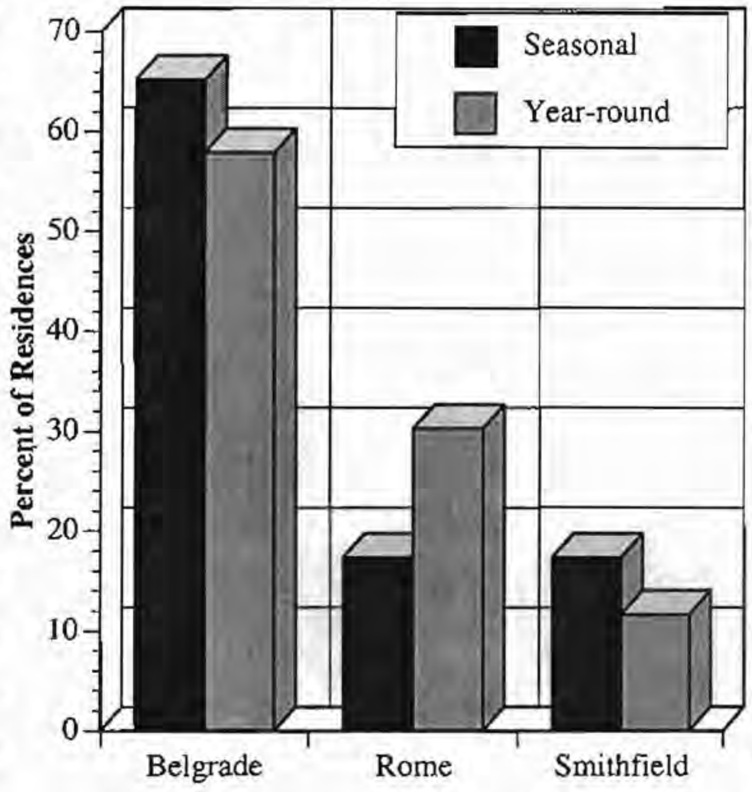

Figure 41. Percent of seasonal and year- round non-shoreline residences in the Great Pond Watershed. The percentages were based on results from the Residential Survey (see Appendix G).

A significant amount of the Great Pond shoreline has been developed. Tax maps revealed that there are 455 lots along the Belgrade shoreline. House count surveys conducted by CEAT (see Land Use: Residential Land) yielded a total of 265 houses on the Belgrade shore, indicating that 58.2 percent of the shoreline in Belgrade has been developed. This development is concentrated in Pinkhams Cove, Hatch Cove, Foster Point, Hoyt Island, from Snake Point to Stony Point, and from Long Point to Austin Bog.

Tax maps indicate that there are 268 lots along the shoreline in Rome, although 340 houses were counted in the house count surveys. This inconsistency may have been caused by several factors. Houses may have been counted twice if they were counted by both CEAT car surveyors and boat surveyors. Garages or sheds may have been counted as houses. It is likely that some lots had more than one house present on them. In addition, numerous summer camps may have been counted as multiple houses, when in fact they are only built on one lot, and share one septic system. It is possible, although less likely, that CEAT members had difficulty distinguishing if a house was less than or greater than 200 ft from the

shore. Thus, shoreline and non-shoreline counts would be skewed. Survey teams may also have judged this distance differently. In addition, houses that are only 200 ft away from the shore may be built on lots that do not abut the water. In other words, some houses were counted as shoreline houses, although there is not a corresponding shoreline lot.

The First Selectman office in Rome contains the records of shoreline lot development. The First Selectman of Rome revealed that there are no more undeveloped lots along the shoreline in Rome (Moreau, pers. comm.). It follows that 100 percent of the shoreline in Rome has been developed. Most of these houses are concentrated on Coe Point, Jamacia Point, and Ram Island.

Austin Bog and North Bay are two areas in the watershed that have experienced little development. Because these areas qualify as wetlands, they are not suitable for development or septic systems (see Development Implications of Land Characteristics: Septic Suitability). The stretch of shoreline from Hatch Cove to Pinkhams Cove is also unsuitable for development because it is classified as a high erodibility area (see Development Implications of Land Characteristics: Erodibility).

The index of shoreline development, which is a measurement of the density of residences, is expressed as the number of houses per 1000 ft of shoreline. The shoreline index in Belgrade is 1.73. The index for Rome is 4.47. This higher number corresponds to the fact that Rome's shoreline is fully developed.

Almost three-fourths (73.7 percent) of the Great Pond shoreline has been developed. This is comparable to Messalonskee Lake and North Pond, where 77.7 percent and 66.7 percent of the shorelines are developed, respectively (BI493 1998, BI493 1997). The North Basin and South Basin of Long Pond had 63.4 percent and 66.2 percent of their shorelines developed, respectively (BI493 1995, 1996). Long Pond, the lake with the smallest amount of development along the shore, has been said to have the best water quality of the Belgrade Lakes (BI493 1997). These data suggest that the amount of development has an impact on the quality of the water, especially when the development is so close to the water's edge.

Our analysis also revealed that 80.0 percent of the shoreline houses were seasonal. This particularly large number causes an increase in traffic, water activities, and septic uses during the summer months. North Pond has a similar trend, where 88.3 percent of the

shoreline residences are seasonal (BI493, 1997).

In Smithfield, development seems to be slowing down (Turner, pers. comm.). Steps have been taken to slow development in Rome also. The Belgrade Lakes Conservation Corps has bought the larger wooded areas in Rome. These acres of land are being reserved for biking and hiking trails and will not be developed in the future. With the exception of several large plots of land (farms) in Rome that could potentially be sold and developed, there are no more available lots in Rome or Belgrade that could be sub-divided and developed in the future (Moreau, pers. comm.).

Shoreline Buffer Strips

Current set back regulations do not allow development within a strip of land extending 100 ft horizontal shoreline distance inland from the normal high-water line of a great pond or a river flowing to a great pond. Set back regulations also define a zone of 75 ft horizontal shoreline distance, from any other water body, tributary stream, or the upland edge of a wetland (Belgrade 1991).

Buffer strips are areas of vegetation between water bodies and areas of development such as homes. Buffer strips reduce phosphorus and total suspended solid loading from developed areas into surrounding water bodies (Woodard and Rock 1991). Ideally, slopes within the buffer zone should be less than two percent (i.e., a drop of 2 ft per 100 ft of length), in order to increase absorption and lessen the force of the water on the buffer strip. Steep slopes are susceptible to erosion and render buffer strips ineffective. The most effective buffer strips are composed of thick, dense, forest litter (leaves, twigs, bark, and decaying matter) and native vegetation such as red maple, paper birch, burning bush, and winterberry (Fact Sheet #05 Cumberland County Soil and Water Conservation District). Buffer strips also work to slow and disperse water flowing from a driveway, lawn, or footpath (Woodard and Rock 1991). Installing gutters or diversions to direct runoff water away from the lake and into a well-vegetated area is an option (Fact Sheet #05 Cumberland County Soil and Water Conservation District). These are often used in combination with buffer strips and behind buffer strips.

Rip-rap can be an effective method of preventing shoreline erosion by protecting the shoreline and the adjacent upland against heavy wave action (Fact Sheet #09 Cumberland County Soil and Water Conservation District). Rip-rap is made up of three components: the stone layer, the filter layer, and the toe protection. The stone layer is composed of rough, angular rock. The filter layer consists of special filter cloth or six inches of well-graded gravel, allows groundwater drainage, and prevents the soil beneath the rip-rap from being washed through the stone layer. The toe protection prevents settlement or removal of the lower edge of the rip-rap. Rip-rap depends on the soil beneath it for support and should be built only on stable shores or bank slopes. Vegetation should be considered before rip-rap because of its ability to provide shade and nutrients for aquatic habitat and prevent erosion. Vegetation dissipates rainfall energy and increases the porosity of the soil, thereby increasing water infiltration (Novotny and Olem 1994). Rip-rap has several limitations because it only protects land immediately behind it, not the areas adjacent to it. Erosion near the rip-rap may be accelerated by wave reflection from the structure itself. Rip-rap alone is not a good habitat for wildlife; however, a combination of rip-rap and plants will protect the shoreline and provide vegetative cover for fish (Fact Sheet #09 Cumberland County Soil and Water Conservation District).

Methods

The Great Pond Watershed area was divided into six regions and assessed via boat on 14-Sep-98, 21-Sep-98, and 22-Oct-98 by the Colby Environmental Assessment Team (CEAT). Buffer strips were evaluated in terms of buffer strip coverage versus lot width (percent), buffer strip depth back from shoreline (ft), composition (percent trees, shrubs, flowers, and ground cover), and rip-rap (present or absent) and scored on the Buffer Strip Survey Form (see Appendix H).

Results and Discussion

In order to assess buffer strip quality, an index was developed. Buffer strips were categorized as adequately buffered, partially buffered, or poorly buffered based on their

buffer strip survey score. Adequately buffered zones received buffer strip scores ranging from 15 to 18 and contain buffer strips which cover at least 75 percent of the shoreline lot. Adequately buffered areas contain buffer strips which are greater than 50 ft deep and are composed of at least 50 percent trees, shrubs, flowers, and ground cover. Partially buffered zones have buffer strip scores ranging from 8 to 14 and are characterized by buffer strip widths composing 25 percent to 75 percent of the shoreline and a buffer strip depth of 25 ft to 50 ft. These buffer zones are composed of 25 percent or less of trees, shrubs, flowers, and ground cover. Poorly buffered areas have buffer strip scores less than seven, contain buffer strip widths comprising 1 percent to 25 percent of the shoreline, a depth of less than 25 ft, and are composed of 0 percent trees, shrubs, flowers, and ground cover. Presence or absence of rip-rap was not factored into the buffer survey results and was considered as a separate shoreline component.

Of all the buffer strips surveyed, 6.5 percent are adequately buffered, 65.2 percent are partially buffered, and 28.3 percent are rated as poorly buffered. Rip-rap coverage is strong throughout the lake shoreline with 87.8 percent of residences containing adequate rip-rap and only 12.2 percent containing inadequate rip-rap. The majority of the buffer strips surveyed (n=718) are not wide enough and are therefore rated partially or poorly buffered; 35.8 percent of residences contain buffer strips which comprise greater than 75 percent of the lot shoreline while 64.2 percent of the residences contain buffer strips making up less than 75 percent of the lot shoreline. Buffer strip composition was examined in terms of percent shrubs and flowers present: 39.7 percent of buffer strips contain adequate vegetative composition while 60.3 percent of buffer strips have inadequate vegetative composition. Buffer strips with inadequate composition (little shrubbery and few trees present) will not be able to filter phosphorus and other nutrients from incoming water as efficiently as buffer strips containing dense shrubbery and trees. Buffer strips comprised of 50 percent to 100 percent shrubs and flowers are rated adequate while buffer strips comprised of 0 percent to 25 percent shrubs and flowers are rated inadequate.

Of all six regions surveyed, the Foster Point/Long Point region has the highest percentage of buffer strip composition scores ranging from 0 percent to 25 percent shrubs and flowers (74.2 %) while the west side of Pinkhams Cove region possesses the highest

percentage of buffer strip composition scores ranging from 50 percent to 100 percent shrubs and flowers (56.1 %). Total buffer strip composition scores indicate that 60.3 percent of residences have 0 percent to 25 percent shrubs and flowers while 39.7 percent of residences have 50 percent to 100 percent shrubs and flowers. The Hatch Cove/Stony Point/Horse Point/Snake Point region has the highest percentage of buffer strips with widths greater than 75 ft (48.9 %) while the Crooked Island/Chute Island/Jamaica Point region has the highest percentage of buffer strip widths less than 75 ft (71.6 %). The Hatch Cove/Stony Point/Horse Point/Snake Point region has the highest percentage of adequately buffered residences (16.0 %) while the West Pinkhams Cove region has the highest percentage of poorly buffered residences (41.9 %). The Hoyt Island/West Long Point/Abena Point region has the highest percentage of partially buffered residences (77.4 %) (Fig. 42).

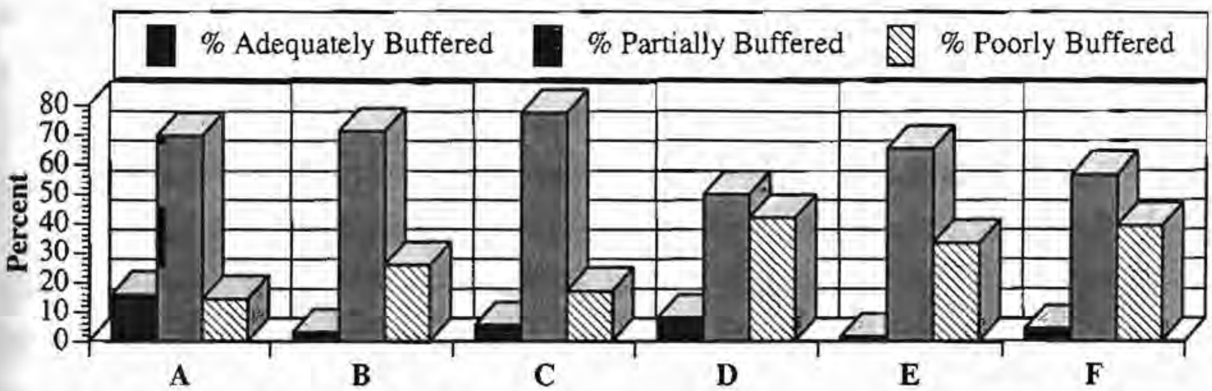

Figure 42. Percent of adequately, partially, and poorly buffered shoreline residences along Great Pond in six different areas. Area A=Hatch Cove, Stony Point, Horse Point, and Snake Point; Area B=East Pinkhams Cove; Area C=Hoyt's Island, West Long Point, and Abena Point; Area D=West Pinkhams Cove; Area E=Foster Point and East Long Point; and Area F=Crooked Island, Chute Island, and Jamaica Point. Adequate buffer coverage implies buffer strip widths comprising at least 75 percent of the shoreline and composed of at least 50 percent trees, shrubs, flowers, and ground cover. Adequately buffered zones have buffer strip depths greater than 50 ft. Partially buffered strips comprise 25 to 75 percent of the shoreline and are composed of 25 percent or less of trees, shrubs, flowers, and ground cover. Partially buffered strips have depths from 25 to 50 ft. Poorly buffered areas comprise 1 to 25 percent of the shoreline and contain 0 percent trees, shrubs, flowers, and ground cover. Poorly buffered areas have depths less than 25 ft.

Adequately buffered residences along shorelines are a necessity. Phosphorus inputs into lakes from lawn runoff in residential areas is five to ten times higher than that of undeveloped land (Woodard and Rock 1991). Areas which are partially or poorly buffered

can be improved through the installation of rip-rap on shoreline, a well designed buffer strip, and behind buffer strip vegetation (trees, shrubs, flowers, and ground cover). Buffer strip and rip-rap installation requires a MDEP permit. With proper planning, adequately buffered shorelines can also be aesthetically appealing.

Roads

Methods

All roads within the Great Pond watershed were surveyed using either the Detailed or Non-Detailed Road Survey Forms (see Appendices I and J). Roads having a paved or dirt surface were assessed using the Detailed Survey Form and were located lake side of Routes 8, 27, and 225 within the Great Pond watershed. These roads include camp roads, which are those dirt roads in the watershed that lead directly to seasonal or year-round residences on the shoreline. Non-detail-surveyed roads, which also have paved and dirt surfaces, can be found within the Great Pond Watershed boundaries on the non-lake side of the major routes.

Detail-surveyed Roads

Camp roads may alter the ecological balance of an area. They may change the drainage pattern and topography of the land and strip the protective vegetative cover from the watershed. Camp roads are responsible for loading nutrients, including phosphorus, and sediment into a lake system. Phosphorus, which is a limiting nutrient in a water body, easily attaches to soil particles and sediment and is carried into a lake by storm run-off. Camp road construction is responsible for up to 85 percent of all erosion and sedimentation problems in a water body. Camp roads are typically the biggest environmental problem in urban and rural lake watersheds (Michaud 1992).

Camp roads were partitioned into four classes according to their Road Total Index values, which were calculated from the Detailed Road Survey Form (Appendix I). The Road Total Index value is the summation of the four factors: Surface Total, Ditch Total, Culvert Total, and Water Diversion Total. These four Road Total Classes were used to categorize the quality of the individual camp roads in terms of potential phosphorus loading. Class 1 camp

roads indicated a low phosphorus loading potential and Class 4 camp roads indicated a high phosphorus loading potential. High phosphorus loading accelerates cultural eutrophication in a lake ecosystem.

Class 1 camp roads were specified as Good with a range of Road Total Index values from 10 to less than 39. A Good camp road would present a crown that diverts water off of the road surface into properly vegetated ditches through clean, working culverts (if needed), toward water diversions that empty the water into a forested buffer zone well before reaching the lake water line. Class 2 roads were found to be in Acceptable condition with values ranging from 39 to less than 80. Acceptable roads received slightly higher scores because they had one road factor out of the four in inadequate conditions. Class 3 roads were in Needing Work condition with values ranging from 80 to less than 230. Roads classified as Needing Work had even higher scores because two or more of the four road factors were in inadequate conditions. Class 4 roads were considered in Poor condition with values ranging from 230 to less than 376. Poor roads were inadequate in three or four of the road factors. These Poor camp roads serve as a potentially large and harmful source of phosphorus loading into the lake system.

Members of the Colby Environmental Assessment Team (CEAT) traveled around the perimeter of Great Pond on 28-Sept.-98, 5-Oct.-98, 22-Oct.-98, 24-Oct.-98, 26-Oct.-98, and 31-Oct.-98 using the Detailed Road Survey Form to assess the quality of watershed roads. CEAT measured the length (miles) of roads by car odometer, measured the width of roads with meter tape, estimated the total number of water diversions and culverts missing and needed, and estimated the overall slope of the road.

Surface hardness, edge condition, road base (gravel, sand, or clay), usage (seasonal or year-round), and overall surface condition were evaluated. Measurements of crown height were also taken, using a string, level, and meter stick. A crown is essentially a hump in the middle of the road that allows water to drain off the road surface quickly in the event of a storm. Optimal crown height is 6 inches or higher with a gradual slope from the middle to the edge of the road. Poor crown conditions are characterized by potholes, ruts and a zero-inch height. The ideal crown height is 0.5 to 0.75 inches of crown for each foot of width, meaning a 12 ft wide road should have a 6 inch crown (Michaud 1992). Gravel roads are

graded periodically, which involves dragging materials from the side of the road to the center, recreating a crown, and eliminating potholes and ruts in the process. Year-round usage of roads wears down the crown more rapidly than seasonal usage (Fig. 43). A hard road surface improves the quality of the road. Dusty and loose road surfaces create the potential for large amounts of soil erosion and increased sediment loading into a lake. The base of the road can play a major role in the hardness and permeability of the road surface. A base with a mixture of gravel and sand particles provides a highly permeable, well drained surface, which increases the probability that the runoff will be absorbed instead of flowing along the surface and causing erosion. Alternatively, clay particles have low permeability and erode very easily.

CEAT examined the road edges for the presence of berms, which are ridges that run the length of the road and prevent water from running off the road surface into an adjacent ditch. Berms can be caused by winter plowing. In general, roads that have a berm are roads that are used year-round.

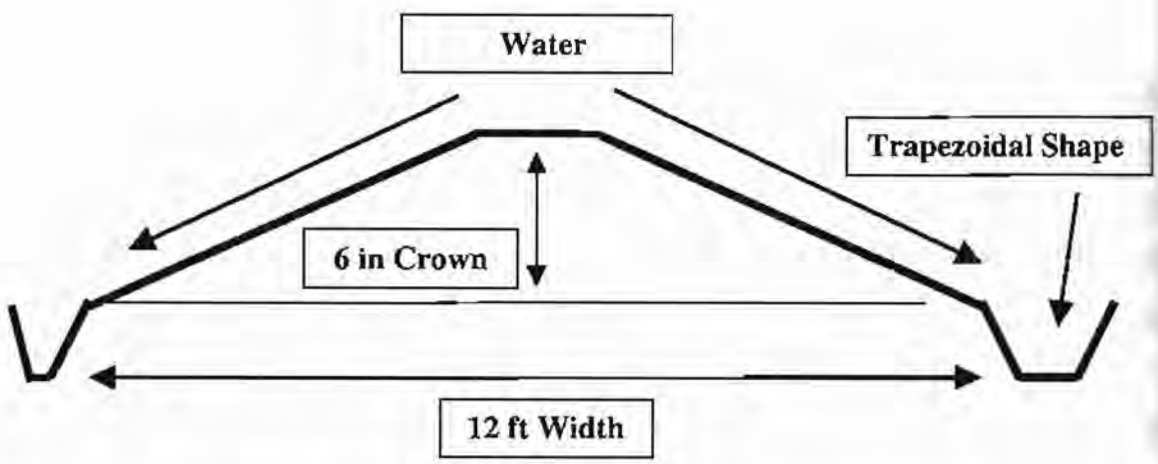

Figure 43. Diagram of an ideal camp road crown, which shows a ratio of half of an inch of height to each foot of width. The crown drains water running off the road surface into well-vegetated, trapezoidal ditches, which would reduce the amount of sediment and nutrients flowing into the lake (Michaud 1992).

Ditches channel surface water and runoff away from the road. They provide a storage area for water after a large storm and should be free of debris. Flat and trapezoidal shaped

ditches are ideal. Narrow, V-shaped ditches are more prone to erosion. A ditch with sediment build-up or a muddy surface shows evidence of erosion. The water in a ditch should never be closer than 1 ft from the edge of the road. Ditches can be stabilized with vegetation or stones, which slow down the velocity of the water running along the ditch and decrease potential erosion (Michaud, 1992; Fig. 44).

Diversions serve as channels, leading to large buffer zones in the form of forested areas or grassy, vegetated stretches of flat land. Diversions facilitate the absorption of phosphorus and nutrients before they reach the lake, clean silt from runoff, and slow the velocity of the water moving down slope toward the lake. Various organisms living in the organic litter and topsoil layer covering of a forest floor remove nutrients trapped in the silts. Wildflowers and mosses can be planted in areas where runoff is diverted and used to absorb nutrients before the runoff reaches the water body (Michaud 1992).

Figure 44. Ditches lie along either side of the road. This ditch is lined with stones, slowing the drainage of water flow, allowing water and sediments to seep into the ground rather than traveling straight to the lake.

Culverts are pipes placed under the surface of a road to direct the flow of water, allowing natural drainage to flow as it did before the construction of the road began (China Lakes Pamphlet). Culverts are needed any time streams, brooks, or seasonal runoff areas intersect a road, or when so much surface flow accumulates that it cannot be contained in a ditch. Culverts are not only the most expensive part of road maintenance, but also the most overlooked. Culverts can be made of metal or concrete (expensive but long-lasting)

Figure 45. Culverts keep water from eroding the road surface by directing it underneath the road. Properly functioning, clean culverts are crucial for good road quality and reduced sediment loading into the lake.

or plastic or wood (cheaper materials, although they break more easily). Proper size and installation of a culvert are important. If a culvert is too small, water will run over the surface of the road. If a culvert is placed in the ground incorrectly, it will be crushed by the weight of traffic. Culverts should have a diameter between 16 and 27 inches, depending on the length of the culvert, and the width and depth of the stream of runoff. They should be covered with 1 ft of road material to prevent crushing from traffic. Culverts need to be kept clear of debris and checked regularly to ensure that water is able to flow through them (Michaud 1992; Fig. 45). The values from the Detailed Road Survey Form (see Appendix I) were collated and the general conditions of the Detail-surveyed roads within the Great Pond Watershed were defined.

Non-detailed-surveyed Roads

Although farther from the water, roads that were surveyed with the Non-Detailed Survey Form (see Appendix J) are also important to the potential of phosphorus loading into the lake. The larger area of these roads are paved and used year-round. They are treated with sand and salt in the winter, which add to the potential amount of sediment that can be carried into the lake during storm runoff. Their close proximity to tributaries allows for indirect sediment loading into the aquatic ecosystem. Members of CEAT analyzed the Non-detail-

surveyed roads on 5-Oct-98 and 31-Oct-98. Length (miles) and width (feet) of the roads were measured using car odometers and meter tapes. The road surface type was evaluated in terms of pavement or dirt. Road usage was evaluated by checking to see if houses were year-round or seasonal (See House Counts, methods). The Non-detail-surveyed roads were not surveyed in terms of their quality, like the Detail-surveyed roads were. The information gained from the Non-Detailed Survey Forms was used to help calculate the total acreage of roads in the watershed (dirt, paved, and total acreage), define maintenance (state, town, or privately maintained), and calculate number of seasonal and year-round houses, commercial businesses and summer camps.

Results and Discussion

The Colby Environmental Assessment Team (CEAT) surveyed a total of 149 roads, extending 88.2 miles (Fig. 46), within the Great Pond Watershed using the Detailed and Non-

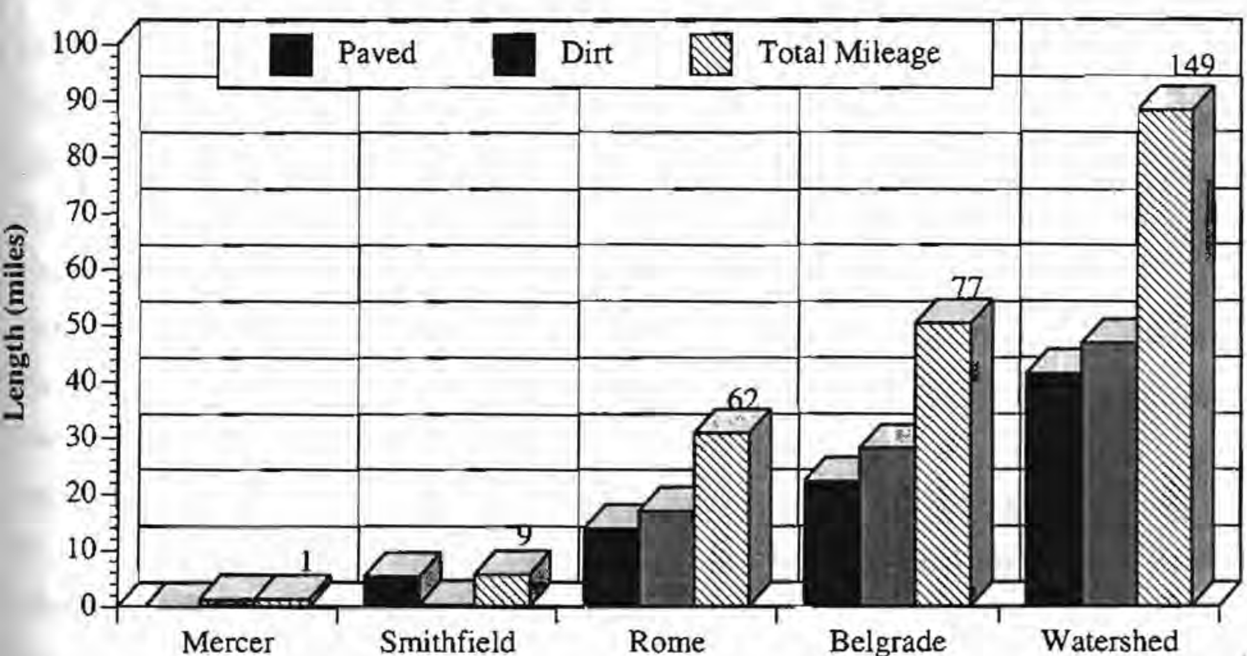

Figure 46. Length (in miles) of all dirt and paved roads for Mercer, Smithfield, Rome, Belgrade and the entire Great Pond Watershed. The numbers above the total mileage values represent the total number of roads for each town and for the entire watershed.

Detailed Road Survey Forms (see Appendices I and J). These roads constitute 230 acres or

1.1 percent of the watershed (see Appendix K). Roads within the Great Pond Watershed can be found in the Towns of Belgrade, Mercer, Rome, and Smithfield (Fig. 47). Seventy-seven roads exist in Belgrade, sixty-two in Rome, nine in Smithfield, and a portion of the Ladd Corner Road is found within Mercer. Eighty percent of the roads (119 roads) in the watershed have a dirt surface and include a total of 46.8 miles (Fig. 46). The 20 percent of paved roads (30 roads) in the watershed include a total of 41.4 miles. These data indicate a large number of short dirt roads and a small number of longer paved roads within the watershed. Not all roads in the watershed were accessible to the CEAT surveying teams. Some roads indicated on maps could not be found, were converted into short private driveways, were gated off, or were overgrown and no longer exist. However, these non-surveyed roads comprise a very small number and total mileage of roads within the watershed.

Detail-surveyed Roads

Detail-surveyed roads are those roads located lakeside of Rts 8, 27 and 255 and surveyed by the Detailed Road Survey Form (see Appendix I). There are 111 Detail-surveyed roads in the Great Pond Watershed including 101 dirt roads and 10 paved roads. Detail-surveyed roads were surveyed using the Belgrade and Rome are the only two towns in the watershed that have Detail-surveyed roads, indicative of the fact that only these two towns include the shoreline of Great Pond. The dirt, Detail- surveyed roads are broken into four classes that measure road quality and condition. The results of these class groupings are displayed as percentages of surveyed roads within the entire Great Pond Watershed. Belgrade has 13 roads (12.9 % of the total roads in the watershed) while Rome has 12 roads (11.9 %) in Class 1 (<u>Good</u> condition). Belgrade has 9 roads (8.9 %) while Rome has 10 roads (9.9 %) in the Class 2 (<u>Acceptable</u> condition). Belgrade has 28 roads (27.4 %) while Rome has 20 (19.6 %) in the Class 3 (<u>Needing Work</u> condition). Belgrade has eight roads (7.8 %) while Rome has one (1.0 %) road in Class 4 (<u>Poor</u> roads; Fig. 48). These values indicate 56.4 percent of the Detail-surveyed roads within the Great Pond Watershed are in inadequate conditions, classified as <u>Needing Work</u> or in <u>Poor</u> conditions.

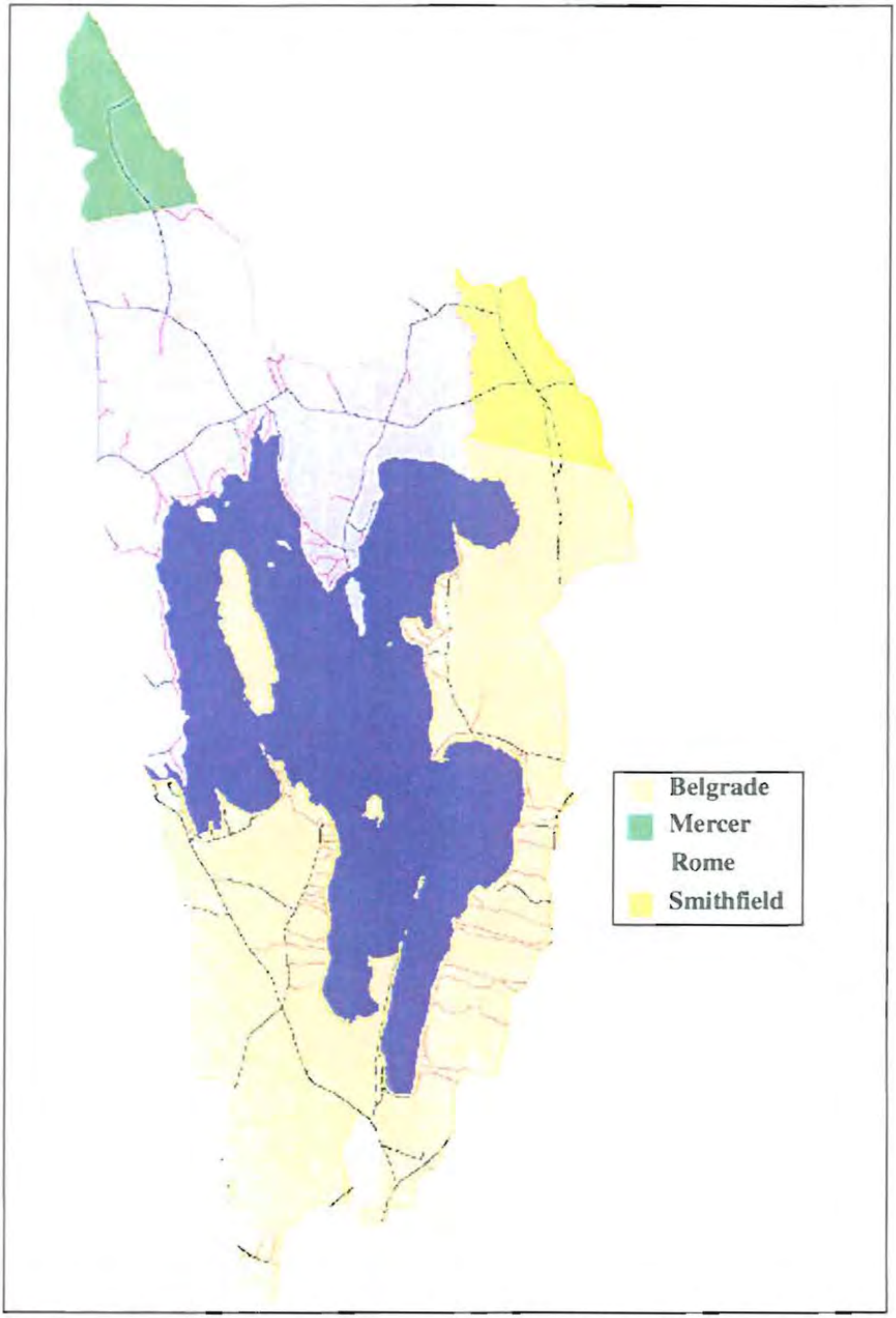

Figure 47. Town boundaries within the Great Pond Watershed. Paved roads (in black) and non-paved roads (in red) are indicated throughoutthe Great Pond Watershed. Town and road information from US Geological Survey (1980) and BI493 field survey. Approximate scale: 1 inch = 1.5 miles.

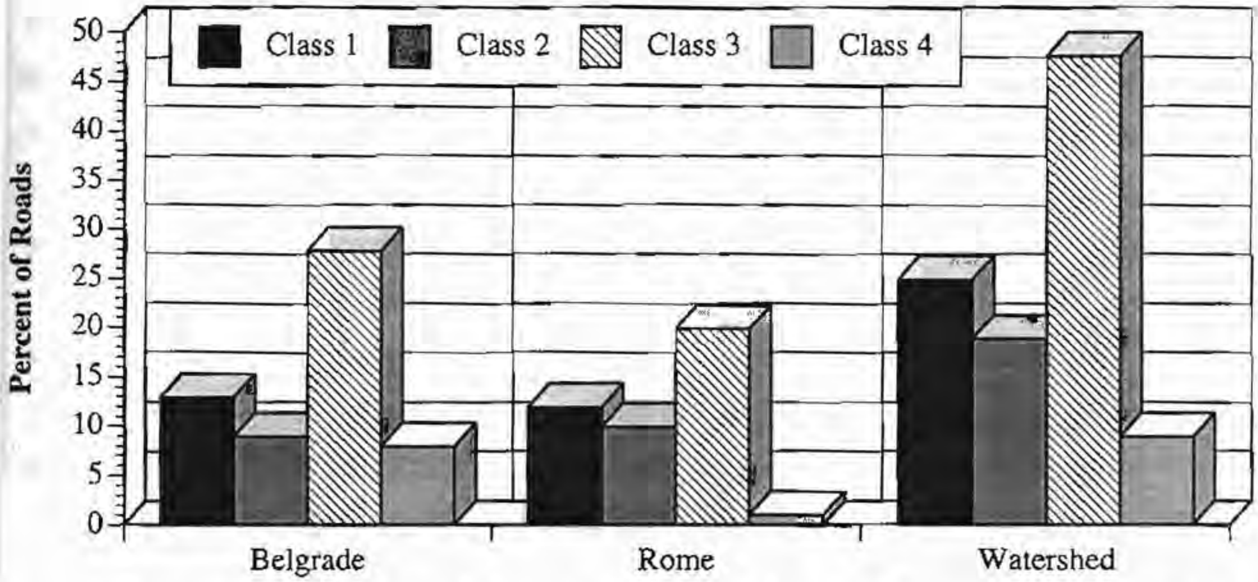

Figure 48. Percentage of dirt roads within Belgrade, Rome and the Great Pond Watershed that were analyzed using the Detailed Road Survey (see Appendix K). Percentages are calculated from the Road Total Index (RTI) values obtained from the Detailed Road Surveys. The RTI values range from 10 to 376. Roads were divided into four classes with Class One indicating roads in Good condition and Class Four indicating roads in Poor conditions.

Since these roads are closest to Great Pond, they have the most potential of loading phosphorus into the lake. Approximately 43.6 percent of the Detail-surveyed roads are in acceptable conditions, classified as Good and Acceptable, indicating a fairly substantial number of roads in the watershed not providing significant phosphorus loading. Overall, there is concern for the present and future health of Great Pond in terms of phosphorus loading. The dirt, Detail-surveyed roads provide a large amount of phosphorus loading that will help contribute to the acceleration of eutrophication in the lake ecosystem.

Concentrated areas of roads around the lake that are in Needing Work or Poor conditions are as follows: the east side of Pinkhams Cove, north to the lower part of Hatch Cove; the west side of Pinkhams Cove; most of the numerous camp roads branching off Point Road; south of The Mountain to the dam; Mosher Hill or the northwestern section of North Bay; and the area from Stony Point, north on Horse Point Road. When looking at these areas on the Development Suitability and Erodibility GIS Maps (see Development Implications of Land Characteristics), road conditions related to the development suitability and erodibility can be summarized to indicate rates of potential phosphorus loading. Soil

type and slope are the major determinants of erodibility and development suitability. Certain soil types are characterized as being more erodible than others and an increased slope has more potential for erosion than a slight slope. Erodibility ranges from slight to severe, while development suitability ranges from very high suitability to very low suitability. The combination of road conditions, development suitability, and erodibility contribute to the amount of potential phosphorus and sediment loading into the lake over time.

The concentrated areas of camp roads in Needing Work and Poor conditions in relation to development suitability and erodibility of these areas are listed below:

1. East side of Pinkhams Cove, north to the lower part of Hatch Cove: ranges from high to medium development suitability, changing from low to very low in the areas of increased slope. Erodibility in this area ranges from moderate to slight, also becoming higher in value in areas of increased slope.

2. West side of Pinkhams Cove: has medium to low development suitability due to its slope and close proximity to a wetland but a slight erodibility possibly due to the mature and transitional forests that cover the area.

3. Camp roads off from Point Road: vary slightly according to their locations. The northern half of Point Road has a high development suitability, except at the very northern point of the road and land within the area, where a medium development suitability is present. The southern half of Point Road is in close proximity to wetlands and therefore has a low development suitability. The erodibility for the entire area ranges from moderate to slight due to the slight slope and the large amount of mature and transitional forests present.

4. Moving south from The Mountain to the dam: shows an increase in development suitability as the slope decreases. The erodibility shows a decrease from high to medium also due to the decrease in slope.

5. Mosher Hill or the northwestern section of North Bay: shows a low development suitability and severe to high erodibility. Both characteristics are due to the increasing slope of the area.

6. North from Stony Point to the end of Horse Point Road: has a development suitability ranging from medium to low and an erodibility of high to moderate due to the increased slope of the area.

Well-developed and maintained roads in any of these areas will create less potential phosphorus loading than roads that are not properly developed or maintained. The presence of mature or transitional forests can help to lessen the erodibility and overall phosphorus loading potential of an area even if the slope is greatly increased. There are multiple factors that may contribute to potential phosphorus loading of a land area.

Most Detail-surveyed roads are short in length, have dirt surfaces, and are camp roads, but there are also ten paved roads defined within the Detail-surveyed roads grouping that were not looked at in detail due to their paved status. Paved roads carry less sediment during runoff and are in good condition because they are usually state or town maintained. These roads are year-round access routes to the many seasonal and year-round camp roads along the shoreline. However, problem areas can still be found on these paved roads. Chandler Road had a culvert that was clogged with large amounts of debris restricting water flow (Fig. 49).

Figure 49. Clogged culvert on Chandler Road. A temporary fixing of water flow using three PVC pipes and a wire fence to keep debris out of the opening of the culvert. Further maintenance measures of this trouble spot should be taken.

The culvert was so clogged that three PVC pipes were placed through the debris into the culvert, allowing the water in the culvert to empty into a wetland area. The PVC pipes are a temporary solution to the restricted water flow problem, but maintenance of the culvert is needed in the future. Another area of concern on Chandler Road is a plot of land (off from the road) that is being developed without the use of silt fences or hay bales. This practice is permitting large amounts of sediment accumulation in ditches alongside the road,

contributing to the overall increase of sediment and potential phosphorus loading into the lake.

Camp Road Quality of All Belgrade Lakes

Since Great Pond is the last of the Belgrade Lakes to be reported on, an important aspect of this report is the comparison of Great Pond results with the results of the other Belgrade Lakes. It is important to note that the road data for all lakes was not collected uniformly and that each year slightly different ways of classifying the calculated results were used (Fig. 50).

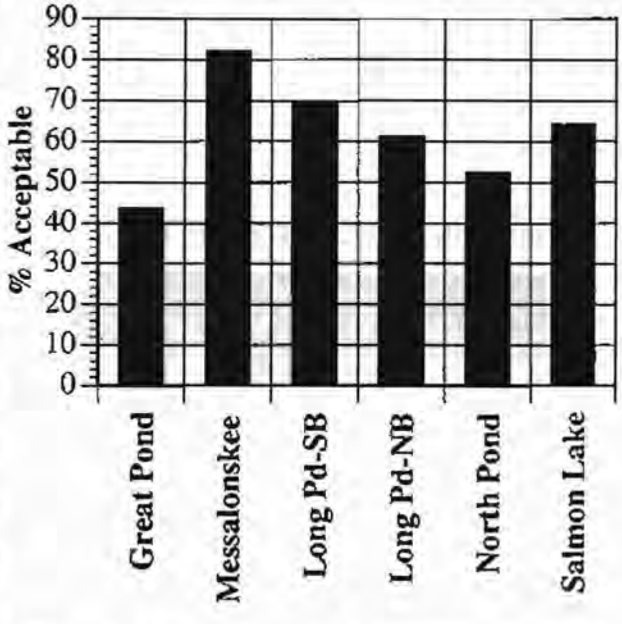

Figure 50. Percent of acceptable camp roads for all Belgrade Lakes Region Watersheds, except for East Pond. SB and NB refer to the South Basin and North Basins of Long Pond.

There were 107 Detail-surveyed roads of the Messalonskee Lake Watershed (BI493 1998). The Road Total Index values were split into six classification groups, with Class 1 being the best condition and Class 6 being the worst. Eighty-four percent of the roads fell into a range of acceptable road conditions.

The Detail-surveyed roads of the North Pond watershed were classified into four different groups with Class 1 being the best and Class 4 being the worst. More than 50 percent of the roads were placed in Classes 1 and 2, with 30 percent in Class 2. Overall the roads were reported to have a fairly even distribution throughout the classification groups (BI493 1997).

The Long Pond-South Basin Watershed had a total of 26 Detail-surveyed roads with a total of 84.7 percent falling into the first three of five classification groups to qualify them as being in acceptable condition (BI493 1996). The Long Pond-North Basin Watershed had a

total of 31 Detail-surveyed roads with only 11 reaching the Department of Environmental Protection's (DEP) standards of being acceptable roads (BI493 1995).

Non-detail-surveyed Roads

Non-detail-surveyed roads in the Great Pond Watershed are defined as any road non-lakeside of Rts 8, 27, and 225 that was surveyed using the Non-detailed Road Survey Form (see Appendix J). The number of Non-detail-surveyed roads (38) is one third the number of detail-surveyed roads (111), but the difference in their total mileage is only 11.8 miles (see Appendices N and O). These data show that although there are fewer Non-Detail surveyed roads, they cover a large area of the watershed because of their long lengths. Large contributors to the Non-detail-surveyed total mileage are: Belgrade-Rt 8 (4.4 mi) and Rt 27 (5.6 mi); Rome-Rt 225 (4.9 mi), Mercer Road (2.7 mi), and Worster Hill Road (2.4 mi). Non-detail-surveyed roads typically are further away from the waters of Great Pond than the Detail-surveyed roads. However, because these roads are within the watershed, they still have a potential effect on nutrient loading into the lake through their impact on groundwater, surface runoff, and tributaries.

General Land Use Trends Overview

The Great Pond watershed between 1965/66 and 1998 showed trends in land use. Wetlands, mature forest and cleared land area decreased. Transitional land (including logging land), developed land (including residential, and municipal/industrial land), and roads increased (Fig. 38 and Fig. 39). These general trends are similar to those found in the watersheds of the other Belgrade Lakes.

The amount of wetland area in the watersheds of the Belgrade Lakes shows a decreasing trend. There were two exceptions, North Pond and East Pond, in which the total wetland area remained stable. Wetlands in the Great Pond Watershed decreased by 4.7 percent (Table 7). This was the greatest decrease in wetland area for all the Belgrade Lakes. Wetlands probably decreased by a greater amount in the Great Pond Watershed because it showed the greatest increase in transitional land (Fig. 39 and Table 8).

Table 7. Percent change in land use for the Belgrade Lakes Watersheds based on aerial photography. Transitional land includes logging, reverting, and regenerating land. Developed land includes residential, municipal/industrial, and commercial land. Cleared land includes agricultural, crop, and grazing land. Data compiled by BI 493 courses 1991-1999. The northwest portion of the Great Pond Watershed (1998) was based on aerial photos from 1991.

	Great Pond	Messalonskee Lake	Long Pond-South Basin	Long Pond-North Basin	North Pond	Salmon Lake	East Pond
Wetlands	(4.0)	(0.4)	(0.2)	(0.2)	0.0	(0.5)	0.0
Mature Forest	(7.5)	30.8	39.3	(14.0)	(2.6)	0.0	(1.0)
Transitional Land	12.2	(34.6)	(34.6)	10.8	1.2	2.5	(1.0)
Developed Land	3.1	5.2	5.2	2.0	3.2	1.0	4.0
Roads	0.4	0.6	0.6	0.4	0.5	0.0	0.4
Cleared Land	(4.2)	(3.6)	(3.6)	0.6	(2.2)	(1.0)	(2.0)

Forests in the watersheds were subdivided into mature forest and transitional land. The mature forest area decreased by 8.5 percent for the Great Pond Watershed between 1965/66 and 1998 (Table 8 and Fig. 38). This figure was within the range for the other watersheds that showed a decrease in mature forest (1.0 percent to 14.0 percent) (Table 7). In all the watersheds of the Belgrade Lakes, mature forest decreased due to growth in development and logging. However, the watersheds of Long Pond-South Basin and Messalonskee Lake differed from the other five lakes. These two watersheds showed an increase in mature forest area (Table 7). This positive trend was due to transitional land naturally developing into mature forest. Also development may not have threatened the mature areas in the watersheds of Long Pond and Messalonskee Lake as greatly as in the other watersheds.

In the watersheds of Great Pond, North Pond, East Pond, Salmon Lake and Long Pond-North Basin transitional land increased while mature forest decreased. Transitional land in

Table 8 Land use area by percent composition of watershed for the Belgrade Lakes based on aerial photography. Transitional land includes logging, regenerating, and reverting land. Developed land includes residential, municipal/industrial, and commercial land. Cleared land includes agricultural, crop, and grazing land. Data compiled for two time periods by BI 493 courses 1991-1998. The northwest portion of the Great Pond Watershed (1998 only) was based on aerial photographs from 1991.

	Great Pond		Messalonskee Lake		Long Pond (South Basin)		Long Pond (North Basin)		North Pond		Salmon Lake		East Pond	
Year	1965/66	1998	1965/66	1991/1992	1965/66	1991	1980	1991	1965/66	1991	1980	1991	1965/66	1991
Wetlands	11.2	7.2	13.9	13.5	8.1	8.3	4.4	4.2	7.1	7.1	1.5	1.0	3.0	3.0
Mature Forest	41.4	33.9	27.6	58.4	18.7	58.0	82.0	68.0	77.9	75.3	83.0	83.0	78.0	77.0
Transitional Forest	33.3	45.3	38.7	4.1	61.6	27.0	3.8	14.6	0.8	2.0	0.5	3.0	3.0	2.0
Developed Land	2.8	5.9	3.6	8.8	3.6	5.7	7.0	9.0	1.5	4.0	3.0	4.0	10.0	14.0
Roads	0.4	0.8	0.7	1.3	0.3	0.5	0.6	1.0	0.2	0.7	1.0	1.0	1.6	2.0
Cleared Land	10.9	6.7	17.5	39.0	7.7	3.5	2.6	3.2	12.4	10.2	10.0	9.0	4.0	2.0

the Great Pond Watershed increased by 12.2 percent (Table 8). This value was the greatest for all the watersheds that showed an increase in transitional lands. The higher value corresponds with the relatively large decrease in cleared land (3.1 %) compared to the other watersheds (Table 8). The decrease in cleared land was due to grazing and crop land being left to undergo natural succession. The loss of cleared land and the increase in transitional land was greatest in the Great Pond Watershed. The Long Pond-South Basin and Messalonskee Lake Watersheds differed from the other lakes, showing a decrease of greater than 30.0 percent of transitional land (Table 8 and Fig. 38). However, the decrease in transitional land is similar in magnitude to the percent increase in mature forest for the two watersheds. This implies two things. The first is that transitional land in the Messalonskee Lake Watershed naturally succeeded to mature forest and the second is that development occurred on transitional land as opposed to mature forest.

Changes in mature forest and transitional land area in the watersheds of the Belgrade Lakes resemble each other. Generally, where mature forest increased, transitional land decreased. Correspondingly, where transitional land increased, mature forest decreased. The only exception to this general trend is East Pond. In this watershed, mature forest and transitional land decreased by 1.0 percent (Table 7). Part of the loss in forested areas was compensated in all the watersheds, except East Pond and Great Pond where there was a net loss in forested lands (Fig. 38).

The obvious discrepancies in the forest area of Long Pond-South Basin and Messalonskee Lake Watersheds with the other Belgrade Lake Watersheds could be due to differences with grouping land areas within different categories (Table 7). Each watershed study categorized land use types slightly differently. In some cases, this caused comparisons between watersheds to be misleading.

Developed land area showed positive trends in all the watersheds of the Belgrade Lakes Regions (Table 7 and Fig. 39). The developed land in Great Pond increased by 3.3 percent. This increase was greater than the development value for the other Belgrade Lakes, with the exception of Messalonskee Lake (5.2 %) and East Pond (4.0 %) (Table 7). Where developed land increased there was a corresponding net loss in forested lands, except in East Pond and Great Pond (Table 7).

The total road area in all the watersheds in the Belgrade Lakes Region increased, with the exception of Salmon Lake. Development in the Great Pond Watershed (0.4 %) was in the middle of the range for total road area of the other Belgrade Lakes (0.2 % to 0.6 %; Table 7 and Fig. 39). The lack of increased road area for the Salmon Lake Watershed suggests that even though developed land increased (1.0 %), the development increased along preexisting roads.

Cleared land decreased in all the watersheds except the Long Pond-North Basin Watershed (see Land Use: Cleared Land) (Fig. 39). The cleared area in Great Pond decreased by 3.1 percent (Table 7). This value was higher than the corresponding value for the other Belgrade Lake Watersheds with the exception of Messalonskee Lake. Generally, cleared land is usually replaced with developed land. As technology improves and household incomes are no longer dependent on land yields, decreases in cleared land correspond with increases in development (see Historical Perspectives). Cleared land that was no longer needed for agricultural based incomes or developed land that was left fallow ultimately resulted in forested areas. Consequently, transitional land increased as cleared land decreased. This trend has been observed in the Great Pond, North Pond and Salmon Lake Watersheds.

GIS Methodology

Geographic Information Systems (GIS) are computer hardware and software packages designed to store, analyze, and display spatially referenced data (information that can be related to some form of a map). The program utilized by Colby Environmental Assessment Team is macGIS - Version 3.0, created by Kit Larsen and David Hulse. This is a raster-based system, in which grid cells are the basic functional unit used to represent data. GIS maps differ from traditional maps in several important ways. Traditional paper maps are composite maps consisting of geographic features, such as lakes, forests, marshes, towns, roads, houses, and topographic lines representing elevation, all on one map. GIS maps can be used to represent the same information, but they separate each of these components into individual data layers.

A data layer is another name for a computerized map. Each data layer represents a single type of information, such as the land use type, roads, or topographic information. A data layer is composed of uniformly sized grid cells that are assigned numerical values, corresponding to geographic characteristics. Together these data layers form a database that can be combined to create composite maps. A series of data layers, each dealing with specific characteristics, may be mathematically manipulated and superimposed. New information may become apparent when two characteristics overlap in a specific area. Moreover, since the data are in a numeric form, quantitative analysis can be performed on the data using statistics that characterize pattern and variations in spatial distribution of data.

Before the GIS database was created, the size represented by each grid cell was determined. Ideally, the scale should be no more than 5 m per grid cell, since this is the width of most camp roads, the smallest resolution item on our maps. Increased resolution corresponds to increased number of grid cells in the watershed, particularly for large watersheds like the Great Pond Watershed. Due to time constraints, a balance had to be reached between the number of grid cells used and the size they represent. In our study, a grid cell size of 13 m by 13 m was used leading to a map with a more manageable number of grid cells (1.6 million). An initial map, using the scale and defining the number of rows and columns according to that scale, was used as the base map from which all other maps were created.

High resolution photographs of a culture and drainage map and topographic map were scanned into the computer. To create these two maps, CEAT combined US Geological Service mylar maps of the Belgrade, Belgrade Lake, Mercer, and Rome Quadrangles, 7.5 minute series, field checked 1974 through 1979 and edited 1980 through 1982. The scans were resized to fit the boundaries defined by the initial base map, and the scale was verified by counting the number of grid cells between mercator lines (lines on the map that are fixed distances apart). All of the GIS maps in the database were created using the culture-drainage map as a reference. Thus, all data layers were registered to each other.

Information was gathered from existing maps, aerial photographs, and field survey information and then converted into digital form. The process of assigning the numerical values to the map layer is the digitizing step. The numerical values often have no inherent relation to the geographic characteristics that they represent. For example, it does not matter if forested areas are labeled as 1 and marshes as 2, or the other way around, because forests and marshes are not inherently numeric. However, with topographic lines, the number represents the actual geographic feature, the elevation at that point. Independent of the numeric assignment, the categories represented by each number serve to encapsulate a large amount of quantitative and qualitative information.

Five maps were directly digitized from existing maps and form the basis of the GIS database. These were the lake and watershed map, the topographic contours map, the roads map, the soils map, and the land use map. The lake and watershed areas were digitized first, and serve to define the study area for all subsequent maps. Using the culture and drainage map as a reference, the area of the watershed and lake was traced onto a data layer.

The second map directly digitized was the topographical contours map. The topographic lines were traced onto the map layer at 50 ft intervals, and the computer interpolated the areas between the traced lines to create the relief map. The depths of the lake were digitized as discrete points from a bathymetric map of Great Pond, produced as part of the Navigational Aids Program for the Belgrade Lake Association by the Maine Department of Conservation, Bureau of Parks and Lands (printed July 1998). The computer interpolated the depths between these points to create the bathymetric map of the lake (Fig. 13). Data from the combination of these two maps created the relief map seen on the cover of this report.

The roads were traced onto a data layer from the culture and drainage map. Corrections were made to more closely reflect the roads surveyed in the watershed (see Land Use: Roads). The specifics of the soils map and land use map will be discussed in later sections.

Soil Types

It is imperative to have an understanding of the types and characteristics of soils when planning to develop an area in a lake watershed. Different soil characteristics, such as permeability, water table depth, and slope play an integral role in determining which sites may be suitable for development and/or septic use. Knowledge of these soil characteristics is useful in determining phosphorus loading budgets and land use development suitability.

Methods

The Great Pond Watershed contains twenty-five different soil series (Arno et al. 1972, Faust and LaFlamme 1978). A soil series consists of soils which have a similar profile. Each series has major horizons that are similar in thickness, arrangement, and other important characteristics. Variances within a soil series, such as surface texture, slope, or stoniness are used to classify a soil into a soil phase. A total of thirty different soil classifications of varying soil series and phase (Table 9) were digitized and entered into a macGIS data layer (see GIS Methodology). The data layer was used for creating subsequent maps (erodibility, septic suitability, and development suitability maps). These soil classifications were then grouped into five associations, for interpretive purposes, based on designations made by the USDA Soil Conservation Service for Kennebec County, Maine. A soil association is a landscape that has a distinctive pattern of soils in defined proportions, and is useful in giving a general idea of the soils in a survey area. Adams was the only soil series present in Somerset County and not present in Kennebec County. It was placed into the Hinckley-Windsor-Deerfield association based on its drainage properties, localities, and parent material. Leicester and Ridgebury soils were named as different soil series in each county, even though they share the same soil series characteristics (Arno et al. 1972, Faust and LaFlamme 1978). This soil will be referred to as Ridgebury hereafter.

Table 9. Composition and K-factor* values of the major soil types found in the Great Pond Watershed. Data obtained from Soil Interpretation Record (USDA Soil Conservation Service, unpublished document).

Soil Type	Composition	K-Factor
Adams	Loamy sand	0.17
Berkshire	Fine sandy loam	0.20 to 0.32
Berkshire	Very stony fine sandy loam	0.20 to 0.32
Biddeford	Mucky peat	0.32 to 0.49
Buxton	Silt loam	0.32 to 0.49
Deerfield	Loamy fine sand	0.17
Hartland	Very fine sandy loam	0.49 to 0.64
Hinckley	Gravelly sandy loam	0.17
Hollis	Fine sandy loam	0.20 to 0.32
Limerick	Silt loam	0.32
Lyman	Loam	0.20 to 0.32
Paxton	Fine sandy loam	0.20 to 0.32
Paxton	Very stony fine sandy loam	0.20 to 0.32
Paxton-Charlton	Fine sandy loam	0.20 to 0.32
Paxton-Charlton	Very stony fine sandy loam	0.20 to 0.32
Peru	Fine sandy loam	0.20 to 0.32
Peru	Very stony fine sandy loam	0.20 to 0.32
Ridgebury	Fine sandy loam	0.24 to 0.32
Ridgebury	Very stony fine sandy loam	0.24 to 0.32
Rifle	Peat and muck	< 0.10
Saco	Very fine sandy loam	0.32
Scantic	Silt loam	0.32 to 0.49
Scarboro	Mucky peat	0.17
Scio	Very fine sandy loam	0.49 to 0.64
Suffield	Silt loam	0.32
Togus	Fibrous peat	< 0.10
Vassalboro	Fibrous peat	< 0.10
Windsor	Loamy sand	0.17
Woodbridge	Fine sandy loam	0.20 to 0.32
Woodbridge	Very stony fine sandy loam	0.20 to 0.32

*Soil K-factor values range from 0 to 1; 0 = nonerodible, 1 = severely erodible

Soils of the Hollis-Paxton-Charlton-Woodbridge association are shallow and deep, somewhat excessively drained to moderately drained, gently sloping to moderately steep, moderately coarse textured soils found on hills and ridges (Faust and LaFlamme 1978). The major soils in this association were formed in glacial till.

Soils of the Buxton-Scio-Scantic association are deep, moderately well drained to poorly drained, nearly level to sloping, medium textured soils found in flat areas and near waterways (Faust and LaFlamme 1978). The major soils in this association were formed in marine and lacustrine sediments. The minor soils are Rifle, Suffield, Biddeford, and Hartland soils.

Soils of the Berkshire-Lyman-Peru association are deep and shallow, somewhat excessively drained to moderately well drained, gently sloping to moderately steep, medium textured and moderately coarse textured soils found on hills and ridges (Faust and LaFlamme 1978). The major soils in this association were formed in glacial till.

Soils of the Hinckley-Windsor-Deerfield association are deep, excessively drained and moderately well drained, nearly level to moderately steep, coarse textured and moderately coarse textured soils found mainly on outwash terraces and plains (Faust and LaFlamme 1978). The major soils in this association were formed in glacial outwash deposits. The minor soils are Vassalboro and Adams soils.

Soils of the Scantic-Ridgebury-Buxton association are deep, poorly drained to moderately well drained, nearly level to sloping, medium textured soils in flat areas or depressions found on upland ridges (i.e., not lowland areas or near waterways; Faust and LaFlamme 1978). The major soils in this association formed in marine or lacustrine sediments and in glacial till. The minor soils are Limerick, Scarboro, Saco, and Togus soils.

Results and Discussion

The most dominant soil series found in the Great Pond Watershed, in order of percent abundance, are; Berkshire, Woodbridge, Paxton-Charlton, and Peru soils. The most abundant soil association in the Great Pond Watershed is the Berkshire-Lyman-Peru association, consisting of 38.9 percent of the watershed (Fig. 51). This association dominates the northern and western portions of the watershed. The Hollis-Paxton-Charlton-Woodbridge association consists of 23.9 percent of the watershed and is found mainly in the southwest and eastern sides of the watershed. The Buxton-Scio-Scantic association consists of 20.6 percent of the watershed and is mainly found in the south central and northeastern parts of the watershed. The Scantic-Ridgebury-Buxton association consists of 9.5 percent of

the watershed, and the Hinckley-Windsor-Deerfield association consists of 7.1 percent of the watershed (Fig. 51).

Soil trends found in the different lake watersheds within the Belgrade Lakes Region were based on past BI493 reports and Soil Survey data from Somerset and Kennebec Counties (Arno et al. 1972, Faust and LaFlamme 1978, BI493 1994, BI493 1995, BI493 1996, BI493 1997, BI493 1998).

In the Long Pond-North Basin Watershed, Berkshire soils dominated the north and western side of the watershed; Lyman and Peru soil were also abundant on the western side of the watershed (BI493 1995). In the South Basin of Long Pond, Paxton soils were the most abundant soils and were scattered throughout the watershed; Lyman was abundant in the north end and Lyman-Hollis soils were scattered throughout the watershed area (BI493 1996).

In the North Pond Watershed, Berkshire soils were the most dominant, located on the north and western areas of the watershed (BI493 1997). Suffield soils were present on the eastern lake shore, and Adams soils were prevalent on the eastern side of the watershed, due to sand deposits left behind from a glacier (part of the Belgrade Esker/Delta Complex) (Kehoe 1982).

The Belgrade Esker/Delta Complex can also be found on the western part of the East Pond Watershed, where Adams soils are prevalent. Berkshire and Peru soils dominate the eastern part of the East Pond Watershed (Arno et al. 1972).

In the Salmon Lake Watershed, Berkshire soils are the most dominant and are located in the northwestern section of the watershed. Paxton-Charlton soils are present on the eastern side of the lake, and Woodbridge soils are found on the east side and scattered elsewhere throughout the watershed (BI493 1994).

Finally, in the Messalonskee Lake Watershed, Peru-Woodbridge-Paxton soils are the most abundant. They dominate the eastern and some northern portions of the watershed area (BI493 1998).

General soil trends of the Belgrade Lakes Region suggest a Berkshire dominated soil substrate. This is appropriate since Berkshire soils are formed in glacial till. The presence of Paxton soils on the south and southeastern portion of the region is also an indicator of glacial till. The presence of sandy soils, such as Adams soils, in the northern part of the region

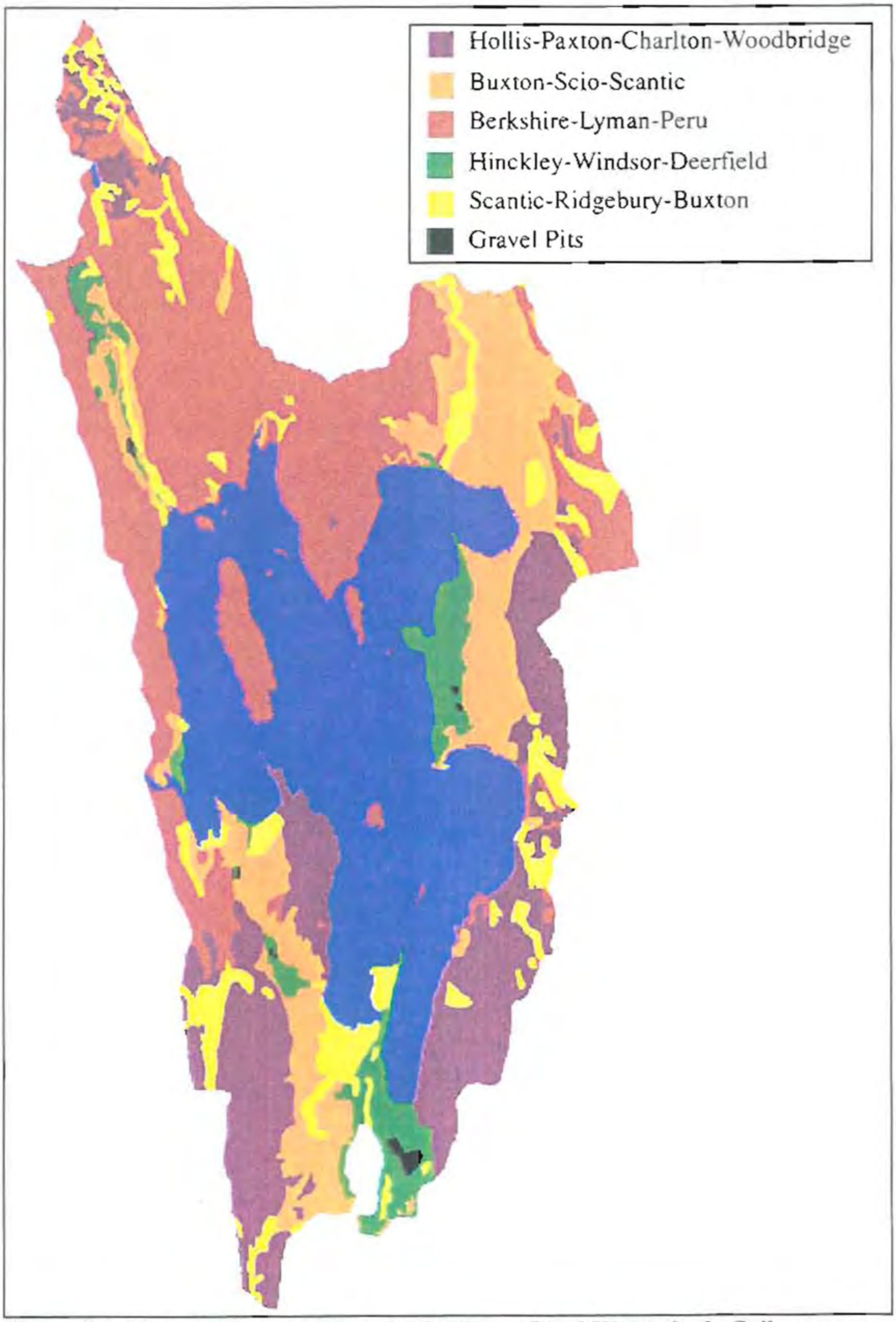

Figure 51. Major soil associations in the Great Pond Watershed. Soils map was based on data from the soil surveys of Kennebec and Somerset Counties, Maine (Arno et al. 1972, Faust and LaFlamme 1978). Soil associations were classified according to the Kennebec County, Maine, USDA, Soil Conservation Service. Approximate scale: 1 inch = 1.5 miles.

between North and East Ponds, is a relic of the Belgrade Esker/Delta Complex. It is one of many deltas associated with this complex found in the region. One can observe the esker/delta complex trend southward throughout the Great Pond Watershed by following the Horse Point esker south, through Pine Island and Foster Point. One can notice another delta complex just south of the Lake Messalonskee Watershed near Summerhaven, Maine.

The soil trends in the Great Pond Watershed are consistent with the observed regional trends. However, one must keep in mind that soil associations are a general classification of soils for a particular region. Therefore, it is suggested that for future land development in the Belgrade Lakes region, one would assess the soil quality on a site-by-site basis. Geology is an ongoing process. Soils age and change over time and so will their suitability for development.

Development Implications of Land Characteristics

Erodibility

Soil erosion is a potential source of lake pollution. Through the erosion process, soil particles may be carried into the lake by runoff. The removal of these soil particles by wind and runoff leaves the land area devoid of topsoil. The loss of the upper layers of absorptive soil exposes the less absorptive layers, resulting in more runoff of soil into the lake (Smith and Smith 1998). This increase in sedimentation has several negative effects. The nutrients that are carried into the lake by the soil, specifically phosphorus, stimulate algal blooms. These algal blooms accelerate the process of eutrophication (Novotny and Olem 1994). Erosion damages the aquatic habitat through this process because the lake may become anoxic. These algal blooms may also diminish the aesthetic value of the lake.

The human impact on the rate of erosion has been substantial. Different land uses such as agriculture and development typically accelerate the natural process of erosion. Soil compaction and the loss of vegetation are two major problems caused by development. Soil compaction is a reduction in the available space between the soil particles that prevents the soil from absorbing water properly and causes increased runoff. Machinery and agriculture

contribute to soil compaction. Development also causes a loss of vegetation when the area is cleared. The logging and plowing involved disrupts intricate root systems that hold the soil together, potentially allowing for more soil to be carried away with water. To determine the impact of these processes on erosion, the erodibility of the land in the Great Pond Watershed was examined.

Novotny and Olem (1994) explain that some soils may be more susceptible to wind and water stresses than others. Erodibility is a function of the soil particle size, texture of the material, water content, composition, and the presence or absence of a protective vegetative cover in the area. The soil erodibility factor (k-factor) is a measurement of the cohesiveness of the soil particles. According to Novotny and Olem (1994), the k-factor is a function of soil texture and composition, and is calculated in tonnes/unit using a rainfall erosion index for a 22 m flow length on a nine percent slope. Soil texture affects permeability and erodibility. A k-factor value of zero indicates that the area is not erodible and a value of one indicates that the soil is highly erodible. To determine the erodibility of an area, the k-factor and slope must be examined together. The slope of the land influences the retention and movement of water, which affects the rate of erosion. Since the k-factor is determined using a nine percent slope, the different slopes of the watershed need to be evaluated to adjust for slopes above and below nine percent.

Methods

An erodibility map was created using macGIS to determine which areas in the watershed were prone to different levels of erodibility. This information can be used in planning future development as well as re-evaluating current establishments that are experiencing problems with erosion.

The slope map was created from the relief map of the Great Pond Watershed (see GIS Methodology). The computer calculates the percent slope for each grid cell by averaging the eight surrounding grid cells. The watershed was divided into the following percent slope categories: 0 percent to 3 percent, 4 percent to 8 percent, 9 percent to 15 percent, 16 percent to 30 percent, and above 30 percent. These categories were assigned numerical values for further manipulations.

A k-factor data layer was created from the soil map by grouping the soils according to their specific k-factors (USDA Soil Conservation Service, unpublished data). Some soil types had a range given for the k-factor, so the mean value was used as the k-factor.

The slope map and the k-factor data layer were combined to create the erodibility map. Qualitative ranges for examining the percent slope and k-factor were established with help from District Conservationist Peter Newkirk to determine the different levels of erodibility: slight, moderate, high, and severe (Table 10). These new categories were assigned values to create the Erodibility Map.

Table 10. The level of erodibility as determined by K-factor (USDA Soil Conservation Service, unpublished data) and percent slope. Qualitative ranges established in consultation with District Conservationist Peter Newkirk (pers. comm., USDA-Natural Resource Conservation Service, Augusta).

K-factor	0-3%	4-8%	9-15%	16-30%	>30%
0.10	Slight	Slight	Moderate	High	High
0.17	Slight	Slight	Moderate	High	High
0.26	Slight	Moderate	High	High	Severe
0.28	Slight	Moderate	High	High	Severe
0.32	Moderate	Moderate	High	Severe	Severe
0.41	Moderate	Moderate	High	Severe	Severe
0.49	Moderate	Moderate	High	Severe	Severe
0.57	Moderate	High	High	Severe	Severe

Results and Discussion

The erodibility map was used to determine which areas of the Great Pond Watershed had different levels of susceptibility to erosion. Based on our analysis, the majority of the watershed is categorized as slightly or moderately erodible. The areas with high and severe erodibility categories are found in the steepest areas, as well as in some areas along the shoreline. The gravel pits were not taken into account when calculating these percentages. Gravel pits contribute to nutrient loading in the lake, but they were not included in the soil categories.

Slightly erodible areas were found in 44.3 percent of the Great Pond Watershed land area (Fig. 52). The most common soils found in the slightly erodible soils are included in the Scantic-Ridgebury-Buxton association. The slightly erodible areas are located primarily along the southern shorelines and in surrounding areas of the lake, occurring along with

moderately erodible soils. Shoreline homes constitute 49.3 percent of total homes in the watershed (see Land Use: Residence Count). It is reassuring to know that some of these houses are located along only slightly erodible soils. Using the criteria established for erodibility (Table 10), wetlands fall into the slightly erodible category because of their soil type and low percent slope. However, wetlands are not suitable for any type of development. Wetlands are nutrient sources and sinks, and should be left undisturbed because they have poor drainage and unstable sediments (Thompson 1979). Austin Bog is one of the wetlands in the Great Pond Watershed. The bog is classified as slightly erodible, but should not be developed.

Moderately erodible areas are found in 29.9 percent of the watershed land area (Fig. 52) These areas are found throughout the watershed, as well as in the marshland in the North Bay area. The soils in the North Bay area are included in the Buxton-Scio-Scantic association. Development is not suitable here because it is a wetland. Development can occur on other moderately erodible soils if proper precautions are taken (see below).

Highly erodible areas are found in 23.5 percent of the watershed land area (Fig. 52). The most common soils found in the highly erodible areas are included in the Berkshire-Lyman-Peru association, the Hollis-Paxton-Charlton-Woodbridge association, and the Hinckley-Windsor-Deerfield association. Highly erodible areas are found along the Horse Point shoreline, the Pinkhams Cove shoreline, The Mountain, Mount Philip, and Mosher Hill. A large amount of highly erodible land is found in the northwest corner of the watershed, due to the high slopes found there. The green lines shown on the map (slightly and moderately erodible) in the Mosher Hill area (Fig. 52). are the result of the computer calculations. These areas are highly erodible, due to the high slopes found here. The computer calculates the mean percent slope of 13 m by 13 m grid cells, resulting in some plateaus of low slope which are misleading. There are also several other highly erodible areas scattered throughout the watershed. Proper precautions should be taken in the areas along the Horse Point and Pinkhams Cove shorelines that are already developed to prevent further erosion. Future development should be researched and carefully planned in these areas to avoid erosion. Thirteen percent of shoreline houses in the watershed are located in eastern Pinkhams Cove, and the buffer strips in this area received a low rating (see Land Use: Shoreline Buffer Strips). This is a cause for concern, because the area is categorized as high

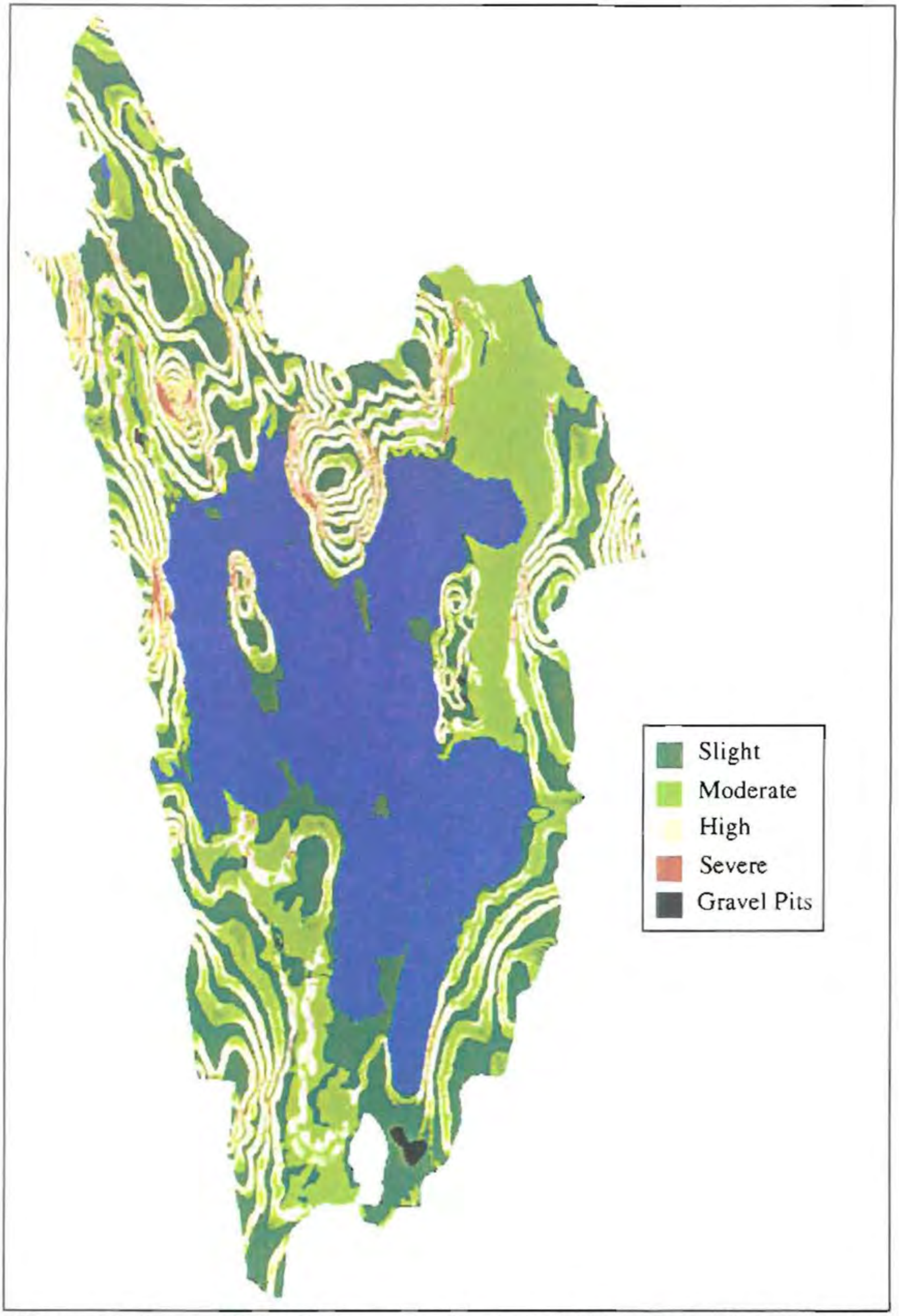

Figure 52. Levels of Erodibility in the Great Pond Watershed. Erodibility is the ease with which soil particles are carried away by run-off. Severe erodibility indicates areas likely to contribute large amounts of sediment into the lake water. Qualitative ranges established with District Conservationist Peter Newkirk (pers. comm., USDA-NRCS, Augusta). Approximate scale: 1 inch = 1.5 miles.

erodibility, contains a large percentage of homes, and is poorly protected from runoff. The result of these problems could be excessive sedimentation in the lake. The Hatch Cove/Horse Point/Stony Point Area consists of 19.0 percent of shoreline houses, and is also a highly erodible area. Jamaica Point, Chute Island, and Crooked Island make up 27.0 percent of shoreline houses, and have high erodibility ratings. These areas need to be examined further and action needs to be taken to prevent erosion in these highly developed areas.

Severely erodible areas are found in 2.4 percent of the watershed land area (Fig. 52). These areas are found along the high elevations including Mosher Hill, Mount Philip, and The Mountain, as well as a few other areas throughout the watershed. Development is not suitable in these areas.

The residents in areas along the shoreline that have moderate or highly erodible soils need to take the proper precautions to avoid an increase in nutrient loading into the lake. There are several methods available to reduce erodibility in existing developed areas (see Land Use: Shoreline Buffer Strips).

Several preventative measures can be taken to minimize erosion during construction. Construction increases the rate of erosion 200 to 2000 times the natural rate (Fact Sheet #03, Cumberland County Soil and Water Conservation District (SWCD)). Erosion from construction generally forms gullies (Novotny and Olem 1994). It is recommended that a study be performed before construction begins to ensure that the soil type is adequate for the planned development. It is also important to know the natural drainage pattern of the area and to plan development accordingly if at all possible. Preserving existing vegetation and preventing excessive use of heavy machinery is important in stopping erosion (Fact Sheet #03, Cumberland County SWCD). Prior to construction, it is important to fit the plans to the climate, topography, soil type, and vegetative cover of the area (Powell, Winter, and Bowditch 1970). During construction, the area of disruption and duration of exposed soils should be reduced. When construction is halted, the exposed soils must be covered, either by mulch, fast-growing vegetation, hay bales, fiber mats, plastic, or straw. Silt fences can be erected during construction to prevent erosion. Another option is to stockpile the soils during construction, ensuring that the quality topsoil is replaced on top (Powell, Winter, and Bowditch 1970).

Before comparing the results for the Great Pond study to the other Belgrade Lakes, it is important to compare the methodology of the studies. The methods used for creating the erodibility map for the Great Pond Watershed differed from previous studies. Each individual soil type was digitized, as opposed to grouping them into associations first, and then digitizing. This change in methods gives more accurate results for each area of the watershed. Different criteria for the Great Pond Watershed categories were established, since more soils were present and some k-factor values were averaged. The number of erodibility categories established differed among the studies, as did the number of slope categories.

There was no information available on erodibility from the Long Pond-North Basin (BI493 1995) and Long Pond-South Basin (BI493 1996) studies. GIS was not used in the East Pond study, however potential erosion was evaluated by examining gravel pits and construction sites located near the lake (BI493 1991).

The Messalonskee Lake study found that 56.0 percent of the land area was slightly erodible, 34.5 percent was moderately erodible, 8.8 percent was highly erodible, and 0.4 percent was severely erodible. These results are similar to the Great Pond study that also found the majority of the watershed land area to be slightly or moderately erodible. The slightly erodible areas in the Messalonskee Watershed were found in the marsh areas and along minor slopes, which is similar to the results for Great Pond. The moderate areas of erodibility were along the shoreline, which was also found in Great Pond (BI493 1998).

The North Pond study defined two categories for erodibility classification: Not Highly Erodible Land and Highly Erodible Land. The study found that 41.2 percent of their watershed area was highly erodible (BI493 1997).

The Salmon Lake study found that 52.0 percent of the watershed area had low erodibility, 24.0 percent had moderate erodibility, and 24.0 percent had high erodibility (BI493 1994).

Erodibility potential should be used to determine whether an area is suitable for development or not. In the Great Pond Watershed, the majority of the land area is categorized as slightly or moderately erodible, due to the soils and slopes present in these areas. However, there are several shoreline areas that have high erodibility, and residents in these areas should take the proper precautions to prevent erosion.

Septic Suitability

Increased development in the Great Pond Watershed results in a greater number of septic systems, which increases the potential phosphorus loading into the lake. It is important to examine the septic suitability of an area when considering development. Septic suitability is a rating describing the ability of the land to allow for the leaching of sewage from septic systems without harming or contaminating the land and surrounding water. The United States Department of Agriculture (USDA) Soil Conservation Service cites texture, permeability, depth to water table, depth to restricting layer, depth to bedrock, flooding, stone cover, natural drainage class, and slope as factors affecting septic suitability (USDA Soil Potential Ratings for Low Density Development in Kennebec County Soil and Water Conservation District). With the exception of slope, these are all characteristics of soil type (see Soil Types).

Hydric soils, which have a permanently high water table, and areas with a seasonally high water table cause contamination of groundwater due to insufficient leach field capacity (USDA Soil Potential Ratings). Maximum water heights in seasonally wet soils generally occur in April, as snow is melting and the ground is thawing. A shallow depth to bedrock does not provide a sufficient leach field for sewage and may also cause an artificially high water table, resulting in contamination of groundwater. Permeability, which is defined as the rate at which water moves vertically through the soil, has varying implications. High permeability results in the leaching of water through the soil before sewage decomposition is complete, thus contaminating groundwater. However, low permeability prevents effluent from diffusing into the leach field, causing increased surface runoff and direct contamination of the lake. Steep slopes may cause lateral seepage and flow of effluent into the lake as well. Special design of septic systems may be necessary in areas of 3 percent to 15 percent slope. Slopes greater than 15 percent are considered unsuitable for septic systems (USDA Soil Potential Ratings).

With the exception of hydric soils and extremely steep slopes, mitigation can be undertaken to increase the septic suitability and decrease the possibility of water contamination from sewage. In the cases of hydric soils and steep slopes, corrective measures would be so expensive and unrealistic that septic systems are essentially prohibited in these areas (USDA Soil Potential Ratings).

Methods

The soil and slope maps were combined in order to make a map layer consisting of soil types separated into slope categories: 0 percent to 3 percent, 3 percent to 8 percent, 8 percent to 15 percent, 15 percent to 30 percent, and greater than 30 percent. The rating system included in Soil Survey Data for Growth Management in Kennebec County, Maine, published by the USDA Soil Conservation Service, was used to group the soil and slope categories into very high, high, medium, low, and very low ratings of septic suitability (USDA 1989, see Appendix P). These soil potential index ratings reflect the soil potential, costs of corrective measures, and continuing costs required to enable development (USDA Soil Potential Ratings). A very high rating indicates the soil conditions and properties are favorable (without any of the limitations discussed above), and the septic installation costs should be relatively low. A very low rating indicates severe soil limitations and extremely high, prohibitive costs.

The USDA Soil Conservation Service rating system did not include ratings for some of the soil types as well as soil and slope category combinations found in the Great Pond Watershed; thus some adjustments and extrapolations were necessary in order to complete the map. The Adams soil type was not rated in the Soil Survey Data for Growth Management in Kennebec County, Maine because it is found in Somerset County. No comparable listings were available for Somerset County; thus Adams was rated according to its characteristics and compared with similar soil types found in Kennebec County. In cases where ratings were given for more than one slope category for a given soil, we used the rating pattern to extrapolate the ratings for slope categories not given. In cases where only one slope category was given, we used the rating pattern in similar soil types to infer the slope categories not included. A rating of very low was assigned to all soils found in the slope categories 15 percent to 30 percent and greater than 30 percent, as septic systems are not recommended in these areas. Gravel pits, which are unsuitable for septic systems regardless of slope, were not rated by the USDA in the publication used and were displayed separately in the septic suitability map.

Results and Discussion

Areas of very high septic suitability comprise 20.4 percent of the total land area within the watershed, excluding gravel pits (Fig. 53). In these areas, septic development has the least potential effects on the watershed and water quality of Great Pond. The majority of these areas are found away from the shoreline of the lake with the exception of the area on Long Point. The area on Long Point consists primarily of Woodbridge soils, which are deep and moderately well drained. In addition, it is an area of shallow slope resulting in very high septic suitability. Areas of high septic suitability comprise 33.5 percent of the total land area (Fig. 53). This rating includes much of the shoreline where development has already occurred and is likely to continue in the future. Areas of medium septic suitability comprise 12.6 percent of the total land area within the watershed (Fig. 53). These areas are mostly present on the esker area, from Snake Point to Stony Point, consisting of Hinckley soils. These soils are excessively drained, which can contribute to groundwater contamination. Low septic suitability areas constitute only 1.3 percent of the land area in the watershed and are found mainly on areas with increasing slopes (Fig. 53). Septic construction should be limited and appropriate precautions should be taken in these areas. Very low septic suitability areas constitute 32.2 percent of the land area, indicating areas that are unsuitable for septic systems (Fig. 53). There is one large area of very low septic suitability around North Bay and extending south, inland of Horse Point. This is largely due to the bog and swamps found in this region. The hydric soils are unsuitable for septic systems and corrective measures are ineffective in these areas. A similar area exists at the south end of Great Pond around Austin Bog. Other areas of very low septic suitability are found on steep slopes, particularly in much of the northern portion of the watershed, around areas such as Mount Phillip, Mosher Hill, and The Mountain. Septic construction should be avoided in these areas.

The methodologies of the various studies of all of the Belgrade Lakes varied in terms of septic suitability. Many of the previous studies used rating categories of suitable, moderately suitable, and unsuitable for septic systems (BI493 1995, BI493 1997). In addition, the method for classifying soil types and slope also varied, thus the criteria for each septic suitability rating may be different in each study. For example, the 1997 North Pond study used perched and apparent (soil characteristics), depth to water table, depth to bedrock,

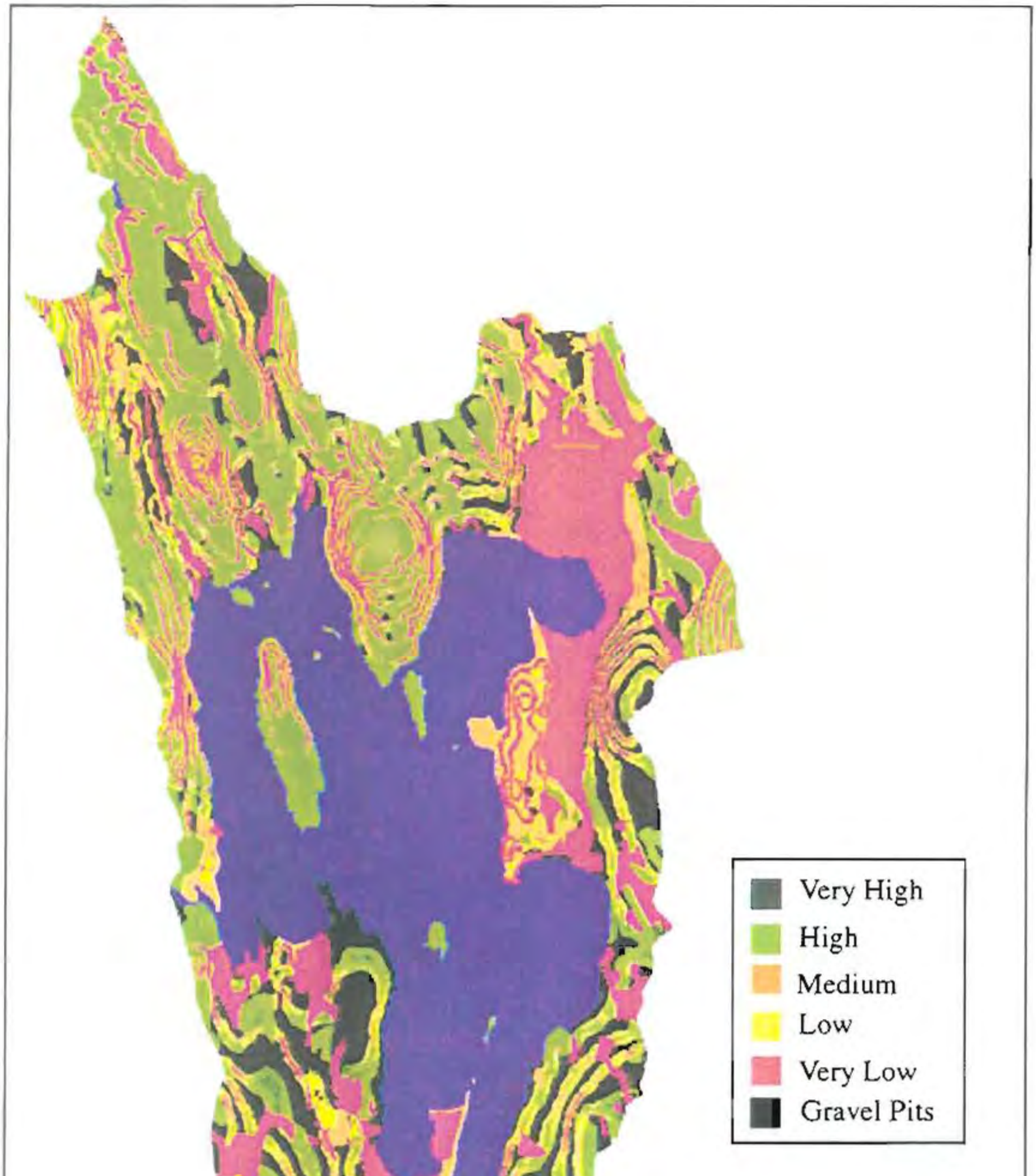

Figure 53. Septic suitability in the Great Pond Watershed. Very High suitability indicates areas where soil and slope conditions are adequate to prevent sewage contamination of groundwater and lake water. Very Low suitability indicates areas where soil and slope conditions will likely result in sewage contamination. Ratings from USDA Soil Conservation Service (1989).
Approximate scale: 1 inch = 1.5 miles.

hydric soil, and slope as criteria for septic suitability classification, while the 1995 Long Pond-North Basin study used erodibility, depth to bedrock, and slope (BI493 1995, BI493 1997).

Keeping these discrepancies in mind, septic suitability was compared for Great Pond, North Pond, and Long Pond-North Basin (Fig. 54). For this comparison, very high and high ratings in Great Pond were grouped as suitable, medium was used for moderate, and the low and very low ratings were grouped as unsuitable. Of the three lakes, Great Pond shows the largest percentage of land area suitable for septic systems. Due to the discrepancies in methodologies and the lack of comparable information for Messalonskee Lake, Long Pond-South Basin, Salmon Lake, or East Pond further research is necessary to accurately compare all of the lakes in the Belgrade Lakes Region.

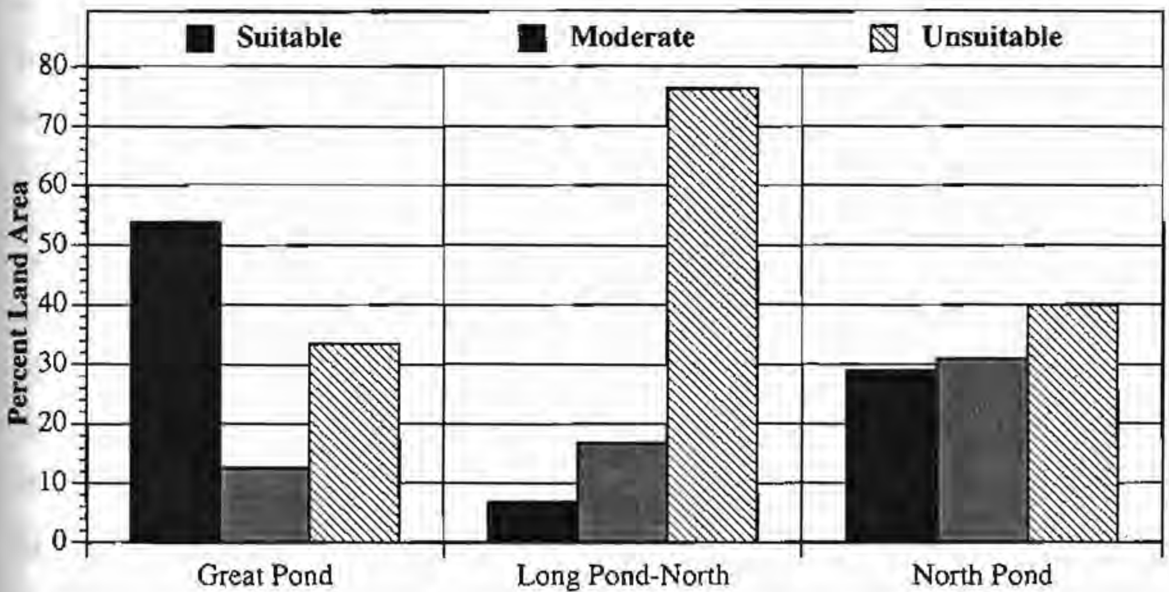

Figure 54. Comparison of septic suitability for three of the Belgrade Lakes. Suitable indicates areas where soil and slope conditions are adequate to prevent sewage contamination of groundwater and lake water. Moderate indicates areas less appropriate for septic systems. Unsuitable indicates areas where soil and slope conditions will likely result in sewage contamination of groundwater or lake water. Data from BI493 1995, 1997, and 1999.

Great Pond is one of the most developed lakes in the Belgrade Lakes Region. It is important to consider septic suitability when examining current and future development. Three specific areas of concern due to low septic suitability ratings and the presence of existing development are along the shoreline in Pinkhams Cove, particularly western

Pinkhams Cove, northern Hatch Cove, and from Stony Point to Snake Point. These are areas of medium or lower septic suitability ratings where development is heavy (see Land Use: Residential Land). Corrective measures are particularly important in these areas.

The USDA Soil Conservation Service lists corrective measures necessary for various factors limiting septic suitability (USDA Soil Potential Ratings). Areas with a depth to water table ranging from 4.00 ft to 1.25 ft can be filled to prevent damage from septic systems. In areas with a depth to water table less than 1.25 ft, special septic system design and replacement septic systems are necessary. Areas of steeper slopes (equal to or greater than 8 percent) require site preparation, fill, and sometimes erosion control, to prevent damage from septic systems. Depth to bedrock is another common limiting factor for septic suitability. In areas where depth to bedrock is 24 inches to 48 inches, site selection, preparation, and fill are necessary precautions. Areas of depth to bedrock 15 inches to 24 inches require special septic system design and areas less than 15 inches prohibit new septic system installment (USDA Soil Potential Ratings). All of these corrective measures can be expensive, and effectiveness varies according to installment and upkeep of the septic systems. The Great Pond Watershed has many areas of higher septic suitability, some along the shoreline, providing numerous locations for future development.

Development Suitability

Methods

Development suitability is important for evaluating current and future development. The Colby Environmental Assessment Team (CEAT) followed the same methodology for determining development suitability as described in the Septic Suitability section (see Septic Suitability, Appendix P). For this study, the slope map and the soil map were combined to create a data layer with soil types separated by slope categories. CEAT used a ranking system to group the categories into very high, high, medium, low, and very low ratings of development suitability. This ranking system is based on the definition of Low Density Development given by the USDA. This development is based on single family unit residences with basements, septic absorption fields, and roads (USDA Soil Potential Ratings for Low Density Development in Kennebec County Soil and Water Conservation District).

Septic tank absorption fields are expected to function year-round without polluting the groundwater. Dwellings with basements are evaluated to ensure that the concrete wall is built on undisturbed soil and has proper drainage. The roads are examined to ensure that culverts are present and that vegetative cover is used to prevent erosion (USDA Soil Potential Ratings). The development suitability ratings were determined by a weighted average of the following soil potentials: 45 percent septic tank absorption fields, 20 percent dwellings with basements, and 35 percent local roads and streets (USDA 1989). A rating of very high indicates the area is very suitable for development. Similar adjustments were made to the development suitability ranking system, as described in the Septic Suitability section, for soils that were found in the Great Pond Watershed that were not included in this system (see Septic Suitability).

Results and Discussion

Areas of very high development suitability constitute 0.3 percent of the total land area within the watershed, excluding gravel pits (Fig. 55). This consists of a few small areas, mostly along the outer edges of the watershed. It is these areas which are best suited for development when considering septic tank absorption fields, dwellings with basements, and local roads and streets. While areas of very high development suitability represent a small percentage of the watershed, high development suitability areas consist of 39.7 percent of the land area. These areas are primarily concentrated in the northern section of the watershed, including some shorelines, particularly those along the western and northern sides of Great Pond. These areas present many options for shoreline and non-shoreline development. Medium development suitability areas constitute 28.5 percent of the land area. These areas are concentrated in the southwestern and northeastern sections of the watershed, particularly in areas surrounding the wetlands. Only 0.9 percent of the land area has a low development suitability rating. The majority of this land is in areas of increasing slope. However, 30.6 percent of the land area has a very low development suitability rating indicating areas where development should not take place (Fig. 55). These areas are primarily found in the wetland area of North Bay, extending south, inland of Horse Point in the north, and the wetland area of Austin Bog in the south, where hydric soils largely limit development possibilities.

These trends for development suitability are similar to those found for septic suitability, although when considering additional factors of dwellings with basements and

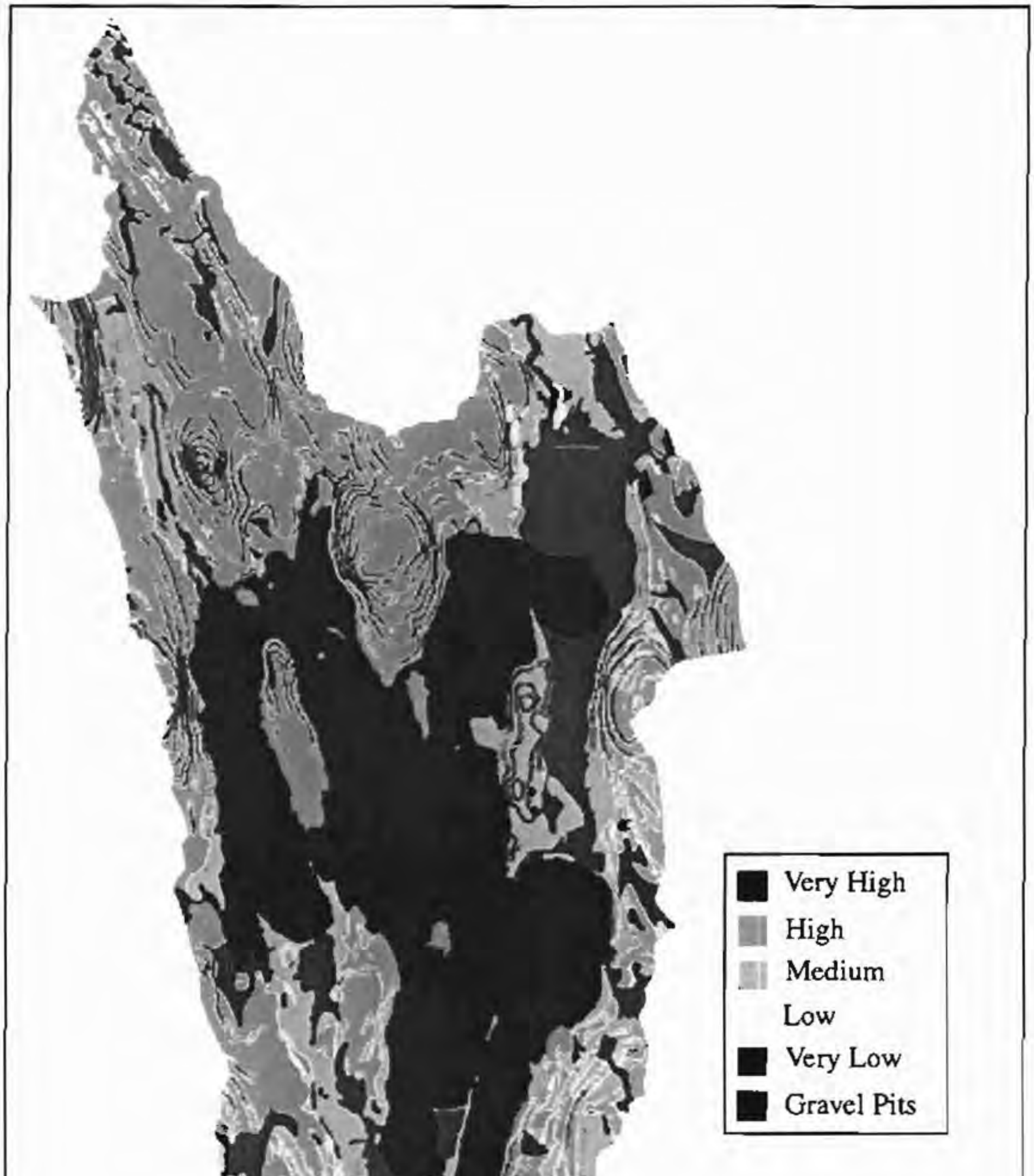

Figure 55. Development suitability in the Great Pond Watershed. Very High development suitability indicates areas where soil and slope conditions are most appropriate for septic systems, dwellings with basements, and roads. Very Low development suitability indicates areas where soil and slope conditions prohibit such development. Ratings from USDA Soil Conservation Service (1989). Approximate scale: 1 inch = 1.5 miles.

local roads and streets, the areas suitable for development are more limited. It is important to consider these factors when evaluating potential development projects. Development should be avoided in areas of very low development suitability. In other areas, corrective measures, similar to those suggested for septic suitability, may be necessary to protect the Great Pond Watershed and the water quality in Great Pond (see Septic Suitability).

Of all the lakes in the Belgrade Lakes Region, development suitability has only been evaluated by the Colby Environmental Assessment Team for Salmon Lake and Great Pond. In the Salmon Lake study, development suitability was classified using the following criteria: soil permeability, erodibility, and septic suitability (BI493 1994). The different criteria used in the Salmon Lake and Great Pond studies prevent exact comparisons. Keeping in mind these differences, the Salmon Lake study shows 36.0 percent of the Salmon Lake Watershed land area as suitable for development (BI493 1994). Similarly, in the Great Pond Watershed, 40.0 percent of the land area is highly suitable for development if the very high and high ratings for development suitability are combined. Further study is necessary to make comparisons for development suitability in all of the Belgrade Lakes.

Logging Suitability

Methods

Logging suitability is an important factor for evaluating future land use decisions involving the removal of vegetation. To make the Land Use map, information found in aerial photographs was digitized into macGIS based on the established categories of transitional forest, mature forest, logged land, wetlands, industrial/municipal uses, cleared land, and residential land (see Land Use: Land Use Methodology).

A data layer of the transitional and mature forest areas was created to separate these forested areas from the other land use types in the watershed. This data layer was combined with the erodibility map to establish forested areas that have different logging suitability levels, based on slope and soil types. Erodibility levels depend on soil type, slope and vegetative cover. If an area is logged, the machinery used may cause an increase in soil compaction and lead to accelerated erosion levels (see Erodibility). Skidder trails create erosion lanes that are left as bare soil and enable runoff to flow into the lake more easily,

potentially increasing sediment and phosphorus loading. The logging suitability categories established were high, moderate, low, and very low. High logging suitability indicates that the forested area has slight erodibility. Moderate logging suitability indicates a moderately erodible forested area. Low logging suitability indicates that the forested area is highly erodible, and very low logging suitability indicates the forested area is severely erodible.

Results and Discussion

Forested areas represent approximately 75 percent of the land area in the Great Pond Watershed. Further logging within the watershed is likely. As discussed in the Land Use section of this report, the amount of logging within the Great Pond Watershed has increased over time. It is important to consider the logging suitability of an area when evaluating future logging plans. Logging suitability trends can be seen on the logging suitability map (Fig. 56).

Of the total forested area within the watershed, nearly half (46.3 percent) is classified as highly suitable for logging. The areas of high suitability occur throughout the watershed. The largest continuous areas of high suitability occur in the northern portion and the southeastern areas of the watershed. As discussed in the Erodibility section of this report, there is some artifact due to the resolution of the data. It is unlikely that the mountains plateau in the way illustrated in the Erodibility and Logging Suitability figures (see Erodibility). Thus, the highly suitable areas occurring in concentric bands of low suitability are not recommended for logging use, despite the highly suitable rating. Despite high suitability ratings, the shoreline of the lake and surrounding wetland areas are not recommended for logging. Areas close to the shoreline have insufficient buffering capabilities for logging development, and logging in these areas could lead to severe erosion problems.

As shown in the Land Use map (Fig. 35), the largest patches of undisturbed mature forest are in the northern portion of the watershed. It is therefore especially important to_examine the suitability of this area for logging. In general, this area coincides with large patches of land that is rated highly suitable for logging (Fig. 56).__Therefore_ the trend of increased logging in the Great Pond Watershed, as described in the Land Use section of this report, is likely to continue.

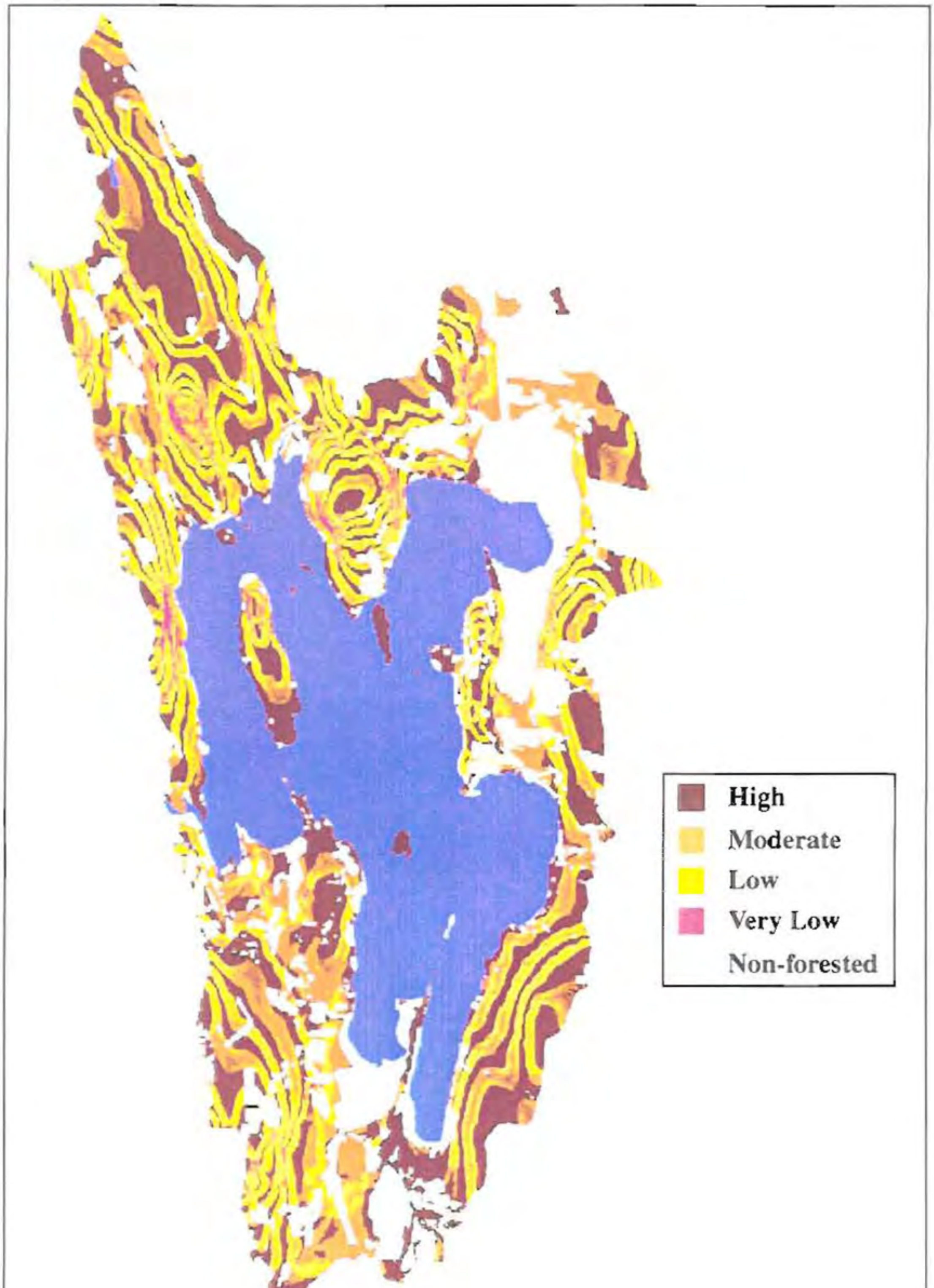

Figure 56. Logging suitability in the Great Pond Watershed. High suitability indicates areas where soil and slope conditions appear adequate to prevent erosion during logging. Approximate scale: 1 inch = 1.5 miles.

Of the remaining forested areas, 24.4 percent are considered moderately suitable for logging. These areas occur mostly in the northeast around the bog and wetland areas and in areas of increasing slope. Less than 30 percent of the total forested land within the watershed is considered to have low or very low suitability for logging. Low suitability constitutes 26.5 percent of the forested areas. These areas occur mostly on the slopes within the Great Pond Watershed. Only 2.8 percent is very low logging suitability. These areas of very low suitability occur only in areas of steep slope, such as Mosher Hill, Mount Phillip, and The Mountain.

Because of limited data, comparison of Logging Suitability maps was only possible with one other Belgrade Lake, North Pond (BI493 1997). Less than 30 percent of the Great Pond Watershed was found to be of low or very low suitability for logging due to highly erodible soils whereas the North Pond Study found 43.7 percent of forested land to be on highly erodible soils. Some of this difference may be attributed to differences in creation of the Erodibility maps within each study (see GIS: Erodibility).

Development Corridors

Methods

The development corridors map was created directly from the roads map (see GIS Methodology). Since an additional utility pole is required for all houses more than 200 ft from the road, utility companies charge additional hook-up fees for these developments. For this study, Colby Environmental Assessment Team therefore assumed that most short term future development would occur within a 200 ft corridor around existing roads. Further, the shoreline area of the lake is most sensitive to degradation during development. The shoreline region was defined as the area within 200 ft of the lake. This area was highlighted in red on the development corridors map to signify the increased environmental risk of development in this area.

Results and Discussion

The total area of the watershed that falls within the development corridors is about 4100 acres, representing 20 percent of the total land area in the watershed (Fig. 57).

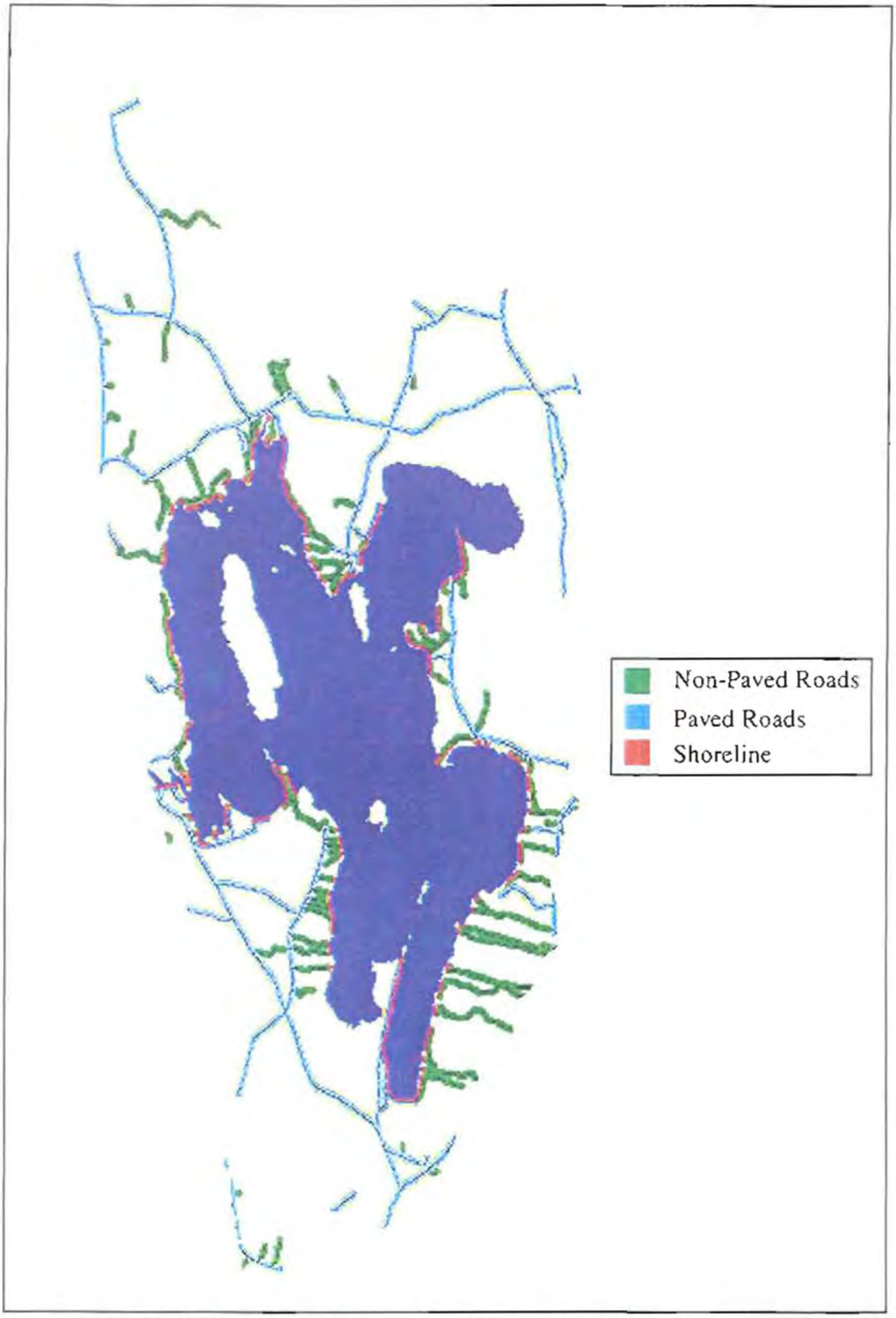

Figure 57. Development corridors in the Great Pond Watershed. Development corridors (areas likely for future development) are designated as extending 200 ft on either side of existing roads. Shoreline area is designated as extending 200 ft from the shoreline of the lake. Road information from US Geological Survey (1980) and BI493 field survey. Approximate scale: 1 inch = 1.5 miles.

Development is likely to occur along existing roads within the watershed, increasing the traffic. This is a concern along poorly surfaced dirt roads within the watershed, as increased traffic is likely to mean an increase in the problems associated with these roads (see Land Use: Roads). Many of the roads within the watershed are in poor condition, and will further deteriorate with increased usage resulting from the increase in development along the roads.

About 30 percent of the total shoreline area falls within the development corridors. Most of this area has already been developed (see Land Use: Residential Land). The total area of the watershed classified as shoreline land is approximately 1000 acres. Of this, about 30 percent (300 acres) of the shoreline is developed. This represents all of the shoreline that falls within the development corridors.

The most heavily developed shoreline areas are Pinkhams Cove, Hatch Cove, Snake Point to Stony Point, and Coe and Jamaica Points. These areas fall within the shoreline development corridors, reinforcing the idea that the shoreline areas within the development corridors are already developed (Fig. 57). Much of the shoreline that has not been developed is located along wetlands, such as Austin Bog, and falls within areas which are unsuitable for development (Fig. 55). Existing development, such as in the Pinkhams Cove area, falls within development corridors but also corresponds to areas of very low development suitability (see Development Suitability). The area between Abena Point and Long Point is another area of concern. This area is of medium to very low suitability for development, but falls within the development corridors of the shoreline. This area, despite the low suitability, has been or is likely to be developed.

When the development corridors map of the Great Pond Watershed is compared to the maps of the other Belgrade Lakes Watersheds, similar trends are apparent. In general, much of the area within the development corridors is already developed, especially along the shoreline of the lakes. However, due to differences among GIS methodology and reporting, more concrete comparisons are not possible.

PHOSPHORUS LOADING

Introduction

The Phosphorus Loading Model is a model used to approximate the total amount of phosphorus entering a body of water from a variety of sources in a given year (Reckhow and Chapra 1983). A critical tool in assessing overall water quality, it is used to identify problem sources of phosphorus loading in the watershed. In addition, the model can also be used to predict the phosphorus loading consequences of development, changes in land use, and future population changes within the watershed (see Future Trends: Factors Influencing Phosphorus Loading).

Methods

The model for total phosphorus loading used in this investigation was adapted from Reckhow and Chapra (1983) to estimate the total amount of phosphorus entering Great Pond from the atmosphere and surrounding watershed in 1998.

$$\mathbf{W} = (Ec_a \times A_s) + (Ec_f \times Area_f) + (Ec_l \times Area_l) + (Ec_t \times Area_t) + (Ec_w \times Area_w) + (Ec_c \times Area_c) + (Ec_r \times Area_r) + (Ec_{m/i} \times Area_{m/i}) + (Ec_s \times Area_s) + (Ec_n \times Area_n) + [(Ec_{ss} \times \#\ \text{Capita years}_1 \times (1\text{-}SR_1)) + (Ec_{ns} \times \#\ \text{Capita Years}_2 \times (1\text{-}SR_2)) + (I \times (1\text{-}SR_3))] + PSI_1 + PSI_2$$

In this equation, W represents the total mass of phosphorus in kilograms per year entering Great Pond. The Ec terms represent export coefficients, or the expected amount of phosphorus loaded into the system from each source per unit area (see Appendices Q and R). Sources of input include the atmosphere, a variety of forest types (mature, transitional, and logged), wetlands, cleared land, and point sources such as Great Meadow Stream and Salmon Lake. Roads, development (shoreline and non-shoreline), summer camps, and municipal and industrial land are significant sources of phosphorus loading into Great Pond. In addition, shoreline, non-shoreline, and summer camp septic tank systems are accounted for in the model. Soil type, septic type, age, number of people, and the number of septic system use per year are also factors influencing the phosphorus loading in Great Pond (see Appendix Q).

Shoreline and non-shoreline septic system septic system export coefficients were multiplied by the number of capita years and by one minus the coefficient values for soil retention, SR. Capita Years is a value based on the average duration of occupancy of each residence and the average family size in each town. Capita Years is smaller for shoreline residences because they are assumed to be occupied seasonally rather than year-round, thus contributing less phosphorus per year. Soil retention is a measure of how well phosphorus and other nutrients are retained by the various soils in the watershed.

High and low export coefficient values were modified from values in case studies of watersheds similar to Great Pond (Reckhow and Chapra 1983, BI493 1991, BI493 1993, BI493 1994, BI493 1995, BI493 1996, BI493 1997). The range of export coefficient values compensates for uncertainty in phosphorus loading estimates. Uncertainty is due to bias (human judgement errors) as well as natural fluctuations in biological systems. The actual value of phosphorus loading falls between the low and high estimates. The areas for the lake and each land use type within the watershed were determined through the use of a digitizing program (see Land Use: Land Use Methodology), United States Geological Survey topographical maps, and aerial photographs. The areas of shoreline and non-shoreline residences were calculated using Maine Department of Environmental Protection estimates for shoreline and non-shoreline lot sizes. These values were then multiplied by the number of shoreline and non-shoreline residences to determine total area.

Utilizing the high and low range values for total phosphorus loading (W) and water budget data for Great Pond (see Appendices Q and R), a range of phosphorus concentrations for the lake was calculated through the use of the following equations (Reckow and Chapra 1983):

$$L = W/A_s$$

The amount of phosphorus loaded from the watershed into the lake per square meter of water annually (L, in $kg/m^2/yr$) was calculated by dividing the annual rate of phosphorus inflow (W, in kg/yr) by the surface area of the lake (A_s, in m^2). Annual atmospheric water loading (q_s, in m/yr) was calculated by dividing the total volume of water inflow (Q_{total}, in m^3/yr) by the surface area of the lake (see Appendix B).

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

The predicted phosphorus concentration ranges (P, in ppb) were calculated by dividing the annual atmospheric phosphorus loading (L) by the settling velocity of phosphorus in a lake ($11.6 + 1.2\ q_s$).

$$\mathbf{P} = L / (11.6 + 1.2\ q_s)$$

After calibrating the model by adjusting the export coefficient values, estimated range of 5.2 ppb to 12.6 ppb was generated for Great Pond. The actual phosphorus concentration in Great Pond fell between these high and low estimates, indicating the accuracy and credibility of the model (see Appendices Q and R).

Results and Discussion

The Export coefficient value and the area of the contributing source determine the severity of loading impact on the lake (Reckhow and Chapra 1983). Sources with low export coefficients can often be a significant source of phosphorus if the area of that source is large enough.

The total mass input of phosphorus into the lake (W) as projected by the model ranges between 2887.4 kg/yr and 7007.0 kg/yr. The atmosphere, transitional forests, and mature forests contribute between 47 percent and 53 percent of the annual phosphorus load to Great Pond (Fig. 58). While each of these inputs has a relatively small export coefficient, the area of each source is large enough to have a significant impact on phosphorus loading into the lake (see Appendix Q). The lake surface, transitional forests, and mature forests represent almost 84 percent of the total area of the watershed.

Estimated low and high phosphorus loading from cleared land (4.8 percent to 10.3 percent), logged land (2.2 percent to 1.3 percent), and wetlands (1.0 percent to 1.8 percent) contribute between 8.0 percent to 13.4 percent of the phosphorus load per year. Municipal and industrial land contributes between 1.5 percent and 1.6 percent of the phosphorus load per year. Shoreline development and septic systems contribute between 5.5 percent and 9.1

percent while non-shoreline activity contributes between 4.8 percent and 6.7 percent annually. This is a very large percentage considering that these sources comprise only 1.1 percent and 3.2 percent of the area of the watershed respectively. Roads in the watershed are responsible for annual input ranging from 2.5 percent to 3.1 percent while they represent less than 1 percent of the total area. While human activity does not contribute the largest amount of total phosphorus to the lake in terms of actual mass, development, cleared land, and roads are the most significant sources per unit area.

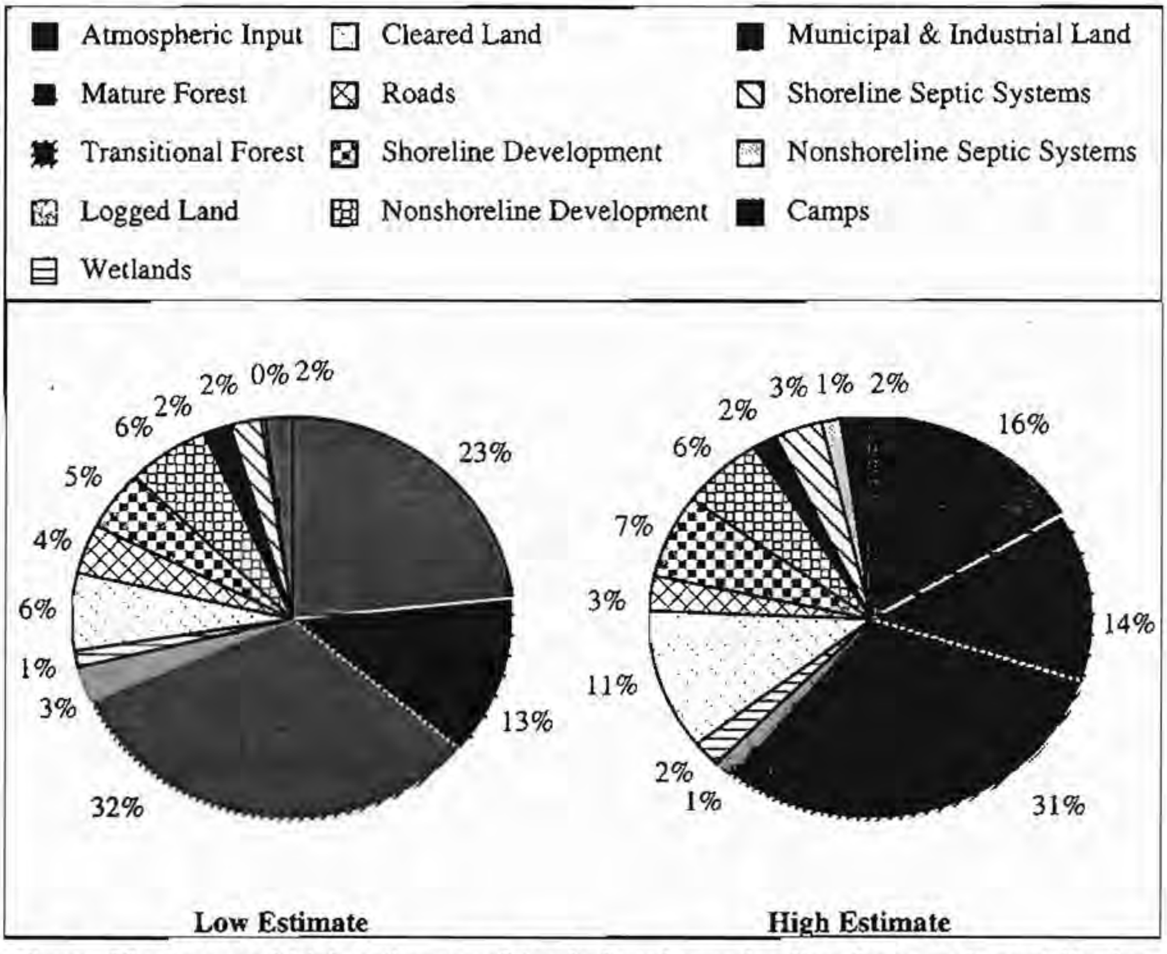

Figure 58. Low and high estimates of total phosphorus loading from each contributing source in the Great Pond Watershed. For detailed explanation of the estimates and phosphorus budget calculations, see Appendices Q and R.

The range of total phosphorus concentrations generated by the loading model was 5.2 ppb to 12.6 ppb. The actual mean phosphorus concentration of the lake surface as measured by CEAT was 8.8 ppb ± 0.8 (see Lake Water Quality: Total Phosphorus). Because the

measured value lies within the predicted range, lending credibility to the model, it can be used to predict the trophic status of Great Pond.

The MDEP indicates that lakes with a phosphorus concentration of 12.0 ppb demand immediate concern and monitoring because the critical phosphorus limit is recognized as 15.0 ppb. According to the phosphorus budget calculations, Great Pond has acceptable total phosphorus concentrations.

FUTURE TRENDS

Introduction

Although Maine has a weaker economy than most other states in the United States (LaMarche, pers. comm.), this has not been a deterrent for expanded population growth and development. The epitome of "the way life should be," Maine attracts more tourists and year-round residents each year. Subsequently, the influx of more people has perpetuated rapid growth and development throughout the state (KVCOG 1997b).

Disproportional growth has occurred particularly in Central Maine and the Belgrade Lakes Region. This area has experienced rapid population growth and development for a number of reasons, including good environmental quality, small town atmosphere, availability of lakes, and convenience to larger communities (Belgrade 1998).

Communities in the Belgrade Lakes Region are conveniently located close to Augusta and Waterville, two of the larger cities in the state. Augusta and Waterville are important economic centers for the region providing employment, goods, and services for surrounding communities. Proximity to Augusta and Waterville is important both in terms of regional economic development and in creating "spillover" effects in the Belgrade Lakes Region.

Invariably, as Waterville and Augusta become more populated and more development occurs in these towns, some of this growth may spread to surrounding communities. Kennebec Valley (which includes Augusta, Waterville and the Belgrade Lakes Region) has experienced a 9.0 percent growth in population from 1980 to 1990. During this same time, 10,746 new residential units were also built in this area. (KVCOG 1997a).

Sustaining such growth and development, without careful management and planning, may jeopardize the very things Maine residents have come to treasure. Increased population and development pressures could adversely affect the water quality of Great Pond. Studies indicate that developed residential land can export five to ten times more total phosphorus runoff than undisturbed forest lands (Woodard and Rock 1991). In turn, a decrease in water quality or clarity could decrease property values by ten percent (Belgrade 1998). These realizations are important to consider when devising future management strategies that will protect the natural resources and lakes of Maine as well as foster economic growth.

population is under age 18. This is consistent with regional average of 28.4 percent. This means that in 10 to 20 years, one third of the population will be of child-bearing age, which could have profound effects on the demography of Smithfield and implicitly the water quality of Great Pond.

Population pressure in Smithfield is also compounded by an influx of 2000 seasonal residents during the summer (BI493 1997). The average in-migration of seasonal residents along Great Pond, however, is approximately 68 persons. This compares to a 1696 person increase in seasonal residents for the entire watershed. (These numbers were derived by multiplying the total number of seasonal houses by 2.7, the approximate family size in the Belgrade Lakes Region) (see Appendix T).

Less demographic information is available for the remaining two towns in the watershed, Mercer and Rome. Neither town is included in the national census reports because of their small size, nor do they have comprehensive land use plans which outline population and development trends. State profile census data, however, reveal that these two towns are also rapidly growing. Population in Mercer has increased from 272 in 1960 and 313 in 1970 to 593 in 1990 (United States Bureau of Census 1970, United States Bureau of Census 1990). Current population is approximately 618 people with no seasonal residents. The current growth rate in Mercer is 1.5 percent (KVCOG 1997b). Population is expected to increase by another 150 people in the next 15 years (KVCOG 1996). Like other towns in the Great Pond Watershed, Mercer has a very young cohort with approximately 30.0 percent of the population under 18 years old (see Appendix S).

Similarly, the population of Rome has gone from 362 in 1960 and 367 in 1970 to 758 in 1990. There are currently 925 people residing in the town and 819 seasonal residents each year (KVCOG 1997b). The population of Rome is expected to increase to 1300 by 2015. Overall, the mean growth rate in Rome has been slightly higher than the mean for the Great Pond Watershed. The growth rate of Rome for the past 30 years has been 1.6 percent versus the average of 1.5 percent for communities along Great Pond. Like Mercer and Smithfield, Rome has a young age structure with an average of 25.6 percent of the population under age 18 (KVCOG 1997b). The largest fluxes in population occur seasonally, not annually, with seasonal immigration. This is evident by the fact that approximately 60 percent of the homes in Rome are seasonal (see Appendix U).

Overall, population growth in the Great Pond Watershed closely follows the growth patterns of the entire Belgrade Lakes Region, characterized by high in-migration, young population structure, rapidly expanding populations in shoreline and non-shoreline areas, and many seasonal residents. The future annual growth rate for the region is estimated at 1.5 percent (based upon current trends). Population within the Great Pond Watershed is predicted to increase by 2252 people by 2015 (KVCOG 1997b).

DEVELOPMENT TRENDS

Increased population in Belgrade, Mercer, Rome, and Smithfield has also coincided with heightened development activity. Development is gauged in terms of road construction, utilities, residential and commercial structures, and municipal infrastructure (such as recreational or administrative facilities, and water and septic treatment operations). It is also a function of the creation of new industries, jobs, markets and economies. Finally, development denotes a degree of environmental destruction, in terms of vegetative clearing and other alterations to the natural ecosystems.

Of the four towns, development has been the most pronounced in Belgrade. Commercial and residential development in Belgrade is ever increasing. Development in Belgrade is underscored by the construction of many new houses (shoreline and non-shoreline), as well as the conversion of seasonal homes to year-round residences. Since 1980, 177 residential permits, making up 36.0 percent of Belgrade's total houses, have been issued.

Shoreline development has been most prevalent in the conversion of seasonal to year-round homes. For example, from 1970 to 1980, seasonal houses constituted 46 percent of the total residences in Belgrade (BI493 1997). From 1980 to 1990, the number of seasonal houses decreased to 42.3 percent (BI493 1997). Currently there are 810 seasonal houses in Belgrade (KVCOG 1997) but year-round houses now constitute 57 percent of the total residences (Belgrade 1998). This is compared to 35 percent in 1970 (Belgrade 1998). The majority of these converted houses are shoreline properties. Although conversion is common, no new seasonal homes have been built in Belgrade since 1990 (see Appendix T).

Although residential development is the most common development pattern in Belgrade, there is also an increased emphasis on commercial and industrial development. Seven commercial building permits have been issued since 1980 (Belgrade 1998). Another permit was recently authorized allowing the possible construction of a multi-acre recreational facility to be situated on the old campground next to the marina. If current population and development trends continue, it may become necessary to construct another public landfill. Belgrade currently has a 6.6 acre landfill which is expected to be filled to capacity by 2000 (Belgrade 1998). Although this landfill is outside of the watershed (Edgerly, pers. comm.), it is still an important consideration when devising future development strategies.

Ongoing development in Belgrade has implications not only for Great Pond but also for every other lake in the Belgrade Lakes ecosystem. Of all the towns in the Belgrade Lakes Region, Belgrade has the highest percentage of shoreline property for both Great Pond and Messalonskee Lake. Belgrade also has the second highest percentage of shoreline development for Long Pond (Belgrade 1998). Bordering Great Pond, Messalonskee Lake, Long Pond-South Basin, Long Pond-North Basin, and Salmon Lake, Belgrade constitutes 41 percent of the Belgrade Lakes Watershed area (Belgrade 1998). Thus, Belgrade residents have a unique responsibility in protecting water quality throughout the Belgrade Lakes Region. Consequently, it is imperative for the community to continue to promote sound water quality management practices and policies.

The onus of responsibility, however, is not exclusive to Belgrade. Other shoreline communities also need to promote proactive management strategies to ensure future lake water quality. This is especially important for other towns in the watershed that also are experiencing rapid population growth and development.

Like Belgrade, the communities of Mercer, Rome and Smithfield, are also gradually changing from rural resort and agricultural communities to residential suburbs (Belgrade 1998). This tendency may be compounded by the construction of 330 acre Business Park which was approved in 1-Oct-98. The predominant industries in the "Superpark" would include financial services, precision manufacturing (manufacturing of electronics and other small, technical products), and biotechnology industries (Dow, pers. comm.). The initiative is supported by 28 of the 50 towns in Kennebec Valley, including five towns in the Belgrade Lakes Region (KVCOG 1998).

Although the "Superpark" will foster regional economic development, future development may be hampered by a lack of available land in the Belgrade Lakes Region. Since all property in the Great Pond Watershed has been privatized already (see Land Use: Residence Count), this may limit the construction of new buildings. Consequently, future development may be take the form of heightened seasonal conversion and shoreline development.

Shoreline development will probably be concentrated in Belgrade as 42 percent of the shoreline in Belgrade has not been developed yet (Belgrade Comprehensive Plan, 1997). A possible exception to the continued shoreline development trend is Rome. While seasonal conversion is still common in Rome, the majority of future development in Rome may be concentrated in non-shoreline areas. This is because 100 percent of all shoreline properties in Rome are already developed (see Land Use: Residential Land). In addition, there are no large plots in Rome that could be subdivided. Since 1990, only eight new seasonal houses have been built in Mercer, Rome, and Smithfield.

The trend of converting seasonal homes and increasing shoreline development will probably also occur on Messalonskee Lake, Long Pond-North Basin, Long Pond-South Basin, North Pond, and East Pond Long. Total residences in Long Pond increased by 19.0 percent from 1970 to 1980. Two-thirds of the structures in the watershed are year-round residences, yet 76.5 percent of shoreline houses are seasonal.

Similarly, half of Smithfield residents living along North Pond-North Basin reside in seasonal shoreline houses during the summer. Only 40.6 percent of the population of Smithfield live in year-round, non-shoreline residences (BI493 1995). 70.0 percent of Rome residents living along North Pond-South Basin live in seasonal shoreline houses, whereas only 30.0 percent of the population constitute year-round, non-shoreline residents (BI493 1996). Property card information indicates that the majority of residents live out of state during the winter months. Likewise, one-half of Mercer residents live in year-round shoreline homes along North Pond (BI493 1996).

Of the 56.0 percent of land that could be developed in the East Pond watershed, approximately 22.0 percent of development occurring in the next 50 years will be residential shoreline development (BI 493 1991). Currently, 80.0 percent of existing houses around East Pond are seasonal (BI493 1996).

Messalonskee Lake is also characterized by many seasonal, shoreline residences. To date, 77.7 percent of shoreline lots are developed and 62.3 percent of non-shoreline lots are developed. Sixty-two percent of shoreline houses in the Messalonskee Lake watershed are seasonal. In 1980, 15.2 percent of the total houses in Oakland were seasonal and in 1990 12.7 percent were seasonal. The total shoreline houses in Sidney on Messalonskee Lake changed from 17. 5 percent in 1980 to 15.8 percent in 1990 (BI493 1998).

FACTORS INFLUENCING PHOSPHORUS LOADING

The Great Pond Watershed is located in an area experiencing rapid population growth (see Population Trends). To accommodate this population increase, development will increase in an effort to meet these housing needs. This will result in an increase in the number of roads, municipal and industrial land, and forested land while reducing the area of mature and transitional forests. In addition, the conversion of existing seasonal homes to year round homes will increase the amount of waste contributed to the septic systems in the watershed. Using the Phosphorus Loading model, the impact of these trends on total phosphorus loading can be projected (Fig. 59). In calculating the phosphorus budget for 2015, the same export coefficients as those used in the 1998 model. Rather, trends in population growth, land use, and development were considered (see Future Trends: Population Trends, Development Trends).

By the year 2015, the Colby Environmental Assessment Team predicted that the annual mass rate of total phosphorus inflow would be between 3224 kg/yr and 8402 kg/yr. This corresponds to a phosphorus concentration range of 5.8 ppb to 15.1 ppb, with a median value of 10.5 ppb. This is an increase of 1.7 ppb from the value of 8.8 $\pm$ 0.8 ppb, which is the median of the 1998 model, measured by CEAT from surface and epicore samples.

In the 1998 model, 66 percent of the mean contribution of phosphorus into the lake from atmospheric sources, transitional forest, mature forest, and wetlands was 66 percent. In the 2015 model, these sources comprised 55 percent of the phosphorus load. Similarly, logged and cleared land, roads, shoreline and non-shoreline development, municipal and industrial land, shoreline and non-shoreline septic systems, and youth camps increased from 34 percent to 45 percent of the mean phosphorus input into Great Pond (Fig. 59). Because

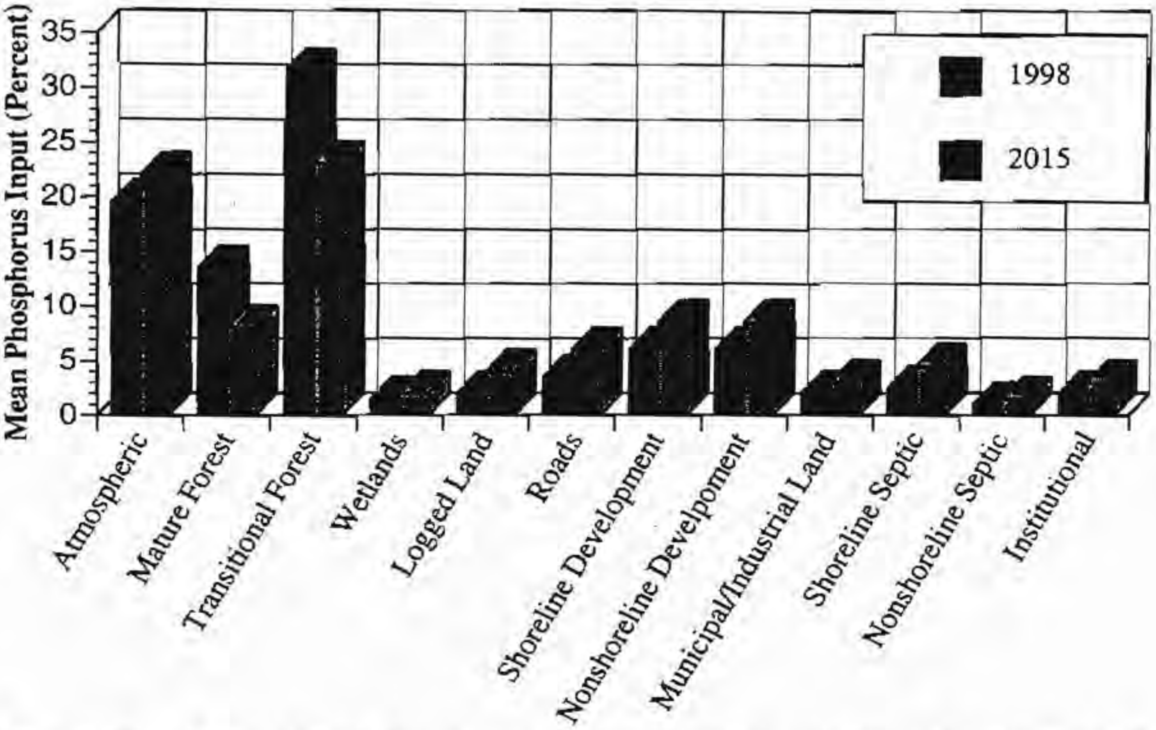

Figure 59. Current and future mean phosphorus input from the sources of phosphorus loading in the Great Pond Watershed in 1998 and 2015.

the export coefficients of these sources are large, any increase in the land area of the sources will greatly increase the amount of phosphorus entering the lake in a given year.

The Maine Department of Environmental Protection recognizes 15.0 ppb as the critical phosphorus concentration at which algal blooms will occur. This value is included in the projected range for 2015. Because eutrophication is a natural process, any additional phosphorus entering a lake will accelerate this process (see Lake Characteristics). In order to reduce human impact on the rate of eutrophication, measures should be taken to reduce, as much as possible, the annual mass rate of phosphorus loading from cultural activity. Using the phosphorus budget model, state and local municipalities could further examine the role of changing population, development, and land use patterns on phosphorus loading potential, and focus their efforts an reducing the input from problem sources.

SUMMARY

WATER QUALITY OF GREAT POND AND TRIBUTARIES

General Chemistry and Tributaries

An overall assessment of general water chemistry was important in developing a comprehensive evaluation of the present water quality of Great Pond. Transparency levels classified the lake as mesotrophic, indicating that it is moderately productive concerning algae growth. The transparency levels are decreasing over time, indicating possible nutrient increases. This trend indicates a gradual shift, which, if not halted, could move towards a eutrophic status in which nutrient concentrations are high enough to cause algal blooms. The level at which anoxia occurs in late fall is becoming more shallow over time. This could also be evidence of increasing productivity.

Other chemical data indicates that Great Pond has better water quality than many other Maine Lakes. The color value of Great Pond was low compared to other Belgrade Lakes, indicating negligible concentrations of natural dissolved acids such as tannins and lignins. Low levels could allow primary production to occur at a lower depth, increasing primary production overall. The pH of the lake was normal and the alkalinity tests indicated that Great Pond is well buffered against acid inputs. The conductivity levels found in the lake were also classified as normal for Maine lakes, although this value has increased slightly over time.

Conductivity levels were higher in the tributaries than in the lake. Tributaries also had higher turbidity levels than the lake, with Trout Brook (8T) having the highest level. This is of concern since high turbidity and high conductivity can indicate an influx of sediments bringing nutrients into the lake. The color values of the tributaries were variable and Robbins Mill Stream (9T) and Pinkhams Cove Tributary (12T) showed high levels. Great Meadow Stream (10T), the main input into the lake, had a low pH.

Water and Phosphorus Budget

The water budget is used to determine the amount of water entering Great Pond and the flushing rate of the lake. Great Pond has a low flushing rate of 0.52 flushes per year. The low flushing rate can allow nutrients to build up in the water column and bottom sediments, which can lead to an increased rate of eutrophication for the lake. Movement of water within the lake can also affect water quality. Great Pond has a number of bays and deep holes in which the water can become trapped and not easily mix with water in the rest of the lake. Nutrients can build up in these bays because the water may not be mixing with the water in the rest of the lake. Managing the level of water in the lake can also affect water quality. Opening the dam at the outlet of Great Pond allows some of the water and nutrients to be flushed out of the lake. Lowering the water level in the fall also reduces the probability of flooding in the spring due to increased runoff and tributary inputs from snowmelt.

Over the past 30 years, lake areas in Maine have witnessed dramatic changes in land use coupled with population growth. These changes contribute directly to the phosphorus budget of the lake. Using a model for phosphorus loading, the annual phosphorus budget of Great Pond was calculated to be between 5.2 ppb and 12.6 ppb. This range was consistent with the total phosphorus concentrations measured by The Colby Environmental Assessment Team. Based on the accuracy of the Phosphorus Loading Model and the critical analysis of population, development and land use trends, CEAT is confident that development of the Great Pond Watershed will likely result in an increase in the annual phosphorus input into the lake, possibly accelerating the rate of eutrophication. The Maine Department of Environmental Protection recognizes a concentration of 15.0 ppb to be the critical limit beyond which algal blooms will result, while concentrations of 12.0 ppb are a cause for serious concern. The projected range for 2015 includes these values indicating that the phosphorus concentrations in Great Pond will likely be close to the critical concentrations within the next 20 years.

LAND USE

Residential Land

The quality of septic systems in the Great Pond Watershed is relatively good, with low risk of contamination or nutrient loading from individual systems. It is estimated that only a small number of pre-1974 septic systems are still in use due to high replacement rates over the last decade. Better constructed components of the new septic systems reduce the risk of contamination through leakage and stricter regulations for the site design of shoreline septic systems have reduced the potential for high phosphorus loading from septic systems. Improvements in septic systems in the Great Pond Watershed have not been limited to residential systems. The septic systems of youth camps on Great Pond have all had recent repairs or replacements as well. As a result, phosphorus loading from individual systems is probably not a major concern.

While individual systems may release little phosphorus, the aggregate effect of subsurface wastewater disposal systems is a major source of concern. Great Pond is highly developed, and in many cases the development is concentrated in small areas along the shoreline. This is a problem for two reasons. First, no regular inspection schedule exists, so malfunctioning systems are not recognized until the problem is large enough for a neighbor to notice obvious leaks or odors. Once a problem of this magnitude arises, it has already affected residences surrounding it and water quality in the area. The second cause for concern is that concentrated areas of development tend to have smaller lots which reduce the area for soil infiltration. This effect is magnified on properties that have poor septic suitability but have received variances (special permission from MDEP) and continue producing high sewage volume.

The Sub-Surface Waste Water Disposal Act, and the State of Maine Guidelines for Shoreland Zoning protect Great Pond by reducing the potential for nutrient loading from each system. Great Pond is still at risk because of the large number of systems currently in use.

Roads

Roads make up a total of 230 acres or 1.1 percent of the land in the watershed. One hundred and nineteen roads are dirt, while 30 roads are paved. The majority (77) of the roads in the watershed are found in Belgrade. Rome has the second largest number of roads (62),

while Smithfield and Mercer have a total of ten roads in the watershed. One hundred and one of these dirt roads can be defined as camp roads, which are the closest roads to the lake. Fifty-seven of these camp roads were classified as being in Needing Work or Poor condition, indicating the potential to load large amounts of phosphorus into the lake. The number of the camp roads in acceptable conditions for Great Pond is low compared to the number of acceptable camp roads for other Belgrade Lakes.

Managed Land

Cleared and municipal/industrial land did not exhibit similar changes between 1965/66 and 1998. Total cleared land area decreased while municipal/industrial land area increased. Cleared land decreased by 834.4 acres (3.1 percent). Cropped land composed 68.6 percent and grazed land composed 38.0 percent of this total decline. In 1965/66 and 1998 cropped land was the dominant type of cleared land. Municipal/industrial land increased by 183.25 acres (1.1 percent) between 1965/66 and 1998. The majority of this growth was due to the increase of gravel pits. Also contributing to the increase was the addition of an 18-hole golf course along Rt 27 in Belgrade.

Natural Land

Mature forest decreased in the Great Pond Watershed by 1771.8 acres (8.5 percent) from 1965/66 to 1998. Transitional forest increased in the watershed by 2523.0 acres (12.2 percent) from 1965/66 to 1998. Wetlands decreased in the watershed by 981.0 acres (4.7 percent) from 1965/66 to 1998. Some of the forested land has been converted to transitional forest because of selective logging. Forested land has also been the victim of increased development. Some of the wetlands have developed into transitional forest due to succession along edges. The total area of natural land has decreased as the area of managed land has increased over the past 30 years.

RECOMMENDATIONS

INTRODUCTION

The biggest threat to Great Pond is cultural eutrophication. This is caused by the input of phosphorus and nitrogen in the watershed accelerated by development and other activities, especially along the shores of the lake. All of the towns in the Great Pond Watershed are experiencing a steady increase in population leading to an increase in development. While this study shows that Great Pond is not in immediate danger of severe cultural eutrophication, there are signs of degrading quality. It is important to implement preventative measures in order to mitigate a future decline in water quality. The Colby Environmental Assessment Team has produced a set of guidelines that will aid in the long-term preservation of the water quality of Great Pond.

MONITORING SUGGESTIONS

Water Quality

The Maine Department of Environmental Protection has monitored Great Pond at the mid-pond and Hoyt Island sites (Characterization Sites 1 and 2) since 1974. In order to obtain more comprehensive analyses of the water quality of Great Pond additional water testing should be conducted. We recommend that:

- the number of Characterization Sites be increased to include the following:
  - -North Bay (Site 3)
  - -Pine Island (Site 4)
  - -Hatch Cove (Site 5)
- phosphorus and transparency testing be conducted at least three times a year, to account for seasonal changes:
  - -late May
  - -during the summer months
  - -in the fall.
- surface and epicore samples be tested for phosphorus and transparency

- dissolved oxygen and temperature profiles are taken on approximately the same date each year at Characterization Sites 1 and 2.

Development

This report has established that the water quality of Great Pond is most threatened by development activities along the perimeter of the lake. Residences on the shoreline have a potentially large impact on the water quality of the lake because of their proximity to the shoreline. Development in the form of driveways and roads makes the land more impervious to runoff, allowing it to travel more quickly to the lake water. Lack of properly maintained buffer strips and rip-rap have similar effects. Measures can be taken by the township, the community, and individual residents of the area to mitigate these effects.

Regulatory Measures

- reduce development on agricultural land and promote the progression from transitional to old-growth forests within the watershed
- encourage sustainable forestry practices and avoid logging near lake shorelines and on steep slopes
- preserve large tracts of mature forest
- conduct regular surveys of the road condition to keep up maintenance of road trouble spots
- eliminate berms and avoid the formation of potholes and drainage paths across road surfaces
- keep culverts clean and functional, making certain that ditches are well-vegetated and ensuring that water is diverted into a buffered area before entering the lake
- limit the development of new roads where possible, especially near the lake
- limit industrial development near lake shorelines
- continue to enforce zoning laws concerning the development of new homes on shoreline property
- encourage the streamlining of the buffer zone and rip-rap permit processes through the Maine Department of Environmental Protection

- special precautions should be taken prior to development by preventing severe runoff with silt or hay fences surrounding the construction area
- consider a 30 percent ruling which would trade zoning lenience for better buffer strip and rip-rap quality

Community Measures

- plant native trees and shrubs over the entire length of the shoreline in order to improve inadequate buffer zones
- encourage lake associations or private landowner groups to raise money to implement maintenance and

  upgrading of roads
- focus on road and buffer strip improvement in Pinkhams Cove
- avoid future development in Pinkhams Cove and other areas with low development suitability

Residential Measures

- maintain/create buffer zones of a desired depth from shore of 75 ft by replanting trees and hedges
- decrease the use of lawn fertilizers
- encourage natural plant growth on residential plots rather than excessive landscaping

Septic System Recommendations

Septic systems, though hidden from view, can have a dramatic effect upon the water quality of the nearby lake through the leaching of phosphorus, nitrogen and microorganisms. Great Pond is surrounded by a significant number of residences that require the use of septic systems. While the individual septic systems do not pose a significant threat to Great Pond, it is the aggregate number of systems that can cause problems. In order to preserve the water quality of Great Pond, measures need to be taken to lessen such an impact on the lake water.

- continue the replacement of pre-1974 septic systems regardless of their functioning status
- encourage the use of the MDEP grant program and Kennebec Valley Action Program low interest loan programs for the replacement of septic systems
- establish a maintenance inspection schedule to ensure that problems are detected as early as possible
- continue regulating the switch from seasonal to year-round septic system use
- continue to enforce compliance with septic system regulations and put a stringent standard on the type of system used for new and old tanks

Education

One of the best ways to improve the future water quality of Great Pond is to inform residents of the watershed about the impact of their daily activities on the water quality of Great Pond. The general public may not be fully aware of the relationship between land use, development, and water quality.

- encourage the availability of this report to the following:
  - -residents of the Great Pond Watershed
  - -Belgrade Lake Association
  - -local libraries
- Belgrade, Rome and Smithfield school systems could incorporate lake education into their curriculum and possibly involve local schoolchildren in the monitoring of the lake and its surrounding watershed.
- pamphlet production and media attention may be another source of information for the residents of the area, promoted by efforts of the Lake Association.
- town officials, in conjunction with the Maine Department of Environmental Protection, could hold workshop sessions to educate residents of towns within the watershed on what defines effective roads and buffer strips.

Overall, the Colby Environmental Assessment Team has come to the conclusion that Great Pond has good water quality in comparison to other Belgrade Lakes. However, the

threat of accelerated eutrophication from development within the watershed cannot be underestimated. It is important to take proper measures to preserve this invaluable resource.

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PERSONAL COMMUNICATION

Some people who provided the Colby Environmental Assessment Team with relevant information were:

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Denny McNeish	Maine Department of Inland Fisheries and Wildlife
Bobby Moreau	First Selectman, Town of Rome
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APPENDIX A. FISH SPECIES LIST

A list of common fish species that occur in Great Pond based on the Maine Department of Inland Fisheries and Wildlife Lake Inventory 1996 Update.

Common Name	Scientific Name
Alewife	*Pomolobus pseudo-harengus*
Bass, Largemouth*	*Micropterus salmoides*
Bass, Smallmouth*	*Micropterus dolomieui*
Bullhead, Brown	*Ictalurus nebulosus*
Crappie, Black*	*Pomoxis nigromaculatus*
Eel, American	*Anguilla rostrata*
Fallfish	*Semotilus corporalis*
Perch, White*	*Morone americana*
Perch, Yellow	*Perca flavescens*
Pickerel, Chain*	*Exos niger*
Pike, Northern *	*Exos lucius*
Pike, Walleye	*Stizostedion vitreum*
Salmon, Landlocked*	*Salmo salar*
Shiner, Golden	*Notemigonus crysoleucas*
Smelt, Rainbow	*Osmerus moradax*
Sucker, Common	*Catostomus commersonnii commersonnii*
Sunfish, Pumpkinseed	*Lepomis gibbosus*
Trout, Brook	*Salvelinus fontinalis*
Trout, Brown	*Salmo trutta*

*Principle Fishery

APPENDIX B. WATER BUDGET VALUES AND CALCULATIONS

Parameters	Units	Values
Precipitation[a]	meters/year	1.008
Evaporation[b]	meters/year	0.560
Runoff[c]	meters/year	0.622
Land Area	square meters	84,384,000
Lake Area	square meters	34,860,000
Mean Depth[d]	meters	6.0
I_{net} North Pond	cubic meters	23,296,582
I_{net} Salmon Lake	cubic meters	16,480,434
I_{net} Great Pond	cubic meters/year	107,881,144
$Q_{(Great\ Pond)}$	cubic meters/year	87,625,728
$Q_{(Total)}$	cubic meters/year	127,402,744
Flushing Rate	flushes/year	0.52

[a] Precipitation was calculated as a ten-year mean of data (NOAA 1987-1997, yearly averages were calculated for the Augusta Airport recording site data and the Waterville Sanitary Plant recording site and these values were then averaged)

[b] Evaporation is a constant and was obtained from a study of the Lower Kennebec River Basin (Prescott 1969)

[c] Runoff is a constant obtained from a ten-year mean of runoff in the Kennebec River Basin from 1958-1967 (North Kennebec Regional Planning Commission, unpublished data)

[d] Mean depth was obtained from the Maine Department of Environmental Protection MIDAS data (1994)

I_{net} = (Runoff x Land Area) + (Precipitation x Lake Area) - (Evaporation x Lake Area)

$Q_{(Great\ Pond)}$ = I_{net} Great Pond + (Evaporation x Lake Area)

$Q_{(Total)}$ = $Q_{(Great\ Pond)}$ + I_{net} North Pond + I_{net} Salmon Lake

Flushing Rate = (I_{net} Great Pond + I_{net} North Pond + I_{net} Salmon Lake)/(Mean Depth Great Pond x Lake Area)

APPENDIX C. ON SITE AND LABORATORY WATER QUALITY TESTS

List of sample dates and measurements for Great Pond Characterization, Spot, and Tributary Sites. See site map for site locations (Fig 11). Tests or measurements marked with an asterisk were conducted in the field. All other tests were conducted by the Colby Environmental Assessment Team at the Colby Environmental Analysis Laboratory, Waterville, ME.

Test or Measurement	Sample Date	Sample Site
Physical Factors		
Depth *	21-Sep-98	1,2,2-B,3,4,4-B,5,5-B,6,7,8-T,11-T, 12-T,13-T(down),13-T(up)
DO/Temperature *	25-Jun-98	1,2,3,4,5
	17-Jul-98	1,2,3,4,5
	13-Aug-98	1,2,3,4,5
	21-Sep-98	1,2,2-B,3,4,4-B,5,5-B,6,7,8-T,
	5-Oct-98	2-B,4-B,7,8-T,10-T,11-T,12-T,13-T
Flow Rate *	21-Sep-98	8-T,11-T,13-T(down),13T(up)
	5-Oct-98	12-T
Transparency *	25-Jun-98	1,2,3,4,5
	17-Jul-98	1,2,3
	13-Aug-98	1,3
	21-Sep-98	1,2,2-B,3,6
Conductivity	21-Sep-98	1,2,2-B,3,4,4-B,5,5-B,6,7
	5-Oct-98	1,2-B,4-B,6,7,8-T,9-T,10-T,11-T,12-T, 13-T
Turbidity	21-Sep-98	1,2,2-B,3,4,4-B,5,5-B,6,7,8-T,11-T, 12-T,13-T(down),13-T(up)
	5-Oct-98	8-T,9-T,10-T,11-T,12-T,13-T
Chemical Factors		
Alkalinity	21-Sep-98	1,2,6,7
Color	21-Sep-98	1,2,3,4,5,6,7,8-T,11-T,12-T,13-T(down),13-T(up)
	5-Oct-98	1,2-B,4-B,6,7,8-T,9-T,10-T,11-T,12-T, 13-T

Appendix C. (cont.)

Test or Measurement	Sample Date	Sample Site
Hardness	21-Sep-98	1,2,2-B
Nitrates	21-Sep-98	1,2,3,4,5-B,7
pH	25-Jun-98	1,2,3,4,5
	17-Jul-98	1,2,3,4,5
	13-Aug-98	1,2,3,4,5
	21-Sep-98	1,2,2-B,3,4,4-B,5,5-B,6,7,8-T,11-T, 12-T,13-T(down),13-T(up)
Phosphorus	25-Jun-98	1,2,3,4,5
	17-Jul-98	1,2,3,4,5
	13-Aug-98	1,2,3,4,5
	21-Sep-98	1,2,2-B,3,4,4-B,5,5-B,6,7,8-T,11-T
	5-Oct-98	1,2-B,4-B,6,8-T,9-T,10-T,11-T,12-T, 13-T

APPENDIX D. QUALITY ASSURANCE

The Great Pond study followed a quality assurance plan that standardized the procedures of the BI493 environmental consultants. The following document was modified from BI493 (1998).

BOTTLE PREPARATION

1. All samples for total phosphorus analyses were triple acid rinsed with 1:1 HCL before use, to ensure that nothing would contaminate the sample.
2. A one to one ratio of HCL is 1 L of E-pure water and 1 L of concentrated hydrochloric acid.
3. If an epicore sample was taken, the mixing bottle was triple acid rinsed once before each sampling trip and was rinsed out with E-pure after each sampling was completed.

APPROACHING SITE

1. When approaching the test site, speed up first, then kill the engine and coast to the sampling site.
2. Always sample from the bow of the boat, into the wind.

SURFACE SAMPLING

1. Remove cap from sample bottle without touching lip of bottle or edge of cap.
2. Invert and immerse bottle to approximately 0.5 m down. Turn bottle on its side and move it through the water away from the boat.
3. Tilt bottle upright, remove from water, and cap. Place bottle in cooler.

SECCHI DISK

1. Duplicate reading on every 10th sample.
2. Use Aqua-scope to view the disk.
3. Lower until the disk is out of sight, then record the depth.
4. Lower the disk an extra meter, then bring it back into sight and record the depth.
5. Bring the disk back to the surface and repeat the process two more times.

MEASURING DEPTH

A. LCD Digital Sounder (Depth Finder)

1. Put the lanyard of the depth finder around your wrist.
2. Put the depth finder in the water and push the switch towards the bottom of the lake (in the direction of the arrow). Hold for 3 seconds.
3. The depth finder must be pointed straight down. Record this depth.
4. Repeat this process one time.

B. Drop line/Measuring Tape

1. Drop the depth line into the water quickly and vertically until you feel slack, then

gently pull the slack out of the line, bringing it through the muck and being careful not to lift the sinker off the bottom. Record this depth by counting the black tick marks on the line. Each black tick is 1 m.

2. Repeat this process one time.

CONDUCTIVITY

1. Use the 250 mL Nalgene bottle labeled for conductivity test.
2. Follow surface sampling procedure.
3. Place water sample on ice in cooler.

TURBIDITY

1. Use the 250 mL Nalgene bottle labeled for turbidity test.
2. Follow surface sampling procedure.
3. Put water sample on ice in cooler.

ACIDIFICATION OF HARDNESS SAMPLES

1. Rinse bottle lids with distilled water and add a small amount of the sample to the lid.
2. Test the water's pH in the sample bottle lid. If it is lower than 2, discard, rinse the lid, and cap the bottle. If the pH is greater than 2, add concentrated nitric acid (HNO_3) to your sample drop by drop until it is below 2.
3. The same number of drops of acid should be added to all the other bottles of the same size and same test.

ACIDIFICATION OF NITRATE SAMPLES

1. Rinse bottle lids with distilled water, and add a small amount of the sample to the lid.
2. Test the water's pH in the sample bottle lid. If it is lower than 2, discard, rinse the lid, and cap the bottle. If the pH is greater than 2, add concentrated sulfuric acid (H_2SO_4) to your nitrate test sample drop by drop until it is below 2.
3. The same number of drops of acid should be added to all the other bottles of the same size and same test.

USING pH METER

A. Proper calibration method. (Before any testing is done, the pH meter must be calibrated using a 2-point calibration method at 7, and 4. This should be done only once during the testing day, as long as the meter's calibration is not accidentally deleted).

1. Press the POWER button. The pH meter automatically enters the measurement.
2. Apply the pH 7 solution by opening the sensor guard and wetting the entire probe well.
3. Press the CAL button one. The sensor guard will display 7.0 and a CAL symbol will appear at the bottom right hand corner followed by a smiley face indicating it is done.
4. After calibration, rinse the sensor well with E-pure (highly filtered and de-ionized

water).
5. Repeat calibration for pH 4.
6. Check that probe is working properly by measuring aerated de-ionized water. The meter should return to a value of 5.65.
7. Take care to rinse probe with distilled water prior to and following each measurement.

B. Measurement
1. Lift the lid to the probe well and immerse the pH meter 0.5m to 1.0 m below the surface.
2. Close the lid. Bring the meter to the surface and record the reading after the smiley face has appeared in the bottom right hand corner.

C. Quality Assurance
1. Take the pH reading twice at each site to assure accuracy.

DISSOLVED OXYGEN (DO) METER

1. Lower DO/Temperature meter into water, shaking it to make sure there are no bubbles around the probe.
2. Immerse probe until covered. Record DO and temperature readings.
3. Lower probe 1 m at a time. Record DO and temperature for every meter until the bottom is reached.

MID-DEPTH and BOTTOM SAMPLE

1. Pull rubber stoppers out of the ends of the bottom sampler.
2. Hook metal cables to the two small pegs located at the top of the sampler.
3. After taking depth reading, lower sampler to mid-depth sample depth.
4. Release sliding weight to close water sampler.
5. Pull out water sampler. Open air valve and open black tap by pushing outside ring of tap in. Drain tap for a few seconds.
6. Fill sample bottle to bottom of neck and cap. Place bottle in cooler.
7. Empty water sampler. Repeat sampling procedure for Bottom sample.
8. Take bottom sample 1 m above bottom.

EPICORE

1. Rinse the tube three times by lowering it down into the lake water and pulling it back out.
2. For sites with great depth lower the tube down to 1 m below the thermocline (measured in the DO profile).
3. For shallow sites (all other sites) lower the epicore 1 m from the bottom.
4. The tape marks indicate 1 m.
5. Crimp the tubing just above the water (this is best done by bending it tightly and then holding it in your hand).
6. Pull the tubing up making sure that the excess tubing goes into the water. Be careful

not to touch the end at which the water comes out.

7. Allow the water to drain into the large bottle being careful not to touch the inside of the bottle or the cap or the end of the tube.
8. Make sure to keep the non-pouring end of the tube up so the water does not drain out of it and that it does not take up surface water.
9. Hold up the crimped area and undo the crimp. Continue raising the tubing and move towards the draining end.
10. Repeat process three times, draining all of the water into the epicore mixing bottle.
11. Pour about 125 ml of this water into two Erlenmeyer flasks (fill to just below the neck). Again be careful not to contaminate the bottles by touching the inside of the bottle or the inside of the bottle cap.
12. Discard the remaining water and rinse the mixer with E-Pure water. Place all samples into the cooler.

FLO-MATE

1. Turn the meter on. Place the black sensor entirely underwater, with the bulb facing upstream.
2. The meter will read the flow in either ft/s or m/s. Press the on/c and off keys at the same time to switch between the two.
3. Fixed Point Average (FPA) will take more accurate readings (hold up and down arrows at the same time). A time bar will move across the screen. When it reaches the far side, a new average velocity will be displayed.
4. Divide the topography of the stream into equal sections and measure the flow in each segment.

GLOBAL POSITIONING SYSTEM(GPS)

1. Record three objects to triangulate your position. Concentrate on the distance from shore, try to approximate these distances.
2. Turn on the GPS.
3. When the unit says PRESS POS WHEN READY, press POS. It will say WAITING FOR FIX. Make sure there are six numbers at the bottom of the screen.
4. At the desired location press "enter". This stores your waypoint, labeling it W001 or W002, etc. After pressing enter, record the coordinates and name/number of the site.

FLAGGING TAPE

1. After locating tributary site, mark location using flagging tape.
2. Tie the tape in a locatable, yet discrete spot. This will avoid complaints and removal of tape.

QUALITY CONTROL SAMPLING

1. E-pure samples were spiked (in groups of ten) with a known amount of concentrated standard and run against a standard curve to confirm accuracy of technician before water samples were analyzed for each test. This accuracy test was run until the values

of the test samples were within 10 percent of each other.

2. Duplicate samples were taken every tenth sample to test the accuracy of sampling procedures.
3. Samples were split every tenth sample in the laboratory to test lab procedure.

TOTAL PHOSPHORUS

1. For every ten samples, splits and duplicates were collected or made.
2. Known concentrations of phosphorus in E-pure water were made on every run to test lab precision.
3. Reagent blanks were used to make a standard curve to determine the concentration of phosphorus studied. The standard curve shouuld have a minimum of 6 points.
4. The accuracy of the Ascorbic Acid method used for total phosphorus analysis had a detection point less than 1 ppb.
5. Water samples were preserved for the analysis of total phosphorus by digesting them with sulfuric acid and ammonium peroxydisulfate, and then autoclaved at 15 psi for 30 minutes.
6. Analysis was conducted within 28 days of sampling date.

HARDNESS

1. For every ten samples, splits and duplicates were collected or made.
2. The water samples were preserved for the analysis of hardness by adding nitric acid in the field until the pH was less than 2.
3. A HACH titration method, adapted from the EDTA Titrimetric Method was used to measure hardness (HACH 1997).
4. The limit of detection for the HACH DR/4000 spectrophotometer Hardness test is 0.03 ppm $CaCO_3$. The range of the test is 0.03 ppm to 4.00 ppm $CaCO_3$.
5. Analysis was conducted within 14 days of sampling date.

ALKALINITY

1. One duplicate sample was taken for every ten samples.
2. The Potentiometric Method was used to analyze the samples (Eaton, Clesceri, and Greenberg 1995).
3. Analysis was conducted within 14 days of sampling date.

COLOR

1. One duplicate sample was taken for every ten samples.
2. Color should not vary more than ± 5 SPU.
3. Color standards were kept in the dark and protected from evaporation.
4. The HACH Platinum-Cobalt Standard Method and HACH DR/4000U spectrophotometer were used for the color test (HACH 1997).
5. The limit of detection for the test is 2 units Pt-Co. The range of the test is 0 units to 500 units.
6. Analysis was conducted within 48 hours of sampling date.

CONDUCTIVITY

1. One duplicate sample was taken for every ten samples.
2. Results should not vary more than 1 µmhos/cm^2.
3. De-ionized water should read less than 1 µmhos/cm^2.
4. The water sampler was used at the desired stratification.
5. The water sample was poured into its specified conductivity bottle.
6. A Model 31A YSI Conductance Bridge was used to measure conductivity in the Colby Environmental Laboratory.
7. Analysis was conducted within 28 days of sampling date.

TURBIDITY

1. For every ten samples, splits and duplicates were collected or made.
2. Turbidity was measured using the HACH Attenuated Radiation Method and the HACH DR/4000U spectrophotometer (HACH 1997).
3. Analysis was conducted within 48 hours of sampling date.

NITRATES

1. For every ten samples, splits and duplicates were collected or made.
2. Nitrates were analyzed using the HACH UV Direct Reading and the HACH DR/4000U Spectrophotometer (HACH 1997).
3. The limit of detection for the test is 0.2 ppm NO_3-N. The range for the test is 0.0 ppm to 10.2 ppm NO_3-N.
4. Analysis was conducted within 48 hours of sampling date.

APPENDIX E. RESULTS OF GREAT POND WATER QUALITY ANALYSIS

Table 1. Summer analysis for total phosphorus concentrations from Characterization Sites taken between 25-Jun-98 and 13-Aug-98 by Colby Environmental Assessment Team. See site map for site locations (Fig. 11).

Site	Date	Concentration	Location	Quality Control
1	25-Jun-98	5.1	surface	
1	25-Jun-98	7.6	mid-depth	
1	25-Jun-98	13.9	bottom	
1	25-Jun-98	21.3	epicore	
1	17-Jul-98	28.3	surface	
1	17-Jul-98	5.4	mid-depth	
1	17-Jul-98	9.0	epicore	
1	13-Aug-98	9.4	surface	
1	13-Aug-98	8.5	mid-depth	
1	13-Aug-98	24.9	bottom	
1	13-Aug-98	26.1	bottom	duplicate
1	13-Aug-98	7.6	epicore	
2	25-Jun-98	4.8	surface	
2	25-Jun-98	15.7	mid-depth	
2	25-Jun-98	8.7	mid-depth	duplicate
2	25-Jun-98	5.0	bottom	
2	25-Jun-98	12.2	epicore	
2	17-Jul-98	3.0	surface	
2	17-Jul-98	7.8	mid-depth	
2	17-Jul-98	19.4	bottom	
2	17-Jul-98	6.7	epicore	
2	13-Aug-98	5.2	surface	
2	13-Aug-98	6.8	mid-depth	
2	13-Aug-98	25.6	bottom	
2	13-Aug-98	27.0	bottom	duplicate
2	13-Aug-98	93.1	epicore	
2	13-Aug-98	108.1	epicore	duplicate
3	25-Jun-98	10.3	surface	
3	25-Jun-98	5.3	mid-depth	
3	25-Jun-98	13.0	bottom	
3	17-Jul-98	6.3	surface	
3	17-Jul-98	9.3	mid-depth	
3	17-Jul-98	10.1	bottom	
3	17-Jul-98	5.2	epicore	

Table 1. (cont.)

Site	Date	Concentration	Location	Quality Control
3	13-Aug-98	7.1	surface	
3	13-Aug-98	27.1	epicore	
3	13-Aug-98	27.3	epicore	duplicate
4	25-Jun-98	4.5	surface	duplicate
4	25-Jun-98	9.7	mid-depth	
4	25-Jun-98	5.2	bottom	
4	25-Jun-98	5.3	epicore	
4	17-Jul-98	18.6	surface	
4	17-Jul-98	3.3	epicore	
4	13-Aug-98	5.7	surface	
4	13-Aug-98	6.3	epicore	
5	25-Jun-98	4.2	surface	
5	25-Jun-98	10.4	bottom	
5	25-Jun-98	7.0	epicore	
5	17-Jul-98	5.9	surface	
5	17-Jul-98	8.6	bottom	
5	17-Jul-98	5.8	epicore	
5	13-Aug-98	8.5	surface	
5	13-Aug-98	5.2	epicore	

Table 2. Fall analysis for total phosphorus concentrations from all sites taken on 21-Sep-98 and 5-Oct-98 in the Great Pond Watershed by Colby Environmental Assessment Team. See site map for site locations (Fig. 11).

Site	Date	Concentration	Location	Quality Control
1	21-Sep-98	7.6	surface	
1	21-Sep-98	7.7	epicore	
1	21-Sep-98	10.0	epicore	duplicate
1	21-Sep-98	11.8	mid-depth	
1	21-Sep-98	100.4	bottom	
1	05-Oct-98	7.1	surface	
2	21-Sep-98	5.0	surface	
2	21-Sep-98	5.2	mid-depth	
2	21-Sep-98	7.3	epicore	duplicate
2	21-Sep-98	7.5	epicore	
2	21-Sep-98	4.7	epicore	duplicate
2	21-Sep-98	14.4	bottom	

Table 2 (cont.)

Site	Date	Concentration	Location	Quality Control
2B	21-Sep-98	10.3	surface	
2B	21-Sep-98	16.5	epicore	
2B	21-Sep-98	23.2	epicore	duplicate
2B	21-Sep-98	35.9	mid-depth	
2B	21-Sep-98	5.8	bottom	
2B	05-Oct-98	7.2	surface	
2B	05-Oct-98	7.1	surface	duplicate
2B	05-Oct-98	8.5	bottom	
3	21-Sep-98	9.6	surface	
3	21-Sep-98	10.0	mid-depth	
3	21-Sep-98	8.0	epicore	duplicate
3	21-Sep-98	12.3	epicore	
3	21-Sep-98	8.9	bottom	
3	21-Sep-98	9.2	bottom	split
4	21-Sep-98	6.6	surface	
4	21-Sep-98	6.0	mid-depth	
4	21-Sep-98	9.4	epicore	
4	21-Sep-98	5.1	epicore	duplicate
4B	21-Sep-98	11.6	surface	
4B	21-Sep-98	5.7	surface	split
4B	21-Sep-98	11.4	mid-depth	
4B	21-Sep-98	6.3	epicore	
4B	21-Sep-98	10.3	epicore	duplicate
4B	05-Oct-98	6.2	epicore	
4B	05-Oct-98	5.8	epicore	duplicate
4B	05-Oct-98	7.6	surface	
5	21-Sep-98	8.1	surface	
5	21-Sep-98	8.1	epicore	
5	21-Sep-98	7.8	epicore	duplicate
5	21-Sep-98	9.5	mid-depth	
5B	21-Sep-98	5.1	surface	
5B	21-Sep-98	8.6	mid-depth	
5B	21-Sep-98	5.8	epicore	
5B	21-Sep-98	6.7	epicore	duplicate
6	21-Sep-98	8.9	surface	

Table 2 (cont.)

Site	Date	Concentration	Location	Quality Control
6	21-Sep-98	7.1	epicore	
6	21-Sep-98	5.5	epicore	duplicate
6	21-Sep-98	6.1	bottom	
6	21-Sep-98	7.4	mid-depth	
6	05-Oct-98	6.7	surface	
6	05-Oct-98	7.7	surface	duplicate
8T	05-Oct-98	12.0	surface	
9T	05-Oct-98	11.7	surface	
10T	05-Oct-98	29.2	surface	
12T	05-Oct-98	19.2	surface	duplicate
13T	21-Sep-98	68.0	surface	split
13T	05-Oct-98	20.4	surface	

Table 3. Water quality results for 21-Sep-98 from all sample sites in the Great Pond Watershed by Colby Environmental Assessment Team. See site map for site locations (Fig. 11).

Site	pH	Alkalinity (ppm)	Turbidity (FTU)	Quality Control
1	7.47	9*	3.38	
1		8*		duplicate
1			3.71	duplicate
1				split
2	7.28	8*	1.26	
2				•split
2-B	6.52		3.20	
2-B				duplicate
3	6.89		20.70	
3				duplicate
4	6.88		2.51	
4				split
4-B	7.18		2.56	
5	6.97		1.26	
5			1.57	split

Table 3 (cont.)

Site	pH	Alkalinity (ppm)	Turbidity (FTU)	
5-B	6.98		2.06	
6	6.99	10**	3.86	
7	6.67	9**	2.27	
7		8**		split
7				split
8-T	6.99		12.10	
9-T	7.13		5.92	
10-T	5.69			
11-T	7.80		4.84	
11-T			5.01	split
11-T				split
12-T	6.94		29.40	
13-T(down)	7.00		6.57	
13-T(up)	7.11		6.42	

* epicore sample
** surface sample

Table 4. Water quality results for 21-Sep-98 from all sample sites in the Great Pond Watershed by Colby Environmental Assessment Team. See site map for site locations (Fig. 11).

Site	Hardness (ppm)	Transparency (m)	Color (SPU)	Conductivity (μMHPs/cm)	Quality Control
1	2.97	4.75	7.00	30.00	
1					duplicate
1					duplicate
1			6.00		split
2	3.05	5.75	5.00	31.00	
2	3.00				split
2-B		5.00		33.50	
2-B				32.00	duplicate
3		5.25	7.00	32.00	
3			12.00		duplicate
4			12.00	34.00	
4					split
4-B				30.50	
5			25.00	40.00	
5					split
5-B				30.00	

Table 4. (cont.)

Site	Hardness (ppm)	Transparency (m)	Color (SPU)	Conductivity (μMHPs/cm)	Quality Control
6		6.07	8.00	30.00	
7			19.00	31.00	
7					split
7				31.00	split
8-T			28.00		
9-T			57.00		
10-T			25.00		
11-T			10.00		
11-T					split
11-T			8.00		split
12-T			130.00		
13-T(down)			27.00		
13-T(up)			25.00		

Table 5. Water quality results for 5-Oct-98 from all sample sites in the Great Pond Watershed by Colby Environmental Assessment Team. See site map for site locations (Fig. 11).

Site	Turbidity (NTU)	Color (SPU)	Conductivity (μMHOs/cm)	Quality Control
1		10	30.00	
1		11		split
2B		24	32.00	
2B			32.00	duplicate
4B		24	30.00	
4B			29.50	split
6		11	29.80	
7		12	30.00	
8T	4.97	47	17.50	
8T	5.55			duplicate
9T	5.00	63	29.00	
10T	4.55	25	36.00	
11T	1.68	9	19.50	
11T	1.68			split
12T	3.28	90	9.10	
12T		89		duplicate
13T	8.94	57	10.00	

APPENDIX F. RAW FLOW RATE DATA

Tributary Site	Distance from Bank (ft)	Depth (ft)	Cell length (ft)	Mean Cell Depth (ft)	Velocity (fps)	Average cell velocity (fps)	Cell Flow Rate (cfs)	Tributary Flow Rate (cfs)
8-T pt. 1	1.33	0.55			0.26			
	2.33	0.80	1.00	0.67	0.14	0.20	0.13	
8-T pt. 2	2.00	0.20			0.52			
	6.42	0.60	4.41	0.40	0.24	0.38	0.67	
	7.50	1.60	1.08	1.10	0.00	0.12	0.14	
	9.00	1.00	1.50	1.30	0.00	0.00	0.00	0.94
11-T	3.85	0.50			0.10			
	6.92	1.80	3.08	1.15	0.03	0.06	0.23	
	10.38	1.85	3.46	1.82	0.03	0.03	0.21	
	13.85	1.65	3.46	1.75	0.06	0.05	0.30	
	17.38	1.70	3.54	1.67	0.03	0.05	0.30	
	20.77	1.10	3.38	1.40	0.03	0.03	0.15	
	24.23	0.75	3.46	0.92	0.03	0.03	0.10	
	27.69	0.25	3.46	0.50	0.03	0.03	0.06	
	31.15	0.50	3.46	0.37	0.03	0.03	0.04	1.39
12-T	1.00	0.50	1.00	0.50	0.00	0.00	0.00	0.00
13-T	0.00	1.90			0.10			
	10.00	2.63	10.00	2.26	0.06	0.08	1.86	
	20.00	2.20	10.00	2.41	0.10	0.08	1.98	
	30.00	1.50	10.00	1.85	0.10	0.10	1.80	
	40.00	1.40	10.00	1.45	0.03	0.06	0.93	6.57

APPENDIX G. RESIDENTIAL SURVEY FORM

Date:________________ Surveyor's Name(s):____________________

	Residences < 200 ft of water			Residences > 200 ft of water		
Road Name	# Seasonal	# Year-round	Total	# Seasonal	# Year-round	Total

APPENDIX H. BUFFER STRIP SURVEY

Date:______________ Surveyors:______________ ______________

House #:________	0	1 – 25	26 - 50	51 - 75	> 75	Score:
Lakeshore coverage (%)	0	1	2	3	4	
Buffer depth from shore(ft.)	0	1	2	3	4	
Slope b/w shore & house:	> 50	50 - 26	25 - 1	0		
100 % equals 45° slope	0	1	2	3		
Composition:	100%	75%	50%	25%	0%	
Trees	4	3	2	1	0	
Shrubs/Flowers	10	8	6	4	0	
Riprap needed:	YES	NO				
	0	2				
					Total:	

House #:________	0	1 – 25	26 - 50	51 - 75	> 75	Score:
Lakeshore coverage (%)	0	1	2	3	4	
Buffer depth from shore(ft.)	0	1	2	3	4	
Slope b/w shore & house:	> 50	50 - 26	25 - 1	0		
100 % equals 45° slope	0	1	2	3		
Composition:	100%	75%	50%	25%	0%	
Trees	4	3	2	1	0	
Shrubs/Flowers	10	8	6	4	0	
Riprap needed:	YES	NO				
	0	2				
					Total:	

House #:________	0	1 – 25	26 - 50	51 - 75	> 75	Score:
Lakeshore coverage (%)	0	1	2	3	4	
Buffer depth from shore(ft.)	0	1	2	3	4	
Slope b/w shore & house:	> 50	50 - 26	25 - 1	0		
100 % equals 45° slope	0	1	2	3		
Composition:	100%	75%	50%	25%	0%	
Trees	4	3	2	1	0	
Shrubs/Flowers	10	8	6	4	0	
Riprap needed:	YES	NO				
	0	2				
					Total:	

House #:________	0	1 – 25	26-50	51 - 75	> 75	Score:
Lakeshore coverage (%)	0	1	2	3	4	
Buffer depth from shore(ft.)	0	1	2	3	4	
Slope b/w shore & house:	> 50	50 - 26	25 - 1	0		
100 % equals 45° slope	0	1	2	3		
Composition:	100%	75%	50%	25%	0%	
Trees	4	3	2	1	0	
Shrubs/Flowers	10	8	6	4	0	
Riprap needed:	YES	NO				
	0	2				
					Total:	

APPENDIX I. DETAILED ROAD SURVEY FORM

DATE:__________ SURVEYOR'S NAME(S):__________

ROAD NAME/NUMBER:__________

GENERAL DESCRIPTION

ROAD DIMENSIONS: Length (miles):_____ Average Width (feet):_____

TOTAL NO. OF WATER DIVERSIONS:______ NO. OF MISSING WATER DIVERSIONS:______

NUMBER OF MISSING CULVERTS NEEDED:______

SLOPE DESCRIPTION:__________

DESCRIPTION OF ROAD SURFACE

Starting away from the lake, score each 0.5 mile section of road with checkmark [√] in appropriate column of each row (last road segment may be shorter). When survey is complete, compute average score for each characteristic using values shown in parentheses.

	Good	Acceptable	Fair	Poor	Big Problem		Average Score
Crown	____(1)	____(2)	____(4)	____(6)	____(8)		____
	6 in.	4 in.	2 in.	0 in./potholes	0 in./ruts		
Surface (dry)	____(1) hard w/o dust		____(3) hard w/ dust	____(4) loose	____(5) dusty & loose		____
OR Surface (wet)	____(1) hard	____(2) hard & slick	____(3) slick & loose		____(5) mud		____
Edge	____(0) no berm/ridge				____(5) berm/ridge prevents surface runoff		____
Base	____(1) Gravel/sand		____(3) dirt		____(5) clay		____
					SURFACE TOTAL	[a]	____
USAGE	____(1) seasonal				____(5) year-round	[b]	____
OVERALL SURFACE CONDITION	____(1) 100%good	____(2) 75%good	____(3) 50%good	____(4) 25%good	____(5) 0%good	[c]	____

______ **X** ______ **X** ______ = ______

SURFACE [a] USAGE [b] CONDITION [c] SURFACE TOTAL [d]

DESCRIPTION OF ROAD DITCHING

Score the quality of culverts for the entire road with checkmark [√] in appropriate column of summary evaluation. Use the descriptions provided to determine the overall ditch condition.

	Good	Acceptable	Fair	Poor	Big Problem	Average Score
Need	____(1) ample/none needed		____(5) some needed		____(15) badly needed	____
Vegetation	____(1) turf, wooded, or rip rap	____(2) grass	____(3) weeds	____(4) brush	____(5) bare soil	____
Sediments	____(1) none	____(2) 1 inch deep	____(3) 2 inches deep	____(4) 4 inches deep	____(5) >4 inches deep	____
					TOTAL [e]	____
SUMMARY OF DITCH CONDITION	____(1) 100%good, or none needed	____(2) 75%good	____(3) 50%good	____(4) 25%good	____(5) 0%good, or no ditch present but needed	
					[f]	____

________ X ________ = ________

DITCHES [e] **CONDITION [f]** **DITCH TOTAL [g]**

DESCRIPTION OF CULVERTS

Score the quality of culverts for the entire road with checkmark [√] in appropriate column of summary evaluation. Use the descriptions provided to determine the overall culvert condition.

	Good	Acceptable	Fair	Poor	Big Problem	Ave. Score
Need	____(1) ample/none needed		____(5) some not working		____(10) badly needed	____
Insides	____(1) clean	____(2) some rocks	____(3) ≤2 in. silt	____(4) >2 in. silt		____
					TOTAL [h]	____
OVERALL CULVERT CONDITION	____(1) 100%good, or none needed	____(2) 75%good	____(3) 50%good	____(4) 25%good	____(5) 0%good, no culvert present but needed	
					[I]	____

________ X ________ = ________

CULVERTS [h] **CONDITION [i]** **CULVERT TOTAL [j]**

DESCRIPTION OF WATER DIVERSIONS

Score the quality of water diversions for the entire road with checkmark [√] in appropriate column of each row. Use the descriptions provided to determine the overall water diversion condition.

	Good(1)	Acceptable(2)	Fair(3)	Poor(4)	Big Problem(5)		Average Score
Need	ample/none needed				badly needed		____
Where does diverted water go?	Woods(1)	field or lawn(2)	gully in woods(3)	Stream(4)	Lake(5)		____
					TOTAL	[k]	____
OVERALL WATER DIVERSION CONDITION	____(1) 100%good, or none needed	____(2) 75%good	____(3) 50%good	____(4) 25%good	____(5) 0%good, no diversions present but needed	[l]	____

________ **X** __________ = _____________

WATER DIVERSIONS [k] **CONDITION[l]** **WATER DIVERSIONS TOTAL [m]**

FINAL EVALUATION OF THE ROAD

________ + _______ + _________ + _____________ = ________

[d] [g] [j] [m]

SURFACE + DITCHES + CULVERTS + WATER DIVERSIONS = ROAD TOTAL

The lower the total, the better the score for an individual road. Having a low or acceptable score does not mean that road maintenance is unnecessary, but a high score indicates the need for work, and can be used as a guide for making decisions about where and what type of work is needed. As a rule, if any item checked was worth more than two points, it should be given priority when developing a road maintenance plan.

APPENDIX J. NON-DETAILED ROAD SURVEY FORM

DATE________ SURVEYOR NAMES:________________

ROAD NAME/NUMBER (if no name visible, name it as follows: your group # followed by a letter starting with A, then B, C, etc. in a clockwise formation around the map):

GENERAL DESCRIPTION

ROAD DIMENSIONS: Length (miles)______ Mean Width (feet)_______
(Includes shoulder and breakdown lane)

(Note: If road surface is not uniform, record length of pavement and dirt separately)

ROAD SURFACE IS:

________	________	_____	___________	_____
Hard (w/o dust)	Hard (w/ dust)	Loose	Dusty and Loose	Paved

USAGE: __________ Seasonal __________ Year-round

COMMENTS ON ROAD SURFACE:

IS ROAD: STATE MAINTAINED____ TOWN OWNED____ PRIVATE____

HOUSE COUNT: _________ Seasonal _________ Year-round

COMMERCIAL BUSINESS COUNT:
_______ Restaurants
_______ Gas Station
_______ Condominiums
_______ Other (Please specify)
____
____

SUMMER COMMERCIAL CAMP COUNT: ________

SURVEY PAGE NUMBER: ________
(Including camp road surveys)

APPENDIX K. AREA OF ROADS

The area (acres) of paved and nonpaved detail surveyed and non-detail surveyed roads for each town and the total area of each type of road in the Great Pond Watershed.

Town	Detail Surveyed		Non-Detail Surveyed	
	Paved	Non-paved	Paved	Non-paved
Belgrade	19	41	64	2
Rome	11	22	40	6
Smithfield	2	0	19	1
Mercer	0	0	0	3
Total	32	63	123	12

APPENDIX L. RESULTS OF DETAIL-SURVEYED ROADS

Table 1. Results of 65 Belgrade roads surveyed using the Detailed Road Survey Form. See Appendix K for the description of the road characteristics: Surface Total, Ditch Total, Culvert Total, Water Diversion Total. Road Total Index is the sum of these four components and an index of road quality.

Road Name	Surface Total	Ditch Total	Culvert Total	Water Diversion Total	Road Total Index
Loon Cove Road (FR-S4)	PAVED				
S2	16.6	17.1	2.0	9.3	45.0
S1	52.0	20.0	70.0	47.5	289.5
Hemlock Point Road (FR 0.11)	219.9	45.2	12.0	10.9	288.0
FR 0.10	26.4	16.0	14.0	16.0	72.4
Pinkham Cove Road (FR 0.7)	20.0	78.9	33.0	50.0	181.9
Grandview Road (FR 0.6A)	60.0	42.0	2.0	50.0	154.0
FR 04R	25.0	36.0	12.0	8.0	81.0
FR 04L	80.0	16.0	2.0	6.0	104.0
Foster Point Road	156.3	91.4	2.0	9.0	258.7
Dead End of Foster Point Rd.	187.5	44.0	2.0	24.0	257.5
Pinkham Road	80.0	3.0	2.0	2.0	87.0
Point Road	PAVED				
FR 1	32.0	110.0	5.0	50.0	242.0
FR 2	90.0	24.0	2.0	2.0	118.0
FR 3	120.0	18.0	2.0	3.0	143.0
Chandler Road	PAVED				
FR 4	22.0	95.0	8.0	20.0	145.0
FR 5	12.0	44.0	8.0	20.0	84.0
FR 6	60.0	12.0	6.0	50.0	128.0
FR 7	22.0	90.0	2.0	50.0	164.0
FR 8	12.0	4.0	2.0	50.0	68.0
FR 9	20.0	20.0	2.0	12.0	54.0
FR 10	21.0	3.0	2.0	2.0	28.0
FR 11	80.0	18.0	1.0	4.0	103.0
FR 13	60.0	85.0	2.0	10.0	157.0
FR 14	12.5	20.0	2.0	15.0	49.5
Woodland Camp (FR 15)	42.5	78.7	2.0	15.9	139.1
FR 17	36.0	27.0	4.0	15.0	82.0
FR 18	12.0	3.0	2.0	6.0	23.0

Table 1. (cont.).

Road Name	Surface Total	Ditch Total	Culvert Total	Water Diversion Total	Road Total Index
Oakwood Drive	150.0	3.0	2.0	2.0	157.0
Sahagian $Road_{paved}$	PAVED				
Sahagian $Road_{dirt}$	100.0	14.0	32.0	12.0	158.0
SR 1	30.0	3.0	2.0	3.0	38.0
Abena Shores	30.0	3.0	2.0	2.0	37.0
Abena Shores (3A)	80.0	3.0	2.0	2.0	87.0
Great Pond Marina	80.0	18.0	2.0	2.0	102.0
Great Pond Campground	60.0	3.0	2.0	2.0	67.0
FR A8	12.0	3.0	2.0	2.0	19.0
FR A9	80.0	3.0	2.0	2.0	87.0
FR A10	12.0	3.0	2.0	2.0	19.0
FR A11	12.0	3.0	2.0	2.0	19.0
School Street	PAVED				
Snug Harbor Road (S9)	10.0	6.0	2.0	2.0	20.0
Damren Road (S7A)	PAVED				
Hatch Cove Road (S6)	80.0	33.0	24.0	2.0	139.0
S5	60.0	3.0	27.0	2.0	92.0
S3	39.0	22.0	10.0	50.0	121.0
Horse Point $Road_{paved}$	PAVED				
Horse Point $Road_{dirt}$	80.0	32.0	70.0	50.0	232.0
H2	10.0	14.0	2.0	2.0	28.0
H3	16.0	3.0	2.0	2.0	23.0
H4	33.0	3.0	2.0	2.0	40.0
H5	8.0	3.0	2.0	2.0	15.0
H6	8.0	3.0	2.0	2.0	15.0
H7	80.0	16.0	2.0	2.0	100.0
H8	45.5	90.0	2.0	2.0	139.5
H10	24.0	3.0	2.0	2.0	31.0
H11 NF[1]	39.0	33.0	2.0	2.0	76.0
H11 SF[2]	60.0	125.0	2.0	2.0	189.0
H12	120.0	3.0	2.0	2.0	127.0
H12A	40.0	3.0	2.0	3.0	48.0
H13	52.0	125.0	50.0	50.0	277.0
H13A	30.0	125.0	70.0	50.0	275.0
H13D	39.0	60.0	2.0	50.0	151.0

[1] NF = North Fork of H11

[2] SF = South Fork of H11

Table 2. Results of 46 Rome roads surveyed using the Detailed Road Survey Form. See Appendix K for the description of the road characteristics: Road Surface Total, Ditch Total, Culvert Total, and Water Diversion Total. Road Total Index is the sum of these four components and an index of road quality.

Road Name	Surface Total	Ditch Total	Culvert Total	Water Diversion Totals	Road Total Index
Hulin Road	PAVED				
Wings Hill Road	80.0	3.0	2.0	2.0	87.0
Colby Fire Road (FR 27-0A)	80.0	3.0	2.0	2.0	87.0
27-1A	80.0	10.0	2.0	2.0	94.0
No Name-1st Left Off Wings Hill Road	80.0	3.0	2.0	2.0	87.0
Richardson Road FR RVFD 27-0	PAVED				
Locke Road	80.0	3.0	2.0	30.0	115.0
Crane Rd. (FR 27-2)	339.3	110.0	21.3	8.5	479.1
FR 27-2A	120.0	27.0	12.0	2.0	161.0
Lambert Road (FR 225-10)	120.0	3.0	2.0	2.0	127.0
FR 225-10A	120.0	3.0	2.0	2.0	127.0
FR 225-10B	100.0	3.0	2.0	2.0	107.0
Horton's Cove	18.0	27.0	50.0	2.0	97.0
Hemlock Trail	16.0	14.0	2.0	2.0	34.0
FR 225-7A	20.0	3.0	2.0	24.0	49.0
Starbird Lane	23.3	5.5	5.0	16.0	49.8
Nickerson Lane	48.0	27.0	15.0	1.0	91.0
FR 225-6A	18.0	56.0	14.0	30.0	118.0
Melvin Road	16.0	6.0	15.0	30.0	102.0
Rome Rec. Center	21.0	33.0	25.0	20.0	99.0
Hoyt's Island Camp	37.5	27.0	1.0	12.0	77.5
Crystal Spring Road RVFD 225-4	28.8	22.5	2.0	12.0	65.3
Rome Country Store	42.0	3.0	1.0	2.0	48.0
FR 225-4A	21.0	14.0	2.0	2.0	39.0
FR 225-4B	30.0	4.0	2.0	3.0	39.0
Jamaica Point Road FR 225-2	8.0	4.0	2.0	6.0	20.0
North Pond Road	PAVED				
FR 225-2A	36.0	20.0	22.5	2.0	80.5
FR 225-2A1	48.0	66.0	24.0	2.0	140.0
No name-1st Right off Jamaica Point Rd	65.0	3.0	12.0	2.0	82.0
Crane Lane (225-2B)	30.0	4.0	27.0	30.0	91.0

Table 2. (Cont.)

Road Name	Surface Total	Ditch Total	Culvert Total	Water Diversion Totals	Road Total Index
South Crane Lane (225-2B1)	60.0	27.0	20.0	30.0	137.0
North Crane Lane	30.0	16.0	27.0	2.0	75.0
Hathaway Lane (225-2E)	8.0	3.0	50.0	2.0	63.0
Paris Lane (225-2D)	12.0	3.0	30.0	2.0	47.0
225-2F	8.0	3.0	2.0	2.0	15.0
225-2F1	8.0	3.0	2.0	2.0	15.0
225-2F2	16.0	3.0	2.0	2.0	23.0
225-2F2A	4.0	2.0	2.0	2.0	10.0
225-2F3	4.0	3.0	2.0	2.0	11.0
225-2G	10.0	3.0	2.0	2.0	17.0
225-2E1	4.0	3.0	2.0	2.0	11.0
225-7B	16.0	14.0	56.0	6.0	92.0
Knauer/Delisle	16.0	16.0	2.0	8.0	42.0
Mayberry Private Dr.	16.0	3.0	2.0	2.0	23.0
Eagle Crest Road	40.0	4.0	2.0	2.0	48.0

APPENDIX M. CLASSES OF ROAD TOTAL INDEX VALUES

Classes of 101 Detail surveyed dirt roads within the Great Pond Watershed surveyed using the Detailed Road Survey Form. These roads represent 74.5 percent of the roads in the watershed and are closest to the lake. These roads are classified using their Road Total Index values (see Appendix K). Classes refer to road conditions as follows: Class 1 indicates a road in Good condition; Class 2 indicates a road in Acceptable condition; Class 3 indicates a road in a Needs Work condition; and Class 4 indicates a road in Poor condition.

Class 1	Class 2	Class 3	Class 3 (cont.)	Class 4
Belgrade				
H5	H4	FR 04R	FR 6	Horse Pt Rd$_{dirt}$
H6	S2	FR 17	Hatch Cove Rd[8]	FR 1
Snug Harbor Rd[1]	Great Pond	Great Pond	Pinkhams Cove	Dead End of
FR A10	Campground	Marina	Road[9]	Foster Point Rd
FR A11	FR 14	Pinkham Road	H8	Foster Point Rd
FR A8	FR 9	Abena Shores[4]	FR 3	H13A
FR 18	H12A	FR A9	FR 4	H13
H3	FR 8	S5	H13D	Hemlock Pt Rd[15]
FR 10	FR 0.10	H7	Grandview Rd[10]	S1
H2		FR 5	Woodland	
H10		FR 11	Camp[11]	
Abena Shores		FR 04L	Oakwood Drive	
SR 1		FR 2	Sahagian Road$_{dirt}$	
H11-North Fork		S3	FR 7	
		H12	FR 13	
			H11-South Fork	
Rome				
225-2F2A	FR 225-7A	FR 225-2A	No name[12]	Crane Road
225-2E1	Hathaway Lane	225-7B	Rome Rec. Ctr.	
225-2F3	Paris Lane [3]	FR 225-10B	Melvin Road	
225-2F2	Crystal Spring Rd	27-1A	Lambert Road[13]	
Jamaica Pt Rd[2]	Eagle Crest Road	Nickerson Ln	Locke Road	
Mayberry Private	Rome Country	FR 225-2A1	FR 225-10A	
Drive	Store			
225-2F	North Crane Lane	Wings Hill Rd	FR 225-6A	
Hemlock Trail	Hoyt's Is Camp	No name[5]	South Crane Ln[14]	
225-2F1	Knaur/Delisle	FR 27-2A		
FR 225-4A	Starbird Lane	Colby Fire Rd[6]		
225-2G		Horton's Cove		
FR 225-4B		Crane Lane[7]		

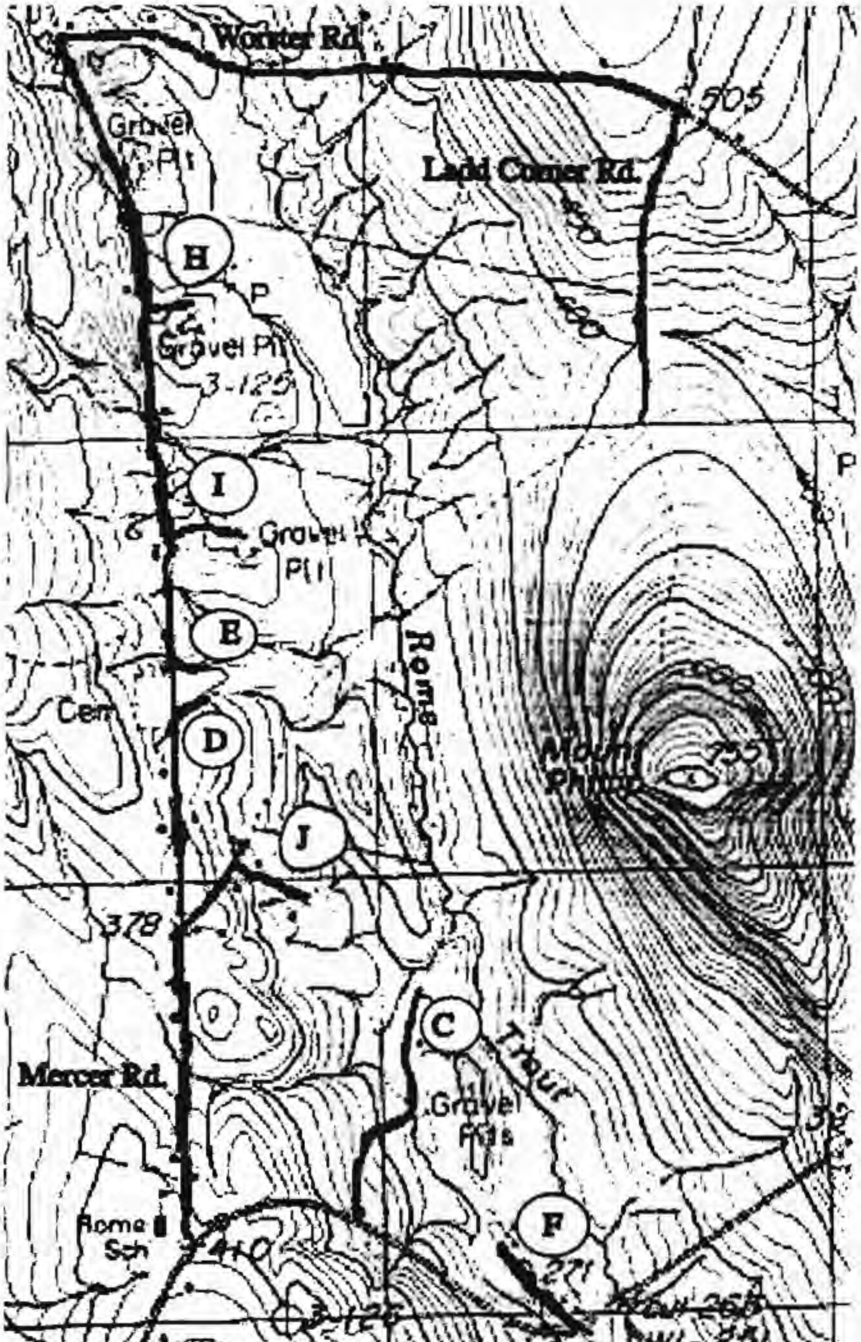
Alternative names for roads: [1]S9, [2]FR 225-2, [3]225-2D, [4]3A, [5] 1st Right off Jamaica Pt Rd,
[6]FR 27-0A, [7]225-2B, [8]S6, [9]FR 0.7, [10]FR 0.6A, [11]FR 15, [12]1st Left off Wings Hill, [13]FR 225-10, [14]225-2B1, [15]FR 0.11.

APPENDIX N. LIST OF ALL NON-DETAIL-SURVEYED ROADS

Road	Paved/Dirt	Length (ft)	Mean Width (ft)
Belgrade			
Route 27	Paved	29601.6	39.0
1A-Pine Grove Cemetery	Paved	2643.0	36.0
2A	Paved	5814.6	33.5
Route 211	Paved	5286.0	39.4
Guptill Road	Paved	5286.0	25.0
West Road	Paved	3171.6	27.3
Pheasant Road	Dirt	2114.4	26.6
Off West Road	Dirt	1057.2	11.0
Gowell Road	Dirt	528.6	15.0
Spaulding Point S-8	Dirt	1057.2	26.0
Route 8	Paved	23258.4	37.8
Old Route 8	Paved	1057.2	18.3
Rome			
4-C	Paved	4493.1	22.4
4-K	Dirt	528.6	12.7
RVFD 225-3	Dirt	1057.2	16.0
Worster Hill	Paved	12686.4	24.3
Ladd Corner Road	Dirt	7929.0	18.0
C	Dirt	2114.4	10.0
D	Dirt	528.6	9.0
E	Dirt	1585.8	11.6
F	Dirt	2114.4	12.7
Mercer Road	Paved	14272.2	20.6
H	Dirt	528.6	18.0
I	Dirt	528.6	11.3
J	Dirt	528.6	19.8
AA	Paved	528.6	18.4
Pine Tree Camp Road	Paved	9779.1	28.0
Route 225	Paved	25637.1	36.3
Smithfield			
S-10	Dirt	158.6	12.8
Route 137	Paved	1057.2	44.5
S-7	Dirt	528.6	12.5
Routes 8/137	Paved	6871.8	30.0
4-F	Dirt	1057.2	18.0
Pine Tree Camp Road	Paved	2643.0	28.0
Route 225	Paved	3700.2	36.3
Route 8	Paved	10043.4	37.8
Old Route 8	Paved	3700.2	18.3
Mercer			
Ladd Corner Road	Dirt	6871.8	18.0

APPENDIX O. UNNAMED NON-DETAIL-SURVEYED ROADS

Unnamed Non-detail-surveyed roads are located just north of Rome Corner.



APPENDIX P. SOIL POTENTIALS BY RATING CLASS FOR KENNEBEC COUNTY, MAINE. MAP UNIT INCLUDES SOIL CLASSIFICATION AND SLOPE (USDA SOIL CONSERVATION SERVICE, 1989).

Map Unit	Septics	Dwellings	Roads	Development
BhB- Berkshire fine sandy loam, 3-8 percent	Very High	Very High	Very High	Very High
BkB- Berkshire very stony fine sandy loam, 3-8 percent	High	High	High	High
BkC- Berkshire very stony fine sandy loam, 8-15 percent	High	High	Medium	High
BkD- Berkshire very stony fine sandy loam, 15-30 percent	Very Low	Medium	Medium	Very Low
Bo- Biddeford mucky peat	Very Low	Very Low	Very Low	Very Low
BuB2- Buxton silt loam, 3-8 percent, eroded	Medium	High	Medium	Medium
BuC2- Buxton silt loam, 8-15 percent, eroded	Medium	Medium	Medium	Medium
DeB- Deerfield loamy fine sand, 0-8 percent	Very Low	High	High	Medium
Ha- Hadley silt loam	Very Low	Very Low	Very Low	Very Low
HfC- Hartland very fine sandy loam, 8-15 percent	Medium	High	Medium	Medium
HfD- Hartland very fine sandy loam, 15-25 percent	Very Low	Medium	Low	Low
HkB- Hinckley gravelly sandy loam, 3-8 percent	Low	Very High	Very High	Medium
HkC- Hinckley gravelly sandy loam, 8-15 percent	Very Low	High	High	Medium
HkD- Hinckley gravelly sandy loam, 15-30 percent	Very Low	Medium	Medium	Very Low
HrB- Hollis fine sandy loam, 3-8 percent	Medium	Medium	High	Medium
HrC- Hollis fine sandy loam, 8-15 percent	Low	Low	Medium	Medium
HrD- Hollis fine sandy loam, 15-25 percent	Very Low	Very Low	Low	Very Low
HtB- Hollis-Rock Outcrop complex, 3-8 percent	Medium	Medium	High	Medium
HtB1- Hollis part	Medium	Medium	High	Medium
HtB2- Rock Outcrop part	Very Low	Very Low	Medium	Very Low
HtC- Hollis-Rock Outcrop complex, 8-15 percent	Low	Low	Medium	Medium
HtC1- Hollis part	Low	Low	Medium	Medium
HtC2- Rock Outcrop part	Very Low	Very Low	Medium	Very Low

APPENDIX P (cont.)

Map Unit	Septics	Dwellings	Roads	Development
HtD- Hollis-Rock Outcrop complex, 15-30 percent	Very Low	Very Low	Low	Very Low
HtD1- Hollis part	Very Low	Very Low	Low	Very Low
HtD2- Rock Outcrop part	Very Low	Very Low	Low	Very Low
Lk- Limerick silt loam	Very Low	Very Low	Very Low	Very Low
LyB- Lyman loam, 3-8 percent	Medium	Medium	High	Medium
LyC- Lyman loam, 8-15 percent	Low	Low	Medium	Medium
LyD- Lyman loam, 15-25 percent	Very Low	Very Low	Low	Very Low
LzC- Lyman-Rock Outcrop complex, 8-15 percent	Low	Low	Medium	Medium
LzC1- Lyman part	Low	Low	Medium	Medium
LzC2- Rock Outcrop part	Very Low	Very Low	Medium	Very Low
MoA- Monarda silt loam, 0-3 percent	Very Low	Very Low	Very Low	Very Low
MrA- Monarda very stony silt loam, 0-3 percent	Very Low	Medium	Medium	Low
PbB- Paxton fine sandy loam, 3-8 percent	High	High	High	High
PbC- Paxton fine sandy loam, 8-15 percent	High	Medium	Medium	Medium
PcB- Paxton very stony fine sandy loam, 3-8 percent	High	High	High	High
PcC- Paxton very stony fine sandy loam, 8-15 percent	Medium	Medium	Medium	Medium
PcD- Paxton very stony fine sandy loam, 15-25 percent	Very Low	Low	Low	Low
PdB- Paxton-Charlton fine sandy loam, 3-8 percent	High	High	High	High
PdB1- Paxton part	High	High	High	High
PdB2- Charlton part	Very High	Very High	Very High	Very High
PdC2- Paxton-Charlton fine sandy loam, 8-15 percent, eroded	High	Medium	Medium	Medium
PdC21- Paxton part	High	Medium	Medium	Medium
PdC22- Charlton part	High	High	High	High
PdD2- Paxton-Charlton fine sandy loam, 15-30 percent, eroded	Very Low	Medium	Low	Low
PdD21- Paxton part	Very Low	Medium	Low	Low
PdD22- Charlton part	Very Low	Medium	Medium	Low
PeB- Paxton-Charlton very stony fine sandy loam, 3-8 percent	High	High	High	High
PeB1- Paxton part	High	High	High	High
PeB2- Charlton part	High	High	High	High

APPENDIX P (cont.)

Map Unit	Septics	Dwellings	Roads	Development
PeC- Paxton-Charlton very stony fine sandy loam, 8-15 percent	Medium	Medium	Medium	Medium
PeC1- Paxton part	Medium	Medium	Medium	Medium
PeC2- Charlton part	High	High	Medium	High
PeD- Paxton-Charlton very stony fine sandy loam, 15-30 percent	Very Low	Low	Low	Very Low
PeD1- Paxton part	Very Low	Low	Low	Very Low
PeD2- Charlton part	Very Low	Medium	Medium	Very Low
PfB- Peru fine sandy loam, 3-8 percent	High	High	High	High
PkB- Peru very stony fine sandy loam, 3-8 percent	High	High	High	High
PkC- Peru very stony fine sandy loam, 8-15 percent	Medium	Medium	Medium	Medium
RcA- Ridgebury fine sandy loam, 0-3 percent	Very Low	Very Low	Very Low	Very Low
RdA- Ridgebury very stony fine sandy loam, 0-3 percent	Very Low	Very Low	Very Low	Very Low
Rf- Rifle mucky peat	Very Low	Very Low	Very Low	Very Low
Sa- Saco soils	Very Low	Very Low	Very Low	Very Low
ScA- Scantic silt loam, 0-3 percent	Very Low	Very Low	Very Low	Very Low
Sd- Scarboro mucky peat	Very Low	Very Low	Very Low	Very Low
SkB- Scio very fine sandy loam, 3-8 percent	High	High	Medium	Medium
SkC2- Scio very fine sandy loam, 8-15 percent, eroded	Medium	Medium	Medium	Medium
SuC2- Suffield silt loam, 8-15 percent, eroded	Medium	Medium	Medium	Medium
SuD2- Suffield silt loam, 15-25 percent, eroded	Very Low	Medium	Low	Very Low
SuE2- Suffield silt loam, 25-45 percent, eroded	Very Low	Low	Very Low	Very Low
To- Togus fibrous peat	Very Low	Very Low	Very Low	Very Low
Va- Vassalboro fibrous peat	Very Low	Very Low	Very Low	Very Low
WmB- Windsor loamy sand, 3-8 percent	Low	Very High	Very High	Medium
WmC- Windsor loamy sand, 8-15 percent	Very Low	High	High	Medium
WmD- Windsor loamy sand, 15-30 percent	Very Low	Medium	Medium	Very Low
Wn- Winooski silt loam	Very Low	Very Low	Very Low	Very Low

APPENDIX P (CONT.)

Map Unit	Septics	Dwellings	Roads	Development
WrB- Woodbridge fine sandy loam, 3-8 percent	High	High	High	High
WrC- Woodbridge fine sandy loam, 8-15 percent	Medium	Medium	Medium	Medium
WsB- Woodbridge very stony fine sandy loam, 3-8 percent	High	High	High	High
WsC- Woodbridge very stony fine sandy loam, 8-15 percent	Medium	Medium	Medium	Medium

APPENDIX Q. PHOSPHORUS EQUATION

The following equations were used to calculate the amount of phosphorus loaded into a body of water annually (W). The equation considers land use patterns, population, soil quality, land area, and population as sources that contribute to phosphorus loading.

$$W = (Ec_a \times A_s) + (Ec_f \times Area_f) + (Ec_t \times Area_t) + (Ec_l \times Area_l) + (Ec_w \times Area_w) + (Ec_c \times Area_c) + (Ec_r \times Area_r) + (Ec_{m/i} \times Area_{m/i}) + (Ec_s \times Area_s) + (Ec_n \times Area_n) + [(Ec_{ss} \times \#\ Capita\ years_1 \times (1-SR_1)) + (Ec_{us} \times \#\ Capita\ Years_2 \times (1-SR_2)) + (I \times (1-SR_3))] + PSI_1 + PSI_2$$

Ec_a = export coefficient for atmospheric input (kilograms per hectare per year) (kg/ha-yr)

Estimated Range (ER) = 0.15 to 0.30

The export coefficient reported by Reckhow and Chapra (1983) was 0.15 to 0.60 for Higgins Lake in Michigan. A study of Messalonskee Lake, in the Belgrade Lake Region of Maine, used a range of 0.20 to 0.60 (BI493 1998). A slightly lower coefficient range was used in this study because there are fewer sources of atmospheric loading adjacent to the lake.

Ec_f = export coefficient for mature forests (kg/ha-yr)

ER = 0.10 to 0.30

The export coefficient range reported by Reckhow and Chapra (1983) was 0.10 to 0.30 and was based on the percentage of mature forest in the watershed. A study of North Pond (BI493 1997) and Messalonskee Lake (BI493 1998) used the similar coefficients. The coefficient range used for Great Pond was the same range used for Higgins Lake, Michigan, because the forests appear very similar.

Ec_t = export coefficient for transitional land (kg/ha-yr)

ER = 0.2 to 0.55

In this investigation, regenerating land and reverting land were grouped together as transitional land. In a study of Messalonskee Lake (BI 493 1998), a range of 0.15 to 0.65 was used for regenerating land and a range of 0.20 to 0.75 was used for reverting

land. Reverting land is defined as land that was once cleared but is currently undergoing succession while regenerating land is a further maturation of the successional land.

Ec_l = export coefficient for logged land (kg/ha-yr)

ER = 0.30 to 0.80

The export coefficient range for logged land was 0.30 to 0.80. This range was based on the fact that logged land is more susceptible to erosion and therefore contributes more phosphorus annually than other land use types. Therefore it has a larger coefficient than mature or transitional forests.

Ec_w = export coefficient for wetlands (kg/ha-yr)

ER = 0.05 to 0.30

The coefficient range for North Pond (BI493 1997), Long Pond North and South Basins (BI493 1994, BI493 1995) and East Pond (BI493 1991) was 0.03 to 0.20. The Messalonskee Lake study (BI493 1998) used a range of 0.05 to 0.30. The same export coefficient as that used in the Messalonskee Lake study was assigned to Great Pond. This was done to account for the high productivity of the wetlands at various sites such as the area around Great Meadow Stream and Austin Bog.

Ec_c = export coefficient for cleared land (kg/ha-yr)

ER = 0.25 to 1.30

The export coefficient range reported by Reckhow and Chapra (1983) for Higgins Lake, Michigan, was 0.20 to 1.30 for agricultural land which consisted primarily of grazed and pasture land. The Messalonskee Lake study (BI493 1998) reported a range of 0.25 to 1.30 and grouped mowed fields, agricultural land, cleared land, and grazed land into one category. Because the type of cleared land in the Great Pond Watershed is similar to the Messalonskee Lake Watershed, the same range was used in this study.

Ec_r = export coefficient for roads (kg/ha-yr)

ER = 0.80 to 1.60

The road conditions in the Great Pond Watershed are similar to the roads in the Salmon Lake (ER = 0.30 to 1.50) and North Pond Watersheds (ER = 0.30 to 1.60). Most

of the roads were in adequate condition (BI493 1994, BI493 1997). However, some roads were in poor condition and undoubtedly contribute more phosphorus to Great Pond than well-built and maintained roads.

$Ec_{m/i}$ = export coefficient for industrial and municipal land (kg/ha-yr)

ER = 0.40 to 1.00

Most of the municipal land in the Great Pond Watershed is located in Belgrade, which is located near the outlet stream, thus having more of impact on phosphorus loading on Long Pond than Great Pond. However, a major component of this land use type is the golf course and nutrients from the extensive use of fertilizers may enter Great Pond. The export coefficient reported by Reckhow and Chapra (1983) in the Higgins Lake study for agricultural land was 0.20 to 1.30, which considered fertilizer runoff. Therefore, CEAT used a similar, yet slightly lower export coefficient for municipal/industrial sources because land other than the golf course will not contribute as much phosphorus to the lake.

Ec_s = export coefficient for shoreline development (kg/ha-yr)

ER = 0.80 to 3.20

The export coefficient range reported by Reckhow and Chapra (1983) for the Higgins Lake study was 0.35 to 2.70, because it was a residential and recreational area serviced by a municipal septic system. North Pond (BI493 1997) and Messalonskee Lake (BI493 1998) used larger coefficient ranges (ER = 0.80 to 3.50 and 0.90 to 3.55 respectively) because many shoreline houses were poorly buffered, with steeply sloped lawns extending to the edge of the property. The shoreline of Great Pond is similar to both of these lakes and has no municipal septic system. Therefore, a similar range was used for Great Pond.

Ec_n = export coefficient for non-shoreline development (kg/ha-yr)

ER = 0.35 to 1.00

With increased distance from the water, residential development has less of an impact on phosphorus loading and is assigned a lower export coefficient. Because development on nonshoreline land in the Great Pond Watershed is similar to developed

areas of Messalonskee Lake, Long Pond North Basin, Long Pond South Basin, Salmon Lake and North Pond Watersheds, the same coefficient was used.

Ec_{ss} = export coefficient for shoreline septic tank systems (kg/ha-yr)

ER = 0.50 to 1.30

The North Pond study used a coefficient range of 0.50 to 1.30 because of a high number of grandfathered septic systems in areas of poor soil suitability (BI493 1997). The septic systems on the shoreline of Great Pond are in good condition. However, certain locations around the lake have soil with moderate to poor septic suitability (e.g., the southern end of Pinkhams Cove). Therefore, a conservative range was used.

Ec_{ns} = export coefficient for non-shoreline septic tank systems (kg/ha-yr)

ER = 0.40 to 0.90

The majority of the Great Pond Watershed has very good soil and septic systems, therefore, there is little chance that the effluent will leach directly into the lake from this source. As a result, the Messalonskee Lake coefficient range was used in this investigation (BI493 1998).

Capita $years_1$ = capita years for shoreline development

This term accounts for the number of people potentially contributing waste to shoreline septic tank systems. Based on the 1990 United States Census for Kennebec and Somerset Counties, the mean family size for each of the 628 shoreline homes on Great Pond was 2.75. Seasonal residence time was estimated to be 70 days per year. This is the same value used in the North Pond and Messalonskee Lake studies and was based on personal communications with residents (BI493 1997, BI493 1998).

SR_1 = soil retention coefficient for shoreline development

ER = 0.70 to 0.50

Soil retention is a measurement of how efficient different soils hold nutrients such as phosphorus. Ranked on a scale from 0 to 1, soils with a high value retain more phosphorus than soils with a low value. While some of the soils around the shoreline of

Great Pond have moderate or poor septic suitability, most soils have good septic suitability, therefore, they have a higher rating.

Capita $Years_2$ = capita years for nonshoreline development

Based on 1990 census reports for Belgrade, Mercer, Smithfield and Rome, it was estimated that 2.75 people live in each of the 654 nonshoreline residences in the watershed. Taking into consideration vacation time spent away from home, mean residence time was estimated at 355 days per year.

SR_2 = soil retention coefficient for nonshoreline development

ER = 0.95 to 0.70

In the study of the Messalonskee Lake Watershed, the soil retention coefficient range was estimated at 1.00 to 0.50 (BI493 1998). While portions of the nonshoreline land have very poor soil suitability, the majority of the nonshoreline areas of the Great Pond Watershed have soils with very high septic suitability ratings, therefore, a high soil retention coefficient range was used.

I = combined export coefficient and number of per capita years for institutional sources (youth camps)

ER = 57.92 kg/ha-yr to 116.27 kg/ha-yr

This coefficient was calculated using USEPA data and camp information obtained from personal communications. The design manual written by the USEPA (1980) lists pollutant concentrations of major residential wastewater fractions (23 mg/L) and wastewater flow from institutional sources (52.8 gal-day/unit to 106 gal-day/unit). Pine Island Camp is open from June 26 to August 9 and is home to 85 campers and 22 staff. Camp Runoia is open from mid-June to mid-August and houses 100 people per day. Camp Bomazeen is open from June to August, however, CEAT was unable to obtain information regarding the number of campers.

SR_3 – soil retention coefficient for institutional sources (youth camps)

ER = 0.40 to 0.10

Camp Bomazeen is located on Horse Point Road, an area of the watershed with poor septic suitability. As a result, it has a low soil rating. Pine Island Camp is located on Pine Island, an area with high septic suitability and should therefore have a high soil rating. However, considering the size of the island and the fact that there is no septic system, the soil rating is lower.

PSI_1 – point source input from Great Meadow Stream

ER = 446.82 kg/yr

Using seasonal data from 1993, the phosphorus concentration of Great Meadow Stream was calculated to be 19.2 ppb. From this data, the total mass input of phosphorus from this point source was calculated to be 44.82 kg/yr.

PSI_2 = point source input from Salmon Lake

ER = 207.65 kg/yr

The phosphorus concentration of Salmon Lake was 8.8 ppb (BI493 1994). The total mass input of phosphorus from this point source was calculated to be 207.65 kg/yr.

Areas for land use components and per capita year values:

A_s = area of Great Pond = 3486.00 hectares

$Area_f$ = area of mature forests = 2908.80 hectares

$Area_t$ = area of transitional forests = 3581.00 hectares

$Area_l$ = area of logged forests = 163.43 hectares

$Area_w$ = area of wetlands = 590.60 hectares

$Area_c$ = area of cleared land = 558.40 hectares

$Area_r$ = area of roads = 112.00 hectares

$Area_{m/i}$ = area of municipal and industrial land = 115.00 hectares

$Area_s$ = area of shoreline development = 133.00 hectares

$Area_n$ = area of nonshoreline development = 384.00 hectares

capita $years_1$ = 337.74

capita $years_2$ = 333.51

APPENDIX R. PREDICTIONS FOR ANNUAL MASS RATE OF PHOSPHORUS INFLOW

The phosphorus loading model used by the Colby Environmental Assessment Team (CEAT) expresses the annual total phosphorus input as a loading (kilograms) per unit lake surface area (hectares). This was done by dividing the total phosphorus inflow (W) by the surface area of Great Pond (As) (Reckhow and Chapra 1983):

$$\mathbf{L} = W/A_s$$

L = areal phosphorus loading (kg/ha-yr)
W = annual mass rate of phosphorus inflow (kg/yr)
A_s = surface area of the lake (m^2)

Atmospheric water loading was calculated by dividing the total inflow water volume by the surface area of the lake (As) (Reckhow and Chapra 1983):

$$\mathbf{q_s} = Q_{(total)}/A_s$$

q_s = areal water loading (m/yr)
$Q_{(total)}$ = total inflow water volume (m^3/yr)

Low and high estimates of the total phosphorus concentration were then calculated by dividing the total atmospheric phosphorus loading by the approximation of the settling velocity of phosphorus in the lake (Reckhow and Chapra 1983):

$$\mathbf{P} = L/(11.6 + 1.2q_s)$$

P = total phosphorus concentration (kg/m^3)

Constants for low and high predictions for Great Pond:

A_s = 84,384,000 m^2
$Q_{(total)}$ = 127,402,744 m^3
q_s = 3.65 m/yr

<u>Low Prediction</u>:

W = 2887.30 kg/yr
L = 8.28×10^{-2} kg/ha-yr
P = 5.18 ppb

<u>High Prediction</u>:

W = 7007.03 kg/yr
L = 2.01×10^{-1} kg/ha-yr
P = 12.57 ppb

APPENDIX S. DEMOGRAPHIC TRANSITIONS

Demographic transitions and age cohorts from 1960-1997 from six towns in the Belgrade Lakes Region. Projected population size for the same six towns in the Belgrade Lakes Region for 2015 based upon current annual growth rates. Data were collected from Belgrade, Mercer, Mt. Vernon, Norridgewock, Rome and Smithfield. Data were obtained from Federal Census Data compiled by the Kennebec Valley Council of Governments in 1997. Data demarcated by NA were not tabulated in Federal Census Data.

Characteristic Size	Belgrade*	Mercer*	Mt. Vernon	Norridgewock*	Rome*	Smithfield*
1960 Population[1]	1102	272	596	1634	362	382
1970 Population[2]	1302	313	680	1964	367	527
1980 Population[2]	2043	448	1021	2552	627	748
1990 Population[2]	2375	593	1362	3105	758	865
1997 Population[2]	2682	618	NA	3258	925	923
% of Population Under 18 Years Old (1990)[2]	NA	29.5%	29.4%	NA	25.6%	29.0%
% of Population Over 65 Years Old (1990)[2]	11.0%	11.1%	10.1%	10.0%	12.3%	9.6%
Growth Rate (1960-1990)[3]	46.4%	45.9%	43.8%	52.6%	47.8%	44.2%
Mean Annual Growth Rate[4]	1.5%	1.5%	1.5%	1.8%	1.6%	1.5%
Projected Population Size in (2015)[1]	4000	900	3000	4300	1300	1200

1. US Bureau of Census 1970
2. Kennebec Valley Council of Governments 1997
3. Calculated by dividing 1990 population by 1960 population
4. Calculated by dividing the growth rate from 1960-1990 by 30

* Signifies towns within the Great Pond Watershed

APPENDIX T. SEASONAL HOUSE DISTRIBUTION FOR SIX TOWNS IN THE BELGRADE LAKES WATERSHED

Seasonal house and population distribution in six towns in the Belgrade Lakes Region. Data was collected from Belgrade, Mercer, Mt. Vernon, Norridgewock, Rome and Smithfield. Statistical Data was obtained from the Kennebec Valley Council of Governments Census Department.

Characteristic	Belgrade		Norridgewock		Mercer*		Mt. Vernon		Rome*		Smithfield*	
	1980	1990	1980	1990	1980	1990	1980	1990	1980	1990	1980	1990
Total Number of Houses (1980)[1]	1381	1621	902	1215	279	326	682	829	777	777	508	559
Total Number of Seasonal Houses (1980)[1]	635	685	15	37	93	97	281	309	469	469	227	230
% of Seasonal Houses (1980)[2]	45.9%	42.3%	1.7%	3.0%	33.3%	29.6%	41.2%	37.3%	60.4%	60.4%	44.5%	41.1%

[1] Kennebec Valley Council of Governments 1997

[2] Calculated by dividing total number of seasonal houses into total number of houses

* Signifies towns within the Great Pond Watershed

APPENDIX U: SEASONAL RESIDENCES ALONG GREAT POND

Information obtained from field reconnaissance data collected by the CEAT 1999. Houses were individually counted and ascribed a seasonal or year-round status with a subjective survey (see Residence Count: Methods).

	Belgrade	Mercer	Rome	Smithfield
Total Number of Houses along Great Pond[1]	631	0	515	81
Total Number of Seasonal Houses along Great Pond[1]	300	0	303	25
% of Seasonal Houses along Great Pond[2]	47.5%	0.0%	58.8%	30.9%

[1] CEAT 1999

[2] Calculated by dividing total number of seasonal houses in to the total number of houses