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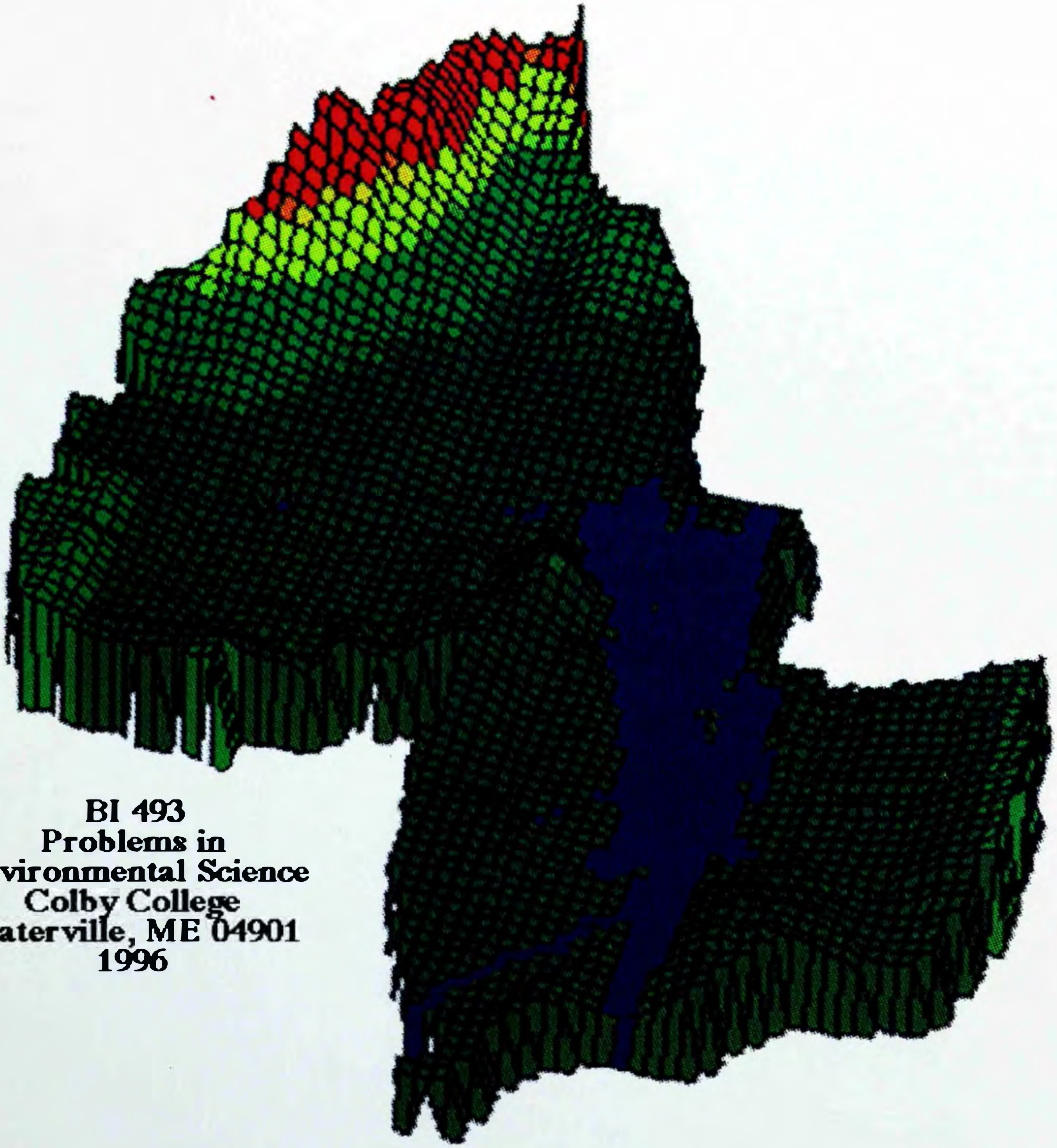
Land Use Patterns in Relation to Lake Water Quality in the Long Pond, South Basin Watershed

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

Colby College

LAND USE PATTERNS IN RELATION TO LAKE WATER QUALITY IN THE LONG POND, SOUTH BASIN WATERSHED



BI 493
Problems in Environmental Science
Colby College
Waterville, ME 04901
1996

MEMO

DATE: April 18, 1996

TO: Report recipients

FROM: Professors Russell Cole and Katie O'Reilly

RE: Class report on Long Pond, South Basin 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 1995. 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 most 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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This study of Long Pond, South Basin was conducted by the students of the Biology 493: Problems in Environmental Science class at Colby College, Waterville, Maine. The students were:

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INTRODUCTION

General nature of study

Lakes are invaluable natural resources, and affect the land surrounding them in many ways. They support wildlife, define the nature of the surrounding ecosystem, and serve as sources of drinking water and recreation. The prolonged presence of human activity in a watershed can greatly affect the physical and chemical nature of the lake and its ecosystem (Henderson-Sellers and Markland 1987).

Over time, lakes will naturally undergo eutrophication, a product of the natural aging of the lake by which organic matter accumulates in the lake basin and the increased decomposition process significantly depletes dissolved oxygen levels in the water. As a result, the organisms which are dependent upon a high level of dissolved oxygen will die off, decreasing the species diversity and overall health of the ecosystem (Henderson-Sellers and Markand 1987). The impact of humans can accelerate the eutrophication process. Human development can increase the addition of nutrients such as phosphorus and nitrogen into the water body (Fernandez et al. 1992). This increased nutrient loading can lead to sharp rises in populations of algae, known as algal blooms. Algal blooms are the reason that many New England lakes 'turn green' during the summer months. Bacterial populations will grow due to the increasing food source from dead algae, and their utilization of dissolved oxygen will severely deplete the levels in the lake (Henderson-Sellers and Markland 1987). A sharp decrease in dissolved oxygen levels, due to algal blooms, can lead to the rapid death of all types of lake fauna, a process known as a fishkill.

The south basin of Long Pond straddles the Belgrade Lakes Quadrangle and the Readfield, ME Quadrangle at a latitude 44° 29′ N, and longitude 69° 55′ E in the Belgrade Lakes Region of south-central Maine. The lake watershed lies in four separate towns, Belgrade, Mt. Vernon, Rome, and Vienna. The watershed covers 3370 ha of land, and the surface of the lake covers 522 ha. Approximately two thirds of the watershed and two thirds of the water surface area are located in Mt. Vernon. Belgrade lies east of Mt. Vernon, and contains roughly one third of the water surface and one quarter of the watershed. Rome and Vienna, both located in the Northwest corner, contain less than one tenth of the watershed and none of the water surface. The portion of the watershed in Vienna contains no roads or residencies, and thus it was not included in our study.

Long Pond, South Basin receives nutrient inputs from a variety of sources, including roads, construction projects, logging practices, and human waste from subsurface waste disposal systems. If any of these sources are near tributaries or the shoreline, the nutrients can be easily transported into the lake itself. The lake is also used recreationally for boating, fishing and swimming, and is utilized as a source of drinking water for seasonal shoreline residences. The watershed contains the Mt. Vernon and Belgrade transfer stations, and the dump has been capped at each of these stations.

Historically, Long Pond, South Basin has not suffered from summer algal blooms, but increases in development in the watershed will put greater stress on the ecosystem, and may disrupt the balance of natural nutrient cycling enough to induce future problems, including algal blooms. The south basin will also be affected by activities and changes in other lakes of the interconnected Belgrade Lakes system that drain into Long Pond, including East Pond, North Pond, Salmon Lake, and Great Pond, all of which drain through Long Pond, North Basin and into the South Basin.

A major purpose of our study was to analyze the present land use patterns and their impacts on water quality of Long Pond, South Basin, including the biotic and abiotic parameters which influence it. Other important components of the study included:

- Assessment of the potential for nutrient loading from tributaries and runoff from roads, residential, and other cultural structures and activities.
- Determination of the influence of current and past land use patterns upon lake water quality. Production of flushing rates and water budgets for Long Pond, South Basin so as to determine residence time. This is an important step in constructing a phosphorus loading model.
- Make future projections concerning phosphorus and nutrient levels of Long Pond, South Basin. These will be based upon assessing future development and land use potential. Make recommendations for the Belgrade Lake Association, Maine Department of Environmental Protection, and the towns of Belgrade, Mt. Vernon, Rome, and Vienna for ways to reduce or halt unnatural eutrophication processes.

Background

LAKE CHARACTERISTICS

Distinction Between Lakes and Ponds

Lakes and ponds are inland bodies of water, which may have been formed naturally or constructed by people or other animals (Niering 1985). The ecosystems in which they are contained have well-defined boundaries, which contain the standing body of water. Environmental conditions may vary from lake to pond, but there are certain characteristics that are shared between the two (Smith 1992).

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

Temperature, which changes with the seasons and depth, is an important factor in both pond and lake ecosystems (Smith 1992). Because water is most dense at approximately 4°C, many species are able to survive in an aquatic environment throughout the year, and ice remains on the surface and prevents most lakes from freezing solid during the winter. During the summer, lake water stratifies according to temperature, 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 reduces mixing of oxygen and nutrients within a lake. Ponds, due to their shallow waters, do not thermally stratify during the summer months. By definition, Long Pond, South Basin is a lake and thermally stratifies due to its depth. During the summer it stratifies vertically into the three distinct layers defined above. Long Pond, South Basin is dependent on the spring and fall (see next section) to redistribute oxygen and nutrients. Variations in oxygen and temperature strongly influence the adaptations for life and the buffering capabilities for pollutants in ponds and lakes (Smith 1992).

General Characteristics of Maine Lakes

Lakes prove to be a vital natural resource in Maine (Davis et al. 1978). Nine percent of Maine's approximately 5700 lakes have areas greater than 1 km^2, and there has been relatively little research conducted with regard to their systems and potential (Davis et al. 1978).

The majority of Maine's lakes owe their formation to the most recent glaciation (Wisconsin) of the Pleistocene period (about 10,000 years ago) (Davis et al. 1978). Because most of Maine was once covered by glaciers, 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 or even mesoeutrophic (Davis et al. 1978).

The movement of the glaciers in Maine was predominantly southeasterly, and hence the orientation of many of Maine's lakes reflects this as 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 4-5 months out of the year. While Davis et al. (1978) noted that much of the state's lake watersheds 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 nutrient loads of many of Maine's lakes and ponds. Because these projects can result in significant disturbances if they are in close proximity to the shoreline, they have the potential to have a significant impact on the aquatic ecosystems. In watersheds where agricultural practices have been less significant, both residential development and forestry practices may be the most acute causes of anthropogenic nutrient loading.

The levels 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 (Davis et al. 1978). Also, lake morphometry, as mentioned above, (e.g., depth and surface area) can function to change the lake's 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. For the south basin of Long Pond, the depth is sufficient to allow for stratification of the water column as well as seasonal turnovers, both of which are important functions of the lake ecosystem (Roy Bouchard pers. comm.). Most temperate lakes illustrate a degree of turnover, and lakes that turnover completely in both the spring and fall are referred to as dimictic (BI493 1994).

Because stratification is such a vital component in lake ecosystem functioning, its principles should be understood. Water has the unique property of having its maximum density at 3.94° C, whereas all other substances increase their densities 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

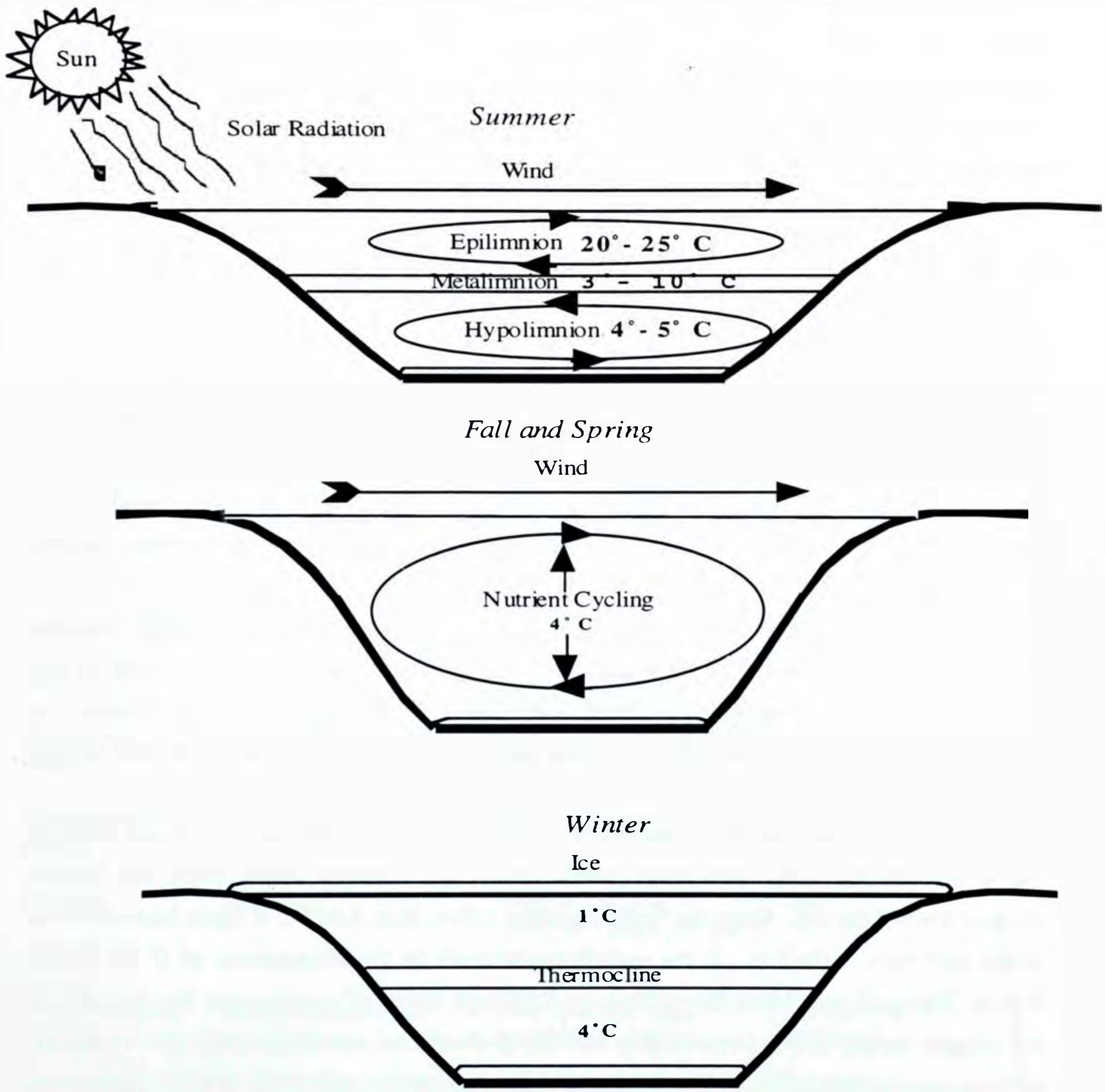

Figure 1. Mixing by means of lake turnover in dimictic lakes. During the summer, lakes are stratified into three layers (epilimnion, metalimnion, and hypolimnion). During the fall and spring, the isothermal temperature and density facilitate the lake turnover and redistribution of nutrients. In the winter,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

water due to differences in temperature. This stratification follows a seasonal pattern in conjunction with the changes in solar radiation received by the lake water.

Due to direct radiation, the upper levels of the water column warm up more quickly and remain there to form an epilimnion (Figure 1). While usually no deeper than about 7 to

8 m in northeastern lakes, the epilimnion hosts the most abundant floral communities (Davis et al. 1978). This, in effect, 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 (Russell Cole pers. comm.), and may remain depleted until the turnover of early fall (BI493 1994).

Below the epilimnion is a layer of sharp temperature decline, known as the metalimnion (Smith 1992). 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 1992). This thermocline separates the epilimnion from the hypolimnion, the lowest layer of a lake. In most Maine lakes the hypolimnion is beyond the depth to which sufficient light can penetrate in order to facilitate effective photosynthesis. It is an area in 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 and water surface, and the depth of the lake (Davis et al. 1978).

As autumn arrives, the water in the epilimnion cools quickly as it cools and sinks in the water column. This instability creates convective currents which force the bottom stratum toward the top. Once the water becomes colder than 3.94° C it again becomes less dense and rises to the top. If the surface water cools to the temperature of 0° C, it will freeze. The cold water near the surface can hold high levels of oxygen and the demand on the oxygen supply is also considerably less due to decreased activities of aquatic organisms at these temperatures (Smith 1992). 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 fishkills (Russell 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, stratification will again become evident, and the temperature profiles will return to that of the summer (Smith 1992).

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 three major categories: oligotrophic, eutrophic, and dystrophic (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 transparency	High	Low	Low
Water color	Green or blue	Green or yellow	Brown
Dissolved solids	Low, deficient in N	High, especially in N and Ca	Low, deficient in Ca
Suspended solids	Low	High	Low
Oxygen	High	High at surface, deficient under ice and thermocline	High
Phytoplankton	Many species, low numbers	Few species, high numbers	Few species, low numbers
Macrophytes	Few species, rarely abundant, yet found in deeper water	Many species, abundant in shallow water	Few species, some species are abundant in shallow water
Zooplankton	Many species, low numbers	Few species, high numbers	Few species, low numbers
Zoobenthos	Many species, low numbers	Few species, high numbers	Few species, low numbers
Fish	Few species, salmon and trout characteristic	Many species, especially minnows	Extremely few species, often none

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 do not allow extensive growth of rooted vegetation; there is no extensive, 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 (see Table 1).

Eutrophic lakes are nutrient enriched (Chapman 1992) 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 (see 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 1992). This stimulates even further growth of phytoplankton (Smith 1992). 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 1992). 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 (see Table 1). Eventually the invasion of rooted aquatic macrophytes chokes the aquatic habitat with plant growth (Goldman and Horne 1983), and the lake basin is filled in, resulting in the development of a terrestrial ecosystem.

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 show succession (replacement of one community by another) (Goldman and Horne 1983). Nutrient enrichment and the filling in of lakes are natural phenomena. These processes, however, can be greatly affected by anthropogenic activities which increase the rate at which nutrient loading occurs and the amounts of nutrients going into the lake. 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 1992).

Phosphorus and Nitrogen Cycles

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 we may devise better techniques to control high levels of these nutrients.

Phosphorus is generally considered the most important nutrient in lakes because it is the limiting nutrient for plant growth in freshwater systems (Maitland 1990). It naturally occurs in lakes in minute quantities (measured in parts per billion), 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 of phosphorus to a lake (COLA 1992), but there is also a large source from 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 Figure 2. DP is an inorganic form of phosphorus which is readily available for plant use in primary production; it is the 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 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

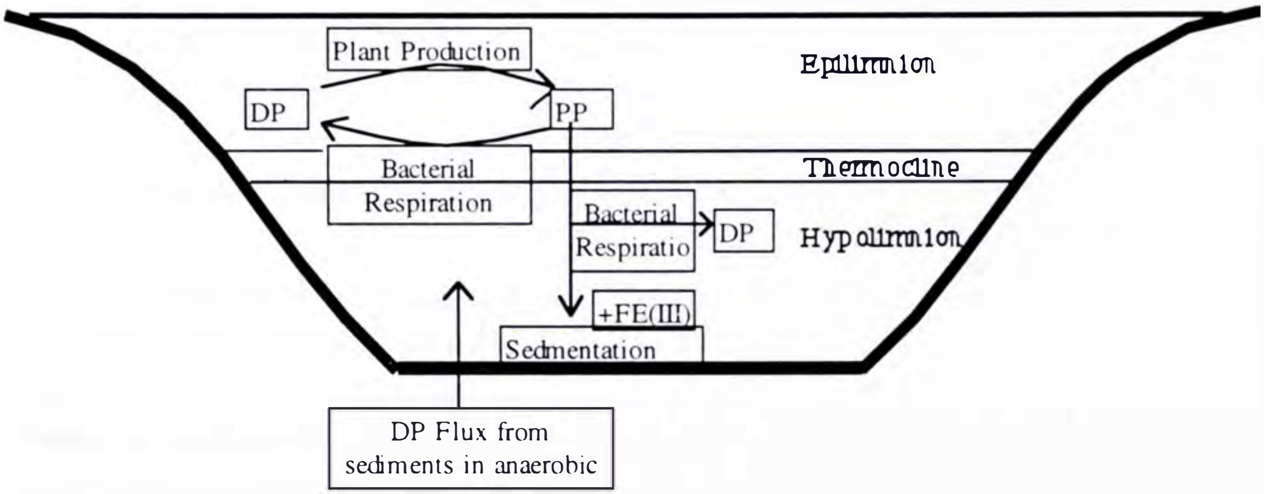

Figure 2. A modle of the cycle of the major forms of phosphorus,dissolved (DP) and particulate (PP), within a lake ecosystem. The sedementation of DP through complexation with Fe(III) contributes to the build up of DP in the sediments. Note the production of DP in the hypolimnion due to bacterial decompostion 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).

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 1992). 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 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 overturn. The fall overturn 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 1992).

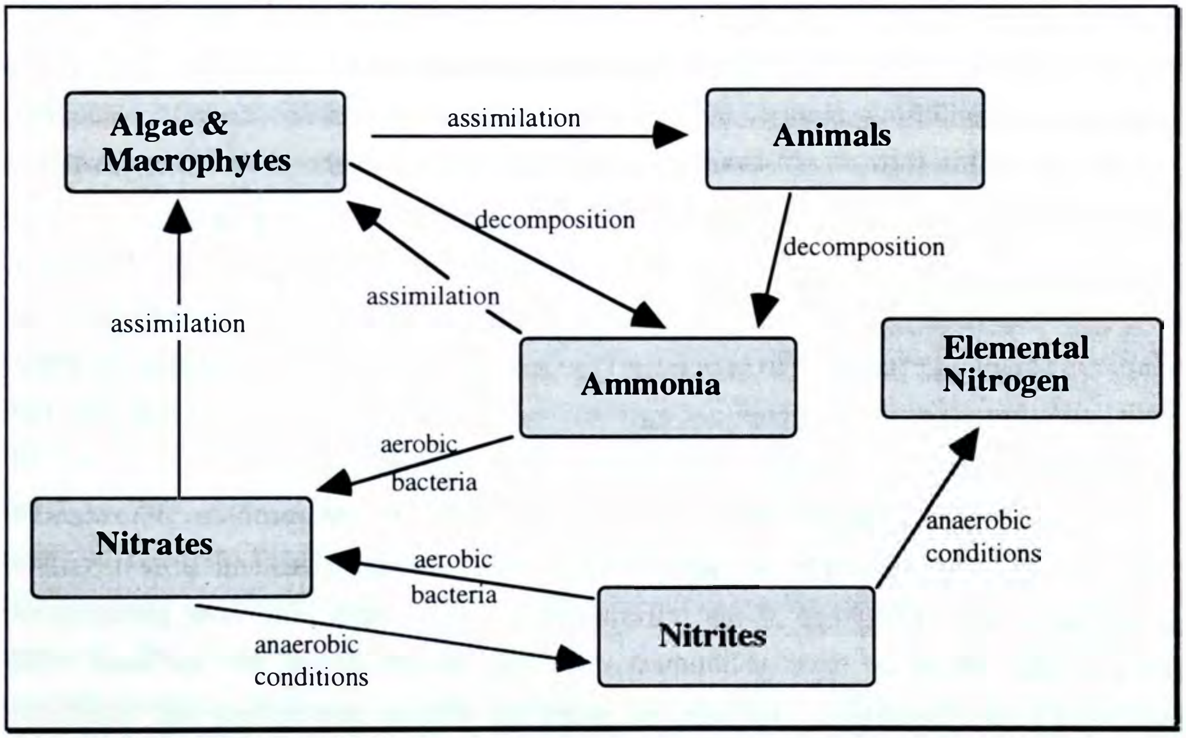

Figure 3. A diagram of the various forms of nitrogen that occur in the nitrogen cycle within a lake ecosystem. It is important to note that in aerobic conditions both ammonia and nitrites are converted to nitrates which are available for use by plants.

The other major plant nutrient, nitrogen, is not usually the limiting factor for plant growth in a lake (Chapman 1992). 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 in water used as a source of drinking water can lead to the development of the condition in infants known as methemoglobinemia (Greenberg et al. 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 Figure 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 (Figure 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 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 is 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 them significantly 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 iron (Fe III) 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 at the sediment/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 (BI493 1995). 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 remove the source of nutrients from the sediments by removing the sediments themselves. This is known as dredging, and although it is effective, it is extremely expensive due to the large cost of 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, due to the complexity of the cycling within the lake. The ideal manner to control nutrients in a lake is to limit the input levels so that the natural processes of the lake will be able to compensate levels without large accumulations over time.

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 1992). Agricultural runoff adds excess nitrogen and phosphorus, the primary limiting agents in a lake ecosystem, into the lake.

Table 2. Descriptions of site characteristics and plant populations of different types of fresh inland wetlands (Smith 1992).

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, bullrushes, spike rushes, cattails, arrowhead, pickerel weed
Deep fresh marshes	Soil covered with 15 cm to 1 m of water	Cattails, bullrushes, 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

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-soil substrates such as peat. Wetlands also contain hydrophyte vegetation which is adapted for life in saturated and anaerobic soils (Chiras 1991).

In the Long Pond, South Basin watershed, there are several wetlands located around various water sources. There are wetlands abutting most of the west side of the lake, and the entire Ingham Stream/Ingham Pond area (See Figure 12).

WATERSHED LAND USE

Land Use Types

A watershed is defined by the total land area that contributes water to a particular lake. It is bounded by the highest points surrounding the lake 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 (BI493 1994). 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 of 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, erosion, and therefore nutrient loading, can increase with subsequent decline in lake water quality in an

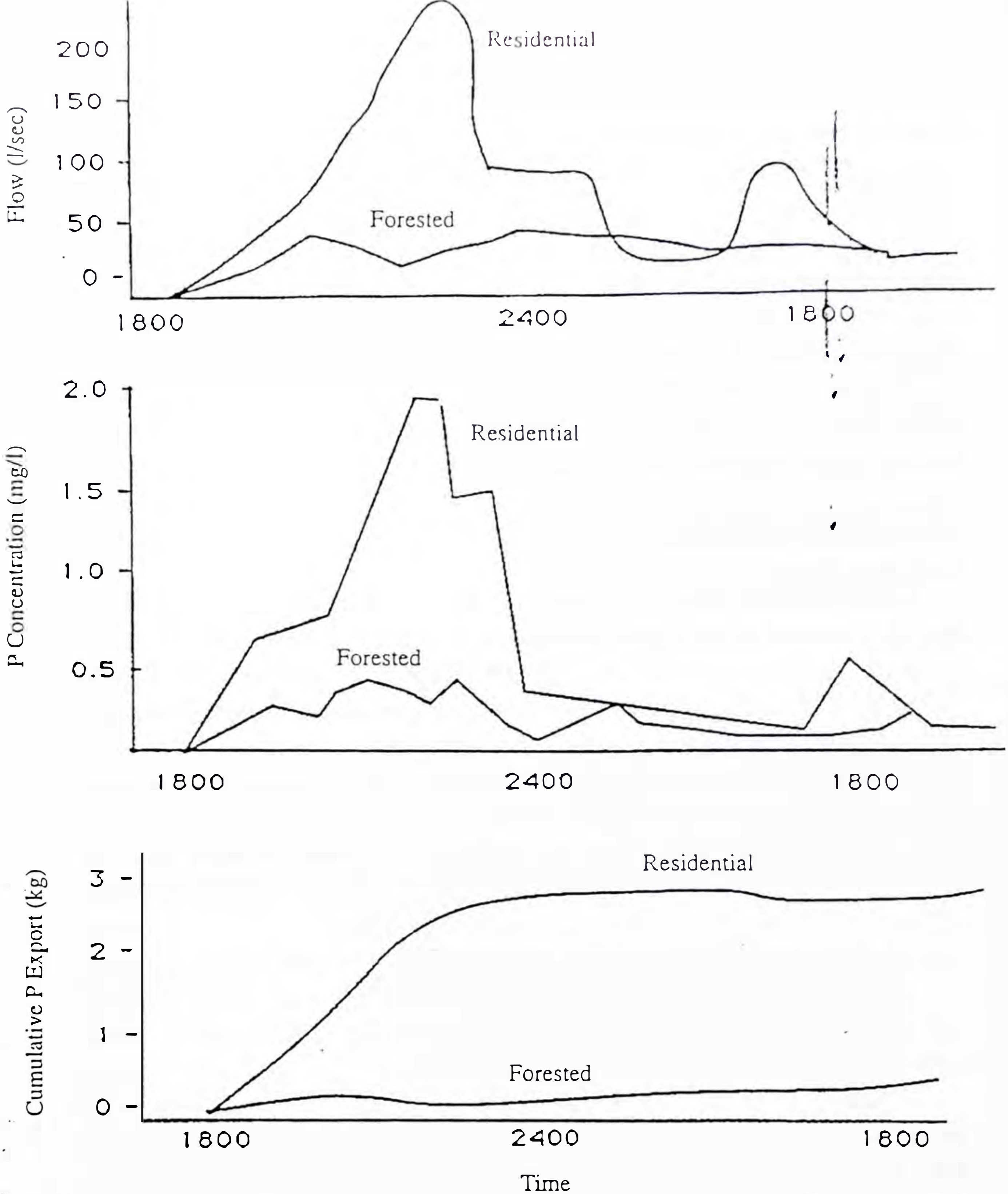

Figure 4. Comparisons of runoff after an April rain storm in two neighboring Watersheds near Augusta, ME. Top: volume of immediate runoff over a 12 hour period:Middle: phophorus concentration in the runoff; Bottom: total amount of phosphorus exported into local streams and lakes from the storm (Dennis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

area that previously acted as a buffer zone. 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 (see Figure 4) (Dennis 1986a).

Residential areas are separated into shoreline and nonshoreline homes that can be either permanent or seasonal residences (see Analytical Procedures and Findings: Residential Areas). Residential areas in a watershed generally contain lawns, driveways, parking areas, rooftops, and other impervious surfaces that reduce percolation, thereby causing runoff accumulation. 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 (BI493 1993). 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) 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 (EPA 1990).

Commercial uses of forested land, such as logging and tree harvesting, remove the cover of the canopy, thereby exposing the soil to direct rainfall. This facilitates erosion. Skid trails may pose a problem when they run adjacent to or through streams (Karen Hahnel pers. comm.). Shoreland zoning ordinances have established that a 75 ft strip of vegetation be maintainted between a skid trail and the normal high water line of a water body or upland edge of a wetland (MDEP 1990a) in order to alleviate the potential impact harvesting may have on a water body. 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, dirt, and fire roads) and can have varying degrees of nutrient loading potential. Roads (and also driveways) leading down to shoreline areas or streams provide easy access to the lake for run-off and can contribute large amounts of nutrients if they are not well constructed or maintained (KCSWCD 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 coefficient. 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 system.

Buffer Strips

Buffer strips are important for control of nutrients entering the lake (MDEP 1990b). 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 100 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,

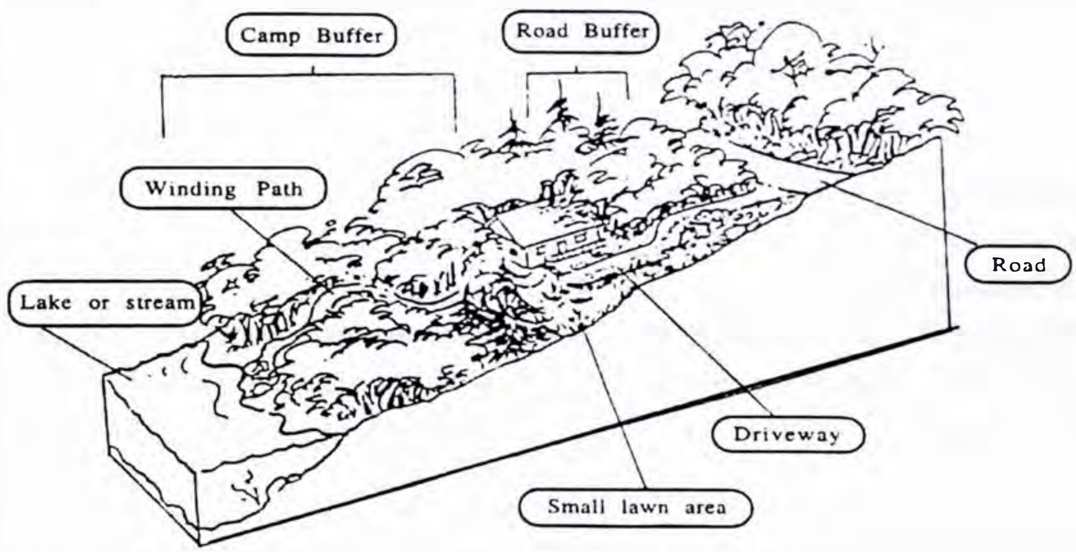

Figure 5. Diagram of an ideally buffered home.

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 Figure 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 1990b). 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. Most buffer strips on Long Pond, South Basin, 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, however, there are many houses in the south basin of Long Pond which are surrounded by large green lawns. Such lawns do not provide adequate nutrient uptake before runoff enters the lake.

Nutrient Loading

Nutrient loading into a lake can be affected by both natural and anthropogenic processes (Hem 1970). Human activity, however, 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 flat 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 varying degrees of eutrophication.

Total phosphorus loading to a lake can be determined using a phosphorus loading model (see Watershed Land Use: Phosphorus Loading). This model takes into account the various aspects upon which the phosphorus concentration in the lake basin is dependent, such as lake size, volume, flushing rate, and land use patterns within the watershed (Cooke et al. 1986). 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 to be made. The accuracy of the predictions is based on the accuracy of the assumptions (EPA 1990b).

Soil Types

Nutrient loading in lake ecosystems is a function of the soil types and their respective characteristics (BI493 1994). Both their physical features, such as permeability, depth, particle size, organic content, and the presence of an impermeable layer (hardpan), as well as the natural 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 generally best able to accommodate 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 organics, 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

In general, the purpose of zoning and development ordinances are to maintain safe, healthful 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 to anticipate the impacts of development (Belgrade 1991). Shoreland 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 1992). 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 households (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 zones consist of an area of natural vegetation growing between a structure and the body of water in question. Town ordinances in Belgrade and Rome regulate buffer strip widths, thereby influencing phosphorus loading to the lake (see Buffer Strips).

Households that have lawns leading directly down to the shore have no obstacles to run-off, and movement of phosphorus can 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 homes (MDEP 1992a).

Maine summer camps or guest houses, 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 shoreland zoning laws. Although seasonal, they may involve large numbers of people. Therefore, phosphorus export from these areas is likely to increase during this time because of their concentrated use. In the Long Pond, South Basin watershed, there are some specific areas that contain multiple residences per lot. These can be found in the Sandy Cove area and on Pinewood Point (penninsula at north end of lake, south of

Narrows Road). The effects of these plots on nutrient loading depend on factors such as septic system location and condition (see Septic Systems).

Nonshoreline Residential Areas

Although not as important in phosphorus loading as shoreline areas, inland 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 miles 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, houses 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 nonshoreline homes are not as threatening as shoreline homes, watersheds having large residential areas with improper drainage can have a significant effect on phosphorus loading.

Similar restrictions and regulations used for shoreline homes also apply to homes along streams leading into the lake in question, since even when back from the shoreline, a house can have a significant impact when near a stream. Tributaries can serve to make inland as well as shoreline homes nutrient loading hazards. Any phosphorus washed from a residential lawn without buffer strips can enter into a stream, and eventually into the lake.

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 watershed of Long Pond, South Basin.

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 able to be 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 due to infiltration of waste into the upper soil levels (BI493 1994).

Holding Tank

Holding tanks are watertight, airtight chambers, usually with an alarm, that hold 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 residence 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.

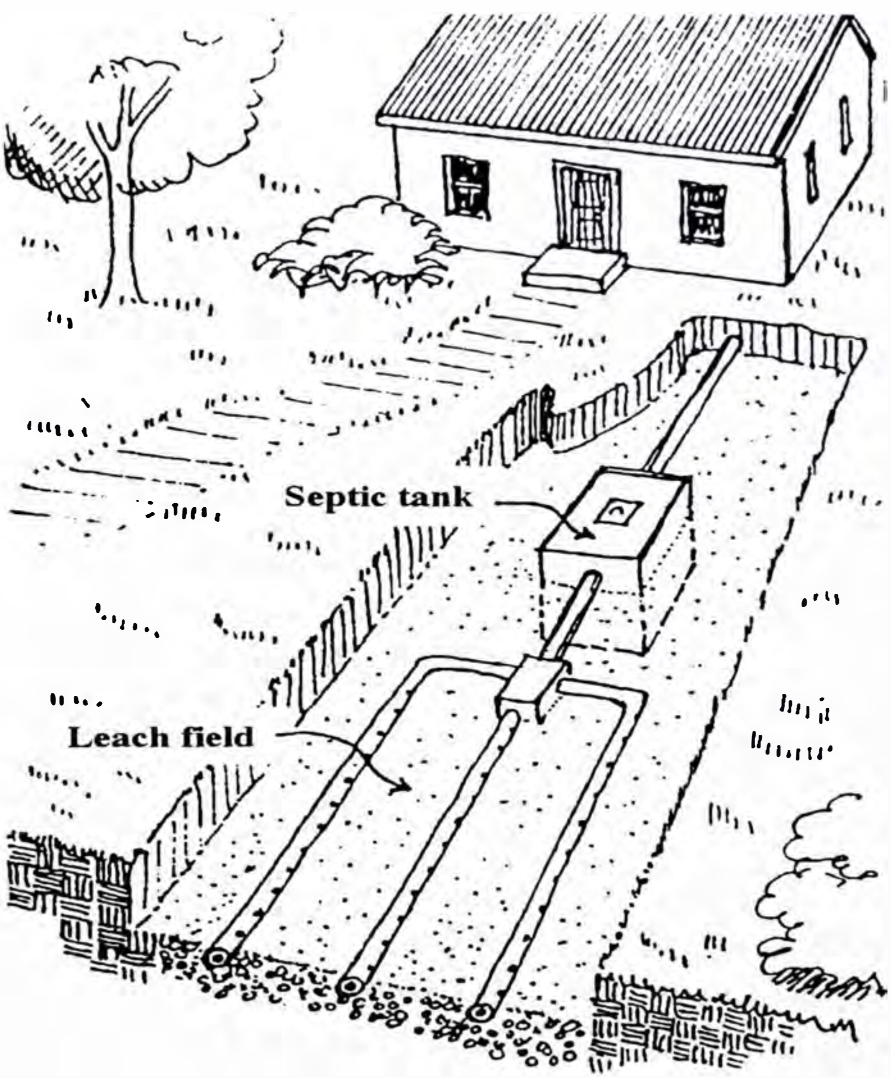

Figure 6. Diagram of a properly installed septic system (COLA 1992).

Septic System

Septic systems are the most widely used of subsurface disposal systems. They are also the most complex system for wastewater disposal. Figure 6 shows the basic layout of the components of a typical septic system. 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). 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 and Rome state that septic systems need to be at least 100 ft away from a lake and 75 ft away from streams (Rome 1990, 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 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 graywater 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. Figure 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

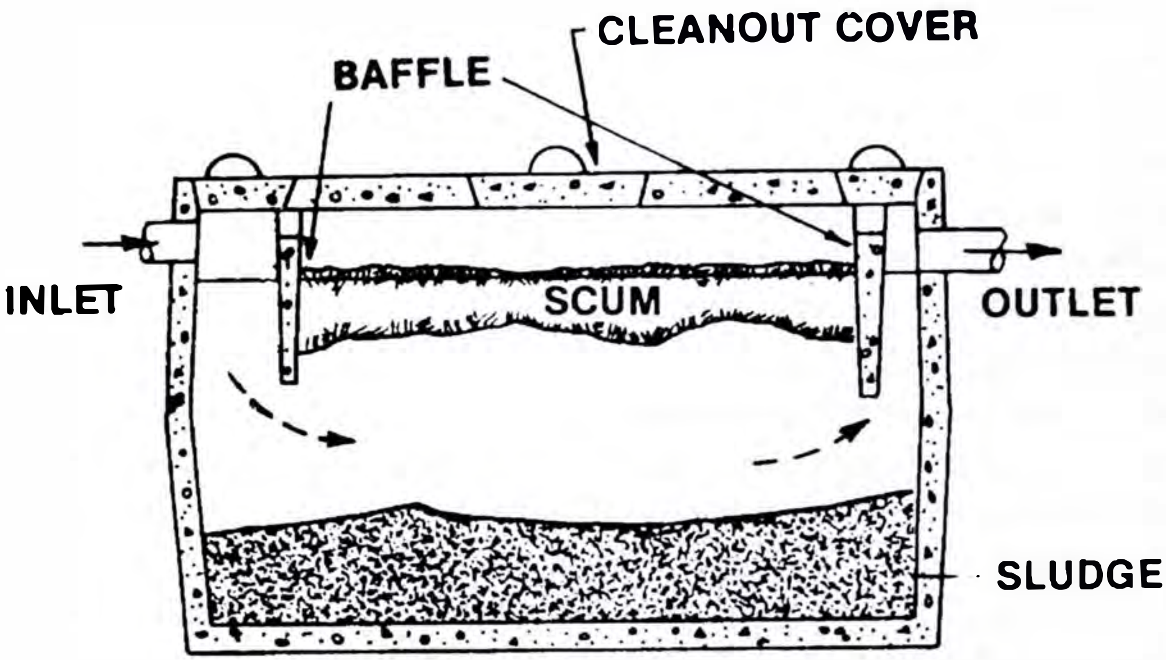

Figure 7. The cross-section of a typical treatment tank showing the movement of effluent through the tank as well as the separation of the scum and sludge (MDHS 1983).

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 it 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 (BI493 1994). 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, 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 (COLA 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 (COLA 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 (COLA 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 (10-20%) 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 run-off and purification (MDHS 1983). Table 3 shows the soil conditions and types that are needed to install an effective septic system. Soil cannot be too porous, otherwise water runs through too quickly and is not sufficiently treated. Depth to 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 (BI493 1994). If a soil drains too quickly, loam and clay can be added to slow the movement down (BI493 1994).

Table 3. Soil characteristics that determine the soil suitability for a septic system (MDHS 1983).

PARENT MATERIAL	SOIL PROFILE	TEXTURAL CLASSIFICATION and DESCRIPTIONS	SOIL CONDITIONS: SHALLOW to BEDROCK — A BEDROCK — I less than 10"	A BEDROCK — II 10" to 14"	A BEDROCK — III between [15"-48"]	DRAINAGE — B WELL DRAINED Ground Water Table greater than 48"	DRAINAGE — C MODERATELY WELL DRAINED Ground Water Table between [48" to 15"]	DRAINAGE — D SOMEWHAT POORLY DRAINED Ground Water Table between [15" to 6"]	DRAINAGE — E VERY POORLY DRAINED Ground Water Table less than 6"	DISPOSAL AREA RATING SEC. 12
GLACIAL TILL	1	Silt loam soils which tend to become more compact with depth. A restrictive layer may be present. Angular coarse fragments may be present.		4	2	1	1	3	4	LARGE
GLACIAL TILL	2	Loam to sandy loam soils which do not have a restrictive layer. Angular coarse fragments may be present.		4	2	1	1	3	4	MEDIUM LARGE
GLACIAL TILL	3	Loam, sandy loam to loamy sand soils with a restrictive layer. Angular coarse fragments may be present.		4	2	1	1	3	4	MEDIUM LARGE
GLACIAL TILL	4	Sandy loam to loamy sand overlying loamy sand soils derived from ablation till. Coarse fragments (angular to rounded) may be present. No restrictive layer throughout profile.		4	2	1	1	3	4	MEDIUM
STRATIFIED DRIFT	5	Loam to sandy loam soils overlying stratified fine and medium sands. Rounded coarse fragments may be present		4	2	2	2	3	4	MEDIUM
STRATIFIED DRIFT	6	Loamy sand soils overlying stratified coarse sands and gravel. Round coarse fragments may be present		4	2	2	2	3	4	SMALL
MIXED ORIGIN	7	Loamy sand to sand overlying a restrictive layer of silt to silty clay which occurs at a depth of 15 inches or greater. Coarse fragments may be present in upper horizons but usually absent in lower horizons		4	2	1	1	3	4	MEDIUM LARGE
LACUSTRINE MARINE	8	Loam to fine sand overlying firmer silt loam to silt. A restrictive layer may be present. Coarse fragments usually absent. Stratified lenses of very fine sand, silts and clays may be present in the substratum		4	2	1	1	3	4	LARGE
LACUSTRINE MARINE	9	Silt loam soils overlying firm silt loams to silty clays exhibiting a restrictive layer of coarse fragments are usually absent.		4	2	1	1	3	4	EXTRA LARGE
ORGANIC	10	Soils composed of organic materials in various stages of decomposition.								
ALLUVIAL, DUNE, BEACH	11	Variable in texture. Exhibiting very little weathering. Deposited in flood plain, sand dune or beach environment				5	5			SEC. 11.F 11.G

ALL SYSTEMS PERMITTED Note 1 See 11.C.2.a.I for Separation Distances. Note 2 See 11.C.2.a.II and 11.C.2.b for Separation Distances	Severe Limitations REPLACEMENT SYSTEMS MAY BE PERMITTED (Sec.15) Note 3 See Sec. 15 for Replacement System Variance by LPI. See 11.C.2.a & 11.C.2.b for Separation Distances.	Very Severe Limitations REPLACEMENT SYSTEMS MAY BE PERMITTED if no alternative. NEW SYSTEMS NOT PERMITTED. Note 4 See Sec. 15 for Replacement System Variance with Department Review. See 11.C.2. for Separation Distances.	Extremely Severe Limitations. SYSTEMS NOT PERMITTED Note 5 See Sec. 11.F for Coastal Sand Dune limitations. See Sec. 11.G for Flood Plain limitations.

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 such as shoreline zoning. The MDEP, the Department of Conservation, and local Code Enforcement Officers are responsible for overseeing the enforcement of these laws.

Since 1974, state mandates have prevented septic systems from being installed without a site evaluation, or within 100 ft from the high water mark. Other regulations include: 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 any 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 around Long Pond, South Basin as well as for the ecosystem within the lake. By following these mandates, safe and efficient septic systems can be installed and used.

Figure 8. Example of a poorly constructed camp road leading directly into the Long Pond, South Basin. (BI493 1995)

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 (Figure 8). 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. Rain storms help to deteriorate the road even more rapidly by dislodging particles from the road surface and carrying them away. These particles may then run off 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 (KCSWCD 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 wetponds and catch basins (as well as culverts and ditches), and maximize the lifetime and durability of the road (MDEP 1990b). 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 1990b). 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 Rome or Belgrade should not be built with a grade of more than 10%, except for short segments of less than 200 ft (Belgrade 1991 and Rome 1990)

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 must also be considered and is often based upon the maintenance capabilities of the area (Cashat 1984). If a group is not able to maintain the proposed road well 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/gravel surface (Lea et al. 1990). On the other hand, sand/gravel roads erode more quickly and therefore 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/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 to 3/4 inches per foot of width for dirt roads (KCSWCD 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 run-off can flow into a ditch or buffer zone (KCSWCD 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 run-off 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 run-off 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 of a sufficient depth that does not exceed 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, if possible (KCSWCD 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 possibly 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 2-4% (KCSWCD 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 (KCSWCD 1992). It is also important to have a proper crown above the culvert to avoid creating a low center point in the culvert. (KCSWCD 1992). The standard criteria for crowning above culverts is one inch of crown for every ten feet of culvert length (KCSWCD 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 (KCSWCD 1992). Efficient installation and spacing of diversions can also eliminate the use of culverts (KCSWCD 1992).

Maintenance is very important in order 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 therefore be periodically graded, ditches and culverts inspected and cleaned, and regularly inspected in order 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. Tilling of soil 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 (COLA 1992). In order 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 are and therefore could result in decreased water quality and increased erosion (MDEP 1990a). More 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 1990a). 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 when they may be near them to drink (BI493 1994). One solution for this may be to put up grazing 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 a storm. Another method besides pesticides could be used for pest control, such as a biological control or inter-cropping.

Forestry

Forestry is another area 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 (COLA 1992). Again there are shoreline zoning ordinances which relate to these specific problems in order to minimize the damage done to a lake. For example, timber harvesting equipment, such as skidders, cannot use streams as travel routes unless they are frozen or cause no ground movement (MDEP 1990a). There is also an ordinance which prohibits clear-cutting within 100 ft of the shoreline of the lake or river running to the lake. At distances greater than 100 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 1990a). 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 an important component of many watersheds, including Long Pond, South Basin. 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 in order 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 used 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). These areas can be a source of fertilizers and pesticides. Long Pond, South Basin has a number of logging areas as well as a tree farm within its watershed, so logging practices and tree farming are important issues in considering its water quality.

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 a buffer from the vegetation these problems are made even worse (BI493 1994). 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, for example, lawns or parks.

The MDEP (1990a) 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 so the nutrients will have a chance 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.

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). Furthermore, wetlands are important because they contain a variety of wildlife, 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 is not enough encouragement or regulations to protect these areas (SFI Bulletin 1991). Without these regulations, water quality in some areas may decrease.

Although there are regulations controlling wetland use, there has been a trend to destroy them through development due to lack of enforcement of these regulations. 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 on them even though these regulations exist (Nebel 1987). Therefore, the decrease of wetlands and the increase of development on them will most likely have negative effects on the water quality of a lake due to runoff and erosion, and a decrease of natural buffering.

Study Area: South Basin of Long Pond

LONG POND, SOUTH BASIN CHARACTERISTICS

Historical Perspective

Water quality and fishery surveys of Long Pond, South Basin have been conducted since 1939 (Strunk 1973). In 1972, the Department of Inland Fisheries and Game, Fishery Division began to monitor the water quality of Long Pond, South Basin. The following parameters have been studied: depth, transparency, air and water temperature, conductivity, dissolved oxygen, outlet discharge, pH, and alkalinity (MDEP 1994).

The watershed surrounding Long Pond, South Basin was first settled in the late 1700's. The first census in the towns encompassing the Long Pond, South Basin watershed was during the following years: Belgrade, 1790; Mount Vernon, 1850; and Rome, 1800. In all three towns the population peaked in either 1850 or 1860 (Belgrade:1850 pop. 1722, Mount Vernon 1850: pop. 1479, and Rome 1860: pop. 725) and then declined steadily until 1970. Since 1970 Belgrade, Mount Vernon, and Rome have all experienced steady population growth (Maine Register 1994-1995).

There was farming on the eastern shore of Long Pond, South Basin 15 years ago, however, there has been no recent farming in this area (Bob Simpson pers. comm.).

Although there are some small hobby farms, currently there is no large scale row cropping in the Long Pond, South Basin watershed.

Biological Perspective

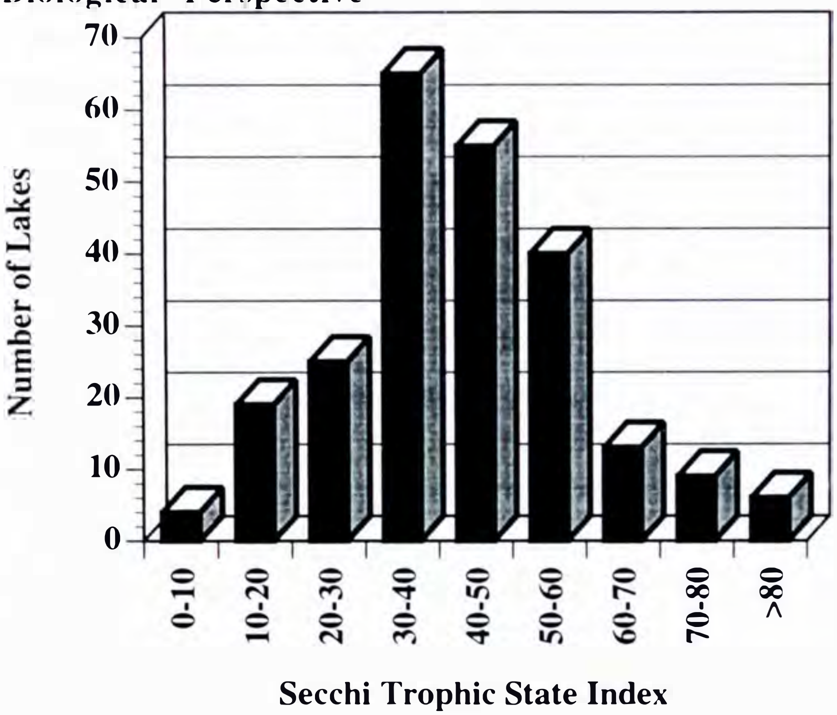

Figure 9. Distribution of 239 Maine lakes among Trophic State Index categories (MDEP 1991, BI493 1994).

Both Long Pond, South Basin and Long Pond, North Basin are oligotrophic lakes, as determined by their primary productivity (see Trophic Status of Lakes). Many indices can be used to measure the trophic status of a lake, such as transparency of a lake measured using a Secchi disc. The Trophic State Index (TSI) can be used to measure algal production (BI493 1994). Based on Secchi disc transparencies the TSI average during the summer for Long Pond, South Basin was 34.0 and the average for the year was 34.0. The average TSI index for Maine lakes is 42.0 (Figure 9) (Davis et al. 1978). The total amount of phosphorous in the water column averaged 4.6 ppb throughout the year (Davis et al. 1978).

Long Pond, South Basin reaches low oxygen levels during the year, but is not completely devoid of oxygen during the winter. This allows Long Pond, South Basin to support a cold water fishery (Davis et al. 1978). Landlocked Atlantic Salmon (*Salmo salar*), the primary sportfish in Long Pond, South Basin, thrive when oxygen levels are 5 ppm or greater (Pearsall 1991). On 13-JUL-95, Long Pond, South Basin had dissolved oxygen levels as low as 6.5 ppm (Owen-Ashley and Wnek 1995). This low value suggests that the cold water fishery may be threatened.

Landlocked Atlantic Salmon is native to Long Pond, South Basin and the lake is stocked each spring with yearlings. The salmon feed primarily on smelt (*Osmerus mordax*). There is a correlation between the amount of Landlocked Atlantic Salmon and the individual fish weights after living in Long Pond, South Basin for two years. When fewer Landlocked Atlantic Salmon are stocked, the average fish weight is higher after two years than a two year period in which a larger number of fish are stocked. This is most likely due to a limited Smelt food source in Long Pond, South Basin. When Long Pond, South Basin was stocked with 2700 Landlocked Atlantic Salmon, these individuals weighed an average of between 1.3 and 1.6 lbs after three years. When 1700 landlocked Landlocked Atlantic Salmon were stocked they grew to an average 2.2 lbs after three years. Only Landlocked Atlantic Salmon are stocked because they are the native species which are most sought by anglers. Northern pike (*Esox lucius*) from Long Pond, South Basin are also fished, however they are an introduced species and are not legally stocked (MDEP 1992b).

From 1980 to 1988 the number of angler days during the open water season on Long Pond, South Basin increased 89.0%, from 6894 to 13027. Ice fishing is not permitted on Long Pond, South Basin and thus data for ice fishing is not included in the increase of angler days. During the 1993 open water season, the percentage of legal fish taken was 69.9% White Perch (*Morone americana*), 13.7% Landlocked Salmon, 8.4% Yellow Perch (*Perca flavescens*), 6.7% Black Bass (*Micropterus salmides*), and 0.3% Chain Pickerel (*Esox niger*). In 1988, a 16.0 in. minimum was established for catching Landlocked Salmon. Before 1988 there was a 14.0 in. minimum. There is a one fish per day limit for Landlocked Salmon. Between 1987 and 1990, 97.5% of the Landlocked Salmon taken (greater than 16.0 in.) were three years of age or less (Roy Bouchard and MDEP 1994).

Long Pond, South Basin supports a variety of freshwater organisms, including bacteria, protists, freshwater algae, and plants, which form the base of the food chain. Also, these organisms help cycle nutrients and gases throughout the lake's ecosystem (Reid 1961). Vascular plants provide food and shelter for animals. Common animals found in freshwater lakes include sponges, hydroids, moss animals, insects, snails, clams, and mussels. Many vertebrates are also present including fish, amphibians, reptiles, birds, and mammals (BI493 1995).

The pH of a body of water can determine the diversity of existing animal species. A lower pH decreases the viability in aquatic organisms' eggs which may lead to localized extinction (Pearsall 1991). At pH levels of less than 6.0, snails and other crustaceans die; levels less than 5.5 kill salmon and whitefish; levels below 5.0 kill pike and perch; and levels less than 4.5 kill eel and brook trout (Bunce 1990). Typical Maine lakes have pH levels ranging from 6.1 to 6.8 (see Figure 10) (Davis et al. 1978). The average pH for Long Pond, South Basin was 6.6. At this level, the pH does not hinder aquatic life. The average pH of lakes in Maine was 6.7, the maximum was 9.4, and the minimum was 4.5 (Davis et al. 1978).

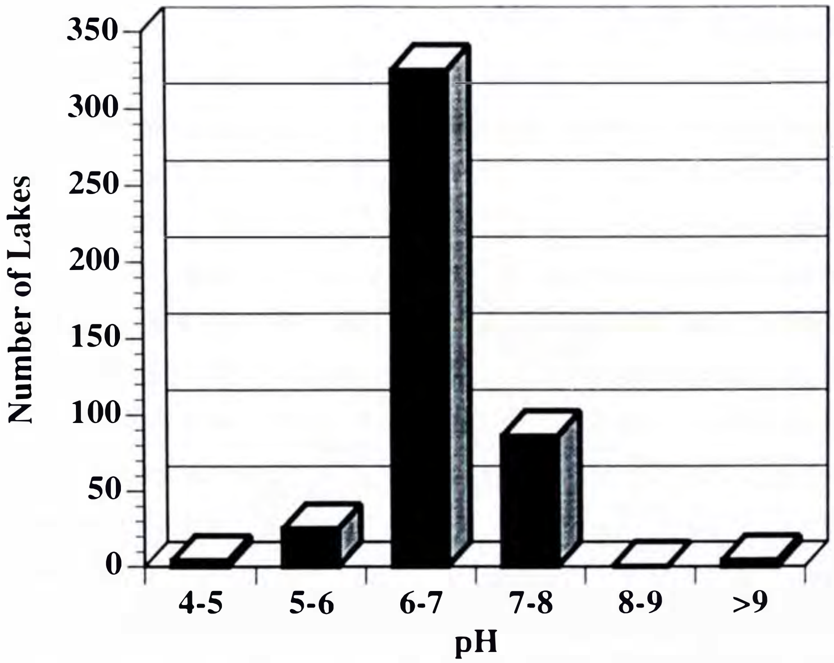

Figure 10. Number of Maine lakes within various pH ranges (MDEP 1991, BI493 1994).

Alkalinity is a measure of carbonate, bicarbonate, and hydroxide in a body of water (Clesceri et al. 1989). The alkalinity, expressed as ppm calcium carbonate ($CaCO_3$), determines the degree of buffering against changes in pH level. An alkalinity level of less than 4.0 ppm increases the likelihood of negative effects due to acid rain (Pearsall 1991). In Maine lakes, the alkalinity mean is 10.1 ppm $CaCO_3$. Long Pond, South Basin's alkalinity ranges from 8.0 to 9.6 ppm $CaCO_3$, depending on the season, with an average of 8.8 ppm $CaCO_3$ (Figure 11) (Davis et al. 1978).

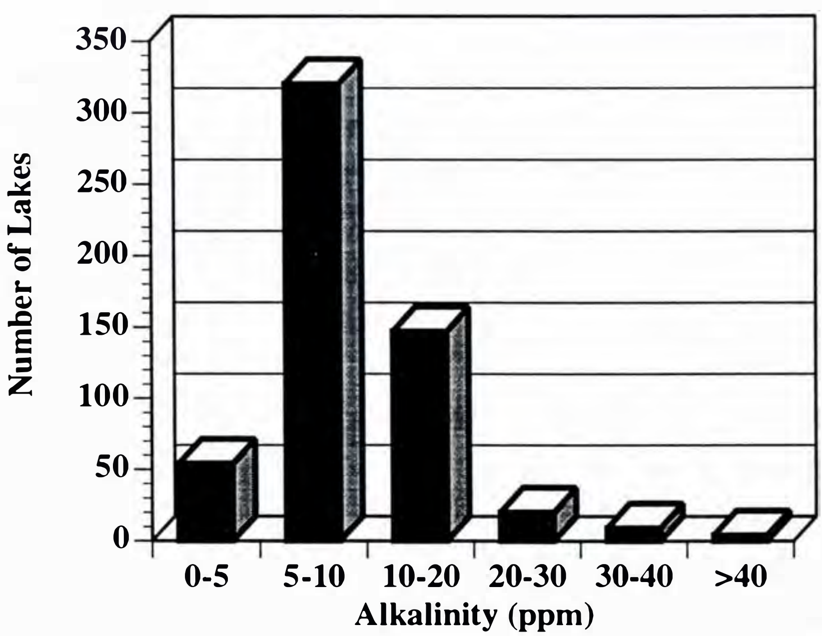

Figure 11. Number of Maine lakes within various alkalinity ranges (MDEP 1991, BI493 1994).

Geological and Hydrological Perspectives

The majority of soil types within the Long Pond, South Basin are composed of sandy loam with a significant amount of silt and clay particles, and are characterized by moderate to low permeability (USDA 1978). The areas of the watershed with the steepest grades are composed of soils with low permeability which are thus highly conducive to causing runoff. These areas are located in the Northwest corner of the watershed, along the southeast shore of the lake, and on the western shore in the Journey's End Road area (see Figure 12). The most common soil type in the watershed is Paxton, and it is characterized by a depth to bedrock of greater than five feet, and also by a perched water table which limits its development potential (Faust and LaFlamme, 1974). A second major soil type present in the watershed is Hollis, which has a much higher permeability than the Paxton soils, and a much shallower depth to bedrock. This soil is primarily composed of glacial till. According to GIS analysis, a large majority of the soil types in the watershed have low suitabilities for septic systems and low water permeability.

Wetlands comprise 8.1% of the watershed, with the majority located along the west shore of the lake. The rest of the shoreline is primarily forested land with some shoreline residential development. Slope to the water line is generally less than 20%, but two of the areas of heaviest residential development occur on the shoreline with the most significant slope to the water. These areas are the southeast shore of the lake and the western shore in the Journey's End Road area (Appendix J).

The hydrology and geology of the watershed have been analyzed through the use of soil, culture and drainage, and topographic maps. Soil characterization and land use studies have been run using GIS and MicroStation computer applications (see GIS Methods and MicroStation Methods) to determine areas of specific land uses, and potential development impacts based on soil types and hydrology.

Soil Types

The soils in the watershed of a lake are an important factor in determining the amount of nutrients reaching the water. Different soils have different buffering capabilities, some will absorb runoff and bind nutrients, while others will not. A soil's buffering capacity is determined by several factors: permeability, slope, particle size, depth to water table, depth to bedrock, organic content, and erodibility (USDA 1978).

A soil which is too permeable will simply act as a conduit for water and nutrients to pass through, contaminating lake water. A soil which is not permeable enough will not allow for proper infiltration causing surface runoff into nearby areas, possibly contaminating lake water. Steep slopes simply increase the probability of runoff occurring. Soils having large particles (such as gravel) will have unsuitably high permeabilities. In addition, nutrients will be unable to bind to the soil particles simply due to their size. When particle size is too small (clay), the soil will be dense, becoming impermeable. In areas where the water table is too close to the surface, contamination of groundwater can occur because of insufficient area for soils to absorb nutrients. When an impermeable layer, or bedrock, is too close to the surface there may be a back-up of water. Water will not be able to percolate downwards, so it will run off the surface. Highly erodible soils are unsuitable for development of any kind and they frequently cause water quality problems (USDA 1978).

Soil type is one of the major factors influencing the fauna and flora in an area, and these components are largely determined by the climate of an area. Any agency creating plans or regulations concerning development of an area should take the climate, habitat, and soils into consideration. Without a basic knowledge of these parameters, formation of a truely comprehensive land use plan is not possible.

Regional Land Use Trends

Generally, watersheds in Maine are heavily forested. Therefore, urbanization and the large point sources of pollution associated with it are usually not a factor affecting water quality. Non-point sources are more common problems, especially pipes leading from shoreline residences into lakes. Studying the two primary non-point sources of nutrient loading (agriculture and residential development) can be helpful to determine the pattern and extent of nutrient loading in Maine lakes (Davis et al. 1978).

The amount of active farmland in Maine has decreased over the past 20 years. In watersheds where agriculture does not exist, residential development and particularly development along shorelines, is the primary cause of anthropogenic nutrient loading. Road maintenance and construction, cutting of forests, improper sewage disposal, and erosion related to the construction of buildings are the most common nutrient loading activities occurring in Maine lakes (Davis et al. 1978).

East Pond is in the same geographic area as Long Pond, South Basin and thus may provide a glimpse into what may be occurring in the Long Pond, South Basin watershed. East Pond is located within the towns of Smithfield, Belgrade, Oakland, and Fairfield. Current development trends have caused the Smithfield planning board to speculate that approximately 56% of the land within the East Pond watershed will be developed within the next 50 years (BI493 1991). It is therefore possible that the land within the Long Pond, South Basin watershed will experience similar trends. The manner in which this land is developed will have far reaching implications upon the future water quality of the lake. In addition to new development, if residences are converted from seasonal to year-round use this will also effect lake water qulaity.

In the Long Pond, North Basin watershed there was a marked reduction between 1980 and 1991 in the amount of forested land. Most of this land is now in the reverting land catagory which might suggest that it had been logged. This trend may create a threat to the water quality of Long Pond, North Basin as there is a correlation between diminished amounts of vegetation and increased amounts of phosphorous loading (Table 4).

Table 4. A comparison of various land use types and trends for the watersheds surrounding, Salmon Lake, East Pond, and Long Pond, North Basin. All vaues in percent total watershed (BI493 1995).

	Salmon Lake		East Pond		Long Pond, North Basin	
Land Use Type	1980	1991	1965	1991	1980	1991
Forest	67	65	78	77	82	69
Wetlands and water bodies	1	1	3	3	4	4
Residential Land	3	3	10	14	7	9
Roads	<1	1	2	2	1	1
Agricultural Land	*	*	4	2	+	+
Cleared Land	8	7	*	*	3	3
Reverting Land	<1	3	3	2	3	14

*No distinction made between agricultural land and cleared land made in the Salmon Lake study.
+No mention made in BI493 1995 Long Pond, North Basin study.

Study Objectives

WATER QUALITY ASSESSMENT

Lake Body

The current water quality of Long Pond, South Basin was assessed through physical measurements and chemical tests used to quantify various parameters such as transparency, turbidity, hardness, dissolved oxygen, total phosphorus, nitrate/nitrogen, pH, conductivity, and alkalinity. These results were compared with data collected in previous years by the Maine Department of Environmental Protection, avolunteer monitor, the Department of Biology at Colby College, and through other environmental surveys from representative lakes throughout the State of Maine. Test results from sites throughout Long Pond, South Basin were compared in order to investigate the effect of various land use practices within the watershed on lake water quality. Test sites were chosen during a field reconnaissance survey. During this survey, areas of high population densities or human activity, hydrological movement, slope, and sedimentation rates were noted as possible sites for water quality testing. The results of such tests were then used to make recommendations regarding future use of the lake and development of the surrounding watershed with regard to water quality.

Tributaries

Physical and chemical parameters of the tributaries flowing into Long Pond, South Basin were measured to determine the nutrient inputs to the lake from these sources. These parameters were measured to determine the possibility of phosphorus and nitrogen loading in an effort to preserve or improve the quality of the lake in the future. Tributaries often run through or near areas of human development and activity, and can therefore act as carriers of human waste and runoff even from land uses not directly on the shoreline. Tributary sampling sites were based on proximity to roads or other human activities that could contribute to pollution of the lake.

Macrophyte populations were also measured to aid in the identification of problem areas in the lake basin. Macrophyte concentrations are high in areas of shallow depth and high nutrient levels, and therefore could be used as indicators of nutrient loading through shoreline land uses or tributaries. Macrophyte populations are particularly high at the mouths of tributaries, indicating the role that tributaries play in sedimentation of lakes from both erosion and nutrient loading.

A storm event water sampling of selected tributaries was performed to determine the amount of phosphorus and sediments that can be in non-flowing or low-flow streambeds. During a dry period, nutrients and sediments can collect in the tributaries. These accumulating substances have a minimal effect on the lake water quality while stagnant in the tributary. During a storm, these substances can be scoured from the substrate and washed into the lake body. The importance of such a sampling is that nutrient and sediment loading from tributaries is not constant; it occurs in pulses. For this reason, discrete lake water quality analyses may not represent the dramatic impact of storm events, and storm event sampling is desirable. This sampling took place during a rainstorm with greater than 1 in of precipitation in order to ensure the release of sediments and nutrients from stream substrata, so that this form of nutrient loading could be quantified.

EFFECT OF LAND USE PATTERNS ON PHOSPHORUS LEVELS

Land use practices within the watershed were determined and the phosphorus input of each use was calculated. By analyzing each land use with regard to phosphorus input, the activities contributing the most phosphorus could be controlled or observed in the future. A phosphorus budget for Long Pond, South Basin was then constructed, for use as a tool in future management efforts to reduce or maintain desired phosphorus levels.

Zoning and development are very important factors to consider when land use strategies are planned for an area. The watershed of the Long Pond, South Basin is shared by the towns of Belgrade, Mt. Vernon, Rome, and Vienna (the area of Vienna that lies within the watershed does not, however, contain developed land and was therefore not included in our study). Therefore, the lake is subject to the town ordinances of all four communities and the responsibility for maintaining water quality is shared. This study has attempted to develop an understanding of those ordinances and how they directly or indirectly affect the water quality of Long Pond, South Basin. This objective relates not only to shoreline and nonshoreline homes in the watershed, but also to waste disposal systems, roads, agriculture, forestry, cleared land, and industry.

The number of residences and area covered by shoreline residential areas was examined to determine the extent of potential phosphorus loading by these areas. This was done for inland residences, as well. Although these residences are not directly on the shore (in this study, a "nonshoreline residence" was defined as being more than 250 ft from the water body), they impact phosphorus levels in the lake due to runoff and tributary flow.

One objective of this study was to determine the percentage of septic systems in acceptable condition with regard to nutrient loading. This estimation was based on the approximate age of residences (visual approximations: pre-1974 or post-1974), information from property cards regarding age, condition and type of waste disposal system, and through personal communication with plumbing inspectors from the towns within the watershed. The number of buildings per lot was also an important statistic, as this gives an indication of the amount of use of a particular lot's septic system. As well, the degree of use of a residence (seasonal or year-round) was determined. Taking location and number of residences, their waste disposal systems, as well as other factors within the watershed into account, recommendations for future building and reduction or maintenance of phosphorus levels can be made (see Residential Areas).

A comprehensive road survey was also conducted in order to determine the condition and maintenance level of the roads in the watershed, and to calculate the areas of these roads. From these data, the impact of runoff from roads on phosphorus loading was determined, and problem roads were identified in the hope that attempts will be made to repair them, thereby reducing future phosphorus loading.

Cleared land (including farmland for crops or livestock) and logging are important factors when determining the phosphorus loading into the lake because of the large areas of land that they require. The potential for runoff of nutrient and sediment loaded water from such areas is high. Agriculture, which is an ongoing process, has the potential to have a higher impact over time as compared to transient logging activities. By comparing 1966 and 1992 aerial photos, land use changes in recent decades were determined. These land use categories were examined to determine how they have contributed, are presently contributing, and could contribute in the future to the nutrient loading of Long Pond, South Basin. Large amounts of land have been logged and are being logged in the western section of the watershed, while land being used for agricultural purposes is not as extensive. Cleared, non-agricultural lands are also found within the watershed, and therefore could add additional phosphorus to the lake.

ANALYTICAL PROCEDURES AND FINDINGS

Water Quality Study Sites

Twenty-three sample sites were chosen to characterize the water quality of Long Pond, South Basin. These sites were at deep water, shoreline, marshland, and tributary locations, and were broken into Characterization, Spot, and Tributary Sites (Figure 12). Characterization Sites 2, 4, and 12 were used to assess the water quality of the complete water column. Spot Sites, Site 1 as the major inlet to the basin, and Site 6 as the major outlet from the basin, were intended to investigate the impacts of highly residential offshore areas and the north basin. Tributary Sites 7, 8, and 15 through 22 were used to analyze the potential for nutrient loading along municipal roads, acting as direct routes for high surface runoff. All twenty-three sample sites were chosen after the lake and watershed reconnaissance on 10-SEP-95 by BI493, based on topography, lake morphology, and hydrology; contributing to the lake's possible cultural eutrophication via residential development, agriculture, forestry, or surface runoff from municipal, state, and camp roads. All sites were sampled and surveyed on 18-SEP-95 and 25-SEP-95, and Tributary Sites 19, 21, and 22 were sampled again during the storm event of 6-OCT-95. Physical analyses were performed on site, with chemical analyses conducted at the Colby Environmental Laboratory, following the BI493 Quality Assurance Plan (Appendices A and B). Point and non-point input sources from areas within the watershed and contributing to Long Pond, South Basin's watershed, as well as wetland sources and sinks for the south basin, were included in the study.

Long Pond South Basin Study Sites:

Site 1: North Basin Inflow

Located in the upper Northeast quadrant of the watershed, just southeast of Castle Island, 150 ft off the eastern shore.

Site 2: The Deep Hole

At a depth of 91 ft, located 1375 ft east of Green Island's easternmost shore.

Site 3: Northeastern Cove

Northernmost of the large eastern coves off Green Island, 500 ft into the lake from the cove's inlet.

Site 4: Middle of Lake

Northwest of Sandy Cove, 2000 ft equidistant from the western and eastern shorelines

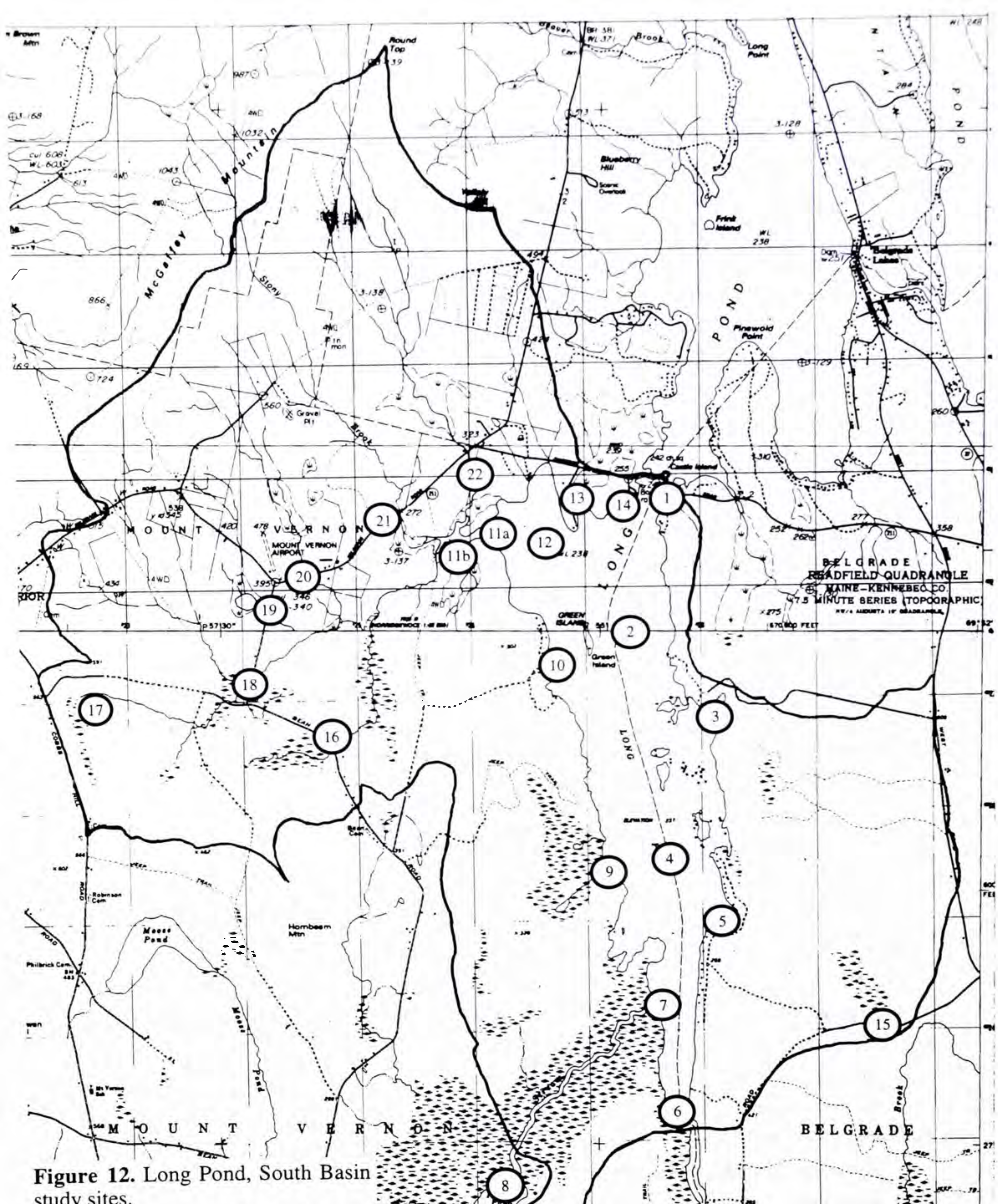

Figure 12. Long Pond, South Basin study sites.

Site 5: Sandy Cove

Located 150 ft offshore from the Public Beach access point and 300 ft east of the Westernmost point in Sandy Cove.

Site 6: Southern Point

Southernmost point of the watershed containing Long Pond, South Basin. Located 10,000 ft north of Wings Mills Dam, 150 ft from the Eastern shore bay.

Site 7: Ingham Stream

Mouth of the stream entering into Long Pond, South Basin, 100 ft equidistant from the Northern and Southern shores of the mouth, 50 ft downstream.

Site 8: Ingham Pond

Center of Ingham Pond, 575 ft equidistant from the Northern and Southern shores. This site is outside of Long Pond, South Basin's watershed.

Site 9: Marsh Mouth

Located 150 ft offshore from the Western marshland and tributary, in the Western bay of Long Pond, South Basin.

Site 10: Journey's End Shore

Located 10 ft offshore from the central road of Journey's End Road, 950 ft southwest of the Southernmost tip of Green Island.

Site 11a: Stony Brook Tributary

Central quadrant of the watershed, in the Northwest cove of Long Pond, South Basin. The sample site is 150 ft into the tributary.

Site 11b: Below Stony Brook Tributary

Central quadrant of the watershed, empties into the same cove as the Stony Brook Tributary, but at the Southeastern end of the peninsula of the cove and 150 ft into the tributary.

Site 12: Northwest Bay

Located 1100 ft west of the Southernmost tip of Narrow's Road peninsula.

Site 13: Eastern Cove off Narrow's Peninsula

Located 650 ft south of the inlet, and 210 ft off of the peninsula's Eastern shore.

Site 14: Boat Ramp

Located in line and equidistant from the end of the boat dock and the opposite shore, southwest of Castle Island.

Site 15: Belgrade Landfill

Located in the Eastern quadrant of the watershed, just south of the Easternmost marsh within the watershed, north of Meadow Brook, 1875 ft east of Sandy Cove Road, on West Road.

Site 16: Bean Road Marsh

Tributary 150 ft southwest of Bean Road, just inside the marshland, 2600 ft northwest of Bean Cemetery.

Site 17: Mount Vernon Dump

Located just east of the marsh along Cobbs Road, 900 ft east of Cobbs Road, 900 ft south of Bean Road, in the Western quadrant of the watershed.

Site 18: Bean Road Tributary

Tributary 900 ft north of Bean Road fork, 2700 ft south of the Bean and Belgrade Road junction, and east of the marshland.

Site 19: Mount Vernon Tributary

Located 2000 ft north of Bean Road Tributary (Site 18), downslope from Mount Vernon Airport, 900 ft south of the Bean and Belgrade Road junction, at the inflow end of the culvert.

Site 20: Airport Tributary

Located 900 ft east of the Bean and Belgrade Road junction along Belgrade Road, southeast of the Mount Vernon Airport, crossing Route 211.

Site 21: Stony Brook

Located 200 ft south of Belgrade Road, sampled just outside the culvert, 1900 ft northwest of Site 11a.

Site 22: Belgrade Road Tributary

Located 2700 ft northeast of Stony Brook Road, south of Belgrade Road, 500 ft south of the Belgrade and Narrow's Road junction.

Water Quality Methods

Following the Quality Assurance Plan (Appendix B), two main types of water samples were taken for use in water quality testing. The first kind is a core sample, which gives a representative amount of the phosphorus present in the water column. The core is obtained by lowering a tube to 1.0 m below the epilimnion (see Lake Basin Characteristics), pinching the tube, and then raising it out of the water. If the lake is not stratified, the core is taken from the surface to 1.0 m above the bottom of the lake. This is repeated three times, mixing the three cores in a mixing bottle. The sample is then taken from this mix. The second type of sample was collected in order to compare the chemical characteristics of the three stratification layers of the lake: surface, mid-depth, and bottom samples. The bottom and mid-depth samples were taken by lowering an Alpha type water sampler to the desired depth, bringing the sampler back to the surface, and collecting the water. Surface grabs were used to collect the top samples.

The samples were preserved in the field according to the procedures described in the Quality Assurance Plan (Appendix B). The samples were frozen and returned to the Colby Environmental Laboratory, where they were subsequently analyzed according to the specific procedures for each chemical property investigated (Appendix A). Three procedures were used to assess the accuracy of the laboratory and the sampling techniques, as described in the Quality Assurance Plan (Appendix B). Most of the results of these procedures fell within 2.0 ppb of their expected values, a reasonable margin of error.

LAKE WATER QUALITY

Physical Measurements

Depth

The various depths for Long Pond, South Basin were measured with a Humminbird depth finder or a weighted depth line. Depths for all sites excluding 11a, 11b, 17, 20, 21, and 22 were measured on 18-SEP-95; Sites 2, 4, 9, 11b, 16, and 19 were measured on 25-SEP-95 (see Figure 12). On 6-OCT-95, the change in depth for tributary Sites 19, 21, and 22 were measured during the storm event. For sites with more than one measurement, depths were averaged for the two sampling dates. Depths obtained during the storm event were considered separately; these measurements did not accurately represent a depth value resulting from the entire summer season.

The most shallow tributary depths for 18-SEP-95 and 25-SEP-95 were 0.02 m, 0.06 m, 0.23 m, and 0.90 m for Sites 18, 19, 16, and 13, respectively. The mean depth for the spot sites was 2.54 m, with a range 0.90 to 6.70 m. Lake characterization Sites 2, 4, and 12 had depths 27.70 m, 7.80 m, and 11.30 m, respectively (see Figure 12). The major inlet at Site 1 and the major outlet at Site 6 had depths 1.80 m, and 2.10 m, respectively. The average depth for the Long Pond, South Basin was determined to be 9.0 m based on an average of bathymetric depths from unpublished MDEP data; comparing to South Basin's reported mean depth of 11.0 m (MDEP 1994).

Temperature and Dissolved Oxygen

Temperature and dissolved oxygen (DO) profiles for a freshwater lake are important to measure when assessing lake water quality. Dissolved oxygen is inversely dependent on temperature; warmer temperatures hold less oxygen than colder temperatures, but facilitate biological activity for many aquatic species in the water column. During the summer season, the lake stratifies into an upper epilimnion, central metalimnion, and lower hypolimnion. The hypolimnion possesses the lowest temperatures among the three layers. Although low temperatures may hold more DO per cubic centimeter, low temperatures also inhibit algal blooms and the overall biological growth and productivity of the lake (Pearsall 1991). When the lake undergoes temperature stratification during the summers, there is a low degree of mixing in the water between the layers.

The DO levels become stratified and the supply of DO in the hypolimnion does not recharge for the summer season. The main oxygen sources for freshwater ecosystems are atmospheric absorption and the photosynthetic byproducts of algae and plants (Pearsall 1991). Most freshwater fish require a minimum of 5.0 ppm DO in order to maintain normal levels of growth and reproduction, otherwise fish kills may occur. If DO levels fall below 1 ppm, the process of internal cycling of phosphorus from the sediment begins, as oxidized iron releases the phosphorus trapped in the lake sediments (Novotny and Olem 1994). Temperature/DO profiles are important in detecting the potential for lake eutrophication from one year to the next.

The temperature and DO profiles were taken at the lake's deep water characterization sites on 18-SEP-95. The ORION model 840 Oxygen meter was used to measure these sites with a variation of ±0.5 ppm DO. At Sites 2 and 12, a thermocline was apparent, beginning at approximately 10 m (see Figure 13). Site 4 indicates an isothermal condition, in which there is no overturn through the water column, but appropriate conditions are present to facilitate a possible turnover. Site 6 does not provide an accurate Temperature/DO profile for stratification and/or overturn analysis because the site was only 2.6 m deep (see Figure 13). Two DO profiles were taken during the summer, on 16-JUN-95 and 13-JUL-95 (unpublished data), one mile south of Castle Island (near Site 2 of the current Long Pond, South Basin study). The DO concentrations did not show any true stratification on 16-JUN-95, but did show stratification on 13-JUL-95 (see Figure 14). Long Pond, South Basin's surface DO was approximately 10.1 ppm for summer 1995 and had an arithmetic average of 8.8 ppm for the 18-SEP-95 sampling date (see Figure 13)(see Figure 14). The overall decrease in DO concentration may be a result of bacteria consuming oxygen during the summer lake stratification period; it is difficult to determine the start and end of the period; it is difficult to

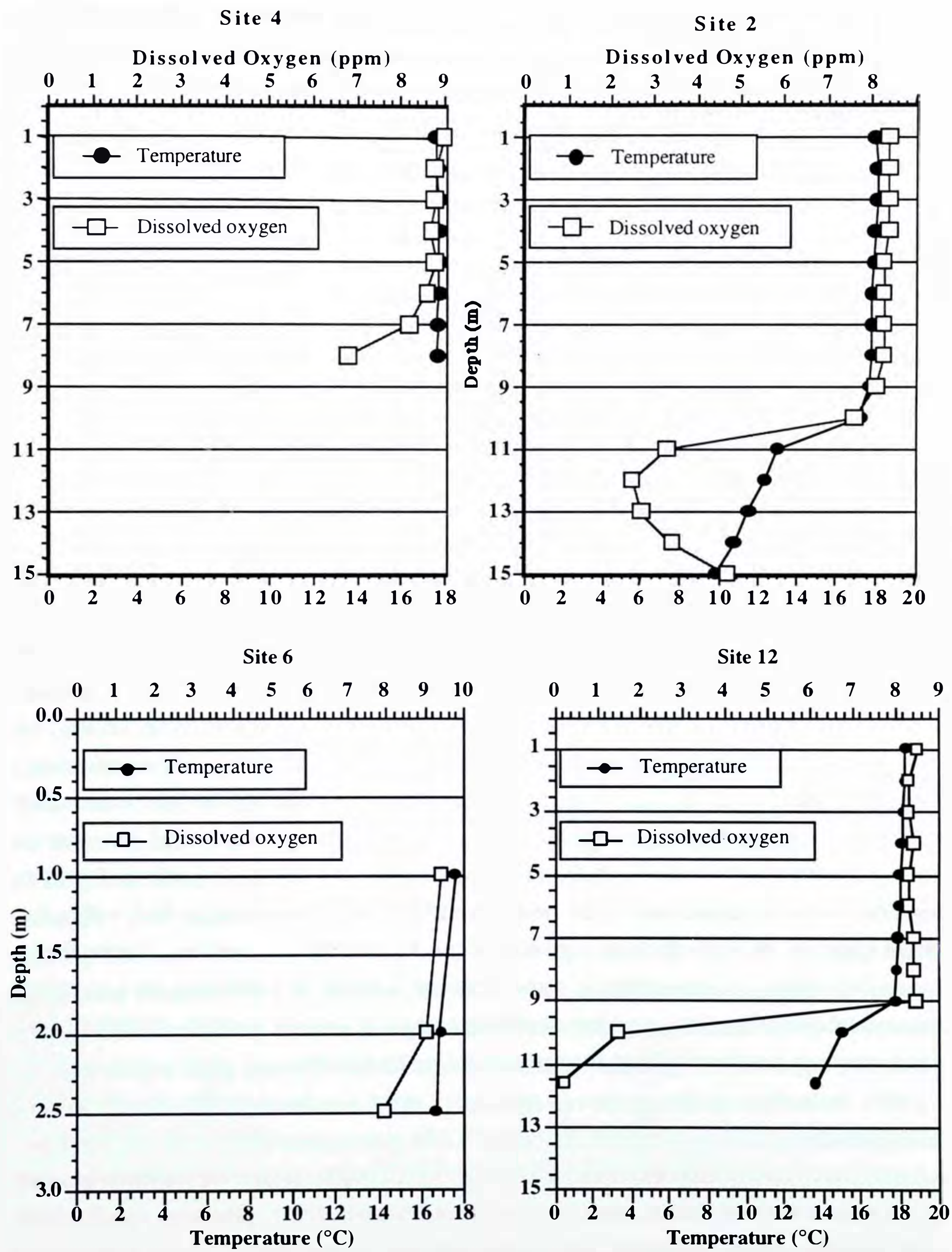

Figure 13. Temperature and dissolved oxygen profiles from Long Pond, South Basin on 18-SEP-95. Sites 2, 4, and 12 are the Characterization Sites, and Site 6 the major outlet of the lake. See Figure 12 for site locations.

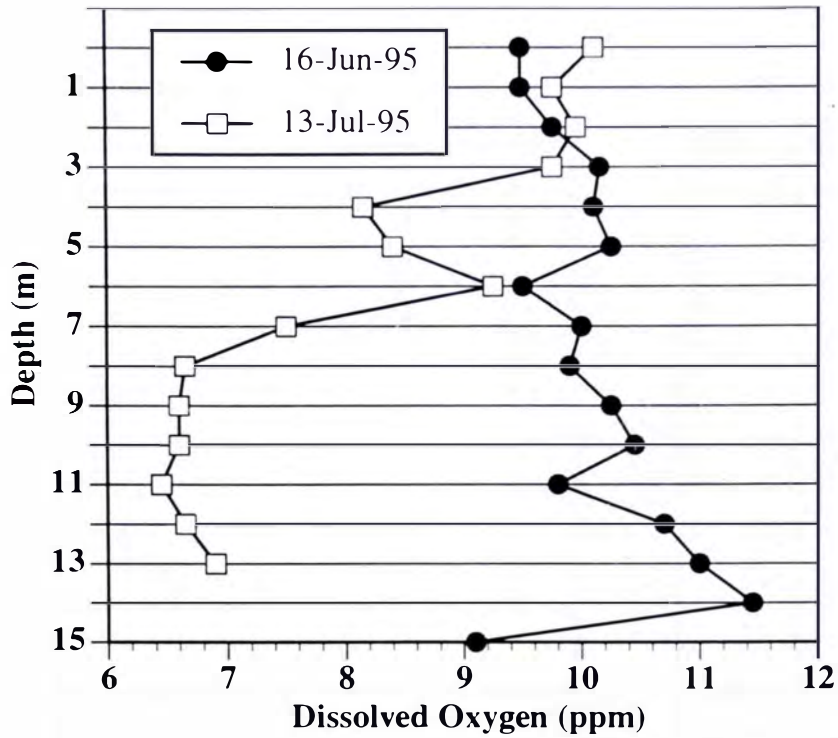

Figure 14. Dissolved oxygen profiles from Long Pond, South Basin at Site 2 (unpublished data). See Figure 12 for site locations.

ascertain a direct cause on surface oxygen concentrations. On 16-JUN-95 and 13-JUL-95, the DO concentrations for each thermocline dropped to a low of 6.5 ppm at 11.0 m, whereas on 25-SEP-95, Sites 2 and 12 dropped to lows of 2.5 ppm at 12 m and 0.2 ppm at 11.6 m, respectively (see Figures 13 and 14). At Site 2, the low level of DO falls well below the 5.0 ppm minimum for normal fish growth and reproduction, and Site 12 falls well below the 1.0 ppm minimum for internal cycling of phosphorus. This may have resulted from warmer summer temperatures, or from the postponement of fall overturn as a result of dramatic temperature stratification, decreasing the DO concentration in the hypolimnion by isolating oxygen consuming bacteria. Although the summer profiles do not suggest anoxic or potential phosphorus stress conditions in the water column, the fall profiles do, and that is a significant factor to consider for future projections of the lake. The DO level did not abruptly shift within the thermocline on 16-JUN-95 in comparison to the 25-SEP-95 fall profiles. September's lower DO values in comparison to those from the summer of 1995 may be a result of unseasonably warm and dry weather conditions in the late summer and fall of 1995, further decreasing any turnover between the layers of the water column.

Transparency

Transparency measures water clarity, which is used as an indirect indicator of algal and zooplankton populations, water color, and silt (Pearsall 1991). Readings can fluctuate with variable weather conditions and weather can turn over the water column and bottom sediments at shallow sampling sites. The presence or absence of variable algal populations also affects transparency. Often, the best transparency readings are obtained in the spring and early summer, where cold water conditions minimize algal population size (Pearsall 1991). Readings with low algal concentrations can be used for comparisons to late season readings, when algal populations and human activity increases in July and August. Comparisons for one site can be made between months and years, and comparisons between different sites can also be made. Readings of less than 4.0 m indicate a highly productive lake, 4.0 to 7.0 m a moderately productive lake, and greater than 7.0 m an unproductive lake.

Transparency headings were taken at Sites 2, 5, and 12 on 18-SEP-95, and Site 4 on 25-SEP-95 using a Secchi disk and Aqua-Scope (see Figures 12 and 15). Site 5 was a shallow sampling site with a depth of only 3.0 m, in comparison to Sites 2, 4, and 12 with depths of 27.7 m, 7.6 m, and 11.6 m, respectively (see Figure 15). Because the sediment at Site 5 may have been stirred into the water column at the time of sampling, resulting in an unusually low transparency reading, the data were not considered in analysis. The historical mean for Long Pond, south basin from 1970 to 1993 is 6.7 m (MDEP 1994), and the current mean transparency reading for all sampling sites on Long Pond, South Basin was 6.5 m. This difference indicates only a slight increase in productivity for the South Basin. The range of mean transparency for all Maine lakes is 3.0 to 7.0 m, with an average of 5.6 m (Pearsall 1991). East Pond had an average transparency of 4.0 m (BI493 1992), Pattee Pond an average of 1.9 m (BI493 1993), Salmon Lake an average of 5.2 m (BI493 1994), and Long Pond, North Basin an average of 6.9 m (BI493 1995). Long Pond, South Basin mean transparency falls within the range of all Maine Lakes, well above the transparencies for East Pond, Pattee Pond, and Salmon Lake, and only 0.4 m below Long Pond, North Basin. The range of transparency readings, 3.0 to 6.5 m, taken at Sites 5, 2, and 12 on

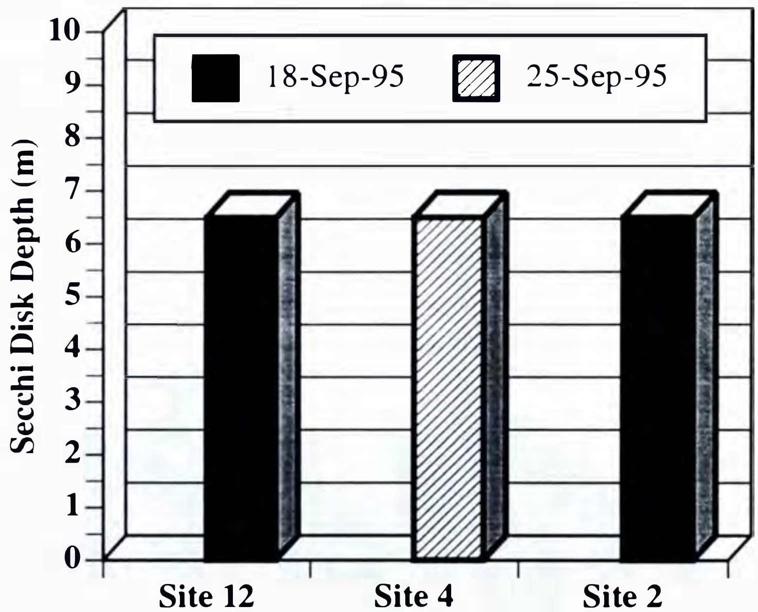

Figure 15. Secchi Disk measurements for selected lake Characterization Sites from Long Pond, South Basin. See Figure 12 for site locations.

18-SEP-95 and Site 4 on 25-SEP-95 falls within the range of all Maine lakes at 3.0 to 7.0 m (Pearsall 1991).

Turbidity

Turbidity measures water clarity and is dependent on the type and concentration of suspended matter. Suspended matter includes the following: silt, fine particles of organic and inorganic matter, soluble organic compounds, plankton, and other microscopic organisms (Chapman 1992).

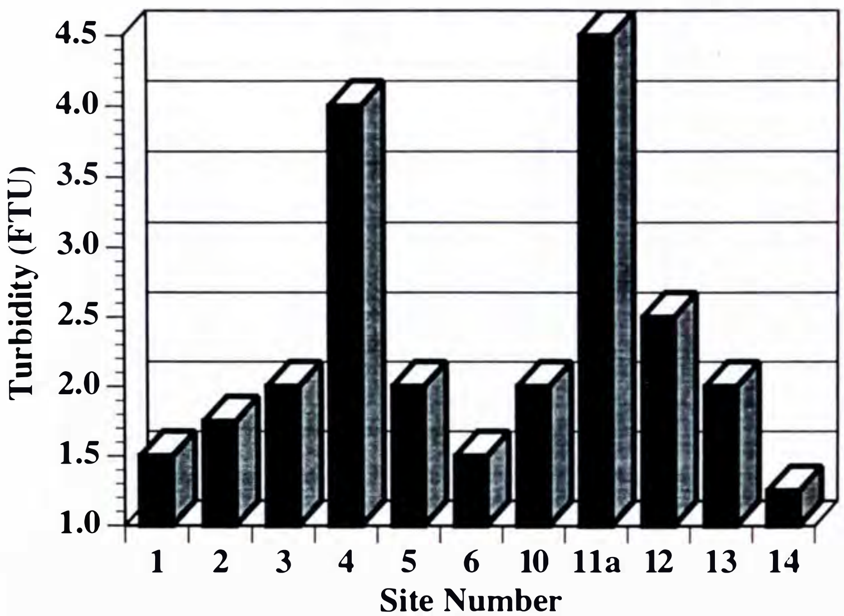

Figure 16. Turbidity measurements for surface samples from Long Pond, South Basin on 25-SEP-95. See Figure 12 for site locations.

Surface samples for turbidity were taken from Long Pond, South Basin on 25-SEP-95 at the following Spot and Lake Characterization Sites: 1, 2, 3, 4, 5, 6, 10, 11a, 12, 13, and 14 (see Figure 12). In the Colby Environmental Laboratory, the samples were analyzed using the HACH DR/3000 Spectrophotometer Absorptometric Method for Turbidity derived from Standard Methods (Clesceri et al. 1989). Results are expressed in Formazin Turbidity Units (FTU). Our sample mean was 2.3 FTU (Figure 16). Our sample range was from 1.2 to 4.5 FTU compared with turbidity values for Long Pond, North Basin open water sites, which had a range of 3.0 to 4.0 FTU (BI493 95). However, all but three turbidity readings were less than or equal to 2.0 FTU in the south basin, suggesting that North Basin has more turbid waters than South Basin. It is difficult, however, to compare turbidity readings between two systems at different times, as the site types and storm activity can have localized effects. The highest reading was from Site 11a, a marsh at the Northwest corner of the lake. This may be due to the high amount of sediments and organic matter in the water column from the major tributary located approximately 900 ft away from the testing site. The second highest reading was from Site 4, located in the middle of the lake off the shore of the Northern boundary of the Sandy Cove development, possibly due to the large number of houses in the area. The lowest reading was measured just off of the boat ramp near Castle Island (Site 14).

Conductivity

Conductivity is a numerical expression of the ability of water to carry an electrical current (Clesceri et al. 1989). This directly relates to the amount of dissolved ions and solids in the water (Clesceri et al. 1989). Conductivity measurements can be used to identify water with high ion concentrations, which can then be tested further for specific ions that effect the water quality. Conductivity measurements were made using a YSI model 31A Conductance Bridge in the Colby Environmental Laboratory. Surface samples were collected on 18-SEP-95 at Lake Characterization Sites 2, 4, 6, 12 and Spot Sites 1, 3, 5, 10, 11a, 13, and 14 (see Figure 12). Middle, bottom and core samples were also collected at Sites 2, 4, 6, and 12. All samples were analyzed immediately upon return from the field. Results are expressed in µmhos/cm^2.

Conductivity measurements for surface samples ranged from 27.4 to 47.0 µmhos/ cm^2 and the mean was 35.0 µmhos/cm^2. The historical mean for Long Pond, South Basin is 29 µmhos/cm^2 and was calculated from five yearly means between the years of 1970 and 1994 (MDEP 1994). The mean for Long Pond, North Basin was 31.1 µmhos/cm^2 (BI493 1995). Most of the measurements were between 27.4 and 40.0 µmhos/cm^2, which is within the average range for Maine lakes of 20.0 and 40.0 µmhos/cm^2 (see Figure 17) (Pearsall 1991). The range and mean for Sites 2, 4, 6, and 12 was 27.4 to 34.9 µmhos/cm^2 and 30.1µmhos/cm^2,

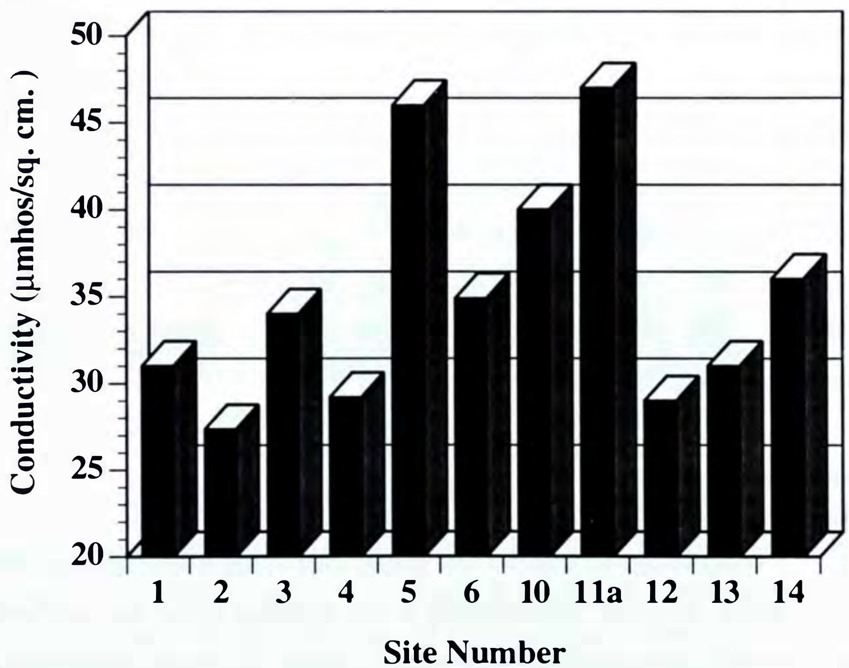

Figure 17. Conductivity measurements for surface samples taken from Long Pond, South Basin on 18-SEP-95. See Figure 12 for site locations.

while the range and mean for Sites 1, 3, 5, 10, 11a, 13, and 14 was 31.0 to 47.0 µmhos/cm^2 and 37.1 µmhos/cm^2. The former sites were all mid-lake sites where the depth was fairly deep, while the latter sites were all close to shore where depths would be shallow. The higher range and mean conductivity at the latter sites can probably be attributed to greater mixing of sediment at these sites because of shallow depths. Sites 5 and 11a had the highest conductivity readings of 46.0 and 47.0µmhos/cm^2 respectively. The high reading at Site 5 could be due to runoff or poorly sited or overloaded septic systems from the Sandy Cove residential area, although large inputs from septic systems are required to change conductivity. It could also be due to runoff from the portion of the watershed east of Site 5. This area has steep topography and includes the Belgrade Landfill and a wetland (see Municipal Land Uses). Site 11a is a receiving point for the tributaries that carry runoff from the majority of the Northwest and Southwest sections of the watershed. Therefore, the high conductivity reading is probably due to the sediment rich water that flows into this area from the tributaries.

At Site 2 surface, middle, and bottom, and core samples were collected. The surface, middle, and bottom results were 27.4, 26.0, 27.7 µmhos/cm^2 respectively as compared to a core sample of 34.9 µmhos/cm^2. This suggests that there was little difference between conductivity and depth. At Site 12, the same sampling scheme was completed and similar results were obtained. The surface sample had a conductivity reading of 29.0 µmhos/cm^2, followed by the middle with 29.1, the bottom with 29.0, and the core with 31.0. At Sites 4 and 6, due to possible sampling errors, a completion of surface, middle, bottom, and core sampling did not occur (Appendix C). Therefore, no comparisons can be made.

Chemical Analyses

Total Phosphorus

Phosphorus is one of the most important nutrients involved in lake eutrophication for two main reasons: phosphorus is the limiting agent for primary productivity (algal and plant growth) and phosphorus loading causes the most noticeable changes in water quality (MDEP 1992a). Phosphorus is constantly cycling through the lake in two different forms, particulate phosphorus and dissolved phosphorus (see Introduction: Phosphorus and Nitrogen Cycles). The analysis that was used in this study took both forms into account to determine the total phosphorus concentration of the water samples. The samples were digested in order to convert the particulate phosphorus to dissolved phosphorus, and then the samples were analyzed using the Ascorbic Acid total phosphorus method (Clesceri et al. 1989) and Milton Roy Spectronic 1001+ Spectrophotometer.

Samples were taken from five Characterization Sites on the lake (Sites 1, 2, 4, 6, and 12) (see Figure 12). The purpose of the characterization sampling was to determine the overall water quality of the lake and to notice any specific problem areas. The sampling was done on 18-SEP-95 and 25-SEP-95. The surface grabs from Site 1, where the flow comes in from Long Pond, North Basin, and Site 6, the outflow of the lake in the south, had similar total phosphorus readings, of 4.5 ppb and 5.5 ppb, respectively. The mid-depth value at Site 6 was slightly higher (6.9 ppb) than the surface grabs at both sites, possibly reflecting sediment contamination of the sample.

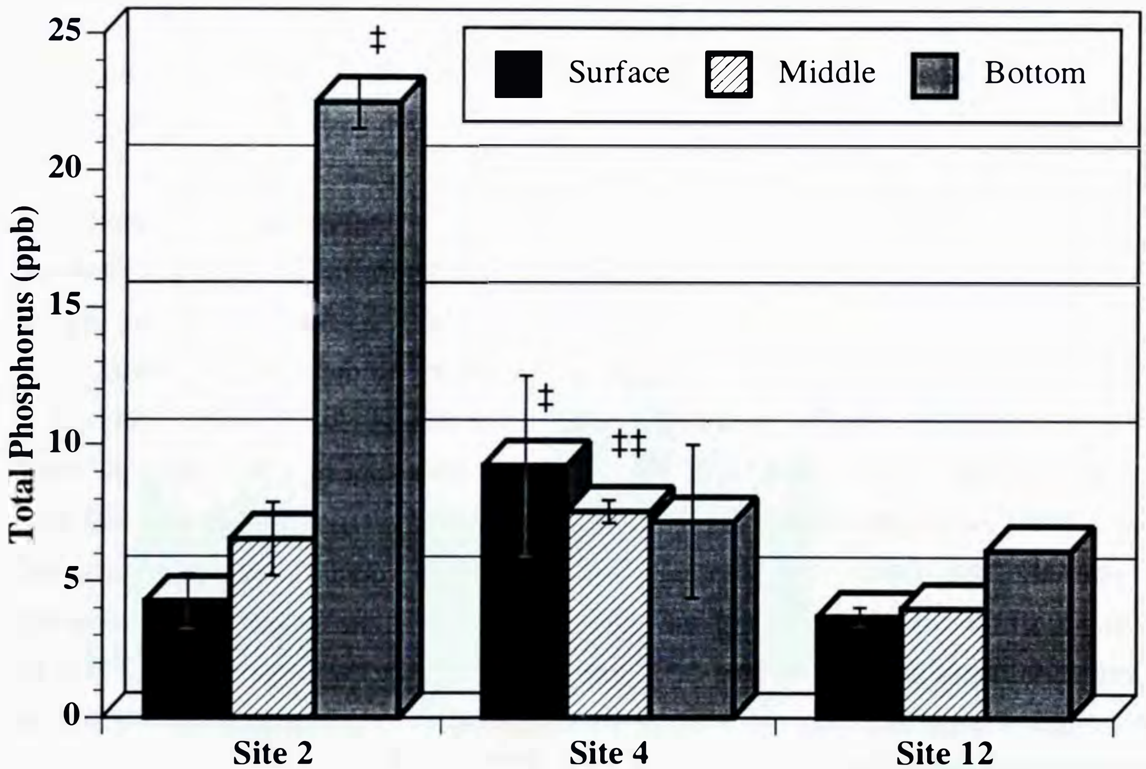

Figure 18. Total phosphorus concentrations for surface, middle, and bottom samples from Long Pond, South Basin characterization sites. One cross indicates an average of three values, and two crosses indicate an average of four values. All other values are an average of two values. Error bars represent one standard error around the mean. See Figure 12 for site locations.

At Site 2, the deepest point of the lake (27.7 m), the phosphorus levels from the bottom sample were much higher than the middle and surface samples (see Figure 18). This could be due to phosphorus being released from the organic sediments because of low dissolved oxygen concentrations, approximately 2.0 ppm, at that depth (see Figure 13). The core phosphorus concentration, 11.8 ppb, was higher than the values for the surface and mid-depth samples, suggesting that phosphorus from the bottom stratum was included in this core, or there was contamination from the sediment.

At Site 4 (7.6 m deep), offshore from Sandy Cove and a residential area, the phosphorus values were fairly uniform for the three layer samples (see Figure 18). The depth at Site 4 was only 7.6 m, so the lack of stratification lead to a more uniform dissolved oxygen profile (see Figure 13). Compared to surface grabs from other sites, there was one high surface value (14.7 ppb) which was taken on 25-SEP-95. This is most likely because of mixing of the lake layers as a result of fall turnover. The high value is probably not due to contamination because high concentrations were also recorded at the mid-depth sample from Site 4 and the core sample from Site 12 for the same date. The high concentrations could reflect a recent storm runoff of phosphorus into Long Pond, South Basin.

At Site 12 in the Northwest bay, the core sample concentration (8.9 ppb) was higher than any of the layer values from that site (top, 3.7 ppb; middle, 4.0 ppb; bottom, 6.1 ppb), but it was taken on 25-SEP-95, as was the high surface value from Site 4. Again, this could be due to an increased amount of turnover by the second sampling date, or because of increased phosphorus runoff from tributaries at Sites 11a and b during a recent storm (see Figure 12). At Site 12 the three layer phosphorus concentrations were also fairly similar (see Figure 18). The bottom values were between 2.0 ppb and 3.0 ppb higher than the other layers, suggesting that phosphorus could be escaping from the sediments due to the decline in dissolved oxygen near the bottom or is being released by settling material from the recent storm (see Figure 13). This site was approximately 4.0 m deeper than Site 4, and the dissolved oxygen concentration does decrease at the bottom of Site 12 more than it did at Site 4.

The surface grabs from the Characterization Sites were very similar with the exception of the previously mentioned grab from Site 4 on 25-SEP-95 (see Figure 18). Of the surface grabs, the highest value was 14.7 ppb at Site 4 (25-SEP-95), and the lowest value was 3.3 ppb at Site 2 (18-SEP-95), the deep hole. Again, the high value at Site 4 may be due to overturn in the water column between sampling dates. The low value at Site 2 may indicate that there is little runoff from the surrounding shoreline or that the impact of runoff from the shoreline might disappear by Site 2 because it is in the middle of the lake. Because Long Pond, South Basin has a relatively high flushing rate, it is also probable that there is adequate flushing to prevent buildup of phosphorus in that area. The mid-depth samples were also very similar, between 4.0 ppb and 7.9 ppb, with the highest value at Site 4 from 25-SEP-95 (see Figure 18). When comparing all of the bottom samples from the Characterization Sites, the highest concentration is found at the deepest point, Site 2 (see Figure 18). Bottom samples from Site 12 and Site 4 have similar total phosphorus concentrations and are relatively shallow compared to Site 2, suggesting that the amount of phosphorus found increases as the depth increases.

In general, the phosphorus concentrations from the Characterization Sites are well below the 15.0 ppb level that typically supports algal blooms (Pearsall 1991). The lake would most likely be considered moderately productive, with most phosphorus values ranging from 6.0 ppb to 13.0 ppb (Pearsall 1991). Despite the bottom sample concentrations from Site 2, Long Pond, South Basin does not appear to be in danger of eutrophication or algal blooms as a result of high phosphorus concentrations in the short term.

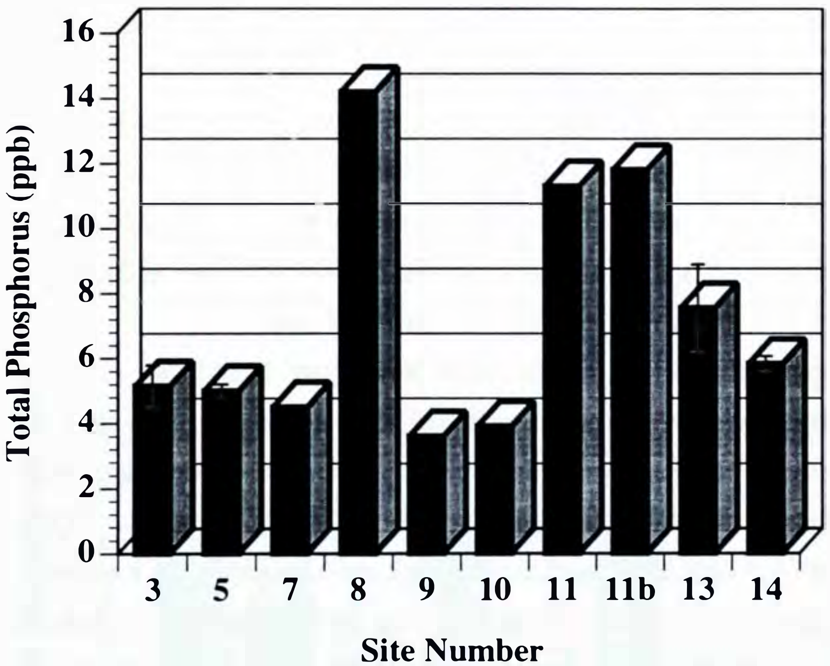

Figure 19. Total phosphorus measurements from surface grabs at Long Pond, South Basin spot sites. Site 8 (Ingham Pond) is not in the watershed, but flows into Long Pond, South Basin via Ingham Stream. Site 14 is an average of three values, Sites 3, 5, and 13 of two values, and all other sites are represented by one sample. See Figure 12 for site locations.

During the initial shoreline reconnaissance, certain sampling sites were chosen because of their proximity to potential phosphorus loading problem areas, such as developments and tributaries. At all of these spot sites, surface grabs were taken and total phosphorus analyses were performed (see Figure 12). The total phosphorus concentrations measured at lake Sites 3, 5, 7, 9, and 10 were all less than 6.0 ppb (see Figure 19). These values are extremely low in comparison to 15 ppb, the level at which algal blooms occur. This indicates that there was not a phosphorus loading problem at these specific sites when the sampling was performed. The phosphorus concentrations at Sites 3 and 10, which are located on opposite shorelines from Characterization Site 2, are both within 1.0 ppb of the amount of phosphorus measured near the center of the lake. Evidently, the phosphorus is already present in the water column, and the concentration was not being increased by runoff from the shoreline developments at these two sites at the time of sampling. Sample 5 was taken directly off shore from the Sandy Cove development, on the Eastern shore of Long Pond, South Basin. The phosphorus concentrations measured further offshore, at Characterization Site 4, are greater, further suggesting that little phosphorus is entering the lake from the Sandy Cove development. Site 9 is located near the wetlands on the Mid-western shore of the basin. The low concentration measured at this site is probably the result of two factors: the adjacent shoreline is not developed and the bordering wetlands may be acting as a sink by buffering runoff containing phosphorus. Site 7, at the mouth of Ingham Stream, was also found to have an extremely low phosphorus concentration (4.5 ppb). This value could be representative either of the wetlands buffering the outflow from Ingham Pond or of mixing with backflow from Long Pond, South Basin.

Lake Sites 13 and 14, both at the north end of Long Pond, South Basin, were found to have slightly higher total phosphorus concentrations of 7.5 ppb and 5.8 ppb respectively (see Figure 19). This suggests that the developments along Narrows Road and in the surrounding area may be contributing some phosphorus to the lake. However, these concentrations are still low enough that algal blooms are not a threat.

Sites 11a, 11b, and 8 appear to be the problem areas (see Figure 19). Sites 11a and 11b are both located where tributaries feed into Long Pond, South Basin. Site 11a is located in a marsh at the confluence of two tributaries, while Site 11b was taken about 900 ft from the mouth of the southern tributary feeding into the marsh at Site 11a. This southern tributary appears to pass through a wetland area, which may be acting as a source, depositing phosphorus into the tributary. The northern tributary feeding into the marsh at Site 11a appears to be coming from Stony Brook, which includes the gravel pit and airport in its drainage basin. This land use may be causing the high phosphorus levels in the tributary. Both tributaries have phosphorus levels close to 11.0 ppb and are depositing this relatively high phosphorus concentration into Long Pond, South Basin.

The total phosphorus concentration of Ingham Pond (Site 8), which is not located in the watershed studied for land use analyses but does flow into Long Pond, South Basin, was found to be close to 14.0 ppb. This high concentration, relative to the values recorded in Long Pond, South Basin may be caused by the surrounding development, then amplified by the small amount of flow and mixing that this shallow pond experiences. In spite of the high concentrations at the center of the pond, phosphorus levels at the mouth of Ingham Stream feeding into Long Pond, South Basin were low (4.5 ppb). Depending on if this value represents water flowing out of Ingham Pond or backflow from Long Pond, South

Basin, it is possible that the wetlands bordering the stream could be buffering the phosphorus before it enters Long Pond, South Basin.

The value for average total phosphorus in Long Pond, South Basin, 6.2 ppb, is similar to the value of 5.9 ppb that was calculated in the Fall 1994 for Long Pond, North Basin (see Table 5) (BI493 1995). This suggests that the two lake basins are at comparable states of eutrophication.

Table 5. Total phosphorus measurements for all sampling sites from Long Pond, North Basin surface grabs (BI493 1995) and Long Pond, South Basin surface grabs (taken in the present study).

Basin of Long Pond	Low Value (ppb)	High Value (ppb)	Average Total Phosphorus (ppb)
North	3.1	14.5	5.9
South	3.3	14.7	6.2

As external loading exists for all lakes this suggests that the south basin has an assimilation capacity such that a phosphorus concentration equivalent to that of the north basin occurs. The bordering wetlands could be playing a major role in the quality of the water (Paul Doss, pers. comm.). When comparing surface grab concentrations over the past twenty years, there is no definite trend in phosphorus concen-trations (see Figure 20) (MDEP 1994). Although the concentrations for 1995 (6.2 ppb) and 1992 (6.5 ppb) are less than the concentration from 1988 (13.0 ppb), there is not enough evidence to support a downward trend. The pattern for core samples is similar in that no definite pattern is evident (Figure 21, MDEP 1994). The 1995

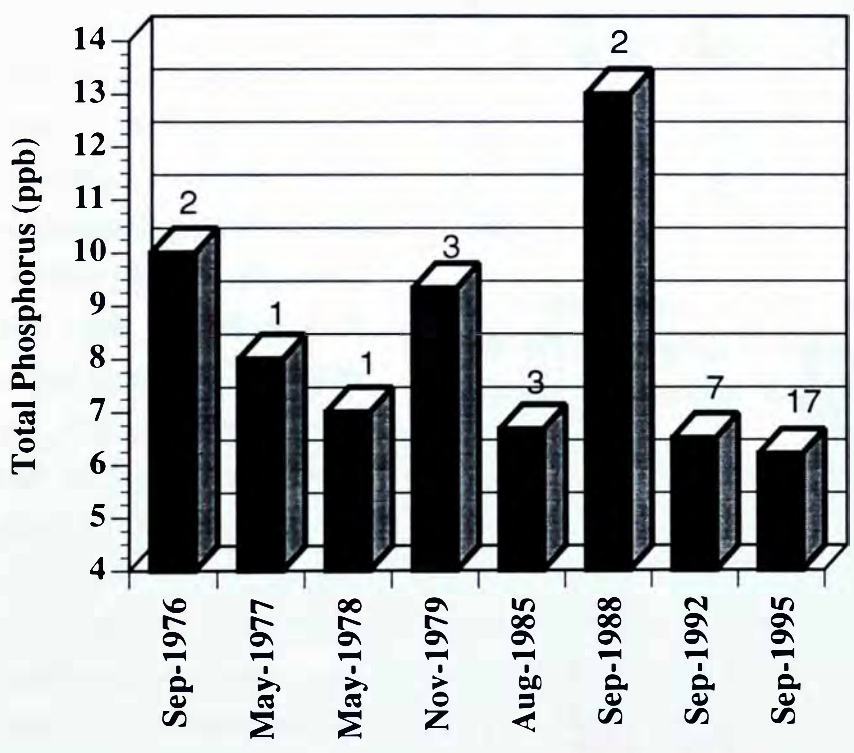

Figure 20. Total phosphorus concentrations from Long Pond, South Basin surface grabs, 1976 to 1995 (MDEP 1994). Sample size for each period is shown by the number above the bar.

level (10.3 ppb) is about 4 ppb higher than the recorded 1992 value (6.0 ppb), but concentrations have oscillated so much in past years that this upward indication is inconclusive. Phosphorus levels need to be continually monitored; future concentrations and trends cannot be predicted by the historical data alone.

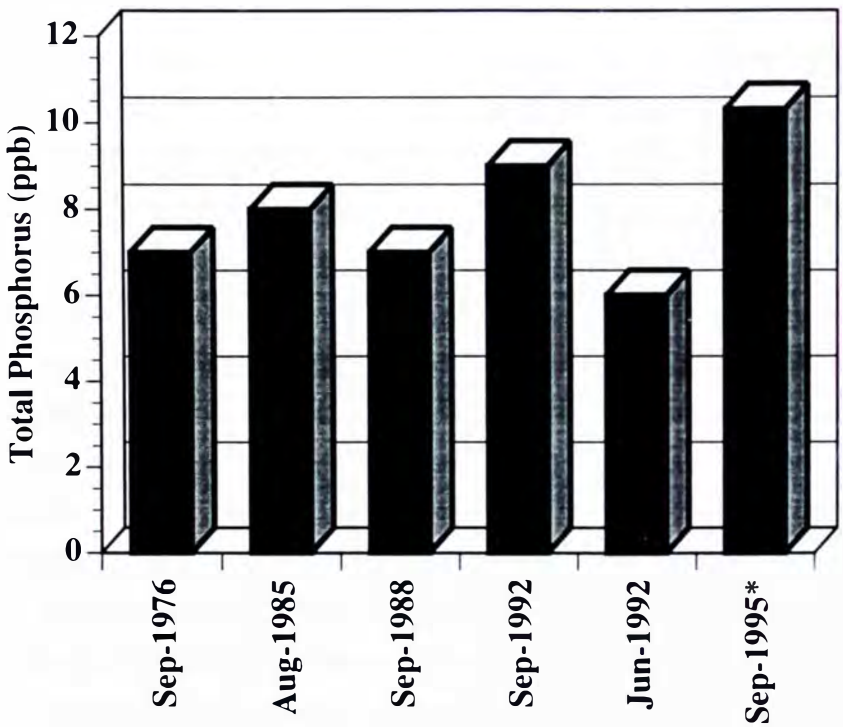

Figure 21. Total phosphorus concentrations from Long Pond, South Basin core samples, 1976 to 1995 (MDEP 1994). An asterisk indicates an average of samples from that month.

The average surface value of 6.2 ppb for Long Pond, South Basin for 1995 is generally lower than other lakes in the Belgrade Lakes area. Surface grab averages over the past twenty years for Great Pond (9.0 ppb), Salmon Lake (20.0 ppb), East Pond (15.0 ppb), North Pond (9.0 ppb), and Mess-alonskee Lake all fall between 9.0 ppb and 20.0 ppb (MDEP 1994). This indicates that the water quality for Long Pond, South Basin is above average for the Belgrade Lakes area. The low phosphorus concentration could be the result of the high flushing rate of Long Pond, South Basin.

In the future, it is crucial not only to continue to monitor the phosphorus in the water, but it is also necessary to characterize the wetlands in the area to determine how they are affecting the phosphorus levels of Long Pond, South Basin. Wetlands border the water in several areas, and could be playing a major role in influencing the amount of phosphorus present. Further study is necessary to determine whether they are acting as sources or sinks for phosphorus loading into the lake. Although there are some areas of concern, in general, Long Pond, South Basin is not currently in danger of algal blooms or significant changes in water quality as a result of high phosphorus concentrations. It is important to continue to monitor lake phosphorus values in order to detect trends, characterize the wetland areas around the lake, and observe potential problem sites.

Nitrate (NO_3)/Nitrogen (N)

Combined nitrogen can be found in natural waters as nitrates and nitrites. Natural sources of nitrogen are erosion of igneous rock, land drainage, and plant and animal debris. Human sources of nitrogen include municipal and industrial waste and inorganic fertilizers. Municipal and industrial waste may include leachate from waste disposal sites and sanitary landfills (Chapman 1992). Nitrate/nitrogen along with phosphorus can promote algal blooms in water bodies. More specifically, nitrate/nitrogen levels greater than 0.2 ppm can stimulate algal growth (Chapman 1992). Naturally occurring nitrate/nitrogen levels rarely exceed 0.1 ppm (Chapman 1992). Levels greater than 5.0 ppm usually indicate pollution by human and/or animal wastes (Chapman 1992).

Water samples for nitrate/nitrogen analysis were taken from Long Pond, South Basin on 18-SEP-95 at the following Spot and Lake Characterization Sites: 1, 2, 3, 4, 5, 10, 12, and 13 (see Figure 12). All water samples were obtained from the surface of the lake except for Sites 2, 4, and 12, where core and bottom water samples were taken. In the Colby Environmental Laboratory, the samples were analyzed using the Cadmium Reduction Method and HACH DR/3000 Spectrophotometer. This method of measuring nitrate/nitrogen has a precision of ± 0.02 ppm (Hach 1991).

Our sample mean was 0.05 ppm and the range was between 0.04 and 0.07 ppm (n=13). Our sample mean was slightly higher than that of Long Pond, North Basin (0.04 ppm) but within their range of 0.02 to 0.06 ppm (BI493 1995). However, South Basin's higher sample mean may be attributed to the testing error. Our nitrate/nitrogen readings were below the natural levels, 0.1 ppm,

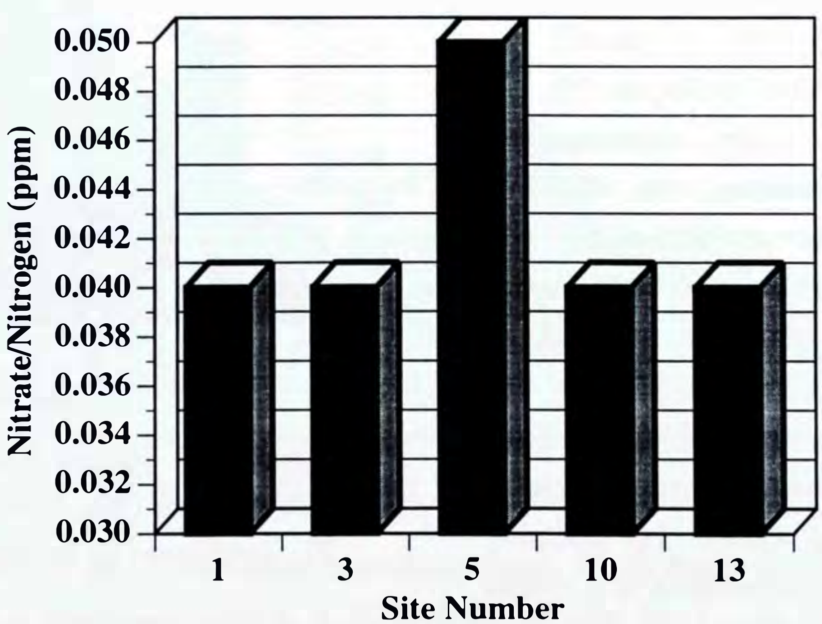

Figure 22. Nitrate/Nitrogen measurements for surface samples from Long Pond, South Basin on 18-SEP-95. See Figure 12 for site locations.

found in lakes (see Figure 22) (Chapman 1992). The highest nitrate/nitrogen readings during our study of Long Pond, South Basin occurred at Site 2 (bottom and core), the deepest point of the lake, 0.07 and 0.06 ppm, respectively. Site 5 also had a moderately high nitrate/nitrogen level of 0.05 ppm, possibly due to sampling error, development in the area, and/or runoff from the Belgrade Dump which had very high nitrate/nitrogen levels at well sites (see Municipal Land Uses). A further study should assess whether Site 5's turbidity reading was caused by the large number of residences in Sandy Cove, the Belgrade Dump, or the more probable explanation of testing error, especially when taking into consideration the precision of the test.

Hardness

Hardness is a measurement of the dissolved calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions in water and is expressed as parts per million calcium carbonate (ppm $CaCO_3$) (Chapman 1992). Water containing less than 60.0 ppm $CaCO_3$ is termed soft water (Hem 1970). Soft water is beneficial for fish growth, but it may make the fish more susceptible to toxic elements such as copper (Cu) and zinc (Zn) (McKee and Wolf 1963).

Surface samples from Long Pond, South Basin were collected on 18-SEP-95 at Spot and Lake Characterization Sites: 1, 2, 3, 5, 6 ,10, 11a, 12, 13, and 14 (see Figure 12). In the Colby Environmental Laboratory, the samples were analyzed using the HACH DR/4000 Spectrophotometer Calmagite Colorimetric Method for Hardness derived from Standard Methods (Clesceri et al. 1989). The precision for this method is ± 0.026 ppm $CaCO_3$ (Hach 1991). Our sample mean was 3.6 ppm, suggesting that Long Pond, South Basin's very soft water is conducive to fish growth but may be making them more

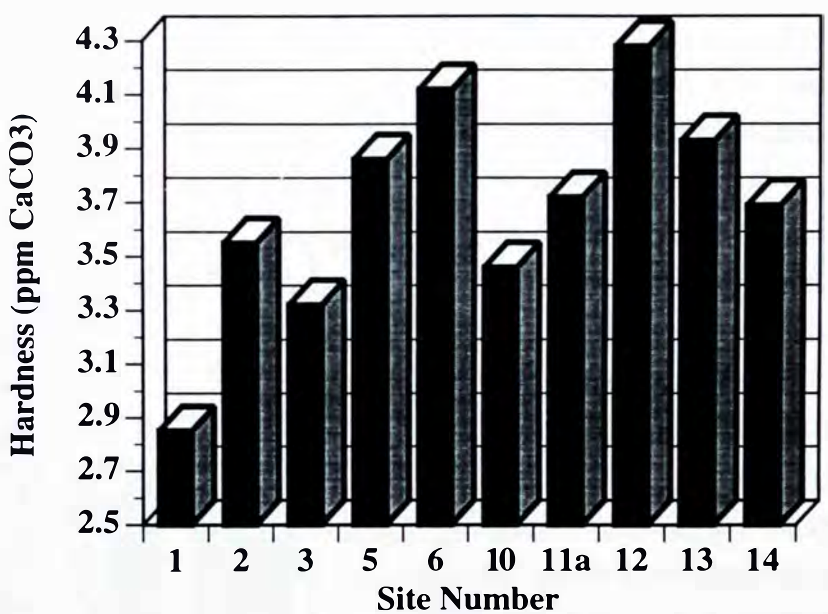

Figure 23. Hardness measurements for surface samples from Long Pond, South Basin on 18-Sep-95. See Figure 12 for site locations.

susceptible to toxins (McKee and Wolf 1963) (see Figure 23). The highest hardness reading, 4.3 ppm $CaCO_3$, was from the Northwest corner of Long Pond, South Basin (Site 12); whereas, the lowest hardness reading of 2.8 ppm $CaCO_3$ was from the point of inflow from Long Pond, North Basin to Long Pond, South Basin (Site 1). A further study should examine the effects of the steep slope and large area in the Northwest region of the watershed on Long Pond, South Basin, especially when considering the Northwest corner contains the airport and gravel pit.

Hardness at the point of major inflow from Long Pond, North Basin (Site 1) was relatively low in comparison to the southern most point of the watershed (Site 6), indicating an increase of Ca^{2+} and Mg^{2+} ions from north to south on Long Pond, South Basin, 2.8 and 4.1 ppm $CaCO_3$, respectively. In 1995, BI493 studied Long Pond, North Basin and found hardness readings between 12.1 ppm and 13.9 ppm. These hardness readings are well above our range for Long Pond, South Basin, 2.8 to 4.3 ppm $CaCO_3$, either suggesting that dissolved Ca^{2+} and Mg^{2+} ions are higher in concentration in Long Pond, North Basin than in Long Pond, South Basin or that there was a sampling or testing error. Further analysis should be conducted to determine whether or not there is a significant difference in hardness between the north and south basin of Long Pond. If a difference is found between the two lakes, it may be due to the abundance of wetlands acting as a sink to the Ca^{2+} and Mg^{2+} ions; thus decreasing the hardness values. A future study should measure hardness from north to south in both North and South Basin, Long Pond to determine whether the wetlands act as a sink or source.

Color

Color is a measurement of the amount of dissolved organic acids, such as tannins and lignins, in water. It does not contribute to algal production, but reduces transparency readings and increases total phosphorus readings (Chapman 1992). In addition, color influences the amount of productivity possible by affecting the rate of photosynthesis of the algae in water (Pearsall 1991). Uncolored water is less than or equal to 25.0 Standard Platinum Units (SPU); colored water is greater than or equal to 26.0 SPU. High color is common in boggy areas due to the tannins and lignins from the decaying vegetation (Pearsall 1991).

Water samples for color analysis were taken from Long Pond, South Basin on 18-SEP-95 at Spot and Lake Characterization Sites 1, 2, 3, 4, 5, 6, 10, 11a, 12, 13, and 14 (see Figure 12). Surface grabs were taken at all sites. Middle and bottom samples were taken at Sites 2, 4, and 6. Samples were analyzed immediately upon return from the field in the Colby Environmental Laboratory with the HACH DR/4000 Spectrophotometer Platinum-Cobalt Method for color derived from Standard Methods (Clesceri et al. 1989). This method has a precision of ± 5.0 SPU.

Our sample mean was 10.5 SPU (see Figure 24), below the historical mean of 18.0 SPU for Long Pond, South Basin, and below the historical range for Long Pond, South Basin, which is 12.0 to 25.0 SPU (MDEP 1994) and that of Maine lakes, 11.0 to 25.0 SPU (BI493 1995). These low readings indicate that Long Pond, South Basin has relatively clear water, suggesting that the color is not adversely affecting the rate of photosynthesis of the algae in the lake (Pearsall 1991). Given the low color readings in the lake basin, slow flow through wetlands is not a predominant factor in the water budget. The highest reading of 26.0 SPU was from Site 11a, a marsh off the Northwest corner of the lake containing a large species diversity and abundance of macrophytes. This high color reading is probably due to the large amount of tannic acids and lignins from decaying vegetation in the area. The lowest reading of 4.0 SPU came from Site 5, near the public beach access point in the Sandy Cove region. This low reading may be caused by the low amount of vegetation in this area.

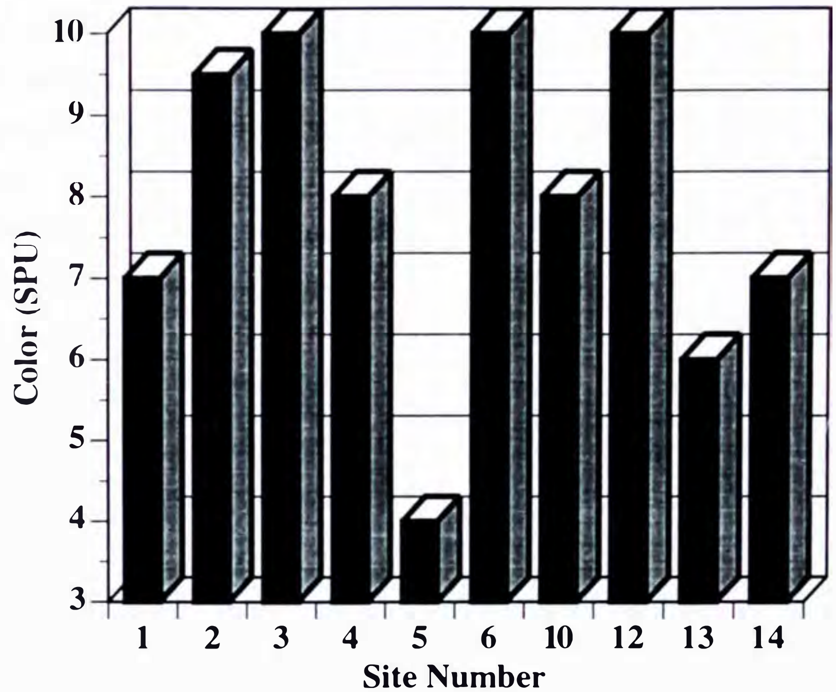

Figure 24. Color measurements for surface samples from Long Pond, South Basin on 18-SEP-95. See Figure 12 for site locations.

pH

pH measures the concentration of hydrogen ions in the water. These ions are added by naturally occurring organic acids flowing into the water system. Acid rain is no longer considered to significantly increase the acidity of Maine lake ecosystems located less than 2,000 ft in elevation; in general acid rain only slightly affects lakes at greater than 2,000 ft elevations (Pearsall 1991). The pH can determine what species of plants and animals inhabit the lake. A low pH can impair the enzymatic reactions of many aquatic organisms, as well as release some of the soil surface's heavier toxic metals (Pearsall 1991). A eutrophic lake (see Trophic Status of Lakes) also tends to be acidic with the build up of organic acids and release of heavy toxic metals (Pearsall 1991).

Sites 1, 3, 5, 10, 11, 13, and 14 were measured on 18-SEP-95, and Sites 2, 4, 6, and 12 on 25-SEP-95, using the Horiba Compact pH meter B-213 (Appendix C). The mean pH for Long Pond, South Basin for these sample periods was 6.7. The historical pH mean was 6.6 with a range of 6.2 to 7.3 for South Basin from 1970-1993 (MDEP 1994). These values indicate relatively no change in pH over the past 25 years. Both the historical and present study's mean values fall within the pH range for all Maine lakes, 6.1 to 6.8 (Pearsall 1991). A pH reading between 6.0 and 6.5 results in a small decrease in species diversity of the planktonic and benthic communities relative to its original state, but overall presents no measurable change in the total community abundance or production (Novotny and Olem 1994). Since Long Pond, South Basin has an average pH value between 6.0 and 6.5, there are currently no strong concerns regarding a decrease in species diversity.

Alkalinity

The alkalinity of water is a measure of its acid-neutralizing ability or buffering capacity, and is a direct measure of the concentration of carbonate, bicarbonate, and hydroxide in the water (Clesceri et al. 1989). At higher elevations, where acid rain is effecting the quality of a water body a reduction in alkalinity will occur before a reduction in pH (Pearsall 1991). Surface samples were collected at Characterization Sites 2, 4, 6, and 12 on 18-SEP-95 and at Site 1 on 25-SEP-95 (see Figure 12). Samples were analyzed within 24 hrs of collection in the Colby Environmental Laboratory. To determine alkalinity, a potentiometric titration was performed, which was adapted from Clesceri et al. (1989). Results are expressed in parts per millon calcium carbonate (ppm $CaCO_3$).

The results ranged from 8.0 to 9.6 ppm with a mean of 8.8 ppm (Appendix C). The historical range and mean, from the south basin are slightly larger at 8.0 to 12.0 ppm and 10.1 ppm, respectively (MDEP 1994). Historical means for other Belgrade lakes include 16.9 ppm for Salmon Lake, 9.3 ppm for Great Pond, 9.0 ppm for Long Pond, North Basin, 8.3 ppm for North Pond, and 7.9 ppm for East Pond (MDEP 1994).

Alkalinity measurements in Long Pond, South Basin are sufficiently above a level at which water has the ability to buffer pH change (Pearsall 1991). Future sampling is necessary to indicate if the buffering capacity of the lake is actually decreasing. On the basis of these results, alkalinity levels of Long Pond, South Basin are not a concern in terms of overall water quality at this time.

Biotic Measurements

Macrophytes

Macrophytes grow in areas of the lake that are shallow and have high levels of nutrients and sedimentation. The root systems of these plants help to stabilize sediments in the water. Since macrophyte growth is limited by phosphorous, areas of dense macrophyte growth reflect locally high levels of phosphorus (COLA 1992). Describing patterns of macrophyte growth aids in determining possible areas of phosphorus input.

To characterize the macrophyte growth along the shore of Long Pond, South Basin, the shoreline was assessed from canoes and boats. This was done on 25-SEP-95. Areas of macrophyte growth were mapped and grouped into three categories according to the following system:

1. a few scattered plants present
2. plants clearly established
3. many different plants present; plants thick and entangled

Several areas of macrophyte growth were noted along the Long Pond, South Basin shoreline. Macrophyte growth was found on approximately 37% of the shoreline. The most common macrophyte species seen included floating brownleaf, tapegrass, watershield, arrowhead, yellow pond lily, and bullrush. Areas of greatest macrophyte variety and abundance (categories 2 and 3) were found near Sites 1, 7, 11, 13; in the area south of the southernmost house in the Sandy Cove residence area; and in an area between Sites 9 and 10. Populations of macrophytes grouped in category 1 were found near Sites 3, 9, 10 along the shoreline.

The areas with a substantial amount of macrophyte growth may indicate areas of high phosphorus loading into the lake. Macrophyte populations were most frequently found near developed shoreland and in areas where tributaries enter the lake body. At Site 11, for example, two tributaries coming from developed areas enter the lake. Some of the greatest abundance in macrophyte growth was noted here, and all of the above mentioned macrophyte species were seen. The area between Sites 9 and 10 was noted as being an area of consistent macrophyte growth. The shoreland between Sites 9 and 10 is one of the areas of most dense development along the lake. It is important to decide whether or not the areas of macrophyte growth are directly related to the amount of nutrient loading from runoff, erosion, and removal of vegetation in those areas. In the case of tributaries, an abundance of macrophyte growth at the mouth of the tributary may indicate that the tributary water contains a substantial amount of nutrient-filled sediment by the time it reaches the lake. In addition, sedimentation produces proper substrate and rooting conditions, especially on protected shores and coves.

Buffer Strips

A buffer strip is an area of natural vegetation along the shore of a lake. The root systems of the vegetation in the buffer strip help to stabilize the shoreline soil. By preventing soil erosion, buffer strips decrease nutrient loading into the lake (COLA 1992). Buffer strips also help to filter out the nutrients in runoff, especially phosphorus, which contributes to algal blooms and increases a lake's eutrophication rate (see Phosphorous and Nitrogen Cycles). The state and municipal Shoreland Zoning Ordinances require any development to be set back at least 100 ft from the water. Ordinances also recommend a buffer strip that consists of deeply rooted vegetation that provides a canopy to divert rainfall, and a thick understory to further prevent runoff and erosion. One of the objectives of the watershed survey was to look closely at each residence's buffer strip, rate the quality of the buffer strip, and consider the effectiveness of existing buffer strips as moderators of phosphorus loading.

Four teams of about three students each spent several hours assessing the entire shoreline of Long Pond, South Basin for areas of development and characterizing buffer strips in these areas. Approximately 28% of the shoreline of the lake is developed with buffer strips. Development is concentrated in the following areas: Sandy Cove residence area (the Southeastern shore of the lake), shoreland east and west of Green Island, the northern tip of the lake near Castle Island, and the Northwest corner of the lake in areas on both sides of the tributaries at Site 11. The teams assessed the shoreline from boats and

Table 6. Guidelines for buffer strip characterization.

Buffer Strip type	Zone Distance (ft)	Zone Slope (%)	Overstory	Understory
1: ideal	>100*	<30	many, deep-rooted, large trees	very thick layer of shrubs, saplings, etc.
2: good	75- 100	<30	deep-rooted, large trees	thick layer of shrubs, saplings
3: average	50- 75	30	scattered trees	thin, scattered
4: poor	25- 50	>30	scattered, spindly trees	little to none; sparse grasses
5: worst	<25	>30	none/ lawn	none/ lawn

*100 ft refers to distance from shoreline to homes canoes, traveling close to the shoreline in order to get a clear view of the buffer strip. A total of 90 buffer strips were characterized. The characterization followed guidelines that assigned the buffer strips a value from 1 to 5, with 1 being an ideal buffer strip and 5 representing the worst scenario (see Table 6).

Most of the buffer strips fall into the category of average, as defined by the guidelines in Table 6 (see Figure 25). Poor buffer strips (categories 4 and 5) outnumbered good buffer strips (categories 1 and 2). The results show that there is a greater number of insufficient buffer strips than buffer strips which have the capacity to curb erosion of the shoreline and nutrient loading into the lake. Specific problem areas are difficult to pinpoint, since in each area of development, buffer strip quality varies from house to house. However, many developed areas along the shore have less than ideal buffer strips, such as open lawns that extend all the way to the water's edge and steep slopes with little vegetation. Areas in which several poor buffer strips were noted include the southern part of Sandy Cove and the cove north of Site 12. On the other hand, a particularly good area in terms of buffer strip quality was found north of Site 10. Average buffer strips predominated in the other areas of development.

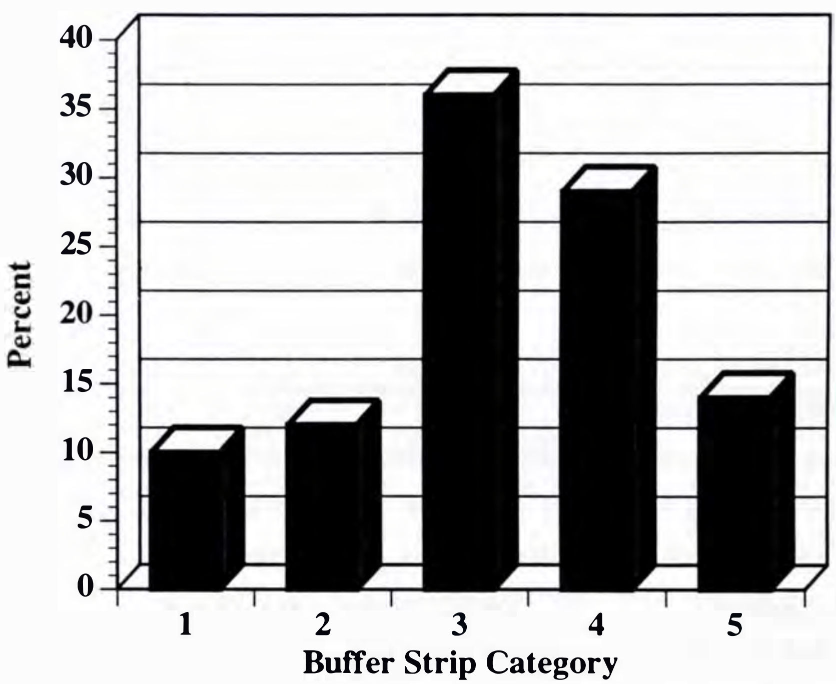

Figure 25. Percent of buffer strips in Long Pond, South Basin within each buffer strip category. Category 1 represents ideal, 3 represents average, and 5 represents the worst buffer strips (Table 6).

State of Maine zoning ordinances mandate a setback of 100 ft from the normal high-water line of the lake for development. The ordinances also specify that within the 100-ft setback, a buffer strip of vegetation which meets several specific requirements must be preserved, except to allow for development of permitted uses such as footpaths or structures (town ordinances do not differ from the state ordinances regarding the clearing of vegetation for development). One of the requirements is to not remove any ground cover or existing vegetation under three feet in height. Selective cutting is allowed within buffer strips, provided that a "well-distributed stand of trees " is maintained (MDEP 1990a). This is defined using a point-scoring system in which, for example, trees with diameters of 4-12 inches at 4.5 ft above ground level receive 2 points, and trees with diameters greater than 12 inches receive 4 points. A certain amount of points must be maintained for each 25-ft by 25-ft square area within the property adjacent to the lake, tributary, or wetland, thereby ensuring adequate vegetation in buffer strips. Ordinances also address aspects such as pruning of trees and replanting areas damaged in storms or by the fall of dead trees. Our results show that several developed areas have insufficient buffer strips; however, these properties could have been grandfathered into the new zoning regulations. An education campaign directed towards shoreland lot owners would be effective in illuminating the benefits of the new ordinances and teaching lot owners what changes they can make to comply.

Coliform

The most common risk to human health associated with water is the presence of disease causing microorganisms (Chapman 1992). The majority of these pathogenic bacteria are found in human and animal waste that leaches into ground or surface water. Sources of human and animal waste include failing septic systems and runoff from livestock farms. Excrement polluted waters are not only harmful to humans but they also promote eutrophication because of their high phosphorus content (see Phosphorus and Nitrogen Cycles). Measuring the amount of benign coliform bacteria in a water sample gives a direct indication of the amount of pathogenic bacteria within that sample (Chapman 1992). Samples for coliform analysis were collected at Spot Sites 3, 5, 10, and 13 which were close to shorelines with major residential areas, on 25-SEP-95 (see Figure 12). The samples were brought to Northeast Laboratory in Waterville, ME within 24 hours of collection for analysis. Results are expressed in number of colonies/100 mL.

Site 5 had the highest measurement: 3 colonies/100 mL. This is below the instantaneous GPA waters standard of 194 colonies/100 mL (). This level is most likely due to leaching of human wastes from septic systems associated with the Sandy Cove residential area, which includes approximately 40 seasonal residences. Many of these residences are fairly old structures, which increases the possibility of failing septic systems. However, since Long Pond, South Basin is not a source of municipal drinking water for the watershed area there is little risk to human health due to this measurement. Sites 3 and 10 had counts of 1 and 2 colonies/100 mL, respectively. These readings are also probably due to leaching of septic systems from the residential areas directly along the shore line. There are approximately five residences along the shoreline at Site 3, while there are approximately 20 residences along the shoreline at Site 10. Both of these areas appear to have more recently built homes suggesting a greater number of properly functioning septic systems. Site 13 had a measurement of 0 colonies/100mL. Although it is offshore of a substantial residential area (approximately 10 residences), the reading suggests that the septic systems are operating properly. Another possibility is that the cove is flushed sufficiently by the wetland, which receives water from Long Pond, North Basin and flows into the cove.

A better representation of the effect that human and animal wastes have on the water quality might result if samples were collected in the summer months when the shoreline residences and the lake are at peak use. If there is a problem with the shoreline septic systems, this would be a better time to gauge it. Sampling over time would also give a better representation of the problem.

Another possibility to obtain more conclusive representation of human and animal wastes entering the water is to sample during a storm period when runoff is at a peak. If the storm produces sufficient rainfall (greater than 1 in), runoff from a larger portion of the watershed will enter the lake.

The range for coliform levels in twenty-two Maine lakes in 1978 was between 0 and 8 colonies/ 100 mL (Davis et al. 1978). In a past study of Long Pond, North Basin coliform results ranged between 0 and 2 colonies/100mL at the same time of year as this study (BI493 1995). Our results are comparable to this range, but more comprehensive sampling is needed when making an accurate comparison.

TRIBUTARY WATER QUALITY

Physical Measurements

Flow Rates

Tributaries are significant sources of both water and nutrients for a water body. Determining a tributary's flow rate and nutrient concentrations can help identify the tributary's relative contribution of water and nutrients to the lake. Twelve tributary sites were sampled during this study. Tributary sites included Sites 7, 8, 11a ,11b, 15, 16, 17, 18, 19, 20, 21, and 22 (see Figure 12).

A Marsh-McBirney, Inc. Flow Mate flow meter was used to measure the flow at tributaries with running water on 18-SEP-95 and 25-SEP-95. Flow for each tributary was measured at a cross section of the tributary where the flow disturbance was minimal. Flow and depth were recorded at measured points along the cross section, with each pair of points on the cross section creating a two dimensional cell. The flow in each cell was calculated using the following formula.

Stream flow per cell (m^3/s) = [width of the cell (m)] x [average depth of the cell (m)] x [average cell velocity (m/s)]

Width of the cell is the measured distance between any point (a) and point (b) along the transect line. The number of cells created at each of the different tributaries varied with the basin shape of each tributary. The average depth of the cell was the sum of the depth at points (a) and (b) divided by two. The average velocity of the cell was the sum of the velocities at points (a) and (b) divided by two. The sum of the flows for all the cells along a transect is the total flow for the tributary.

A second method was used to measure the flow for tributaries which were too shallow to use the cell method and flowed out of culverts. Flow measurements for these tributaries were measured using a container with a known volume, recording the time it took for the container to fill with water coming out of the culvert. This process was repeated several times and an average flow rate was calculated. This value was then converted to m^3/s. This procedure for measuring flow was used at Sites 19 and 22.

Of the twelve tributary sites sampled during the study, only three (Sites 7, 19 and 22) were flowing on 18-SEP-95 and 25-SEP-95 (see Table 7). On 25-SEP-95 Sites 7, 19 and 22 had flow rates of 1.20 m^3/s, 1.35 x 10^{-3} m^3/s, and 1.56 x 10^{-3} m^3/s, respectively (see Table 7).

Table 7. Flow rates (m^3/s) for Long Pond, South Basin tributaries on 18-SEP-95 and 25-SEP-95. See Figure12 for site locations.

Site	18-SEP-95	25-SEP-95
7	*	1.20
19	1.08 x 10^{-3}	1.35 x 10^{-3}
22	0.95 x 10^{-3}	1.56 x 10^{-3}

* indicates flow was not measured on this date

Sites 11a and 11b were flowing, however, no flow measurements were recorded at these sites because of equipment failure. The flow at Site 19 may be indicative of the flows at 11a and 11b because it is an upstream input to Sites 11a and 11b (see Table 7).

The amount of flow a tributary experiences during the course of a year indicates the size of the diameter of culverts within the tributary. Culverts are typoically designed to accomodate the highest flow a tributary will experience during the course of a year. During this study we assumed that tributaries with larger culvert diameters experienced higher flows than those tributaries with smaller culvert diameters.

Sites that have culverts are Sites 16, 18, 20, 21, and 22 (see Figure 12). Sites 21 and 22 both have culverts with diameters of approximately 1.5 m, suggesting that flows in these tributaries during spring runoff or storms may be significantly higher than the flows reported in Table 7. A one meter culvert at Site 20 suggests similar flows to Sites 21 and 22 during storms and spring runoff. Sites 16 and 18 have culverts that are less than 1 m in size. Although theses sites were not flowing during the sampling dates, the culvert size indicates that these tributaries experience higher flows during other times of the year.

Drainage areas and watershed topography at certain tributaries were also used as indicators of potential flow. Sites 21 and 22 drain high-relief areas of the watershed, suggesting that Sites 21 and 22 may experience high flows during spring runoff and heavy rainfall. High flows at Sites 21 and 22 are confirmed by the large culvert diameters found at these sites. Sites 16 and 18 do not drain areas of relatively high elevation, but are responsible for draining major portions of the wetlands in the Western watershed. Site 19 was consistently flowing on both sample dates confirming that this tributary is responsible for draining a large portion of the watershed. Site 17 is on terrain with little relief at the edge of the watershed, and probably has only a small contribution to watershed drainage. Site 7 was delivering a relatively large amount of water (1.20 m^3/s) on 25-SEP-95. Site 7 drains all of Ingham Pond (Site 8) and the surrounding basin, including the large Southwestern wetland, and is adjacent to Long Pond, South Basin.

In summary, tributaries that probably contribute large volumes of water to Long Pond, South Basin include Sites 7, 11b, 19, 20, 21, and 22 (see Figure 12). These sites were chosen on the basis of potential drainage, position in the watershed, culvert diameter, and flow on 18-SEP-95 and 25-SEP-95. Flow in these tributaries may have significant seasonal flow variation and nutrient levels in these particular tributaries should be closely examined.

Turbidity

Turbidity is a measure of concentration of suspended matter in water. Suspended matter includes silt, clay, fine particles of organic and inorganic matter, soluble organic compounds, plankton, and other microscopic organisms (Chapman 1992). Tributaries can potentially have a significant effect on lake water quality because they carry runoff containing sediment from agricultural land, residential lawns, and roads into the lake. These sediments may carry high amounts of phosphorus and other nutrients that contribute to the eutrophication and declining quality of a lake (Chapman 1992).

Turbidities of flowing tributaries ranged from 0.0 FTU to 10.0 FTU. Sites 19 and 22 had the highest turbidity with readings of 10.0 FTU and 8.0 FTU, respectively (see Figure 12). Turbidities in these tributaries may be higher because of the large size and steep grade of the land area they drain.

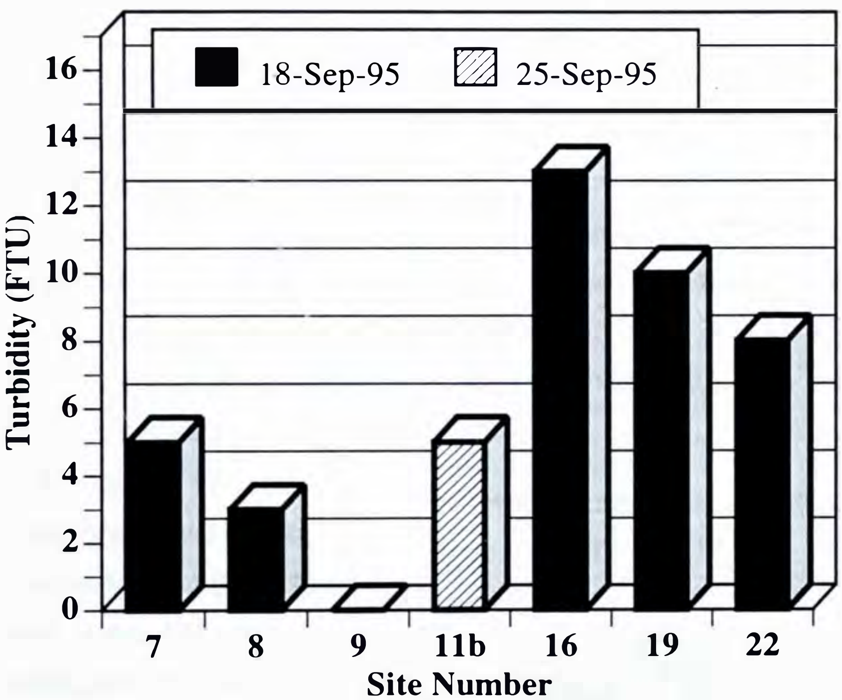

Figure 26. Turbidity measurements from tributary sites at Long Pond, South Basin and Ingham Pond (Site 8), which is not in the watershed. Site 16 was not flowing on the sampling date. Site 18 has been excluded because of probable sampling error. See Figure 12 for site locations.

Turbidity samples can easily become contaminated if the tributary is very shallow or if the sample is taken from a standing pool of water because more sediment is usually suspended in these situations than when the water is flowing. A reading of 13.0 FTU was obtained from tributary Site 16 (see Figure 26). This high reading is probably not an indicator of the sediment being carried by this tributary because it was taken from a standing pool when the tributary was not flowing. A reading of 121.0 FTU from Site 18 was excluded from the report because of probable contamination while obtaining the water sample.

Increased flow rate due to rainfall can suspend sediments and result in elevated turbidity levels in tributaries. This is discussed in detail later in the study (see Tributary Storm Event).

Conductivity

Conductivity is a measure of the ability of water to conduct an electrical current. It is directly related to turbidity, as a high amount of sediment results in a high amount of dissolved ions, which increases conductivity (Chapman 1992). This view is supported by our data which shows greater mean conductivities and turbidities in the tributaries as compared to the open water sites.

Flowing water conductivities ranged from 37.0 μmhos/cm^2 to 78.0 μmhos/cm^2 (see Figure 27). Conductivities for most Maine lakes fall between 20 and 40 μmhos/cm^2 (Pearsall 1991). Site 19 (78.0 μmhos/cm^2) was well above normal and had a notably higher conductivity than the other samples taken on the same day (see Figure 12). This may be a result of the slow flow of the water in Site 19 possibly allowing ions to accumulate in the water. Conductivity measurements for Site 18 were taken from the same sample as the turbidity measurements, therefore the conductivity data was excluded because of probable contamination.

Other studies have shown that ions may be exported from wetlands (BI493 1995). The elevated conductivity at Site 19 may be attributable to magnesium and calcium ions possibly being exported from the wetlands drained by this tributary.

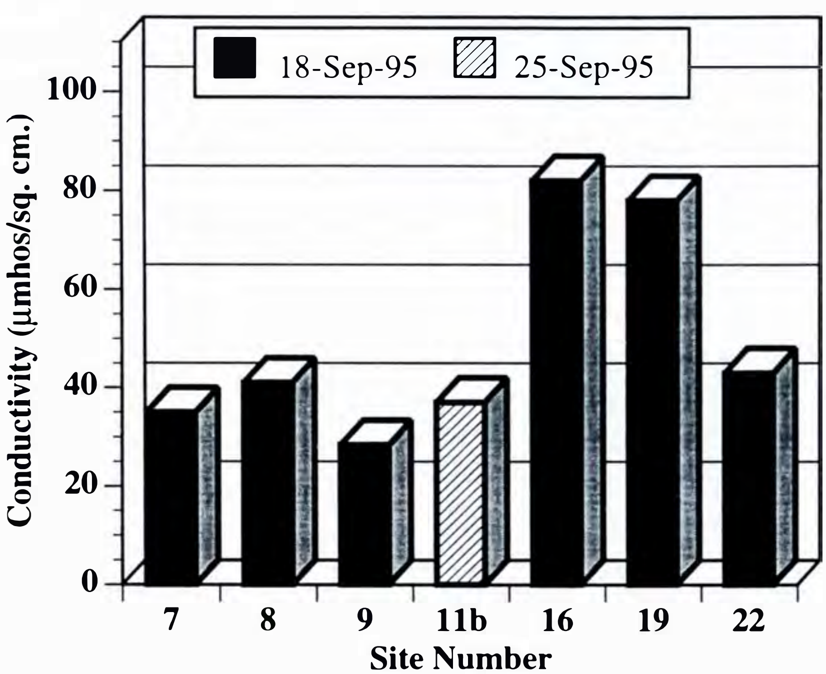

Figure 27. Conductivity measurements from tributary sites at Long Pond, South Basin and Ingham Pond (Site 8). See Figure 12 for site locations.

Chemical Analyses

Phosphorus

Phosphorus generally controls the amount of primary productivity in water bodies and therefore warrants special concern in our study of Long Pond, South Basin. An effective way of determining an important external source of phosphorus input to a water body is to measure the nutrient load being carried in its tributaries. Runoff collected by a tributary can contain elevated levels of phosphorus if it has come in contact with fertilizers, detergents, or sewage in addition to the amount of phosphorus naturally occuring in the soil.

Samples were taken from every major tributary contributing to the south basin of Long Pond. Concentrations ranged from 3.6 ppb at Site 9 to 18.8 ppb at Site 16 (see Figure 28) (see Figure 12). Site 9 is located at the mouth of a tributary which flows through a wetland before emptying into Long Pond, South Basin. The low concentration of phosphorus in this tributary may be due to the wetland acting as a sink and absorbing phosphorus (Paul Doss pers. comm.). The Site 16 sample was taken from a standing pool of water and therefore may have contained suspended sediments which raised the concentration.

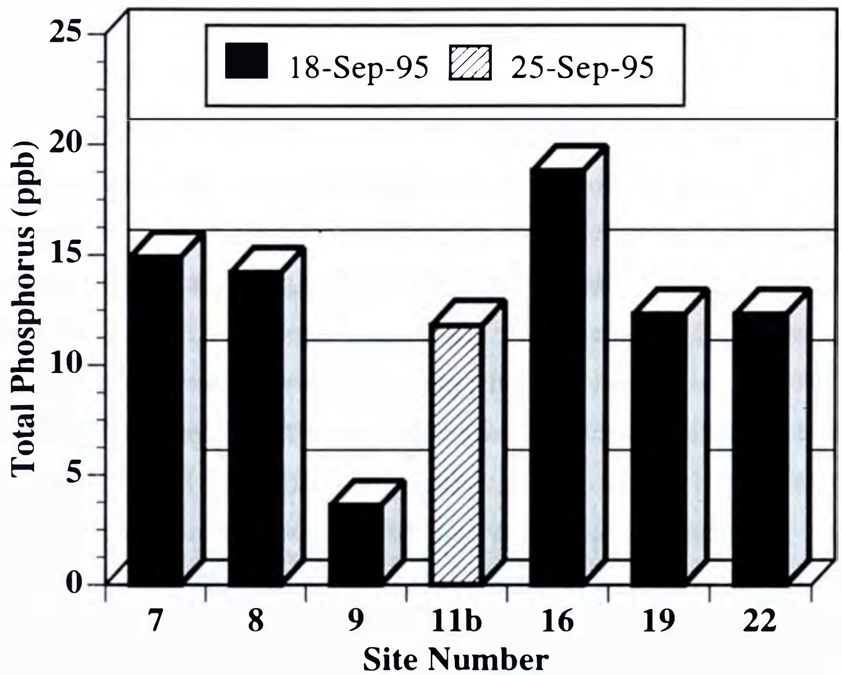

Figure 28. Total phosphorus measurements from tributary sites at Long Pond, South Basin and Ingham Pond (Site 8). Sites 16 and 18 were not flowing on the sampling date. See Figure 12 for site locations.

Whereas the mean phosphorus concentration at the surface of the Lake Characterization Sites was 6.5 ppb, the concentrations for most tributaries measured ranged between 11.8 ppb and 14.9 ppb (see Lake Water Quality: Total Phosphorous). This is close to the mean total phosphorus of 10.6 ppb (BI493 1995) and 14.7 ppb (BI493 1994) in tributaries flowing into Long Pond, North Basin and Salmon Lake, respectively, but considerably lower than the mean total phosphorus of 44.1 ppb in tributaries flowing into China Lake (SCOALE 1989). It is difficult to compare tributary phosphorus concentrations between watersheds without extensive sampling.

Most samples for Long Pond, South Basin tributaries fall below the critical level of 15.0 ppb, but they are all very close to this level. It is important to note that on 18-SEP-

95, when these samples were taken, there had not been a rain storm for over a week, which might make phosphorus levels low since no phosphorus runoff from the soil in the elevations above the tributaries had occured recently. This may be cause for concern because phosphorus loading often comes in pulses when precipitation flushes phosphorus from the soil into the tributaries, causing phosphorus concentrations to rise significantly (see Tributary Storm Event).

Nitrate (NO_3) / Nitrogen (N)

Unlike phosphorus, nitrogen is not the limiting nutrient to algal growth in aquatic ecosystems; however, in combination with phosphorus, nitrate/nitrogen can contribute to increased lake productivity. Tributaries play a key role in nitrate/nitrogen loading because tributaries can carry high nitrate/nitrogen runoff from non-shoreline agricultural lands and industrial sites. Nitrate/nitrogen levels were measured at two tributary sites on 18-SEP-95. Site 8 (Ingham Pond) had a reading of 0.05 ppm and Site 19 had a reading of 0.03 ppm (see Figure 12). Site 8 and Site 19 both drain major portions of the Western watershed and are good representative sites in which to measure nitrogen levels. Nitrate/nitrogen levels from the 1995 Long Pond, North Basin study (BI493 1995) ranged from 0.03 to 0.07 ppm and are comparable to the tributary nitrate/nitrogen values for the south basin. The nitrate/nitrogen levels fall below the 0.20 ppm point set by Chapman (1992) that would contribute to algal growth. The low nitrate/nitrogen levels in the tributaries also correspond with the low nitrate/nitrogen levels in the lake.

pH

Many biological and chemical processes within a lake are pH dependent. The pH levels were recorded at tributary Sites 7, 8, 16, 18, and 19 on 18-SEP-95 (see Figure 12). The pH at the sites ranged from 6.5 to 7.3 and all values were interpreted as neutral. This is similar to the range of 6.9 to 7.3 in Long Pond, North Basin (BI493 1995).

The pH variation in Northeastern United States lakes is normally neutral or slightly acidic. The low variation of pH in Long Pond, South Basin tributaries may be due to the small amount of rainfall during the two weeks of sampling. Rainfall is slightly acidic in the Northeastern United States (Charles 1991). Low rainfall also means low flow and decreased drainage. If the tributaries sampled did not have large volumes of water moving through them on the sampling dates, then they might not have been carrying large amounts of acidic rainwater or organic acids that would have lowered the pH at these sites. The pH levels in the tributaries investigated are all relatively neutral and pose no threat to the lake basin at this time.

Hardness

Hardness is a measure of Ca^{2+} and Mg^{2+} ions in water. The types of soil through which a tributary flows can effect the Ca^{2+} and Mg^{2+} ion concentrations of the water. Water between 0.0 and 60.0 ppm $CaCO_3$ is considered to be soft. Aquatic organisms that live in softer waters may be more susceptible to mineral toxins containing copper and zinc. Unlike other nutrients, Ca^{2+} and Mg^{2+} are more likely to load into slower moving tributaries or standing water. Under these conditions the water is in contact with the sediments for a longer period of time and can pick up greater ion concentrations.

Water hardness was measured at three tributary sites in Long Pond, South Basin on 18-SEP-95. On the whole the water was considerably soft. Hardness for tributary sites on 18-SEP-95 ranged from 2.9 to 3.8 ppm $CaCO_3$. These values are lower in comparison to the Long Pond, South Basin lake sites ranging from 9.7 ppm to 36.2 ppm $CaCO_3$. These large differences between the two basins are most likely due to error within the sampling or analysis procedures. Site 8 (Ingham Pond) had the highest hardness of all the tributaries in Long Pond, South Basin at 3.8 ppm $CaCO_3$ (see Figure 12).

The soft water in Long Pond, South Basin means that if certain mineral toxins were to be introduced to the south basin at some point in the future, aquatic life in the south basin may become more sensitive to these toxins.

TRIBUTARY STORM EVENT

As the amount of rainfall during a storm increases to greater than 1 in, the soil in the areas surrounding a lake's tributaries approaches its point of saturation. Once saturated, the soil can no longer absorb the precipitation and a portion of the falling water runs directly into the tributaries. Several days of light precipitation preceded the occurence of a rainstorm of greater than 1.0 in of rain on 6-OCT-95. From 3:00 AM to 8:30 AM on 6-OCT-95 flow measurements were recorded and samples were collected for turbidity and phosphorus analysis.

All of the tributaries sampled during the storm event are located in the Northwest portion of the watershed. Sites 19, 21, and 22 were selected as representative tributaries based on the following reasons: the Northwest portion of the watershed is the largest and steepest area draining into Long Pond, South Basin, and there is a gravel pit, the Mount Vernon airport, and an abundance of camp roads present in this area (see Figure 12). All of these factors have possible implications concerning nutrient and sediment loading which will be described in the sections to follow. The close proximity of these sites to each other made it possible for a limited number of people to effectively take all of the necessary samples.

It is important to remember that all flowing tributaries contribute to the lake's water and nutrient inputs, and that the amount of nutrient input during each storm event varies with frequency and length of storms. In the absence of storms, nutrients are allowed to accumulate in the sediments making the potential nutrient loading during each storm event different. It may be beneficial for future studies to take storm event samples for several storms as well as at a greater number of tributaries in order to quantify their inputs and the possible effect on lake water quality.

Physical Measurements

<u>Flow rate</u>

During the storm event of 6-OCT-95 flow rate measurements were taken in the Northwest portion of the watershed at tributary Sites 19, 21, and 22 using a Marsh-McBirney, Inc. FloMate flow meter (see Figure 12).

At each site a transect was set across the tributary in a location where little flow disturbance was present. At each of the three measured points along the transect, depth and flow rate measurements were taken every half-hour over a period of several hours, varying in duration by site. Sites 19, 21, and 22 were measured for 5.5 hrs, 2.5 hrs, and 4.0 hrs, respectively.

Each pair of points in the transect formed a separate cell and the flows were calculated for each cell at each sampling time using the methodology described previously (see Tributary Water Quality). The sum of the flows of each cell at a certain time is equal to the total flow of the stream at that time in cubic meters per second. This methodology is used to reflect the changing shape of the tributary bottom over the course of the storm event.

The flow rates measured for tributary Sites 19, 21, and 22 during the storm event were higher than the rates measured on 25-SEP-95. Stream depths increased as well, due to the increased runoff caused by the large amount of precipitation. A lag from the onset of the storm was expected during which flow rates were low while the soil was becoming saturated, followed by a steady increase of flow rate over time, as more of the runoff entered the tributary. This trend is evident at Sites 19 and 21, but not at Site 22 which showed a cyclic pattern (see Figures 29,26, and 30). Site 21 showed a flow increase from 0 m^3/s at the beginning of the sampling time to 0.013 m^3/s after 2.5 hours. The flow rates at Site 19 more than doubled, increasing from 0.006 to 0.014 m^3/s in 4 hours. A possible reason for Site 22 having a cyclic rather than steadily increasing flow change is that it may take certain types of soils longer than others to become saturated depending on their porosity. The depth to bedrock for certain areas may also be greater, necesitating a greater amount of soil to become saturated and therefore increasing the time to satuaration. It is also probable that the flow meter was not put in the exact same place in the tributary for each reading.

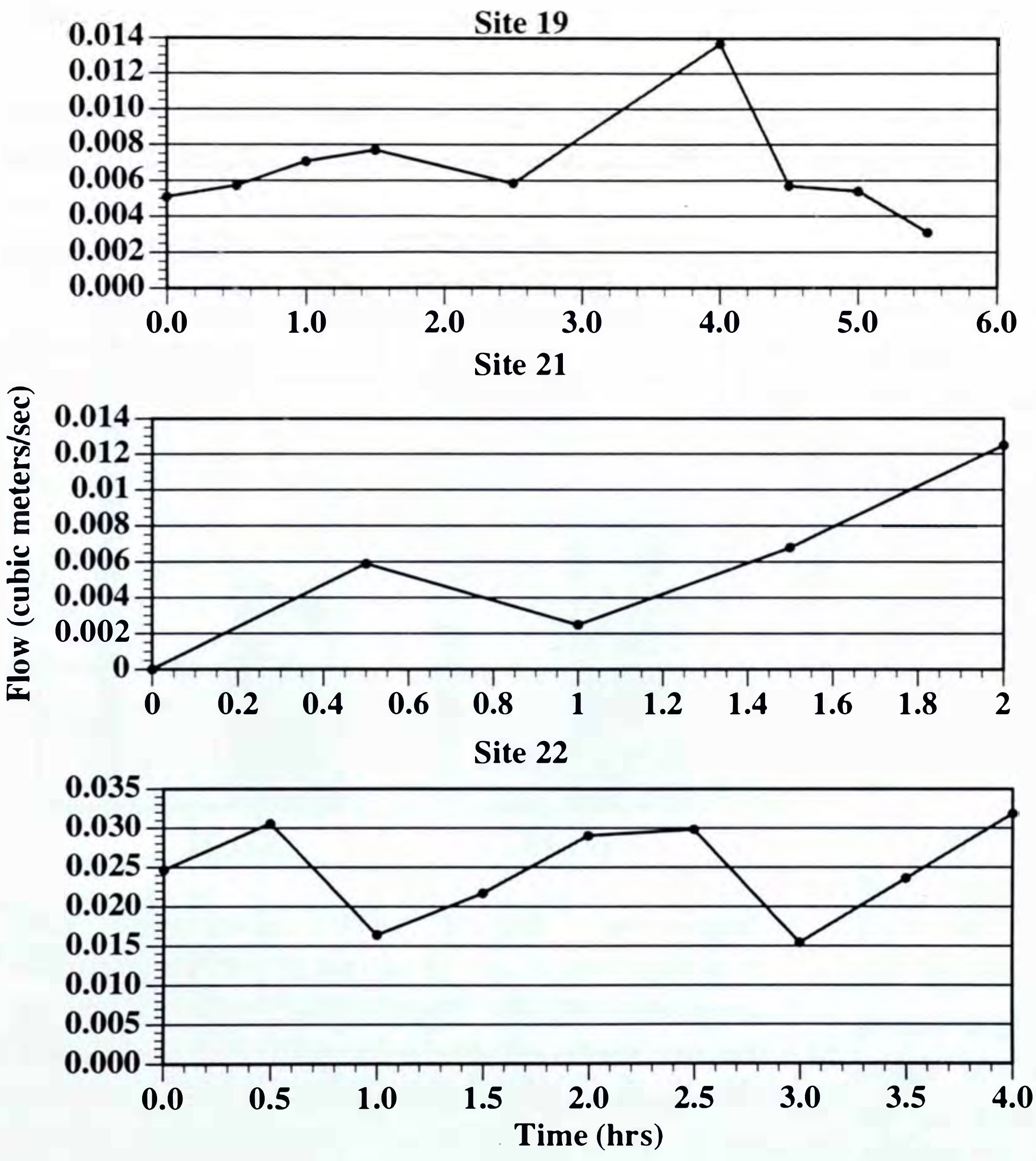

Figure 29. Flow rate measurements from Long Pond, South Basin tributary Sites 19, 21, and 22 during the storm event of 6-OCT-95. See Figure 12 for site locations.

The highest flow rates recorded at Site 22 were more than twice as fast as those recorded at Sites 19 and 21. We attribute this to the larger land area drained by this tributary as well as the steepness of the grade present in that area.

Turbidity

Turbidity is a measure of the amount of suspended material in water. During the storm event of 6-OCT-95 we took surface grabs, according to the protocol outlined in the QAP (Appendix B), along the transect line at each of the three sampling sites. Samples were taken for turbidity every half hour at the same time as flow rates and phosphorus samples.

Turbidity samples were analyzed in the Colby Environmental Laboratory using the HACH DR/3000 Spectrophotometer Absorptometric method for turbidity derived from Standard Methods (Clesceri et al. 1989).

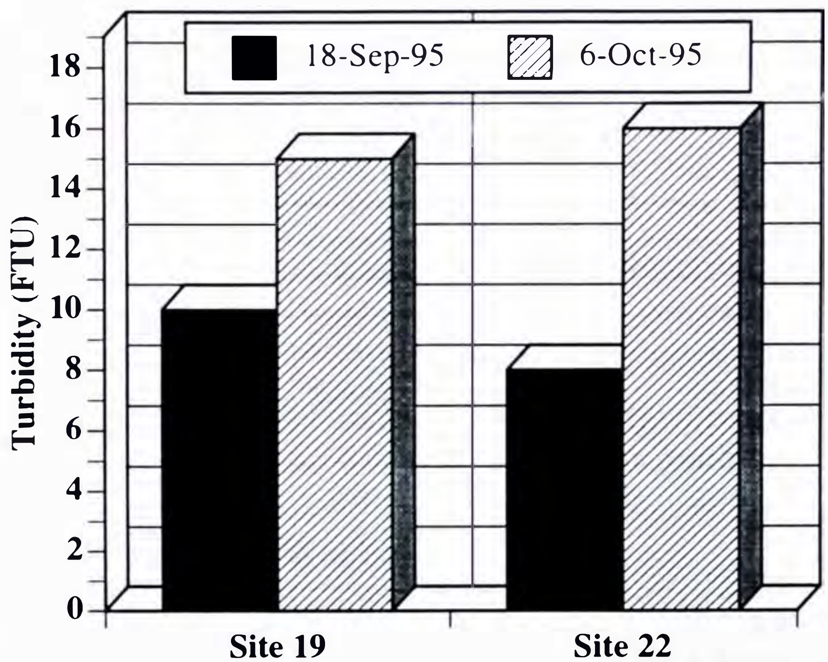

Figure 30. Turbidity (FTU) measurements from tributary Sites 19 and 22 on 18-SEPT-95 and the storm event of 6-OCT-95. The 6-OCT-95 measurements are the maximum values recorded during the storm event. See Figure 12 for site locations.

Unlike flow rates, turbidity levels showed no trend over time during the storm event. However, turbidity levels of samples taken during the storm event were considerably higher than those taken on 18-SEP-95. At Site 19 the turbidity level on 18-SEP-95 was 10.5 FTU while the highest level measured during the storm event was 15.0 FTU (see Figure 30). For Site 22 the highest storm event sample was almost twice as turbid as the sample taken on 18-SEP-95, with readings of 16.5 FTU and 8.5 FTU, respectively (see Figure 30). Samples taken at Site 21 were excluded from analysis based on lack of flow and the shallow depth of that tributary, and probable contamination of the sample.

The large difference in turbidity levels measured at Site 22 on the two sampling dates could be due to the large size and the character of the Northwest portion of the watershed drained by this tributary. The abundance of dirt roads and paths in disrepair in this area combined with the steepness of the grade creates a high potential for runoff carrying sediment to be deposited into the tributaries (see Roads). If camp roads are not properly drained and maintained so that water runs off into forested land to be filtered, they can act as rivers during heavy rain carrying large amounts of sediments into the tributary. High tributary turbidity leads to sedimentation at the mouth of the tributary and accelerates eutrophication of the receiving water body (see Phosphorus and Nitrogen Cycles).

Another, possibly more important concern is the effect that the sediments deposited in the tributary have on the lake water chemistry. Runoff from agricultural land, residential lawns, and livestock holds can carry nutrients such as phosphorus and nitrates and bacteria such as *E. coli*, which have detrimental affects on lake water quality (see Tributary Storm Event: Phosphorus) .

Chemical Analyses

Phosphorus

Since phosphorus is bound to sediment particles (see Introduction: Background), the increase of flow and turbidity in a tributary, during a heavy rainfall, is accompanied by an increase in phosphorus. For this reason, phosphorus was expected to follow the same pulse pattern as described previously for flow rate. After the initial increase of flow rate and phosphorus, the phosphorus levels in the tributary should gradually decrease and level off once the accumulated phosphorus has been flushed out of the soil and flow rate has decreased. The sampling methods to measure total phosphorus concentration during the storm event are similar to those previously described for turbidity. Surface grabs were collected approximately every 0.5 hr for the duration of the sampling period. The samples were packed in ice and transported to the Colby Environmental Laboratory and analyzed for total phosphorus according to the Ascorbic Acid method (see Water Quality Methods: Chemical Analysis).

The results for Site 19 were exactly as expected (see Figure 31). Although the initial lag period was missed, the peak was found to be around 40.0 ppb after 0.5 hrs of sampling. The total phosphorus concentrations began to level off after 2.0 hours with a concentration of 17.0 ppb. Site 22 did not follow the anticipated pattern (see Figure 32). Total phosphorus concentrations oscillated and two peaks were recorded. However, the total phosphorus concentration did follow a similar pattern to the flow rate; concentrations

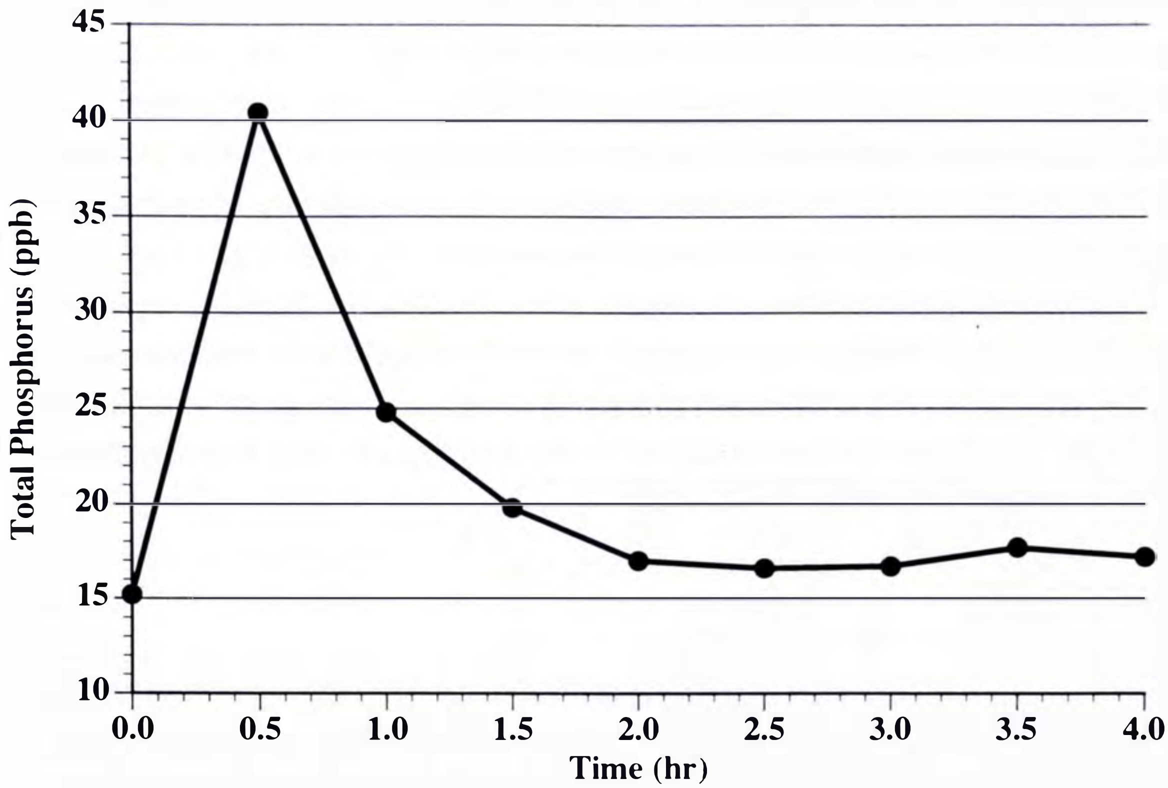

Figure 31. Total phosphorus measurements from tributary at Site 19 of Long Pond, South Basin during the storm event of 6-OCT-95. See Figure 12 for site locations.

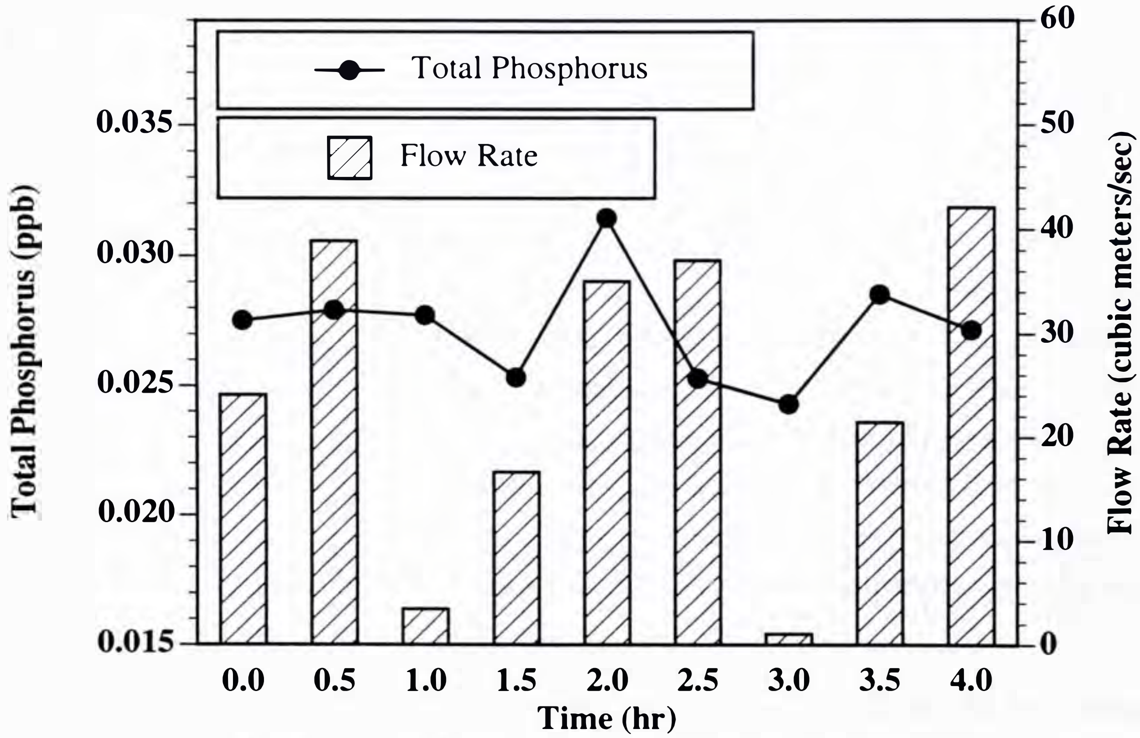

Figure 32. Total Phosphorus and flow rate measurements from tributary Site 22 in Long Pond, South Basin during the storm event of 6-OCT-95. See Figure 12 for site location.

increased when flow rate increased, and decreased when flow rate decreased (see Figure 32). Our data demonstrate that during a heavy rainfall, both of these tributaries have the potential to contribute significant amounts of phosphorus to Long Pond, South Basin. These tributaries are located in the Northwest quadrant of the watershed, which has both the largest land area and the greatest slope. Surrounding the tributaries, there are several camp roads with inadequate surfaces and drainage. Through erosion these roads could be contributing a great deal of sediment containing phosphorus to the runoff. Additionally, a gravel pit, dump, and airport are all in close proximity and could be adding significant amounts of phosphorus. Much of the phosphorus measured in these tributaries during heavy rainfall will eventually be deposited in Long Pond, South Basin where it may ultimately lead to an increase in the eutrophication rate (see Introduction: Phosphorus and Nitrogen Cycles).

QUANTITATIVE WATER MEASUREMENTS AND CALCULATIONS

Water Budget

The water budget is a series of calculations that uses the net water inputs into Long Pond, South Basin from other lakes, precipitation, and land runoff to calculate the flushing rate of the lake and the I_{net} for the lake. The flushing rate is the number of times the volume of the lake basin is completely replaced per year. The I_{net} of a lake is the net volume of water entering the lake basin from the lake's watershed and precipitation, subtracting the amount of water lost through evaporation. The net input for Long Pond, South Basin was calculated as follows:

$$I_{net} = (\text{runoff x land area m}^2) + (\text{precipitation x lake area m}^2) - (\text{evaporation x lake area m}^2)$$

The following are the inputs for the Long Pond, South Basin I_{net} equation:

Runoff = 0.622 m/yr
Precipitation = 1.003 m/yr
Evaporation = 0.56 m/yr
Long Pond, South Basin water surface area = 5,220,000 m^2
Long Pond, South Basin watershed area = 33,700,000 m^2
Average Depth = 9.0 m

The runoff portion of the equation is a constant that was determined using a ten-year average runoff for the Kennebec River Basin, 1958 to 1967 (BI493 1995). The evaporation portion of the equation is also a constant and was calculated in a study by Prescott (1969) for the lower Kennebec River Basin. The precipitation portion of the equation was taken from a nine-year average of rainfall in Waterville and Augusta from 1985 to 1994 (NOAA 1985-1994). Lake area and land area were determined using ZIDAS methods. The average depth for Long Pond, South Basin was determined using bathometric data from MDEP.

Theoretically all of the water flowing from lakes upstream from Long Pond, South Basin must eventually pass through the south basin. Because Long Pond, South Basin is last in a chain of lakes, the I_{net} of all upstream watersheds must be considered in calculating the flushing rate for the south basin. These watersheds included; Ingham Pond, Moose Pond, North Basin of Long Pond, Great Pond, North Pond, Salmon Lake, East Pond, Whitier Pond, Watson Pond, and Kidder Pond. I_{net} values for the contributing watersheds were calculated in the same manner as described for the Long Pond, South Basin watershed.

The flushing rate for Long Pond, South Basin was calculated by adding all of the upstream I_{net} values to the Q value for Long Pond, South Basin and then dividing the value by the volume of the south basin. Q is defined as the I_{net} of Long Pond, South Basin plus the volume of water the lake loses through evaporation per year. With the inclusion of the I_{net} values of all upstream watersheds, the flushing was calculated as follows:

Flushing Rate = (Q of Long Pond, South Basin + I_{net} of Ingham Pond + I_{net} of Moose Pond + I_{net} of Long Pond North Basin + I_{net} of Whitier Pond + I_{net} of Watson Pond + I_{net} of Kidder Pond + I_{net} of Great Pond + I_{net} of North Pond + I_{net} of Salmon Lake + I_{net} of East Pond) / (Long Pond, South Basin lake area x Long Pond, South Basin average depth)

The flushing rates and I_{net} of all upstream lakes are reported in Appendix A. A flushing rate of 4.50 flushes/yr was calculated for Long Pond, South Basin. This means that the volume of water is replaced 4.50 time per year. Residence time refers to the amount of time water sits in a lake before it is flushed out; a lower flushing rate indicates a higher residence time. Because of Long Pond, South Basin's relatively high flushing rate, the water in the south basin has a low residence time. A low residence time means that phosphorus and other nutrients are flushed quickly through the lake and do not have a chance to accumulate in the water column. This keeps lake productivity relatively low and maintains high water quality. If nutrient loading were to increase in Long Pond, South Basin, eutrophication may be offset by the high flushing rate.

Lake Level Management

Dams are often built at the outflow point of lakes where they serve many purposes ranging from generating hydro-electricity to regulating water level and flow into other lakes and rivers downstream. The two basic types of dams operating in Maine are ridge dams and valve dams. A ridge dam regulates water levels by raising or lowering an adjustable barrier across the flow area. The barrier can be moved up or down depending on the desired lake level. A valve dam consists of a valved opening in the dam itself through which water can flow when opened (BI493 1995).

The Wings Mills dam is a ridge dam located between Long Pond, South Basin and Belgrade Stream in Mount Vernon, ME (see Figure 12). Built in 1915 of concrete and timber, it is presently under the direction of the Belgrade Area Dams Committee. The goals of the committee are to maintain a full pond during the summer for recreational uses, to draw down water levels during winter months, and to prevent flooding of the watershed during spring runoff (MDEP 1993).

Area residents and ecologists often disapprove of the installation of dams because of the numerous impacts they can have on surrounding areas (Cooke et al. 1993). The installation of a dam can change the natural environment by causing a rise in water level, which may flood nearby basins and wetlands, as well as slowing the flushing rate of the water body. A decreased flushing rate causes longer residence time of the water, allowing nutrients entering the system to accumulate longer, thereby decreasing water quality (BI493 1995).

The effect of winter drawdown on water bodies is also a controversial issue. Winter drawdown in Long Pond, South Basin consists of decreasing the water level by approximately 2.5 ft November 1 through April 1 (MDEP 1993). The decreased amount of water present in a lake during these months exposes the shoreline sediments to freezing and thawing (Cooke et al. 1993). While this can effectively control macrophyte populations as well as allow for dock repair and sediment removal, it may also have negative impacts. Algal blooms can occur after some drawdowns in some lakes due to increased nutrient release from the sediments. Oxygen levels may also decrease in the remaining water pool. These factors can significantly reduce benthic invertebrate populations which may lead to massive fishkills. Drawdown may expose much of the wetland adjacent to Long Pond, South Basin, which can have an impact on the viability of plant and animal species present there.

Watershed Land Use

PHOSPHORUS LOADING INTRODUCTION

Phosphorus is the main limiting factor for the rate of primary productivity (plant and algal growth) in temperate freshwater lakes and ponds (Pearsall 1991). High phosphorus levels (above 15 ppb) can cause algal blooms, which often have adverse effects on the water quality of a lake (McKee and Wolf 1963).

These effects can be of an aesthetic, chemical or biological nature. The cycle of algal growth from high phosphorus levels, death and then decomposition of this algae can lead to discoloration of a water body or unpleasant odors and tastes. Additionally, the decomposition of algae by aerobic bacteria in the lower strata of the lake can lead to reduced levels of dissolved oxygen. Dissolved oxygen influences nearly all chemical and biological processes in freshwater lakes, and low dissolved oxygen levels can have negative effects on living organisms, causing fishkills for example (Chapman 1992) (see Background). For these reasons, phosphorus levels are often used as an indicator of water quality (BI 493 1995).

Phosphorus loading is the addition of phosphorus to a water body due to human activity, thereby raising total phosphorus levels. This addition of phosphorus can have drastic effects on the recreational, municipal, and economic benefits that surrounding communities receive from lakes and ponds. These effects are due to both the direct and indirect influences that phosphorus levels have on the biotic components of a lake. There are many human activities within a watershed that can result in phosphorus loading (e.g., agriculture, logging, and human waste disposal). It is for this reason that an analysis of land use and phosphorus loading should accompany any study of lake water quality, and thus is a component of this study of Long Pond, South Basin.

Analyses of land uses within a watershed, taking into account their phosphorus loading ability, were used to help determine the particular uses that result in high phosphorus input to the lake. Roads can be a source of phosphorus loading, also. Pavement, high-grade slopes leading toward the water body, and poor drainage on or around a paved surface all can lead to phosphorus loading by roads. Human development, specifically on-shore or inland waste disposal systems, can also be responsible for phosphorus loading.

These components were integrated into a spreadsheet model (Phosphorus Loading), which was used to project future phosphorus loading based on the data collected in this study. A high and low future phosphorus loading (by mass) was estimated to approximate the range within which the future level of phosphorus loading would most likely occur. Through estimation of phosphorus loading and analyses of the various components of the watershed contributing to phosphorus loading, conclusions were made regarding high phosphorus input sources. Recommendations were made to control phosphorus loading within the watershed and to help maintain or improve future water quality in the south basin of Long Pond (see Recommendations).

GIS METHODS

The Geographic Information System (GIS) is a useful tool for interfacing two or more informational maps with attatched data and creating other maps with compiled information. GIS is useful in this study in that it enables us to combine and present numerical, and physical data, such as soil types, in the form of computer generated maps, in order to make predictions and give recommendations concerning the future development and land uses of the watershed of Long Pond, South Basin. We used MacGIS software because of its simplicity and the ease with which the basic tools can be learned.

The first step of this process entailed scanning two mylar composite maps created from United States Geological Survey (USGS) maps, dated 1982. The watershed boundary of Long Pond, South Basin was traced onto the transparent USGS maps. The first map, a topographical map of the Long Pond, South Basin watershed with contour lines at 10.0 ft intervals, was created from two USGS topographic maps, the Belgrade Lakes quadrangle and the Readfield, ME quadrangle, both 7.5 Minute Series (Topographic). The second map, a culture and drainage map, was composed using culture and drainage maps from the same two quadrangles, which highlighted the cultural aspects of the watershed such as roads, buildings, political boundaries and landmarks (i.e., gravel pits). Also of significance on this map are wetlands and tributaries that have a direct effect on the lake. These mylar composite maps were scanned using a Power Macintosh 8100/80 and the Applescan application. The maps were then transferred into MacGIS 2.0 and referenced to fit a grid cell pattern. Each cell represented an area of 10.0 m^2 on the map, which was saved as a PICT (Picture) file in MacGIS. These cells define the resolution of the map. Smaller cells provide more accurate rendering of physical features, such as soil type, in the watershed.

Using the scanned base maps as references, data was inserted into the system, cell by cell, to produce data layers. Previously mentioned cultural features, such as roads, were used as references to transfer information, such as soil type, from outside sources. For example, the soil types data layer was created using the USDA Soil Survey of Kennebec County (1978). The information from the Soil Survey maps was transferred manually onto a culture and drainage base map. A different value was assigned to each soil type as it was entered. Contour lines were transferred to the data layer in 50.0 ft intervals. Once these individual layers were created, it was then possible to combine information on two or more of the maps in order to produce new maps which represent specific characteristics of the watershed, such as the combination of maps specified for slope and soil type to present septic suitability in each 10.0 m^2 area in the watershed.

The following is a list of the maps created by GIS for the study of Long Pond, South Basin: depth to bedrock, permeability (hydrologic soil classes), septic suitability and logging suitability, all using the soil types data layer; future development area using a data layer of potentially developable areas along roads; a bathymetry map outlining the topography of the lake basin; and various land use maps using information provided by the MicroStation team.

Individual maps allowed for basic observation of each characteristic within the study area and the maps indicated the approximate area of each land use type and physical characteristic within the watershed, therefore suggesting the potential role of each characteristic in the nutrient loading of Long Pond, South Basin. Combining individual maps may show characteristics within the watershed that would otherwise have been unapparent when viewed separately.

GIS RESULTS AND DISCUSSION

An important aspect of GIS analysis for this study is the use of a data layer showing the present soil types within the watershed. This data layer could then be used to make recommendations regarding locations with limitations for particular land uses (logging or development, for example) within the watershed. We constructed a data layer of soil types using a USGS Soil Survey of Kennebec County (Faust and LaFlamme 1974). This data layer revealed that the soil types most commonly found in the Long Pond, South Basin watershed were Paxton, Berkshire, Hollis, Ridgebury, and Woodbridge (see Figure 33 and Table 8). We classified 14 soil types in the watershed (n some cases, similar soil types were combined as the differences were not great enough to merit separate categories for our purposes), And then divided these into four hydrologic soil classes each of which have different characteristics (see Soil Methods).

The most abundant soil type in the watershed was Paxton, which is present in the two most significant areas of shoreline development: The Journey's End Road region, and the Pinewood Point residential area. Paxton has good depth and moderate permeability, but it has a perched water table due to the presence of a phragipan, a compacted layer of

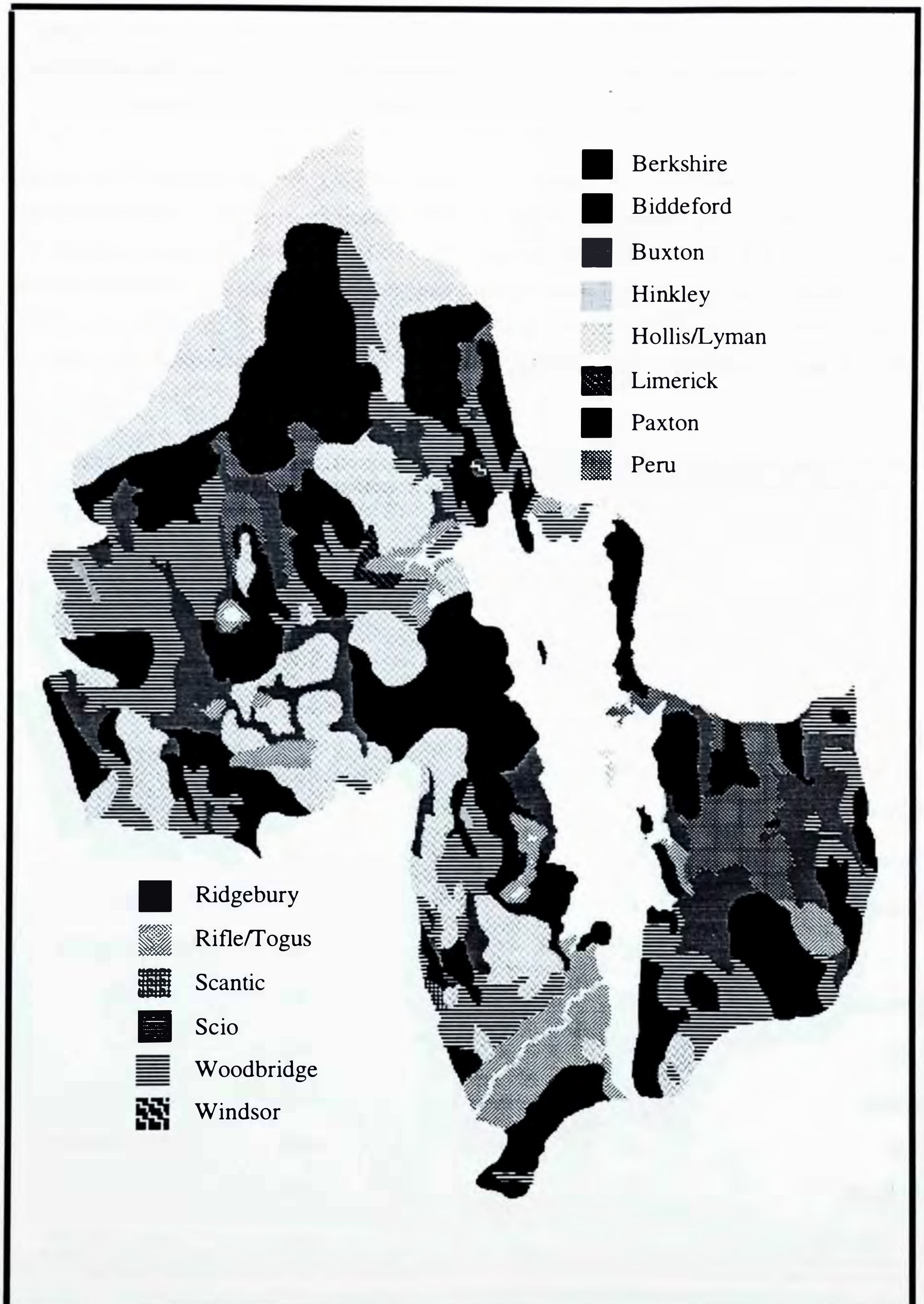

Figure 33. Soil Types in the Long Pond, South Basin watershed.

soil that occurs at a deceptively shallow depth in the soil (Tim Christensen pers. comm.). The presence of a phragipan will cause Paxton soils to saturate much earlier than would be expected, and lead to runoff and possible release of nutrients from septic systems.

Using the classifications given by the USDA (1978), we created a map illustrating septic suitability for the watershed (Figure 34). Permeability, erodibility, and slope will limit suitability for septic system installation. The USDA classifies all soils as limited in consideration of the amount of septic inputs that any soil can absorb. Included in the consideration of septic suitability was slope. In areas of greater than an 8.0% grade and with highly erodible or poorly drained soils, limitations on septic

Table 8. Hydrologic class, hydric quality, depth to bedrock, and erodibility coefficient for soil types found in the Long Pond, South Basin watershed (USDA 1992). Erodibility coefficients are not for organic soils, and multiple coefficients are given for those soil types that have different coefficients at different depths.

Soil Type	Hydrologic Class[1]	Hydric (Y/N)	Depth to Bedrock (cm)	Erodibility (K-factor)
Berkshire	B	N	>60	0.32
Biddeford	D	Y	>60	0.32/0.49
Buxton	C	N	>60	0.32/0.49
Hinckley	A	N	>60	0.24
Hollis	D	N	10-20	0.32
Limerick	C	Y	>60	0.32/0.49
Paxton	C	N	>60	0.24
Peru	C	N	>60	0.24/0.32/0.37
Ridgebury	C	Y	>60	0.32
Rifle	D	Y	>60	----
Scantic	D	Y	>60	0.32/0.49
Scio	C	N	>60	0.49/0.64/0.49
Windsor	A	N	>60	0.17
Woodbridge	C	N	>60	0.24/0.32/0.37

[1] See text for descriptions of hydrologic classes

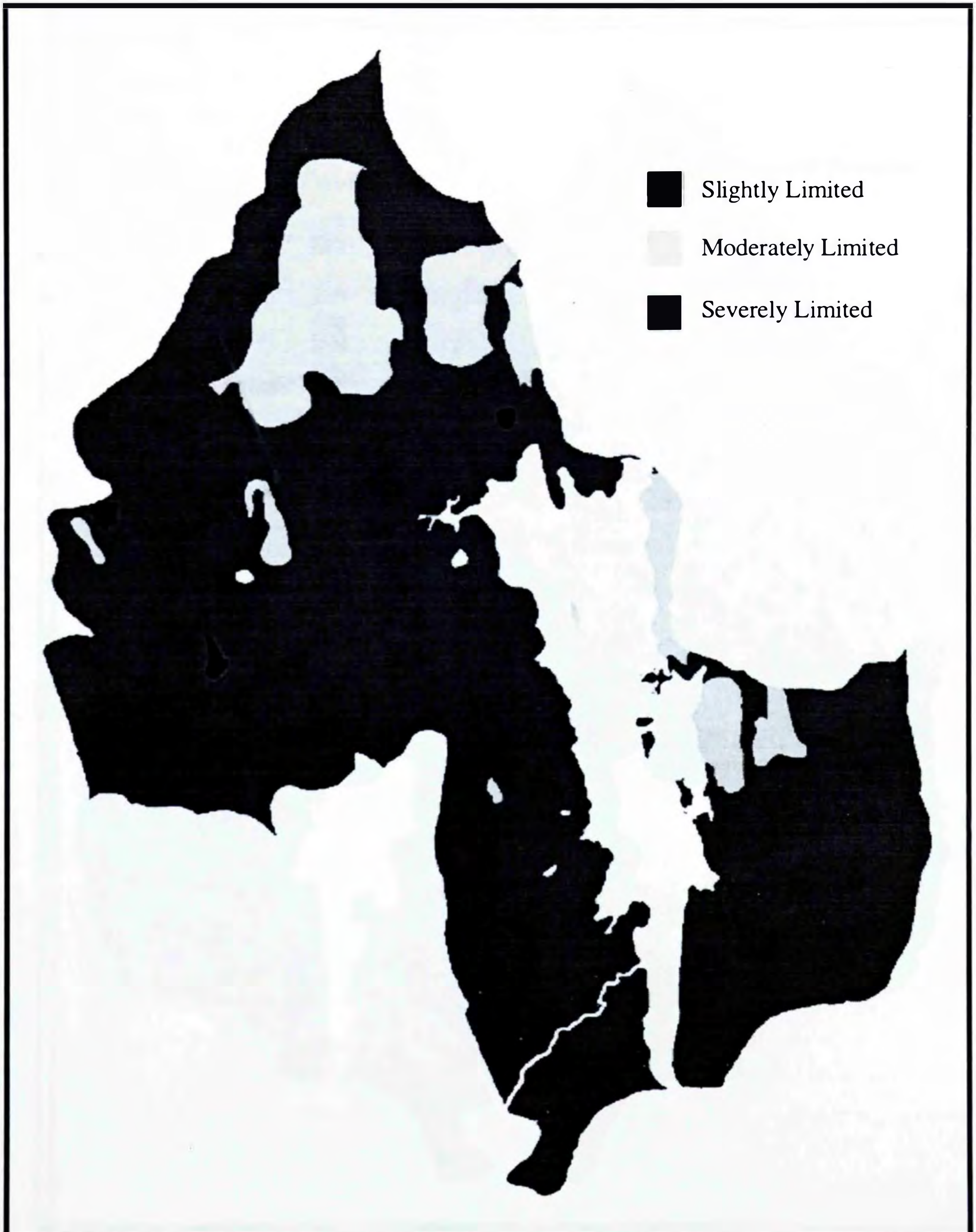

Figure 34. Suitability of soils for installation of subsurface wastewater disposal systems based on soil permeability, erodibility, and topography.

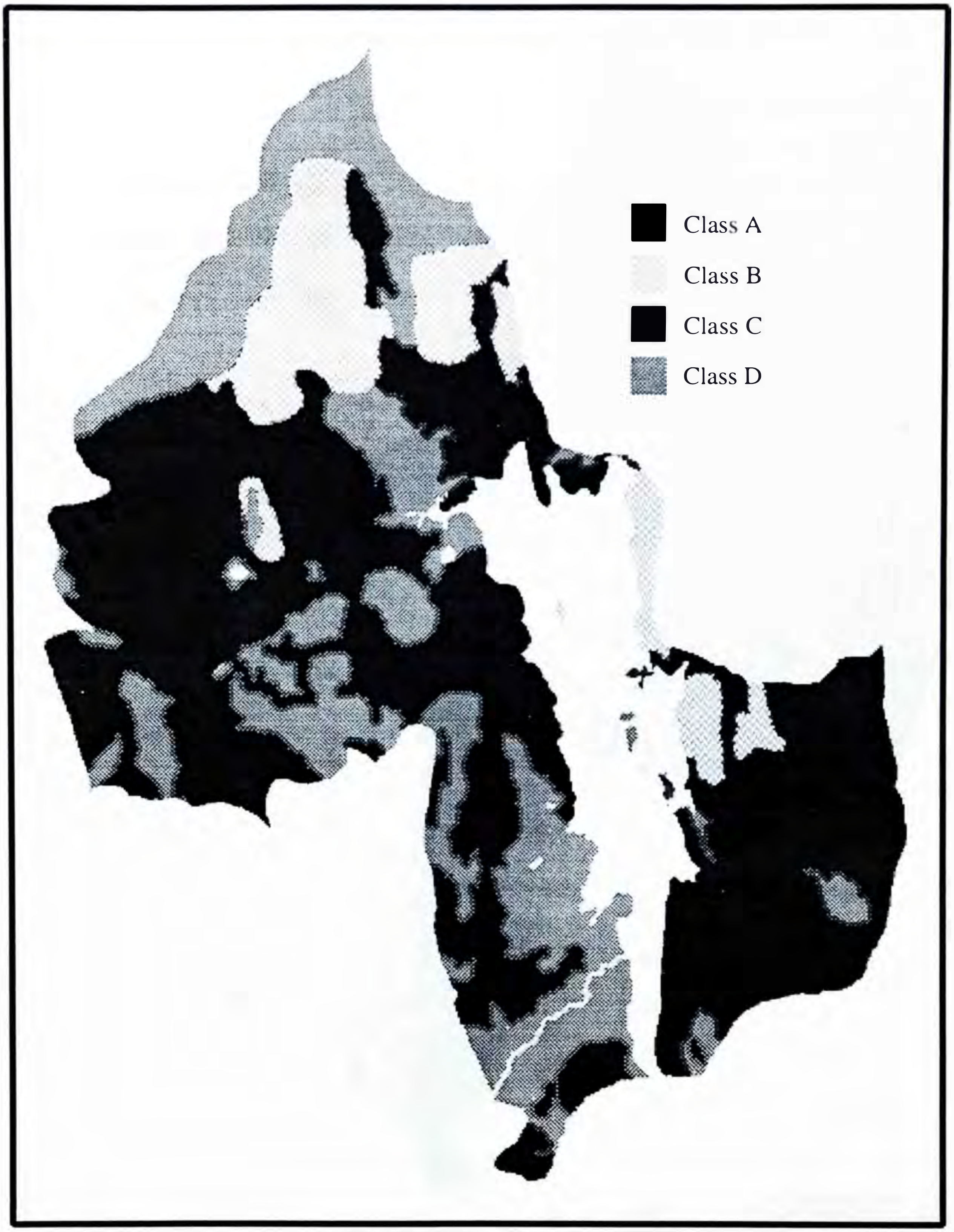

Figure 35. Hydrologic soil classifications based on soil type permeability in the Long Pond, South Basin watershed.

Figure 36. Development projections based on soil suitability and exisiting roads and power lines. High potential area is a 50m spread around existing roads.

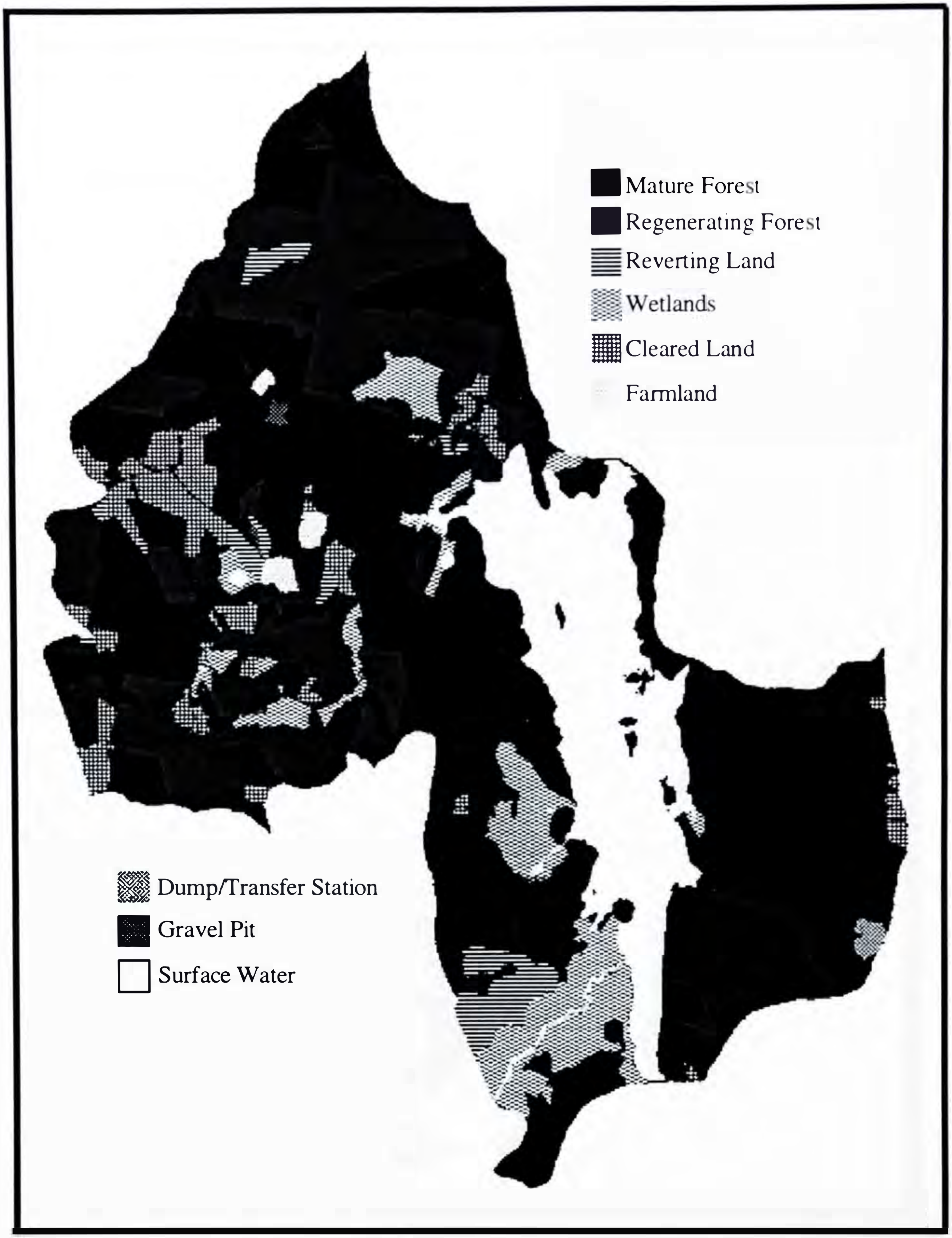

Figure 37. Characterization of land uses in the Long Pond, South Basin watershed.

suitability resulted. The majority of the watershed, including the Journey's End Road, Pinewood Point, and Sandy Cove residential areas, is classified as severely limited in septic system suitability. These areas include most of the major areas of residential development within the watershed. The nature of these limitations seems to oppose the current good water quality of Long Pond, South Basin, as the areas of high development are situated on limited soil types. Areas of limitations should be noted, and considerations regarding septic limitations should be made prior to future development to avoid future water quality problems.

Soil types were classified into the four hydrologic classes, A-D, as defined by the USDA (1992). These classifications are based on permeability, with A having the highest level of permeability and D the lowest (see Soil Methods). The USDA considers B class soils as favorable for future development based on adequate permeability and low erodibility. The majority of the watershed is composed of class C and D soils (see Figure 35). We considered class A and D soils to be unsuitable for future development because class A soils have too high an erosion potential, and class D soils are generally too saturated and comprise the wetlands of the watershed. Class C soils were included for possible development despite their septic and drainage limitations because these soils support most of the developed land in the watershed. For this reason it seems likely that class C soils would be developed in the future (see Figure 36). It is important to note that these soil types cover large areas and individual plots may contain areas of soil consistent with the plumbing code's septic system suitability.

In addition to soil types, proximity to roads was considered in determining future development. In general, short-term future development potential is dependent on proximity to roads and power lines. If development occurs greater than 50.0 m away from established power lines, additional fees are charged to residents for each telephone pole beyond that distance (Tim Christensen, pers. comm.). On the GIS map Future Development, areas of likely future development are shown. These developable areas represent suitable soil types (B and C class) when they occur within 50.0 m of an established road. For this study, it was assumed that all roads within the Long Pond, South Basin watershed had power lines, as data regarding location of power lines on roads in the Long Pond, South Basin watershed were not available for this study. The actual area of land suitable for future development may be smaller than what is represented because of the presence of roads without powerlines.

To analyze land use trends and potential of future land use in the watershed, we used graphical data consisting of layers of different land uses in the watershed from the Microstation team. We combined this data to create a complete map characterizing

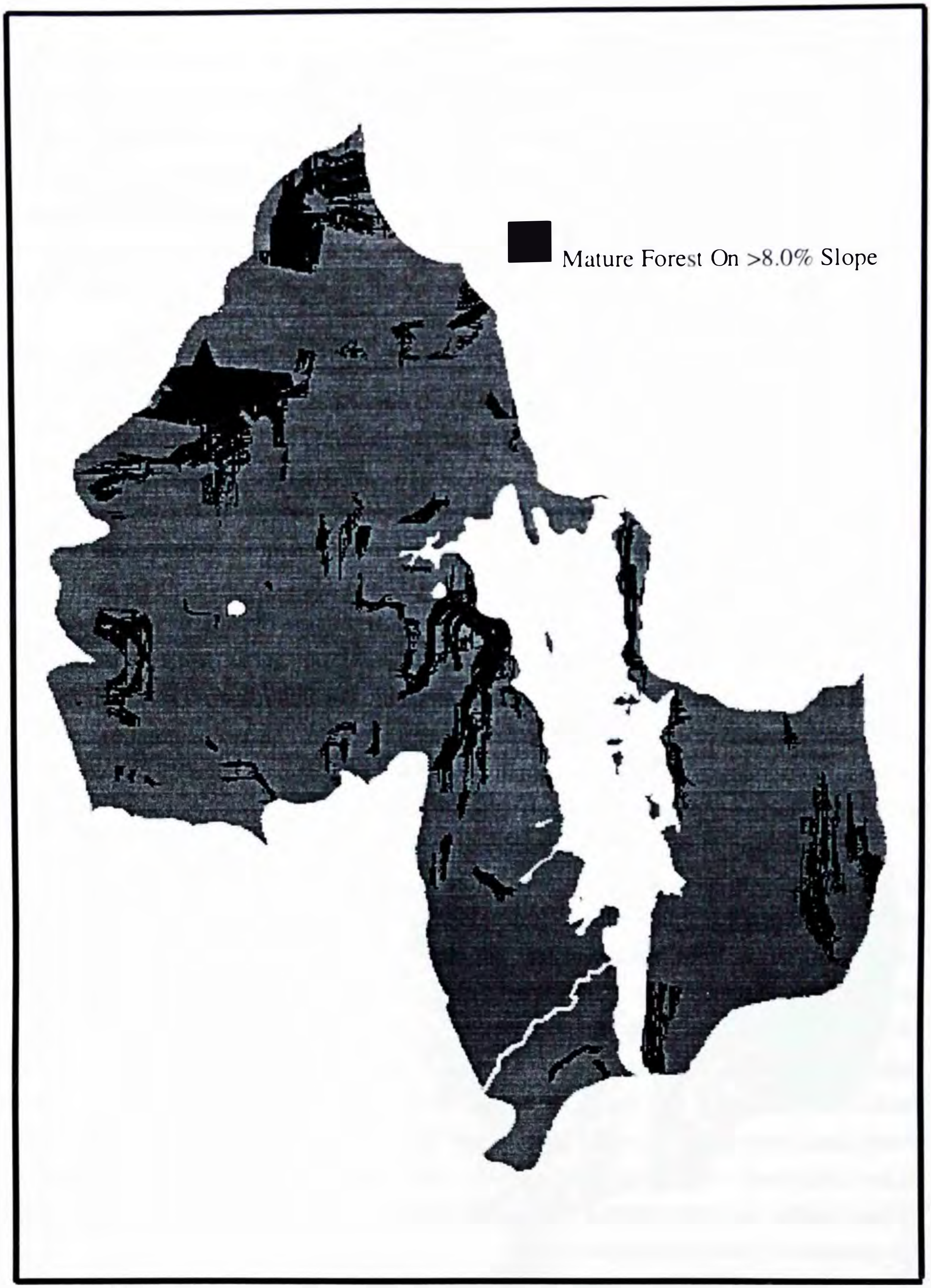

Figure 38. Restrictions for future logging in the Long Pond, South Basin watershed. Stands of mature forest located on areas with >8.0% slope are considered restricted from future logging due to potential nutrient loading impacts through soil erosion.

watershed land use (see Figure 37). This map illustrates that the majority of the watershed is comprised of mature or regenerating forest. Wetlands and cleared lands are also significant types of land use. We considered mature forest stands eligible for future logging practices, and considered areas of mature forest on slopes of greater than 8.0% as being unacceptable for logging. Clear-cutting and the subsequent exposure of steeply graded, highly erodible soils would facilitate the release of high levels of nutrients which could reach the lake basin via tributaries. We created a data layer illustrating areas of mature forest on 8.0% or greater slopes to suggest future logging restrictions (see Figure 38).

Discussion and Recommendations

We can conclude from current patterns of residential development occurring on land with severe septic limitations that current residences are having an impact on nutrient loading in the lake. Future building may amplify this impact. Some significant areas of residential development also occur on shoreline areas with slopes of greater than 8.0%. This increases the potential for nutrient loading into the lake due to septic systems, exposed, erodible soils, and the creation of impermeable, high-runoff areas such as driveways. Because Long Pond, South Basin has not suffered from algal blooms or fishkills over the past summers, it seems that the current development on these limited soils has been sustainable. It is necessary to further examine slope and soil conditions within the Long Pond, South Basin watershed to dtermine the capacity for additional development. Many of the areas with high development potential may fall on these limited soils and should be monitored (see Figure 36).

Considering the good water quality and general health of the watershed, current development, and the severe limitations of the developed soils, the analysis of soils in the future in terms of septic system suitability should be revised. Inspection procedures to determine whether soils are appropriate for septic system installation should include tests to determine the soil's ability to process fecal coliform, percolate water, and to process organic material and nitrogen. These are factors which need to be considered in order to properly protect the lake basin from increasing nutrient loading levels.

Our map of logging projections suggests similar cautions as to the nature of future land uses in the watershed. Development, in terms of logging or land clearing for agricultural or livestock production, must be done with careful consideration of limiting parameters, such as slope and soil type (including septic suitability and erodibility). By considering the past trends in logging, as illustrated by regenerating forest (see Figure 37), it is evident that these considerations were overlooked in past practices. Analysis of land use patterns and soil limitations in future development can allow for relatively simple adjustments in planning that can be very significant factors in maintaining the health of the watershed.

MICROSTATION METHODS

MicroStation is a computer aided design program that enables users to create shapes and take precise measurements of the area or length of these shapes. Photographs may be digitized and placed in a MicroStation file, and objects in the photographs may be traced with these measurable shapes. Measurements made by the program are in arbitrary, unchanging units referred to as map units (mu). By comparison with objects of known length or area in standard units, the values in mu were converted to the standard units. Using this technique, we measured land use types and delineations visible in aerial photographs and maps. Areas of land use types in both 1991-1992 and 1966 are useful for comparing past and current land use patterns, and are necessary for modeling phosphorus loading into Long Pond, South Basin. Tax maps were measured to find the average lot size which is also necessary for the phosphorous equation. Additionally, we used MicroStation to print the created shapes, which were then used to create land use maps for incorporation into GIS (see GIS Methods).

Image analysis of photographs and maps was performed using a Power Macintosh 7100/66 and a Lacie Silverscanner II. Software employed included MicroStation Mac Version 5, Adobe Photoshop Version 3.0, and Microsoft Excel 5.0. A Topcon stereoscope was used in conjunction with aerial photographs to clarify images and differentiate vertical distances. The stereoscope allows three dimensional viewing of overlapping pairs of photographs which aided in the identification of, for example, cleared lands and logging patterns.

Aerial photos were provided by the United States Department of Agriculture High Altitude Photography Program. The scales of the 1966 and 1991-1992 photographs were determined to be 1:9789 and 1:19578, respectively. Photographs were chosen such that all areas within the watershed of Long Pond, South Basin were represented. A clear sheet of mylar was fastened to each photograph. Using an overhead projector, a transparency copy of topographical map was projected onto each photograph, and the watershed boundary obtained from DEP was then traced onto the mylar sheet.

Each aerial photo was scanned in at 400 dots per inch (dpi) and 200 dpi using Adobe Photoshop. The higher resolution images were kept in long term data storage to use as more precise references. The lower resolution pictures were saved in TIFF format, a file format compatible with MicroStation, and subsequently imported into MicroStation.

Each digital image imported into MicroStation was placed in an individual file that had a separate MicroStation "layer" and object color assigned to each land use type or type of delineation (municipal boundaries, watershed boundaries, etc.). The image was locked to the bottom layer and the "layer lock" was applied to ensure that only one type of land use be edited at one time. For each land type or delineation, appropriate areas on the photograph were traced using the "polygon" tool. Those regions which had more polygon surfaces than supported by MicroStation were assigned multiple, non-overlapping polygons whose composite equaled the total region. Each polygon was "tagged" with an arbitrary index number and its area in square map units (mu^2) as calculated by MicroStation.

It was necessary to define delineations or borders between overlapping photo images in order to avoid duplication of land use areas in the final totals. Borders were defined using specific landmarks that were visible on all overlapping photos and were drawn using the "line" tool on a separate layer. For each image file, only those areas within the watershed and the inter-photo boundaries were measured.

To convert map units into metric units, a road segment from each photo was measured in MicroStation using the line tool. This value in map units was then compared to the actual length of a 1468 ft road segment of Narrows Road, as determined on site by using a measuring wheel. "Tagged" values and index numbers from the MicroStation files were exported to Microsoft Excel where each area in square map units was converted into square meters. It was necessary to calibrate each photo file separately, as MicroStation map units may vary with respect to the scaling that occurs during placement of the graphic into the MicroStation file. In some photos where the Narrows Road segment was not visible, another previously calibrated photo was used to measure a segment common to both photographs. This secondary segment length was then used to calibrate the distances in the new photo. The areas of the land use shapes were totaled among all the photographs, and percentages of the total watershed were calculated.

Tax maps were scanned to find individual lot sizes in a similar fashion. Tax maps for the town of Belgrade that had lots within the watershed were scanned at 150 dpi and imported into MicroStation. Polygons inscribing each lot were drawn on a single layer and measured as described above. To create a conversion factor between square map units and square meters, five lot edges for which the length in feet was shown on the tax map were selected. Each lot edge was measured in MicroStation map units and used to calculate a calibration between map units and meters. The average of these five conversion factors was used as the final calibration for that tax map. Lots were characterized as developed shoreline, undeveloped shoreline, developed non-shoreline, or non-developed non-shoreline. Total acreage of each category was calculated.

To provide information for GIS use, each MicroStation "layer" was printed using the same scale onto an acetate transparency. These transparencies could be individually overlaid onto a wireframe of the watershed boundary that was also printed using the same scale. With the original aerial photos as a reference, the polygons that inscribed the various land use types were converted into GIS format (see GIS Methods).

ZIDAS METHODS

A Zeiss Interactive Digital Analysis System (ZIDAS) was used to quantify lake and watershed areas for use in the water budget equation. These values are important in determining exactly how much water enters Long Pond, South Basin and the frequency with which the basin is completely flushed.

Clear mylar was overlaid on a 1972 USGS 7.5 Minute Series Belgrade Lakes Quadrangle map and the watershed and lake outlines set by MDEP for Long Pond, South Basin, Ingham Pond, and Moose Pond were traced using a black marker. Using the ZIDAS mouse, each mylar outline was then traced ten times and averaged to obtain the reported area.

ZONING AND DEVELOPMENT METHODS

Shoreland Zoning Ordinances

Shoreland zoning ordinances play a large role in determining how much shoreline development will affect water quality. The State of Maine has ordinances in effect which specify guidelines for land use in the following areas: shoreline residences, timber harvesting, agriculture, road construction, septic waste disposal, industrial and commercial development (MDEP 1990a). Individual municipalities may build upon state regulations in order to make them more appropriate for a specific location. The municipalities that comprise the shoreland of Long Pond, South Basin, Belgrade and Mount Vernon, have all added to the ordinances designed by the State of Maine. However, since the ordinances for the specific towns in terms of shoreland land use are usually the same as the State of Maine ordinances, the information in this section focuses on ordinances set by the State of Maine.

Land use ordinances in the shoreland zone are designed to protect water bodies from excessive nutrient loading, erosion, and runoff. One of the limits imposed by ordinances is a minimum lot size. Different minimum lot standards are set for shoreline residences, commercial/ industrial activities, and any other land uses within the shoreland zone. Towns may set minimums that are slightly larger than those set by the state to limit development.

Another important aspect of the ordinances pertains to setbacks ,the distance back from the normal high water mark, of development along the shoreline. Setbacks are determined for roads, driveways, houses, campsites, timber harvesting, waste disposal, manure stockpiles, and tilling in agriculture. Other than timber harvesting, all of these activities are restricted to a distance that is at least 100 ft from the normal high-water line of the lake and its tributaries, and at least 75 ft from other water bodies, such as streams and wetlands. There is a greater setback for roads with steeper slopes. Within the setback area, ordinances also specify requirements for maintaining proper buffer strips between water bodies and development (see Buffer Strips). Timber harvesting must be at least 75 ft from the normal high-water line of the lake or tributary.

Several measures which directly prevent soil erosion are included in the ordinances. Roads must be constructed in such a way that runoff is directed into a buffer strip of at least 50 ft plus two times the average slope. Activities that involve filling, grading, excavation, or other activities which result in unstable soil conditions, must submit a Soil Erosion and Sedimentation Control Plan. This plan includes proposals for revegetation of disturbed soil and temporary run-off control structures, probably for use in areas where construction is occurring close to the lake or its tributaries.

The ordinances are effective in placing controls on recent development. However, several lots and structures exist within the shoreland zone which do not conform to the standards, most likely because they were purchased and/or developed before the ordinances came into effect. For cases such as these, there is a separate category of ordinances. These ordinances allow the non-conforming use to continue, provided that the non-conformity of the structure and its usage do not increase.

By knowing the limits and regulations placed on specific land uses found within the shoreland zone of Long Pond, South Basin, we can better predict how future development will affect the overall lake water quality, and the extent to which this development can occur.

Inland Zoning Ordinances

Zoning regulations which apply to residences located back from the shoreline must be taken into consideration when assessing the phosphorus loading in a watershed. Although individual inland lots may not be as critical a component of the phosphorus loading into a lake when compared with shoreline lots, total inland area occupies a disproportionate area in the watershed and may outweigh shoreline input (Roy Bouchard pers. comm.). In Mount Vernon, there is a minimum lot size requirement of two acres. Residences must be set back at least 75 ft from the centerline of roads (50 ft in the village and on minor public roads) and at least 75 ft from any tributaries or wetlands. In addition to meeting the minimum lot size requirement, multiple unit developments require a minimum of 200 ft between each unit (Mount Vernon Land Use Ordinance 1995). These requirements make it economically unfeasible to develop multiple unit dwellings, such as condominiums (Peter McManus pers. comm.). Belgrade and Rome did not have non-shoreline zoning regulations available at the time our research was conducted, and therefore it is assumed that these towns meet the minimum state regulation requirements for inland zoning. The MDEP requires that towns meet the minimum regulations set by the state; if a town develops more stringent regulations, it is up to the individual town to enforce them (Karen Hahnel pers. comm.). The towns in our watershed tend to have more specific zoning regulations for shoreland development than they have for inland development, when related to water quality concerns (see Shoreland Zoning Regulations).

SOIL METHODS

Soils around lakes often affect the impact that development has on the lake ecosystem. When considering development in the watershed, it is important to recognize the respective distribution and characteristics of soil types. Data published by the USDA illustrates four classifications for particular soil types (1992). This classification, A through D, is based on hydrologic information and was developed to relate a soil's permeability to its resulting potential for phosphorous loading.

Class A soils are composed of sand and gravel, and have a very high permeability (greater than 15.0 cm/hr). This type of soil permits high infiltration of water and low levels of runoff. Very little binding of phosphorous to soil occurs because of the large grain size of Class A soils. Phosphorous leaches rapidly through the soil and becomes incorporated in the water system.

Class B soils are typically sandy loams that have a relatively high permeability (5.0-15.0 cm/hr). This is the best class of soil for general development, because the soil particles are small enough to bind phosphorous.

Class C soils are those with a lower permeability (0.5-15.0 cm/hr) usually due to increased amounts of silt and clay particles. Soil particles are small and have low permeability, therefore, significantly less water infiltrates the soil. Surface runoff is intensified and this soil delivers more particulate and dissolved phosphorous to tributaries and the pond.

Class D soils are the least permeable (0.5-5.0 cm/hr). They are composed of fibrous or mucky peat, clays, or silts. Peat soils are generally located in flat lowlands and wetland areas, where a lack of drainage results in waterlogged soils. Class D soils only allow restricted infiltration and movement of water.

Development proposals must take the particular soil type at a given site into consideration because residential and commercial development inevitably involve a degree of soil surface disturbance (USDA 1992). In addition to recognizing the soil types in a given area, the following parameters must be considered, which will influence the degree to which a development will contribute to the nutrient load in a given body of water (BI493 1995).

Slope - Using GIS (see Analytical Procedures: Geographical Information System Methods), slopes for the entire watershed were extrapolated from an elevation data layer. This data layer contained elevation values based on the United States Geological Survey (USGS) topographical maps, the Belgrade Lakes quadrangle, and the Readfield, ME quadrangle of the watershed.

Erodibility - The potential for erosion increases with an increase in slope (USDA 1978). Erodibility is a direct function of slope and is expressed as a K factor. This erodibility coefficient provides a relative value for a given site which may be compared to other sites when considering development. K factors range from 0.20 to 0.49 (USDA 1992). This range can be divided into three categories: low erodibility (K factor 0.20-0.29), medium erodibility (K factor 0.30-0.39) and high erodibility (K factor 0.40-0.49) (BI493 1995).

Bedrock - The depth to bedrock is an important development factor as well. Sites where the bedrock layer lies less than 5.0 ft below the soil surface are considered inappropriate for development and septic system installation (BI493 1994). According to Maine State Plumbing Criteria (USDA 1989), 15.0 in is the minimum depth to a limiting factor (bedrock) that plumbing codes allow for the installation of a new subsurface waste disposal system.

Hydric Soils - These are soils in which the water table (the saturated part of the soil) is within one foot of the surface. This shallow depth hinders the ability of the soil to properly filter waste, therefore making it unsuitable for residential development and implementation of septic systems (USDA 1992). The vulnerability of the water table to contamination when hydric soils are present must be taken into account. Because hydric soils may exist in small areas and their boundaries may be so ambiguous that they are unidentifiable from aerial photographs or soil type data layers on the GIS program, it is important to recognize indications of this soil type's presence in the field (USDA 1989). The most common hydric soils within Kennebec County, ME are the peat soils such as Biddeford and Togus (USDA 1989). These are typically located in the wetland areas of the watershed where there is little to no water drainage. These soils have neutral to low pH and are fairly deep (greater than 5.0 ft) (USDA 1978). Hydric soils may be recognized by the presence of up to 6.0 in of sphagnum moss at the surface, an organic content of mainly herbaceous fiber, and/or apparent saturation of the soils (USDA 1978).

Given the parameters and ranking scheme for the different soil type characteristics, described above, areas within the Long Pond, South Basin may be classified in terms of their suitability for development and septic system construction. Using GIS, individual maps can be created for each of these parameters so that their relationships become more apparent. This in turn will help to determine the suitability of land use in particular areas, as well as identify areas within the watershed which may or may not be suitable for future development.

LAND USE METHODS

General Land Use Trends

Aerial photographs from 1966 and 1991-1992 provided by the United States Department of Agriculture (USDA) High Altitude Photography Program were analyzed using MicroStation (see MicroStation Methods) to assess trends in land use patterns in the watershed of Long Pond, South Basin over time. The watershed has undergone biological and cultural changes since 1966 (see Table 9).

The watershed of Long Pond, South Basin is 8323.2 acres and is made up of four towns. Vienna occupies 186.2 acres of forested land along the Northwest border of the watershed and, due to its small area, has been included into the area of Mount Vernon for the purposes of comparison with the other municipalities. Mount Vernon and Vienna occupy 64.3% of the watershed, Belgrade occupies 22.8%, and Rome occupies 12.9% (see Table 9).

Forestry and logging appear to have been the major land use type in 1966 with areas of incomplete forests or recently cut over forest occupying 61.6% of watershed land area. This land use dropped to only 27.0% of the watershed by 1991. This observation corresponds with an increase in mature forest from 18.7% in 1966 to 58.0% in 1991 (see Table 9). These data suggest that logging has decreased significantly since 1966.

Large residential growth is evident in the increases in residential areas and roads. Non-shoreline residential areas increased slightly, but shoreline development showed a dramatic increase from 0.5% in 1966 to 5.7% in 1991. The town of Belgrade alone showed an increase in shoreline residential area from 2.4% in 1966 to 12.5% in 1991 (see Table 9). The increase in paved and camp road area was most likely to accommodate these new residences.

Table 9. Types of land use in Rome, Belgrade, and Mount Vernon expressed as a percentage of town land area as determined by Microstation analysis of USDA aerial photographs.

	Rome		Belgrade		Mount Vernon	
Land Use	**1966**	**1991**	**1966**	**1991**	**1966**	**1991**
Mature Forest	23.6	6.7	35.2	70.8	12.2	53.8
Regenerating Forest	50.4	85.0	53.0	13.1	54.0	19.5
Reverting Land	14.4	0.3	5.7	0.1	12.9	3.2
Wetlands	4.6	5.0	0.3	0.4	10.9	10.9
Cleared Land[1]	6.0	2.4	6.0	0.7	9.7	6.3
Municipal Land[2]	0.0	0.0	0.3	1.1	0.0	0.3
Shoreline Residential	0.0	0.005	2.4	12.5	0.0	3.8
Non-Shoreline Residential	0.0	0.1	0.0	0.7	0.0	1.4
Paved Roads	0.1	0.1	0.1	0.3	0.2	0.3
Camp Roads	0.5	0.4	1.3	0.3[3]	0.8[3]	0.2

[1] Includes lawns, pastures, and other agricultural land.

[2] Includes the Belgrade Dump, Mt. Vernon Gravel Pit, and Castle Island boat ramp.

[3] Decrease may be due to error in reading 1966 arial phtotgraphs or roads may have been paved since 1966.

Agricultural and cleared lands, including pastures and large lawns, decreased from 7.7% of the watershed land area in 1966 to 4.8% in 1991 (see Table 9). This suggests a decreasing trend in farming which may be a result of the increasing trend in residential areas.

Forestry and Logging

Forested land was measured using the 1966 and 1991-1992 aerial photographs provided by the USDA High Altitude Photography Program and MicroStation (see MicroStation Methods). Forested lands were divided into two categories which were quantified separately: mature forest and regenerating forest. Mature forests were characterized as areas susceptible to logging with fully grown trees and full canopies. Regenerating forests were considered to be all areas which had been cleared at some point in the past and are regrowing to mature forest. Regenerting forest areas were characterized by patchy woodland, the presence of skidder trails, and areas of clear cutting or strip cutting. A discussion of other reverting lands is presented in the section below. The aerial photos were viewed with a stereoscope to determine the borders of mature forest and regenerating forest by comparison of canopy cover and tree height.

Areas of mature forest were determined to occupy 4826.4 acres, or 58.0% of land area in Long Pond, South Basin. This is a more than two fold increase from the 1558.9 acres (18.7%) of mature forest in 1966. These data correspond to a decrease in regenerating forest from 4505.1 acres in 1966 to 2064.1 acres in 1991. It is likely that decreased logging activity has precipitated these changes as clear cut areas occupied 332.1 acres or 0.4% of the Long Pond, South Basin watershed in 1966 and no instances of strip cutting were seen in the 1991 photos.

Mature forest occupied a smaller percentage (58.0%) of the Long Pond, South Basin in 1991 than was seen in the surrounding watersheds of Long Pond, North Basin, Salmon Lake, and East Pond with 62.1% (BI493 1995), 83% (BI493 1991), and 77% (BI493 1991) respectively. However, these were measured using a different method, and if areas of regenerating land were included, the percentages would be much more similar. Taking both mature forest and regenerating land into account the resultant area occupies 85.0% of Long Pond, South Basin in 1991, 79.6% of Long Pond, North Basin, 86.0% of

Table 10. Comparison of percentage land use in the watersheds of Long Pond, South Basin, Long Pond, North Basin, Salmon Lake, and East Pond. Data from MicroStation analysis of USDA aerial photographs.

Land Use Type	Long Pond, South Basin	Long Pond, North Basin[1]	Salmon Lake[2]	East Pond[3]
Mature Forest	58.0	62.1	83.0	77.0
Regenerating Land[4]	27.0	17.5	3.0	2.0
Wetland	8.3	4.9	1.0	3.0
Cleared Land[5]	5.3	3.9	9.0	2.0
Residential	6.7	10.5	3.0	14.0
Roads	0.5	1.1	1.0	2.0

[1] (BI493 1995)
[2] (BI493 1991)
[3] (BI493 1991)
[4] Includes reverting land.
[5] Includes agricultural land and municipal land

Salmon Lake, and 79% of East Pond (see Table 10).

While there does not appear to be a large amount of active logging in Long Pond, South Basin, there are several areas of mature forests which may be susceptible to future logging and therefore should be monitored.

Reverting Land

Reverting land was determined and quantified using the 1966 and 1991-1992 USDA aerial photos and MicroStation. Reverting lands were determined to be areas that had recently been cut or released from cultivation and left to regrow. These areas are characterized by early successional vegetation such as tall grasses, shrubs, and young trees.

Reverting land was determined to occupy 185.6 acres or 2.2% of the watershed land area. The area of reverting land in the 1966 photos was determined to be 627.8 acres or 7.5 % of land area (see Table 9). This decrease suggests more land was being released from cultivation in 1966. These data corespond to the decreased percentage of cleared land in the watershed of Long Pond, South Basin in 1991 (see Cleared Land).

Cleared Land

Cleared lands were determined and quantified using the 1966 and 1991-1992 USDA aerial photos and MicroStation. These lands were differentiated into four categories: pasture land, lawn, row crops, and other. Pasture lands were determined during reconnaissance and classified as large tracts that are periodically cut over for hay. Lawns were classified as tracts associated with a residence and maintained as short grass. Areas of row crops, or the intensive monoculture of crops in rows, were determined during reconnaissance. The category of other includes a chicken hatchery, a greenhouse, two Christmas tree farms, and several hobby farms. As reconnaissance was not available for the 1966 photos, all agricultural lands were classified as either pasture lands or lawns with the exception one area of row cropping identifiable in the photograph.

Cleared land was determined to occupy 405.0 acres which makes up 4.8% of the watershed land area. This represents a decrease from 642.8 acres of cleared land in 1966. Decreases in cleared land from 1966 to 1991 were seen in all three municipalities but were most remarkable in Belgrade which went from 6.0% of the watershed area to 0.7% (see Table 9).

Of cleared land in 1991 only 0.5% was determined to be row cropping. Lawn area increased from 11.7% of cleared land in 1966 to 19.0% in 1991 suggesting an increase in residential development. Pasture land showed a decrease from 87.1% of cleared land area in 1966 to 70.7% in 1991. This is offset however by the category of other which occupied 9.8% of cleared land area in 1991 and was not observed in 1966 (see Table 11).

Table 11. Types of cleared land expressed as percentage of total cleared land in the watershed of Long Pond, South Basin in 1966 and 1991 as determined using MicroStation and USDA aerial photographs.

Land Use Type	1966	1991
Lawns	11.7	19.0
Pasture	87.1	70.7
Row Crops	1.1	0.5
Other	0.0[1]	9.8

[1] No instances observed in 1966 photos

The 4.8% of watershed land area occupied by cleared land in Long Pond, South Basin in 1991 compares to 3.9% in the Long Pond, North Basin watershed (BI493 1995), 9.0% in Salmon Lake watershed (BI493 1991), and 2.0% in the East Pond watershed (BI493 1991)(see Table 10).

Wetlands

Areas were designated as wetlands using topographical maps and confirmed by field reconnaissance and analysis of the aerial photos using MicroStation and a stereoscope. A wetland is characterized by standing water or high soil moisture, either year round or seasonally (Paul Doss, pers. comm.). Many wetlands border water bodies, and most wetlands are low elevation points to where water from the surrounding topography is diverted (i.e., basins or ravines). Reeds, tall grasses, and water-loving shrubs are characteristic vegetation of wetlands which appear flat and dark on the aerial photos. Using the stereoscope, delineations between wetlands and surrounding forests can also be made by observable differences in vegetation height.

The largest region of wetlands in the watershed is the area that surrounds Ingham Stream. Another significant wetland region is located approximately 0.5 km north from the mouth of Ingham Stream surrounding two or three small pools that are connected to the lake. One km east of the mouth of Ingham Stream lies an inland patch that meets Dunn Road and is north of and at slightly lower elevation than Meadow Brook. Approximately 1.5 km to the southeast of Green Island is another inland patch. 1.0 km west of Green Island is the location of the only other large patch of wetlands. This inland region is unified by a small tributary that comes from the Southwest and crosses Bean Road. A small inland wetland runs parallel to Cobbs Road on its east side.

Wetlands in 1991 were measured to occupy 687.2 acres, which constitutes 8.3% of the watershed area (see Table 10). This is nearly double the wetland concentration from the 4.2% of wetlands of the Long Pond, North Basin (BI493 1995) and eight times the 1% wetlands of Salmon Lake (BI493 1991).

Wetlands in 1966 occupied 674.0 m^2 which is 8.1 % of the watershed. As no reconnaissance data was available, only those regions identified as wetlands in 1991 were considered wetland regions. The similarity between 1966 and 1991 agrees with our initial prediction that, due to the lack of large scale human intervention that would significantly alter drainage, the wetland total area should vary little over a 25 year span. Studies of Long Pond, North Basin and of McGrath and Ellis Ponds have demonstrated similar constancy over a twelve year period (BI493, 1994; 1995). The slight variation may have been due to inaccuracy in the data aquisition.

The impact of the percentage of wetlands is inconclusive unless the role of each wetland zone is considered. There are several hydrogeologic characteristics and processes typical of wetlands. Evapotranspiration from wetland surfaces can raise relative concentrations of nutrients and the wetland can act as a highly concentrated nutrient source. Alternatively, heavy vegetation and slow water passage through wetland areas can cause wetlands to filter out nutrients from the water and to act as a nutrient sink (Paul Doss, pers. comm.). Most likely, both of these processes are occurring in the wetlands of the watershed. The role of each could be found by measuring the pH and nutrient levels of soil or water samples in intervals across an altitudinal gradient and comparing the values with the flow of the stream. For example, a dramatic decrease in pH as the water travels through the wetland would suggest that the wetland is contributing nutrients to the migrating water, as a decrease in pH implies a higher concentration of dissolved ions.

Residential Areas

Residential area surveys, encompassing the entire watershed, were completed using two different methods. The first method involved assessing all of the roads in the watershed and counting residences by "windshield" vehicle surveys. The second method assessed each lot from the information recorded on property cards located in the town offices of Belgrade, Mount Vernon, and Rome. Vienna does not have any residences located within our watershed, therefore it was not included in either the vehicle surveys or the property card analyses.

Road Survey Methods

The watershed of Long Pond, South Basin was divided up into five sections to conduct the "windshield" vehicle survey (Appendix J). The surveys were conducted on the afternoons of 2-OCT-95 and 16-OCT-95. All of the major roads and significant camp roads located within the watershed were surveyed. The following counts and assessments were made: total residences, number of shoreline and inland residences, number of seasonal and year-round residences, quality or overall condition of residence driveways (Appendix G, Figure 7), and number of pre and post-1974 residences. In 1974 an ordinance was enacted requiring residence owners to have site evaluations before installing subsurface waste disposal systems; by assessing age we could estimate the quality of subsurface waste disposal systems.

Road Survey Results and Discussion

The results from the residential windshield vehicle survey are believed to be an accurate assessment of actual residences present in the watershed, due to the thoroughness of our survey. We were unable to assess a small number of residences, since some roads were distinctly labeled as private, or were closed off by gates. The data were analyzed for both the entire watershed, and specifically for shoreline residences only, since these residences potentially have a larger impact on the water quality of Long Pond, South Basin.

A total of 239 residences were counted in the Long Pond, South Basin watershed. 58.2% of the residences were located inland and 41.8% were located along the shoreline (defined as a residence on a lot which directly abuts the water). Of the total residences in the watershed, 36.8% were seasonal and 63.2% were year-round. Out of the 94 shoreline residences, 73.4% were classified as seasonal. 69.2% of the 91 shoreline driveways (some houses share driveways; so the number of driveways does not equal the number of residences) were classified as adequate and 30.8% were classified as inadequate. Driveways defined as adequate were those made of stable surface materials (i.e., gravel), had waterbars (water diversions) if necessary, had a moderate slope (less than 20%), and did not channel runoff directly into the lake. Driveways defined as inadequate were made of poor surface materials (i.e., loose dirt), had no waterbars when needed, exhibited a severe slope (greater than 20%) down to the water, and channeled runoff directly into the lake. The pre and post-1974 construction estimates were closely divided for shoreline residences, at 54.3% pre-1974 and 45.7% post-1974. The majority of the 25 year-round shoreline residences were constructed after 1974 (88.0%), while the majority of the 69 seasonal shoreline residences were constructed before 1974 (69.6%).

The seasonal and year-round determinations were based upon our observations of the residences (i.e., presence of a garage, boat still on the dock or not, size of the structure, presence of chimney, and foundation material and construction). It is possible that inaccurate determinations of some residences were made, since decisions were based simply on our observations.

The driveway condition analyses were somewhat subjective since we did not develop a specific numeric rating system for classifying them. No driveways were seen with extremely deep ruts and/or severe erosion problems. The majority of driveway surfaces in the watershed were gravel. The driveways classified as inadequate generally had problems which could be easily mitigated, by re-surfacing or by installing waterbars where necessary. It is important to take notice of areas on the shoreline which exhibit both inadequate driveways and poor buffer strips, as these combined forces could have a serious impact on the phosphorus loading into the lake (see Buffer Strips). The driveway results were only analyzed for the shoreline residences, since the inland driveways generally do not exert as great an influence upon the lake water quality.

Tax Map and Property Card Methods

Tax maps were obtained from the towns of Mount Vernon, Belgrade, and Rome. (The town of Vienna was not included in our study as it occupied only a small portion of the watershed and was undeveloped). The tax maps were analyzed and the numbers for those lots which were within the Long Pond, South Basin watershed were recorded. We then returned to each of the town municipal offices to analyze property cards for the recorded lots. In analyzing the property cards, we obtained the acreage per lot, and whether each lot was developed or not. In comparing developed and undeveloped lots in the watershed of Long Pond, South Basin, percentages of acreage on developed and undeveloped shoreline and inland lots were determined for each town and for the total watershed. If developed, we looked at whether or not there was a residence. If a residence was present we looked at whether or not it was used seasonally or year round, and whether or not there was a septic system present. To determine if the residence was seasonal or year round, we looked at the presence or types of heating systems, the presence of insulation, and the permanent address of the owner (Often, if the address of the owner is long distance, it suggests a seasonal residence.). To determine whether or not a septic system was present at each residence, we looked on the property card for indications of plumbing and bathrooms. For some residences, we were unable to determine the presence or absence of a septic system. The information obtained from the property cards was then analyzed and compiled for each town, individually, and for the total watershed (all three towns combined).

It should be noted that in obtaining information from the property cards there were several possible areas of error. In some instances it was necessary to make an educated guess as to whether a residence was seasonal or year round. If there was too little information, "unknown" was recorded. Also, it was not known how accurate the acreage noted on the property cards for each lot was as it is uncertain how the property inspector determined the acreage per lot, and whether property cards were updated as lots were divided. A comparison of Microstation analysis and property card analysis was done for the lot sizes in the town of Belgrade. The results of the comparison showed a difference between the two methods, suggesting error in one or both of the methods. For example, the average lot sizes were 12.2 acres by MicroStation analysis and 4.4 acres by property card analysis for developed inland lots, 17.4 and 33.3 acres for undeveloped shoreline lots, and 13.6 and 10.0 acres for undeveloped inland lots. The results below are from the method of property card analysis.

Shoreline Results and Discussion

Of the 308 lots in Mount Vernon, 22.7% were on the shoreline. 34.2% more shoreline lots were developed than were undeveloped. 54.2% of Belgrade's 153 lots were shoreline. Of those shoreline lots (70), a greater percentage were developed than undeveloped; 65.1% versus 34.9%, respectively. Rome had only 1 shoreline lot, and this lot was developed. Of the shoreline lots within the total watershed (154) (Mount Vernon, Belgrade, and Rome), 32.4% more were developed than undeveloped. (seeTable 12).

A greater percentage of shoreline lot acreage was developed than not in Mount Vernon (4.0% more) and Rome (100.0% more) , and a greater percentage shoreline lot acreage was undeveloped than developed in Belgrade (63.8%). In the total watershed, a greater percentage (46.2% more) of shoreline lot acreage was undeveloped (see Table 12). In Mount Vernon, and Belgrade, the average undeveloped shoreline lot sizes were, respectively, 4.1 and 29.3 acres greater than the average developed lot size (see Figure 39).

There were 46 shoreline residences in Mount Vernon, 55 in Belgrade, 1 in Rome, and 102 in total. Of these shoreline residences a greater percentage were seasonal than were year round or unknown (respectively, 58.7%, 91.0%, and 100.0% were seasonal) (see Table 12) (see Figure 40). In Mount Vernon, 78.3% of the shoreline residences and 94.5% of the shoreline residences in Belgrade had known septic systems. It was not determined whether or not the one shoreline residence in Rome had a septic system. (see Table 12)(Figure 41).

Table 12. Percentage of developed and undeveloped lots, total acreage on developed and undeveloped lots, seasonal, year round, or unknown residences, and residences regarding septic system status out of the total number (per town) of shoreline and non-shoreline (inland) lots within the Long Pond, South Basin watershed as of SEP-95. The town of Vienna was not included as it only occupied a small portion of the watershed and was undeveloped.

Characteristic	Mt. Vernon	Belgrade	Rome	Total Watershed
Shoreline				
	(n=70 lots, 46 residences)	(n=83 lots, 55 residences)	(n=1 lot, 1residence)	(n=154 lots, 102 residences)
Development				
% Developed	67.1	65.1	100.0	66.2
% Undeveloped	32.9	34.9	0.0	33.8
Acreage				
% Acreage on developed lots	52.0	18.1	100.0	26.9
% Acreage on undeveloped lots	48.0	81.9	0.0	73.1
Residence status				
% Seasonal	58.7	91.0	100.0	76.5
% Year round	34.8	9.0	0.0	20.6
% Unknown	6.5	0.0	0.0	2.9
Septic				
% Septic	78.3	94.5	0.0	86.3
% No septic	17.4	1.8	0.0	8.8
% Unknown	4.3	3.7	100.0	4.9
Non-shoreline				
	(n=238 lots, 106 residences)	(n=70 lots, 16 residences)	(n=18 lots, 14 residences)	(n=326 lots, 136 residences)
Development				
% Developed	47.1	24.3	66.7	43.3
% Undeveloped	52.9	75.7	33.3	56.7
Acreage				
% Acreage on developed lots	38.5	12.4	60.9	37.1
% Acreage on undeveloped lots	61.5	87.6	39.1	62.9
Residence status				
% Seasonal	31.1	56.3	0.0	30.9
% Year round	59.4	25.0	92.9	58.8
% Unknown	9.5	18.7	7.1	10.3
Septic				
% Septic	85.9	100.0	92.9	88.2
% No septic	14.1	0.0	0.0	11.0
% Unknown	0.0	0.0	7.1	0.8

Table 13. Number of shoreline and non-shoreline, developed and undeveloped lots within the Long Pond, South Basin watershed, categorized into specific acreage sizes and by town as of SEP-95. The town of Vienna was not included as it only occupied a small portion of the watershed and was undeveloped.

		Shoreline		Non-shoreline	
	Acreage	# Lots developed	# Lots undeveloped	# Lots developed	# Lots undeveloped
Mt. Vernon	0-1	24	9	17	7
	1-10	19	12	61	58
	10-20	0	1	8	22
	20-30	1	0	9	13
	30-40	0	0	8	4
	40-50	2	0	1	3
	>50	1	1	8	19
	Unknown	0	0	0	0
Belgrade	0-1	27	9	1	15
	1-10	24	15	4	29
	10-20	0	0	0	1
	20-30	0	0	1	2
	30-40	0	0	1	1
	40-50	0	0	0	3
	>50	2	5	0	1
	Unknown	1	0	10	0
Rome	0-1	1	0	1	3
	1-10	0	0	7	0
	10-20	0	0	1	0
	20-30	0	0	1	1
	30-40	0	0	0	1
	40-50	0	0	1	0
	>50	0	0	1	1
	Unknown	0	0	0	0
Total Watershed	0-1	52	18	19	25
	1-10	43	27	72	87
	10-20	0	1	9	23
	20-30	1	0	11	16
	30-40	0	0	9	6
	40-50	2	0	2	6
	>50	3	6	9	22
	Unknown	1	0	10	0

Inland Results and Discussion

Of the 308 lots in Mount Vernon, 77.3% were inland (non-shoreline). Of those inland lots (238), 52.9% were undeveloped and 47.1% were developed. 45.8% of the 153 Belgrade lots were inland. Of those inland lots (70), 75.7% were undeveloped and 24.3%

were developed. Rome had 18 inland lots, 66.7% of which were developed. Of the 480 lots within the total watershed, 67.7 % were inland , and a greater percentage of inland lots were undeveloped than developed (see Table 12).

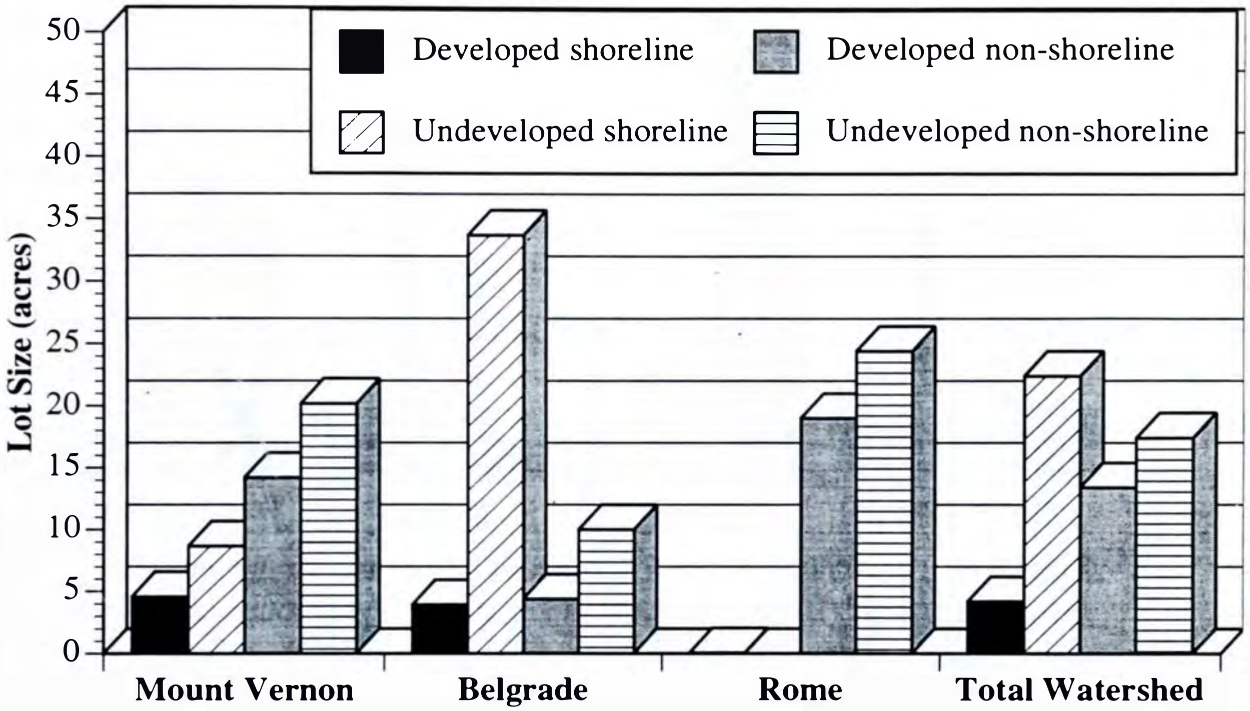

Figure 39. Average developed and undeveloped, shoreline and non-shoreline lot sizes for the Long Pond, South Basin, shown by town as of SEP-95.

Of the inland lots within the Long Pond, South Basin watershed, there was a greater percentage of acreage on undeveloped lots than on developed lots in Mount Vernon (23.0% more) and Belgrade (75.2% more). This was also true for the total watershed (see Table 12). The average undeveloped, inland lot size was greater than the average developed lot size for all three of the towns, and also for the total watershed (see Figure 13). This could indicate a high potential for future development and consequently increased phosphorus loading on the lake. (see Future Projections: Development Trends and Potential).

There were 106 inland residences in Mount Vernon, 16 in Belgrade, 14 in Rome, and 136 in total. In Mount Vernon and Rome, a greater percentage had the status of year round residency rather than seasonal or unknown. Belgrade had a greater percentage of seasonal residences (56.3%) than year-round or unknown (see Table 12)(Figure 40). There was a much greater percentage of inland residences in all of the towns and in the total watershed with septic systems than without or unknown. (see Table 12)(Figure 41).

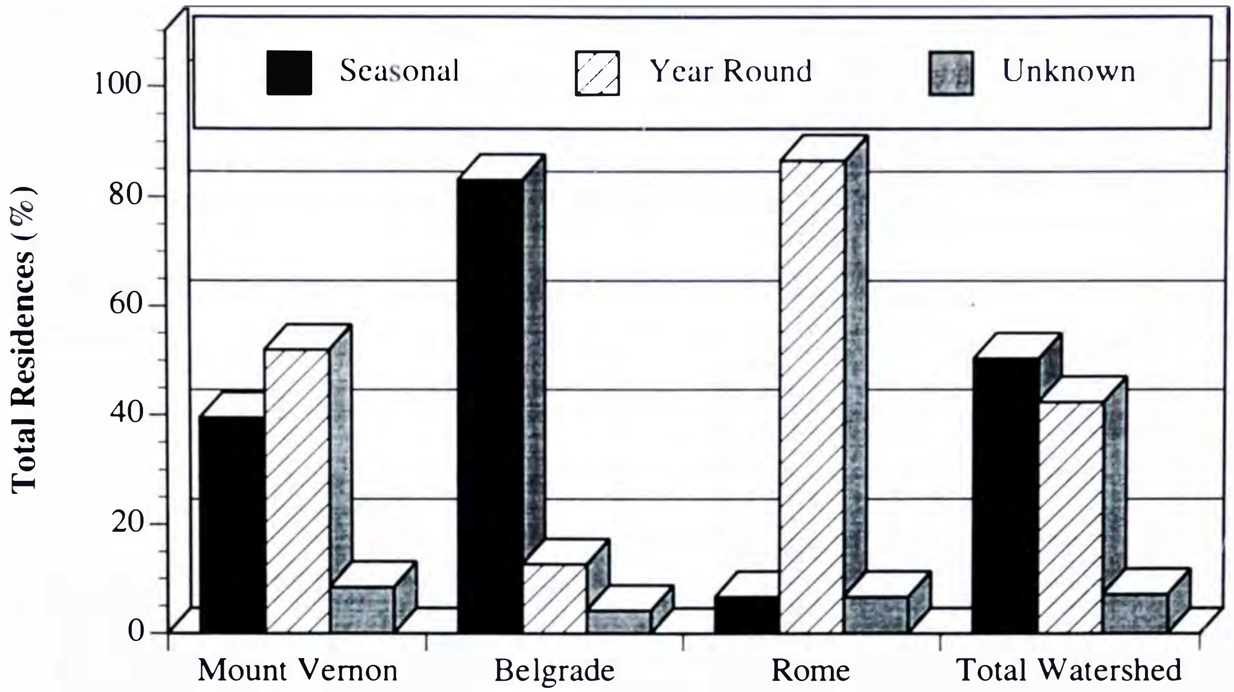

Figure 40. Percentage of total residences (shoreline and non-shoreline) in Long Pond, South Basin watershed, with seasonal, year round, and unknown status, shown by town as of SEP-95

A greater understanding of our results may be achieved by comparing the results of our study to other studies of lakes in the region. Through analysis of a 1980 topographical map of the Belgrade Lakes region, in general, the shoreline of Long Pond, South Basin appeared to have a lower percentage of development than other lakes in the region. In comparing Long Pond, South Basin with other lakes in the region, including Salmon Lake and East Pond, percentages of shoreline developed, and percentages of seasonal and year round residences were very similar (BI493 1994 and BI493 1991). In 1994, Salmon Lake was found to have 70.0% of its shoreline developed (BI493 1994). In comparison, our study of Long Pond, South Basin found that it had 66.2% of its shoreline developed. In the summer of 1988, a study of East Pond found that 80% of its residences were seasonal, while 20.0% were year round (BI493 1991). In comparison, 76.5% of Long Pond, South Basin's shoreline residences were seasonal, while 20.6% were year round, and 30.9% of the inland residences were seasonal, while 58.8% were year round. Long Pond, South Basin and East Pond (BI493 1991) also had similar percentages of septic systems. In Long Pond, South Basin 86.3% of the shoreline residences had septic systems, while 88.2% of the inland residences had septic systems. In comparison, a 1988 study the East Pond residences found 90.0% with septic systems (BI493 1991). Shoreline residences in

Long Pond, South Basin had a greater percentage of septic systems than did the shoreline residences of Pattee Pond (86.3% versus 30.7%) (BI493 1993).

It is important to look at the development in each of the communities and in the watershed as a whole as development and residential land use are key components in determining the phosphorus loading of a lake. The shoreline of Mount Vernon has a greater percentage of developed than undeveloped lots, and poses a threat of phosphorus loading. Most of those residences in Belgrade, and on the shoreline of Mount Vernon and Rome are seasonal which may lessen the impact and amount of phosphorus loading on the lake. The prevalence of seasonal conversion to year-round homes within the watershed is unknown. This conversion would also increase the potential for phosphorus loading. However, due to the large amount of undeveloped land in Belgrade, and the inland lots of Mount Vernon and Rome, there is a high potential for future development, and thus increased phosphorus loading. The potential for development assumes that the undeveloped areas are on developable land, considering soil type and proximity to roads. (see Future Predictions: Development Trends and Potential).

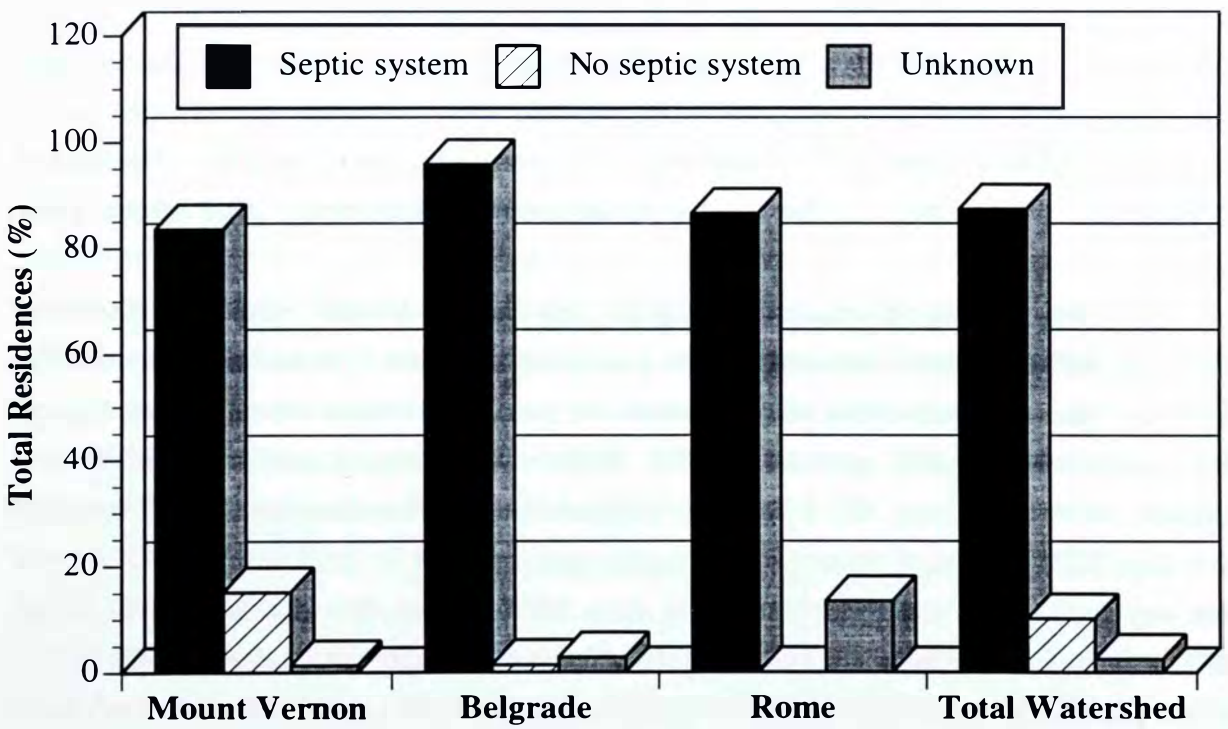

Figure 41. Percentage of total residences (shoreline and non-shoreline) in the Long Pond, South Basin watershed, regarding septic system status, shown by town as of SEP-95.

Subsurface Water Disposal Systems

Results and Discussion

Subsurface waste disposal systems are critical factors to take into account when determining the phosphorus loading into a lake. In Long Pond, South Basin, nearly all of the subsurface waste disposal systems are septic systems (Bob Martin pers. comm.). The integral components of a septic system are the settling tank, porous pipes, and a leach field (See Introduction).

Varying regulatory standards for septic systems exist in the Long Pond, South Basin watershed because of the different standards set by each town. Installation standards for the towns of Belgrade and Rome conform with the State of Maine Subsurface Wastewater Disposal Rules of 1988. Included among these regulations are a minimum setback of 100 ft from the normal high-water line. Replacement systems must meet these regulations as well. In 1987, Belgrade noted that they should inventory failing septic systems (Draft, Town of Belgrade Comprehensive Land Use Plan). Mt. Vernon regulations conform to the Maine State Plumbing Code.

Bob Martin, the plumbing inspector for Belgrade, stated that for home owners who are planning on converting their residences from seasonal to year-round, there is a code to follow, which applies only to shoreland residences that are within 250 ft of the lake's edge. These codes have stricter requirements for subsurface waste disposal systems than are in effect for inland residences. Septic tank sizes are larger now than in the past. The size of the septic tank is a function of the number of bedrooms in a residence (Bob Martin pers. comm.).

The residence age estimates obtained through the "windshield" vehicle road surveys aided in establishing initial estimates of the quality of the septic systems in the watershed. In 1974, it became required that site evaluations be performed before installing any type of subsurface waste disposal systems (MDHS 1988). Other stipulations of the 1974 state mandates include: at least 300 ft between a subsurface septic system and a well that uses more than 2000 gallons of water per day, septic systems must be built at least 100 ft away from any well when the system uses less than 2000 gallons per day, and 20% is the maximum slope of the land supporting a subsurface waste disposal system (MDHS 1988).

Septic systems are not the common problems they used to be; issues now tend to be more site specific (Karen Hahnel pers. comm.). Aging septic systems pose potential problems in that failure of the system results in a mass exodus of surface and/or subsurface discharge into the lake. There was a general consensus among the local officials we interviewed that there are no specific problem areas in the Long Pond, South Basin watershed.

The likely source of septic phosphorus loading to lakes is mostly due to older systems that are seasonally innundated or in contact with high grounwater eg. during spring. Bob Martin stated that recently he has been inspecting more new systems than old ones. When he does inspect old systems, he often has to recommend replacement of the entire system as a result of malfunctions, such as old cesspools no longer functioning, or plugged up leachfields emitting effluent up to the surface. Metal tanks have been a historic concern as well, because of their tendency to corrode over time; however, most in the watershed have now been replaced. Replacement systems have been put in for some residences in the Sandy Cove area, located on the eastern shore of Long Pond, South Basin (Bob Martin pers. comm.). He also noted that there are not many old pit privies located in the Long Pond, South Basin watershed (see Table 12). Mr. Martin said that as of July 1995 (the first upgrade since 1974), there must be a licensed site evaluator, more specific design concepts, and better soil requirements for putting in subsurface waste disposal systems for residences in the State of Maine, however, site evaluations have been an integral part of septic design for many years now.

Roads

Road Survey Methods

A comprehensive field survey was conducted on the paved roads, camp roads, and driveways contained in the watershed of the Long Pond, South Basin. The survey was conducted on 2-OCT-95 and 16-OCT-95, by groups of students both on foot and by car to evaluate the possible impact of the roads on the water quality of Long Pond, South Basin. Paved roads were divided into segments, the length of the segments were dependent on the differences in road conditions. Camp roads were surveyed in tenth of a mile sections, measured with either a measuring wheel or a car odometer. Widths for both types of roads were taken with either a measuring wheel or a tape measure. The road widths did not include adjacent ditches, but did include the road shoulder.

Paved Road Methods

Paved roads were evaluated using an integer scale from 1 to 5; 1 being the worst possible road and 5 being the best road. The roads were defined with the following categories:

5: Road was not crowned, very uneven with many cracks, large potholes, and severe gullying. The ditches were not always present, and when they were, they were not vegetated. Culverts were in poor condition (clogged and/or rusted) and were not always present when necessary.

4: Road was not crowned, had many cracks, potholes, and gullying and ditches were not thoroughly vegetated but were present when necessary. Culverts were in poor condition.

3: Road was unevenly crowned with few small potholes, few cracks, and minor gullying. The ditches were vegetated and present when necessary and culverts were in good condition.

2: Road was evenly crowned with no potholes, few cracks, and minor gullying. The ditches were vegetated and were present when necessary. Culverts were in good condition.

1: Road was evenly crowned with no potholes, cracks, heaving, or gullying; the ditches were vegetated and were present when necessary. Culverts were present and were in good condition.

The evaluation form for the paved roads contained a section for storm drain evaluation. It was noted whether an infiltration system was present, whether the sewer empties into the lake, and how many drains were present on the road (Appendix G).

Camp Road Methods

The camp road survey was conducted. The form we used was divided into eight sections: road surface, ditches, culverts, water diversions, road total, road segment total, road segment average, and a road sketch (Appendix G).

The Road Surface Total Index for camp roads was computed, based on data from field observations, to give an idea of the overall road condition. This evaluation consisted of the quality of the road's crown, surface constituents, edge, road material, and usage. A summary of the surface condition was determined by the survey with a scale of 1 to 5, 1 being the best possible road and 5 being the worst (Appendix G). The crown is important in draining the water off of the road surface as fast as possible with the least amount of time spent in contact with the road surface, so as to decrease the amount of erosion of the road and siltation of the runoff water. Crowns are most efficient when their heights are 0.5 to 0.75 in for every ft of road width (KCSWCD 1992). Although they are inexpensive and easy to maintain, crowns are most often neglected. It was first determined whether the surface was wet or dry on the particular day of observation, then the surface was further evaluated for its condition (Appendix G). Since a hard surface is less susceptible to erosion, it is the most desirable as opposed to muddy or dusty and loose. The road material was marked as gravel, gravel/sand, dirt, sand/clay, or clay, with gravel being the best and quality decreasing respectively, again due to erosion factors (Appendix G). Usage was recorded as either seasonal or year round, based on observations of the residences which the road served.

The Ditch Total Index is an evaluation of the road's ditches. The factors considered for evaluation were the presence or need for ditching, the depth and width of the ditch, the type of vegetation, and the shape of the ditch. When ditches are properly constructed and maintained, they serve to collect subsurface water that causes structural problems in the road, collect road and surface runoff and channel it to a proper collection and crossing point in the road, serve as a storage area for large amounts of rainfall, and collect soil particles that normally would be washed into a channel way (KCSWCD 1992).

The Culvert Total Index represents the overall culvert condition of the road. The culvert index was determined by evaluating the number present and/or needed, weathering (aging), size, internal contents (rocks, water, or silt), and covering material. These factors were examined and an overall culvert condition was estimated. Culverts are important in allowing water to cross the road surface, either above or below, without erosion or danger to vehicle traffic (KCSWCD 1992). Culverts should be installed when a stream, brook, or seasonal runoff intersects a road or when surface and subsurface flows accumulate and form flows that are difficult to contain in a ditch (KCSWCD 1992).

The Water Diversion Total Index is an evaluation of the turnouts and outlets for water running off the road. An overall water diversion condition was estimated by considering the number of water diversions present and/or needed, as well as where the water is diverted. A diversion into the woods was the best scenario and a diversion leading directly into the lake was the worst. Diversions are an effective means of decreasing the impact of surface water runoff on camp roads. They eliminate or reduce the need of culverts, allow for natural filters to clean silt from runoff, and prevent water from gaining velocity down the road bed and decrease volumes through increased filtrations (KCSWCD 1992).

The Road Total Index is a cumulative index which gives an overall evaluation of road condition based on four criteria: the sum of the surface total, ditch total, culvert total, and water diversion total.

Paved Roads

Bean Road received the top score of 1, the best condition. Also, the crowning, culverts, and the ditching on this road were sufficient. This road appeared to be newly paved. Belgrade Road was given a rating of 2 and 3 on the two sections that were surveyed. Narrows Road was rated as a 2 and Dunn Road received a score of 3 (see Table 14). These two roads are in generally worse condition than other paved roads in this

Table 14. Paved road evaluation, based on scale of 1 to 5, with 5 being the best condition.

Road	**Evaluation Number**
Belgrade Road (S of Castle Island)	2
Belgrade Road (N of Castle Island)	3
Narrows Road	2
Dunn Road	3
Bean Road	1

survey. Dunn road was unevenly crowned and had many cracks, potholes, and minor gullying. It is important to note that, in the case of all roads surveyed, the culverts were mainly in good condition, and the ditches were mostly vegetated and present when necessary.

Camp Roads

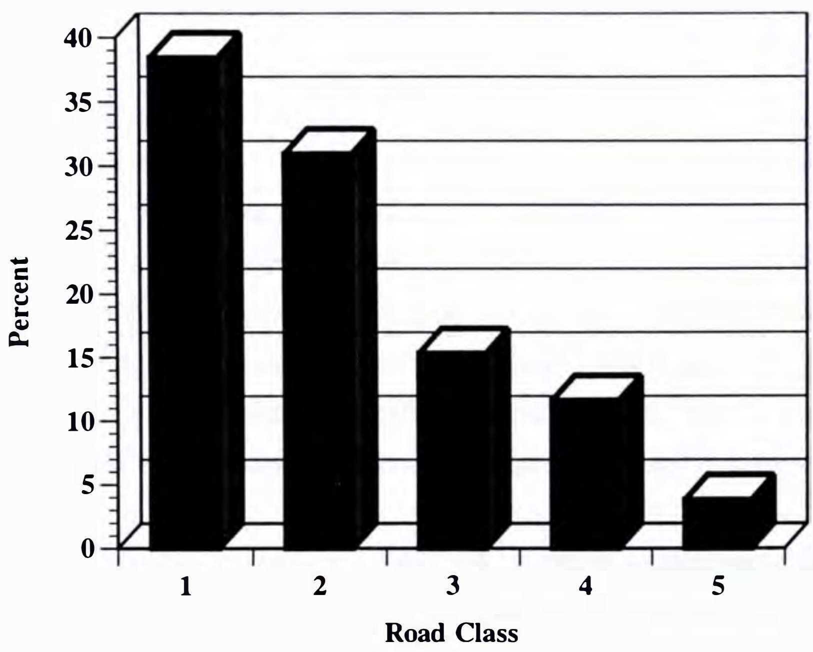

Figure 42. Percentage of roads within each road class based on the Road Total Index. Those roads in the first class have the best Road Total Index, and those in the fifth class have the worst.

Our study surveyed twenty-six camp roads with a general estimated surface area of 622,239.5 ft^2. The Road Total Index was divided into five classes: Road Total Index ranging from 37.0 to 103.6; RTI ranging from 103.6 to 170.2; RTI ranging from 170.2 to 236.8; RTI ranging from 236.8 to 303.4; and RTI ranging from 303.4 to 370 (see Figure 42). Of the 26 roads surveyed one, Road B, was in class 5, the worst category. There were three roads (11.6%) in class 4. These roads were: Carr Hill, Old Rome Rd, and Road C (see Figure 12). Most of the roads fell into the first class, the best category. However, it is important to look at the individual factors of each road.

Although the road may have a good Road Total Index, it may have rated poorly in one of the indices such as Road Surface Index, indicating the need for improvement.

The area where most roads were rated poorly was the Surface Total Index. The best possible score for this index is 4. The Surface Total Index of the surveyed roads ranged from 15.5 to 173.1 (Appendix G). Old Rome Road had a rating of 173.1, an excessively high number, and repairs and maintenance should be considered. The Ditch Total Index for the surveyed roads ranged from 1.0 to 200.0 Appendix G). Section one contained the most roads with poor ditching, this section as a whole should be repaired, especially because of its close proximity to Long Pond, South Basin (Appendix J). The Culvert Total Index and the Water Diversion Total Index were, for the most part, not deciding factors for the Road Total Index. Nevertheless, those roads with poor culverts or water diversions should not be overlooked.

Road B, located in the Northern section of the watershed, was classified as a 5, with a Total Road Evaluation Index of 370.0. Both the Surface Total Index and the Ditch Total Index were extremely high, 163.0 and 200.0 respectively. The surface was described by the survey team as having potholes and no crown. These factors combined seemed to be the biggest problem and it is therefore suggested that grading be considered to create a crown of 4-6 in. The high Ditch Total Index was due to the road's lack of ditching. With the installation of ditches along the road, this high figure should be mitigated. Since this road is used year round, improvement is necessary.

Carr Hill, located in the Northwest section of the watershed, also had a high Total Road Evaluation Index, with a value of 280.0 (see Table 15). The culverts and ditching are in good condition, however, diversions were not present and should be established. The surface was described as loose, which could lead to erosion, and should be improved.

Old Rome Road, also located in the Northwest section of the watershed, had a Total Road Evaluation Index of 265.4 (see Table 15). Excessive scores were recorded for the Surface Total Index and the Ditch Total Index. The surface of this road was mostly loose, and thus susceptible to erosion. There was some evidence of ridging, and the crown was fair. In some areas, however, the crowning was missing. General surface improvement and maintenance should be implemented, especially since there was a great deal of soil erosion found further down the road. Since this road is also used year round, it is important to improve and maintain the quality of this road.

Due to the lack of ditching present, Road C scored extremely high on the Ditch Total Index, leading to the high Road Total Index. The culverts and water diversions were in good shape. It is therefore suggested that the road surface and ditching be repaired and maintained.

Table 15. Surface Total Index, Ditch Total Index, Culvert Total Index, and Road Total Index Index for roads within the Long Pond, South Basin watershed.

Road	Surface	Ditch	Culvert	Diversion	Road Total Index
N5	15.5	125.0	5.0	2.0	147.5
Arden Cove	90.0	103.5	5.0	4.0	202.5
Road B	163.5	200.0	8.0	3.0	370.0
Road C	52.0	180.0	5.0	2.0	238.0
Road F	16.0	46.5	5.0	2.0	69.5
Pinewood Point	100.0	96.0	17.0	4.0	217.0
SE 1	20.0	1.0	5.0	2.0	37.0
Sandy Cove Road	123.0	92.5	5.0	2.0	222.5
Sandy Cove North	27.4	112.6	27.0	2.0	169.0
Sandy Cove South	21.0	32.7	17.0	2.0	72.7
East West Road	43.4	48.0	5.0	4.0	100.4
W2	48.7	80.8	5.0	2.0	139.4
Journey's End Road	127.5	11.7	8.0	2.0	149.2
J1	83.3	14.3	5.0	2.0	104.6
J2	76.7	13.3	5.0	2.0	97.0
J3A	27.0	10.0	8.0	2.0	47.0
J3B	49.3	10.7	5.0	2.0	70.0
J3	32.0	10.0	5.0	2.0	49.0
J4	19.5	22.6	5.0	2.0	49.1
Long Acres Assoc.	90.0	14.1	5.0	2.0	111.1
Taylor Road	94.0	48.9	5.0	3.0	150.9
Road H	90.0	115.0	8.0	2.0	215.0
Mooar Hill Road	73.3	62.7	5.0	3.0	144.0
Old Rome Rd	173.1	71.3	17.0	4.0	265.4
Carr Hill	30.8	20.8	5.0	15.0	280.0
Carr Hill Rd	20.8	30.8	5.0	2.0	58.6

Many of the roads were lacking in only one or two areas, such as Journey's End Road and Road C (see Table 15). Although it is still prudent to develop solutions to roads with specific problem areas, limited resources may necessitate concentration on those roads which fell into the worst classes.

The areas with the worst conditions were in the Northwest corner of the watershed, sections 1 and 4 (Appendix J). The roads located in Section 1 were located within a mile of the lake proper, increasing their potential impact on Long Pond, South Basin. For example, Pinewood Point and Arden Cove Lane run almost directly to the edge of the lake. For this reason, they should be repaired and maintained. Section 4, which was found by the survey team to have several roads in poor condition, should be an area of primary concern. Furthermore, the close proximity of the roads in this section to the Mt. Vernon dump and airport, areas of potentially high input of nutrients, make the repair and maintenance of the roads even more necessary.

In summary, the roads within class 5 and class 4, with more than one problem area may be the most vital to observe and repair initially. The location of the roads within the watershed affects their impact. Those roads located in close proximity to the lake will have more of an impact and therefore should have a higher priority for repaire and maintainece.

Road Runoff and Phosphorus Loading

Soil erosion can carry sediments and phosphorus into a water body. Slope length and grade are factors which determine the velocity and volume of this runoff (KCSWCD 1992). A goal of the road survey was to characterize the phosphorus loading potential of the roads in the Long Pond, South Basin watershed.

Clinometer readings were taken over lengths of 50, 100, 200, 500, and 1000 feet and expressed as percent grade. The data were collected following our Camp Road Survey sheet (Appendix G). Segment length and percent grade were related to a erosion potential coefficient; phosphorus loading potential was calcualted by tabulating all the erosion potential coefficients for a given road. The phosphorus loading potential is a relative index which characterizes the potential loading of phosphorus based on runoff from steep road segments.

The data were used to calculate the road segment average, the high phosphorus scores for sections within each road (if the erosion potential coefficient was greater than 23), the phosphorus loading potentials by sections of the watershed, and the percentage of each road with a grade greater than 7%.

As defined in the Camp Road Survey sheet, the road segment average is an index of the overall phosphorus loading potential of the road. The segment averages ranged from 6.7 to 42.5. Carr Hill had the largest road segment average at 42.5 (see Figure 43).
With a road segment average of 31.0, Road C was second on the list. Mooar Hill Road and Taylor Road also had high segment averages of 19.8 and 23.8, respectively.

The Camp Road Survey sheet has shaded areas for road segments with erosion potential coefficients of 23 and greater to represent high phosphorus loading potential. Therefore, trouble areas were defined as segments with an erosion potential coefficient of 23 and greater. With phosphorus coefficients of 73, some troublespots included segments on Taylor Road, Carr Hill, and Mooar Hill Road (see Figure 44).

Roads with steep grades contribute more to erosion and phosphorus loading than those with more shallow grades (KCSWCD, 1992). Road segments were classified as having a grade greater than or less than 7%. This value was arbitrarily chosen in order to separate the data and show which road segments had a relatively steep grade. These roads were then placed into four geographic regions clockwise around the lake, beginning from Castle Island (see Appendix G). When the percentage of each road with a grade over 7%

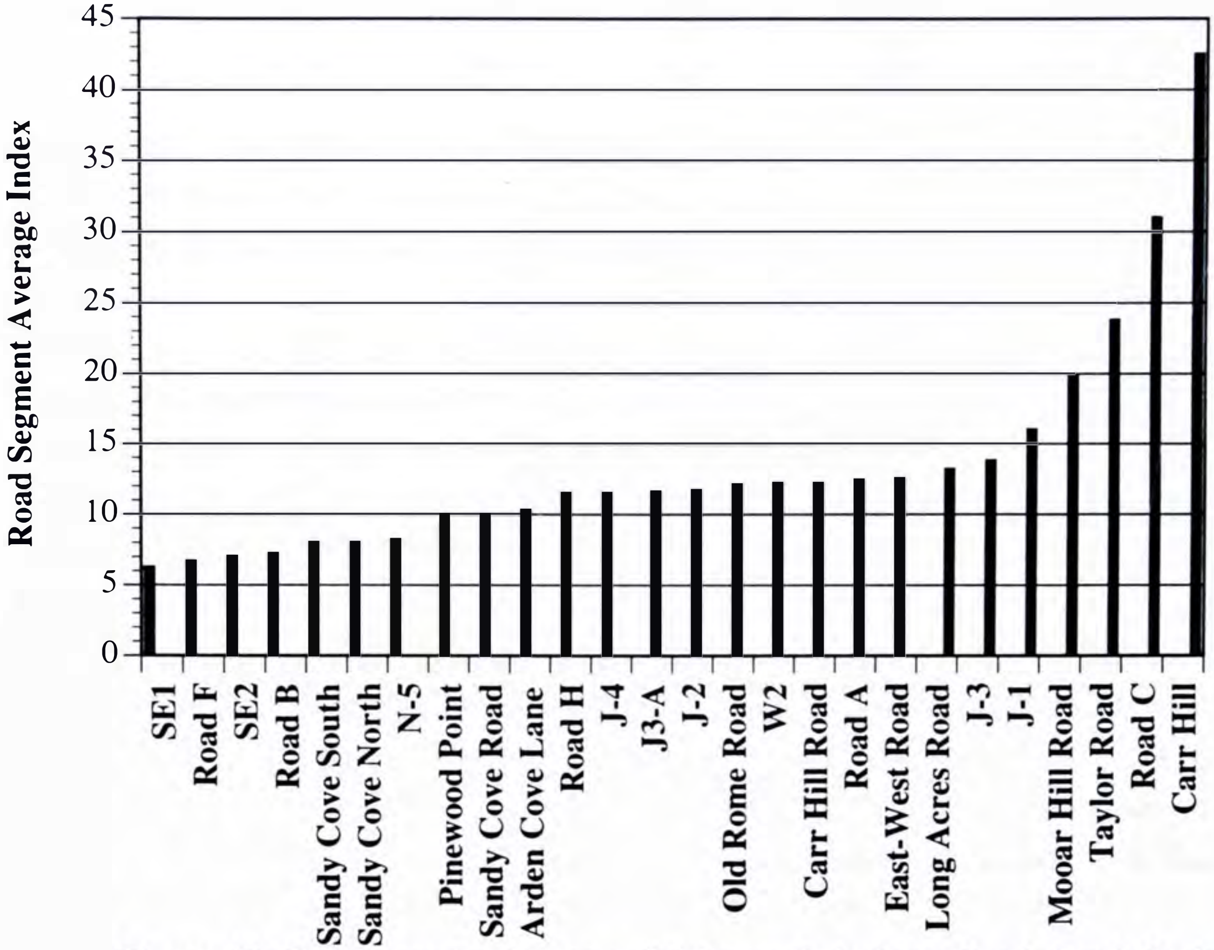

Figure 43. Phosphorus loading potential for roads in Long Pond, South Basin watershed, based on road segment averages. See text for detailed description of analysis.

was calculated, Carr Hill, Mooar Hill Road, and J-3 had the three highest percentages of road over a 7% grade (see Figure 45).

67% of Carr Hill was over a 7% grade. On Mooar Hill Road, 50% of the road had grades greater than 7%. Also, 42% of J-3 had grades of over 7%. These two regions are in the Western and Northwestern areas of the watershed (see Figure 12).

Carr Hill has a high phosphorus loading potential overall. This road had the largest road segment average, one of the highest phosphorus coefficients, and a high percentage of the road above 7% grade. This is mostly due to a 1000 ft segment with a 12% grade. This steep segment greatly increases the potential velocity of water and soil running down it. Other problem roads were Mooar Hill Road and Taylor Road. These roads had relatively

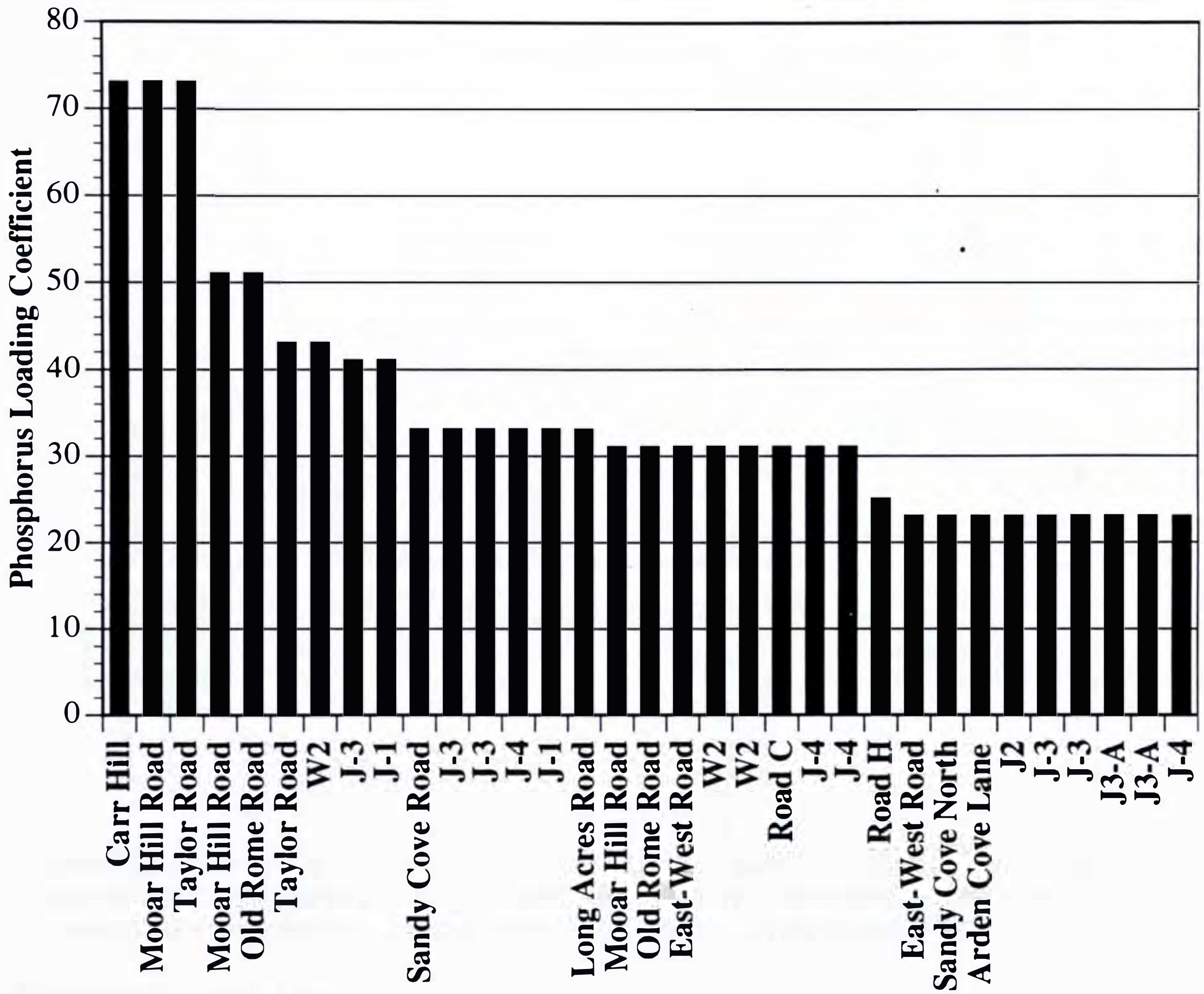

Figure 44. Highest phosphorus coefficients of road sections in the Long Pond, South Basin watershed taken on 02-OCT-95 and 16-OCT-95. Note: Multiple appearances of a road name means that more than one section of the road has a high phosphorus coefficient.

large phosphorus coefficients over certain sections as well as large road segment averages. These problem roads and others should be monitored for road surface quality, potholes, ditching, and culvert quality. These factors can increase phosphorus and erosion potential from roads.

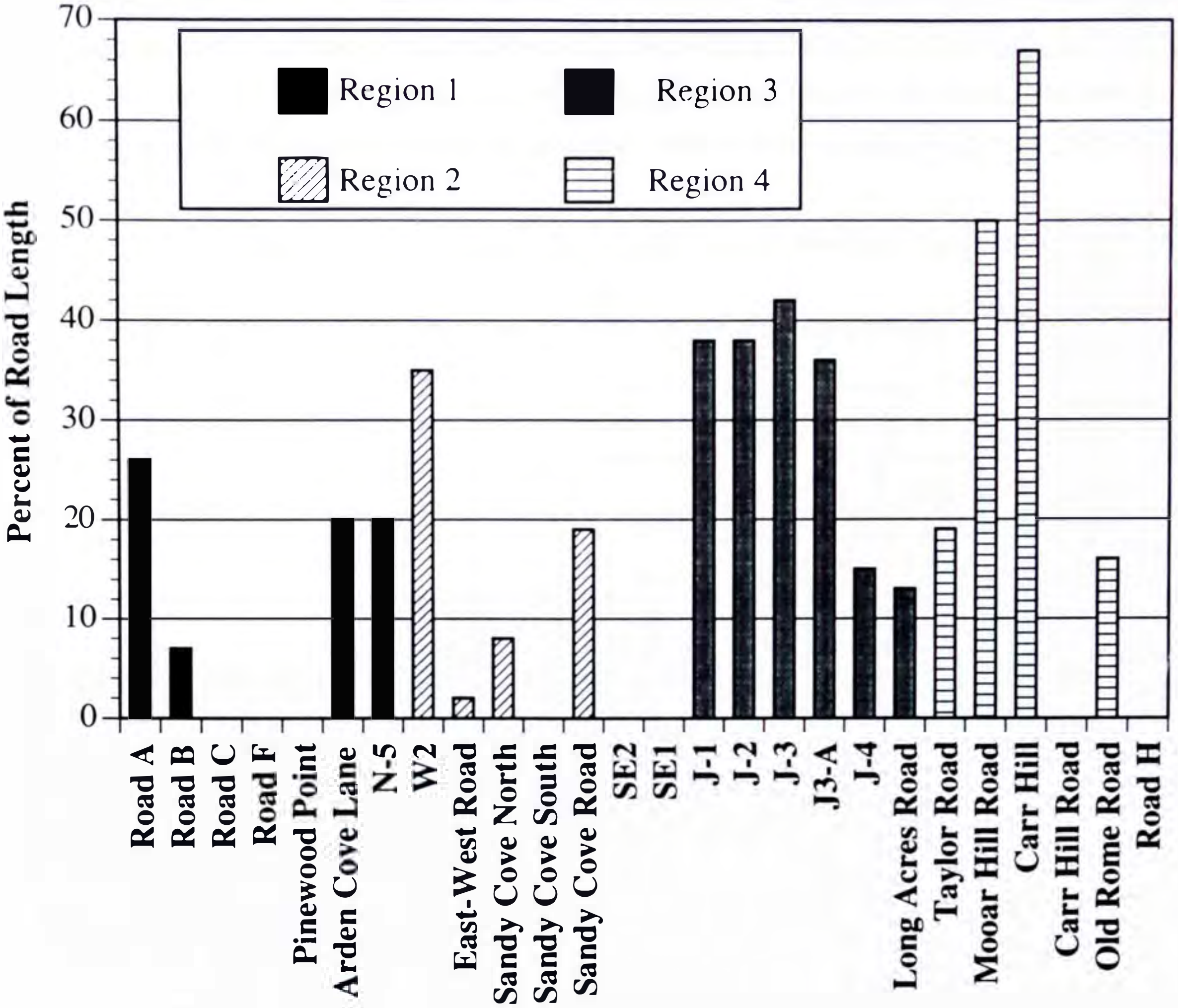

Figure 45. Percent of road length with grade greater than 7% in Long Pond, South Basin watershed, divided into four regions, beginning the Northern quadrant of the South Basin watershed. See Appendix J for quarterly divisions.

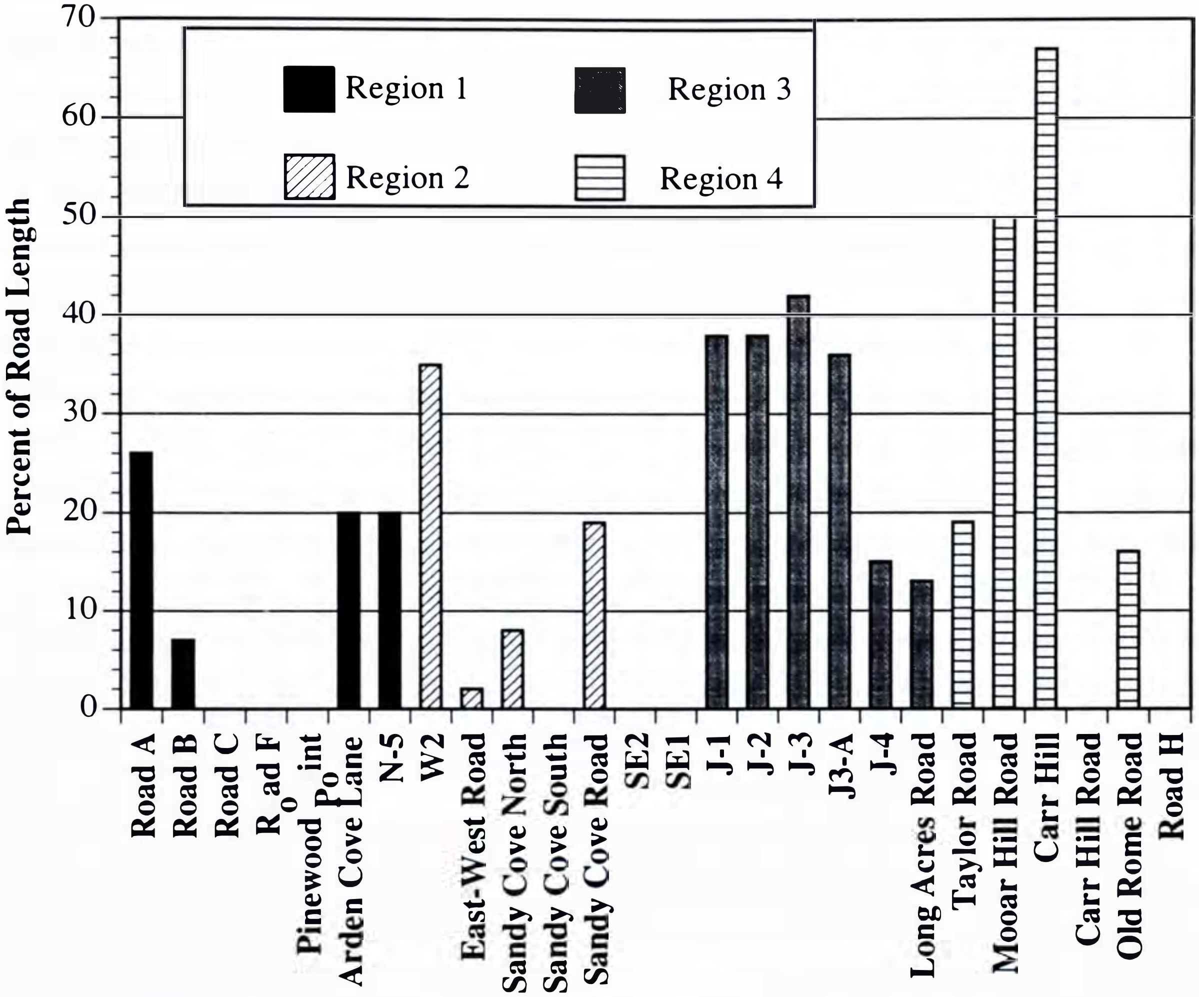

Figure 45. Percent of road length with grade greater than 7% in Long Pond, South Basin watershed, divided into four regions, beginning the Northern quadrant of the South Basin watershed. See Appendix J for quarterly divisions.

Municipal Land Uses

Belgrade Landfill

The Belgrade Landfill is located in the Southeast corner of the Long Pond, South Basin watershed (see Figure 12). The property, which is 37.4 acres, has a varied topography with a general westerly slope. To the west of the site and down slope is a wetland.

The Belgrade Landfill was closed in June of 1993, at which time the Belgrade Landfill Closure Plan was enacted (Belgrade 1995). The approval of this plan by the Maine Department of Environmental Protection was contingent on the development of the Post Closure Monitoring Plan (Belgrade 1995). The purpose of the Post Closure Monitoring Plan is to insure that the site is maintained in accordance with the closure agreement, to establish ground and surface water quality trends, and to determine the extent of any contamination that may affect the site or surrounding areas.

Actual steps taken to accomplish the above goals began in January, 1994. These steps include ground and surface water testing on a quarterly basis at selected monitoring wells and surface monitoring sites for at least thirty years; quarterly site inspections are to be conducted by municipal officials for the first five years after closure, and annually for at least thirty years; off site surface water monitoring annually of adjoining properties until it is determined that leachate flow has ceased; and site ground cover and erosion management for at least thirty years.

Data obtained from the Belgrade Town Office at the time of this report include the identification and location of ground water leachate seeps along the western boundary in the Report of Hydrogeologic Investigation of the Belgrade Landfill (Belgrade 1995). Also, results from water quality tests taken at 12 monitoring wells and 2 surface sites within the landfill between September of 1992 and June of 1995 were obtained (Belgrade 1995)

The monitoring well results suggest that the ground water is relatively high in mineral ions, phosphorous, and other dissolved solids. However, it is difficult to determine whether these levels are affecting the wetland adjacent to the landfill and even more difficult to know whether ground water is reaching the lake itself because of the varying topography of the land in between.

The landfill was closed appropriately with the enactment of the extensive management and monitoring plan. Continued monitoring of the site and the adjacent areas will provide the town of Belgrade and the MDEP with the ability to identify problems if they arise.

Mt. Vernon Transfer Station

The Mt. Vernon dump comprises 3.6 acres of land and is located along the western edge of the watershed in the town of Mt. Vernon (see Figure 12). It occupies an area of fairly steep, eastwardly sloping land and has an access road that is bordered on the west by Cobbs Hill Road and on the east by Bean Road. To the east and down slope is a wetland of considerable size. Currently the dump is used as a transfer station and a recycling center. We did not assess the procedure with which this dump was closed.

Gravel Pit

The Gravel Pit comprises 13.7 acres of land and is located in the Northwest area of the watershed, directly southeast of a tree farm and Old Rome Road in the town of Mt. Vernon. (see Figure 12). It occupies an area of generally flat topography and has a 0.8 mile access road that begins where Belgrade Road meets Bean Road. It did not appear to be active at the time of reconnaissance, but was probably active no more than a few years ago.

Mt. Vernon Airport

The Mt. Vernon Airport lies on a lot of 100.0 acres and is located in the Northwest area of the watershed, directly north of Belgrade Road where it meets with Bean Road (see Figure 12). It was not located during reconnaissance, but from the watershed map appears to occupy an area of generally flat topography. No information on its status of activity was acertained at the time of this report.

PHOSPHORUS LOADING

Methods

A model for total external phosphorus loading was adapted from Reckhow and Chapra (1983), and used to examine the input of atmospheric and land use phosphorus into Long Pond, South Basin. The phosphorus loading model is described by the following equation:

$$\mathbf{W} = (Ec_a \times A_{s1})+(Ec_f \times Area_f)+(Ec_{rf} \times Area_{cf})+(Ec_w \times Area_w)+(Ec_c \times Area_c)+(Ec_r \times Area_r)+(Ec_s \times Area_s)+(Ec_n \times Area_n)+[(Ec_{ss} \times \# \text{ of capita years}_1 \times (1-SR_1))+(Ec_{ns} \times \# \text{ of capita years}_2 \times (1-SR_2))]+PSI$$

In this equation **W** is the total mass of phosphorus entering Long Pond, South Basin each year. Ec is the export loading coefficient of each category (a = atmospheric input, f = forested land, rf = regenerating forest, w = wetlands, c = cleared land, r = roads, s = shoreline development, n = non-shoreline development, ss = shoreline septic, ns = non-shoreline septic). Low and high coefficients were modified from coefficients defined by Reckhow and Chapra (1983), and the following case studies: Higgins Lake (Reckhow and Chapra 1983), East Pond (BI493 1991), Pattee Pond (BI493 1993), Salmon Lake (BI493 1994), and Long Pond, North Basin (BI493 1995). The range between low and high coefficients represents the uncertainty in the loading estimates. Each coefficient was multiplied by the area corresponding to the specific category (As_1 = area of the lake, PSI = total of all point source inputs). Shoreline septic (Ec_{ss}) and non-shoreline septic (Ec_{ns}) were multiplied by the number of capita years (subscripts 1 and 2 respectively), and then by one minus the coefficients for soil retention (SR_1 and SR_2 respectively). Point source input (PSI) represents the phosphorus concentrations entering Long Pond, South Basin at the major points of inflow (see Appendix D). A detailed explanation of how the export loading coefficients, # of capita $years_1$ and $years_2$, and the PSI were determined is located in Appendix E.

The area of the lake and each land use in the watershed was obtained from ZIDAS and MicroStation Analysis, using a topographical map of the watershed and 1966, 1991, and 1992 aerial photos (see MicroStation Methods and ZIDAS methods). These areas were converted from square meters to hectares, for calculation of the total mass of phosphorus loading into Long Pond, South Basin per year (W) (1 ha = 10,000 m^2). The area of shoreline and non-shoreline development was determined by establishing a separate average lot size for shoreline and non-shoreline lots using Belgrade tax maps. These average lot sizes were then multiplied by developed shoreline and non-shoreline lots within the watershed.

Using the high and low total phosphorus loading results and the water budget for Long Pond, South Basin (see Appendix D), a low and high range estimate of the phosphorus concentration for Long Pond, South Basin was determined using the following equations from Reckhow and Chapra (1983):

$$\mathbf{L} = W/A_s$$

L is the annual areal phosphorus loading (the loading from the watershed area spread over the lake), and is calculated by dividing W (the annual mass rate of phosphorus inflow) by A_s (surface area of the lake).

$$\mathbf{q_s} = Q/A_s$$

In this equation, q_s is the annual areal water loading and is calculated by dividing Q (water inflow volume) by A_s (surface area of the lake). The Q for Long Pond, South Basin is the sum total of each I_{net} and its specific evaporation for the following lakes contributing to the South Basin of Long Pond: East Pond; Great Pond; Ingham Pond; Kidder Pond; Long Pond, North Basin; Long Pond, South Basin; Moose Pond; North Pond; Salmon Lake; Watson Pond; and Whittier Pond.

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

P is the predicted phosphorus concentration for Long Pond, South Basin. See Appendix F for calculations and results.

The phosphorus concentration coefficients were used to project loading changes as a result of an increase in development and a decrease in forested land over the next 20 years. Based on DOC data the average population growth for the watershed of Long Pond, North Basin is 16% over the next 10 years, resulting in an approximate 35% increase in development over the next 20 years (BI493 1995). This development prediction was used in a future projection of phosphorus loading for Long Pond, South Basin, since the two watersheds are similar in land use and development (see Future Trends section: Ramifications for Phosphorus Loading).

Results and Discussion

The Long Pond, South Basin watereshed incorporates 3892.0 ha. Mature and regenerating forest comprise 50.0% and 21.0% of the total watershed, respectively. Cleared land and wetland areas each comprise 7.0% of the total watershed, while shoreline residences, non-shoreline residences, and roads comprise only 5.0%, 1.0%, and 0.5% of the watershed, respectively.

Phosphorus loading coefficients were assigned both low and high range values for each land use in the phosphorus loading and mass rate of inflow model. The overall phosphorus concentration range, in parts per billion, from this loading model was compared to the actual phosphorus concentration range ascertained from Colby Environmental Laboratory analysis. The model's low and high values, of 3.9 to 12.2 ppb (Appendix F), were within the actual range values determined by laboratory analysis of surface samples (3.3 ppb to 14.7 ppb). The mean phosphorus concentration of surface samples for Long Pond, South Basin was 6.2 ppb.

The total amount of phosphorus loading into Long Pond, South Basin was estimated using the phosphorus loading model, multiplying the high and low coefficients by the areas of respective association (Appendix E). The low and high range values for this estimate were 1400.7 to 4376.4 kg-P/yr, respectively. Point source inputs contributed the greatest percentage of loading for both high and low estimates at 44.0% and 36.0%, respectively (see Figure 46). Although the actual loading in kg/yr increases near three fold from the low to high estimate, the percent contribution for point source inputs decreases because of greater loading increases from other sources.

Forested land contributes the second greatest percentage of the total phosphorus loading in the low estimate value at 22.0%, but only contributes the third greatest percentage in the high estimate value at 14.0% (see Figure 46). This decrease may be due to the greater loading increases from other sources. Regenerating forest contributes the third greatest percentage of total loading in the low estimate value at 18.0%, but contributes

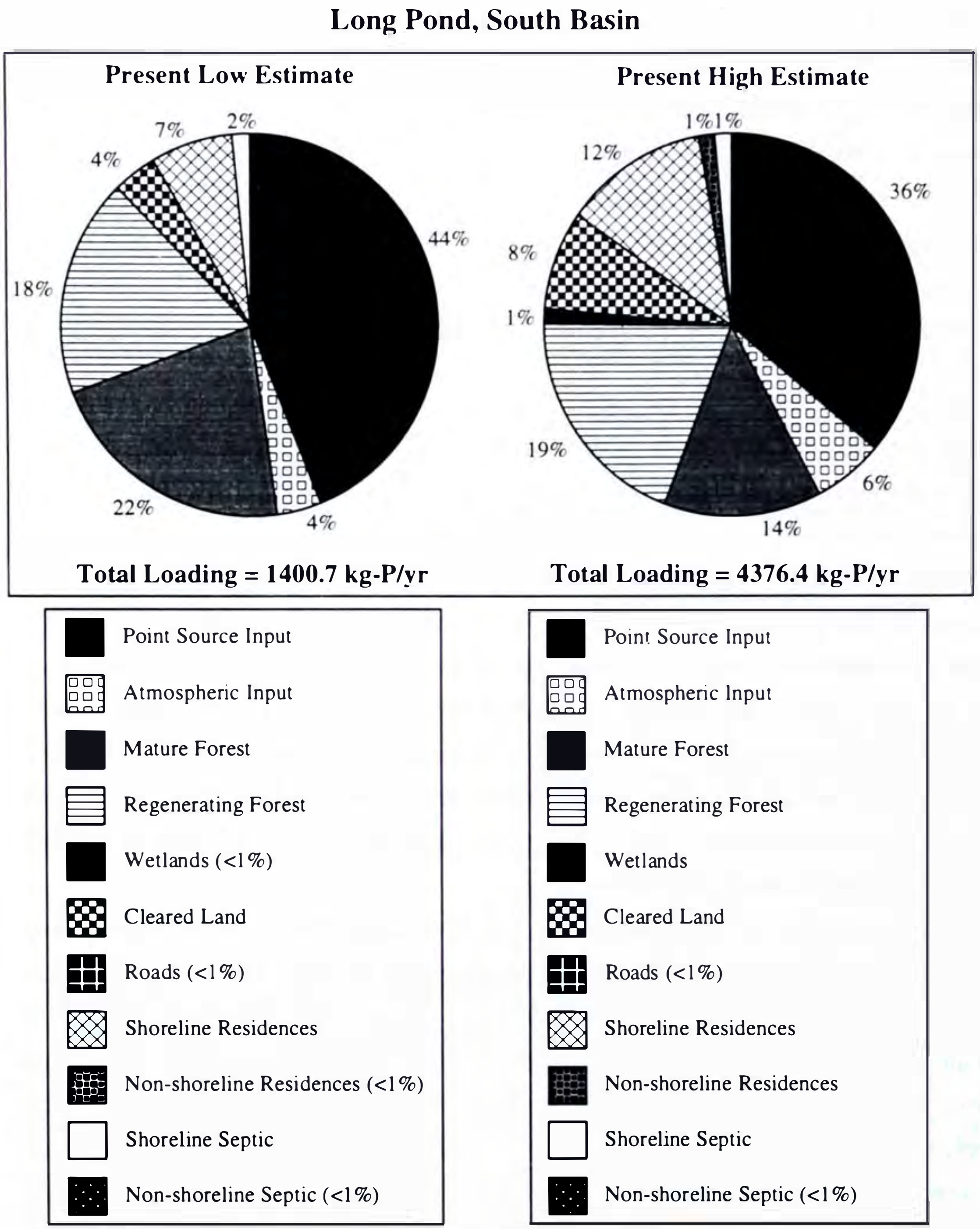

Figure 46. Low and high estimates of total phosphorus export loading from each land use within Long Pond, South Basin watershed. See Appendix E and Phosphorus Loading Methods for a detailed description of methods.

the second greatest percentage in the high estimate value at 19.0%. Regardless of this switch in contribution, these high values suggest the greatest overall percentage of land area contributing to phosphorus loading in the watershed is mature and regenerating forest land.

Although regenerating forest covers a smaller percentage of the total watershed than mature forest, it has a greater ability to contribute phosphorus to the lake because of its higher assigned coefficients due to higher runoff potential (Appendix E). Regenerating forest has a smaller phosphorus absorbing capability than mature forest, as a result of its composition and structure (see Phosphorus and Nitrogen Cycles).

Long Pond, North Basin's regenerating forests accounted for only 3.0 to 10.0% of total phosphorus loading (BI493 1995). This smaller percentage may be because regenerating forest in Long Pond, North Basin's watershed comprises only 14.0% of the watershed area, compared to the 21.0% of Long Pond, South Basin.

Shoreline residences contributed 7.0 to 12.0% of total phosphorus loading, while non-shoreline residences contribute less than 1.0 to 1.0% (see Figure 46). This may be a result of the closer proximity of shoreline residences to the lake, and the larger amount of watershed area shoreline residences occupy compared to non-shoreline residences, giving shoreline residences a larger phophorus export coefficient (Appendix E). Although shoreline residences contribute a significant amount of loading according to the model, shoreline septic systems only contribute 2.0% in the low estimate and 1.0% in the high estimate.

Atmospheric input and cleared land account for 4.0 to 6.0% and 4.0 to 8.0% of phosphorus loading, respectively (see Figure 46). The contribution of cleared land to Long Pond, North Basin's watershed was only 1.0 to 4.0% (BI493 1995). The higher estimate for Long Pond, South Basin may be due to the larger area of cleared lands in the watershed, and the greater number of active farms than in Long Pond, North Basin.

Wetland systems, roads, and non-shoreline septic systems contributed the least amount of phosphorus loading into Long Pond, South Basin. All values were less than or equal to 1.0% in both low and high estimate values.

The phosphorus loading model is an important tool in establishing which land uses could be contributing the most phosphorus to a lake and enhanceing decision making to monitor certain land uses or point sources in a watershed. This model can be used to examine future land use trends and the phosphorus loading changes that would result from these trends. What effect increased development would have on phosphorus loading is of particular importance (see Future Trends: Ramifications for Phosphorus Loading).

BATHYMETRY

Introduction

When considering the amount of phosphorus loading in a lake it is important to take into account lake sediments, which can act as a significant internal source of phosphorus (see Background: Phosphorus). Stratification of a lake can cause water in the hypolimnion to become anoxic. This lack of oxygen in water overlying the sediment facilitates the release of phosphorus from its P-Fe bond (Nürnberg 1987a). Determination of the anoxic factor of a lake can help quantify this internal phosphorus load because it takes into consideration the duration and areal extent of anoxia (Nürnberg 1987a) which, along with the rate at which phosphorus is liberated from sediments, are factors that determine the rate of internal phosphorus recycling.

The importance of sediment-derived phosphorus becomes especially evident in lakes with recently reduced external phosphorus loading (Nürnberg 1987a), since the amount of internal recycling can be as high as the external phosphorus inputs (Nürnberg 1987b). This has important implications when making recommendations for limiting phosphorus inputs in a water body. Measures taken to reduce phosphorus concentrations in lakes with high amounts of internal loading are very often difficult and extremely expensive (Roy Bouchard pers. comm.), therefore it is of utmost importance to prevent excessive amounts of external phosphorus from initially entering the lake.

In an attempt to determine the potential internal load of phosphorus for both the north and south basins of Long Pond, we calculated their anoxic factors and compared them with known values of other lakes in the area.

Bathymetry Calculations

Anoxic Factor

We first determined the oxycline from oxygen profiles provided by MDEP's "Water Quality for Long Pond" (1994). Dissolved oxygen (DO) levels less than or equal to 2.0 ppm were used as our criteria for calculating the days of anoxia and hypolimnetic area below the oxycline, since we wanted a conservative estimate. We calculated the number of days of anoxia, by noting the first and last day of anoxic hypolimnion in each basin and taking the difference between the two. On 7-SEP-94, the hypolimnion was anoxic at 23.5 m. Since this was the final sampling date for Long Pond, South Basin in 1994, we estimated an additional 30 days of anoxia. This 30 day period is an estimate and the exact anoxic period depends on the water column turnover for the lake. A depression of the thermocline, or early turnover, in the fall could possibly reduce the overall anoxic contact time below the 30 day estamate. The hypolimnetic area below oxycline was calculated by noting the depth at which anoxia occurred and adding all the hypolimnetic areas, which were given by MDEP as 1.0 m depth intervals (1994). If anoxia occurred between two depths, an average of the two areas was taken to determine the specific hypolimnetic area. The lake surface area for Long, Pond North Basin was provided by BI493 (1995) Zeiss

Interactive Digital Analysis System (ZIDAS) and data for South Basin was from MicroStation analysis. The anoxic factor is calculated as the following (Nürnberg 1987c):

$AF=(\sum t_x*a_x)/A$

where:

t_x= the period of anoxia (number of days)

a_x= hypolimnetic area (m^2)

A= lake surface area (m^2)

Total Phosphorus Change

To determine the total phosphorus change in kilograms, we needed to calculate the mass of phosphorus present before and after stratification of the lake. Our value for phosphorus concentration before the lake had been stratified (P_b) was based on measurements taken from MDEP on 7-JULY-94. This was early enough in the season that complete stratification had not yet occurred, possibly due to a fairly uniform temperature in the lake during the spring (Tim Christensen, pers. comm.). The phosphorus concentrations after lake stratification (P_a) were based on levels recorded by MDEP (1994) on 2-AUG-94 and 17-AUG-94, however, these dates do not account for potential phosphorus release in the last 4-6 weeks of stratification. We used the same volumes (v) when quantifying phosphorus amounts before and after lake stratification. Phosphorus concentrations (P_a and P_b) and volumes were multiplied to determine the amount of phosphorus before and after stratification. The total phosphorus change was calculated by subtracting the amount of phosphorus before stratification from the amount after stratification:

$(P_a*v)-(P_b*v)=TP$ (kg)

Total Phosphorus Release Rate ($mg*m^{-2}*d^{-1}$)

The total phosphorus release rate was calculated by dividing the change in total phosphorus by the contact area (10^6 m^2) and then dividing this by the anoxic period (number of days). Contact area was determined by the amount of sediment in contact with hypolimnetic water, given by the MDEP (1994). Finally, two values were calculated for Long Pond, North and South Basins using data from early and late July to get a estimate of the release rate during two different periods of lake stratification.

Results and Discussion

Anoxic Factor

Lakes whose sides slope evenly to their depth often have higher anoxic factor values than lakes which have narrow, deep holes because of the difference in sediment area that interfaces the anoxic water. The number of days that a lake's hypolimnion is anoxic also has a significant affect on the anoxic factor. In late summer months, lakes can become stratified when the surface water is heated and there is minimal mixing with the deep water. The isolated deep water is eventually depleted of its oxygen store and the anoxic water then serves to chemically reduce the P-Fe bond, thereby causing the release of phosphorus from the sediments. Lakes in which a large sediment surface area is overlain by anoxic water for an extended period of time can have large amounts of internal cycling of phosphorus.

The difference between the anoxic values for the north and south basins of Long Pond (24.3 days/year and 2.3 days/year, respectively) is probably due mainly to the difference in the shape of the two basins (see Table17). The close proximity of the two

Table 16. Comparative phosphorus and anoxia statistics for Three Mile Pond, China Lake, and Long Pond. Values for Three Mile Pond and China Lake are MDEP mean values from 1983 to 1992 (1994). Values for Long Pond, North and South Basins are 1994 MDEP ranges based on two different periods of anoxia.

	Km^2-Days	Anoxic Factor	TP Release Rate	TP Kg Change
Three Mile Pond	31	7.1	13.0	237
China Lake, Basin 2	54	9.8	4.7	222
China Lake, Basin 3	62	19.4	3.1	196
Long Pond, North Basin	29	24.3	0.36 to 1.35	6.46 to 50.93
Long Pond, South Basin	29	2.3	-1.97 to 6.16	-12.38 to 18.71

basins to each other suggests that events such as rain storms and other weather conditions that can affect lake stratification and thus alter anoxic conditions are similar between the two basins. Although the mean depths for the north and south basins are 8.9 m (BI493 1995) and 9.0 m respectively, their shapes are considerably different. Long Pond, North Basin has a basically evenly sloped basin whereas, Long Pond, South Basin is slightly shallower except for two deep holes. This difference in shape causes the north basin to have considerably more sediment-anoxic water interface area, while the anoxic water in the south basin is mainly concentrated in the deep hole where there is less sediment surface to release phosphorus (see Figure 47).

Figure 47. Bathymetry map of Long Pond, South Basin (MDEP unpublished data) as producded by GIS (see GIS Methods). Darker shades indicate deeper areas.

Whereas both basins of Long Pond are considered to have relatively good water quality, China Lake and Three Mile Pond have had serious problems in recent years with high phosphorus levels causing algal blooms (MDEP data 1980-1995). The anoxic factor for Long Pond, South Basin is lower than those recorded for Three Mile Pond and China Lake, Basin two and Basin three, however the anoxic factor for Long Pond, North Basin is our highest reported value (see Table 16). Using only the anoxic factor values, we would expect that Long Pond, North Basin would have the worst problems related to high phosphorus levels. This is not the case however, and these data lead us to agree with Nurnberg's (1987a) finding that internal phosphorus loading depends not only on the anoxic factor, but also on the rate of phosphorus release, which is related to the chemical quality of sediments. The stability of stratification is also an important determinant in the effect that sediment released phosphorus has on algal production, as a stably stratified lake may not have phosphorus reaching the surface waters.

Change in Phosphorus and Total Phosphorus Release Rate

Internal phosphorus (P) loading can control total lake phosphorus concentration and should be included in mass balance models, especially for lakes with recently reduced external phosphorus loading (Nürnberg 1988). The amount of sediment released phosphorus is dependent on the duration and areal extent of anoxia and on the rate with which phosphorus is discharged from the anoxic sediment surface. The calculated phosphorus release rate (RR) is expressed as $mg*m^{-2}*d^{-1}$. RR values less than or equal to 1.0 $mg*m^{-2}*d^{-1}$ are found in oligotrophic lakes; whereas, RR up to 50.0 $mg*m^{-2}*d^{-1}$ are found in eutrophic lakes (Nürnberg 1988).

Long Pond, North and South Basin's phosphorus change values were 6.5 to 50.9 kg and -12.4 to 18.7 kg, respectively (see Table 16). Both the north and south basins' low and high values were relatively small in comparison to Three Mile Pond and China Lake, which may be caused by the large amount of phosphorus found in these lakes (Tim Christensen pers. comm.). The high amount of phosphorus in China Lake and Three Mile Pond as compared to the North and South Basins of Long Pond may be partly due to the larger volume of water in these lakes than in Long Pond, North and South Basin.

Total phosphorus release rates for Long Pond, North Basin and Long Pond, South Basin were 0.4 to 1.4 $mg*m^{-2}*d^{-1}$ and -2.0 to 6.2 $mg*m^{-2}*d^{-1}$, respectively. Based on Nürnberg's values for lake classification according to release rate, our low value suggests that both lakes are oligotrophic. However, our high values (1.4 and 6.2 for the North and South Basin, respectively), also based on the Nürnberg scale, suggest that both lakes are slightly eutrophic. The difference between the high and low values may be attributed to the difference in lake stratification between the two sampling dates. The high values were calculated with data recorded later in the summer when DO concentrations in the hypolimnion were lower. This decrease in DO concentrations occurs because of lake stratification preventing mixing of hypolimnetic water with oxygenated surface water (see Background: Dissolved Oxygen). Our low value for North Basin was supported by BI493's study (1995) which concluded that Long Pond, North Basin is characterized as an oligotrophic/mesotrophic lake. South Basin's low RR value was slightly lower than North Basin's. Long Pond, South Basin's low range for RR was negative suggesting that phosphorus is being reabsorbed into the sediment. RR's for North and South Basin were both lower than Three Mile Pond and China Lake, Basins two and three (MDEP 1994). This may be the result of North and South Basins' relatively high water quality in comparison to the large amount of phosphorus found in Three Mile Pond and China Lake (Tim Christensen pers. comm.) (see Table 17).

FUTURE PREDICTIONS

Population Trends

Data obtained from the Maine Department of Human Services shows a similarity in the estimated population structures for Belgrade, Rome, and Mount Vernon in 1993. The percentage of the population above the age of 25 was significantly greater than the population below 25 in each municipality. In Belgrade 66% of the population was above the age of 25, in Mount Vernon 63% was above 25, and in Rome 67% was above the age of 25.

Trends in population growth are addressed in the comprehensive plans of specific municipalities. The only approved comprehensive plan available is for Mount Vernon, which projects a 25% growth rate for the next decade (Mount Vernon 1991).

Areas of new development were frequently seen during the analysis of the watershed of Long Pond, South Basin. This is a popular area for summer residences retirement homes. This appeal and popularity may be due to the accessibility of the area and its proximity to Interstate 95, Waterville, and Augusta. Also, the infrastructure and development, in terms of roads, grocery stores, and gas stations make it a comfortable place to live, seasonally or year-round. The municipalities of Belgrade, Rome, and Mount Vernon may soon have to accomodate the population increases and subsequent development increases projected for the remainder of the decade and beyond.

Development Trends and Potential

The number of undeveloped lots located in Long Pond, South Basin is a crucial element in determining the future development potential of the area, and, ultimately, the future water quality of the lake (see Figure 39 and Table 12 for information on undeveloped lots in the Long Pond, South Basin watershed). Mount Vernon, Belgrade, and Rome (Vienna was not included in our study as it occupied only a small portion of the watershed and was undeveloped.) are similar in terms of their proximity to larger cities, types of land use, and general characteristics (BI493 1994). The development within one town may signify the potential development in another. Belgrade is located twenty minutes by car from both Waterville and Augusta, the main areas for employment in the region (Belgrade 1987). This is a significant factor when looking at possibilities for increased development. The towns of Belgrade, Mount Vernon, and Rome are areas which are attractive for future development, due to the appeal of living in a more rural setting, not far from the employer. Also these towns are near I-95, and are therefore easily accessible and very attractive to camp and second home buyers from areas such as Southern Maine, New Hampshire, and the greater Boston area (Belgrade 1987).

Trends in growing development have already been seen in Belgrade, as there was a 19.0% increase in the number of residences between 1970 and 1980. (see Future Predictions: Population Trends, for population growth patterns). Approximately two-thirds of these residences were year round structures (Belgrade 1987).

The availability of undeveloped land is another key factor in determining the development potential of an area. As the property card analysis on the Long Pond, South Basin watershed (see Tax Map and Property Card Methods) revealed, a large percentage of the watershed acreage was undeveloped; 4384.8 acres. Some of this acreage is composed of wetlands which are not developable, and therefore it is necessary to subtract the wetland acreage from the total undeveloped acreage in order to obtain the potentially developable acreage in the watershed. MicroStation analysis revealed that 687.2 acres of the watershed are wetlands. Therefore, of the 4384.8 undeveloped acres in the watershed, 3997.6 acres, not excluding steep slopes and protected resources, (4384.8 - 687.2) are developable.

The size of the undeveloped lots are also important, in that those large lots (greater than 50.0 acres) have the potential to be sub-divided and therefore have the potential to host a large number of new residences and/or other structures. In addition to lot size, lot location may also influence sub-division potential. Of those developable lots, 28 lots were greater than 50.0 acres in size and totaled 2732.8 acres (see Table 13). 6 of those lots were on the shoreline, while 22 were inland.

Another important factor in determining the potential for development in an area is the proximity of undeveloped land to roads. Close proximity to roads indicates easier access for building, and to electricity and phone lines. Therefore, developable lots that are near existing roads have a greater short-term potential for development than those lots that are not near existing roads. Those lots that are not near existing roads may only have long-term development potential. In the total watershed, 1954.0 developable acres are near existing roads and are therefore developable in the short-term; 1065.0 of those acres are in Mount Vernon, 711.0 are in Belgrade, and 178.0 are in Rome. Currently in the total watershed 778.8 developable acres are not near existing roads and are therefore developable only in the long-term; 353.75 of those acres are in Mount Vernon, and 425.0 are in Belgrade. Rome has no developable land near roads.

Current regulations on development in the Long Pond, South Basin watershed are also important in determining development potential. The more strict the regulations are, the less the potential for development and the potential risk to water quality is. The minimum lot size for development is one acre, and existing smaller lots may be devloped

(Bouchard, pers. comm.). Mount Vernon requires 2.0 acres for every building, except for mobile homes that are part of a mobile home park which has been approved by the town, and requires that proposed structures be approved by the Planning Board, Code Enforcement Officer, and/or the Building Inspector (Mount Vernon 1995) (see Shoreland Zoning for more regulations).

In addition to these developable acres on lots of greater than 50.0 acres, there are another 964.8 developable acres (3697.6 total developable acres - 2732.8 developable acres on lots greater than 50 acres), ranging from 0.0-50.0 acre lots (see Table 13). If the laws of Mount Vernon were enforced for the entire watershed, 1848.8 acres of land could potentially be developed (2 acres per structure). Trends indicate that development of the watershed will continue (Belgrade 1987). This poses a potential threat to the water quality of Long Pond, South Basin due to the potential for increased phosphorus loading.

The potential for future development in the Long Pond, South Basin watershed is high. It is recommended that future development should be limited either by number of residences or by increased acreage required for development, and that development should be conducted in such a way as to minimize phosphorus loading to the lake.

Ramifications of Phosphorus Loading

Population increases within the Long Pond, South Basin watershed will eventually lead to an increase in development in the watershed. This growth in development may increase cultural sources of phosphorus and other nutrients, resulting in a decrease in the water quality of the lake. Therefore, it is important to monitor development and to make projections on the effects that increased development will have in the Long Pond, South Basin watershed. The phosphorus loading model was generated to estimate the effects of increased watershed development on the total phosphorus contributions to the lake (see Phosphorus Loading).

METHODS

For the phosphorus loading projections, we used an estimate of 35% increase in development over the next twenty years. This total estimate reflects a 16% increase per 10 year period for areas with population sizes similar to Long Pond, South Basin. We obtained this information from the study on Long Pond, North Basin (BI493 1995) as the two watersheds are very similar in land use and development trends. This 35% increase was divided into 20% shoreline development and 15% non-shoreline development. Future development was also considered to have spatial limitations due to the large area of wetlands and other undevelopable lands along the shoreline. Shoreline development was divided into projected seasonal (79%) and year-round (21%) values based on the current shoreline percentages. The increase in shoreline and non-shoreline development also took into account an increase in the number of capita years for septic contributions. The increased area of development was coupled with an equal decrease in mature and regenerating forest. This projection did not involve changing contributions from any other land uses or point source input although road area would be expected to increase with development. A further description of the phosphorus loading model can be found in the Phosphorus Loading Methods Section.

RESULTS AND DISCUSSION

The twenty-year projection for total phosphorus loading increased from the present low and high estimates of 1400.7 - 4376.4 kg-P/yr to future low and high estimates of 1422.6 - 4495.6 kg-P/yr. (see Figures 46 and 48 for present and future estimates). The projected phosphorus concentrations increased slightly from the current 3.9 - 12.2 ppb, to 4.0 - 12.5 ppb. Point source inputs still contributed the greatest percentage of total phosphorus loading in the low and high estimates of 43% and 35% versus the current estimates of 44% and 36%, respectively. Input from shoreline development increased slightly from 7 - 12% in the current estimates to 8 - 14% in the 20 year future projection (see Figures 46 and 48), and input from non-shoreline development increased from <1 - 1% to 1 - 2%. Development decreased the cummulative phosphorus input for both mature and regenerating forests from 41 - 33% in total present loading to 38 - 31% in total future loading, but caused no change in the contribution from cleared lands at 4 - 8% in both estimates (see Figures 46 and 48).

The increase in shoreline and non-shoreline development decreased the cummulative phosphorus contributions of both mature and regenerating forests to the lake, as future development was considered for only forested land areas. Although an increase in development may also result in an increase in the amount of cleared land, the relatively small percentage of cleared land within the total area of the watershed does not provide any significant increase to the total phosphorus loading. The degree of property and land clearing should be monitored according to state and/or town regulations for development, as these acts may provide a greater phosphorus loading potential via surface runoff and erosion for the future.

Long Pond, South Basin

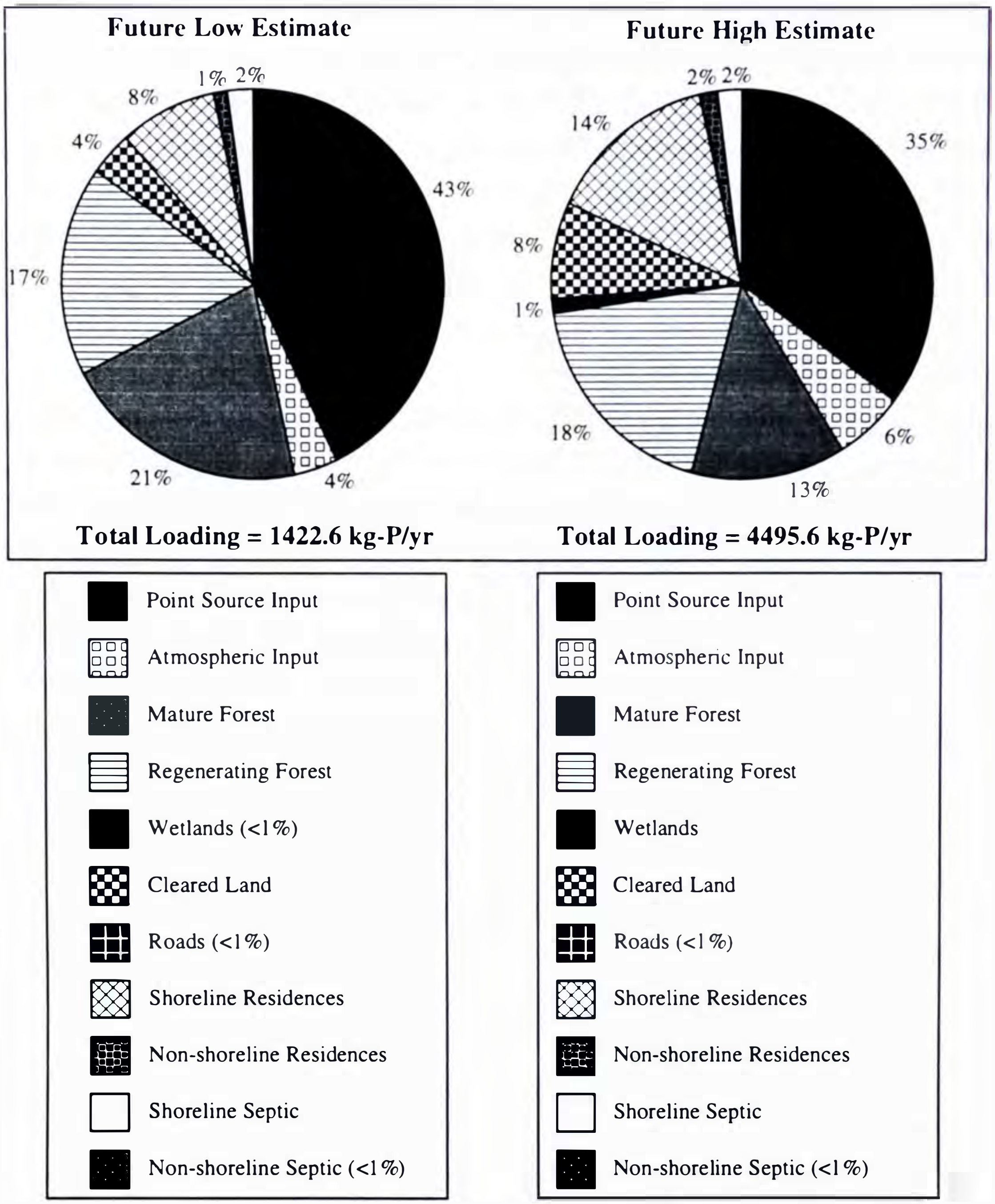

Figure 48. Future projection of low and high phosphorus loading from different land uses within the Long Pond, South Basin watershed. See Ramifications for Phosphorus Loading: Methods for a detailed description of methods.

The phosphorus loading model indicates that Long Pond, South Basin, like Long Pond, North Basin, is able to withstand many of the current cultural eutrophication processes (BI493 1995). Both watersheds are dominated by mature and regenerating forest area; the south basin is characterized by an even greater area than the north basin (Appendix E). The north basin receives a large water supply from Great Pond and other large tributaries, and reportedly has a flushing rate of 2.8 flushes/year, which is high in comparison to other Maine lakes (BI493 1995). The south basin receives its main water supply from the north basin at Site 1 (see Figure 12); and as one of the last major water bodies in the Belgrade Lakes chain, it possesses a high flushing rate of 4.5 flushes/year (Appendix D: Waterbudget). Although a high flushing rate may prevent premature and/or excessive rates of eutrophication to a lake system within one season, the phosphorus levels of Long Pond, South Basin should be maintained by monitoring shoreline and non-shoreline development. It is also important to monitor the total phosphorus loading contributions from all major upstream watersheds loading into Long Pond, South Basin, as they too have a great impact on the lake system (Appendix E for the basin's upstream watersheds).

SUMMARY
WATER QUALITY ANALYSIS OF THE LAKE AND ITS TRIBUTARIES

PHYSICAL AND CHEMICAL MEASUREMENTS

The average amount of dissolved oxygen (DO) at the surface (8.8 ppm) is adequate to support fish life and reproduction. In both the deep hole (Site 2) and in the Northwest bay (Site 12), at depths greater than 11.0 m, DO levels dropped below the threshold necessary for prevention of internal cycling of phosphorus and for fishkills during our sampling period. The measurements for transparency, turbidity, pH, color, alkalinity, nitrates/nitrogen, and hardness all fell within the range of what is typical for Maine lakes, and thus indicate good water quality. Total phosphorus values measured were all below the critical level of 15 ppm, indicating that Long Pond, South Basin is not currently in danger of cultural eutrophication. However, in the deep hole (Site 2) and the Northwest bay (Site 12), total phosphorus measurements at the bottom increased during our sampling period, approaching the level at which algal blooms occur. This was due to a lack of DO and internal cycling of phosphorus. The anoxic factor for Long Pond, South Basin was considerably lower than those of other lake basins in the area. This suggests that there is not a high potential for internal phosphorus cycling in Long Pond, South Basin relative to other area lakes. Furthermore, Long Pond, South Basin had a negative release rate at one point in the season, suggesting reabsorption of phosphorus by the sediment. The low anoxic factor for Long Pond, South Basin could be an important explanation as to why average total phosphorus concentrations were relatively low.

BIOLOGICAL MEASUREMENTS

Typically the buffer strips along the lake contained a fair amount of vegetation; however, there is still room for improvement.

Macrophyte populations were greatest in abundance and had the largest variety of species in areas along the shoreline where both development is concentrated and at the mouths of tributaries.

Of the three sites sampled for coliform, only one site (Site 5 off of Sandy Cove) had a value above the safe level for drinking water. However, all of the sites were far below the safe level for recreational use. It is important to note that these samples were taken in the early fall, when coliform is typically at the highest levels.

TRIBUTARY ANALYSIS

Tributary water turbidity, conductivity, and phosphorus concentrations are all related, since high levels of these measurements are caused primarily by an increased amount of sediment present in the water column. Measurements of these particular aspects of water quality were found to be higher in tributaries than in the open water of the lake. This suggests that the tributaries are supplying the lake with sediment containing ions and nutrients, including phosphorus, and are having a detrimental effect on lake water quality.

When rainfall amounts increase to the saturation point of the soil, much of the subsequent rainfall runs off into the lake tributaries. This runoff can potentially have a detrimental effect on lake water quality because it can carry even greater amounts of sediments and nutrients via the tributaries and into the lake as a result of increased flow rates.

WATER BUDGET

The flushing rate of 4.50 flushes/yr (Appendix G) for Long Pond, South Basin was lower than the flushing rate of 2.99 calculated for the North Basin of Long Pond (MDEP 1994). The higher flushing rate in the South Basin of Long Pond is most likely due to the narrow shape of the basin and the large amount of upstream inputs into the basin. The relatively high flushing rate of Long Pond, South Basin improves water quality, since nutrients are flushed quickly out of the basin and do not have time to accumulate within the water column.

Land Use Analysis

ROADS

Of the twenty-six camp roads surveyed, only four could be calculated as either category 4 or 5 roads, which are of concern. These roads were: Road B, Carr Road, Old Rome Road, and Road C. These roads were generally deficient in only one of the categories, such as surface condition, while the condition of the other factors were acceptable. The other roads in the watershed should not be ignored. Many of them, although acceptable overall, were deficient in one of the specific categories, such as ditching, culverts, or water diversions. A few camp roads, such as Road C, have high phosphorus loading potentials. The majority of these roads are in the north-northwest area of the watershed, an area which is relatively steep. Carr Hill is a steep road in the western part of the watershed, where phosphorus loading potential is high. Although the percent grade of the roads cannot be changed, upkeep of these roads can decrease the amount of phosphorus reaching the lake.

Most of the paved roads in Long Pond, South Basin were in good to very good condition. Crowns are present on the majority of the roads, except for the section of Belgrade Road, north of Castle Island. Culverts on these roads are in good condition. Maintenance should be continued to minimize potential phosphorus loading.

RESIDENTIAL DEVELOPMENT

The majority of shoreline driveways were classified as adequate. No driveways were noted with serious problems, such as deep ditches or severe erosion. Most of the inadequate driveways were classified as such because of poor surface materials or a lack of waterbars present when necessary.

Most residences in the Long Pond, South Basin have septic systems for their subsurface waste disposal system. Overall, the quality of the septic systems in the watershed are in good condition. There was a general consensus among local officials interviewed that there were no specific problem areas in the Long Pond, South Basin watershed. In July 1995, the first upgrade since 1974, it became required to have a licensed site evaluator, more specific design concepts, and better soil requirements for putting in subsurface waste disposal systems for residences in the State of Maine. This will help ensure that future development will not negatively affect lake water quality (Bob Martin pers. comm).

A greater percentage of the shoreline lots in the watershed were developed than undeveloped, and more residences were seasonal than year round. In contrast, a greater percentage of inland (non-shoreline) lots were undeveloped, except in Rome, where a greater percentage were developed. Of the inland residences, a greater percentage were year round than were seasonal, except for Belgrade, where there was a greater percentage of seasonal residences. For both shoreline and inland residences, a much greater percentage had septic systems than did not. The Long Pond, South Basin watershed appears to have a lower percentage of development compared to other lakes in the region. This, coupled with the large percentage of undeveloped land, may indicate a high potential for future development and for increased phosphorus loading.

POPULATION TRENDS

The towns of Mount Vernon, Belgrade, and Rome are very attractive for future development. There is a large amount of undeveloped acreage which does not lie on wetlands, and thus has the potential to be developed. Of the developable acres, 28 lots were greater than 50.0 acres in size. These large lots have the potential to be sub-divided and therefore have the potential to host a large number of new residences and/or other structures.

All three municipalities in the watershed of Long Pond, South Basin: Belgrade, Rome, and Mount Vernon, have populations with similar age structures. These structures are such that the present population probably will not increase rapidly in the region. However, the area around the lake is clearly a popular area for summer residences, retirement, and second home buyers since it is easily accessible from I-95, and because of the region's aesthetic appeal. With new areas of development already occurring in several parts of the watershed, the municipalities of Belgrade, Rome, and Mount Vernon will clearly have to accommodate population increases.

NATURAL LAND

Forested land occupies the greatest percentage of the watershed's land area. There has been substantial regrowth of forests in the last thirty years. This regrowth appears to be the result of decreased logging activity in the watershed.

From aerial photos taken in 1991, wetlands were found to occupy 687.2 acres, which is 8.3% of the watershed. This is approximately double the amount of wetlands in the Long Pond, North Basin watershed. The wetlands in Long Pond, South Basin may function as nutrient sinks, storing nutrients that filter through the region. Alternatively, the wetlands may contain high nutrient concentrations, which they are depositing into the passing water.

MANAGED LAND

Cleared land area in the watershed has decreased greatly over the last thirty years. This decrease suggests a trend away from agriculture and corresponds to an increase in forested areas. Areas with row cropping and pasture land have shown decreases in acreage, while lawn areas have shown increases in acreage. This suggests a trend towards increased residential development.

Recommendations

We would like to offer to the communities of the Long Pond, South Basin watershed, a set of recommendations to help maintain the high water quality of the lake. There are three main categories of recommendations: water quality monitoring, land use management, and educational programs.

Water Quality Monitoring

• Monitor phosphorus concentrations.

Although the present total phosphorus concentrations are not near the critical level that supports algal blooms, it is important to continue to monitor total phosphorus in Long Pond, South Basin. Total phosphorus concentrations at different levels of the water column should be measured at several times during the year, especially in late summer when the lake is most stratified. The monitoring program is also important to detect signs of internal phosphorus cycling.

•Monitor dissolved oxygen and temperature profiles, and turbidity.

It is important to monitor the physical characteristics of oxygen and temperature throughout the summer and fall months, to determine if oxygen levels drop below the 5.0 ppm threshold necessary for normal fish growth and development. Sites 2 and 12 are near threshold levels of anoxia, although the anoxic factor for Long Pond, South Basin was considerably lower than those of other lake basins in the area. These sites should be monitored and compared to phosphorus concentrations at other sites. If anoxic factor values begin to rise, methods of mitigation should be considered. Since turbidity is a good indicator of sediment and nutrient runoff into the lake, it should be monitored, especially in areas of high development and tributary inflows.

• Monitor other chemical and biological characteristics.

In addition to phosphorus, chemical analyses of water quality should be conducted several times during the year to watch for increases in nutrient concentrations. A further study should examine the sediment release rate of nitrate/nitrogen. Also, the effect of the Belgrade Landfill runoff on the water quality of the South Basin should be determined. Finally, coliform analyses should be conducted at areas of high development, especially during the summer when lake usage is high.

• **Monitor tributary water quality and contribution.**

Tributary water turbidity, conductivity, and phosphorus concentrations are all closely related because high levels are caused primarily by increased amount of sediment present in the water column. To reduce the amount of sediment runoff, road maintenance is extremely important near tributaries. It is essential to measure tributary water quality, such as phosphorus levels and flow, during periods of high flow, including the spring runoff, because an increase in flow usually leads to an increase in sediment in the water column.

• **Monitor Macrophyte Growth.**

Location and magnitude of macrophyte growth is often related to the amount of nutrient loading occurring in a specific area of the lake. Noting changes in macrophyte populations can be an indicator of areas with water quality problems.

• **Characterize wetland areas.**

Wetlands may function as nutrient sinks by storing nutrients that filter through the region. Alternatively, wetlands may contribute nutrients to water due to high nutrient concentrations caused by evapotranspiration from wetland surfaces. To determine thus, it is necessary to determine the nutrient buffering potentials of the wetlands by measuring flow, pH, and nutrient levels of the wetland soil across an elevational gradient. Wetlands make up a significant percentage of land area in the Long Pond, South Basin watershed; thus, it is important to investigate their impact on nutrient loading.

Land Use Management

• **Monitor forest growth and logging practices.**

Forested land occupies the greatest percentage of the watershed land area. There has been substantial regrowth of mature forests in the last thirty years, which could lead to an increase in logging pressure. Logging activity should be monitored closely. Slope, soil type, and potential erosion must be considered in placement of logging roads and trails.

• **Maintain roads and driveways.**

Road and driveway maintenance is extremely important in preventing excessive amounts of sediments and nutrients from entering tributaries or the lake directly. Roads and driveways need proper crowning, ditching, water diversions, surface material, and adequate culverts. Diverted water must be channeled into an adequate buffer, and not into tributaries or the lake. For roads with a high percent grade it becomes even more necessary to improve the road condition, since high grades increase the potential of phosphorus loading into the lake.

• Improve buffer strips.

Sites designated for development close to the shoreline should be carefully monitored. Builders should be encouraged to only clear as much vegetation as is needed and to quickly replant cleared areas after construction, so as not to leave loose sediments exposed and easily prone to erosion.

• Maintain proper septic systems.

It is important for residence owners to know how to prolong the life of their system, as well as what methods increase or decrease its effectiveness. Conserving water reduces the overall stress on systems. It is recommended that settling tanks be pumped on a regular basis (annually or bi-annually) so that the system does not get clogged with a build-up of solid waste. Residents should avoid the use of strong chemicals, such as bleach, which kill the microorganisms that consume much of the waste in settling tanks. Construction should not be allowed on top of any type of subsurface waste disposal system, as this could cause a system to collapse. Aging systems need to be monitored to make sure that metal tanks are not corroding and leachfields are not emitting effluent to the surface. It is also important that new septic systems be installed in proper soils.

• Conduct a lot by lot build-out.

Using the model reported in this study, conduct a lot by lot build-out to examine the effect of various development patterns on lake water quality. The results from these different scenarios could be used to establish a definitive development plan for the watershed.

• Monitor and regulate new development.

The potential for future development in the Long Pond, South Basin watershed is high. Future development should be monitored closely. Increased lot size required for development could be considered to decreases the total number of residences.

Educational Programs

• Increase education, awareness, and involvement to increase concurrence with regulations.

It is recommended that educational material such as information on zoning regulations, and other information on watershed property care, be provided to the residents of the watershed. Information on septic maintenance and proper disposal of hazardous materials should also be made available. A simple education campaign directed towards shoreline property owners to improve buffer strip quality should be designed. Towns workshops related to designing an effective buffer strip would be an effective way to convey information to the public. Short newsletters or pamphlets showing properly vegetated buffer strips would also be appropriate, and would not require much effort since educational materials regarding buffer strips already exist. Neighborhood organizations can ensure compliance with regulations.

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APPENDICES

Appendix A. ●n-Site and Laboratory Water Quality Tests

Appendix A. Table 1. Field measurements and laboratory tests of water quality taken from Long Pond, South Basin. See Figure RTGMAP1 for site locations.

Test or Measurement	Sampling Date	Analysis Date	Sample Sites
Physical Factors			
Flow Rate*	18SEP95	18SEP95	12,16,19,22
	25SEP95	25SEP95	7,19,22
Depth*	18SEP95	18SEP95	1,2,3,4,5,6,7,8,10,12,13,14,18, 19
	25SEP95	25SEP95	2,4,7,9,11b,12,16,19
Temperature*	18SEP95	18SEP95	2,4,6,12
Dissolved Oxygen*	18SEP95	18SEP95	2,4,6,12
Transparency*	18SEP95	18SEP95	2,5,7,8,12
	25SEP95	25SEP95	4
Turbidity#	18SEP95	18SEP95	1,2,3,4,5,6,7,8,9,10,11b,12,13, 16,18,19,21,22
	25SEP95	26SEP95	1,2,3,4,5,6,7,8,9,10,11b,12,13, 14,16,19,22
	6OCT95	6OCT95	19,21,22
Conductivity#	18SEP95	18SEP95	1,2,3,4,5,6,7,8,9,10,11b,12,13, 14,16,18,19,21,22
	25SEP95	25SEP95	4,11b
Chemical Factors			
Total Phosphorus#	18SEP95	23SEP95	1,2,3,4,5,6,7,8,9,10,11b,12,13, 14,18,19,21,22
	25SEP95	10OCT95	2,4,5,11b,12,13,14,16,17,19,22
	6OCT95	18OCT95	19,21,22
Alkalinity#	18SEP95	19SEP95	1,2,4,6,12
	25SEP95	26SEP95	1
Nitrate/Nitrogen#	18SEP95	18SEP95	2,4,5,8,10,12,13,14,19
	25SEP95	25SEP95	11
Hardness#	18SEP95	28SEP95	1,2,3,5,6,8,9,10,11b,12,13,14
	25SEP95	25SEP95	11b
Color#	18SEP95	19SEP95	1,2,3,4,5,6,7,8,9,10,11b,12,13, 14,18,19,21,22
	25SEP95	25SEP95	11b
pH*	18SEP95	18SEP95	1,2,3,4,5,6,7,8,10,11b,12,13,14, 16,18,19,22
	25SEP95	25SEP95	2,4,6,9,11b,12
Biotic Factors			
Coliform+	25SEP95	26SEP95	3,5,10,13

*Measurements were made on site
#Analyzed by Colby Environmental Laboratory, Waterville, ME
+Analyzed by Northeast Laboratories, Winslow, ME

Appendix B. Quality Assurance Plan

This is a Quality Assurance Plan explaining the test procedures the BI493 team followed during the Long Pond, South Basin study. The following document was modified from BI493 (1995) and information from Quality Assurance Plan for Clean Lakes Program: Lake Newport (1981).

Sample Bottle Preparation

1. A triple acid rinsing procedure will be used to clean all glassware or bottles used in sampling.

Approaching site and sampling

1. When approaching the test site by boat, travel at normal speed, and turn off the engine approximately 20.0 m away, coasting at maximum 2.0 mph to the sampling site.
2. Always sample from the bow of the boat, facing into the wind, and on the opposite side of the sun.
3. Hands should never touch sampled water. Use non-powdered rubber gloves. Make sure water doesn't drip into bottles from your arms or gloved hands.
4. When surface sampling, hold the bottle inverted to 0.5 m depth, draw water into the bottle from the natural current flow. If there is no strong current, push horizontally away from the sampler to 0.5 m. Then lift bottle out of the water and cap.
5. Bottles and lids should not touch any boat surfaces. Rinse with e-pure water if contact occurs.
6. After samples have been taken, immediately store all containers in ice cooler.

Depth

1. A Humminbird depth finder and weighted depth line was used to determine depth.
2. The weighted depth line must be dropped quickly and vertically, perpendicular to the water surface to ensure the most accurate measurement possible. Let the weighted cord drop to lake bottom until there is little slack. Gradually pull cord vertically upward until first appears completely straight and taut. Record this length as the appropriate depth.

Core Sample

1. Determine the depth to which the core samples will be taken. Core samples should be 1.0 m into the hypolimnion unless the epilimnion extends to the bottom. In this case,

take the core sample from the surface to 2.0 m above the substrate. You will need to use a depth line to locate the core sample tubes.

2. Avoid contamination with hands by wearing non-powdered rubber gloves.

3. Rinse the mixing jug and cover three times with surface water making sure all interior surfaces have been coated.

4. Rinse the container in which the core and jug are stored to avoid contamination.

5. Rinse the plastic 10.0 m core tube three times by lowering it into the water at least 1.0 m greater than the core to be taken, but not lower than 0.5 m from the bottom. Drain all rinsing water into the lake.

6. To obtain core samples, lower the unstoppered tube slowly to the appropriate length. The water inside the core should be about the same level outside the core during the lowering procedure; the sample will be weighted with a disproportionate amount of water from lower levels.

7. Once at the appropriate depth, stopper the core at the water surface tightly to ensure the sample stays within the core. Resample if any of the original is lost.

8. Only the weighted portion of the core should enter the boat.

9. Hold the weighted end over the opening of the pre-rinsed mixing jug. Release the stoppered end of tube, thoroughly draining water into the jug.

Conductivity

1. One duplicate sample for every ten samples.
2. Results should not vary more than 1 $\mu mhos/cm^2$ (or $\mu S/cm$).
3. De-ionized water should not vary more than 1 $\mu mhos/cm^2$ (or $\mu S/cm$).
4. Use the water sampler at the desired stratification.
5. Pour the water sample into its specified conductivity bottle.
6. A Model 31A YSI Conductance Bridge will be used to measure conductivity in the Colby Environmental Laboratory.

Acidification of Hardness and Nitrate/Nitrogen

1. To preserve water samples for analysis of hardness, HNO_3 is added drop by drop in the field until pH is just less than 2.0.

2. To preserve water samples for analysis of nitrates, H_2SO_4 is added drop by drop in the field until pH is just less than 2.0.

Hardness

1. A HACH DR/4000 Spectrophotometer Calmagite Colorimetric Method will be used to

measure hardness.
2. Hardness ppm equals ppm Ca as $CaCO_3$ plus ppm Mg as $CaCO_3$.
3. The precision for this method is $\pm$ 0.026 ppm $CaCO_3$.

Total Phosphorus

1. For every ten samples, duplicates are collected.
2. For every testing event, a split is made on one sample and each component measured. A duplicate sample is also split then spiked.
3. Spike recovery for nutrients should fall into the range of 80-120% to be acceptable.
4. A standard curve is generated to determine concentration of nutrient.
5. At least one externally supplied standard should be run each day of analysis.
6. Five percent of the samples should be reagent blanks. These are used whenever there might be sample carryover or when a sample is close to the detection limit.
7. Based on past studies the accuracy of the phosphorus analysis to be used has a detection point less than 1 ppb. The accuracy of the phosphorus analysis will be redetermined.

Total Nitrate/Nitrogen

1. Total nitrate/nitrogen will be tested using the Nitrogen, Nitrate low range 0.0-0.5 mg/L Cadmium Reduction Method of HACH.
2. This method of measuring nitrate/nitrogen has a precision of $\pm$ 0.02 ppm.

Dissolved Oxygen (DO) and Temperature

1. For every ten profiles, three duplicate readings should be made randomly.
2. Duplicate readings should not vary, more than $\pm$ 0.2 ppm.
3. If readings vary more than 0.5 ppm, repair of the membrane or meter is advised.
4. The electrode must be in circulating water.
5. Record DO measure immediately, if reading decreases keep the electrode moving in the water.

Secchi Disk

1. Duplicate reading on every tenth sample.
2. Use an Aqua-scope to view the disk.
3. Lower the secchi disk from the boat opposite the sun until it 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.

6. The limit of visibility is the mean depth at which the disk visually reappears.

pH

1. Before any testing is performed, the twinpH meter B-213 must be calibrated using a two point calibration method at a pH of 4.0 and 7.0. This needs to be done only once during the testing day as long as the meter's calibration is not deleted.
2. Check that the probe is working properly by measuring aerated de-ionized water. The meter should return to a value of 5.65.
3. Carefully rinse the probe with e- pure water prior to and following each measurement.
4. The accuracy of the twinpH meter B-213 is ± 0.1 pH.

Color

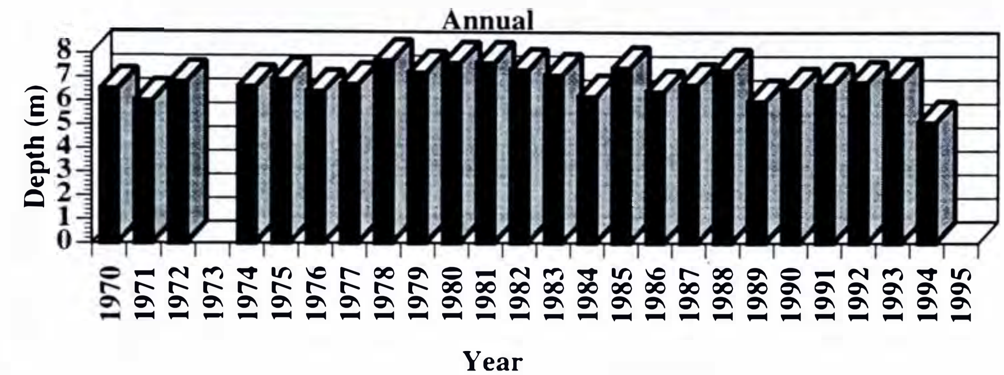
1. For every ten samples, a minimum of one duplicate should be taken.
2. Color should not vary more than ± 5.0 SPU.
3. Color standards should be stored in the dark and protected from evaporation.
4. A Hach DR/43000 Spectrophotometer Platinum-Cobalt Method is used for the color test.

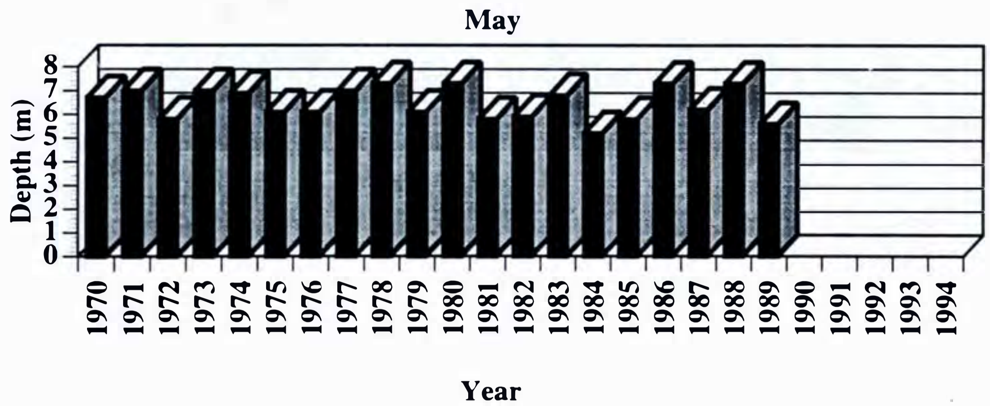
Chain of Custody

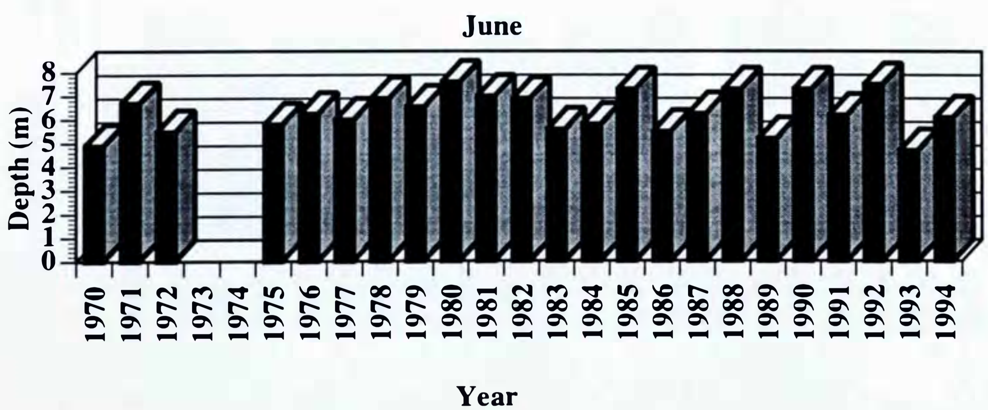
1. Before sampling, fill out contact (Biology 493), location (Long Pond, South Basin), and sampled by sections.
2. During the sampling procedures, enter field identification, date, time, container volume/type, field filtered, preservative, analysis requested (may be done before sampling), and any comments necessary.
3. When samples change hands, record relinquished and received by information on the chain of custody sheet, and the ultimate location of samples when brought back to the lab.

Appendix C. Results of Long Pond, South Basin Water Quality Tests.

Appendix C. Figure 1. Secchi disc readings from 1970 to 1994 by month (May to September) and annual averages for these months (MDEP 1994).







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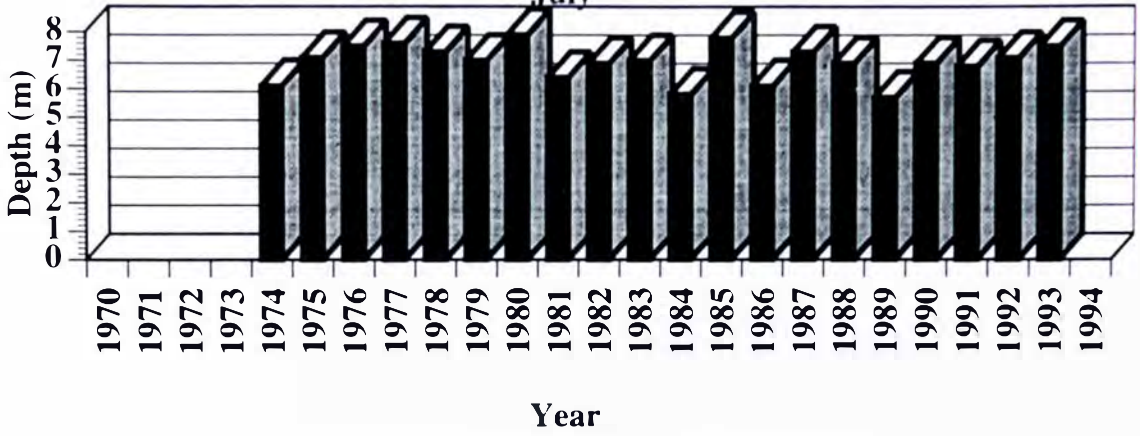

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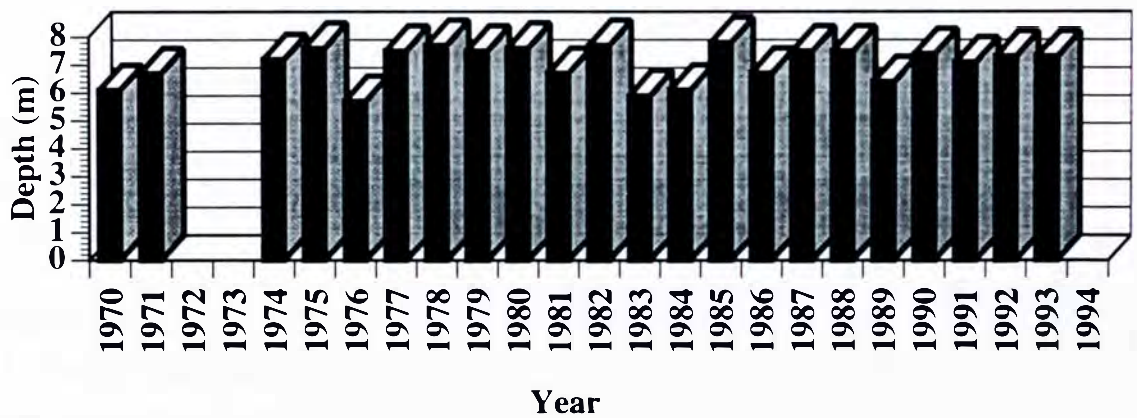

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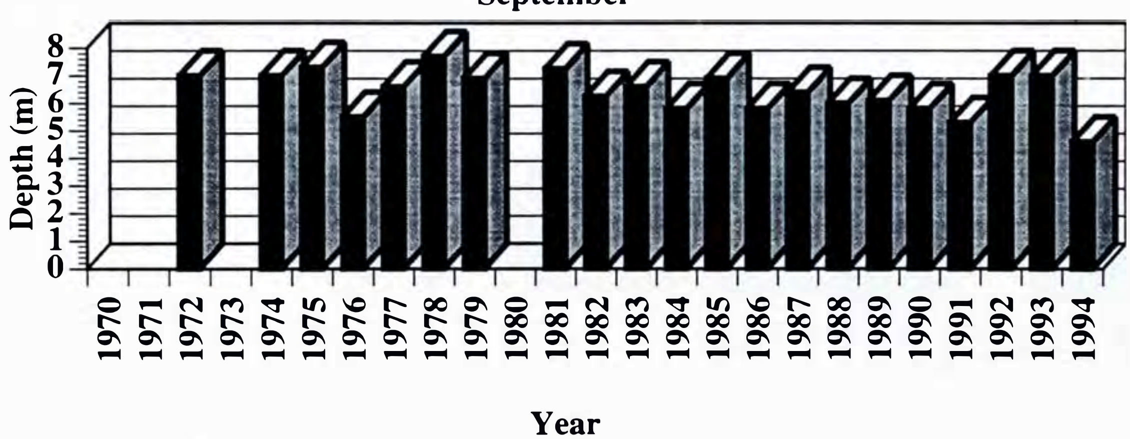


Appendix C. **Table 1**. Summary of the surface water quality tests for Long Pond, South Basin. Samples were collected on 18-SEP-95 unless otherwise noted. See Figure 12 for site locations.

Site	TP (ppb)	NO_3/N (ppm)	Hardness* (ppm)	Color (SPU)	Turbidity* (FTU)	Conductivity (µmhoms/cm^2)	Alkalinity (ppm $CaCO_3$)	pH	Transparency (m)	Surface DO (ppm)	Coliform (colonies/100 ml)
1	4.5†	0.03	1.86	7	1.5	31.0	9.0*	6.8	#	--	--
2	3.3 5.2	--	--	9	2.0	27.2	8.8 7.2	6.3	6.5	8.4	--
3	5.2†	0.04	3.35	10	2.0	34.0	--	6.5	#	8.9	1*
4	5.4 7.6 14.7	--	--	8	4.0	29.2	9.6	6.5	#	9.0	--
5	4.8 5.2*	0.05	3.73	4	2.0	46.0	--	7.3	#	8.9	3*
6	5.5	--	3.94	10	1.5	34.9	9.5	6.8	#	9.4	--
9	3.6	--	3.40	9	5.0	28.4	--	7.0*	#	8.6	--
10	3.9	0.04	3.43	8	2.0	40.0	--	6.8	#	--	2*
11a	11.3	--	3.71	--	--	47.0	--	6.5	#	--	--
12	3.7	--	--	10	2.5	29.0	8.0 8.0	6.0	6.5	8.5	--
13	6.2 8.9*	0.04	3.80	6	2.0	31.0	--	6.2	--	--	0*
14	5.7 6.2†*	--	3.60	7	1.0	36.0	--	6.4	--	--	--

* indicates samples taken on 25-SEP-95
† indicates an average of a split sample
# indicates shallow water with clear view to bottom

Appendix C. **Table 2**. Summary of surface water quality from Long Pond, South Basin tributaries. Samples were collected on 18-SEP-95 unless otherwise noted. See Figure 12 for site locations.

Site	TP (ppb)	Nitrate/Nitrogen (ppm)	Hardness* (mg/l)	Color (SPU)	Turbidity* (FTU)	Conductivity (μmhos/cm^2)	pH
7	4.5	--	--	10	2.0	35	7.0
8	14.2	0.05	0.03	37	7.0	41	6.9
11B	11.8	--	0.03	27*	5.0	--	6.5
15	--	--	--	--	--	--	--
16	18.8	--	0.13	41	8.0	82	7.3
17	--	--	--	--	--	--	--
18	--	--	--	45	--	100	7.9
19	12.3	0.03	--	58	9.0	78	6.3
20	--	--	--	--	--	--	--
21	--	--	--	--	--	--	--
22	12.3	--		45	6.0	43	--

* indicates sample taken on 25-SEP-94

Appendix C. Table 3. Summary of core, mid, and deep water quality tests for Long Pond, South Basin Characterization Sites. Samples were collected on 18-SEP-95. See Figure 12 for site locations.

Site		Total Phosphorus (ppb)	Nitrate/Nitrogen (ppm)	Hardness (mg/l)	Color (SPU)	Conductivity (µmhos/cm^2)
2	Core	11.8	0.06	0.05	--	--
	Surface	3.3 5.2 6.5	--	--	9	27.2
	Mid	--	--	--	9	26.0
	Deep	22.3* 22.6	0.07	--	14	27.5
4	Core	--	--	--	--	--
	Surface	5.4 7.6 14.7	--	--	8	29.2
	Mid	7.3	--	--	8	--
	Deep	7.2 7.8*	0.04	--	8	30.9
12	Core	8.8*	0.04	0.06	--	31.0
	Surface	3.7	--	--	10	29.0
	Mid	4.0	--	--	--	29.1
	Deep	5.8 6.5*	--	--	--	29.0

* indicates sample taken on 24-SEP-95

Appendix C. Table 4. Summary of the dissolved oxygen and temperature measurements at Long Pond, South Basin Characterization Sites. Measurements were made on 18-SEP-95. See Figure 12 for site locations.

	Site 2		Site 4		Site 12	
Depth (m)	DO (ppm)	Temp (°C)	DO (ppm)	Temp (°C)	DO (ppm)	Temp (°C)
1	8.4	18.0	9.0	17.6	8.5	18.3
2	8.4	18.1	8.8	17.7	8.3	18.3
3	8.4	18.1	8.8	17.8	8.3	18.2
4	8.4	18.0	8.7	17.8	8.4	18.1
5	8.3	17.9	8.8	17.8	8.3	18.0
6	8.3	17.8	8.6	17.8	8.3	18.0
7	8.3	17.8	8.2	17.7	8.4	17.9
8	8.3	17.8	6.8	17.7	8.3	17.8
9	8.1	17.7	--	--	1.6	15.3
10	7.6	17.2	--	--	--	--
11	3.3	13.0	--	--	--	--
12	2.5	12.3	--	--	--	--
13	2.7	11.5	--	--	--	--
14	3.4	10.8	--	--	--	--
15	4.7	9.8	--	--	--	--

Appendix C. Table 5. Summary of average values for nitrate/nitrogen, pH, and color measurements from the lake bodies of selected Belgrade Lakes.

Lake	NO_3-N (ppm)	pH	Color (SPU)
Long Pond, South Basin	.056	7.3	11.2
Long Pond, North Basin†	0.035 0.031*	6.8	11.5
North Pond*	0.034	7.0	24.5
Great Pond*	0.029	6.8	21.5
Messalonskee Lake*	0.043	7.0	38.0
Salmon Lake#	0.001	7.8	7.8
East Pond•	0.028	7.1	N/A

* Data taken from Davis et al. (1978)
† Data taken from BI 493 (1995)
\# Data taken from BI 493 (1994)
•Data taken from BI 493 (1992)

Appendix D. Flow Rate Data - Water Budget Calculation

Appendix D. Table 1. Water budget calculations for Long Pond, South Basin.

	units	value
Runoff	meters/yr	0.622
Precipitation	meters/yr	1.00
Evaporation	meters/yr	0.56
Land Area	square meters	33700000.00
Lake Area	square meters	5220000.00
Average Depth, Long Pond South Basin	meters	9.0*

* Depth obtained from MDEP unpublished data.

Inet, Long Pond South Basin (LPSB)	cubic meters/yr	**23,273,901.76**
Q (Long Pond)	cubic meters/yr	**26,197,101.76**
Q (Total)	cubic meters/yr	**214,409,267.64**
I_{net} Great Pond (GP)	cubic meters	102,720,000.00
I_{net} North Pond (NP)	cubic meters	27,485,202.88
I_{net} Long Pond North Basin (LPNB)	cubic meters	17,167,676.00
I_{net} Salmon Lake (SL)	cubic meters	16,480,434.00
I_{net} Ingham Pond (IP)	cubic meters	9,707,924.00
I_{net} East Pond (EP)	cubic meters	9,880,216.00
I_{net} Whittier Pond (WhP)	cubic meters	670,009.00
I_{net} Moose Pond (MP)	cubic meters	1,698,500.00
I_{net} Watson Pond (WP)	cubic meters	1,319,689.00
I_{net} Kidder Pond (KP)	cubic meters	1,082,515.00
Flushing Rate	flushes/yr	**4.50**

I_{net} = (Runoff*Land Area)+(Precip.*Lake Area)-(Evap.*Lake Area)

Flushing Rate = I_{net} LPSB+I_{net} GP+ I_{net} LPNB+ I_{net} SL+ I_{net} IP + I_{net} EP + I_{net} WhP + I_{net} MP + I_{net} + WP + I_{net} KP) / (LPSB Lake Area * LPSB Aver. Depth)

Appendix D. Table 2. Water budget characteristics for contributing watersheds to Long Pond, South obtained from BI493 (1991, 1994, 1995) and MIDAS files (MDEP 1994).

Watershed	Watershed Area (m^2)	Lake Surface Area (m^2)	Flushing Rate (flushes/yr)	Volume (m^3)
Salmon Lake	23,126,300	4,657,500	0.59	2,747,925
East Pond	10,949,000	6,769,624	0.29	33,848,120
North Pond	37,700,000	9,110,000	1.00	35,435,370
Great Pond	82,760,000	33,130,000	0.43	240,649,445
Long Pond, North Basin	24,164,589	5,212,900	2.79	46,284,687
Kidder Pond	1,658,530	124,170	3.54	256,400
Watson Pond	1,939,500	276,390	1.41	879,055
Whittier Pond	10,021,300	105,380	5.92	3,361,621
Long Pond, South Basin	33,700,000	5,220,000	4.50	47,032,200
Ingham Pond	15,364,040	341,960	8.55	1,333,644
Moose Pond	2,532,660	277,840	3.18	533,452

1 I_{net} = (Runoff * Land Area) + (Precipitation * Lake Area) - (Evaporation)

Appendix E. Phosphorus Equation

$W = (Ec_a \times A_{s1})+(Ec_f \times Area_f)+(Ec_{rf} \times Area_{rf})+(Ec_w \times Area_w)+(Ec_c \times Area_c)+(Ec_r \times Area_r)+(Ec_s \times Area_s)+(Ec_n \times Area_n)+[(Ec_{ss} \times \#\text{ of capita years}_1 \times (1-SR_1))+(Ec_{ns} \times \#\text{ of capita years}_2 \times (1-SR_2))]+PSI$

Ec_a = export coefficient for atmospheric input [kg/ha-yr]
0.10 - 0.50
Reckhow and Chapra (1983) report a general range of 0.15 - 0.60, with 0.15 - 0.50 for Higgins Lake. Long Pond, North Basin (BI493 1995) was similar to the Higgins Lake case with little agriculture and industrial activity, and resulting low quantities of airborne phosphorus. Long Pond, South Basin is comparable to the North Basin, and the same coefficients were chosen for the South Basin.

Ec_f = export coefficient for forested land [kg/ha-yr]
0.15 - 0.30
Reckhow and Chapra (1983) assigned a range of 0.10 - 0.30 for Higgins Lake, with the same range for Long Pond, North Basin (BI493 1995). This range was based on the primary land component as being coniferous forest with few deciduous trees, limited agriculture consisting of grazing and pasture, residential/recreational type urban areas, and housing units serviced by septic systems. Since there are only a few shoreline homes without septic systems in Long Pond, South Basin, there is a slight increase in the low coefficient of the North Basin.

Ec_{rf} = export coefficient for regenerating forest [kg/ha-yr]
0.30 - 1.0
Long Pond, North Basin was assigned a range of 0.10 - 0.70 (BI493 1995), values between the forested and cleared land coefficients. These values were based on considerable openings of the regenerating forest canopy, and skidder trails on steep slopes near the lake. The range for Long Pond, South Basin is also between the forested and cleared land high coefficients, with higher values than the North Basin due to more skidder trails and greater areas of cleared land and regenerating forest.

Ec_w = export coefficient for wetlands [kg/ha-yr]
0.03 - 0.20

This coefficient is from Long Pond, North Basin (BI493 1995), Pattee Pond (BI493 1992), and East Pond (BI493 1991; Bouchard 1991), as all share the same range for their respective watersheds as these land uses are similar for all aforementioned watersheds.

Ec_c = export coefficient for cleared land [kg/ha-yr]

0.20 - 1.4

Pattee Pond (BI493 1992) and Long Pond, North Basin (BI493 1995) were assigned a range of 0.10 - 1.0 as there were few farms, except for a dairy, cattle, or strawberry farm contributing little phosphorus to the watershed. Since Long Pond, South Basin has several active nonshoreline farms, including tree farms, hobby farms, and chicken hatcheries, slightly higher coefficients are assigned to both low and high values.

Ec_r = export coefficient for roads [kg/ha-yr]

0.40 - 2.0

Pattee Pond (BI493 1992) was assigned a range of 0.80 - 4.0, considering many unmaintained and eroded roads near the lake. Salmon Lake (BI493 1994) had a range of 0.30 - 1.5 as a result of better road conditions. The same range for Long Pond, North Basin (BI493 1995) is assigned to this basin.

Ec_s = export coefficient for shoreline development [kg/ha-yr]

0.50 - 2.8

Reckhow and Chapra (1983) report a general range of 0.50 - 5.0, and assigned a range of 0.35 - 2.7 to the mostly residential/recreational Higgins Lake case study. Salmon Lake (BI493 1994) was assigned 0.80 - 3.2 as many homes were in close proximity to the shoreline, and Long Pond, North Basin (BI493 1995) was assigned 0.80 - 3.0 as the area was similar to Salmon Lake.

Ec_n = export coefficient for nonshoreline development [kg/(capita-yr)-yr]

0.35 - 1.5

Long Pond, North Basin (BI493 1995) was assigned a range of 0.35 - 1.7 reflecting coefficients chosen for Higgins Lake (Reckhow and Chapra 1983), and because nonshoreline homes have a smaller impact on the watershed as opposed to shoreline homes

Ec_{ss} = export coefficient for shoreline septic tank systems [kg/ha-yr]

0.40 - 1.2

Reckhow and Chapra (1983) report a general range of 0.30 - 1.8, and assign Higgins Lake a range of 0.30 - 1.0. Pattee Pond (BI493 1992) assigned a range of 0.60 - 1.8, and Long Pond, North Basin (BI493 1995) assigned a range of 0.40 - 1.0 as septic systems were in fairly good shape and considered to add little phosphorus loading as a result. Long Pond, South Basin was assigned a slightly higher coefficient than North Basin as a few homes only owned privies for waste disposal.

# of capita $years_1$ = # of persons contributing to septic systems (number of persons x days/yr) x # living units

The same estimate of 3.5 persons per living unit was assigned as Long Pond, North Basin (BI493 1995). The number of days spent in seasonal units was raised to 77 days/yr, in comparison to Pattee Pond and Long Pond, North Basin's 40 days/yr, because while performing road surveys in late September, residences were still inhabiting their homes. The number of seasonal versus year-round residences were determined from road survey data and town property cards. There were 78 seasonal shoreline and 21 year-round shoreline homes, determined from road survey data, and analyzing tax maps and property cards. It was not assumed that seasonal homes would only be located along the shoreline.

SR_1 = soil retention coefficient for shoreline development [dimensionless]

0.40 - 0.60

This assigned range indicates how well the watershed soils retain phosphorus and prevent its flushing into Long Pond, South Basin. The values may range from 0 to 1, with 1 indicating a strong ability to retain all phosphorus, and 0 indicating no ability to retain the phosphorus which enters the soil, eventually reaching the lake (BI493 1995). The above range was given to Long Pond, North Basin and Long Pond, South Basin based on the similarities between the two basins.

Ec_{ns} = export coefficient for nonshoreline septic tank systems [kg/(capita-yr)-yr]

0.30 - 1.0

This assigned value is based on Higgins Lake (Reckhow and Chapra 1983) and Long Pond, North Basin (BI493 1995).

# of capita $years_2$ = # of persons contributing to septic systems (number of persons x days/yr) x # living units (nonshoreline residents)

The same estimate of 3.5 persons per living unit was assigned as Long Pond, North Basin (BI493 1995). The number of days spent in year round units was 355 days/yr, the same value for Long Pond, North Basin (BI493 1995). The number of seasonal versus year-round residences were determined from road survey data and town property cards. There were 80 nonshoreline homes within the watershed, determined from road survey data, and analyzing tax maps and property cards.

SR_2 = soil retention coefficient for nonshoreline development [dimensionless]
0.80 - 0.90

This assigned range is the same as Long Pond, North Basin (BI493 1995) because each watershed consists of similar soil types. Nonshoreline units are further located from Long Pond, South Basin, allowing for a greater soil retention of total phosphorus. However, residential units located near tributaries may have a direct loading of phosphorus to the basin. This increases the soil retension coefficients for the watershed from the very low values that would have been assigned if only the soil types were considered for these coefficients, and not the possible tributary loading of phosphorus.

PSI = point source input [kg/yr]
599.4 - 1558.7

Point source input is first determined by the major points of inflow into Long Pond, South Basin , being the major inlets from North Basin and Ingham Stream (see Figure RBG1 for site locations). For the North Basin, a high and low phosphorus concentration was based on the range determined for mid-lake sites from Long Pond, North Basin (BI493 1995). These values were then multiplied by the sum of the individual I_{net} values for Long Pond, North Basin (including Whittier Pond, Watson Pond, and Kidder Pond), Great Pond, Salmon Lake, North Pond, East Pond, (Appendix D). The product of these values were converted to kg/yr. The phosphorus concentration from Ingham Pond was used as the high value for Ingham Stream, and the phosphorus concentration where Ingham Stream meets Long Pond, South Basin was used as the low value (Appendix C). Ingham Stream's high and low values were multiplied by the sumation of the individual I_{net} values from Moose Pond and Ingham Pond (Appendix D). The product of these values were also converted to kg/yr. All respective high values and respective low values were added together to obtain a total high and low point source input of phosphorus for Long Pond, South Basin.

Area values for land use components and # of capita years

As_1 = area of Long Pond, South Basin = 522.0 ha
$Area_f$ = area of mature forest = 1954.2 ha
$Area_{rf}$ = area of regenerating forest = 835.8 ha

$Area_w$ = area of wetlands = 278.3 ha

$Area_c$ = area of cleared lands = 255.7 ha

$Area_r$ = area of roads = 19.3 ha

$Area_s$ = area of shoreline development = 190.8 ha

$Area_{ns}$ = area of non-shoreline development = 39.4 ha

# of capita $years_1$ = 129.1

# of capita $years_2$ = 272.33

Appendix F. Predictions For Annual Mass Rate of Phosphorus Inflow

Equations

For the phosphorus loading model, annual phosphorus input must be expressed as a loading per unit lake surface area. This is done by dividing annual mass rate of phosphorus inflow, W, by the lake surface area, A_S (Reckhow and Chapra 1983):

$$\mathbf{L = W/A_S}$$

where, L = areal phosphorus loading ($kg/m^2/yr$)

W = annual mass rate of phosphorus inflow (kg/yr)

A_S = surface area of the lake (m^2)

Areal water loading is calculated by dividing inflow water volume by the surface area of the lake, A_S (Reckhow and Chapra 1983):

$$\mathbf{q_S = Q/A_S}$$

where, q_S = areal water loading (m/yr)

Q = inflow water volume (m^3/yr)

The lake phosphorus concentration can now be calculated, for both high and low values, by substituting in values of q_S and L (high and low) (Reckhow and Chapra 1983):

$$\mathbf{P = L/(11.6+1.2q_S)^*}$$

where, P = lake phosphorus concentration (kg/m^3)

Predictions were made from both the low and high values of annual mass rate of P inflow.

Constants for both low and high predictions for Long Pond, South Basin:

A_S = 5220000.00 m^2

Q = 249275194.68 m^3/yr

q_S = 47.75 m/yr

Low Prediction

W(low) = 1400.67 kg/yr

$L(low) = 2.68 \times 10^{-3}\ kg/m^2/yr$

$P(low) = 2.68 \times 10^{-3}\ kg/m^2/yr\ /\ [11.6+1.2(47.75\ m/yr)]$

$= 3.89 \times 10^{-6}\ kg/m^3)(10^6\ mg/kg)(m^3/L^3)(10^3\ ppb/ppm)$

= 3.89 ppb

High Prediction

$W(high) = 4376.36\ kg/yr$

$L(high) = 8.38 \times 10^{-3}\ kg/m^2/yr$

$P(high) = 8.38 \times 10^{-3}\ kg/m^2/yr\ /\ [11.6+1.2(47.75\ m/yr)]$

$= 12.17 \times (10^{-6}\ kg/m^3)(10^6\ mg/kg)(m^3/L^3)(10^3\ ppb/ppm)$

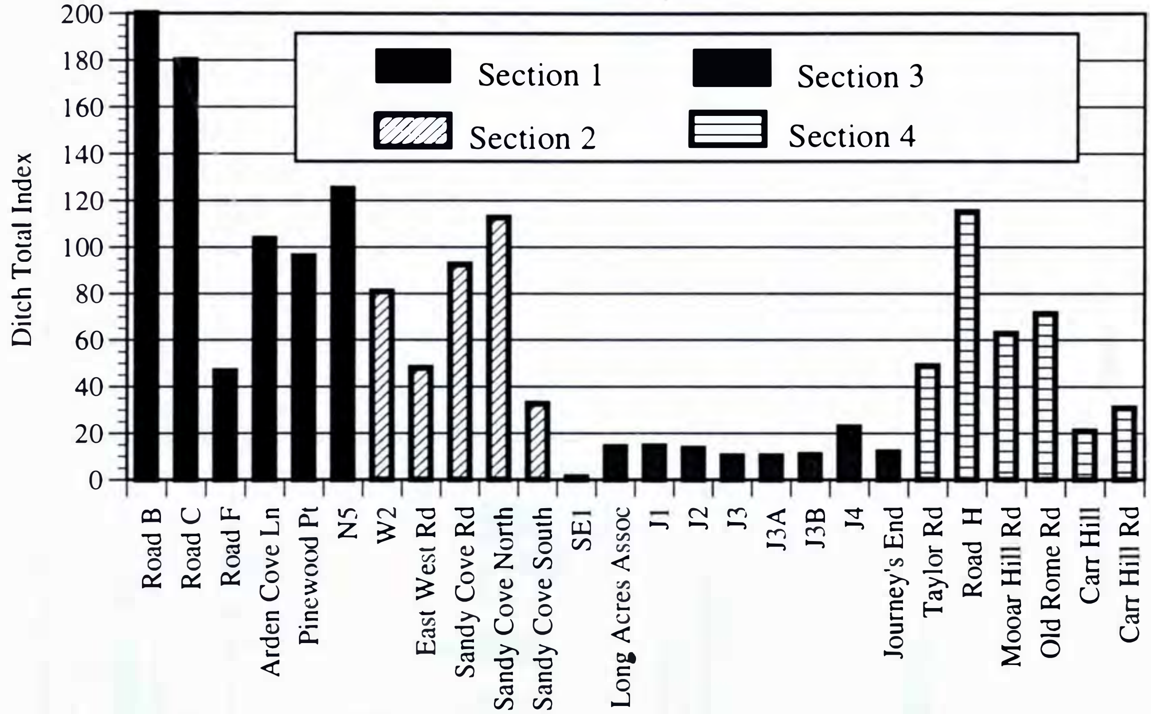
= 12.17 ppb

* equations obtained from Reckhow and Chapra (1983)

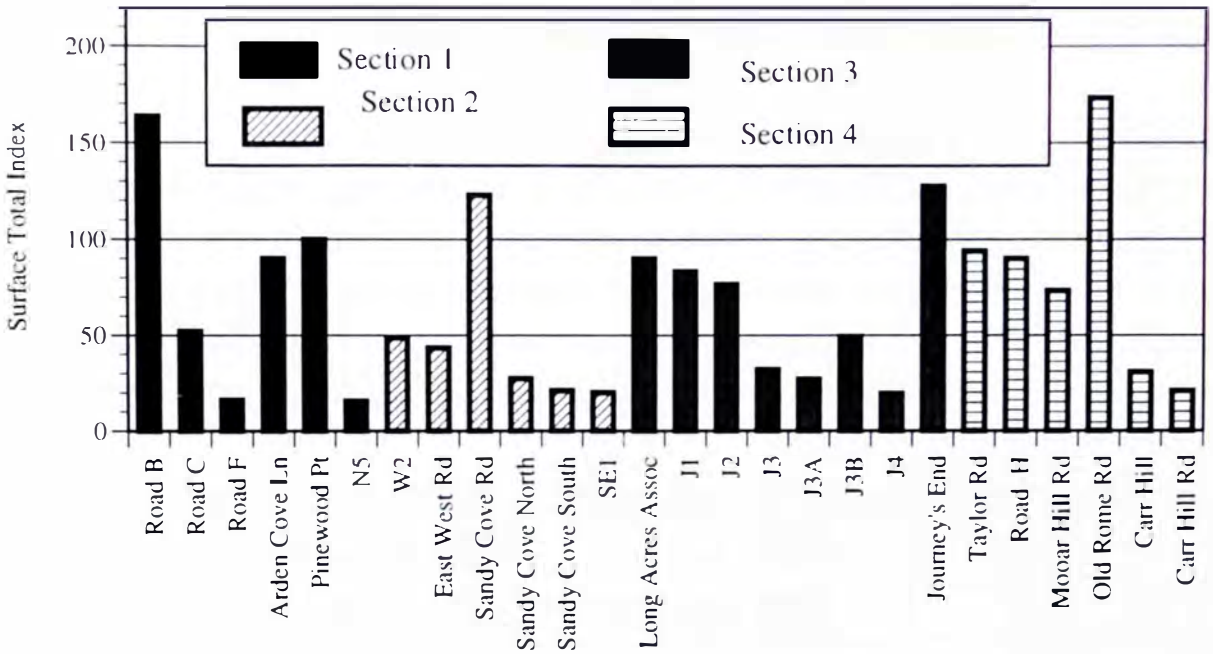
Appendix G. Road Index Figures and Survey Forms

Introduction

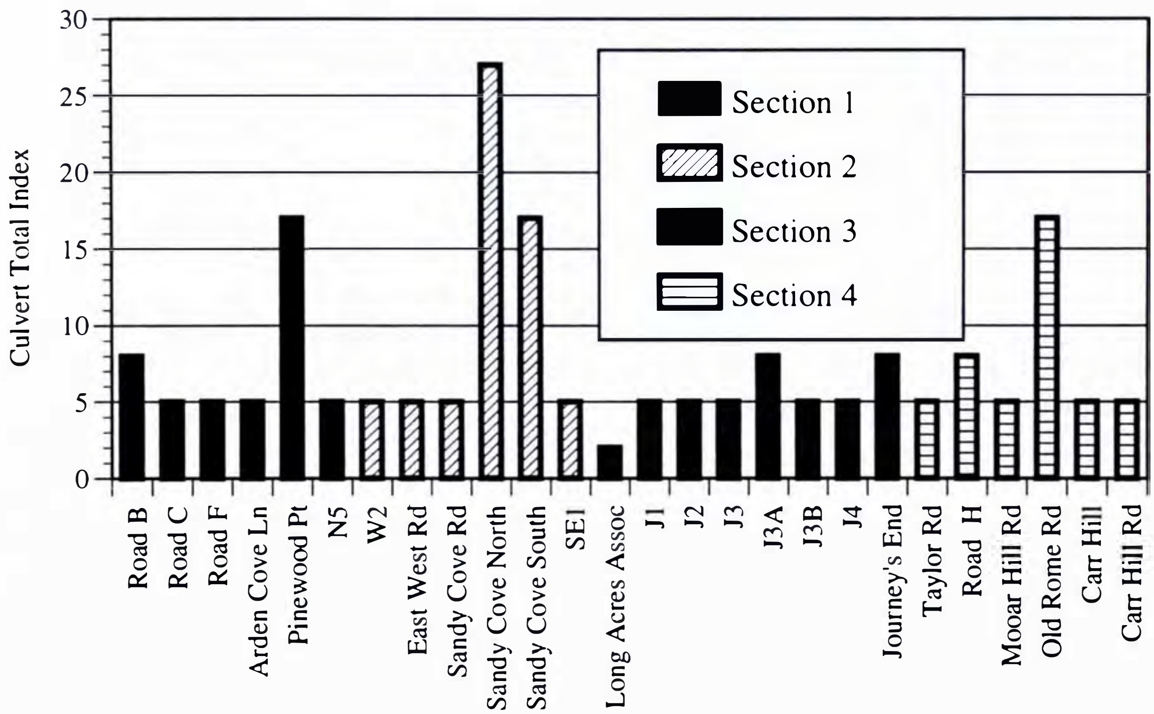
The following graphs are based on indices calculated as part of our road survey. The aspects we looked at for camp roads were road surface, ditching, culverts, and water diversions. The indices were calculated and then summed to give an overall road evaluation. Phosphorus coefficients and loading potentials were calculated for individual road segments. Paved roads were evaluated on a scale of 1 to 5, with 5 being the score given to a road in the best condition.



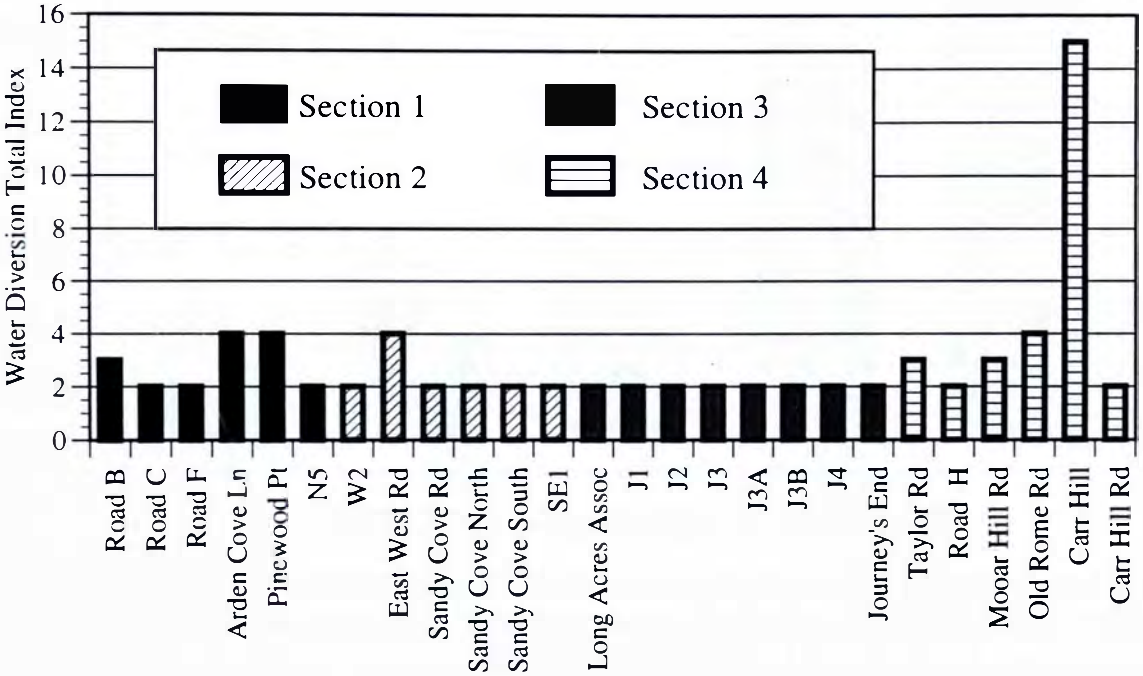
Appendix G. Figure 1. Ditch Total Index, an evaluation of the ditch condition along the camp roads in Long Pond, South Basin watershed, clockwise from the North end of South Basin as defined by section in Appendix J.



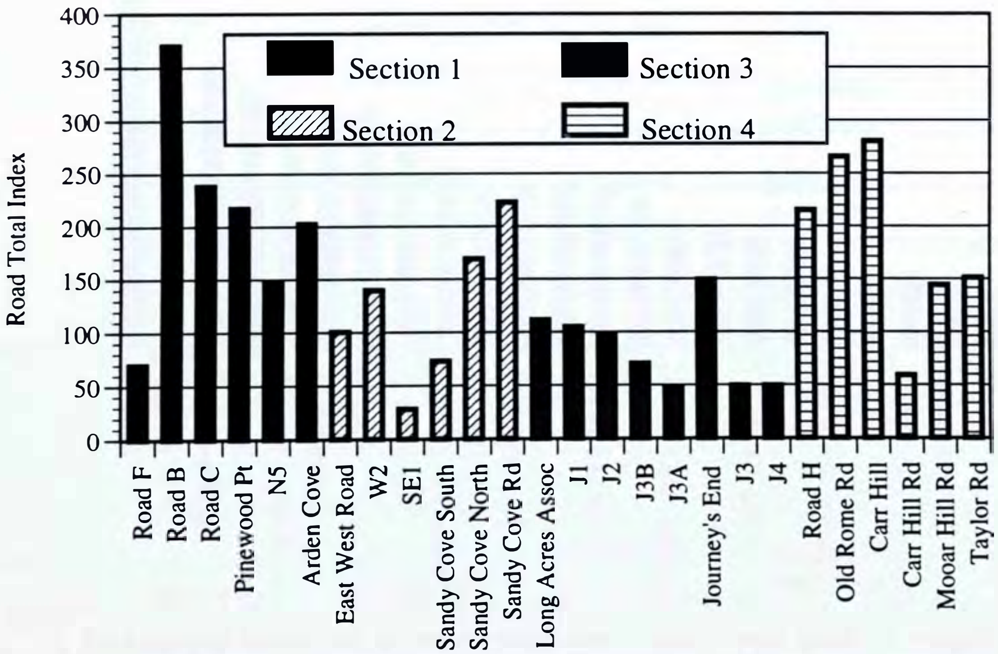
Appendix G Figure 2. Road Surface Total Index, an evaluation of the road surface condition on the camp roads in Long Pond, South Basin watershed, clockwise from the North end of South Basin by section as defined in Appendix J.



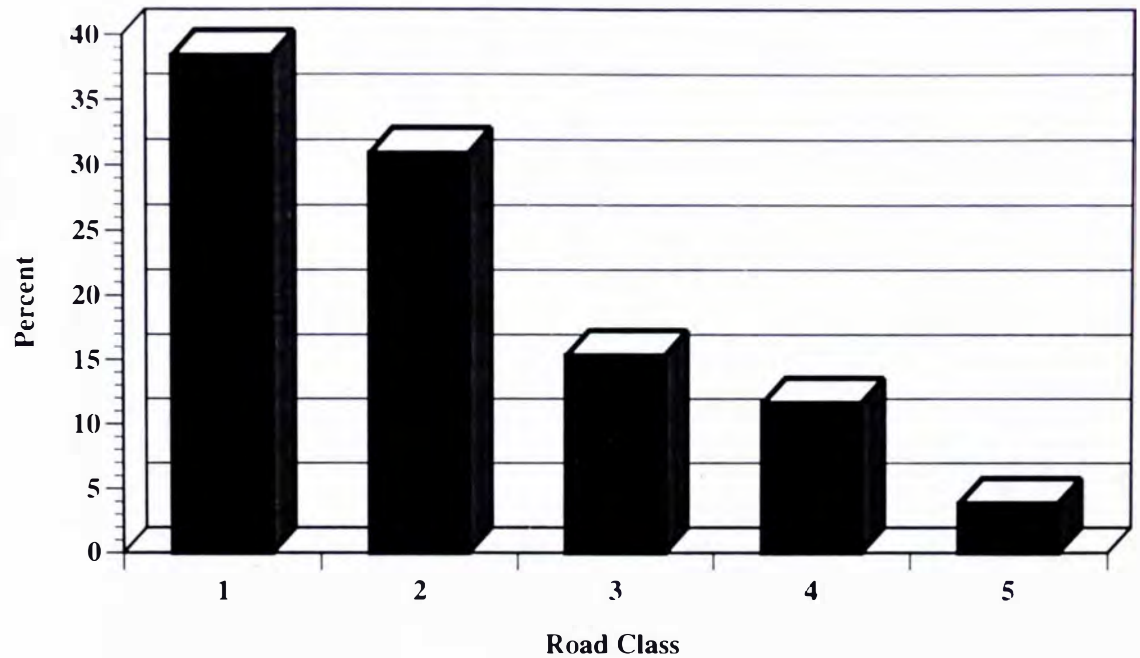
Appendix G Figure 3. Culvert Total Index, an evaluation of the culvert condition on the camp roads in Long Pond, South Basin watershed, clockwise from the North end of South Basin by section as defined in Appendix J.



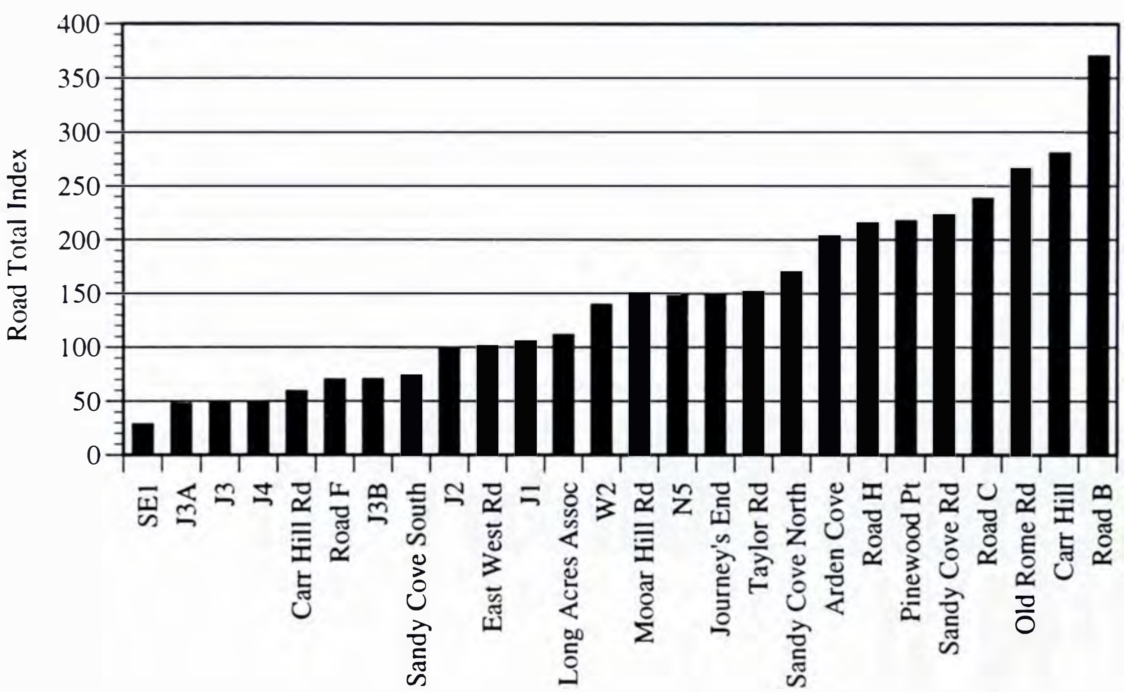
Appendix G Figure 4. Water Diversion Total Index, an evaluation of the water diversions along the camp roads in Long Pond, South Basin watershed, clockwise from the North end of South Basin by section as defined in Appendix J.



Appendix G Figure 5. Road Total Index, a cumulative index of the overall condition of camp roads in Long Pond, South Basin watershed clockwise from the North end of South Basin by section as defined in Appendix J.



Appendix G Figure 6. Percentage of roads within each road class based on the Road Total Index. Those roads in the first class have the best Road Total Index, and those in the fifth class have the worst.



Appendix G Figure 7. Road Total Index, a cumulative index of the overall condition of camp roads in Long Pond, South Basin watershed ordered from best to worst.

Appendix G Figure 8. Road survey forms.

DATE:_______________ SURVEYOR'S NAME(S):______________________________

ROAD NAME/NUMBER:____

GENERAL DESCRIPTION

ROAD DIMENSIONS: Length (miles)_____ Average Width (feet)_____ OVERALL SLOPE (%):_____

TOTAL NO. OF WATER DIVERSIONS:________ NO. OF MISSING WATER DIVERSIONS:________

NUMBER OF MISSING CULVERTS NEEDED:________ SIZE OF CULVERTS NEEDED:__________

DESCRIPTION OF ROAD SURFACE

Score each 0.1 mile section of road with checkmark [√] in appropriate column of each row. 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) 6 in.	_____(2) 4 in.	_____(4) 2 in.	_____(6) 0 in./potholes	_____(8) 0 in./ruts		_____
Surface (dry)	_____(1) hard w/o dust	ØØØØØØ ØØØØØØ	_____(3) hard w/ dust	_____(4) loose	_____(5) dusty & loose		_____
OR Surface (wet)	_____(1) hard	_____(2) hard & slick	_____(3) slick & loose	ØØØØØØ ØØØØØØ	_____(5) mud		_____
Edge	_____(0) no berm/ridge	ØØØØØØ ØØØØØØ	ØØØØØØ ØØØØØØ	ØØØØØØ ØØØØØØ	_____(5) berm/ridge prevents surface runoff		_____
Road Material	_____(1) gravel	_____(2) gravel/sand	_____(3) dirt	_____(4) sand/clay	_____(5) clay		_____
					SURFACE TOTAL	[a]	_____
USAGE	_____(1) seasonal	ØØØØØØ ØØØØØØ	ØØØØØØ ØØØØØØ	ØØØØØØ ØØØØØØ	_____(5) year round	[b]	_____
SUMMARY OF 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]**

DATE:______________ SURVEYOR'S NAME(S):______________________________

ROAD NAME/NUMBER:____

DESCRIPTION OF ROAD DITCHING

Score each 0.1 mile section of road with checkmark [√] in appropriate column of each row. When survey is complete compute average score for each characteristic using values shown in parentheses.

	Good	Acceptable	Fair	Poor	Big Problem		Average Score
Need	_____(1) ample/none needed	ØØØØØØ ØØØØØØ	_____(5) some needed	ØØØØØØ ØØØØØØ	_____(15) badly needed		_____
Depth	_____(1) 2 ft. (or road slopes into adjacent land)	_____(2) 3 ft.	_____(3) 4 ft.	_____(4) 1 ft.	_____(5) no ditch present but needed		_____
Width	_____(1) 8 ft. (or road slopes into adjacent land)	_____(2) 6 ft.	_____(3) 4 ft.	_____(4) 2 ft.	_____(5) no ditch present but needed		_____
Vegetation	_____(1) turf, wooded, or rip rap	ØØØØØØ ØØØØØØ	_____(3) weeds	ØØØØØØ ØØØØØØ	_____(5) bare soil		_____
Sediments	_____(1) none	ØØØØØØ ØØØØØØ	_____(3) 2 inches deep	ØØØØØØ ØØØØØØ	_____(5) >4 inches deep		_____
Shape	_____(1) parabolic	_____(2) trapezoid	_____(3) round	_____(4) v-shaped	_____(5) square or none		_____
					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]**

DATE:_______________ SURVEYOR'S NAME(S):________________________________

ROAD NAME/NUMBER:____

ROAD SEGMENTS

A road segment is defined as a particular length of road which has a relatively continuous angle of incline (% grade). Start and end segments so that their lengths fall into one of the column headings indicated. For each segment recorded in the segment % grade analysis in the upper table, place a check [√] in the appropriate box of the lower table. The upper table is used to identify particularly troublesome road segments, while the lower table is used to characterize the soil erosion potential (phosphorus loading potential) of the road in general [shaded boxes represent high erosion potential].

Segment							Score = Segment Len. X % Grade
A	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
B	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
C	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
D	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
E	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
F	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
G	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
H	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
I	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
J	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
K	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
L	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
M	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
N	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
O	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
					ROAD SEGMENT TOTAL		________

% Grade	Segment Length (feet)				
	50	100	200	500	1000
0-5% Total	____(4)	____(5)	____(8)	____(12)	____(17)
6-10% Total	____(10)	____(14)	____(19)	____(31)	____(43)
11-15% Total	____(16)	____(23)	____(33)	____(51)	____(73)
16-20% Total	____(29)	____(41)	____(58)	____(91)	____(129)

After surveying road, multiply the number of checks in each box by the erosion potential coefficient for that box to obtain a box total. To obtain the Road Segment Average, add all of the box totals and divide by the total number of checks.

ROAD SEGMENT AVERAGE _____ = TOTAL OF ALL BOXES _____ ÷ TOTAL # OF CHECKS _____

CAMP ROAD SURVEY, PAGE 4 of 6

DATE: ____________ SURVEYOR'S NAME(S): ________________________________

ROAD NAME/NUMBER: ____

ROAD SKETCH

First measure total distance of road, then use grid to make a scaled sketch of the road. Show location of culverts, water diversions, changes in slope, location of lake, and any special features that may be helpful for future reference. Road segments from previous page should be indicated on sketch. Indicate location of problem sites (e.g., lack of water diversion, exposed culvert, inadequate ditching, region with poor surface conditions).

DATE:______________ SURVEYOR'S NAME(S):______________________________

ROAD NAME/NUMBER:____

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.

Criteria	Good	Acceptable	Fair	Poor	Big Problem		
Need	ample/none needed	ØØØØØØ ØØØØØØ	some not working	ØØØØØØ ØØØØØØ	badly needed		
Wear	new	aging (some rust)	old (rust holes)	bottom gone	ØØØØØØ ØØØØØØ		
Size	2 ft. diam.	1-1/2 ft. diam	1 ft. diam.	<1 ft. diam.	ØØØØØØ ØØØØØØ		
Insides	clean	some rocks and/or water	≤2 in. silt	>2 in. silt	ØØØØØØ ØØØØØØ		
Covering Material	at least 1 ft. thick or half diameter of large culverts	ØØØØØØ ØØØØØØ	less than 1 ft. thick	covering inadequate to prevent bent culvert	top of culvert showing through road surface		
OVERALL CULVERT CONDITION	_____(5) 100% good, or none needed	_____(8) 75% good	_____(17) 50% good	_____(21) 25% good	_____(27) 0% good, no culvert present but needed	[i]	_____

_______ = _______

CONDITION [i] **CULVERT TOTAL[j]**

DATE ____________ SURVEYOR'S NAME(S):______________________________

ROAD NAME/NUMBER:____

DESCRIPTION OF WATER DIVERSIONS

Score the quality of water diversions for the entire road with checkmark [√] in appropriate column of summary evaluation. Use the descriptions provided to determine the overall water diversion condition.

Need	Good ample/none needed	Acceptable ØØØØØØ	Fair ØØØØØØ	Poor ØØØØØØ	Big Problem badly needed		
Where does diverted water go?	woods	field or lawn	gully in woods	stream	lake		
OVERALL WATER DIVERSION CONDITION	_____(2) 100%good, or none needed	_____(3) 75%good	_____(4) 50%good	_____(5) 25%good	_____(15) 0%good, no diversions present but needed	[l]	_____

___________________________ ___________ =

[m] CONDITION [l] WATER DIVERSIONS TOTAL

FINAL EVALUATION OF THE ROAD

________ + ________ + ________ + ____________ = ________

[d] SURFACE + [g] DITCHES + [j] CULVERTS + [m] 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.

ROAD SEGMENT TOTAL = __________________ (LESS THAN 25 IS MOST DESIRABLE)

ROAD SEGMENT AVERAGE = ____________________

Paved Road Evaluation Form

Date________________ Surveyor's Name(s)__________________

Road Name____

Scoring:

___1. Road was not crowned, was very uneven (heaving) and had many cracks, large potholes, and severe gullying. The ditches were not always present and when they were, they were not vegetated. Culverts were in poor condition and were not always present when necessary.

___2. Road was not crowned, had many cracks and potholes, and gullying. The ditches were not thoroughly vegetated but were present when necessary, and culverts were in poor condition (clogged).

___3. Road was unevenly crowned with few small potholes, cracks, and minor gullying. The ditches were mostly vegetated and were present when necessary. Culverts were in good condition.

___4. Road was evenly crowned with no potholes, few cracks, and minor gullying. The ditches were vegetated and were present when necessary. Culverts were in good condition.

___5. Road was evenly crowned with no potholes, cracks, heaving or gullying; the ditches were vegetated and were present when necessary. Culverts were present and were in good condition.

Width of Road (including the shoulder)__________________________

Storm Drain Evaluation:

__________Infiltration system present __________Sewer empties into lake

Number of Drains present on Road____________________________________

Date:
Group names:
Road name:
(please use a sep. sheet for each road)

Road Evaluation (check the back, some of these sheets are two sided)
*don't write the street #, but #1=1st house evaluated on that rd.
**only the houses directly on the shoreline would get a y, if the house is on the same rd, but on the side opposite the shoreline homes please note that (if possible, mark houses on map, and note if they are on east or west side of the road)
*** for driveway conditions, write the material made of, if a waterbar exists, if its curved or goes directly to the water, etc.
--also, note where qualtiy of road varies and where large culverts are located (does the interface facilitate erosion into the stream?)

*house #	**on shoreline y/n	seasonal or yr. round	guesstimate pre-1972 r post-1972	2nd building on lot, possibly using same septic, y/n	driveway condition	observations and comments

Appendix H. Personal Communications

Names	**Affiliation**
Russell Bailey	Central Maine Power
Roy Bouchard	Department of Environmental Protection
Morris Chiles	Town of Belgrade, Road Commissioner
Russell Cole	Colby College, Department of Biology
Brenda Corkum	Department of Human Services, Office of Data, Research, and Vital Statistics
Tim Christensen	Colby College, Department of Biology
Paul Doss	Colby College, Department of Geology
Gary Fuller	Town of Belgrade, Code Enforcement
Karen Hahnel	Department of Environmental Protection, Augusta
Ellery Keene	Kennebec Valley Council of Governments
Judith Mardin	Maine Department of Inland Fisheries and Wildlife, Sidney Office
Bob Martin	Town of Belgrade, Plumbing Inspector
Peter McManus	President of Belgrade Lakes Association
Katie O'Reilly	Colby College, Department of Biology
Dick Park	Belgrade Lakes Association
Denny Phillips	Town of Rome, Planning Board
Gail Rizzo	Rizzo-Mattson Realtors, Realtor; Town of Rome Planning Board
Bob Simpson	Town of Belgrade, Manager
Barbara Turner	Town of Mount Vernon, Selectman

Appendix I. Legal Perspectives

Shoreland zoning ordinances implement a variety of acts to establish guidelines for development. Ideally, zoning ordinances are used as basic regulations, intended to be further refined in comprehensive plans, specific for each municipality. Belgrade, Mount Vernon, and Rome do not have approved comprehensive plans at this time, although Mount Vernon does have a Land Use Ordinance, which was adopted in 1995. Belgrade, Mount Vernon, and Rome have all added to the minimum shoreland ordinances designed by the State of Maine (Belgrade and Rome have adopted individual Shoreland Zoning Ordinances). The ordinances were created using the following acts (COLA 1991) as a basic framework.

Act to Greater Enhance and Protect Maine's Great Ponds - requires towns within their subdivision ordinances to ensure that the water quality will be protected from long-term and cumulative increases in phosphorus from development in great pond watersheds.

Title 38- Water Classification Program - classifies lakes as GPA (Great Pond Area) when natural land is greater than 10 acres, or manmade and greater than 30 acres. States that no change in land use by itself or in conjunction with other activities can cause water quality degradation in GPA waters which would impair the characteristics and designated uses of downstream lake waters or cause an increase in trophic state of those GPA waters.

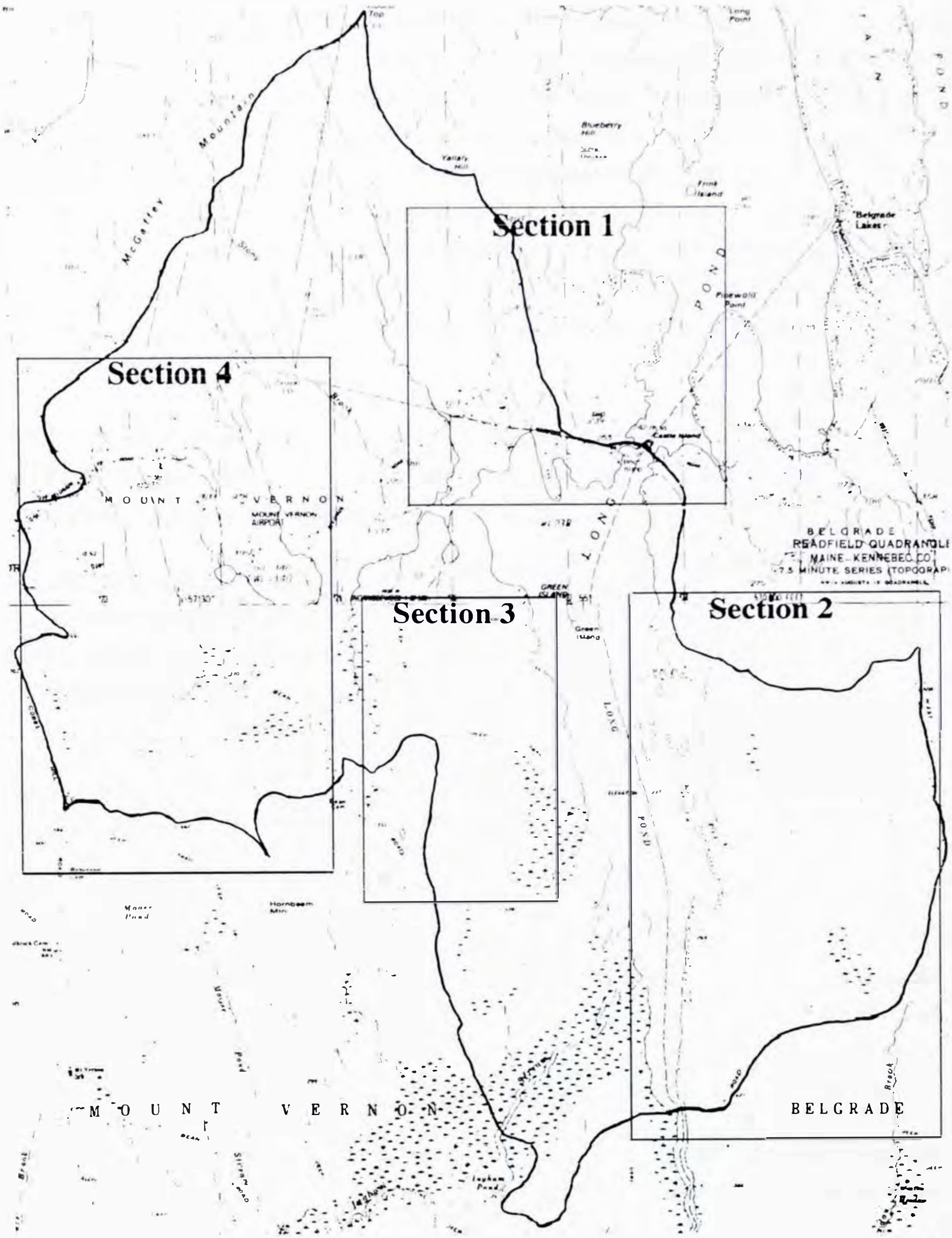
Natural Resources Planning Act (NRPA) - administered by MDEP. Protects great ponds, wetlands, rivers, streams, sand dunes, fragile mountain areas, and significant wildlife habitat. Permit required from DEP for activities that could alter natural areas.

Shoreland Zoning Law - requires all municipalities to establish land use controls for all land areas within 250 ft of ponds and freshwater wetlands that are 10 acres or larger, rivers with watersheds of at least 16,000 acres, coastal wetlands and tidal waters, as well as all land areas within 75 ft of certain streams. Also requires a minimum buffer strip of 100 ft along lake shores and river banks and at least 25 ft along road ditches and intermittent streams.

Maine Site Location of Development Act - administered by the MDEP, generally regulates land parcels of 20 acres or more, which are divided into five or more lots for sale or lease within a 5-year period.

Local Subdivision Ordinances - usually regulates any division of a tract of land into three or more lots within any 5-year period. The ordinances are administered by municipalities within which a subdivision occurs.

Appendix J. Road sections and road names.



Appendix J. Figure 1. Camp road sections within the Long Pond, South Basin watershed.

Section 1

Road A

Road B

Road C

Road F

Narrows Road

Pinewood Point Road

Arden Cove Lane

N5

Section 2

W2

East West Road

Sandy Cove Road

Sandy Cove North

Sandy Cove South

SE1

SE2

Section 3

Journey's End Road

J1

J2

J3

J3A

J3B

J4

Long Acres Association

Section 4

Taylors Road

Mooars Hill Road

Carr Hill Road

Carr Hill

Old Rome Road

Road H