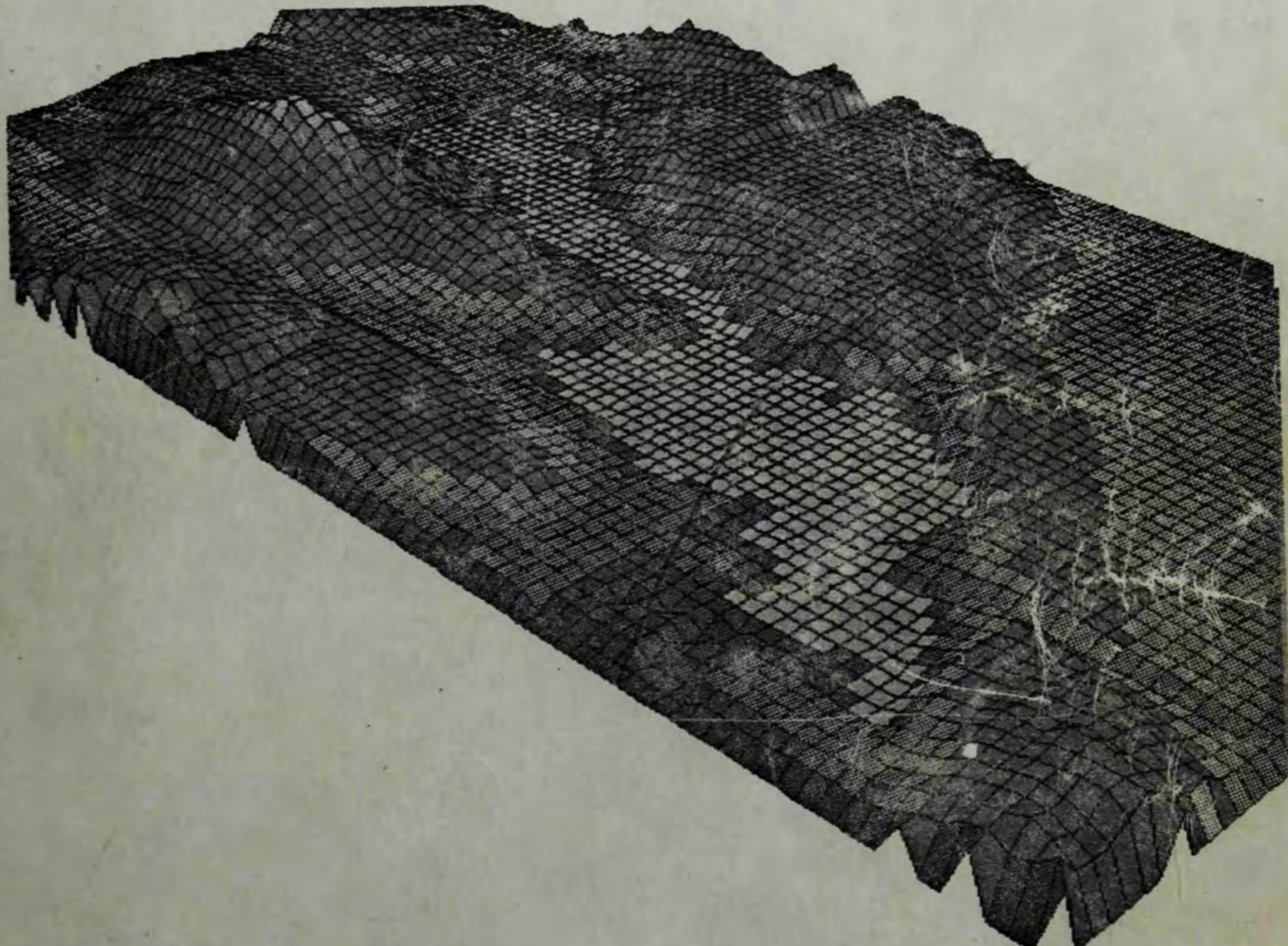
1993

Land Use Patterns in Relation to Lake Water Quality in the Salmon Lake Watershed

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

Colby College

LAND USE PATTERNS IN RELATION TO LAKE WATER QUALITY IN THE SALMON LAKE WATERSHED



Problems in Environmental Science Course
Department of Biology
Colby College
Waterville, ME 04901
1994

MEMO

DATE: January 12, 1994

TO: Report recipients

FROM: Professors David Firmage and Russell Cole

RE: Class report on Salmon Lake (McGrath & Ellis ponds) 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 1993. The course is taken by seniors who are majoring in Biology with a concentration in Environmental Science. The students are treated 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. This year 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.

Authors

This project was carried out by the Biology 493 Problems in Environmental Science Class at Colby College during the fall semester of 1993. The members of the class are as follows:

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The advisors to the project were Professors F. Russell Cole and David Firmage and Teaching Associate Tim Christensen.

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INTRODUCTION

GENERAL NATURE OF STUDY

Lake ecosystems are important natural resources because they provide habitats for many species of flora and fauna, recharge ground water aquifers, supply drinking water and provide outdoor recreation sites for people. However, human activities in the watershed (the drainage area around the lake) can lead to a decline in the lake's water quality through eutrophication (Henderson-Sellers and Markland 1987). Natural lake eutrophication is the natural aging process of a lake in which organic matter accumulates and gradually changes the physical and chemical characteristics of the lake. Cultural eutrophication occurs when anthropogenic influences accelerate the natural aging process. Nutrients, mainly phosphorus and nitrogen, are the elements that limit plant growth and thus the aging of the lake. Land use practices can accelerate eutrophication through the addition of excess nutrients to the water body. Nutrient loading is caused by human activities such as residential development, agriculture, industrial activity, and road construction (Fernandez et al. 1992). Phosphorus and nitrogen lead to a rise in natural production that may result in algal blooms which are good indicators of diminishing water quality in lakes. Other indications of eutrophication include high surface to volume ratio of the water body, highly turbid water, organic-rich bottom sediments, low dissolved oxygen in the water, and low species diversity of aquatic organisms (Dominie and Scudder 1987).

McGrath and Ellis Ponds are important local ecological and recreational resources, forming part of the headwaters of the Belgrade Lake chain. These lakes are locally known as McGrath Pond and Salmon Lake, however, for the purposes of this report, they will be collectively referred to as Salmon Lake, in accordance with U. S. Geological Survey maps. They are located in south-central Maine, in the towns of Oakland and North Belgrade (Lat. 44° 32' 30", Long. 69° 46' 00"). According to Nichols et al. (1984) the Salmon Lake watershed drains 2313 ha of land. The surface area of the two ponds is 466 ha which constitutes about 20 percent of the total Salmon Lake watershed (Nichols et al. 1984).

Salmon Lake has a history of algal blooms which have decreased the recreational and aesthetic value of the lake (Nichols et al. 1984). As early as the 1920's, Salmon Lake was reported to have poor water quality. Algal blooms were reported throughout the 1970's. Numerous complaints led to a study in 1975 by the Maine Department of Environmental Protection (MDEP) and another in 1984 by the U.S. Geological Survey to determine the cause of the accelerated algal growth in the ponds. Both studies concluded that the primary cause of these algal blooms was high concentrations of phosphorus in the water. Though many smaller tributaries exist, three tributaries entering the ponds, Cold Brook and two unnamed streams, were reported to contribute 69% of the phosphorus load. Major potential sources of phosphorus loading in the basin were identified in the 1975 MDEP study, including agricultural activities, logging, and the Oakland landfill.

The six major components of our study are:

- To determine the water quality of Salmon Lake including abiotic and biotic parameters, focusing on phosphorus loading.

- To assess potential nutrient loading areas by determining the water quality of the tributaries and possible sources of phosphorus leading into the lake.
- To determine historical and current land use patterns within the watershed area and their influence on phosphorus levels in the lake.
- To construct flushing rates and water budgets for the lake and the individual ponds. Residence time of lake water is crucial to phosphorus accumulation.
- To make future projections on levels of phosphorus and lake quality as a function of the land use and development in the watershed.
- To make recommendations to the Lake Association, MDEP, and the towns of Belgrade and Oakland regarding ways to protect Salmon Lake from future nutrient loading, potential areas for future development, and areas unsuited for development.

The preservation of Salmon Lake is important because of its aesthetic value, recreational uses, and ecological significance as part of the Belgrade chain, as well as its use as a supply of drinking-water. The goal of this report is to increase understanding of the importance of lake water quality. Informing residents is fundamental to the future quality of Salmon Lake. We hope that this study will encourage residents of Oakland and Belgrade to take an active role in protecting the lake.

BACKGROUND

Lake Characteristics

Distinction between Lakes and Ponds

Lakes and ponds are inland bodies of water, which may be natural or human-made (Niering 1989). Ponds are usually smaller and more shallow than lakes, but it is primarily water temperature that distinguishes between the two types of water bodies. The amount of light penetrating the water is influenced by the time of year (e.g., snow cover on ice), natural attenuation in clear water, turbidity from silt and other material carried into the lake, and from the growth of phytoplankton (Smith 1992). Temperature changes seasonally and with depth. During the summer, warm water is at the top of a lake (epilimnion) while cooler water is at the bottom (hypolimnion). Ponds do not thermally stratify during the summer months as lakes do. Thermal stratification prevents mixing of oxygen and nutrients within a lake. McGrath Pond resembles a pond and does not thermally stratify due to its shallowness. It remains mixed and well oxygenated, whereas Ellis Pond is deeper and becomes stratified (Nichols et al. 1984). During the summer, there are three distinctive horizontal layers (epilimnion, metalimnion, and hypolimnion) present in Ellis Pond, which corresponds well with the characteristics of a lake. The hypolimnion of Ellis Pond becomes anoxic (lack of oxygen) during certain times of the year due to its stratification (Nichols et al. 1984). Ellis Pond is dependent on the spring and fall overturns (refer to Lake Basin Characteristics) to redistribute oxygen and nutrients, while McGrath Pond experiences continual mixing when ice is not covering the lake surface. These variations in oxygen and temperature strongly influence the adaptations for life (Smith 1992) and the buffering capabilities for pollutants in ponds and lakes.

General Characteristics of Maine Lakes

The majority of lakes in the northeastern part of the United States were formed by glaciation during the Pleistocene period (Great Ice Age) approximately 10,000 years ago (Davis et al. 1978). The glaciers dug relatively shallow depressions into the earth's surface creating sinks that eventually filled up with water, and formed inland freshwater resources. The geologic formations in the Northeast are generally sedimentary rock with igneous rock infusions (Davis et al. 1978). The main geologic rock type that makes up lake beds in Maine is granite. Geologic composition has a significant effect on nutrient levels in Maine's lakes and ponds. For example, granite does not neutralize acids very well; therefore, Maine lakes and ponds are generally eutrophic or mesotrophic and can be endangered by increasingly acidic rain in New England (Davis et al. 1978).

Most of Maine was once covered with glaciers, therefore it is not surprising that the main soil type in most watersheds in Maine is glacial till (Davis et al. 1978). Freshwater bodies that are located near the coast may also have a variable amount of marine silt and clay mixed in with the glacial till. Glacial till is a relatively permeable soil type. However, when large amounts of clay and marine silt are present, the till becomes less permeable (Paul Doss pers. comm.).

Surface water in Maine (lakes, ponds, streams) makes up 39% of the freshwater in New England, New York and New Jersey; there are approximately 5672 lakes and ponds in Maine (Davis et al. 1978). The majority of Maine's lakes are located in hilly lowlands, and are frozen 4-5 months out of the year. The land surrounding the lakes (within the watershed) is generally forested with some agricultural acreage. When pollutants enter the Maine water bodies, they are usually linked to small point source pollution directly from shoreline development, or diffuse agricultural run-off (Davis et al. 1978). Since the state has so many lakes and ponds, and water is an important resource to the state, it is easy to understand why many people are concerned with the issues of water quality.

Water quality in Maine is a function of the following variables: ocean proximity, location within Maine, residence time of water within the soil, wetlands, and bedrock chemistry (Davis et al. 1978). To evaluate the quality of Maine's lakes and ponds, their physical, chemical and biological qualities must be examined (Davis et al. 1978). These three qualities are all interrelated and affect one another. The physical characteristics of lakes and ponds include: topographical, environmental and geological aspects. Topographical aspects are reflected in watershed characteristics. They include lowland areas, wetlands, and mountainous and hilly areas (areas of potential run-off). Environmental classifications of the lake include the characteristics of the watershed and the actual water body. Some of these characteristics are temperature, habitat type, and different kinds of terrestrial and aquatic vegetation. Finally, the geology of the lake basin, its watershed and the soils are important to lake characterization. Two physical characteristics that are a function of water temperature are overturn and nutrient cycling.

Lake Basin Characteristics

Lake and pond ecosystems are a function of the physical and chemical properties of water. Temperature is a measure of the average kinetic speed of molecules within a specific area or substance. As a substance warms, its molecules speed up. This increased speed causes the atoms to collide with each other more frequently. As atoms hit each other with increasing speed, they also bounce away from each other with greater force. Consequently, a substance becomes less dense with an increase in temperature. Water is a unique molecule; its maximum density is at 4° C. As water cools below or warms above 4° C it becomes less dense. It reaches its lowest density at 0° C. Less dense substances tend to float above more dense substances (Figure 1).

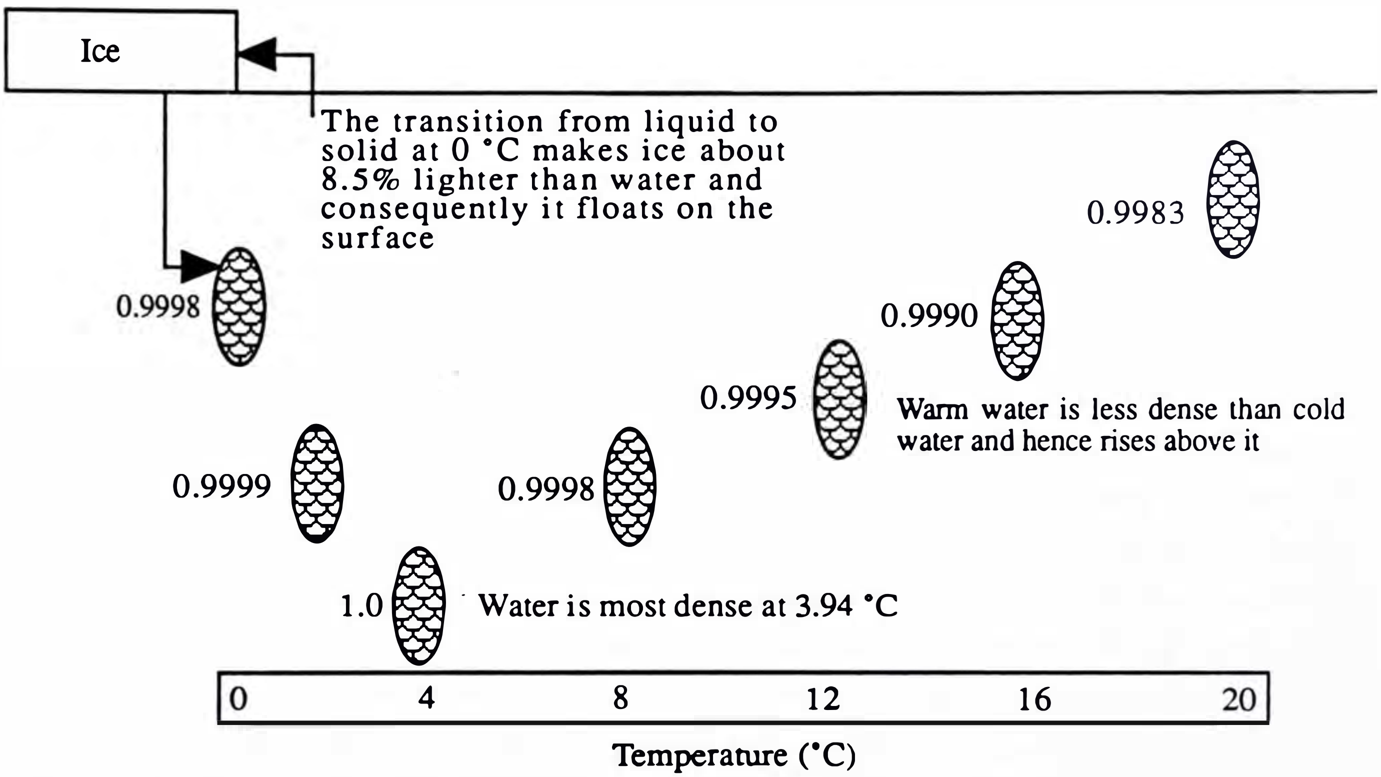


Figure 1. The change in the density of water with temperature differences. The droplets above represent 1 cm of water. The numbers show the måss in grams of this water related to the temperature scale above. As ice melts and becomes liquid, its temperature changes from 0° C to 4° C and becomes more dense. As water warms to more than 4° C, it becomes less dense (Adapted from Burgis and Morris 1987).

The process of stratification in a lake is created by density differences, caused by the differential heating of lake water (Maitland 1990). Lake stratification follows a seasonal pattern related to the net solar radiation it receives. During the spring and summer, solar radiation and atmospheric radiation warm the lake. The surface water receives more of this radiation than the lower levels, making it less dense due to its higher temperature.

The warm water stabilizes at the top portion of the water column forming the epilimnion. A stratified water column is created, with the colder, more dense water sinking beneath the warmer top layers. The lake continues to warm as spring and summer progress and the depth of the warm layer increases.

The epilimnion is usually no deeper than 25 ft in northeast lakes (David Firmage pers. comm.), and continually interacts with the atmosphere through wind action. This interaction maintains a well oxygenated epilimnion as a result of oxygen diffusing from the atmosphere into the water. Rooted plants along the shoreline and phytoplankton are most abundant in the epilimnion and increase oxygen levels by photosynthesis. Nutrients in the epilimnion are readily used by plants and have a tendency to sink in the water column. The epilimnion is usually nutrient deficient until fall and spring overturns replenish the nutrients to the upper layer.

Below the epilimnion is an area of sharp temperature decline. Solar radiation does not significantly influence this region's temperature, hence it has a greater density due to its lower temperature. This area is called the metalimnion. It does not mix with the higher, warmer waters. Within this layer is a thermocline, which is characterized by the greatest temperature gradient in the lake. Approximately every meter downward in this region produces a temperature decline of 1° C (Smith 1992). The thermocline creates a border between the epilimnion and the hypolimnion (the lowest layer of a lake). The temperature gradient in the metalimnion prevents mixing of water from the two layers.

Light does not usually reach the hypolimnion due to refraction. This is the area where the decomposition of dead organic material occurs. Aerobic bacteria break down dead organic material that is deposited in this layer. This process requires oxygen, yet the hypolimnion is usually oxygen deficient and relatively nutrient rich. Anaerobic (not requiring oxygen) bacteria also break down dead organic material, but at a much slower rate (Russell Cole pers. comm.). The oxygen level in the hypolimnion is proportional to the amount of dead organic material that reaches the bottom layer. Aerobic bacteria decreases the oxygen levels overtime. The deepest water will thus become deoxygenated, and as summer progresses, the boundary between the oxygenated and deoxygenated water will move upwards (Burgis and Morris 1987).

Spring and Fall overturns cause nutrient mixing in northeastern lakes. Not all lakes undergo this process, but it is typical of lakes in temperate climates. Overturn is the vertical mixing of layers in a body of water which is made possible by the seasonal changes in temperature. Overturn is dependent on many factors: geographical position of the lake and the combined functions of lake depth with the mixing action of the wind (Maitland 1990). Lakes that turnover completely in the fall and spring are called dimictic (Figure 2).

As autumn arrives, the lake's surface begins to cool. As the water in the epilimnion cools, its density increases and it begins to sink in the water column. This instability creates convective currents within the lake. The water that was once at the surface breaks through the metalimnion, moving downward, forcing the bottom water to the surface. Once the entire lake body reaches a constant temperature and therefore density, (isothermal lake) other processes mix the water. Surface winds churn the water and aid in redistributing nutrients and oxygen. Oxygen is replenished in the hypolimnion and nutrients are

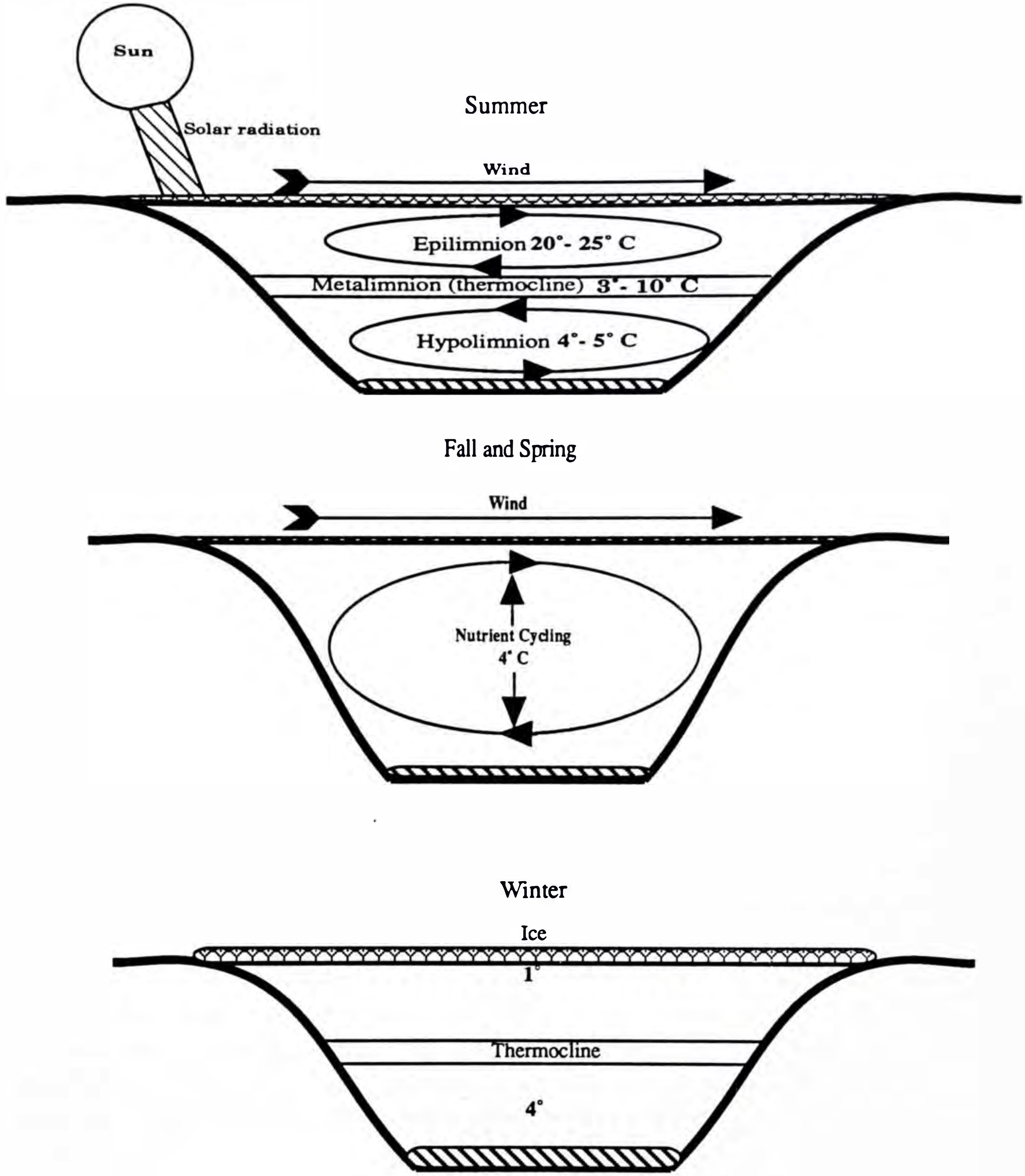


Figure 2. Nutrient mixing by means of lake turnover in dimitic lakes. During the summer, lakes are stratified into three layers (epilimnion, metalimnion, and hypolimnion). During Fall and Spring, the isothermal temperature and density allow the lake to overturn, thus redistributing nutrients. In winter, the lake is stratified with warmer water at the bottom of the lake and ice on the surface.

replaced in the epilimnion.

Once the water becomes colder than 4° C, it becomes less dense. The colder water now floats to the top of the lake, while the warmer water stays below; thus inverse stratification occurs. If the surface water cools to 0° C for a prolonged period, the surface will freeze. Eventually, the entire lake surface may be icebound. The cold water near the surface can hold high amounts of oxygen. Plants and animals use very little oxygen during these winter months because their metabolisms are considerably slower due to the low temperatures. As winter passes, the ice melts and solar radiation warms the lake again. Wind helps mix the water in the isothermal state and redistributes the nutrients again. Oxygen is carried down to the hypolimnion and nutrients are replenished to the epilimnion. By late spring, the lake body starts to resemble the summer stratification. The bottom nutrients are then available to surface organisms for spring and summer productivity.

Trophic Status of Lakes

There are many ways of characterizing a lake and each scheme has its limitations. One of the most useful biological classifications was originally proposed by Thienemann (1925) and later elaborated by others (Maitland 1990). Nutrient levels within a lake are prime requisites for Thienemann's characterization. Lakes are generally divided into three major categories: oligotrophic, eutrophic, and dystrophic. Young or oligotrophic lakes are usually lacking in nutrients, while eutrophic lakes are nutrient rich (Niering 1989). Oligotrophic lakes tend to be deep, oxygen rich with steep-sided lake 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 predestine its productivity. Steep-sided oligotrophic lakes do not allow extensive growth of rooted vegetation; there is no extensive, shallow margin for attachment. Eutrophic lakes tend to be relatively shallow and bowl shaped, which allows for the productivity of rooted plants (Table 1).

Older or eutrophic lakes are nutrient enriched and have a high surface to volume ratio. Eutrophic lakes are generally rich in phytoplankton, which is supported by the increased availability of dissolved nutrients. A eutrophic lake supports a tremendous amount of planktonic algae, yet is usually deficient in oxygen. Increased photosynthetic production leads to an increased regeneration of nutrients and organic compounds, stimulating even further growth (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. Oxygen levels are high, and macrophyte productivity is high, while phytoplankton amounts are low. Eventually the invasion of rooted aquatic

Table 1. Generalized characteristics 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 substrate	Stones and inorganic silt	Fine organic silt	Peaty silt
Lake shoreline	Stony	Weedy	Stony or peaty
Water transparency	High	Low	Low
Water color	Green or blue	Yellow or green	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. Chlor-phyceae typical	Few species, high numbers. Cyano-phyceae typical	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, Salmonidae characteristic	Many species, especially Cyprinidae	Extremely few species, often none

macrophytes chokes the aquatic habitat with plant growth (Goldman and Horne 1983). These are the general conditions witnessed at a bog.

Over time, lakes tend to be enriched by introduced nutrients and age through the process of eutrophication, "All lakes are doomed to die" (Niering 1989). 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 is a natural phenomena. The United States Environmental Protection Agency (USEPA) characterizes the process of eutrophication by the following criteria (Henderson-Sellers and Markland 1987):

1) Decreasing hypolimnetic dissolved oxygen concentrations;
2) Increasing nutrient concentrations;
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.

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, ground water, and run-off. As nutrient availability increases, so does production. Increased production leads to more dead organic material to fill-in lentic systems (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 one of these has its own complex chemical cycle within the lake. 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 ppb), however this is all that is needed for plant growth, due to the high efficiency with which plants 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 an extremely complex one, with some models including seven different forms of phosphorus (Frey 1963). For the purposes of this study, it is necessary only 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 3. DP is inorganic phosphorus which is a form that is usable by plants; it is the form of phosphorus limiting to plant growth. PP is phosphorus that is incorporated into organic matter such as plant 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 form of dead organic matter. If there is oxygen present, this PP will be converted to DP through the decomposition process of aerobic bacteria. If there is no oxygen present, such as is often the case in the sediments of a stratified lake, anaerobic bacterial decomposition of the PP will result in its conversion to DP (Lerman 1978).

Another important reaction that occurs involving DP is in oxygenated water where iron will exist in its oxidized form, Fe(III). This form of iron can bind with DP to form an insoluble complex, ferric phosphate, that settles into the sediments and effectively ties up a large amount of P. Upon decreasing the oxygen levels at the sediment-water interface, such as after extended periods of stratification, the Fe(III) is 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 significant build-up of DP in the sediments. In fact, the sediments of a lake can have P concentrations of 50-500 times the P concentration of the water (Henderson-Sellers and Markland 1987)! This means that a lake's sediments can be an even

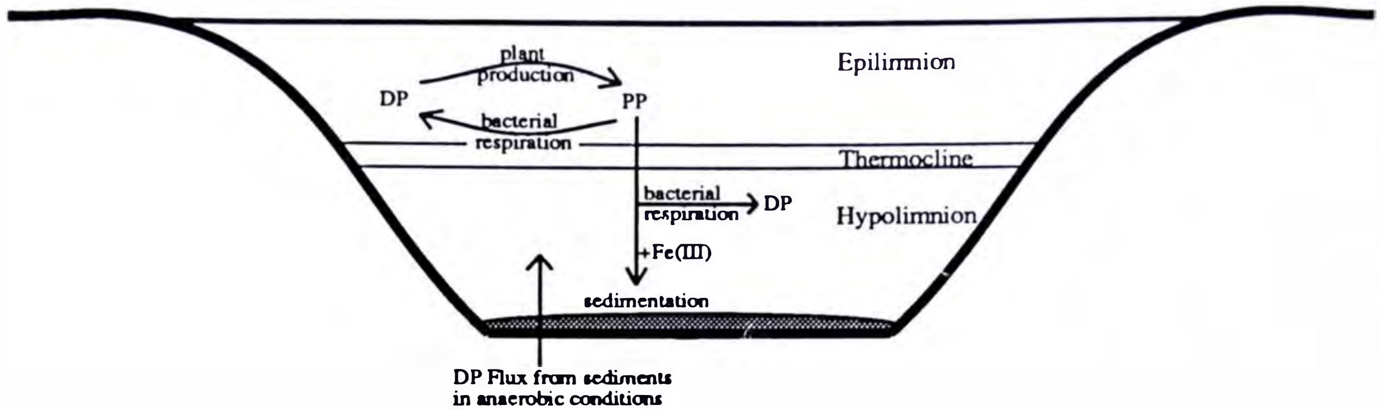


Figure 3. A model of the cycle of the major forms of phosporus, dissolved (DP) and particulate (PP), within a lake ecosystem. The sedimentation of DP through complexation with Fe(III) contributes to the build up of DP in the sediments. Note the production of DP in the hypolimnion due to bacterial decomposition as well as from the release of DP from the Fe complex in the sediments during anaerobic conditions. Critical to the cycle is the fact that the thermocline prevents DP from mixing between the surface and bottom water (Adapted from Lerman 1978).

larger P source than external inputs. Because nutrients are inhibited from mixing into the epilimnion during the summer by the stratification, DP formed in the sediments and lower hypolimnion builds up until fall overturn. The 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 at fall overturn, DP will be converted to PP in the form of algal tissue. The algae will die as winter approaches and settle to the bottom where the PP will be converted back to DP and build up again, allowing for another large nutrient input to the surface water at spring overturn.

The other major plant nutrient, nitrogen, is not usually the limiting factor for plant growth. However, it is still important to understand its cycle because high concentrations can lead to algal blooms in the presence of phosphorus. Also, levels greater than 10 ppm can lead to the development of the condition in infants known as methemoglobinemia if the water is used as a source of drinking water (Greenberg 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 4.

The majority of free nitrogen in a lake exists as nitrates (Maitland 1990). This form of nitrogen is directly available for assimilation by algae and macrophytes (Figure 4). In eutrophic lakes, there may be so much algae and macrophyte growth that most of the nitrates of the lake are incorporated into their growth (Maitland 1990). Nitrites, however, cannot be used by plants. Nitrate-forming bacteria in aerobic conditions, convert nitrites to nitrates. Ammonia, which enters the lake ecosystem as a product of the decomposition of plant and animal tissues and 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 of no use to any plants except for those that have the capability of nitrogen fixation - they can convert N_2 to nitrates. 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 use as a nutrient by plants. So 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 or anaerobic) of the water.

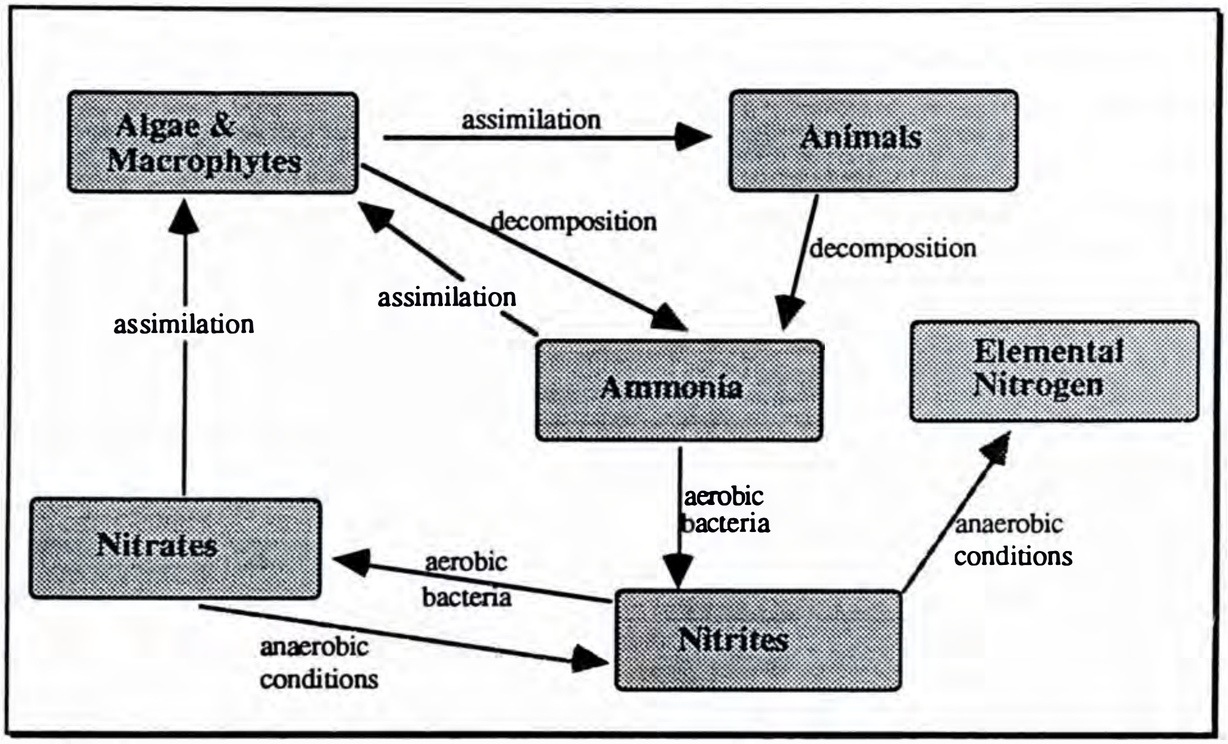


Figure 4. A diagram of the various forms of nitrogen that occur in the nitrogen cycle within a lake ecosystem. It is important to note that in aerobic conditions nitrites are converted to nitrates which are available for use by plants.

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

One of the easiest methods used to eliminate excessive nutrients is to rapidly decrease the lake water level (Henderson-Sellers and Markland 1987). For example, if dams are used to control the outflow of the lake, by opening these widely, so that the lake loses a large volume of water in a short period of time, many of the nutrients located in the epilimnion will 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 temporary 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 requiring a fairly simple piece of equipment 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. By adding an aluminum or iron salt to the water, it will complex with DP to form an insoluble compound that will effectively immobilize the P (Henderson-Sellers and Markland 1987). This is an effective technique but, due to the cost, is not extremely practical for very large lakes. Furthermore the P will eventually be released from this complex, requiring reapplication after several years (Tom Gordon pers. comm.).

Aeration of the hypolimnion is an option that requires some expensive machinery to perform the aeration. It operates on the principle that by increasing the oxygen in the lower levels of the hypolimnion, the amount of DP released from the sediments will be reduced. If there is oxygen present at the soil/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 expensive equipment used and the frequency which the harvesting must be done. This procedure removes all the nutrients that are tied up in the plants at the time of harvest and prevents them from re-entering the lake cycle (as long as the harvested plants are not stored on shore, allowing for the nutrient rich water in the plants to flow back into the lake, (Tom Gordon pers. comm.). There is some debate over the effectiveness of this method however, because plants also act as a sink for nutrients, so at the time of removal, the nutrients that would normally have been taken up by the plants will be available to algae, resulting in an algal bloom (David Firmage pers. comm.). On the other hand, if only the foliage of the plants are 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 effective, it is extremely expensive due to the large cost of the equipment needed (Henderson-Sellers and Markland 1987). Also, there is some question as to ecologically disruptive effects that actions such as this may have on the lake system.

In terms of eliminating nutrients once they have built up in a lake, it is evident from these non-ideal techniques that it is a very challenging task, due to the internal cycling within the lake. Perhaps 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 deal with them without large accumulations over time.

Freshwater Wetlands

Wetlands serve as a transition between aquatic and terrestrial ecosystems. They are among the richest ecosystems and support a large variety of species, both aquatic and terrestrial. Wetlands are often located in prime recreational and commercial areas and because they cannot be used in their natural state, they are often filled and drained. The destruction of wetlands is immense, thousands of acres of wetlands are ruined annually (Nebel 1987).

Problems arise when attempting to classify these delicate ecosystems for management and conservation. There are numerous definitions of the term "wetland". Wetlands are commonly associated with wet areas that support hydrophytes. Most of the complications in defining wetlands are due to the incredible diversity of wetlands. Early definitions that were meant to help identify wetlands for their protection were found to be too vague. In 1956, the United States Fish and Wildlife Service used the following definition that became known as the "Circular 39" (Jorgensen 1978):

> lands covered with shallow and sometimes temporary or intermittent waters....including marshes, swamps, bogs, wet meadows, potholes, sloughs, and river overflow lands....also shallow lakes and ponds with emergent vegetation....not including the permanent waters of streams, reservoirs and deep lakes nor are water areas that are so temporary as to have little or no effect on the development of moist-soil vegetation.

In 1979, the United States Fish and Wildlife Service defined wetlands as areas meeting the following criteria (Gore 1983):

> lands transitional between terrestrial and aquatic systems where the water table is at or near the surface or the land is covered by shallow water....Wetlands must have one or more of the following attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of the year.

The U.S. Army Corps of Engineers (1984) as found in Jorgensen (1978) defined wetlands as:

> those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas (Lyon 1993).

The definitions changed dramatically over the years and the most recent ones serve to protect these valuable ecosystems. An attempt has been made in the definitions to easily and concisely define a very diverse lot of environments. The earlier definitions over-simplified the wetland ecosystem and through this, ecologically valuable areas were not protected.

Over the years, the definitions began to define wetlands by the type of vegetation that they support. Typical plants associated with wetlands include grasses, sedges, and rushes. Shoreline vegetation includes buttonbush, ferns, leatherleaf, shadbush, sweet gale, sweet flag, sheep laurel, and purple loose strife. Common species found in the emergent zone are cattail, bur reed, arrowhead, pickerel weed, sedge (bulrush), reed, and duckweed. Submergent and floating flora such as pond lilies, water shields, and floating brown leaf are characteristic of the deep water wetlands. Wetlands serve as breeding and nesting sites for various waterfowl and as a habitat for other terrestrial or aquatic animals. Table 2 shows a listing of freshwater wetland species.

Wetlands can be found lying at the shoreline of Salmon Lake, such as the marsh at Cold Brook and the southern tip of Ellis Pond, and also within the watershed from the lake. The wetlands in both of these areas must be taken into consideration when assessing nutrient loading. Questions such as whether they increase (a source) or decrease (a sink) nutrient concentrations within the lake must be addressed.

One important biological characteristic of a wetland area is its nutrient uptake and release ability and the effect this may have upon water entering a lake body. Agricultural run-off puts excess nitrogen and phosphorus, the primary limiting agents in a lake system, into the lake. Wetlands absorb some of these nutrients, thereby improving the water quality, and store the nutrients in sediments to be used by plants later (Niering 1985). A wetland is considered a nutrient sink if the inputs of an element are greater than the outputs. It is considered a nutrient source if its outputs exceed its inputs. One wetland can be a sink for one nutrient while another wetland in a different area can be a source for the same nutrient. The results of various studies of freshwater marshes in Wisconsin done in the late 70's and early 80's follow this trend (Mitsch and Gosselink 1993).

Nutrient uptake in wetlands changes from season to season because of the high rate of nutrient uptake by vegetation during the growing season, and due to varying combinations of hydrologic parameters (Mitsch and Gosselink 1993). Mitsch and Gosselink (1993) summarize a 1979 study that describes the general seasonal uptake of nutrients. They found that during the growing season there is a high rate of nutrient uptake from the water and sediments by emergent and submerged vegetation, causing the wetland to act as a nutrient sink. During the fall and early spring nutrients are lost to the water through litterfall, decomposition, and leaching, causing the wetland to act as a nutrient source (Mitsch and Gosselink 1993).

The nutrient trapping ability of wetlands has stimulated research into the possibility of using them to filter pollutants out of the water (Niering 1985). They have the potential to reduce heavy metals and nutrients from various sources including mine drainage, sewage, and industrial wastes (Smith 1990). These pollutants bind to soil and sediment particles making them inert (Finlayson and Moser 1991). Filtering by wetlands helps to increase the water quality of the aquatic ecosystem the wetland borders.

Overall, there have been relatively few studies conducted on natural wetlands. Therefore, practical applications of wetlands to solve environmental problems must be explored to further understand these ecosystems. Some studies have been conducted to see if wetlands are capable of "cleansing" waste waters and sludges by removing toxins from the water before it enters a lake system (Mitsch and

Table 2. Types of Fresh Inland Wetlands (Smith 1990)

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 hard-woods 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 15cm or more of water	Grasses, bulrushes, spike rushes, cattails, arrowhead, pickerel-weed
Deep fresh marshes	Soil covered with 15cm to 1m of water	Cattails, bulrushes, reeds, spike rushes, wild rice
Open freshwater	Water less than 3m deep	Bordered by emergent vegetation such as pondweed, wild celery, water lily
Shrub swamps	Soil waterlogged; often covered with 15cm	Alder, willow, button-bush, dogwoods
Wooded swamps	Soil waterlogged; often covered with 0.3m 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, sedges

Gosselink 1993). Various qualities of a wetland make it more suitable to process pollutants, including flora, water flow patterns, retention time, and soil types (Niering 1985). A study conducted near Philadelphia resulted in a reduction of nitrogen and phosphorus in waste water by 50-60% as it flowed across a 500 acre freshwater marsh (Niering 1985).

Although this "cleansing" method seems like a solution to the waste water disposal problem, not enough is known about the long-term effects of passing this water through the wetland ecosystems to widely use them as waste water recycling systems (Godfrey et al. 1985).

Soil Types

Nutrient loading into lakes and ponds is strongly influenced by the types of soil found in the watershed and the different characteristics of the soil such as permeability, erodibility, slope, average depth of the water table, depth of the soil to underlying bedrock, flooding frequency, rockiness, organic content, and presence of an impermeable layer (USDA 1978). These characteristics will limit the possible uses for different soils. The soils best suited for development are those that have medium permeability, low slope and erodibility potential, deep water tables, low rockiness and organics, and no impermeable layer (USDA 1992). Soils that exist in the presence of an impermeable layer or with low inherent permeability will not allow for proper drainage. They are unsuited for residential septic systems and some types of agriculture. Soils that drain poorly or have water tables that occur too close to the surface are limited by wetness and are unsuitable for residential development as well. Both slope and erodibility of soils limit the possibility for road construction, agriculture, and residential development. If soils are not sufficiently deep, growth of vegetation is limited to species with shallow root systems. In addition, development, excavation, and septic limitations exist in shallow soils. Rocky soils will pose problems for agricultural uses such as crops, but permanent pastures or orchards are possible.

Soils have a direct influence on the occurrence of the various species of flora and fauna that are found in different areas. The soils in the watershed should also dictate the type of land use found there. Towns need to pay attention to the soils in potential areas of development when forming their comprehensive plans for land use.

Watershed Land Use

Land Use Types

A watershed is defined by the total land area that contributes water to a particular lake. It is restricted 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 water quality of a lake. Different types of land use have varying effects on nutrient loading to lakes. Nutrients can bind to soils and, depending on the extent of soil erosion associated with land use practices, this eroded soil can add to the nutrient load. Nutrients from anthropogenic sources have had a serious effect on water quality in numerous Maine lakes (MDEP 1992).

Areas that have been cleared for agricultural, residential, or urban uses can contribute to nutrient loading. The combination of removing vegetation and compacting of soil may result in a significant increase in surface run-off. Surface run-off can increase erosion of both natural sediment and anthropogenic sediments; sediments associated with human activity can contain nitrogen, phosphorus, other plant nutrients, and chemicals (e.g., fertilizers, pesticides, herbicides) (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 run-off. The canopy provides a cover over the soil lessening the impact of rain, and greatly reducing soil erosion. The root systems of the trees further reduce soil erosion and slow run-off allowing water to percolate into the soil. Forested areas act as buffering systems by absorbing the nutrients when they are located in between sources of nutrients and water bodies. By clearing forested areas nutrient loading can be increased and water quality in a lake decreased. A study concerning phosphorus loading in Augusta, Maine revealed that a residential area produced ten times more phosphorus than an adjacent forested area (Dennis 1986).

Much of Maine is covered in forests, and therefore expansion of residential areas usually results in forest clearing. The resulting development provides impervious surfaces that allow the build up of surface run-off. This results in an increase in nutrient loading in an area that previously acted as a buffer zone.

Residential areas are divided into shoreline and non-shoreline homes that are either permanent residences or seasonal homes. Permanent residences located on the lakes shore have the potential for the greatest impact on water quality. However, most shoreline homes in Maine are seasonal (BI493 1993a). Residential areas throughout the watershed generally include lawns, driveways, parking areas, rooftops, and other impervious surfaces that cause run-off accumulation, thereby reducing percolation.

The use of household products in and around the home is also potentially harmful to water quality. Due to their proximity to the lakes, shoreline homes can provide direct sources of nutrients to the lake. Products used in the household (e.g., detergents and soaps) contain phosphorus. Lawns and gardens are maintained with fertilizers that are high in phosphorus. These products used around the home can leak into the water column and lead to lake eutrophication (BI493 1993a). They are drained away in storms by increased surface run-off that accumulates on or near households. Septic systems found at seasonal homes can also be large sources of nutrients if they are not designed or used properly (EPA 1980).

Commercial uses of forested land such as logging and tree harvesting removes the cover of the canopy, thereby exposing the soil to direct rainfall. Two studies by the Land Use Regulation Commission on tree harvesting sites found that erosion and sedimentation problems were occurring on 50% of the active and 20% of the inactive logging sites selected (MDC 1983).

Roads can also provide excessive surface run-off if badly 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 leading down to shoreline areas provide easy access to the lake for run-off and can contribute large amounts of nutrients if they are not well-constructed or maintained.

All land uses are important in determining the water quality of a lake. To maintain water quality there must be regulations in place that prevent an increase in nutrient loading when development occurs. Investigation of land use practices and possible future developments will help further the maintenance of a healthy lake system.

Nutrient Loading

The sources of nutrients associated with algae blooms are frequently anthropogenic. Surface run-off may be increased due to flat, impervious surfaces associated with human activities (parking lots, roads, rooftops, etc.). Sediments associated with human land uses (residential, agriculture, industrial) may carry animal waste, detergents and soaps, sewage, and other chemicals harmful to lake water quality.

Total phosphorus loading can be modeled with a phosphorus loading calculation (refer to Land Use section: Phosphorus loading model) that considers all inputs to the lake. Characteristics such as lake size, flushing rate, volume, and the rate of release of phosphorus from sediments, macrophytes, and other sources in the lake basin are considered in this calculation (Cooke 1986).

Zoning and Development

The purposes of zoning and development ordinances are to maintain safe, healthful conditions, prevent and control water pollution, protect wildlife and freshwater wetlands, control building and placement of structures, control land uses, conserve rural nature, and to anticipate the impacts of development (Belgrade, Town of 1991). Shoreland zoning ordinances regulate development along the shoreline in a manner that reduces the deterioration of lake water quality. Uncontrolled development 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 (Dominie and Scudder 1987).

Shoreline Residential

Shoreline residential areas are especially important due to their proximity to the lake system. Nutrients released by households 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 regulate buffer strip widths thereby influencing phosphorus loading to the lake.

Households that have lawns leading right down to the shore leave no obstacles for run-off and movement of phosphorus directly and immediately to the lake. Buffer strips, when in conjunction with appropriate setback laws for the house, can dramatically reduce the proximity effects of shoreline homes (MDEP 1992a).

In areas where relevant ordinances have been enacted after major development has taken place, grandfathered homes may be left unchanged. These homes would not be required to follow local regulations thereby having a greater impact on lake quality than new homes.

Regulations concerning septic systems are also important in stabilizing nutrient loading. Shoreline residential areas separated from municipal sewage systems often use septic systems to deal with sewage. Due to their proximity to the lake the chances of leaks into the lake are high if the septic systems are badly located or incorrectly maintained (refer to Background section: Septic systems).

Summer Camps

Maine summer camps located on or near the shoreline can contribute to phosphorus loading into the lake system. Although seasonal, they normally involve large numbers of people. Therefore, understanding issues concerning septic systems are essential in determining the role of these recreational areas on water quality. Their effect on nutrient loading depends on factors such as septic system location and condition. Proper gray water disposal is important in terms of preventing it from running directly into the lake especially if it does not enter the septic system. Camps often involve large areas of lawn and impermeable surfaces (e.g., tennis courts) which increase phosphorus run-off.

Non-Shoreline Residential Areas

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

The same restrictions and regulations used for shoreline homes should apply to homes along streams leading into the lake in question. Any phosphorus washed from a residential lawn without buffer strips will enter into a stream and therefore the lake.

Houses located half a mile away from the lake can supply the lake with phosphorus almost directly, because of badly constructed roads. Run-off collecting on roofs and driveways may travel down roads unhindered to the lake. Although non-shoreline homes are not as threatening as shoreline homes, watersheds having large residential areas with improper drainage can have a significant effect on phosphorus loading (David Firmage pers. comm.).

Sewage Disposal Systems

Subsurface waste disposal is the common method for handling household wastes in areas where municipal waste treatment is not an option. Inadequate waste water disposal around a body of water can pose dangers not only to the quality of water, but to human health as well. Understanding how waste disposal systems function can help to lessen the threat to water quality (Miller 1980).

Subsurface waste disposal systems, as defined by the Maine Department of Human Services, refers to any system for disposing of wastes or waste waters on or beneath the surface of the earth (MDHS 1983). There are three major types of disposal systems believed to be in use within the Salmon Lake watershed: privies, holding tanks, and septic systems.

Pit Privy

A pit privy, also known as an outhouse, is the most primitive form of subsurface waste disposal. A privy is a waterless toilet placed over excavation where black waste (human excretion) is deposited (MDHS 1988). Privies are typically small, shallow pits or trenches that normally receive only human waste and paper. Properly constructed pit privies allow effective decomposition and treatment of human wastes. The volume of water introduced to such facilities is relatively small. Thus, problems associated with odors and disease-carrying insects pose more of a threat than ground water contamination. However, if an outhouse is located too close to a body of water, contamination could occur through infiltration in the upper soil zones without getting into the ground water (Miller 1980).

Holding Tank

A holding tank is defined as a watertight receptacle, with an alarm, which receives and holds waste water until it is pumped and disposed of at a properly licensed location. Holding tanks are installed to replace existing residential systems or for commercial or industrial structures when no other reasonable disposal alternative is available (MDHS 1988).

Septic Systems

Septic systems are more complex than both privies and holding tanks, as they receive more waste and a variety of waste products, and have a more complex design. Septic systems are the most common systems for waster disposal and the most frequently reported sources of contamination of ground water. Septic tank systems consist of the septic tank and associated soil absorption system; porous pipes and a leach field. Figure 5 displays the components of the septic absorption system and underlying ground water configuration. In most areas, properly designed, constructed, and maintained septic tank systems are efficient and economical alternatives to public sewage disposal systems (Miller 1980). However, due to poor locations of many septic systems, as well as poor maintenance practices, many septic systems have polluted or have the potential to pollute bodies of water. It is estimated that only 40% of existing septic tanks in the United States function in a proper manner. A related issue is that the designed life of many septic tank systems is about 10-15 years with proper maintenance, but many people do not know this and may be unknowingly contaminating ground water.

The septic system should be placed far enough away from bodies of water so that septic waste does not contaminate the water. Currently, septic systems in Belgrade are required to be set back at least 100 ft away from lakes and 75 ft away from streams (Belgrade, Town of 1991). However, because of grandfathered systems around Salmon Lake, a certain percentage of waste water structures is closer to the lake than recommended. Grandfathered structures that are closer than the current setback requirement or on unsuitable soils due to permeability and topography can place the septic leach field farther back from the shoreline and pump waste up-slope, away from the water body.

Household waste, including gray water and human waste, is transported from the home by a sewer

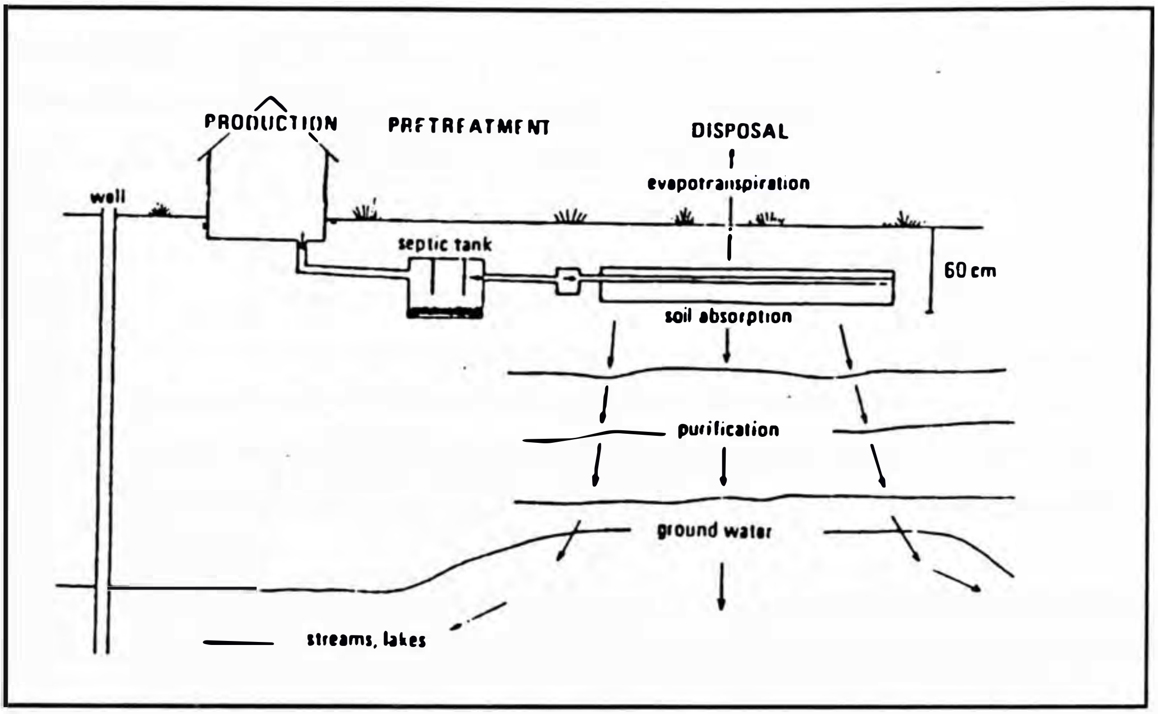


Figure 5. Schematic cross-section through a conventional septic tank soil disposal system for on-site disposal and treatment of domestic waste (Miller 1980).

line to the settling tank. These tanks are buried in water-tight receptacles designed and constructed to receive waste water. A typical two-compartment septic tank for a housing unit is shown in Figure 6. The tank provides for separation of sludge and floatable materials from the waste water and an anaerobic (oxygen-free) environment for decomposition.

In the septic tank, solids settle to the bottom forming a blanket of sludge. The lighter material includes fats and greases, and rises to the surface forming a layer of scum. Anaerobic digestion, the breaking down of materials without oxygen, takes place allowing the solids to be slowly broken down by microorganisms. A considerable portion of the sludge and scum is liquefied through decomposition and digestion processes. The separated fluid drains from the settling tank to porous pipes in the leach field.

The soil absorption component is typically a trench or bed system that allows percolation into the soil layers for natural filtering and purification of the liquid (Figure 7). Beds differ from trenches in that they are wider than three feet and may contain more than one line of distribution piping. The perforated pipes enable the septic effluent to slowly seep into the surrounding soil of the leach field. Any remaining solids are removed from the liquid by aerobic microbial degradation (the break-down of materials with oxygen) and through the naturally occurring filtering capability of the soil, provided that the soil is sufficiently permeable. Ideally, the liquid from the septic tank is free from pathogenic organisms as well as other contaminants by the time it reaches the water table or any body of water (Montgomery 1989).

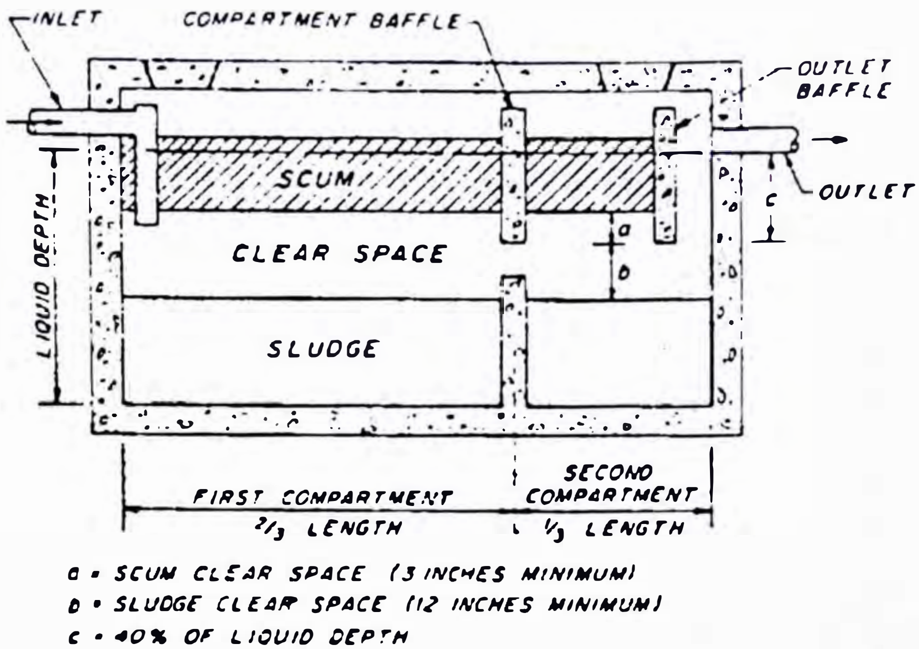


Figure 6. Typical two compartment septic tank (Miller 1980).

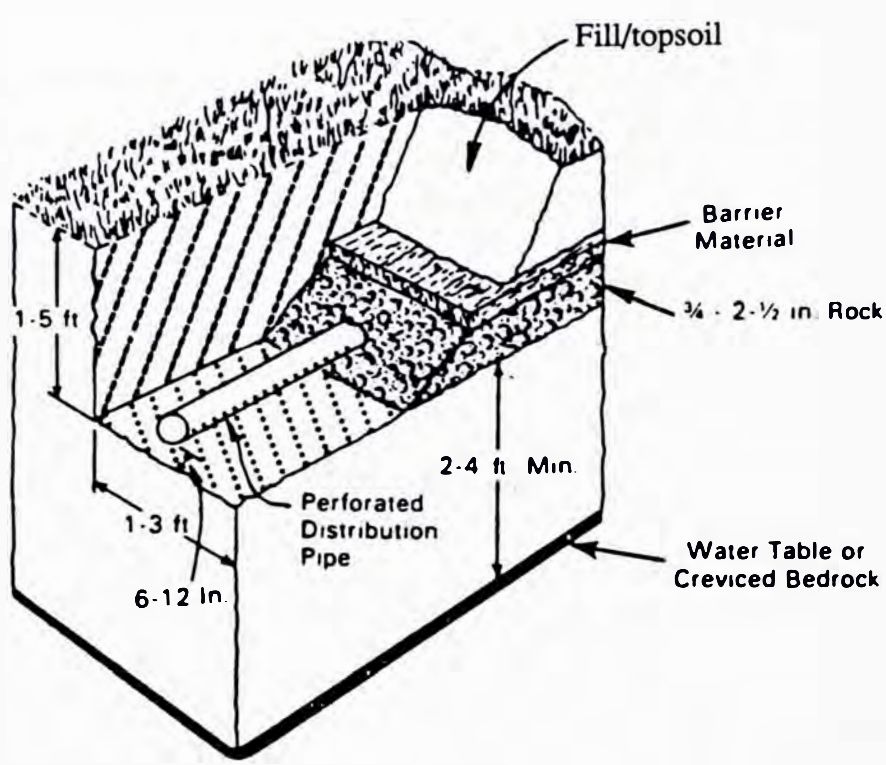


Figure 7. Typical Trench-type Soil Absorption System (Miller 1980).

Septic systems that do not adequately treat wastes can pose threats to water quality, aquatic life, and human health. Increased Biological Oxygen Demand (BOD), eutrophication, and water contamination are three potential effects that sewage can have on a body of water.

BOD describes the amount of oxygen that is needed by microorganisms to aerobically break down organic matter in a body of water. Oxygen is used by organisms involved in the decomposition of organics. The more organic matter is present, the higher the BOD. An increase in organic matter can occur as a result of contamination from human and animal wastes, due to failing septic systems. If the BOD exceeds the amount of dissolved oxygen, aquatic plants and animals that require oxygen begin to die (Montgomery 1989). In lakes where flushing rates are very slow, low dissolved oxygen content can become a very serious long-term problem, affecting the flora and fauna of the lake for many years. Once the dissolved oxygen content declines, the recovery of the lake to prior levels of oxygen can be very slow. The breakdown of organic material present in the lake will continue to decrease the available oxygen that comes from spring and fall overturns.

There are three major components that comprise the waste flowing into the holding tanks and septic tanks receiving water: garbage disposal wastes, black water, and gray water (Mitchell 1974). Each type of waste contributes various amounts of nutrients and microorganisms to the system. Garbage disposal wastes usually consist only of food that is deposited into septic and holding tanks and are a serious component because such wastes have major effects on the proper functioning of the system. Black water consists of toilet wastes contributing nitrogen, phosphorus, and microorganisms from human excretions. The third major type of waste deposited in the septic tank is gray water which includes waste water that comes from sinks, basins, showers, and household appliances such as washing machines and dishwashers. Often, waste water is treated as a harmless substance that can be dumped into bodies of water. On the contrary, waste water can be a major component in the phosphorus loading in a lake or stream. This waste water often contributes chemicals, inorganic material, metals, and phosphorus from detergents that can have serious effects on the water quality of the area and the health of associated flora and fauna (Miller 1980).

Another type of ground water pollution associated with septic systems and other sewage disposal mechanisms is bacterial contamination. Contamination of drinking supplies, lakes, and streams by malfunctioning septic tank systems have caused outbreaks of water-borne communicable diseases (Mitchell 1974). Documented cases of infectious hepatitis, typhoid, cholera, streptococci, salmonella, poliomyelitis, as well as protozoan outbreaks have been transmitted by septic tank system overflows and malfunctions.

A septic system that is properly engineered and maintained provides good treatment of household wastes, and is not a threat to water quality. Unfortunately, few people realize that their septic system needs periodic maintenance. Maintenance begins by limiting what goes into a septic system. Avoid or reduce use of garbage disposals. The extra garbage can cause an unnecessary strain and perhaps permanent failure of the system. Materials such as cigarette butts, diapers, paper towels, and sanitary napkins are not easily broken down by the microorganisms in the septic tank. Flushing these items down the toilet can cause the system to clog (COLA 1991). Household chemicals including bleach, paint, and disinfectants kill the microorganisms that are responsible for breaking down organic wastes in the septic tank. This should be prevented by using only non-phosphate detergents. In addition, decreasing the amount of phosphorus increases the efficiency of septic systems (COLA 1991). Finally, reducing the amount of water that enters the septic tank can prevent the possibility of overflow.

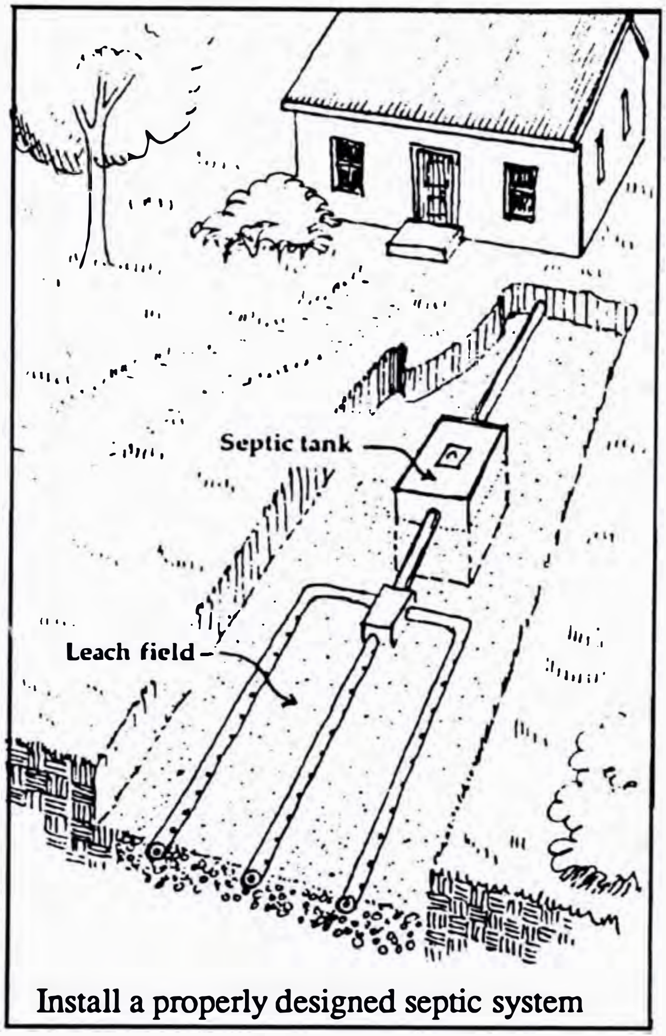
Even a well-maintained septic system needs to be pumped out regularly (Figure 8). Pumping is necessary to prevent the solids that settle on the bottom of the septic tank from flowing into and clogging the leach field and possibly causing a complete system failure (COLA 1991). In general, a septic system should be pumped out when the tank is half full of solids, usually every three to five years depending on the amount of use.

Early detection of problems associated with septic system failure is important in preventing damage to surrounding waters, including ground water and lakes. If water drains slowly or gurgles as it goes down the drain or it smells like sewage anywhere near the house or yard, the septic system may be clogged or overflowing. This could mean the septic tank needs to be pumped out. If grass appears excessively lush and green or the ground is soggy over the septic system, the system could be improperly designed or it may need servicing. Furthermore, a high coliform count in a well or nearby water source is a good indicator of failing septic systems.

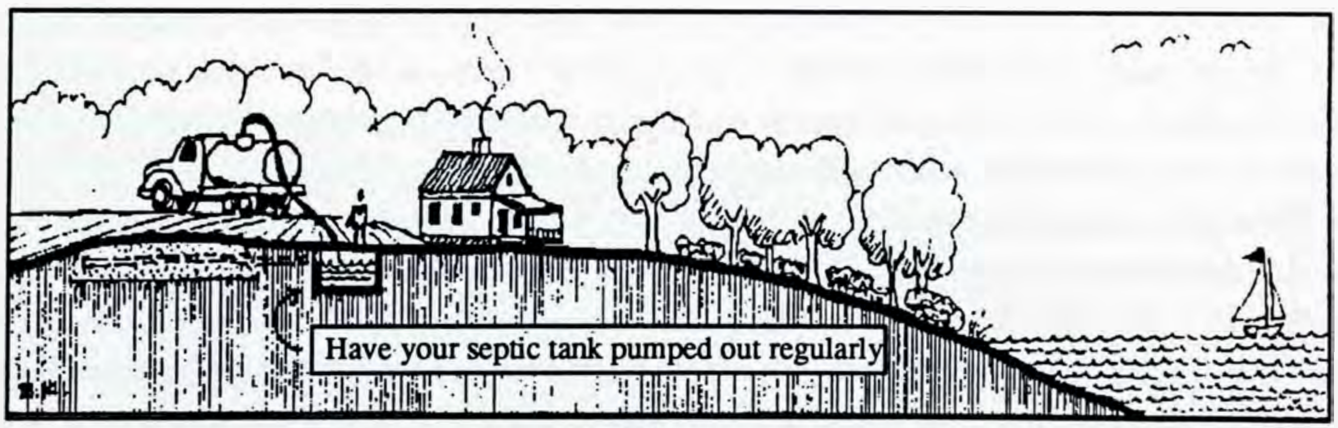
The construction of septic systems and leach fields is an important factor in residential development near lakes and ponds. The proper installment of septic systems is an essential part of ensuring the continued quality of ground water, the shoreline environment, and lake or pond. To allow the proper purification of sewage, soil characteristics and topography of perspective locations of septic systems must be considered. Overlooking the importance of soil characteristics and topography of perspective septic system sites could lead to unsanitary conditions and costly cleanup problems.

The physical environment in which the septic system is to be constructed is an important detail that must be addressed before it is built. Proper soil for sewage treatment should allow the leachate to be purified by the natural movement of the run-off through the leaching field. By travelling through the soil neither too fast nor too slow, the leachate releases its nutrients into the soil, and disposes of its odor and pathogens (Hendler 1973). A soil consisting ofa mixture of loam, sand and gravel deep enough to handle the volume of waste created, is an ideal soil type for proper run-off and purification of leachate (Canter and Knox 1985).

Ignoring soil characteristics in the installment of a septic system could cause problems with the shoreline and lake environment. Porous soils, such as sand, permits sewage to run through the leach field too quickly, polluting ground water and allowing the untreated sewage to enter into the lake. A soil that is not very permeable, such as a clay based soil, will not allow the absorption of the sewage and consequently causes the seepage of waste to the surface of the leach field. Thin soil, or soil too close to bedrock will cause the sewage to deflect back to the surface. Both thin and non-permeable soils will create unsanitary conditions with increased organic waste and nutrient loading to the lake and shoreline environment (Hendler 1973).



(A)



(B)

Figure 8. Use of septic systems to avoid contamination of water bodies. A) Install a properly designed septic system in an appropriate location. B) Pump out your septic tank every three to five years (COLA 1991).

Improper soil type problems can be corrected using soil amendments, specific to the problem at hand (MDHS 1993). For example, if a soil is not permeable enough for a septic system due to an excessive amount of clay, the soil can be made more permeable by adding sand and loam (which are more permeable than clay) into the existing substrate. Conversely, one can add loam and clay, which retain water well, to a soil that is too permeable. Or, if the problem pertains to a lack of soil depth, volumes of soil can be added to the area to increase the depth to acceptable levels (MDHS 1993). The depth of soil needed is a function of the capacity of the septic system.

Consideration of slope should also be a major factor considered in the installment of a septic system. A gentle slope of 10 to 20% is needed for the proper movement and purification of sewage run-off through the leach field. An area without a sufficient slope will have problems with stagnation of run-off in the leaching field causing seepage to the surface and possibly permeation to ground water and wells (Hendler 1973). Conversely, an area with too great a slope (greater than 20%) will allow run-off to flow through the leaching field too quickly, even with the presence of good soil (Canter and Knox 1985). The sewage run-off would not be purified and may leach into the ground water, shoreline environment, and lake. Areas with topographical problems can be corrected by altering the slope by digging or by adding volumes of proper soil.

The Maine Land Use Regulation Commission reported that 52% of the camps and 10% of the year-round homes built in the state's rural areas from 1971 to 1991 were on lakes or ponds (Bradbury 1993). Increased pressure is being put on lakes with the most desirable fisheries, wildlife, and other important resources. Measures are needed to protect these natural resources, the public safety, and water quality from septic system use. Federal, state, and local governments are responsible for these measures, and they have created a special set of laws to mandate proper development and subsurface sewage disposal. These laws protecting the shoreline and shoreline environment fall under the category of zoning ordinances.

Shoreline zoning regulates development within a 250 square foot perimeter around water bodies. Particular zoning ordinances are established to regulate and limit the types and density of new development on the shoreline (MDEP 1992b).

The responsibility for zoning ordinances begins with the federal government, which sets the national minimum standards for subsurface waste disposal. The states, who bear the brunt of the responsibility for zoning ordinances, then set their own minimum standards in accordance to the federally mandated laws. The MDEP and Maine Department of Conservation are responsible for the minimum state standards and their enforcement. Some primary examples of state shoreland zoning ordinances include: the minimum setback distance for subsurface waste disposal from the shoreline, construction in a flood plain, and the minimum lot size requirement. The distance septic systems must be set back is a minimum of 100 horizontal feet from the normal high water line of a perennial water system (MDEP 1992b). Also, there cannot be construction of a subsurface septic system within the limits of a 10-year flood plain (MDHS 1980). Lastly, the state minimum residential lot size requires that lots be at least 20,000 ft^2 (MDEP 1992b).

There are also general examples of Maine state zoning ordinances that apply to the shoreline environment as well as inland areas. First, the proposed site for a septic system must go through an on site evaluation, by a state certified professional, before any construction begins. Secondly, a septic system cannot be less than 100 ft from a well supplying 2,000 gallons or less per day, or 300 ft from a well supplying more than 2,000 gallons per day. And lastly, a septic system must be installed in a site having an original surface slope of no greater than 20% (MDHS 1980).

In the special cases of unorganized territories, the state is responsible for the land use regulation. The responsible group within the state of Maine is L.U.R.C. (Land Use Regulation Commission), a division of the Department of Conservation. Their regulations and classification schemes of lakes and ponds are contained in Maine's Comprehensive Land Use Plan (MDC 1990).

Local governments then set their own standards, in the light of state and federal minimum standards, to ensure their own needs and goals as a community are met. These local standards tend to be more stringent than state set minimums, as in Oakland's minimum lot size requirement of 80,000 ft^2 (compared to Maine's minimum of only 20,000 ft^2) can attest. Generally, local ordinances are contained in the city or town's comprehensive land use plan. If not, they may be found in particular ordinances drawn up for the regulation of the locality's shoreline areas, much the same as Belgrade's shoreline ordinances. Oakland and Belgrade have very similar ordinances, which were based in large part on Maine's minimum standards (refer to Analytical Procedures and Findings section: Zoning and Development). As stated before, if the town is not able to mandate local shoreline land use ordinances, Maine's Comprehensive Land Use Plan would be used to satisfy the area's needs.

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 run-off from land into the lake. This is especially prevalent for roads that lead directly down to the water. Besides adding phosphorus, they may allow easy access for run-off 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.

There are four different types of roads which we classified in the Salmon Lake watershed: state, municipal, fire, and private. Public roads, or those owned or operated by a governmental body, incorporate state, municipal, and some fire roads. State roads are typically the widest roads because they handle the largest volume of traffic. Municipal roads, which are controlled by their respective towns, are either as wide as or slightly narrower than state roads. Both municipal and state roads are typically paved and relatively well maintained. Most fire roads are under town jurisdiction, although some are privately owned. These roads are narrow and typically dirt. Private roads are usually driveways, but may include something more extensive (e.g., some camp roads). Construction and maintenance of private roads is the responsibility of the private owner or group of owners.

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 increase the amount and rate of run-off (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 and nutrient loading to a lake if poor construction, maintenance, and/or erosion control practices occur (BI493 1991).

Road construction should try to achieve the following long-term goals: minimize the surface area covered by the road, minimize run-off and erosion with proper drainage and the placement of wetponds and catch basins (as well as ditches and culverts), and maximize the lifetime and durability of the road (MDEP 1990). Thus, a well constructed road should allow surface water to run-off away from the road and channel road surface waters to prevent excessive amounts of surface run-off, 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 and culverts), and road maintenance (MDEP 1992b).

The location of a road is typically determined by the area that homes are built in, although the State of Maine has set guidelines (MDEP 1990). All roads must be set back at least 100 ft from the shoreline of a lake if they are for residential use, and 200 ft for industrial, commercial, or other non-residential uses involving one or more buildings (MDEP 1991). Along with this limit, a new road in Oakland or Belgrade should not be built with a grade of more that 10%, except for short segments of less than 200 ft (Belgrade, Town of 1991 and Oakland, Town of 1991).

The surface area that a road occupies can also lead to an increased potential for erosion and run-off, 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. This is typically a more effective and less expensive way to develop the road area. It is also more practical (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 dirt surface (Lea et al. 1990). On the other hand, dirt roads erode more quickly and therefore have the potential for emptying more sediment, and therefore more nutrients, into a waterbody. Consequently, pavement is chosen for roads with a high volume of traffic, while dirt 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 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 from the middle downward towards the outer edges. The crown should have a slope of 1/8 to 1/4 in per foot of width for asphalt and 1/2 to 3/4 in per foot of width for dirt roads . This slope allows the surface water to run 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 drainage can occur into a ditch or buffer zone.

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 and/or steep stretches of road to divert water flow off the road and away from a body of water. They are ideally trapezoidal in shape with a flat or rounded bottom, a sufficient depth with a slope of no greater than 2:1 (depth:width), clean and free of debris, and covered with abundant vegetation (KCSWCD 1991). 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 underneath 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^{o} angle downslope with a pitch of 2-4% (KCSWCD 1991). The spacing of culverts is based upon the road grade (Table 3).

Table 3. The relationship of road grade to the spacing of culverts. This table indicates the maximum recommended distance between culverts as it relates to the grade (% vertical increase/horizontal distance) of the road. As can be seen from these data, the steeper the road grade, the less distance there should be between culverts.*

Road Grade (%)	Spacing (ft)
0-2	250
3-5	135-200
6-10	80-100
11-15	60-80
16-20	45-60
21+	40

*This table was taken from the State of Maine Guidelines for Municipal Shoreland Zoning Ordinances, 1990.

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 thus cost more money in the long run to repair. Roads should therefore be periodically graded, ditches and culverts inspected and cleaned, and inspections be carried out in order to assess any problems that may be developing. These practices will help to preserve the water quality of the lake and will add to its aesthetic value.

Industry

Development of industry within the watershed may destroy natural buffers and increase the addition of nutrients into the lake system. As well as destroying natural buffers, some industries are a potential source of other pollutants such as heavy metals and chemicals. The destruction of buffer zones may be caused by the use of heavy equipment in the area. This equipment typically causes increased erosion and thus nutrient loading because of run-off into the lake. The chemicals and heavy metals used in certain industrial processes may also destroy buffer zones and the chemicals may run-off or leach into the lake, thereby contaminating the water and adversely affecting both plant and animal populations. The MDEP (1990) has approved guidelines which prohibit the following industrial uses within the shoreland zone:

a) Auto washing facilities;
b) Auto and other vehicle service and/or repair operations including body shops;
c) Chemical and bacteriological laboratories;
d) Storage of chemicals, including herbicides, pesticides, or fertilizers other than amounts normally associated with individual households or farms;
e) Commercial painting, wood preserving, and furniture stripping;
f) Dry cleaning establishments;
g) Electronic circuit assembly;
h) Laundromats, unless connected to a sanitary sewer;
i) Metal plating, finishing, or polishing;
j) Petroleum or petroleum product storage and/or sale except storage on same property as use occurs and except for storage and sales associated with marinas;
k) Photographic processing;
l) Printing.

These facilities could also cause problems if they are away from the shoreland but near tributaries or other avenues for run-off into the lake.

Landfills

Landfills may be important components of phosphorus loading as well as other pollution to the lake system. Pollutants such as nutrients and toxins can leach through the soil to the ground water and can enter the system through run-off into streams or directly into the lake. Because landfills are basically cleared open areas of soil, erosion and run-off into the lake may occur easily. Increased erosion is also caused by the heavy equipment used in the landfill area. This equipment typically loosens the soil, which may then enter the lake system via run-off (BI493 1991).

The amount of leaching and run-off from landfills is controlled by several factors. Leaching and run-off will decrease as the distance between the landfill and the lake or stream increases. This may be countered by the slope of the land between the landfill and water, with increasing slope causing increased leaching and run-off. The soil type where a landfill is located will also affect leaching and run-off. This is due to differences in permeability, acidity, and water table levels (BI493 1993). If the landfill is located close to the water table, pollutants and nutrients may travel directly into the ground water. Burning of trash will release some of the pollutants as loose ash, which may then be swept into the lake in run-off during a storm event.

Problems with a landfill may be detected by sending a monitoring well into the ground to check on possible pollution flow from the area. If a problem is seen in a landfill area, it may be closed by covering it with a layer of soil that is impervious to water (such as clay). The type of cover material, the amount of material used, and the frequency of applications are other factors which determine how much of a threat the landfill will be in the future (BI493 1991).

Agriculture

Agriculture may have detrimental effects on water quality by causing increased phosphorus and nutrient loading. Animal manure, the most commonly used fertilizer, is the primary contributor to nutrient loading from agricultural practices (COLA 1992). Livestock in a concentrated area, such as a farm, increases the sewage effluent greatly. In fact, a typical dairy farm may have the nutrient output equal to a village of 2,000 people, and it has been shown that one cow excretes the phosphorus equivalent of 16 human beings (BI493 1991). Nutrients from manure may eventually run-off into the water, especially in the winter when they do not have an opportunity to percolate into the soil because of the frozen ground. Cattle may also use streams and tributaries as their drinking source and typically will walk directly into them. Defecation may occur, as well as increased stirring up of sediments due to their movement. Not only is nutrient loading increased, but manure may carry diseases that can be carried into and contaminate the water quality. Some solutions to the problem created by spreading manure on frozen ground are to create winter storage areas and spreading manure only when the ground is unfrozen. If the problem is large enough, the state or town may give subsidies to help pay for the construction of these storage facilities.

Artificial fertilizers and pesticides also contribute to phosphorus and nutrient loading via run-off and travel by air currents if sprayed. Erosion is increased, as well, because of farm equipment, grazing, and improper drainage systems that enhance the transport of sediments and nutrients into the lake (BI493 1991). Turning fields over often or plowing perpendicular to the edge of the body of water will also increase erosion. Phosphorus is carried into the lake on soil particles and will eventually dissolve. If the farm is too near the edge of the water, an important buffering zone may be destroyed in favor of the farm. Thus, many varied types of agricultural practices are able to affect water quality and must be considered when making an evaluation of the lake system.

Forestry

Forestry practices may affect water quality by destroying buffer zone areas and causing increased run-off. For example, surface run-off may be channeled into forests or woodlands from road drainage and will be allowed to percolate and be bound up in the soil. Forests may therefore act as a system for buffering against nutrient loading. Roots are able to prevent erosion and run-off by holding the soil in place and absorbing nutrients before those nutrients can enter the lake. Forests are especially important in areas of the watershed that have a severe slope because they help slow the run-off and prevent too much erosion from taking place. Improper forestry practices may therefore have detrimental effects on water quality (BI493 1991 and 1993). These improper practices include clear cutting and cutting within 250 feet of the shoreland.

Logging primarily contributes to phosphorus loading by causing increased erosion. This erosion is primarily caused by the heavy equipment used when removing cut logs from an area. Heavy equipment operators may illegally use stream beds and tributaries as roads. If there is a heavy rainstorm while an area is still open to cutting or recently closed, run-off may enter these streams and wash any erosional materials caused by the equipment into the lake body. This increased erosion and sedimentation may thereby increase phosphorus loading during run-off. It is therefore better for skidders and other equipment to use areas that don't include natural tributaries.

Cleared Land

Cleared land may contribute to enhanced nutrient loading as well. In this study we have defined cleared land as land which has been cleared of trees and other large natural vegetation which is typical of the area. Thus pastureland falls into this category. By removing vegetation, smoothing the land surface, and compacting the soil, run-off may increase dramatically. This type of land use thereby allows a perfect opportunity for erosion and nutrient loading because there are no substantial roots to hold the soil down or remove excess nutrients from the soil. Sediments from cleared land pose a potentially large problem because they tend to carry large amounts of nitrogen, phosphorus, plant nutrients, and chemicals (including pesticides and fertilizers) (MDEP 1992a). The destruction of natural buffer strips and mowing of fields tends to make these problems worse.

Wetlands

Wetlands are commonly drained and filled because they are considered by many to be "wastelands". These areas are frequently undervalued because they lack economic and recreational worth. Pressure to develop wetlands to make the area suitable for human habitation, agriculture, and other more economical uses is high. The destruction of these ecosystems has an enormous impact on the environment (Nebel 1987).

In the past, the trend has been to develop wetlands. Since wetlands are most commonly found in desirable areas, filling and drainage has been a prevalent practice as to make them accessible for human use. Numerous housing developments, farms, and industries are now located on past wetlands (Nebel 1987). As these precious ecosystems are stripped of their value, there is no incentive to protect and manage them.

The destruction of wetlands has severe ecological implications. Filling and drainage of the wetland results in serious depletion of ground water. Habitat loss also results. Various species of waterfowl, fishes, and other animals that frequent wetlands are displaced (Nebel 1987). Hydrophytes that normally serve as a buffer between the aquatic and terrestrial ecosystems are no longer present. Nutrients cannot be held in the biomass of the wetland and travel directly into the water source, resulting in a lowering of the water quality. It is estimated that for every acre of wetland that is destroyed, losses can amount to $100,000 annually in pollution control and biological diversity (Nebel 1987).

Salmon Lake Characteristics

Historical Perspective

Salmon Lake has a history of water quality problems documented since the 1920's (Nichols et al. 1984). Fish hatcheries were affected by the low dissolved oxygen levels. The recurrence of this problem caused the hatcheries to shut down. However, algal blooms were not reported until the 1970's. Since then, two species of algae have contributed to numerous algal blooms. The species of fish in the hatcheries and the species of algae in the blooms will be discussed in the following section.

Biological Perspectives

Salmon Lake's direct drainage area, water quality category, and phosphorus coefficient in lbs/ppb/yr can be compared to other lakes in Oakland and Belgrade in Table 4 (NKRPC 1993).

Salmon Lake is considered a mesotrophic lake. The average Maine lake has moderate algal production (NKRPC 1993). The Trophic State Index, TSI, can be used to measure algal production. Values less than 25 indicate low algal production while values greater than 60 indicate high algal production, algal blooms or the risk of algal blooms. Figure 9 shows TSI values in Maine range from 8 to 119 ppm. The mean is 42.

The average TSI value for McGrath Pond between 1975 and 1992 was 46 ppm. McGrath Pond has algal production associated with average transparency and average chlorophyll a. It has dissolved oxygen depletion in its bottom waters to levels that slightly reduce the coldwater fish habitat. These levels, however, pose no risk for the development of a significant internal phosphorus recycling problem (NKRPC 1993).

Ellis Pond's average TSI value between 1975 and 1992 was 48 ppm. Ellis Pond has a slightly higher algal production than McGrath, yet it does not support persistent algal blooms. However, the pond experiences dissolved oxygen depletion in its bottom waters during summer that severely reduces the coldwater fishery and is at high risk for the development of a significant phosphorus internal recycling problem (NKRPC 1993).

The buffering capability determines the ability of a lake to neutralize acid and thus resist a change in pH. The pH of a lake reflects its acidity and helps to determine the animal and plant species found in the lake according to their pH tolerances. An increased acidity, decreased pH value, decreases egg viability and kills species (Pearsall 1991). pH levels of 6.0 or lower lead to the death of snails and crustaceans, 5.5 kills salmon and whitefish, 5.0 kills perch and pike, and at low levels of 4.5 eel and brook trout are even affected (Bunce 1990).

In Maine, pH levels typically range from 6.1 to 6.8. Figure 10 shows the distribution of pH in Maine lakes as reported by the MDEP in 1991 (BI493 1991). The mean pH in Maine lakes as reported by the MDEP is 6.71. The range of pH-values taken from Ellis Pond between 1978 and 1990 was 6.67-7.66, averaging 7.07. McGrath Pond's range for the same years was 6.68-7.61, averaging 7.16 (NKRPC 1993). Therefore, Salmon Lake is generally less acidic than the average Maine lake. Neither pH values of the average Maine lake and Salmon Lake fit the criteria for harming aquatic life mentioned previously

Table 4. Direct drainage areas, phosphorus coefficient (F lbs/ppb/yr)*, levels and water quality categories for the Towns of Belgrade and Oackland (NKRPC 1993).

Lake Name	**Direct Drainage Areas (acres)**	**Water Quality Category**	**F (lbs/ppb/yr) ***
Belgrade			
East Pond	9	moderate/sensitive	0.22
Joe Pond	19	moderate/sensitive	0.28
Wellman Pond	32	poor/non-restorable	0.44
Penny Pond	42	moderate/stable	0.83
Stuart Pond	42	moderate/sensitive	0.50
Chamberlain Pond	96	moderate/sensitive	0.72
Hamilton Pond	96	moderate/sensitive	1.36
McGrath Pond	*316*	*moderate/sensitive*	*3.55*
Long Pond	1314	moderate/sensitive	30.89
Ellis Pond	*1667*	*moderate/sensitive*	*30.07*
Long Pond	1714	good	38.12
Great Pond	10941	good	228.72
Messalonskee Lake	11312	moderate/stable	205.74
Oakland			
Great Pond	61	good	1.27
Ellis Pond	*350*	*moderate/sensitive*	*6.32*
East Pond	1270	moderate/sensitive	25.51
McGrath Pond	*2102*	*moderate/sensitive*	*23.59*
Messalonskee Lake	2416	moderate/stable	43.94

* Phosphorus Coefficient = F (lbs/ppb/yr) This coefficient examines the number of pounds of phosphorus entering the lake ecosystem and its effect on the water quality. Water quality is variable from lake to lake depending on natural phosphorus cycling of the sediments, flushing rate, volume, and depth of the lake. A low F value means that the lake is very sensitive to phosphorus entering its ecosystem. A high F value indicates that the lake is tolerant of external phosphorus loading.

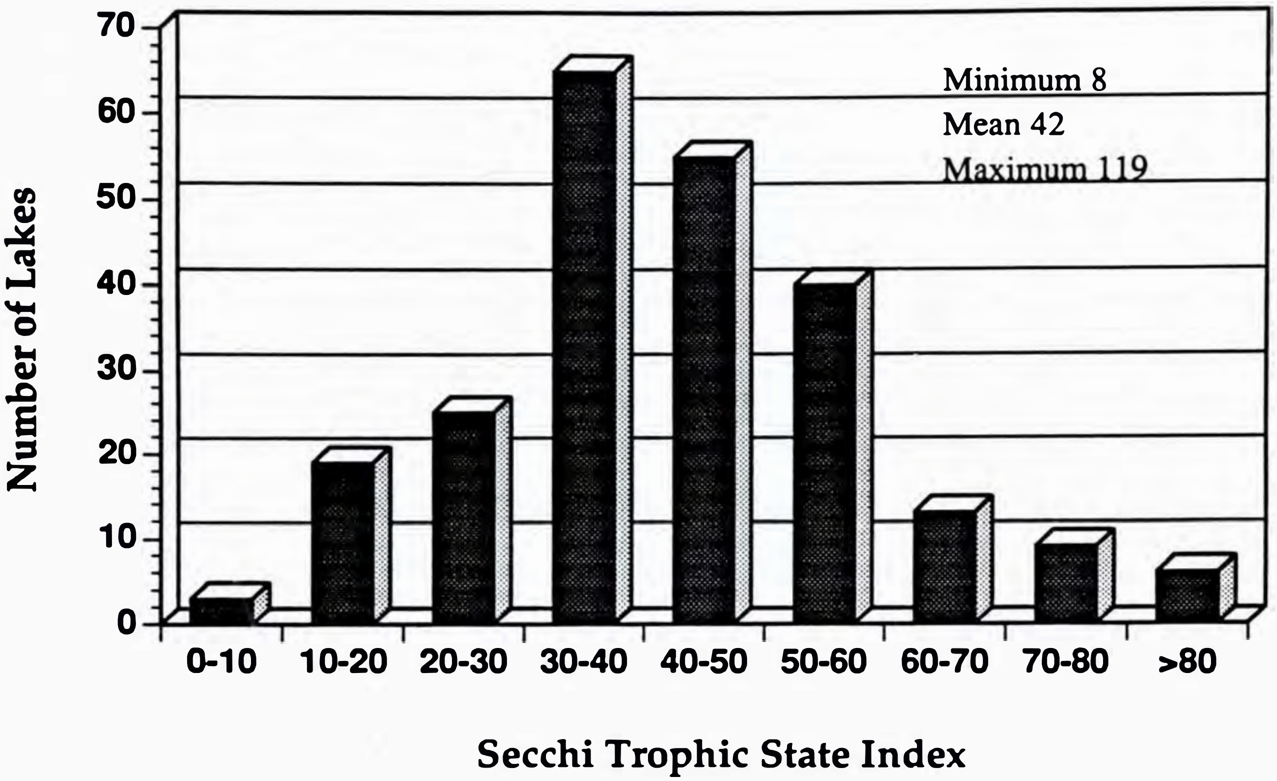


Figure 9. Distribution of lakes among Trophic State Index categories in 239 Maine lakes as reported by the DEP in 1991.

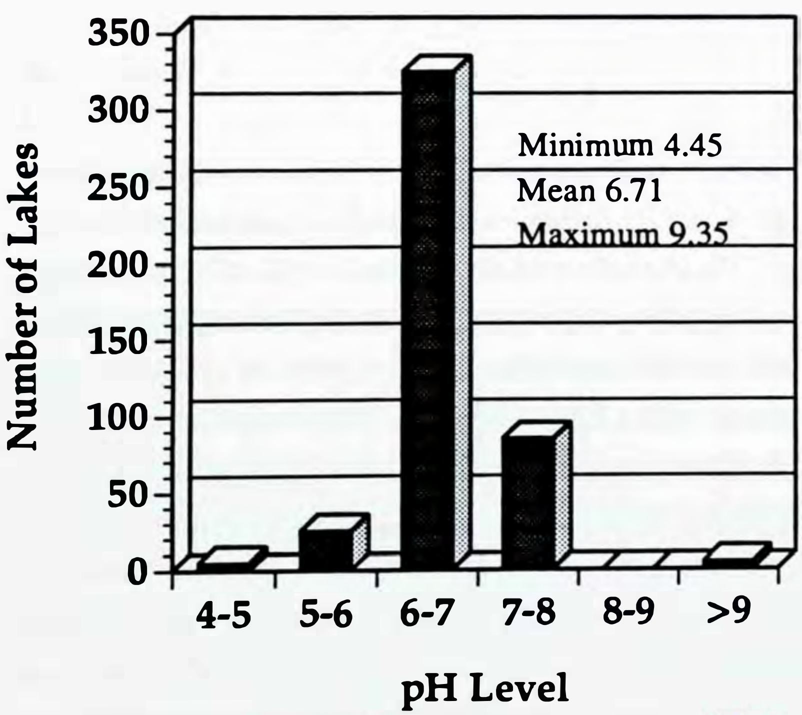


Figure 10. pH values for 453 Maine Lakes sampled as reported by the DEP in 1991.

(Bunce 1990).

The alkalinity test reflects the ability of a lake's water to buffer pH changes. It is a measure of calcium carbonate in the water. As a pH buffer and inorganic carbon reservoir, alkalinity also helps in determining the ability of the water to support algal growth and other aquatic life. A low alkalinity measurement of less than 4 ppm of calcium carbonate indicates a greater susceptibility of the adverse effects of acid rain compared to a lake with a higher value, such as greater than 10 ppm (Pearsall 1991).

In Maine, alkalinity ranges from 4-20 ppm calcium carbonate in lakes (Pearsall 1991). Figure 11 shows the distribution of

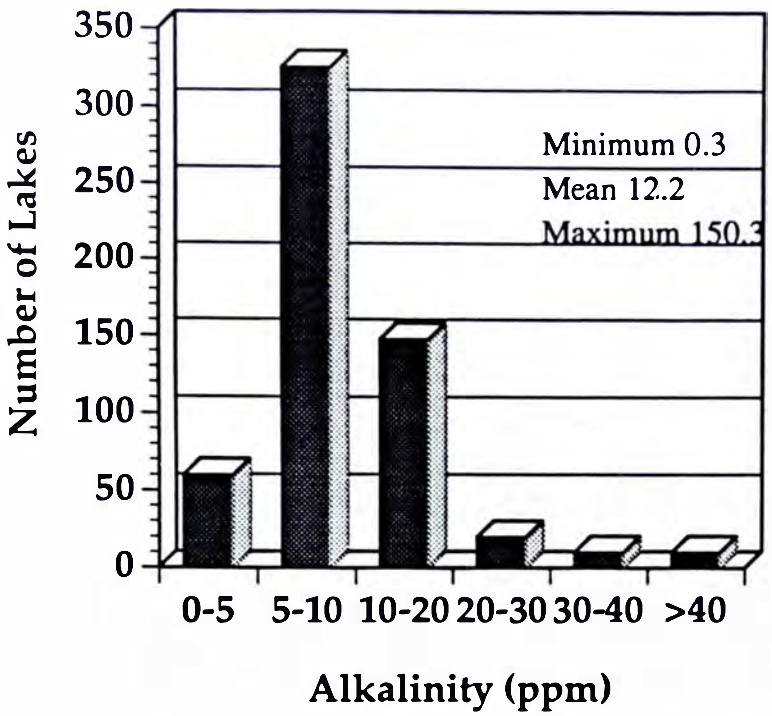


Figure 11. Alkalinity values of 533 Maine Lakes sampled as reported by the DEP in 1991.

alkalinity in Maine lakes as reported by the DEP in 1991 (BI493 1991). The mean alkalinity, in micrograms per liter or ppm, is 12.2 as reported by the MDEP. McGrath Pond ranges from 15.0 to 23.5 ppm over this same period, with an average of 14.9 ppm (NKRPC 1993). The range of alkalinity values taken from Ellis Pond between 1978 and 1990 was 15.7-21.0 ppm, averaging 16.9. A decrease in pH levels in Maine has allowed alkalinity levels to rise. This is because prevention of the decrease in pH of the lakes does not require the use of the calcium carbonate as a buffer. Problems with excessively low pH or alkalinity levels are not evident in the average Maine lake or in Salmon Lake (Stauffer 1990).

Freshwater habitats support a variety of bacteria, protists and plants. These organisms serve to decompose organic material to the elemental state or form the base of the food chain through photosynthesis. Floating plants and shoreline vegetation provide cover and protection for the animal populations. These organisms also contribute to cycles of nutrients and respiratory gases in the ecosystem (Reid 1961).

The major groups of freshwater algae are blue-green algae, green algae, euglenoids, dinoflagellates and diatoms (Reid 1987). Two species of blue-green algae, *Aphani-zorhenon flos-aqua* and *Anabaena planktonica*, were part of the algal blooms of the 1970's in Salmon Lake (Nichols et al. 1984). Diatoms are also important in Maine lakes, often accounting for a majority of the phytoplankton community (Dennis 1975). Fungi, liverworts and mosses also inhabit freshwater areas.

Many species of vascular plants are associated with a lake's habitat. Common pond flora were already discussed in the Wetlands section of this report. Freshwater areas also support animal inhabitants. These include the simplest unicellular organisms, sponges, hydroids and worms, and the more commonly seen moss animals, joint-legged animals (insects and crayfish), snails, clams, and mussels. Vertebrates are also found near or in ponds, such as fishes, amphibians, reptiles, birds, and mammals (Cole and Firmage pers. comm.).

Salmon Lake's water supported a fishery of landlocked salmon in 1926 (Nichols et al. 1984). In 1948, the fishery management at Ellis Pond was changed from a predominantly coldwater fishery to a combination coldwater-warmwater fishery. The salmonid species most tolerant of low dissolved oxygen and warmth, (brown trout and largemouth bass) were introduced to replace the landlocked salmon and brook trout. The fishery had to change in accordance with the changing characteristics of the lake.

Geological and Hydrological Perspective

In the watershed of Salmon Lake, biotite-muscovite granite was replaced by an igneous intrusion. The igneous intrusion melted and penetrated the granite. The low-lying depression at the contact of the two rock types forms the McGrath-Ellis basin (Nichols et al. 1984).

Concerning hydrology, the sources of water inflow and the flushing rate of the lake are also important factors affecting buffering capability and water quality. Cold Brook drains glacial till. Twenty-three of the other 26 sites studied by Nichols et al. in 1984 drained till and were ephemeral. The three others drained basins of till, marine deposits, and stratified drift and flowed all year. An estimate of the flushing rates from the North Kennebec Regional Planning Commission (1993) is .54 flushes/yr for Ellis and .69 flushes/yr for McGrath. Table 11 (refer to Quantitative Water Measurements and Calculations section: Water budget) lists our estimates of the flushing rates.

Geology and hydrology are factors affecting buffering capabilities. Bedrock chemistry has a great influence on water quality because it is the primary determinant of the pH, alkalinity, and nutrient load capacity of a lake's watershed (Davis et al. 1978). The granite that underlies most of the northeast offers little protection in terms of buffering (Bunce 1990).

Soil Types

The soil types in the Salmon Lake watershed vary in composition, permeability, erodibility, location of the water table, depth to bedrock, and many other factors. A soil's characteristics will determine the type of vegetation growing in it, and will also limit the human uses for it (USDA 1992). Composition varies in stoniness and grain size, from very fine silts to larger grained sands, and decomposing organic material called peat. The depth to bedrock ranges from less than 5-12 in to over 60 in. There are over 15 different types of soils in the watershed. The most common soils in the watershed are the very stony fine sandy soils called Berkshire, Woodbridge, and Paxton-Charlton. Various uses for the soils include permanent and seasonal crops, pastures, orchards, and woodland. For more information on the soils in the watershed, refer to the Analytical Procedures and Findings section: Soil types .

Regional Land Use Trends

Most lakes in Maine are in heavily forested watersheds. This lack of urbanization within watersheds of Maine lakes affects the types of pollution that may alter the lake water quality. Due to the nature of land use in Maine, large point sources (e.g., industries) are very unusual in the region. Non-point sources (e.g., agricultural land and residential development) are more common and there are numerous small point sources, which are smaller yet specific pollution sources, found in Maine lakes (e.g., pipes coming from shoreline houses and cabins). Since agricultural land and residential development represent two threats to lake water quality that are common in Maine lake watersheds, their patterns can be particularly helpful when studying overall nutrient loading (Davis et al. 1978).

General patterns of land use for agriculture and residential development in Maine watersheds show where each type of land use is more commonly found and what current trends are. Overall, the amount of farm land in Maine watersheds has decreased in the past twenty years; agriculture is more common in southern Maine than in the more high relief regions such as western Maine. In Cobbossee District lakes (located in southeastern Maine), for example, agriculture is a major source of phosphorus loading and shoreline residential development is a lesser but still significant source (Davis et al. 1978). In lakes that lack notable agricultural land use, residential development is the predominant cause of anthropogenic nutrient loading. The many cottages and houses along the shoreline of moderate- to large-size lakes account for much of the nutrient loading in Maine lakes. Nutrient loading activities that are commonly associated with residential development include road maintenance and construction, forest clearance, building construction, and sewage disposal. Lakeside development in Maine does not just occur sparsely; in a study of seventeen Maine lakes by Davis et al. (1978), all but two had one hundred to several hundred cabins along their shorelines. Often, the cottages were concentrated along particular stretches of land for varying reasons such as, automobile access, economic and political factors, and unsuitability of other stretches of land.

Current trends in land use patterns can be shown by comparing land use in the present to that in the past. The lakes discussed: Pattee Pond, East Pond, and China Lake, are in the same general geographic area as Salmon Lake. In order to develop a basic understanding of what may be found in Salmon Lake, the land use patterns in these Maine lake watersheds will be discussed. The recent patterns of conversion of farm land into residential development and the increasing amount of seasonal homes being changed to year round residences represents possible changes to lake nutrient loading and the overall quality of the lake.

Pattee Pond, East Pond, and China Lake

Pattee Pond, located in the towns of Winslow, Vassalboro, China, and Albion, is a smaller lake with much less development than East Pond and China Lake. East Pond and the Serpentine Tributary are located in the Belgrade Lakes (as is Salmon Lake) area in the towns of Smithfield, Oakland, Fairfield, and Belgrade. On the basis of development trends of the past ten years, the Smithfield Planning Board speculates that approximately 56% of developable land in East Pond will be developed over the next fifty years (BI493 1991). China Lake is located southwest of Waterville in the towns of China, Vassalboro, and Albion. The population of this area grew from 1,850 to 3,553 between 1970 and 1987. At three people per house, this growth represents 120 new houses over a ten year period (BI493 1989). Already, the pattern of increasing residential development to keep up with population growth is becoming obvious.

One of the trends found in many Maine lake watersheds (Davis et al. 1978), which can be seen in Table 5, is the conversion of farm land into subdivided house lots and condominiums. In East Pond and China Lake, the amount of land used for farming decreased by 50% and by 37%, respectively (BI493

Table 5. Comparison of changes in land use for the Pattee Pond, East Pond, and China Lake watersheds. The values represent percentages of total watershed land (BI493 1989, 1991, and 1993).

Land Use Type	Pattee Pond		East Pond		China Lake	
	1975	1991	1965	1991	1965	1985
Forest	76	77	78	77	63	69
Wetlands and water bodies	13	13	3	3	9	9
Residential Land	<1	3	10	14	1	3
Roads	<1	<1	2	2	2	2
Agricultural Land	*	*	4	2	24	15
Reverting Land	*	*	3	2	2	3
Cleared Land	9	7	*	*	*	*

*Distinctions not made between types (crop, pasture, or reverting) of cleared land in Pattee Pond study. This distinction is made in both the East Pond and China Lake studies.

1991 and 1993). The Pattee Pond values do not distinguish between the different types of cleared land (agriculture or reverting land) but the total amount of cleared land showed a 2% decline thus reflecting some change in the use of cleared lands between 1975 and 1991. Land that was previously used for crops or pasture had been allowed to revert or was converted to residential land (BI493 1993). Furthermore, the amount of land use for residential development increased in the lake watersheds for all three of the lakes. Residential land area almost doubled in Pattee Pond and China Lake, and East Pond showed a 40% increase. While residential development area increased because of shifts in the use of farm land, another development pattern not shown in this table is the conversion of seasonal homes into year round homes. This trend cannot be reflected by a change in the number of residences since it would not alter the number of homes in the watershed.

The changes in total area and total phosphorus loading in China Lake watershed between 1965 and 1985 are compared in Table 6. Estimated phosphorus loading for residential areas over these thirty years doubled from 15.4 kg/yr to 34.6 kg/yr. Additionally, looking at changes in total area of roads over this period, the area covered by fire roads increased from 10.8 ha to 16.7 ha. Fire roads are commonly associated with shoreline residential development so an increase in fire roads would probably reflect an increase in shoreline development. Not shown in the table but reflected by the decrease in total area for agricultural land is a 37% decrease in phosphorus loading from farm lands; from 1738 kg/yr to 1106 kg/yr (BI493 1989). Increases in total area used for a type of development, resulted in increased nutrients, particularly phosphorus, loaded into the lake (Table 6). Not included in this table is the external

Table 6. Comparison of changes in total area and total phosphorus loading from residential development and roads in China Lake watershed between 1965 and 1985 (BI 493 1989).

	1965	1985
Residential		
Area		
Shoreline (ha)	34.0	84.0
Inland (ha)	43.0	89.0
Total Phosphorus Loading		
Shoreline (kg/yr)	6.8	16.8
Inland (kg/yr)	8.6	17.8
Roads		
Area		
State (ha)	33.8	33.8
Municipal (ha)	50.6	51.9
Fire (ha)	10.8	16.7
Total Phosphorus Loading		
All roads (kg/yr)	172.0	192.0

phosphorus loading to East Pond and Pattee Pond. Although data on phosphorus loading into the lakes between two periods was not available, the greatest amount of phosphorus in East Pond was coming from residential land in 1991. The Pattee Pond study shows that the forested area of the watershed was contributing the largest amount of phosphorus to the lake. Since forests covered 77% of the watershed at the time of this study and residential land made up a much smaller area (2%), the phosphorus loading values are consistent with watershed land use patterns.

The previous examples were presented to show some of the watershed land use trends around Maine lakes that are similar to and nearby Salmon Lake. The statewide pattern of conversion of seasonal cabins into year round homes (Davis et al. 1978) as well as the current local pattern of decreasing agricultural lands and increasing residential land development are important in analyzing and determining the status of Salmon Lake's water quality and its future.

STUDY OBJECTIVES

The primary objectives of this study are (1) to assess the water quality of McGrath and Ellis Ponds and their tributaries, (2) pinpoint any potential sources of nutrient loading, (3) examine historical and current land use patterns within the watershed area and their effects on phosphorus loading, (4) construct water and phosphorus loading budgets, and (5) make future projections and recommendations to the towns and Lake Association.

Lake Body

Water Quality Assessment

The current water quality of Salmon Lake was assessed by testing various parameters, and the results were compared to the data collected in the past by the Maine Department of Environmental Protection as well as general data from representative lakes throughout Maine. Test results from different sites throughout McGrath and Ellis ponds were compared in order to investigate the effect of various land use practices within the watershed on the water quality.

Tributaries

Water Quality Assessment

Physical, chemical, and biotic parameters of the tributaries flowing into and out of Salmon Lake were measured to determine the nutrient inputs and outflows from the lake water body. These parameters have focused especially on phosphorus loading in an effort to make recommendations concerning the history of algal blooms on the lake. Water quality of the tributaries and point sources of phosphorus leading into the lake were determined in order to assess potential trouble spots. Nichols et al. (1984) found three tributaries that had high levels of phosphorus coming into the lake. These trouble areas were assessed and compared to the past data.

Land Use

Effect of Land Use Patterns on Phosphorus Levels

Categories for land use practice within the watershed were determined and the phosphorus input of each category was calculated. The goal of this study was to calculate the total phosphorus input from each of the individual categories in order to determine the phosphorus sources and the total amount being contributed to the lake. An appropriate phosphorus budget was then determined.

Zoning and development is a very important factor when land use strategies are developed for an area. The Salmon Lake watershed is shared by Belgrade and Oakland. The lake is therefore subject to the town ordinances of both communities and its quality is the responsibility of both towns. This study has attempted to develop an understanding of those ordinances and how they indirectly affect the water quality of Salmon Lake. This objective relates not only to the number of shoreline and non-shoreline homes in the watershed, but also to summer camps, septic systems, roads, agriculture, forestry, cleared land, industry, and landfills.

The number of residences and area covered by shoreline residential areas was examined to determine the extent of phosphorus loading by these areas. This was done for non-shoreline homes, as well, in an attempt to determine the contribution of these areas to phosphorus levels entering the lake. Although these homes are not directly on the shore (within 250 ft), they do have an impact on levels of phosphorus loading.

Summer camps can represent a large input of phosphorus because they typically contain an extensive amount of cleared land. These areas also have a relatively large amount of people for a short period of time and may affect phosphorus loading in this way. The area occupied by these commercial camps was determined and data was collected concerning septic provisions, summer populations, and other relevant information. The corresponding data was combined to determine the amount of phosphorus that may be entering the lake from these camps.

As far as septic systems were concerned, a primary objective was to determine the percentage of systems that may be in good condition based on recent permits. This was done by looking at the permits for new or repaired systems for each township from 1983 to the present. A percentage of systems that were put in before new regulations were in effect was also determined, thus indicating the systems which may be contributing higher phosphorus levels to the lake than they should.

A comprehensive road survey was conducted in order to determine the condition and maintenance of the roads in the watershed, and to calculate the area of these roads. From these data, the impact of roads on phosphorus loading could be determined and problem roads could be identified in the hope that an attempt will be made to repair these problems.

Agriculture, forestry, and cleared land are all important factors when determining the phosphorus loading into the lake because these factors take up so much land area. The amount of past and present farming, forestry, and cleared land was determined. These categories were examined to determine how they have contributed, and are presently contributing to the nutrient loading of Salmon Lake. Most of the land that was once agricultural, has reverted to cleared, unused land (unused pasture), while some forestry practices still exist in the watershed.

Industry and landfills have both typically been important to phosphorus and nutrient levels. The effect of industry on phosphorus loading was determined by finding the area that the industries occupied and determining how much they added to the lake body. The relative status and condition of the landfill contained in the Salmon Lake watershed was also determined. Finally, attempts were made to calculate the effect it has had on the lake water body, as well as the tributaries that drain it.

ANALYTICAL PROCEDURES AND FINDINGS

WATER QUALITY STUDY SITES

Salmon Lake Study Sites

There were thirteen lake sample sites chosen to assess the water quality of Salmon Lake (Figure12). In order to characterize lake water quality, there were two groups of lake sites each chosen based on their location; (1) characterization sites in the center of the lake (including the deep hole in Ellis) and (2) sites near inlets and brooks, wetlands, and residential development in order to examine the impact of the watershed land use on the lake. Sampling for all sites was done from late September through October; lake characterization sites were also sampled during the summer.

McGrath Pond Sites

Site 1: Mutton Hill Cove

This site is located on the water at the bottom of Mutton Hill Road in McGrath Pond, approximately 50 m offshore.

Site 2: Northeast Bay

This is in the bay in the northeast corner of McGrath Pond, approximately 50 m from the shore. It is located north of fire road T1.

Site 3: McGrath Point in Cove

This site is located in McGrath Pond at the end of fire road T2, approximately 50 m offshore.

Site 4: Center of McGrath Pond

This site is located at the center of McGrath Pond, across from the cemetery and tributary site 25 on the west side, where the maximum depth is 27 ft. This is one of the McGrath Pond characterization sites.

Site 5: Old Gravel Pit

This site is near the neck of McGrath Pond (where McGrath narrows) across from the old gravel pit and Oakland Dump which are on the east side of the pond. It is also located across from some residential development on the west side. This is the second McGrath Pond characterization site.

Ellis Pond Sites

Site 6: Birch Point

This site is located in the middle of the northern area of Ellis Pond (near the neck where it changes to McGrath), approximately 350 m west of Birch Point. This is one of the Ellis Pond characterization sites.

Site 7: South Shore of Birch Point

This site is located 50 m from the northern apex of the cove on the southwest tip of Birch Point,

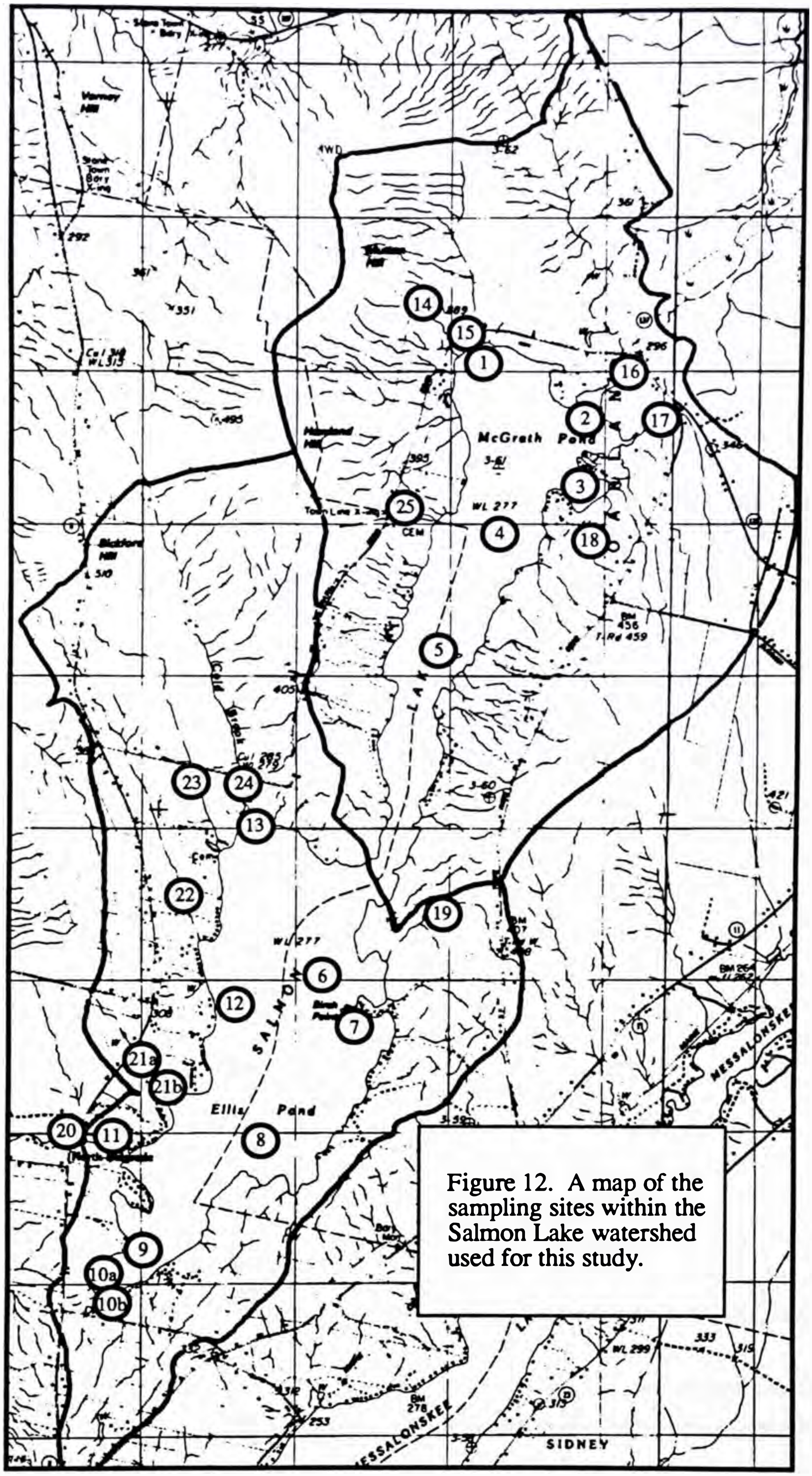


Figure 12. A map of the sampling sites within the Salmon Lake watershed used for this study.

just south of the McGrath Pond inflow. It is a site representative of a dense residential area.

Site 8: Deep Hole on East Side

This site is located in the southeastern section of the pond near the deepest part of the lake, measuring 48 ft. This is the second characterization site for this pond.

Site 9: Southern Cove

This site is located 50 m from the shoreline of fire road S-5 near the southwestern end of Ellis Pond. This site was chosen to characterize the southern cove of the lake.

Site 10a: Southern Marsh

This site is located at the southern tip of the pond. It was chosen to examine the conditions in a shallow area of the lake with large amounts of emergent vegetation and to determine the effects, if any, of the pond at site 10b on the lake.

Site 10b: Horse Stable Pond

This small pond located on private property, where horses are sometimes kept, near the shore of the southern end of Ellis was chosen to determine the impacts this pond might have on the lake if there was any seasonal flow from the pond to the lake.

Site 11: Spaulding Point Cove

This is the area adjacent to the boat launch on Spaulding Point and immediately precedes the dam for the outflow. It was chosen to study the quality of the water leaving the lake.

Site 12: Tukey Brother's Sawmill Inflow

This site is located approximately 50 m off shore from the mouth of the tributary which flows from the Tukey Brother's Sawmill. It was chosen to study the effects of the sawmill industry on soil disruption that eventually washes into the tributary.

Site 13: Cold Brook Inflow

This site is situated 50 m off shore from the mouth of Cold Brook, where it flows into Ellis Pond. This site was chosen to measure the effect of a marsh area on the water quality as it enters the pond.

Tributaries and Storm Sites

These sites are not located in Salmon Lake proper but are numbered starting where the numbering of the lake sites ended. The actual tributary sites begin at the top of McGrath Pond which is not where the lake sites ended. Measurements at the storm sites were to be taken during and after a major storm event to study and compare the amount of nutrients that flow into the pond from the tributaries during a storm and regular conditions. Unfortunately, the weather conditions did not permit this sampling to be done. The tributaries were identified during our 27SEP1993 field reconnaissance of the lake watershed.

McGrath Pond Sites

Site 14: Still Pond on Mutton Hill Road

This pond is located on Mutton Hill Road. A drainage pipe runs from this pond under the road. This site was studied to determine what nutrients, if any, can enter McGrath Pond from this area.

Site 15: Mutton Hill Road Stream

This is the creek coming down from Mutton Hill Road (on the northwestern tip of McGrath Pond) running under the road and entering the pond at the northwest inlet.

Site 16: Pleasant Point Stream

This is the creek located at the intersection of Pleasant Point and McGrath Pond Road (leading into the marsh) on the northeastern tip of the pond.

Site 17: Northeast Bay Stream

This is the large creek leading into Northeast Bay at the northeast section of the pond. This tributary enters McGrath Pond between sites 2 and 3.

Site 18: McGrath Point Stream

This is the stream located on McGrath Point in the middle of the eastern side of the pond across from lake characterization site 4. This site was not tested due to lack of flow.

Site 25: Cemetery Stream

This stream is located near the cemetery in the middle of the west shore of McGrath Pond.

Ellis Pond Sites

Site 19: Northeast Inflow

This site is located in the inlet south of McGrath Pond inflow and north of Birch Point on the northeastern shore of Ellis Pond (near where the ponds change).

Site 20: Hatchery Brook Outflow

This site is located in the Hatchery Brook inlet near North Belgrade. The study site is located on the eastern side of the bridge (Route 308) over Hatchery Brook. The water quality as it left the pond was measured.

Site 21a: Tributary South of Camp Modin

This tributary runs along fire roads S-12 and S-13 from Route 8. The sample was taken in the tributary adjacent to the road.

Site 21b: Tributary South of Camp Modin

This sample was collected from an area of still water, immediately adjacent to the lake. The location of 21a is on the same tributary that leads to this location.

Site 22: Tributary with mouth near fire road S-19

This site is a little north of the center on the west shore of Ellis Pond. This tributary crosses multiple fire roads, so it was chosen to identify the effects of these roads on water quality.

Site 23: Tributary with mouth near the Reich's home

This site is located at the northern end of the west shore of Ellis Pond. This tributary has a relatively large watershed and it crosses under a major road, so it characterizes the input of a large area of inflow into the pond.

Site 24: McGrath Pond Road over Cold Brook

This site is located just south of McGrath Pond Road in Cold Brook. It was chosen to characterize the water quality of the major tributary flowing into Ellis Pond before reaching the marsh.

GEOGRAPHIC INFORMATION SYSTEM METHODOLOGY

The Geographic Information System (GIS) is a useful tool for interfacing two or more informational maps with attached data and creating other maps with compiled information. This study used MacGIS software because of its simplicity and the ease with which basic techniques can be learned.

The first step of the process involved scanning two maps into the computer program. These two maps were then used as base maps. One described the topography of the Salmon Lake area and the second included features such as roads, structures, drainage patterns, and political boundaries. We then placed the scanned maps into an area that was divided into cells or blocks each representing an area of 11,025 ft^2 in the watershed. These cells define the resolution of the map, the smaller the cells the more accurate the map.

Using the scanned base maps as a references, data was then drawn into the computer, one cell at a time, to produce a data layer. Lake boundaries, roads, and town lines were used as references to transfer the data from an outside source (e.g., soil maps) into the computer. When several data layers had been produced their information was combined to produce maps showing, for example, septic suitability (which required maps showing slope and permeability).

All the maps created are useful in several ways. First, combinations and overlays result in the creation of new maps with different information not obvious from studying individual maps. This is extremely useful when maps showing specific issues are unavailable for the area of study. Second, they give a basic overview of a particular characteristic within the watershed. Third, they also give the approximate area of a particular characteristic within the watershed, and are therefore important in determining the effects of particular land use types, soils, or erodibility factors on the nutrient loading into Salmon Lake.

ZIDAS METHODOLOGY

A Zeiss Interactive Digital Analysis System (ZIDAS) was used to quantify land use patterns in the Salmon Lake watershed. Aerial photos from the years 1980 and 1991 were obtained from the Soil Conservation Service of Augusta, Maine. Areas of cleared land, reverted land (abandoned fields), and industrial and commercial land were traced onto a mylar overlay from the aerial photos. Wetland areas were quantified by digitizing the topographical map of the area. The surface area of the lake and the area of the total watershed were measured using the 1975 orthophotoquad of the Salmon Lake region. The total area of roads was calculated using data from the visual survey. The length of every road within the subwatersheds (McGrath and Ellis) was multiplied by the average road width for that particular type of road (paved vs. camp road). To calculate the scales of the photographs, Taylor Woods Road at the bottom of Ellis Pond was measured with a tape measure. Knowing the actual length of this road, we could compare it to the length in the aerial photos for accurate scaling. The aerial photos from 1980 had a scale of 1:16,208. The 1991 photos' scale was 1:24,033. The watersheds of McGrath and Ellis Ponds based on MDEP determinations and the Oakland-Belgrade town line were drawn onto the mylar overlay. The individual areas that were traced onto the overlay were digitized. Ten trials were conducted for each area and an average was calculated. Values for similar land use patterns were summed. The calculation for forested land was then done and the land areas for all of the other land use patterns were added, and that total was subtracted from the total area of the watershed. Totals for each land use were tabulated for use in tables, figures, and the phosphorus loading equation. The determination of area for shoreline and non-shoreline homes was also determined for use in the phosphorus loading equation. For shoreline homes, the total area was quantified by using ZIDAS equipment on parcel maps obtained from the towns of Oakland and Belgrade. The area of non-shoreline homes was calculated by measuring the developed lots and then finding an average lot size. The lot size was then multiplied by the number of non-shoreline homes in the area to produce a total area of non-shoreline homes.

SALMON LAKE WATER QUALITY

Lake Water Quality

There are many different factors that can influence water quality. So, in order to thoroughly assess water quality, there are three broad categories of tests and measurements that were performed: physical, chemical, and biological (Appendix A). Physical measurements included depth, temperature and dissolved oxygen, transparency, and conductivity. Chemical tests included phosphorus, nitrogen, calcium and magnesium (hardness), color, and pH. Biological measurements included chlorophyll a and macrophyte growth. To determine the effects and impacts of watershed land use on the water quality it is necessary to perform these tests at specific sites in the lake which might reflect these effects. In addition, tributaries were studied to gauge their potential role in nutrient loading into the lake.

WATER QUALITY METHODOLOGY

All samples were collected on 27SEP1993 and 4OCT1993 (Appendix B). Some physical measurements were performed on-site, while others and the chemical analyses were done in the Colby lab. The samples for Chlorophyll a were sent to an independent firm for analysis. Both sampling days were overcast but it began raining about an hour into sampling on the 27SEP and did not slow down for the rest of the afternoon. The samples were all taken between 2:00 PM and 5:30 PM on both dates. All samples except for phosphorus were collected in polyethylene bottles that were labeled according to the pond, site, date, and location in the water column. Phosphorus samples were collected in polymethylpentene bottles and treated in the same manner. All sampling procedures followed the Quality Assurance Package (Appendix C), based on an adaptation of the Quality Assurance Plan for Clean Lakes (BI493 1993b).

PHYSICAL MEASUREMENTS

Depth

The depth was measured by using an electronic depth finder and, in areas inaccessible by motor boat, a portable fishing depth finder (Interphase, model 220). The depth measurements, which were taken on 27SEP1993 at various lake sample sites throughout McGrath and Ellis Ponds, are presented in Table 7.

Table 7. Depth (ft) measurements of McGrath (sites 1, 2, 3, 4, 5) and Ellis (sites 6, 8, 12, 13) Ponds. For site locations see Figure 12 and text. All depths were measured on 27SEP1993.

	McGrath					Ellis			
Site	**1**	**2**	**3**	**4**	**5**	**6**	**8**	**12**	**13**
	13	4	19	22	22	29	48	14	3

Dissolved Oxygen and Temperature

Dissolved oxygen (DO) is a measure of the amount of oxygen in the water. The DO of water has an inverse and important relationship to temperature since at higher temperatures, the ability of water to hold dissolved oxygen decreases. Both of these factors influence the ability for aquatic species to survive. At very low DO levels organisms, such as fish, cannot survive. If there is excessive plant growth in a lake, as it decays, the DO levels will be drastically reduced through the respiration of bacteria. The more dead organic matter there is in a lake, the lower the DO levels will be. A healthy lake will have high DO levels, while low levels may indicate algal growth, and thereby excess phosphorus, in the ecosystem. Generally, DO levels of less than 5 ppm are considered stressful for fish, although 6 ppm is the limit for salmonids (Davis et al. 1978), and levels of 2 ppm or lower can lead to internal recycling of phosphorus from sediments (Davis et al. 1978). Most Maine lakes have levels near the surface of about 9 ppm (Davis et al. 1978). DO measurements were taken on-site electrochemically using either a L.G. Nestor dissolved oxygen probe with Clark-type polarographic electrodes or an Orion DO meter (model 840).

Depth and DO profiles taken at the lake characterization sites on McGrath (sites 4, 5) and Ellis (sites 6, 8) Ponds during the summer and fall of 1993 are shown on Figure 13. The weather this past summer was particularly dry with little rainfall, and there was little input to the lake. The lack of input to the lake might affect our DO data causing the levels to be slightly lower. This figure as well as Figure 14 show

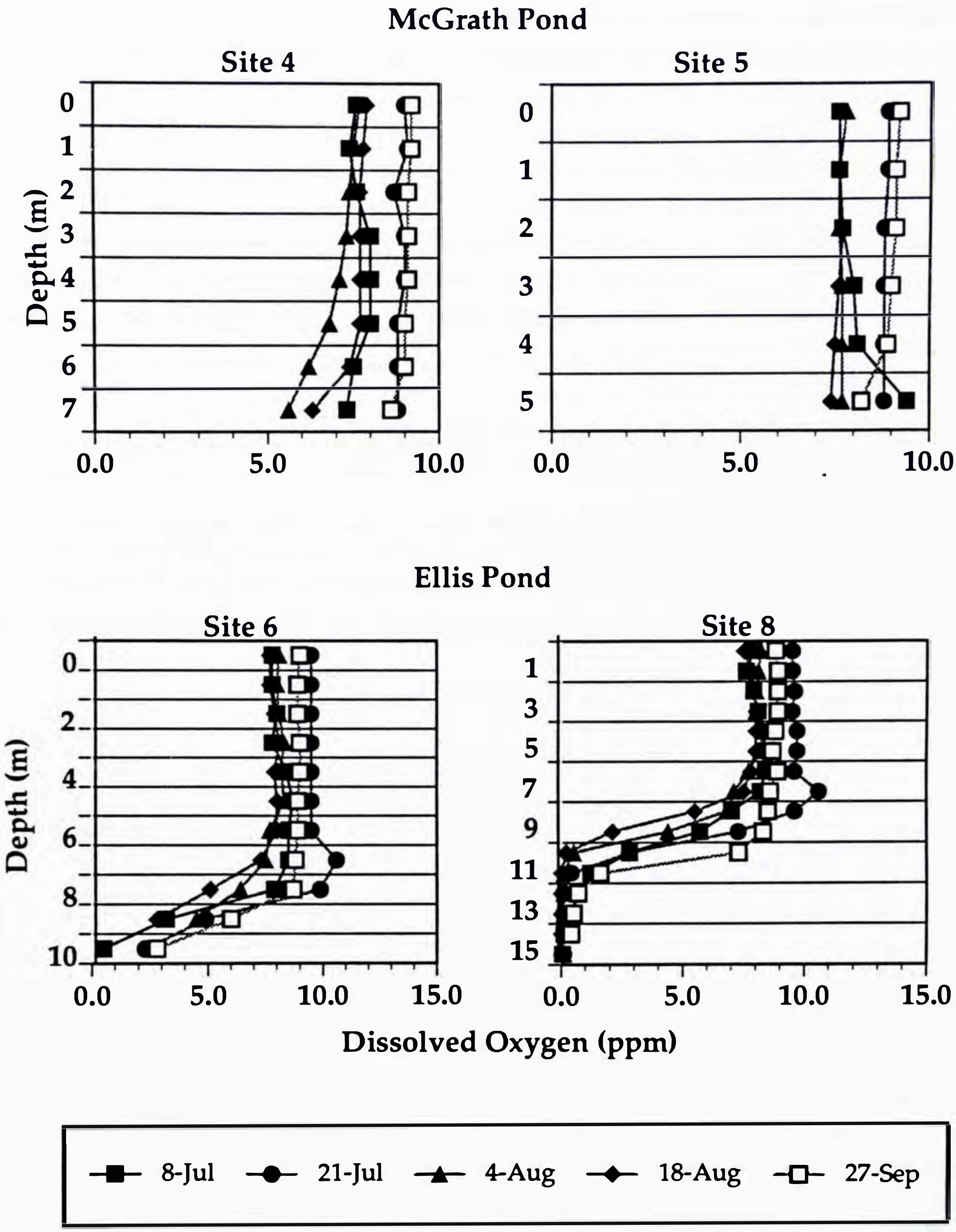


Figure 13. Dissolved Oxygen profiles obtained from McGrath and Ellis Ponds during the summer and fall of 1993.

that McGrath Pond maintains an even DO level throughout its depth (max. 22 ft), while in Ellis there is stratification (max. 48 ft) with a significant decrease in DO as depth increases, particularly below the thermocline (8 m). A particularly low DO level, especially below the thermocline, can be attributed to high decomposition. There was little stratification in Ellis on 27SEP93 when we sampled (except for the deep site). In both of the Ellis sites, which are deeper than the McGrath sites (Table 7), DO drops below 5 ppm. This is significant because the conditions in the lower region of the hypolimnion at these deep sites is virtually anaerobic, facilitating release of phosphorus from the phosphorus-iron complex. This process allows phosphorus that is present in sediments to be recycled back into the water where it can stimulate algal growth in the late summer and early fall (Pearsall 1991). Ellis Pond has had a history of low DO levels; in the 1940's there were anaerobic conditions below 36 ft (Nichols et al. 1984). This caused the salmon and brook trout fishery to disappear; it was replaced by more tolerant species (Nichols et al. 1984). An increase of 4.8 ppm was observed in the dissolved oxygen levels between the summer of 1979 and 1993, a more than 100% improvement. Our data are consistent with 1984 MDEP results for McGrath Pond that indicate this pond to be well-mixed throughout the year; except for a period of several weeks in August when stratification was observed for the top three feet. Both lakes have surface DO values between 8 and 9 ppm (the maximum surface value was 9.2 ppm), indicating that there was no excessive decaying matter in the lake. Overall, the DO and temperature figures are fairly similar. This illustrates the inverse relationship between DO and temperature. When temperatures decreased, the DO levels increased fairly constantly throughout all of the lake sites tested. During summer months, the thermal stratification in the lake resulted in a similar oxidative stratification. With the change in water temperature when summer turned to fall, the DO levels for the whole lake increased. In some cases, the fall overturn caused a reduction in the oxidative stratification present in the summer months.

Transparency

Transparency gives a measure of relative clarity of the water, which is a good indicator of the levels of algal growth (Pearsall 1991). If the transparency reading is low, this suggests a large amount of algae in the water column, indicating large concentrations of nutrients. Specifically, if the transparency reading is <4 m, the lake is considered productive; 4-7 m, moderately productive; and >7 m, unproductive (Pearsall 1991). Most Maine lakes have transparency values ranging from 3 to 7 m (Pearsall 1991). Transparency measurements were performed using a secchi disk. The secchi disk is lowered into the water on a metered chain until the disk can no longer be seen. The average of the depth when the disk disappears and the depth when it reappears is the transparency of the water.

The measurement of transparency was taken at various times throughout the summer at McGrath (site 4) and Ellis (site 8). The average value for McGrath Pond was 5.1 m and for Ellis it was 5.3 m. These values are slightly below the Maine lake average (5.6 m), but are well within the moderate productivity range (Pearsall 1991). Between 1985 and 1993, average transparency of the lake increased from 4.6 m to 5.4 m (MDEP). MDEP tests also show that, historically, McGrath Pond has had a higher average transparency than Ellis which agrees with our findings (Figure 15). The data suggest that the

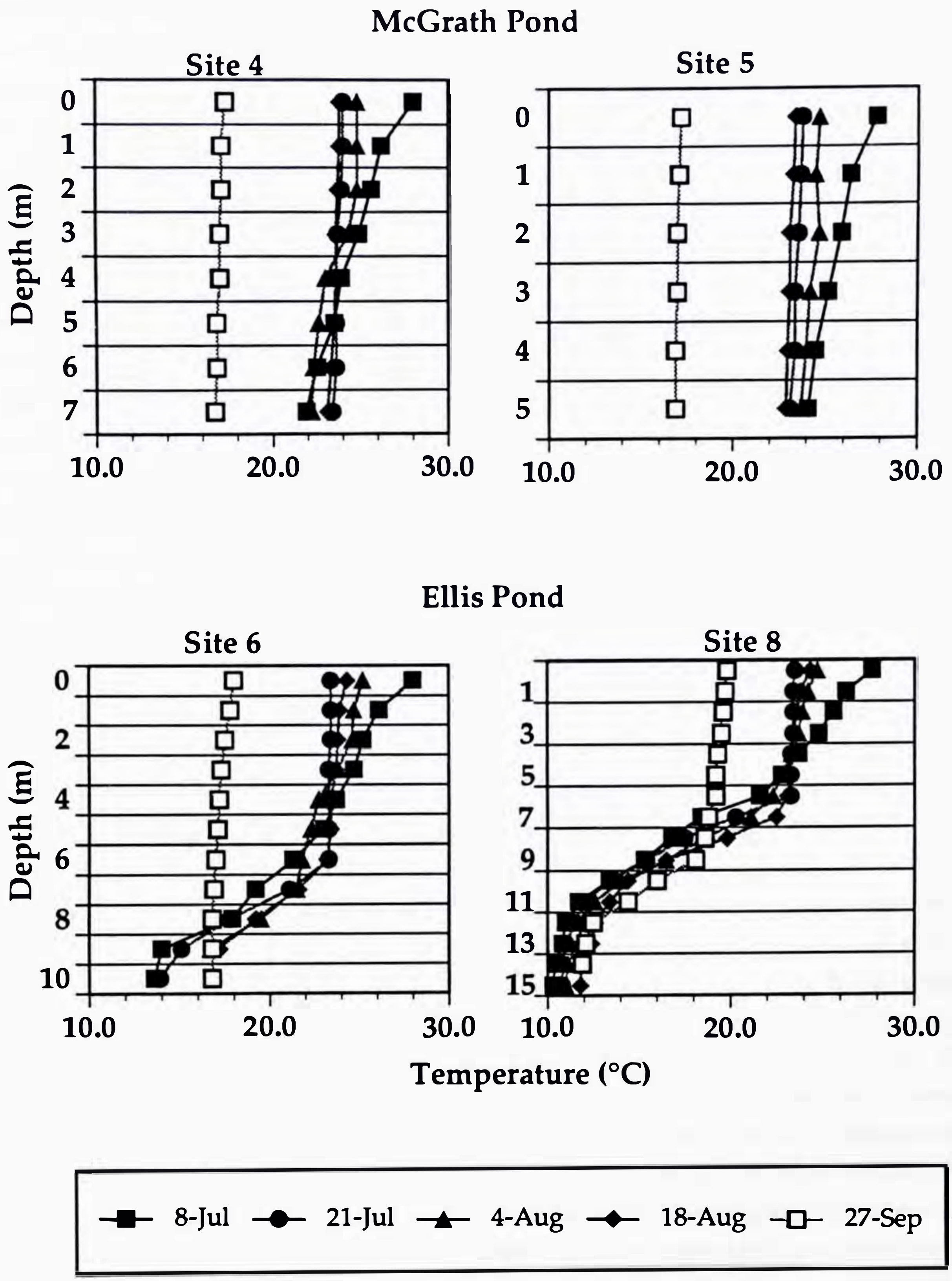


Figure 14. Temperature profiles obtained from McGrath and Ellis Ponds during the summer and fall of 1993.

transparency of Ellis Pond presents more of a threat to the Salmon Lake water quality although the difference between the two lakes is small and both lakes are within the moderate productivity range.

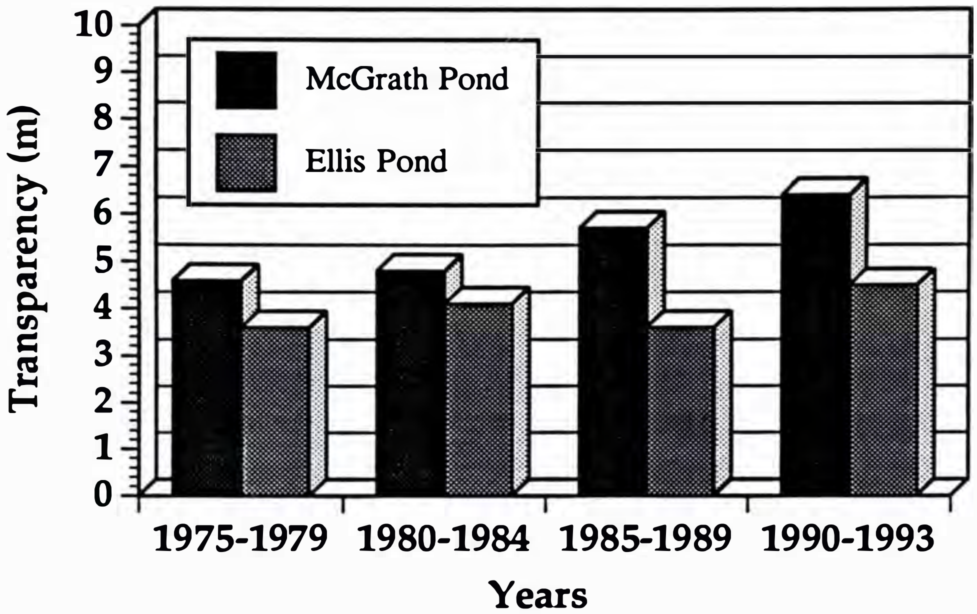


Figure 15. The mean secchi disk transparency values obtained by DEP (1975-1992) and Colby (1993) for McGrath and Ellis Ponds. Transparency provides an index of algal growth, with high transparency values indicating less algae.

Turbidity

Turbidity is a useful measurement for detecting levels of suspended materials in the water. High turbidity can be caused by large amounts of phytoplankton, and/or sediments in the water column so turbidity values are often correlated with transparency values. Determining the levels of suspended solids provides an index of phosphorus loading, because most of the phosphorus entering the lake does so attached to soil particles. Turbidity samples were collected on 27SEP1993 and the tests were done in the Colby laboratory using the DR/3000 Hach Spectrophotometer.

The 1962 United States Public Health Service Drinking Water Standards specifies that turbidity should not exceed 5 units (McKee and Wolf 1963). The maximum allowable turbidity for drinking water has not changed from these 1962 regulations (Chapman 1992). Units of turbidity are measured in formazin turbidity units (FTU). The turbidity values for all of the open water sites of McGrath and Ellis ponds ranged from 1 FTU to 3 FTU's, indicating no excessive sediments or algal growth.

Conductivity

Conductivity is a measure of the ability of water to conduct electrical charges, so it is a good indicator of amounts of ions and dissolved solids. Conductivity measurements were made using the YSI Model 31A Conductance Bridge in the Colby laboratory. All of the samples were collected on 27SEP1993.

The conductivity taken at the lake sites ranged from 45-170 µmhos/cm^2 (Figure 16). The overall average conductivity for all lake sites was 68 µmhos/cm^2 but this value can be misleading due to sites 4 & 10a which were 140 and 170 µmhos/cm^2, respectively. Most values fall between 50-60 µmhos/cm^2. The high value for site 10a can be attributed to sediment contamination possibly from the nearby holding pond on a small horse farm, site 4 is a lake characterization site in the center of McGrath Pond. The large conductivity value at the lake site 4 could be attributed to the high turbidity measured at site 25, which is a fairly close tributary. Since conductivity can be a good indicator of dissolved ions and solids and turbidity is affected by suspended matter in the water, these two measurements can be correlated but since the turbidity was not high at site 4 this relationship is unlikely to be the cause of the high conductivity value. The normal conductivity level of Maine lakes ranges between 20-40 µmhos/cm^2 (Pearsall 1991). However, our values are not unusual; MDEP conductivity data indicate a history of high conductivity

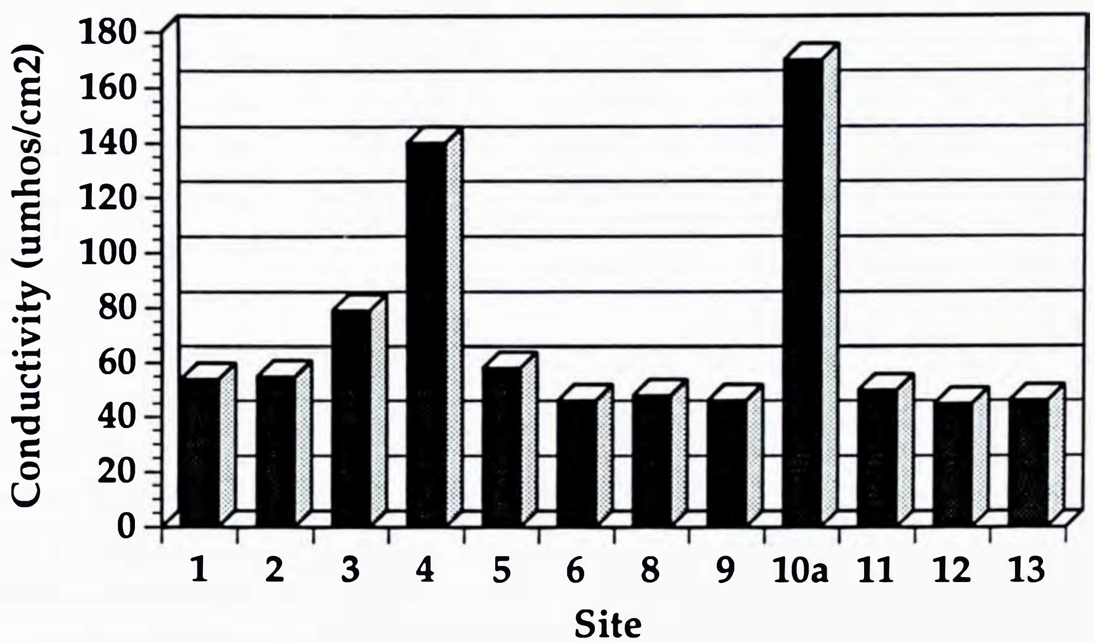


Figure 16. Conductivity values for the sites in McGrath (sites 1, 2, 3, 4, 5) and Ellis (sites 6, 8, 9, 10a, 11, 12, 13) Ponds. All samples were collected on 27SEP93.

for Salmon Lake (a range of 38-90 µmhos/cm^2 for the whole lake). The average of tests conducted between 1975-1977 indicate relatively low conductivity in Ellis Pond (38 µmhos/cm^2), comparable tests for McGrath Pond were not available (MDEP). Conductivity values from 1978 averaged 65 µmhos/cm^2 in Ellis Pond and 73 µmhos/cm^2 in McGrath. Additionally, these values remained fairly constant throughout the 1980's (MDEP). Yet, nationwide drinking water has values ranging from 50-1500 µmhos/cm^2, so Salmon Lake is not out of the normal range (Chapman 1992).

CHEMICAL TESTS

Total Phosphorus

Phosphorus is recognized as the limiting agent for primary productivity (plant growth) in most temperate freshwater lakes, and therefore it is one of the most important factors in determining lake water quality. It is possible to measure the different forms of phosphorus (dissolved and particulate) separately to obtain the amount directly available for plant use (dissolved). However, since phosphorus constantly cycles throughout the lake in its different forms (see Background section: Lake characteristics), total phosphorus (dissolved plus particulate) gives us a better measure of the amount of this nutrient in the lake. This test was performed by taking a water sample, then digesting any particulate phosphorus in the sample with acid to convert it to dissolved phosphorus using methods outlined in Greenberg et al. (1992) with modifications from G. Hunt and C. Evlin (pers. comm.). After digestion, the samples were analyzed for dissolved phosphorus using the ascorbic acid colorometric method and Milton Roy Spectronic 1001 spectrophotometer. To obtain an accurate total phosphorus measurement for the lake as a whole, one of the most recent developments in collecting the samples is to take core samples. By collecting a sample that contains a representative amount of water from the entire water column, the overall total phosphorus level can be assessed. This sample is taken by slowly lowering a length of flexible plastic tubing to the desired depth, pinching the tube at the water surface, raising the tube out of the water, and collecting the water from the tube. In stratified lakes, this core is taken through the epilimnion since this is the region of primary production, while in non-stratified lakes it is taken near the bottom.

Samples for this study were collected at the lake characterization sites at various times throughout the summer and into the fall of 1993. In addition, samples were collected for the other lake sites in the fall on 27SEP1993. The results of the other lake sites display a range of values, with the lowest being in McGrath and the highest in Ellis (Table 8). The high values at sites 7 and 9 may be related to specific shoreline inputs, but it is not clear what those sources may be in these two cases.

Table 8. Total phosphorus values (ppb) for the lake sites other than the characterization sites of McGrath and Ellis Ponds. All values were from surface samples which were collected 27SEP1993.

	McGrath			Ellis						
Site #	**1**	**2**	**3**	**7**	**9**	**10a**	**11**	**12**	**13a**	**13b**
	8.9	8.3	13.6	14.3	16.2	7.9	10.0	9.8	9.1	8.9

Generally, total phosphorus levels greater than 15 ppb can support algal blooms (Pearsall 1991), but lower levels of phosphorus generally do not represent a significant threat to overall lake quality. It is evident that, although the concentrations of the characterization sites in Ellis are slightly greater than those of McGrath, both lakes are below the critical 15 ppb level (Table 9). The difference between the two lakes may be due to the stratification of Ellis, which allows for the development of anaerobic areas in the deep parts of the hypolimnion. Anaerobic conditions can result in the release of greater amounts of phosphorus from the sediments than in lakes in which the water/sediment interface is aerated. Also, since the water from McGrath moves directly into Ellis Pond, Ellis is receiving not only nutrients from

Table 9. Summary of total P values (ppb) at the characterization sites for McGrath and Ellis Ponds collected in the summer and fall of 1993. Samples from sites 4 and 5 are profiles to the bottom of the lake (no epilimnion was evident), while 6 and 8 are profiles through the epilimnion only.

Site #	Sample Depth (m)	25 JUN	8 JUN	21 JUL	4 AUG	18 AUG	27 SEP	Average
McGrath								
4	7	-	8.0	8.8	7.4	11.2	7.3	8.5
5	7	-	7.6	6.4	7.7	8.4	8.9	7.8
Ellis								
6	8	7.8	12.4	8.7	10.0	9.5	14.9	10.6
8	8	-	10.3	8.9	8.8	11.8	11.5	10.3

the watershed and its hypolimnion, but also from McGrath Pond itself.

The low concentrations of Ellis Pond are consistent with the recent trend of decreasing phosphorus levels in Ellis since the late 1970's (Figure 17) when there were numerous algal blooms (Nichols 1984). In fact the decrease in average phosphorus concentrations has been greater than 70% over the past 18 years. In the early 1980's an EPA sponsored lake restoration project helped to reduce the phosphorus input to the lakes from agricultural lands by preventing manure run-off (MDEP 1987). Also, since that time, the importance of agriculture within the watershed has declined (refer to Zoning and Development section). Although the phosphorus concentrations did not drop immediately, which is probably in part due to the sediment retention of phosphorus, it has steadily dropped since that time. The trend of phosphorus in McGrath over the years is relatively low and unchanging, with average values between 7 and 10 ppb (Figure 17).

Nitrates/Nitrites

Nitrogen is a major plant nutrient that, when combined with adequate amounts of phosphorus, promotes algal blooms. Samples from all lake sites were collected on 27SEP or 4OCT1993 (Appendix B) and tested in the Colby lab, using the low-range Cadmium reduction method (Hach 1991) with a Hach DR/3000 spectrophotometer. The results showed no significant concentrations of nitrates/nitrites. Most lake sites had concentrations of 0.00 ppm; two sites (1 & 7) had concentrations less than 0.04 ppm. In lakes, levels greater than 0.2 ppm can stimulate algal growth (Chapman 1992). Levels greater than 5 ppm are generally indicative of contamination by fecal matter, as would occur due to faulty sewer systems and/or run-off from agricultural land (Chapman 1992). It appears that nitrogen is not a significant

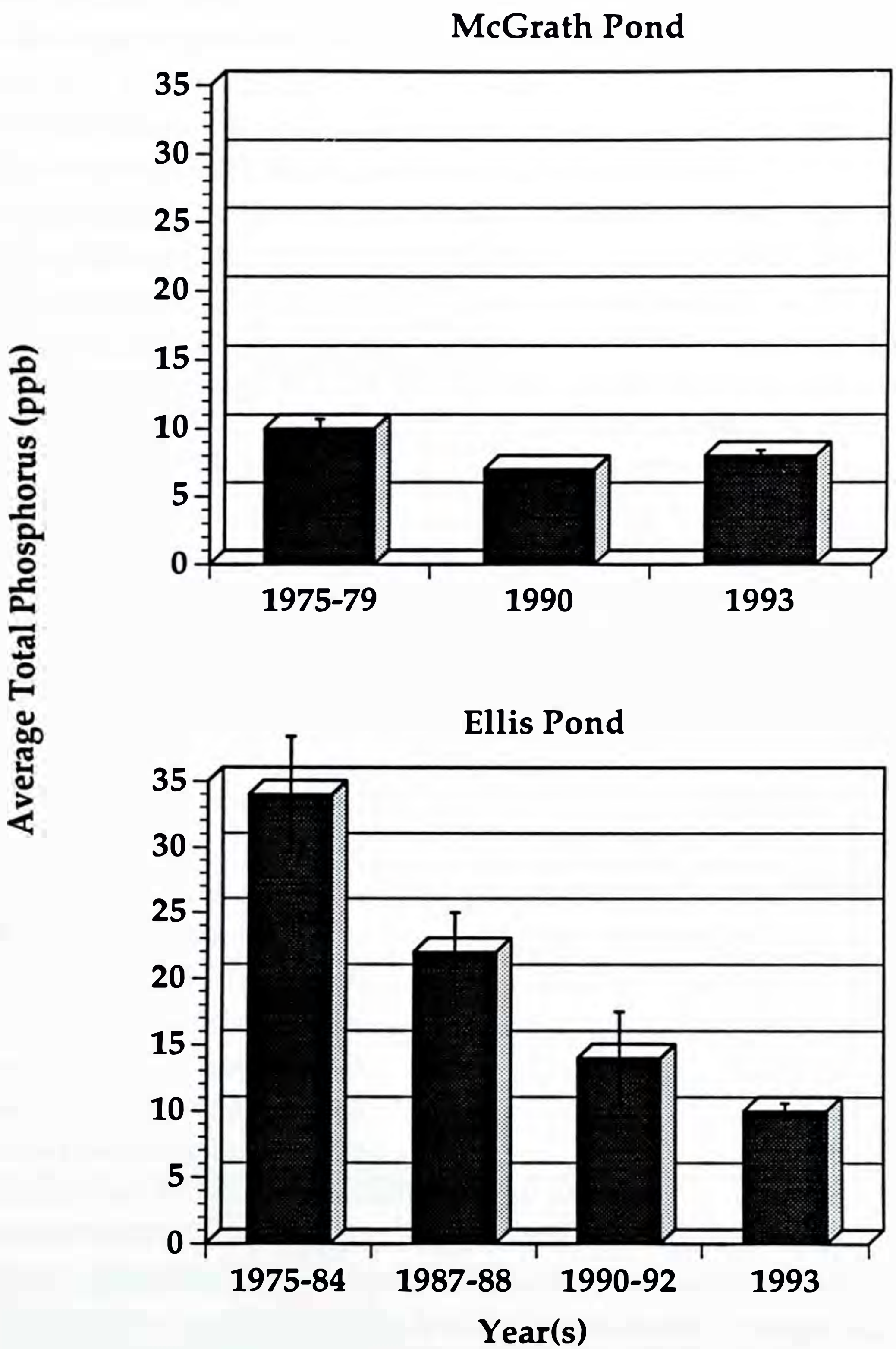


Figure 17. The average total phosphorus values (mean ± SE) obtained by DEP (1975-1992) and by Colby (1993) for McGrath and Ellis Ponds.

influencing factor on the water quality of this lake ecosystem. However, nitrates tend to be assimilated quickly by algae, so tests of total nitrogen might provide a better indication of the amount of this nutrient in the lake.

Hardness

Hardness is a measure of the concentration of dissolved calcium and magnesium salts in the water. Water is considered "soft" if the hardness values are between 0 and 60 mg/l (Chapman 1992). Toxins such as zinc and copper can be more toxic to organisms in the soft water as opposed to hard water (Chapman 1992). On the other hand, it has been found that softer water is conducive to fish growth (McKee and Wolf 1963). Samples for hardness analysis were taken from the surface of the lake. They were tested in Colby's lab using the EDTA Titrimetric method (Greenberg 1992). Figure 18 shows the values from the samples taken on Salmon Lake qualify the water as soft and are slightly higher in McGrath Pond than in Ellis Pond. High levels of these ions could be indicative of industrial pollution, but the small difference seen between these two lakes is probably due to natural inputs.

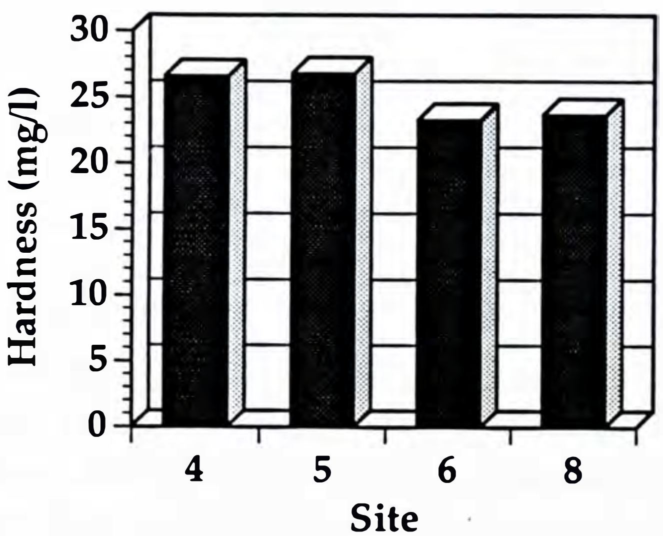


Figure 18. Hardness values for McGrath (sites 4, 5) and Ellis (sites 6, 8) Ponds. Samples from sites 4, 6, 8 collected 27SEP1993 and site 5 collected 4OCT1993.

Color

Measuring color in water provides an indication of levels of plankton, natural metal ions (iron and manganese), and inorganic acids (tannins and lignins) that come from the decomposition of plant matter. There are two types of color that can be measured: true color and apparent color. True color determination requires filtration or centrifugation of the sample to remove suspended matter, and apparent color is determined without any pre-treatment (Greenberg 1992). Since the turbidity values for the open lake sites that we measured were insignificant, we measured only apparent color. This measurement was performed on samples taken from each pond at the characterization sites (McGrath sites 4 and 5; Ellis sites 6 and 8). They were analyzed in the lab within 24 hours using a Hach DR/3000 spectrophotometer (Hach 1991). The values are all below the 26 Standard Platinum units (SPU) level, which is the upper limit for a lake to be defined as uncolored (Figure 19). In general, the averages of these values are slightly lower than the apparent color values obtained by the MDEP in past years (Table 10). Apparent color can be affected by several different factors, so it is impossible to determine exactly what is causing the change from year to year, and the differences between McGrath and Ellis, but they generally seem to follow the trends of the phosphorus values. Since increasing phosphorus levels lead to increasing concentrations of phytoplankton, which results in higher color values, it seems that color should be following the same pattern as phosphorus but the other factors involved could also be having an effect. Thus, even though site 8 had the highest color value, it did not have the highest concentration of phosphorus, so there may have been another factor, such as metal ions from the nearby shoreline rocks or organic acids from the wetland located south of this site.

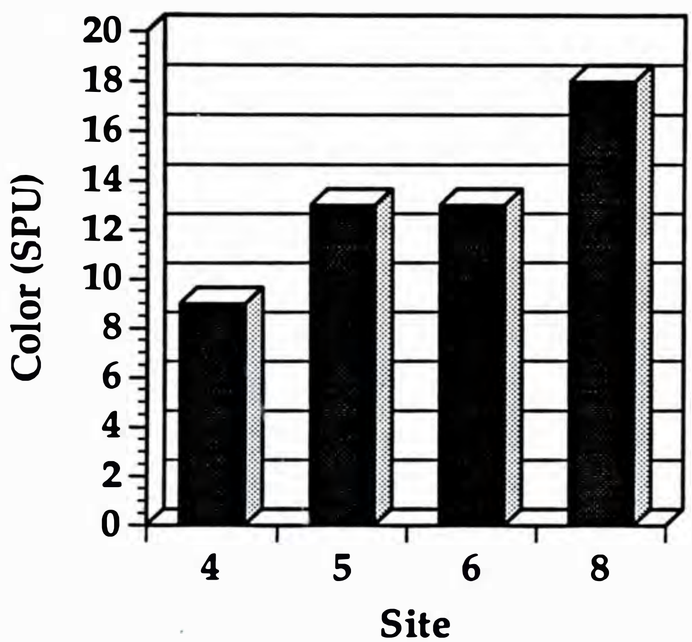


Figure 19. Color values (given in standard platinum units) for the characterization sites of McGrath (sites 4, 5) and Ellis (sites 6, 8) Ponds. All samples were collected on 27SEP1993.

pH

The pH is a measure of H^+ concentration in the water, and since many critical chemical and biological processes are dependent upon the pH level, it is a commonly used measurement of water quality. The average pH for Maine lakes is slightly acidic ranging from 6.1 to 6.8 (Pearsall 1991). Throughout the summer and fall of 1993, pH readings were taken using portable pH meters. The values were consistently 7.8 or 7.9 throughout the summer for all of the characterization sites (4, 5, 6, 8), and ranged from 7.5 (site 8) to 8.0 (site 12) for the readings taken on 27SEP1993. The variation among values may be accounted for by variation in photosynthetic activity and respiration rates of phytoplankton. The process of photosynthesis results in a decrease in CO_2 levels in the water

Table 10. Average apparent color values (in standard platinum units) for McGrath and Ellis Ponds obtained by DEP (1977-92) and Colby (1993).

McGrath Pond		Ellis Pond	
Year(s)	Avg. Color (SPU)	Year(s)	Avg. Color (SPU)
1977-81	16	1977-82	20
1990	15	1992	15
1993	11	1993	16

which leads to an increase in pH, while respiration has the inverse effect (Chapman 1992). The fact that the values are higher in these lakes than most Maine lakes is not explained easily by our data, however measurements of ammonia and other ions in the water might reveal the cause of these relatively high, though not problematic, pH values.

Data from MDEP indicate that over the years the pH of the two ponds has increased. From the 1940's through the early 1980's, values ranged between 6.8 and 7.2. The last MDEP data obtained was from 1990 and the pH of both ponds was 7.6 (MDEP 1993). These high values indicate that neither of these lakes has any current problems with acidification. Acidification problems can lead to the dissolution of elements from the sediments (e.g., aluminum) that are harmful to fish (Maitland 1990). However, on the other extreme, a high pH (>8.5) can lead to the conversion of ammonia to the ammonium ion which is also toxic to fish (Maitland 1990).

BIOLOGICAL TESTS

Chlorophyll a

Chlorophyll is the green pigment present in nearly all photosynthetic organisms. Its measurement in the water column can provide an indication of the amount of algae present in a lake. Three forms of chlorophyll exist (a, b, and c), but most tests focus on the major form, type a (Chapman 1992). In general, oligotrophic lakes have chlorophyll levels less than 2.5 ppb, while levels in eutrophic lakes may range from 5-140 ppb (Chapman 1992). Samples for chlorophyll a testing were collected from the surface of sites 4 and 6 on 27SEP1993. These samples were then sent to Northeast Labs of Winslow, Maine, for analysis. The sample from McGrath (site 4) had a chlorophyll a concentration of 2.2 ppb while the Ellis sample (site 6) was 4.2 ppb. The difference seen between the two lakes is what might be expected because phosphorus levels were also lower in McGrath than in Ellis . The chlorophyll level in McGrath Pond is the same as the normal levels of an oligotrophic lake, while that of Ellis suggests slightly more lake productivity, although it is still not in the eutrophic range. Since this test was only performed on samples taken in the fall, it would be informative to measure chlorophyll a throughout the summer to obtain a more accurate representation of the levels in the lake.

Macrophytes

A good indicator of nutrient levels and the trophic status of a lake is the presence and abundance of macrophytes. In lakes with high levels of nutrients there is often excessive macrophyte growth, such as milfoil and pond lily (Henderson-Sellers and Markland 1987). A simple observation can quickly provide a sense of whether the nutrient levels of the lake are excessive or not. We performed observations of this type during sample collection in the fall of 1993 by travelling the entire perimeter of the two ponds by boat looking for problem areas.

We found little notable macrophyte growth except in a few locations. The first was the northwest corner of McGrath pond near the Mutton Hill run-off area. In this inlet we found sedimentation and significant growth of tape grass and lilies. The growth in this area indicates a problem zone due to high amounts of run-off from the nearby tributary. Samples taken at this tributary showed a high conductivity value (480 μmhos/cm^2) which indicates ions and sediments present in the water. Additionally, the road which runs straight down Mutton Hill towards the lake provides another method for sediments to enter the lake or nearby tributary. Another area with large concentrations of arrowhead and lilies was at the southern end of Ellis. This area was a natural wetland, with very shallow water and excessive sediments, so macrophyte growth of this type would be expected in such an area. Floating brownleaf, pickerel-weed and tapegrass were also observed at the mouths of Cold Brook and tributary 22, due to the sediments in these areas.

Tributary Water Quality

PHYSICAL MEASUREMENTS

Dissolved Oxygen and Temperature

Dissolved oxygen and temperature readings were taken at the McGrath (sites 14, 15, 16, 17, 25) and Ellis (sites 21a, 23, 24) Pond tributary sites on 27SEP1993. The highest DO value was at site 17 (10.1 ppm), which also had one of the highest flows measured for the day (11.7 liters/min). This increased flow allowed for more contact of the water with the air, thus adding to the DO concentration. Most of the tributaries sampled had little or no flow but the rainy weather on the sampling day may have increased the already small flow, especially at some of the last sites sampled after it had been raining for some time. Sites 15 and 16 both had values under 5 ppm and both had temperatures of 13.7°C. Since there was little flow at these sites, these low DO concentrations could be the result of bacterial activity on dead organic matter. Site 25, which had a relatively average DO level of 7.7 ppm, had the highest temperature recorded at 18°C. The lowest temperature was at site 17 which, as expected, also had the highest DO concentration (although bacterial activity can affect DO also). Sites 14, 21a, 23, and 24 all had values between 6.8 and 8.9 ppm.

Turbidity

Turbidity is influenced by the type and concentration of suspended matter in water. Run-off carries soil particles so it is important to test tributaries for the amount of suspended materials since tributaries can ultimately affect lake water quality. On 27SEP1993, samples were taken at all of the tributary sites. However, the rain on the 27SEP1993 sampling may have increased the rate of run-off of eroded materials into the tributaries. Sites 17, in McGrath Pond, and sites 23 and 24, in Ellis Pond, were also tested again on 4OCT1993 (Figure 20). Both sampling days were overcast but it only rained on 27SEP1993. The sites with the highest values were site 25 in McGrath and sites 21a and 24 in Ellis. Site 25, which had one of the highest flow measurements, also had the highest turbidity (39 FTU's). Site 25 reflects real erosion into the lake. Cold Brook (site 24), which is the largest tributart in the watershed, also reflects heavy erosion into the lake. Site 21a was very shallow, so sampling without collecting sediment was difficult, and may have affected the reading. The lowest turbidity was at sites 17 and 20 (3 FTU's). As

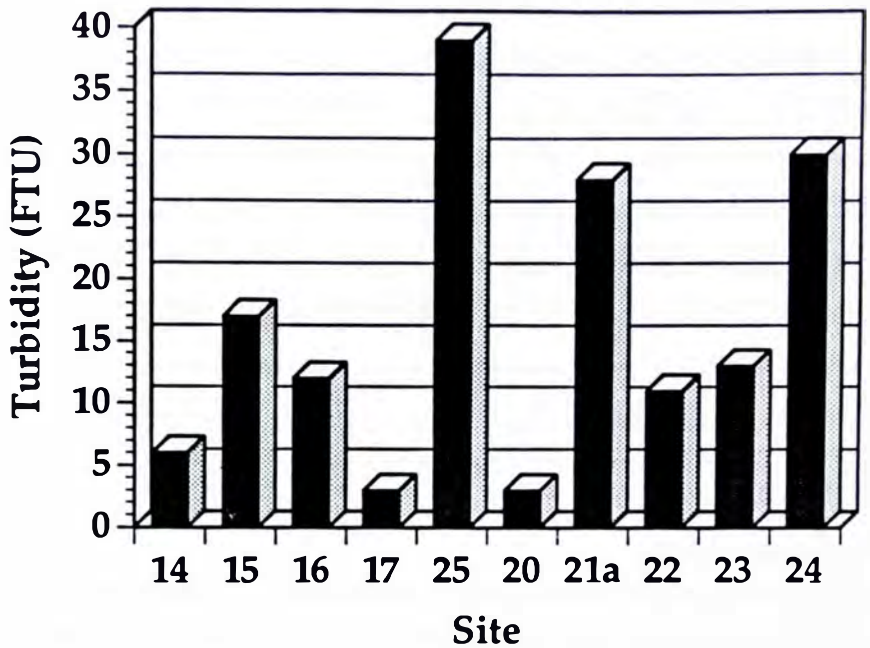


Figure 20. Turbidity values for selected tributaries of the McGrath Pond watershed (sites 14, 15, 16, 17, 25) and the Ellis Pond watershed (sites 20, 21a, 22, 23, 24). Turbidity readings measured in formazin turbidity units (FTU). Values for sites 23 and 24 are an average of samples which were collected on 27SEP1993 and 4OCT1993. All others are from samples which were collected on 27SEP1993.

previously discussed, none of the lake sites that were tested for turbidity had values above 3 FTU's. So, at least at this time of the year, the tributaries do not seem to be adversely affecting turbidity within the lake.

Conductivity

The measurements for conductivity in the tributaries were, on the average, higher than those for the lake. Although this is not unusual, it is important to note that the weather conditions on the 27SEP1993 sampling were not ideal; it began to rain about an hour after sampling began. This rainfall probably caused an increased run-off into the tributaries. All of the selected tributary sites were sampled on 27SEP1993. Sites 23, 24, 25 were sampled again on 4OCT1993 when it did not rain, and an average of the two days was taken. Figure 21 summarizes all of the data from these sampling days. The lowest and highest conductivity values were both found in the McGrath watershed; site 25 had a value of 45 µmhos/cm^2 and site 15 was 480 µmhos/cm^2. The average tributary conductivity value was 182 µmhos/cm^2. Site 15 was the creek coming down Mutton Hill from a holding pond. Interestingly, the pond on Mutton Hill (site 14) had a much lower conductivity, 60 µmhos/cm^2. Because conductivity is an indicator of ions present in water, the run-off sedimentation present in tributaries resulted in higher conductivity

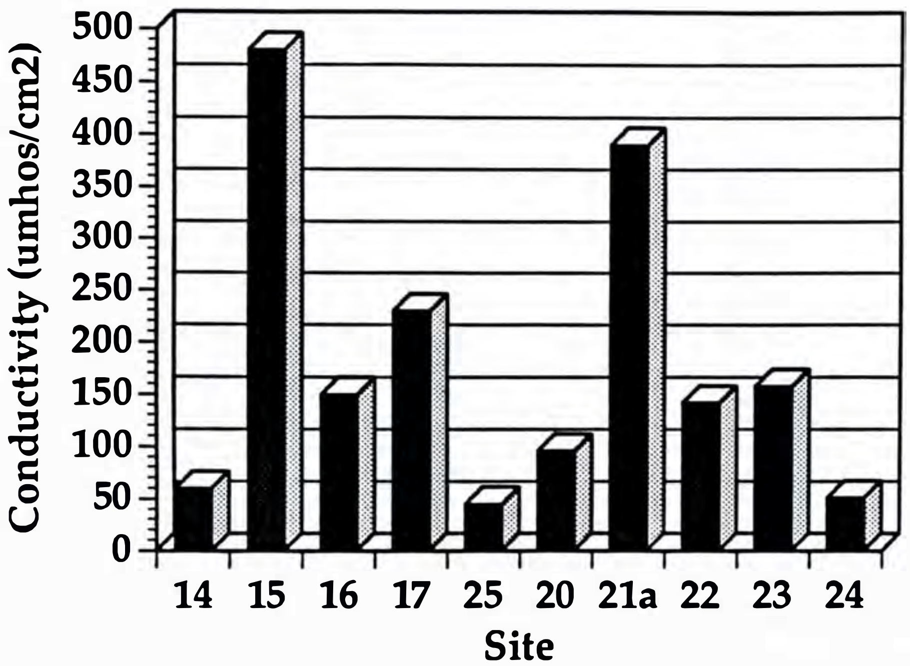


Figure 21. Conductivity values for selected tributaries of the McGrath Pond watershed (sites 14, 15, 16, 17, 25) and the Ellis Pond watershed (sites 20, 21a, 22, 23, 24). Values for sites 23, 24, 25 are an average of samples which were collected on 27SEP1993 and 4OCT1993. All others are from samples which were collected on 27SEP1993.

values. Davis et al. (1978) reported that conductivity concentrations in Maine lakes are greater at inlets and tributaries than at open waters. This is because the open water acts as a dilution basin for the ions and dissolved solids (Davis et al. 1978).

CHEMICAL TESTS

Total Phosphorus

Being the main nutrient of interest in a lake, it is necessary to know how much phosphorus is being delivered to the lake by tributaries. As tributaries pass along agricultural areas or roadways, they can pick up significant amounts of this critical nutrient. Nichols et al. (1984) revealed that the two most important sources of phosphorus to Salmon Lake were from specific tributaries (sites 15 and 22) that passed near farmlands. Samples were collected from all tributaries around both lakes that had adequate amounts of water to sample on 27SEP1993. The sampling was repeated on 4OCT1993 for sites 17, 23, 24, 25 to double-check questionable results and averages from the two days were reported in the results. On the first day of sampling (27SEP1993) it began to rain during the sampling, so some tributaries may have contained higher than normal amounts of phosphorus because they contained the first flush of run-off. Some of the variation between tributaries may be explained with the weather conditions in mind (Figure 22). The two samples with the highest values (sites 21a and 21b) were taken from water that was very shallow, which could have resulted in contamination of the samples with sediments. These sediments can cause high total phosphorus readings. There is also the possibility that during times of high run-off, there can be an input to this tributary from two ponds upstream from the sample location. These ponds are thought to be very rich in phosphorus due to the observation that they were both green during the summer (Len Reisch pers. comm.). The total amount of inflow of the tributary at site 21a to the lake was minimal because it did not directly flow into the lake, but first into the stagnant area of site 21b. It then leached into the lake through the soil. Any time that water is able to leach through the ground, nutrients can be withdrawn from the water.

Sites 15 and 22 also had relatively high total phosphorus concentrations (both were >15 ppb). Site

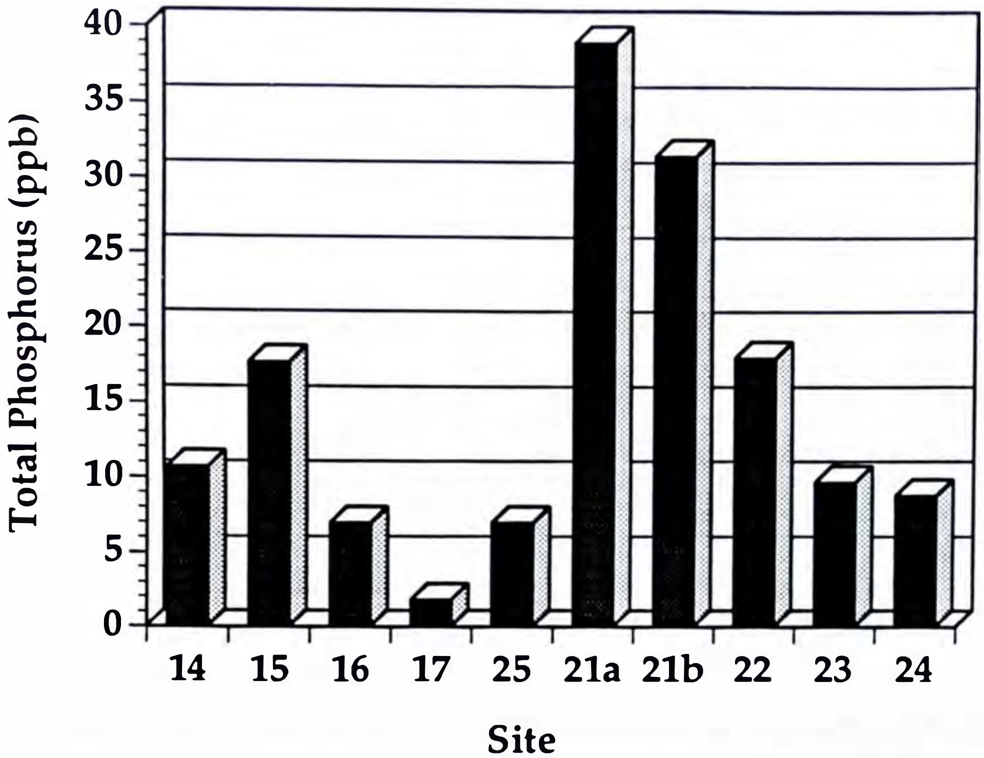


Figure 22. Total Phosphorus values for the selected tributaries of McGrath (sites 14, 15, 16, 17, 25) and Ellis Ponds (sites 21a, 21b, 22, 23, 24). See text for description of each site. Values for sites 17 and 23 are an average of samples which were collected on 27SEP and 4OCT1993. All others are from samples which were collected on 27SEP1993.

15 is in a location that would receive large amounts of direct run-off from McGrath Pond Road; this could explain its high phosphorus level. The lake site into which it flows (site 1) had a fairly low concentration (9 ppb), indicating that this tributary either does not consistently put these amounts of phosphorus into the lake, or if it does, it is not an amount significant enough to raise the lake levels. However, this tributary may have had an unusually low input to the lake due to the low rainfall of this July and August. So it would be advisable to monitor this site more closely throughout the years. Nichols et al. (1984) reported that this tributary was a major phosphorus contributor to the lake. The concentrations that were reported then ranged from 10 ppb to greater than 700 ppb. These past measurements were taken at various seasons of the year, so it would be informative to take measurements from this and other tributaries at other times of the year to see if they ever reach these high levels. Due to the lake restoration project, since that study, which presumably reduced the phosphorus inputs to this and other tributaries, it is expected that throughout the year the values would not be as high as in the past, but it would be interesting to investigate.

Site 22 runs under several camp roads on the west shore of Ellis Pond, so these roads could have had some influence on the phosphorus concentration of this tributary. Once again, however, the lake site into which it flows (site 12) had one of the lower phosphorus values of the entire lake (10 ppb). So the impact of this tributary in terms of phosphorus, does not appear to be significant at this time of year.

The rest of the tributaries all have reasonably low phosphorus levels, all very close to or below 10 ppb. The one tributary that may have been predicted to have a large impact on the water quality of Ellis Pond, due to its size (site 24 - Cold Brook), had a phosphorus concentration of only 9 ppb according to our limited sampling. From this data it appears that this stream has a small negative impact on the lake, and in general, none of the tributaries seem to significantly contribute to phosphorus loading of the lakes. However, one must keep in mind that our sampling focused on a single period of the year, so that while our results show no significant nutrient inputs, it is necessary to do more extensive sampling of the tributaries at different times of the year and immediately following large amounts of rainfall.

Nitrates/Nitrites

Nitrogen is not as crucial to primary productivity as phosphorus, however it also must be measured in tributaries since its presence may be correlated with agricultural or industrial run-off. Nitrate/nitrite measurements were performed for all tributary sites on 27SEP1993 or 4OCT1993 (Appendix B). Site 17 was sampled both times, so an average was reported in the test results. As in the lake sites, most tributaries had zero nitrates/nitrites. Sites 25, 21b and 22 all had minimal concentrations of 0.05, 0.02 and 0.00 ppm, respectively. The one sample with a nearly significant amount of nitrates/nitrites was from site 17, which had a concentration of 0.19 ppm. This is well below the 5 ppm level that can indicate fecal contamination, but close to the 0.20 ppm level that can contribute to excessive algal growth (Chapman 1992). The causes of this higher value could be due to any number of things, such as run-off from a fertilized lawn or very slight leaching from a septic field. Overall, however, the tributaries do not appear to have a significant effect in terms of nitrogen inputs to the lake. This observation is consistent with the measurements obtained from the lake sites which indicated that there are no excessive amounts of nitrogen in the lake itself.

pH

As mentioned in the lake water quality discussion of pH, most biological and chemical processes are pH dependent. Since a large input of water to a lake is from the tributaries, it is important to know the pH of these tributaries. The pH was measured at all tributary sites on 27SEP1993, and the results of this testing is summarized in Figure 23. The variation between the tributaries is much larger than between the lake sites. The pH of a stream is dependent in part upon the type of soil over which it is flowing. Since the beds of these various tributaries undoubtedly varied greatly, the wide range of pH values may be explained. One trend observed from the data, with one exception, is that all sites were acidic. This is contrary to the basic nature of the sites in the lake water. This can partially be explained by the fact that, as previously mentioned, it was raining during this sampling, and rain in the northeast is known to be acidic in nature (Charles 1991). Another contributing factor may be that during decomposition of organic matter pH levels are decreased (Chapman 1992). Even if these values change when there is not rain directly feeding these tributaries, it is obvious that they are feeding some acidic water into the lakes. Since the lakes are basic, this confirms that they must have a reasonable buffering capability protecting them from the acidification process seen in so many lakes in the region.

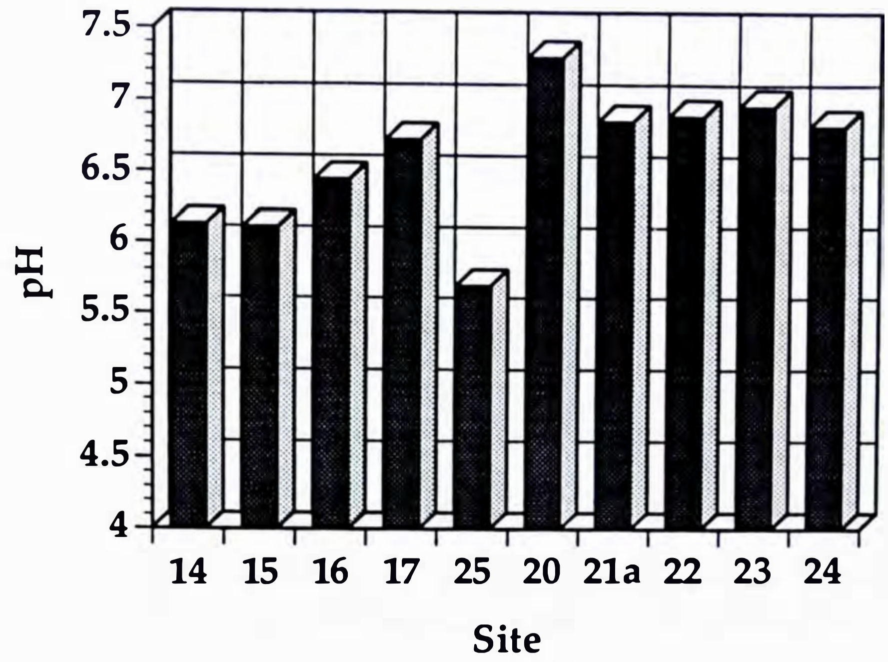


Figure 23. pH values for the tributaries of McGrath (sites 14, 15, 16, 17, 25) and Ellis (sites 20, 21a, 22, 23, 24) Ponds obtained on 27SEP1993.

QUANTITATIVE WATER MEASUREMENTS AND CALCULATIONS

Flow Patterns of Tributaries

Methods

Tributaries are important due to their potential contribution of nutrients to the lake ecosystem. The amount of nutrients entering the lake is dependent on the volume of flow in its tributaries and the contributions of nutrients from adjacent land use practices. Disturbed land produces more nutrients than naturally vegetated land. Increased runoff and decreased infiltration due to urbanization also contributes greater amounts of nutrients.

Although streams do remove some nutrients through sedimentation and biological uptake, most nutrients reach the lake (Shroeder 1979). Therefore the volume of water and the concentration of nutrients in the stream are essential in determining the extent of nutrient loading into the lake. In this study, due to low rainfall during much of the summer many streams had no measurable flow. Flow measurements were made at three separate sites: where Cold Brook crosses McGrath Pond Road (site 24), an unnamed stream that runs parallel and adjacent to Cold Brook (site 23), and at another unnamed stream that crosses the fork of Town Farm Road and Route 128 (site 17).

Two methods of measurements were used to quantify the water flow of the streams. We made measurements with a flow meter at two points along a transect across each stream. Totai width was recorded, and at each measurement point distance from shore and depth were measured. This transect divided the stream into separate cells. The following equation was then used to calculate flow rate expressed in liters/minute:

Stream flow per cell (cms) = [length of cell (m)] x [average depth of cell (m)] x (average cell velocity)

Length of the cell equals the distance measured from the first transect point (a) to the next transect point (b). Since each stream had 2 points within the stream and 2 banks, there was a total of 4 points and 3 cells along the transect.

Average depth of cell equals depth measured at (a) plus depth measured at (b) divided by 2.

Average cell velocity equals the velocity measured at (a) plus velocity measured at (b) divided by 2.

Therefore, the sum of the flow for each cell is the flow of the stream at that point. In cases where it was impossible to use flow meter, a bucket was used. We used 11 liter buckets where there were culverts with flows that could be completely contained by the bucket. The time (in minutes) that it took to fill the buckets was recorded, and flow in liters/minute was established for that stream.

Due to the lack of flow measurements because of low precipitation, we also used a survey of the size culverts along the main roads to indicate the flow patterns. We assumed that the culvert size was proportional to the stream flow expected by the designing engineers. The drainage areas of the streams within the watershed were obtained to support culverts size data, since drainage areas are also proportional to stream flow (Nichols et al. 1984).

Results and Discussion

Ellis Pond was found to have two main streams, Cold Brook and unnamed stream (site 22). At Cold Brook (site 24) we found a flow rate of 283 liters/min and a measured culvert diameter of approximately 5 ft (the largest culvert in the watershed). In comparison the adjacent stream had a flow of 392 liters/min but a culvert diameter of only 2 ft and a drainage area of 52 acres. We did not consider this as one of the main streams entering Ellis because of drainage area and culvert size.

Cold Brook is the largest tributary in the Salmon Lake watershed, draining an area of 544 acres. We were unable to measure the flow in many of the other streams due to their ephemeral nature and the lack of rain in the months previous to the study. Even Cold Brook had an unusually low flow rate. Extensive surveys of flow rates (USGS 1979 and 1980) of Cold Brook recorded an average flow rate of 3424 liters/minute between April 1978 and September 1979 and a range of 135 liters/min to 12,030 liters/min. The values recorded in our study are very close to the lowest values recorded in the 1978 - 1979 studies.

Even though site 23 (stream adjacent to Cold Brook) had a much smaller drainage area than Cold Brook, its flow rate (392 liters/min) was higher than that of Cold Brook. This may be because it was raining for approximately one hour before both streams were sampled and site 23 responded more rapidly to the rain due to different land use practices within its drainage area. The other main stream in the Ellis watershed, located on the eastern side, was chosen because of its large watershed of 198 acres. It was labelled as site 22 for water quality tests.

McGrath Pond was found to have three main streams all in its northern section. The first stream, in the northeast section of McGrath, that passes through site 17 had a smaller flow of 11.7 liters/minute and a culvert diameter of approximately 4 ft. The sample taken at the road fork showed a very low flow (11.7 liters/minute). This value is not proportional to the culvert diameter (5 ft). The stream may normally have a larger flow assuming the culvert size is proportional to the flow rate. In addition the drainage area of this stream is 205 acres suggesting a larger flow than we measured.

The culvert study in combination with drainage pattern sizes suggested two other streams as possible locations for considerable flow. Most culverts in the McGrath watershed are between 1 1/2 and 2 ft wide but two have diameters of 3 ft. These were samples sites chosen on the northern shore of McGrath Pond (sites 15 and 16) but since there was no flow we were unable to quantify their importance. Drainage area for the streams passing through sites 15 and 16 were 422 and 388 acres respectively. This suggests that they may be important sources of flow given normal rainfall conditions.

Streams play an important role in carrying nutrient loads to the lake. Cold Brook is the most important tributary in the Salmon Lake watershed. Other streams could be important but are difficult to quantify over a short period of time due to their ephemeral nature. From this study it appears that, apart from Cold Brook, there are four other streams in the watershed that are important contributors to the lake. Further testing must be done to understand their flow patterns further.

Water Budget

Methods

The water budgets for Salmon Lake and its two constituents, McGrath and Ellis Ponds, were calculated so that the flushing rate and phosphorus budgets could be determined. The amount of new water entering a lake in a given year, in cubic meters, is known as the net input (I_{net}) and is determined by the equation:

I_{net} = (run-off x land area) + (precipitation x lake area) - (evaporation x lake area)

Run-off = 0.622 m/yr

Precipitation = 1.01 m/yr (10 yr average 1983-92)

Evaporation = 0.56 m/yr

The evaporation value was taken from a study done by Prescott (1969) for the lower Kennebec River basin. A ten-year average precipitation was calculated using data from the Waterville Pump Station for the years 1983-1987, and 1991, and data from Augusta Airport for 1988-1990, and 1992 when pump station data were incomplete. Depths for each individual pond were obtained from Bouchard (1988). For the average depth of the entire Salmon Lake system, pond average depths were weighted with the surface area of each pond and then averaged. McGrath Pond comprises 41% and Ellis 59% of the total area of Salmon Lake. Therefore, 4.4 m x 0.41 + 7.3 m x 0.59, gives an average depth of 6.1 m for the combined ponds.

The flushing rate is a measure of the amount of a lake's water volume replaced during one year. It is determined by the formula:

$$\text{Flushing rate} = \frac{I_{net}}{\text{surface area of lake x average depth}}$$

Values were obtained for the land and water surface area by using ZIDAS. (See the ZIDAS Methodology section).

Because McGrath Pond flows directly into Ellis, the watershed of Ellis was actually considered to be that of Salmon Lake. Had we only considered the Ellis subwatershed, an inaccurate value would result because the volume of water that empties from McGrath into Ellis every year (99% of McGrath Pond) would not have been taken into account.

Results and Discussion

Using the preceding values, the input into Salmon Lake (both ponds) per year (I_{net}) was 16,480,434 m^3/yr, and the average depth is 6.1 m. The flushing rate is 0.58 flushes/yr. This means that in one year, 58% of the lake water is replaced. See Table 11 for the flushing rates of the lake and individual ponds. McGrath Pond has a flushing rate of 0.99 flushes/yr, and Ellis Pond 0.78 flushes/yr. The MDEP (1987) found rates of 0.63 flushes/yr (Ellis) and 0.78 flushes/yr (McGrath). They used a surface area value of 1,840,000 m^2 for McGrath Pond and 2,700,000 m^2 for Ellis, whereas our values are slightly larger. Drainage area varied as well: 22,870,000 m^2 compared to our 23,120,000 m^2 for Ellis Pond and 11,336,000 m^2 compared to our 12,000,000 m^2 for McGrath Pond. Precipitation was also very different. We used a current ten-year average of 1.01 m per year, and the MDEP used a lower average precipitation, obtained over a different period of time.

Fifty-eight percent of the water will flow out of the Salmon Lake hydrologic system every year, meaning that it takes just under two years for the entire system to flush itself. This calculation is consistent with the individual flushing rates of each pond, and is important to realize when considering the nutrient status of Salmon Lake. Residence time of water and the nutrients in the water will have

Table 11. Descriptive Characteristics of McGrath Pond, Ellis Pond, and Salmon Lake.

	McGrath Pond	Ellis Pond	Combined Ponds
Watershed area (m^2)	12,000,600	23,126,300	23,126,300
Surface area (m^2)	1,907,800	2,749,700	4,657,500
Mean depth (m)*	4.4	7.3	6.1
Flushing rate (flushes/yr)	0.99	0.78	0.59

*Depths taken from (Bouchard 1988)

important implications on the nutrient loading of a lake. A lake that flushes quickly will not accumulate as much phosphorus as a lake that flushes slowly; rapidly flushing lakes are less prone to eutrophication. Salmon Lake's relatively slow flushing rate is important in that the lake is slow to respond to changes in external nutrient loading. The slower the flushing rate, the longer a lake will need to clear itself of nutrient rich water. Therefore the lake will take longer to recover from nutrient loading than a lake that flushes quickly.

The fact that McGrath and Ellis Ponds are connected has important effects on the water quality of the system. The flow from McGrath into Ellis means that Ellis receives all the water (and dissolved and suspended material) flowing out of McGrath. Ellis Pond might have higher phosphorus levels because it receives most of the phosphorus accumulated in the subwatershed of McGrath, as well as the phosphorus in the Ellis subwatershed. While McGrath Pond flushes almost fully every year, Ellis Pond has a slower flushing rate, taking roughly a year and a quarter to flush. These rates will vary depending on the annual precipitation and the amount of water that is allowed to flow out of the dam. During summers of very low precipitation, the dam is sometimes closed to keep lake water levels from dropping. This will slow down the flushing rate. In the summer of 1993 the dam was closed starting in early August.

Lake Level Management

Dams are often built at the outflows of lakes to regulate the water levels in the lake but also affect water levels in other lakes downstream. Two basic types of dams exist. A ridge dam consists of a barrier across the flow area with an adjustable portion, a ridge, that can be moved up or down to keep the lake level at different heights. The second type of dam regulates water through the size of an opening in the dam itself.

Salmon Lake has a dam consisting of a barrier with a valve regulating the size of an opening letting water flow out of the lake. It is located at the outlet of Ellis Pond, in North Belgrade, near Spaulding Point. Operation is controlled by the Dam Committee. The dam design is less exact than a ridge-type dam because if the valve is not closed when the lake has reached the desired level, water continues to exit. The potential exists for overshooting the desired level, and at times in the history of Salmon Lake, the dam was not shut down and water levels in the lake dropped excessively (Len Reisch pers. comm.). This can have disastrous effects on plants and animals growing and propagating at the water's edge.

The Salmon Lake dam was installed around the turn of the century, raising water levels seven to eight ft (Len Reich pers. comm.). Prior to installation, McGrath and Ellis ponds were connected only by a stream. Water levels are typically lowered in the fall by six to twelve inches to prevent flooding during the spring snowmelts. In June, water levels are permitted to rise again to previous levels (Len Reich pers. comm.).

Dams are often controversial because they may have numerous impacts on the surrounding areas: flooding nearby basins, lowlands and wetlands as well as slowing the flushing rates of water bodies. Indeed, some residents feel that the dam is the primary reason for the current problems in Salmon Lake (Len Reich pers. comm.). The installation of the dam not only caused a rise in water level, but it changed the flushing rates of McGrath and Ellis Ponds by increasing the water volume that must flow out, thereby slowing flushing rate. It is possible that this increased the residence time of the water, allowing nutrients entering the system accumulate longer. The ultimate effect would by increased nutrient loading to Salmon Lake and lower water quality. The stream that existed prior to the dam's installation is now a narrow channel traversable by boats connecting the two ponds and facilitating water exchange. The increased link between the two ponds, and the blockage of water exiting Ellis Pond, may have led to an accumulation of nutrients, phosphorus in particular, in Ellis Pond that has accelerated eutrophication.

SOIL TYPES

Methods

Soils around lakes often influence the impact that development has on the lake ecosystem. It is important to know the individual soil types, and their distributions, and characteristics when planning to develop an area. We therefore feel it is necessary to describe in detail the soils and their characteristics in the Salmon Lake watershed. We used hydrologic data to assign soil types to permeability groups A through D (USDA 1992). This grouping was used to correlate soil permeability to the resulting potential for phosphorus loading. Soils of class A are composed of sand and gravel and have a very high permeability (>6 in/hr). This type of soil permits high infiltration of water and low run-off. The amount of particulate phosphorus brought into bodies of water off these soils is relatively low. However, because of the large grain size there is very little binding of phosphorus to the soil, and phosphorus leaches rapidly through and becomes incorporated in the water system. There are no class A soils in the Salmon Lake watershed.

Class B soils are typically sandy loams that have an adequately high permeability (2-6 in/hr) to prevent a high degree of run-off, but contain soil particles small enough to bind phosphorus. This is therefore the best class of soil in the watershed for general development, with regard to phosphorus binding.

Class C soils have a lower permeability (0.2-6 in/hr), usually due to a higher amount of silts or clays. Particle size is small and binds phosphorus very well, but because the permeability is low, significantly less water infiltrates the soil. This increases the amount of run-off over the surface, increasing the amounts of particulate and dissolved phosphorus delivered to streams and the lake.

Class D soils are the least permeable (0.2-2 in/hr), often composed of fibrous or mucky peat, clays, or silts. In peat soils, run-off is generally not a problem because the soils are located in flat lowlands and wetland areas, where the lack of drainage results in waterlogged soils. In other class D soils, the movement of water through these soils is extremely restricted, resulting in a high degree of run-off in some soils.

There is some degree of soil surface disturbance associated with residential development (USDA 1992). The disturbance of a soil that has a high erodibility results in a high potential for soil particles containing phosphorus to enter the water through erosion and run-off. The erodibility of the soil is directly related to the slope of the land on which it occurs, as soils on steep slopes can be eroded more easily than level soils. The disturbance of a soil on a steep slope can greatly compromise the stability of the soil and may lead to the introduction of phosphorus into streams and lakes.

An engineering parameter used to define the erodibility of a soil is the K factor. A higher K factor corresponds to a more readily erodible soil. The K ranges given by the USDA (1992) ranged from 0.20 to 0.49. This range was divided into three categories: high erodibility (0.40-0.49), medium erodibility (0.30-0.39), and low erodibility (0.20-0.29). These K values are not empirical data that give exact erosion coefficients, but are correlations that are useful as a comparison of the erodibility of the different soils within the watershed.

Using the GIS, soils were grouped according to slope. A USGS (1980) contour map was scanned into the system, and the area between the contour lines smoothed. The system then calculated the slopes for all points on the map. The terrain was divided into four categories of slope: flat (0-3%), low slope (4-8%), intermediate slope (9-15%), steep slope (16-30%), and very steep (>30%). Slope often influences the impact that development, clearing, and installation of septic systems have on the nutrient and sediment loading of the lake. Lesser slopes are better suited for development while steeper slopes have a greater potential for phosphorus loading after development due to the greater probability of erosion.

Soils are not suitable for septic installation if the bedrock is less than five feet below the surface. We designated shallow soils as those less than five feet to bedrock and deep soils as those greater than five feet to bedrock (USDA 1992).

Hydric soils are those in which the water table (the saturated portion of the soil) exists within a foot of the surface—too close to allow for proper filtering of septic waste (USDA 1992). Hydric soils result in contamination of ground water by septics and are therefore unsuitable for residential development.

Combining the parameters and ranking scheme described above, soils were grouped according to their suitability for the construction of residential septic systems. Maps were constructed by grouping all the soils with the same ranks and indicating these groupings graphically. Different patterns on the maps indicate different rankings. This was done for each soil characteristic examined: soil type, slope, depth to bedrock, hydric/non-hydric, erodibility, permeability, and septic suitability. Each of these characteristics was analyzed by the GIS to determine the suitability of an area's use with respect to the area's soil properties, as well as to propose watershed areas which are suitable for future development.

Results and Discussion

There are a total of 17 types of soil in the Salmon Lake Watershed consisting almost exclusively of loams (Figure 24). The arrangement of soils within the watershed indicates that three soil types dominate the area: 1640 acres of Berkshire very stony fine sandy loam, 810 acres of Paxton-Charlton very stony fine sandy loam, and 740 acres of Woodbridge very stony fine sandy loam. The characteristics of each soil are shown in Table 12.

The hydrological groupings of Salmon Lake watershed (Figure 25) shows that soils in the area are

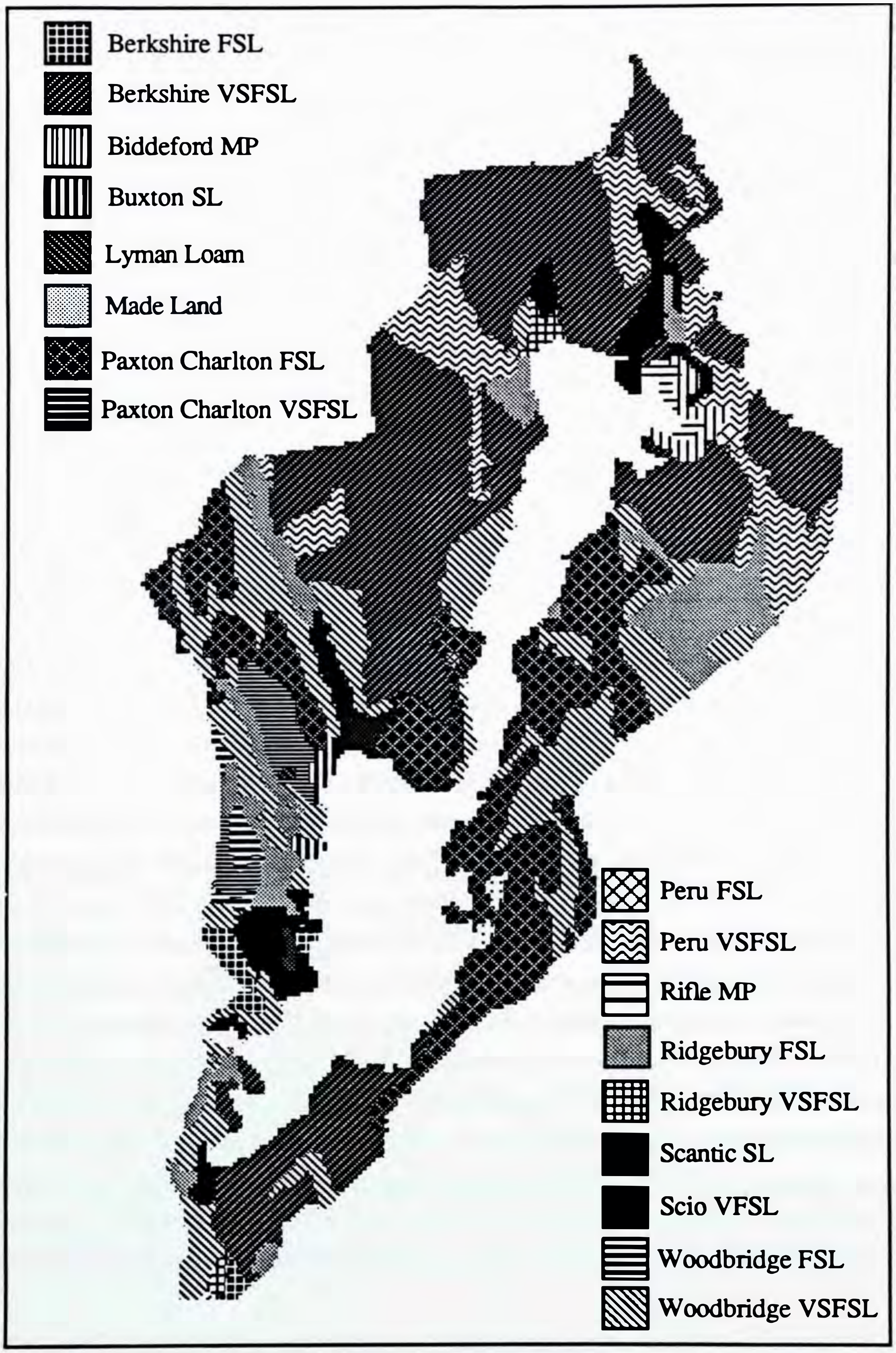


Figure 24. Soil types in the Salmon Lake watershed (USDA, Soil Conservation Service 1978)(SL=Silt Loam, FSL=Fine Sandy Loam, VFSL=Very Fine Sandy Loam, VSFSL=Very Stony Fine Sandy Loam, MP=Mucky Peat)

composed mainly Class B soils, making up approximately 3,760 acres of the watershed (83% of total). Since Class B soils are moderately permeable they allow infiltration of water and therefore reduce runoff. Therefore, in terms of soil class, 83% of the Salmon Lake watershed is ideal for development.

The Class C soils are less abundant, taking up only 600 acres in the watershed (13%); the majority being in scattered groups in the northern sections of the watershed near the northern end of McGrath Pond (Figure 25). There is also a fairly large area of Class C soils located in the southwestern section of the watershed. The reduced permeability make them less suitable for development. However, these areas do coincide somewhat with moderately developed areas. Within the watershed areas of Class C soils coinciding with development may be contributing more to the nutrient load than developed areas with B Class soils.

Approximately 160 acres (4%) are composed of Class D soils (Figure 25). These soils have very low permeability and generally coincide with stream beds and shorelines (BI493 1993). Due to the soil's low permeability they are the least suitable soil class for development. However much of these areas are saturated wetlands and are unsuitable for development. The Class D soils coincide exactly with the wetlands present in the Salmon Lake watershed (see Figure 29). These areas are scattered all around the lake, the two largest sections being located in the northern most sections of both McGrath and Ellis Ponds.

Ideally, development should be limited to areas containing moderately permeable Class B soils. Development in areas with low and very low permeability soils (Classes C and D) could trigger large amounts of phosphorus loading into the lake, thereby reducing lake quality. Therefore, if these areas are developed, additional precautions are needed. If, for example, a septic system was to be built in this area soil additions would have to be made to allow the septic system to function properly.

An examination of erodibility in the Salmon Lake watershed revealed that the majority of the watershed (52%) is comprised of soils with low erodibility (Figure 26). This area of 2,340 acres is scattered throughout the watershed coinciding mainly with the areas of low relief. These areas, in terms of erodibility, are therefore the most suitable for development because erosion should be less significant.

Areas of moderate erodibility and high erodibility are equally represented throughout the watershed (1,070 acres and 1,110 acres respectively) (Figure 26). They are generally located together and are found mainly in the northwestern section of the watershed, in the general vicinity of Howland Hill and Mutton Hill. The steeper eastern shoreline of McGrath Pond also has moderately and highly erodible soils. These areas are less compatible with development, especially the areas with highly erodible soils. Disturbance of highly erodible soils is likely to increase run-off and increase nutrient loading. These areas do have some development, and may contribute a disproportionately large amount of the nutrient load.

The map created to indicate septic suitability revealed that 1,130 acres of the watershed are unsuitable for construction of new septic systems (Figure 27). Criteria for septic suitability included depth of soil to bedrock, soil class, slope and depth of water table. In McGrath Pond both the northeastern and northwestern shorelines have areas that are unsuitable for new septic systems. Ellis Pond has areas

Table 12. Soil names, class, permeability, and septic limitation in the Salmon Lake watershed (USDA 1992).

Soil Name	Soil Class	Permeability	Septic Limitations	Restricting Parameter
Berkshire fine sandy	B	moderate	slight-severe	slopes>15%-seepage
Berkshire very stony fine sandy	B	moderate	moderate	slopes>8%-seepage
Ridgebury very stony fine sandy	B	moderate	severe	poor drainage-wetness
Woodbridge fine sandy	B	moderate	severe	poor drainage-wetness
Ridgebury fine sandy	B	moderately slow	severe	poor drainage-wetness
Woodbridge very stony fine sandy	B	moderately slow	severe	poor drainage
Paxton fine sandy	B	moderately slow	severe	poor drainage
Paxton-Charlton very stony fine sandy	B	moderately slow	severe	poor drainage
Peru very stony fine sandy	C	moderately slow	severe	poor drainage-wetness
Peru fine sandy	C	moderately slow	severe	poor drainage-wetness
Scio very fine sandy	C	moderately slow	severe	poor drainage, wetness
Lyman loam	C	moderately rapid	severe	depth to bedrock
Buxton silt loam	C	slow	severe	poor drainage, wetness
Scantic silt loam	D	slow-very slow	severe	poor drainage
Togus fibrous peat	D	very slow	severe	poor drainage-wetlands
Biddeford mucky peat	D	slow-very slow	severe	poor drainage-wetlands
Rifle mucky peat	D	slow	severe	poor drainage-bogs

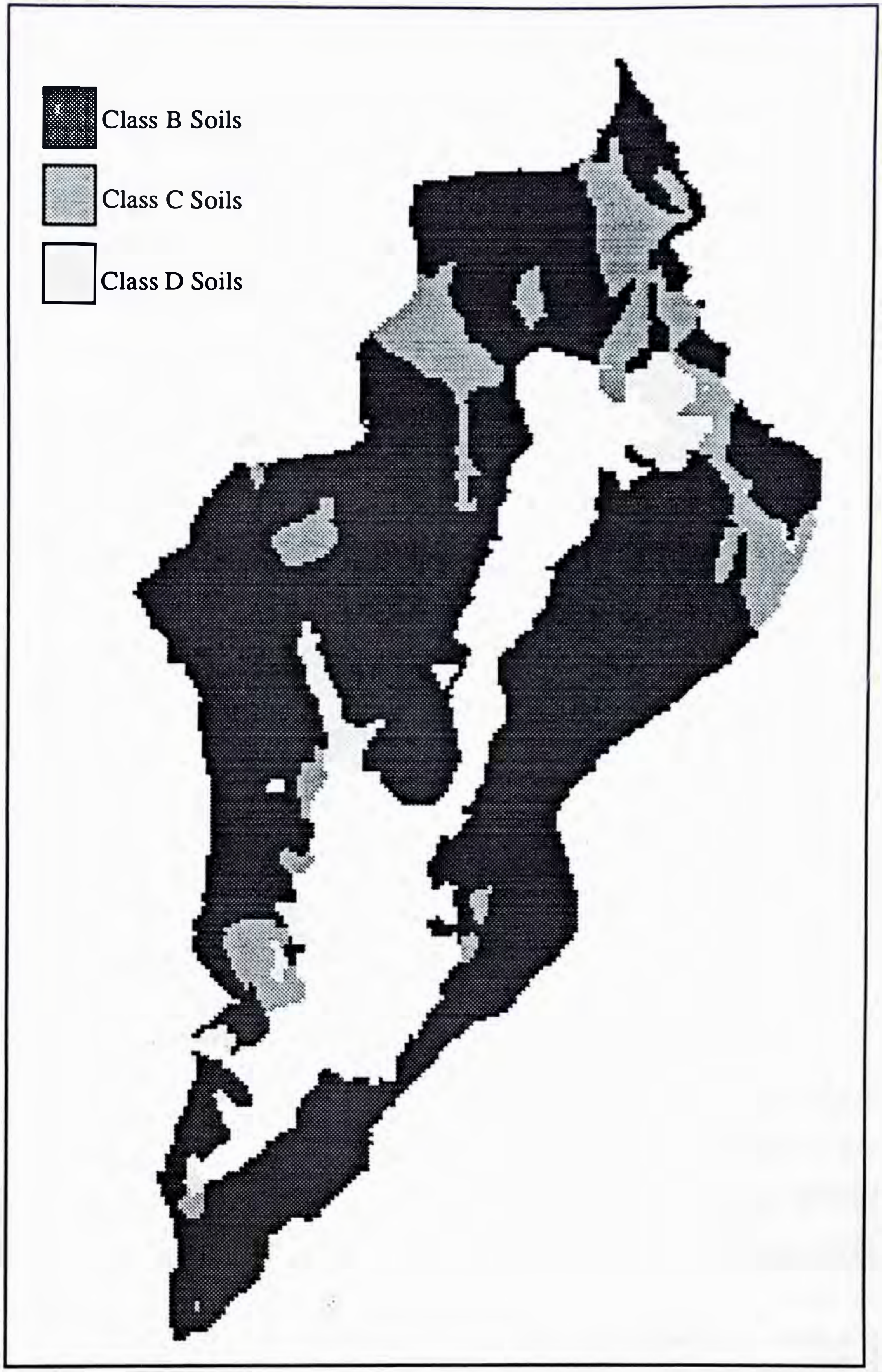


Figure 25. Permeability of Salmon Lake watershed. This varies with Soil Class; Soil Class B having moderate permeability, Soil Class C having low permeability, and Soil Class D having very low permeabilty (USDA 1992). There are no Class A soils in the Salmon Lake watershed.

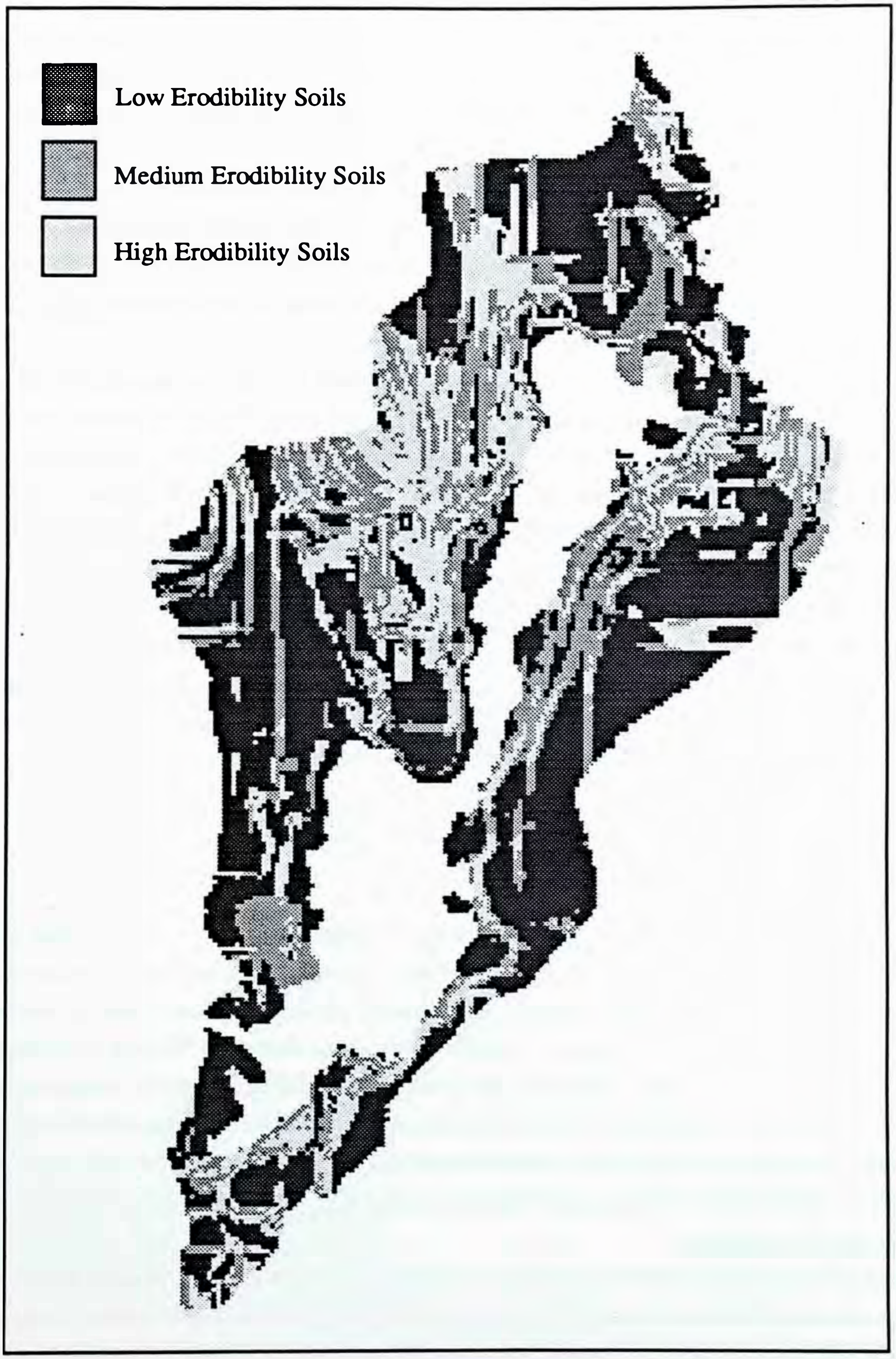


Figure 26. Erodibility of Salmon Lake watershed soils

unsuitable for septic systems scattered all around its shoreline. A fairly large aggregate of unsuitable soils is located in the eastern section of the watershed near the southern end of McGrath Pond. Areas unsuitable for septic systems that coincide with shoreline residential development and current septic system use could be important sources of nutrient loading.

The areas indicating moderate suitability are spread throughout the watershed (Figure 27). The total area of soils with varying suitability is 1,270 acres and does coincide with some shoreline residential areas. Several locations along eastern shore of McGrath Pond and the western shore of Ellis Pond are developed residential areas of moderate septic suitability. Depending on the particular cases, the areas may or may not be compatible with proper septic system use.

The largest area (2,120 acres) in the watershed is comprised of soils that are suitable for septic systems (Figure 27). A majority of the shoreline, where septic suitability is of greatest concern, is suitable for development of new septic systems. Although most of the shoreline is suitable for septic systems, a fair amount is not suitable and therefore should have no future septic systems.

Areas that were suitable for development in terms of soil permeability, erodibility and septic suitability were combined (Figure 28). The resulting figure showed that approximately 36% of the watershed is suitable for development (some of this area may already be developed). A majority of which is located back from the shoreline. The remaining 64% should not be off limits for development but more precautions should be taken for further development in these areas. Shoreline areas in this category are especially important due to their proximity to the lake. Zoning and development ordinances should reflect the greater potential for impact of these areas on Salmon Lake water quality.

ZONING AND DEVELOPMENT

Methods

Initial field reconnaissance of Salmon Lake, both by boat and by car, showed that a large number of residences are built close to the shoreline and have been grandfathered into the Shoreline Zoning regulations passed in 1990 by the State of Maine. This basically means that these homes are not subject to the new shoreline zoning ordinances passed by either Belgrade or Oakland. The lack of buffer zones in front of these homes increases the probability that phosphorus loading from these areas occurs, and has an effect on the lake water quality. It is also clear that, since these homes are grandfathered in, most of the subsurface waste disposal systems in these areas are likely to be inconsistent with the code and may be a potential problem for Salmon Lake. However, some residents have upgraded their systems to conform with recent regulations.

Parcel maps for the areas within the watershed were obtained from the town offices in Belgrade and Oakland. The vacant lots were recorded on these maps as well as structures and the owner's names. An average acreage of both vacant lots and lots with structures on them was determined using ZIDAS. Many people were very helpful in clarifying the information that was found and describing the general development conditions that prevailed in the watershed. Among these was Paul Lussier, the Oakland

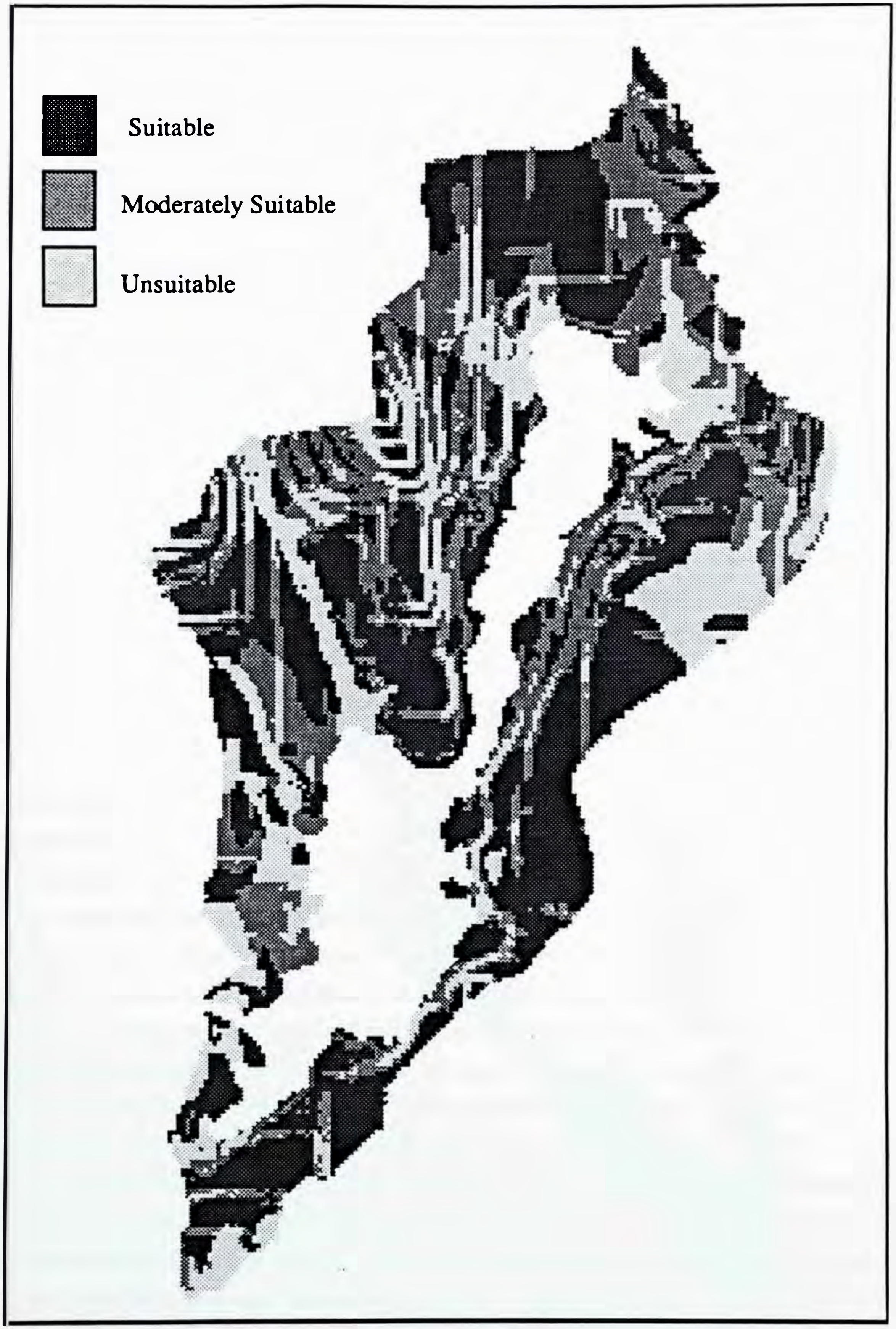


Figure 27. Rating of Salmon Lake watershed soils for new septic system construction

Figure 28. Suitability of Salmon Lake watershed soils for residential development in terms of soil erodibilty, permeability, and septic suitability.

Code Enforcement Officer, who provided information concerning septic regulations and allowed our group access to the town permit files. The full-time plumbing inspector for Belgrade and part-time inspector for Oakland, Bob Martin, made his files on septic information available and helped to clarify some of the details on zoning ordinances. Paula Thompson from the North Kennebec Regional Planning Commission made state zoning ordinances and structure maps available to our group and discussed some of the zoning problems that are facing the towns.

The Comprehensive Land Use Plan for Oakland was referred to for zoning guidelines. Belgrade does not have its own comprehensive plan but instead uses the Comprehensive Land Use Plan designed by the Maine Land Use Regulation Commission, MLURC, (1977). The comprehensive plan is a guideline for managing the changes that occur within a community, as well as shaping the growth of the community in the future (Oakland, Town of 1991). Basically, it is used as an advisory document setting out the community's future goals, and the policies and programs necessary to achieve these goals.

Each town in Maine is also required to have a set of shoreland zoning ordinances, or use those minimum standards set out by the State of Maine. These standards exist to maintain the appearance and value of a lake and to protect and preserve its water quality and wildlife habitats (MDEP 1992b). Land use ordinances that the town may adopt may equate or be more strict than those developed by the state, and help to insure that development meets minimum safe standards for the lake and its ecosystem. These ordinances are not only used to protect the lake ecosystem, but they are also used to protect the surrounding buildings and lands from flooding and accelerated erosion. They therefore attempt to balance human activity and natural ecosystems.

Results and Discussion

Traditionally, land use patterns in Maine have created a unique mixture of "urban village and rural fringe" (Oakland, Town of 1991). Towns and their watersheds have traditionally been made up of everything from farmland to seasonal lakefront dwellings. In recent years, the seasonal lakefront dwellings have given way to year-round use while construction of individual houses and small commercial enterprises have been developed as well. There has also been a decline in the number of farms in the watershed area, thus leaving large areas of fallow pasture. Part of the reason for this upward expansion of development is due to the population growth levels. Data from Oakland for 1970-1987 indicate that the percentage change in population growth for these years is +60.8%. Results during the same time period indicate that the population of Belgrade has increased by 82.2%. The decrease in number of workable farms is primarily due to economic reasons. In fact, Paul Lussier (pers. comm.) believes that there will be no new farms going into the area in the near future. Both Oakland and Belgrade have exhibited this pattern of mixed uses. Also the towns' proximity to the Waterville and Augusta job markets, and their attractiveness for retirement and pre-retirement homes, have led to this growth in development (Oakland, Town of 1991).

Both the comprehensive plans used by each town have the same general goals for future growth. Each town is concerned with the growth it has undergone in the past and wants to control it effectively

(Oakland, Town of 1991). Most of this growth has been residential and can be explained by the rising population of each town. The quality of life in each town is something that both towns are trying to maintain throughout their growth. Many potential problems for the future have been foreseen, and recommendations on how to solve these problems have been outlined in the plans. These recommendations were made primarily as suggestions that the town may consider when developing specific ordinances.

As long as a town has a comprehensive plan with proper and sufficient land use ordinances, it should not experience a significantly deteriorated water quality in its lakes. There is a need for the towns to devise a way of inspecting areas and enforcing these ordinances, however, and both towns seem to have difficulty in doing this (Paul Lussier and Bob Martin pers. comm.). Unfortunately, it seems that there are too many problems that are easily overlooked because larger problems warrant the attention of the enforcement officers. The ordinances of both Belgrade and Oakland cover minimum lot sizes for shoreland and other zones, subdivision development rules, and regulations for commercial development sites. This, of course, works well for a new development, but grandfathered plots seem to slip through the cracks.

Most of the ordinances in Belgrade and Oakland contain a section or clause on non-conformity uses. The use of land in areas that may be non-conforming can continue as is, or be improved to meet the requirements of the new ordinance, but it cannot be changed or expanded into another non-conforming use. If the non-conforming land is not used for a period of 12 consecutive months, a residency cannot be renewed and instead the non-conformance must be improved to follow the new ordinances that are in effect at the time that reuse begins. Also, if the land is sold to a new owner, it must be improved to meet town regulations (Bob Martin pers. comm.).

Since the grandfathered areas of land do not need to be updated unless they go unused or sold, they are likely to be contributing significant amounts of nutrient and soil run-off for some time. These areas may not only be contributing significantly to nutrient levels, but may also be endangering wildlife habitats. However, as long as these land uses were consistent with the past laws, the grandfather clause frees the owner from meeting the new regulations. Incentives are therefore needed to convince these landowners that they should try to comply with the new standards. One idea is to give these landowners tax breaks or a partial subsidy to help them pay for the work that is needed. This will help to improve the quality of the water of Salmon Lake.

The purpose of town land use ordinances is to designate what types of land within a town fall under Resource Protection, Limited Residential-Recreational, or General Development Districts. Resource Protection includes areas in which the development can severely change the water quality, habitats, or scenic values (Town of Oakland 1991). Wetlands, flood plains, and steep sloped areas are all included in this district. This designation also includes the first 250 ft back from the water (referred to as shoreland). These areas are controlled by the town and state guidelines that are outlined in the Shoreland Zoning Ordinances that each town follows.

The fact that a town has a strong set of ordinances and a comprehensive plan to control its development does not necessarily mean that the water quality of a lake will improve or even remain the same. Grandfathered land parcels are still exempt from these ordinances. To counteract the likely nutrient inputs from these areas, parcels that must comply with the updated ordinances should be carefully monitored. Both the Code Enforcement Officers and the state regulators need to be consistent in checking on areas that may not be complying. Nutrient loading from these newly developed areas will therefore be able to be kept under more stringent control and will not add to a lake's present levels. This, along with possible ordinances for grandfathered areas, should improve or at least maintain the quality of the water.

LAND USE

Land Use-General Trends

Numerous trends are apparent in the data obtained from ZIDAS for the years 1980 and 1991. Table 13 shows the actual values in hectares for the various land uses studied. In all of the subwatersheds for the years of 1980 and 1991, forested land areas had the highest values. Most of the cleared land was found in the McGrath Pond watershed. The watershed of McGrath Pond had much of the reverting land areas in 1980 whereas Ellis Pond's watershed contained the majority of reverted lands in 1991. The area of forested land in Salmon Lake's watershed decreased over the time span of eleven years (from 670.0 ha to 647.0 ha in Belgrade and 869.9 ha to 865.8 ha in Oakland). This information would suggest that the total area of cleared land should increase from 1980 to 1991. However, this is not true. Perhaps the explanation for this is that the forested land was cut and did contribute to cleared land areas but that at the same time, the older cleared land areas were reverting. This hypothesis holds true if one compares the total area of reverted land from the two years. Reverted areas increase dramatically from 7.9 ha in 1980 to 61.9 ha in 1991.

Figure 29 shows the current land use patterns within the Salmon Lake watershed. The shading reflects areas of different land use. It is apparent in this figure that much of the watershed remains forested. Many of the wetland areas are localized along the edge of Salmon Lake, although there are a few small wetlands away from the lake. Cleared and reverted areas vary in size throughout the watershed.

The changes in land use patterns for the years 1980 to 1991 in McGrath Pond's watershed are illustrated in Figure 30. The values are taken from ZIDAS data. The area of forested land is not included in this figure as it made up such a large percentage of the watershed that comparisons among other land uses were not possible. Cleared land and reverted land decreased over the 11 year span whereas wetlands, commercial areas, roads, and residential areas remained unchanged. Through the process of succession, some of the cleared lands became reverted land and areas of reverted land became indistinguishable from forested land.

Figure 31 demonstrates the changes in percentages for various land uses in the towns of Oakland and Belgrade within the McGrath Pond watershed in the year 1991. The percentages were calculated from ZIDAS data. Forested land is not included in this figure. Areas of forested land comprised the

Table 13. Areas in hectares for various land uses within the watersheds of McGrath Pond, Ellis Pond, and Salmon Lake for the years 1980 and 1991 from ZIDAS data.

Land Use	Belgrade 1980	Belgrade 1991	Oakland 1980	Oakland 1991
McGrath Pond				
cleared land	6.2	4.8	91.9	85.0
reverted land	7.1		0.8	10.0
wetlands			15.3	15.3
forest	95.7	104.1	734.2	731.5
commercial			7.0	7.3
roads	3.3	3.3	8.9	8.9
shoreline residential	1.2	1.2	32.4	32.4
non-shoreline residential	1.0	1.0	4.4	4.4
Ellis Pond				
cleared land	86.1	67.3		
reverted land		50.5		1.4
wetlands	10.8	10.8		
forest	574.3	542.9	135.7	134.3
commercial	2.2	1.9		
roads	6.3	6.3	1.3	1.3
shoreline residential	4.9	4.9	12.2	12.2
non-shoreline residential	2.5	2.5	0.6	0.6
Salmon Lake				
cleared land	92.3	72.1	91.8	85.0
reverted land	7.1	50.5	0.8	11.4
wetlands	10.8	10.8	15.3	15.3
forest	670.0	647.0	869.9	865.8
commercial	2.2	2.0	7.0	7.3
roads	9.6	14.9	10.2	10.2
shoreline residential	6.1	6.1	44.6	44.6
non-shoreline residential	3.5	3.5	5.0	5.0

majority of McGrath's watershed for both towns. Cleared land, reverted land, wetlands, commercial land, and residential areas all comprised a higher percentage of the watershed in Oakland than in Belgrade. Roads made up a greater percentage of the McGrath Pond watershed in Belgrade than in Oakland. This may be due to the fact that the boundary between the two towns does not divide the watershed equally. Oakland comprises a larger amount of the McGrath Pond watershed.

Figure 32 shows the land use patterns in the Ellis Pond watershed for the years 1980 and 1991. Forested land, although not shown in this figure, comprised most of the area in the watershed (87.1% of the watershed in 1980 and 84.3% of the watershed in 1991). Cleared land decreased by approximately 1.5% in the years 1980 to 1991. Reverted land increased in area by over 4% for the same years. This data suggests that the forested land that was cut became cleared land and at the same time the land that was formerly cleared began reverting. This explains the fact that while forested land areas did decrease, the cleared land areas did not increase.

Figure 33 illustrates the changes of land use patterns in Oakland and Belgrade within the Ellis Pond

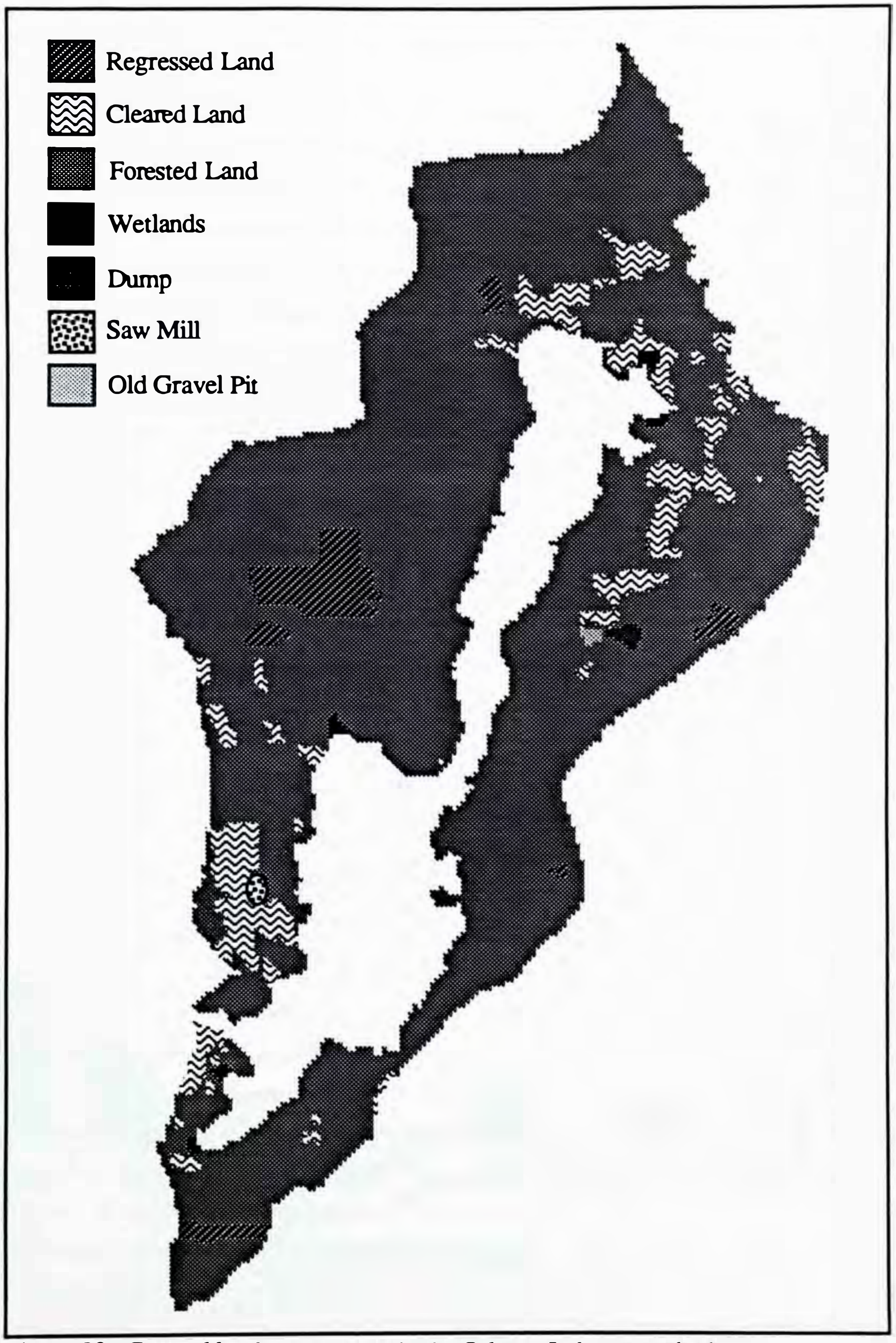


Figure 29. General land use patterns in the Salmon Lake watershed

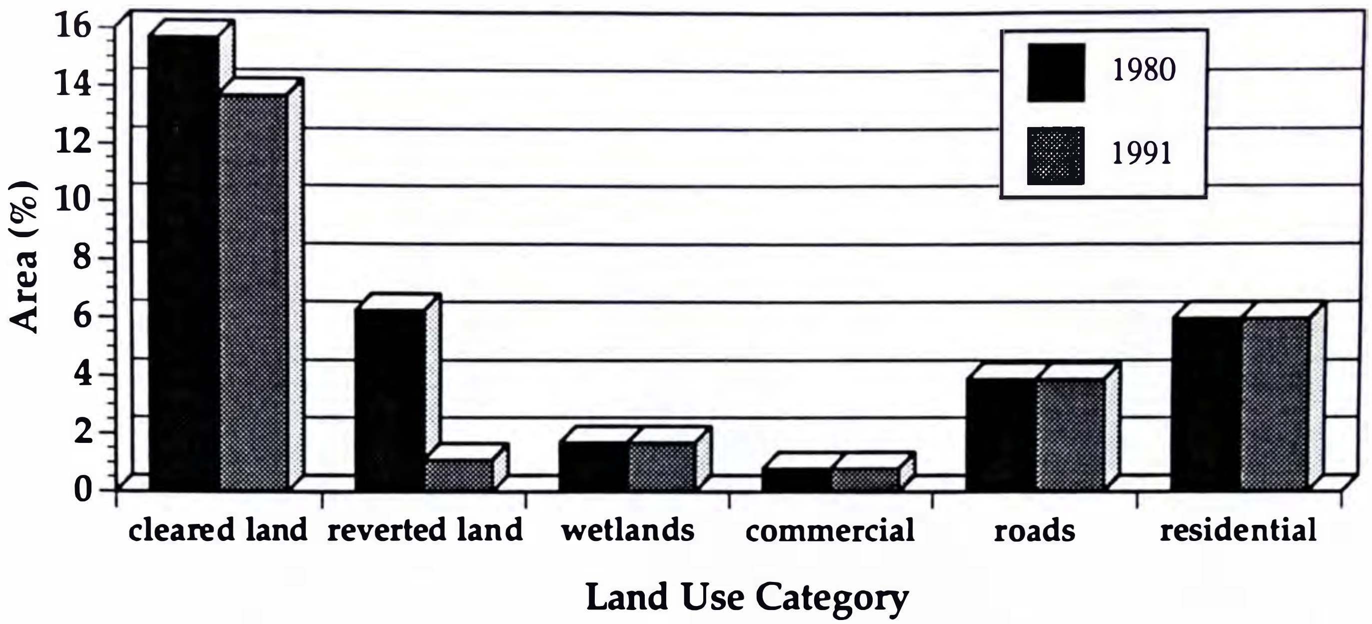


Figure 30. Changes in land use patterns of McGrath Pond's watershed between 1980 and 1991 using ZIDAS data (excluding forests).

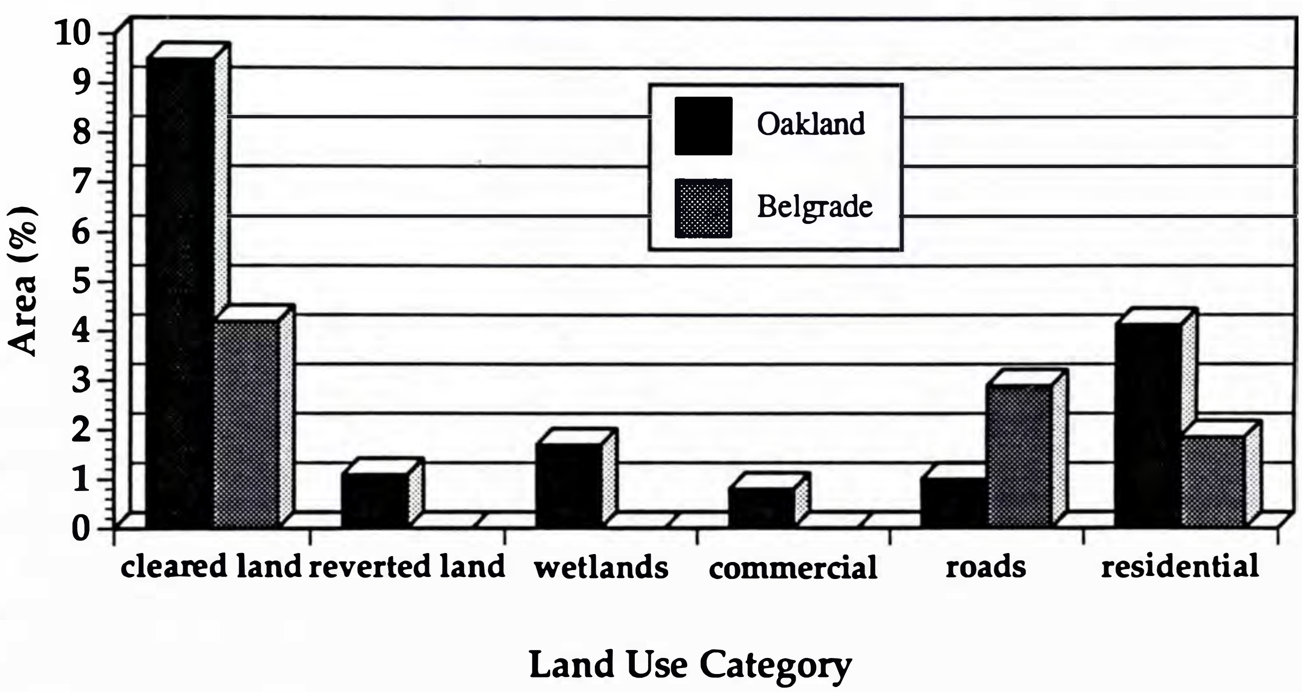


Figure 31. Percentages for various land uses from ZIDAS data for the McGrath Pond subwatersheds in Belgrade and Oakland for 1991 (excluding forests).

watershed for the year 1991. Forested land accounted for the majority of land in the watershed for both years. The area of forested land decreased slightly during the time period of 1980 to 1991. Cleared land areas in Belgrade are a significantly larger percentage of the watershed than cleared areas in Oakland. The same holds true for reverted land, wetlands, and commercial areas. This may be due to the fact that the boundary between the towns of Oakland and Belgrade does not divide the Ellis Pond watershed into two equal halves. Belgrade has a larger area of the Ellis Pond watershed. Residential areas in Oakland made up a dramatically larger percent of Ellis' watershed than those residential areas in Belgrade. This is probably due to the larger average lot size of developed lots in Oakland than in Belgrade.

Figure 34 clearly presents the changes in land use patterns within the entire Salmon Lake watershed over time. Undeveloped lands remained relatively unchanged and those areas that were developed did not alter in size. Wetland areas were not disturbed during this time period. The values of cleared land did show a decrease of 1.5% (10% - 8.5%) over the 11 year span. This may be due to a decrease in the amount of agricultural lands. Forested land (not shown in the figure) was the land use comprising most of the watershed. Forested land accounted for 83% of all land in 1980 and 82% of all land in 1991.

The following sections will discuss the various trends observed over this time period for the individual land uses.

Forestry

Methods

The area of forested land was calculated by using ZIDAS (refer to Analytical Procedures and Findings section: ZIDAS methodology). The measurement of forested land was not done directly; all non-forested areas, including residential areas along the shoreline, in the watershed were digitized and then subtracted from the total area of the watershed. The remaining value was used as the area of the forested land. This value for forested land also included some developed land areas, that is, houses within the forested areas. The issue of timber harvesting was addressed. Inquiries regarding active logging and harvesting practices were directed towards the residents of the area. During the field reconnaissance on 27SEP1993, any areas of active logging or cutting were noted. Logging practices were compared to the regulations outlined in the zoning ordinances of both towns.

Results and Discussion

As can be seen in Table 13, forested land comprised 83% (1540 ha) of the total watershed in 1980 and 82% (1512 ha) of the total watershed in 1991. In 1980, the percentage of forested land in the subdivisions of the total watershed ranged from 82% (734 ha) in the McGrath Pond watershed in Oakland to 90% (136 ha) of the Ellis Pond watershed in the same town. Throughout the time period of 1980-1991, the amount of forested land has not changed dramatically. The difference of the totals of forested land for all of Salmon Lake for the two years only differs by 1% (approximately 19 ha).

According to the Shoreland Zoning Ordinances of the town of Belgrade and Oakland, no harvesting may occur within 75 ft, horizontal distance, from the normal high-water line of the lake, except to remove

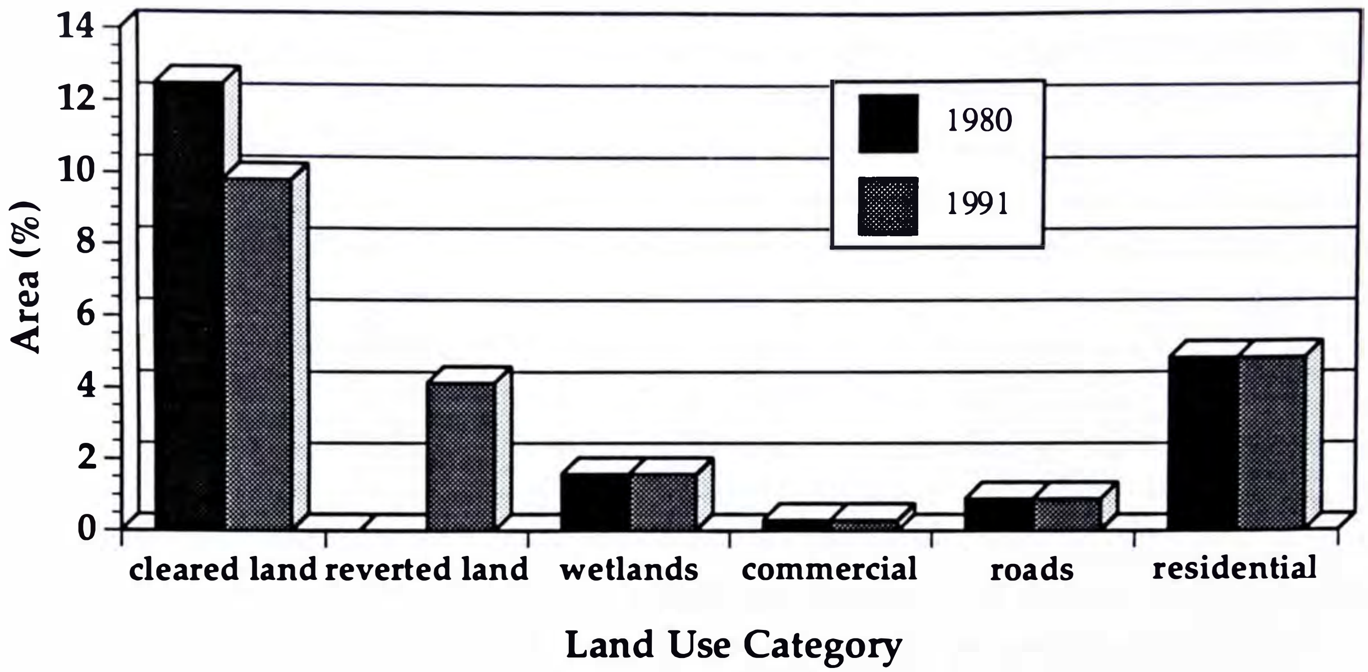


Figure 32. Percentages for various land uses excluding within the Ellis Pond watershed from 1980 and 1991 ZIDAS data (excluding forests).

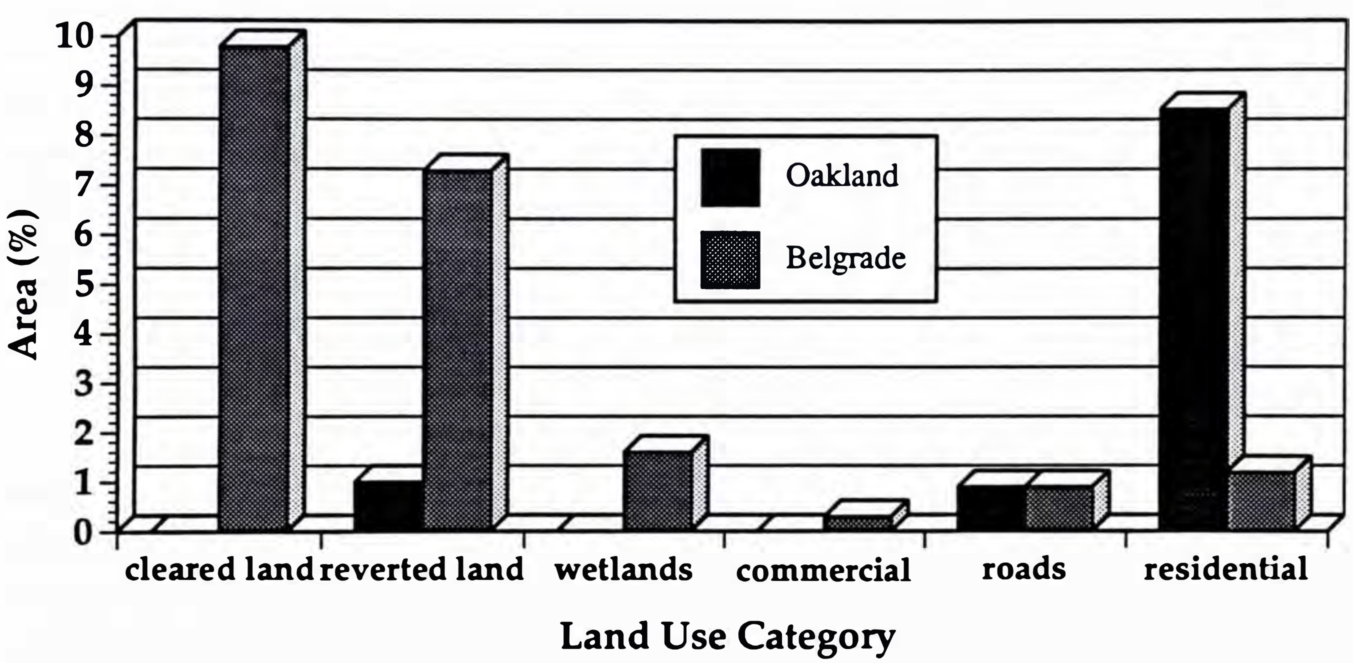


Figure 33. Percentages for various land uses from ZIDAS data for the Ellis Pond subwatersheds in Belgrade and Oakland for 1991 (excluding forests).

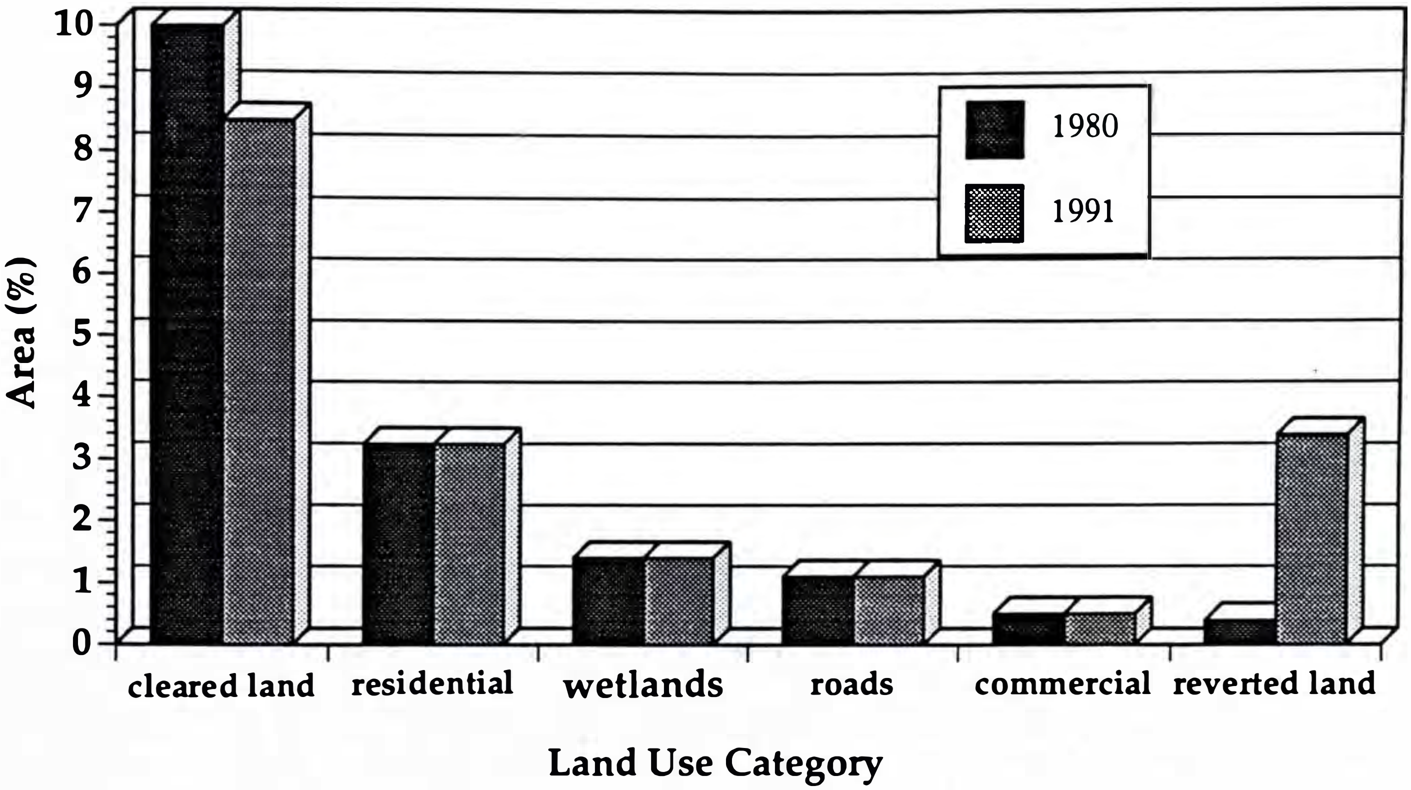


Figure 34. Changes in land use patterns in the Salmon Lake watershed between 1980 and 1991 using ZIDAS data (excluding forests).

safety hazards. If the harvesting area is within 100 ft, horizontal distance, from the normal high-water line of the lake, no clear cutting is permitted. Within 100 ft, harvested areas must maintain a well-distributed stand of trees and other vegetation, including existing ground cover. Clear-cutting is allowed above the 100 ft, distance from the water body, but these clear-cut areas may not exceed 10,000 ft^2 and those areas that are greater than 5,000 ft^2 must be separated by an uncut area of at least 100 ft in width. These uncut areas must also be included in the calculation of the clear-cut area. Slash (debris from timber harvesting) must be removed from the area if it is within 50 ft, horizontal distance, of the normal high-water line of a body of water.

During the field reconnaissance, active or recent logging operations were observed in several areas. The main areas of harvesting were near the camp roads MP1 and T8b. Figure 35 shows the areas of active or recent logging. Extensive logging, but not clear-cutting, was observed on MP1. This area is in close proximity to Cold Brook. It appeared as though the area was being cleared for development; in several sections, new roads seemed to be under construction. The area where the cutting was happening appeared to be set back far enough for town zoning regulations. However, this area near Cold Brook did appear to have some problems with slash (debris from timber harvesting such as sticks, sawdust, and small log sections) as the culvert that runs under McGrath Pond Road had a chicken wire screen around it to prevent the movement of slash into Cold Brook. This screen appeared to catch large amounts of debris as it was clogged during the storm of 27SEP1993. The area should be inspected more thoroughly so that a full

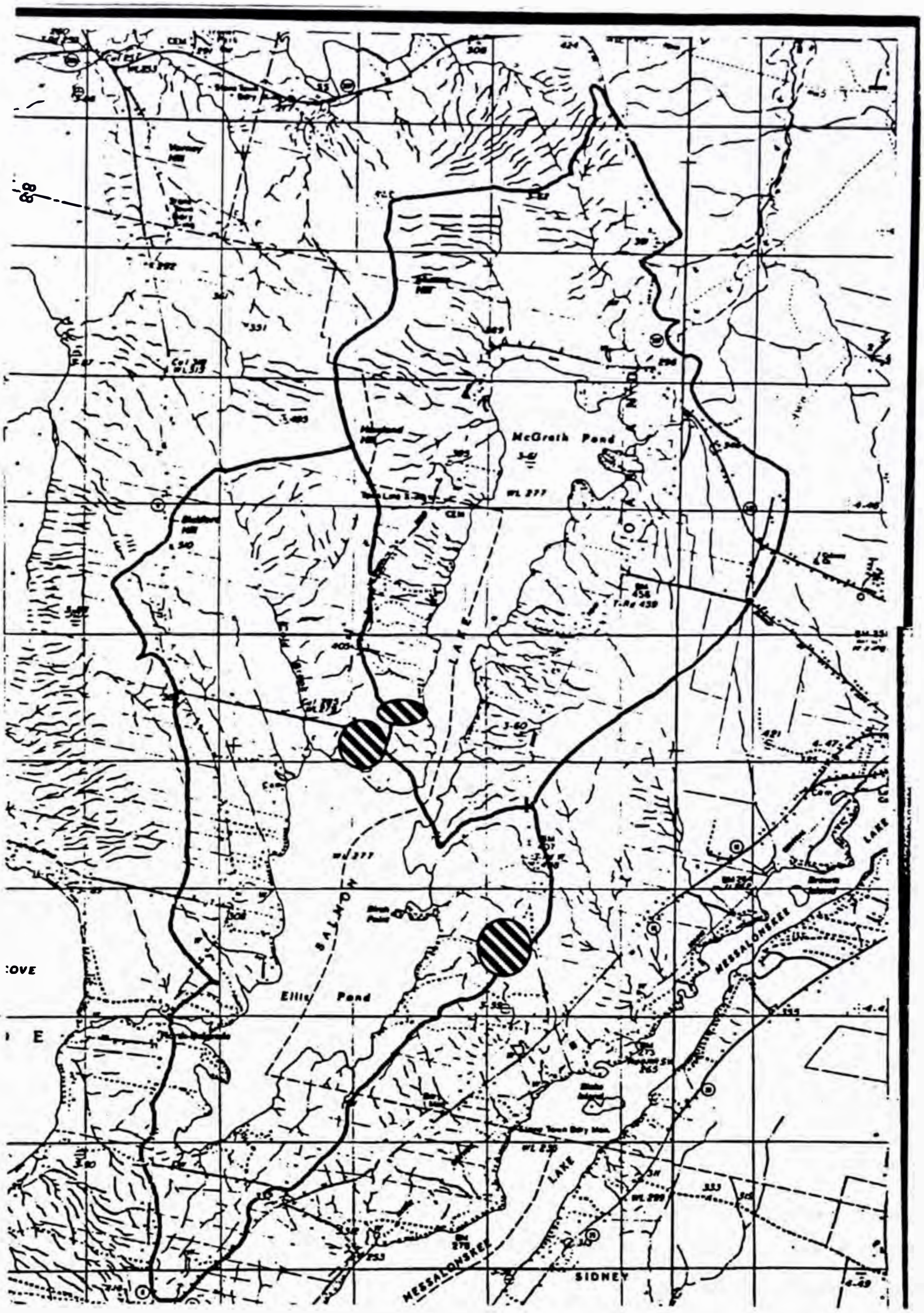


Figure 35. Areas of active logging within the Salmon Lake watershed.

evaluation can be done. Small tributaries in the area and run-off from the surfaces of the cut areas should be addressed. It was difficult to inspect the other area of harvesting because the field reconnaissance was conducted during operation hours. Residents of the area mentioned that an area on the eastern side of Ellis Pond on the point of land north of Birch Point had been clear-cut approximately six years ago. Neither the field reconnaissance, the recent aerial photos taken by the class, nor the aerial photos from 1980 and 1991 could verify this information.

Cleared Land

Methods

Cleared land areas were divided into two categories: recently cleared land and reverted land, with the distinction between the two being that reverted land has growth occurring on it again (e.g., an abandoned field in which trees and shrubs have begun to grow under the normal course of succession) and cleared land remains barren of trees (e.g., crop or pasture land that is plowed or mowed). Using aerial photos from 1980 and 1991, the cleared land areas were digitized using ZIDAS equipment. The location and area of cleared land was compared to the regulations of the clearing of vegetation for development as found in the zoning ordinances for the towns of Oakland and Belgrade. The ordinances were also referred to regarding agricultural practices. The Soil Conservation Service of Augusta was contacted to discuss any interaction they might have with farmers in the Salmon Lake watershed. The Salmon Lake Association mentioned three potential active farming areas they knew about at their November meeting.

Results and Discussion

Cleared land areas found in the McGrath Pond watershed decreased during the years 1980 to 1991 (Figure 30). Areas of cleared land also decreased in the Ellis Pond watershed for the same years (Figure 32). When cleared land areas are compared for all of Salmon Lake, the same trend is apparent. According to the ZIDAS data, the amount of cleared land in the watershed of Salmon Lake decreased from 10% to 9% of the total area during this time. Although the areas of cleared land decreased over the 11-year span, the decrease was not dramatic. If total areas of cleared land are compared, more cleared land was found in Oakland than in Belgrade. This is shown in Table 13.

Cleared land practices in many of the areas seem to follow the zoning ordinances set forth by the towns of Belgrade and Oakland. The zoning ordinances of both towns require a buffer strip to be present between the homesteads and the shore. Occasionally there are localized areas by the shoreline in which there are many houses clustered together and these often do not have buffer strips. These campsites with large numbers of small houses are frequently grandfathered in and therefore are not forced to follow the zoning ordinances. The zoning ordinances in both towns also require that no area greater than 25% of the lot area, or 10,000 ft^2, whichever is greater, including land that was previously developed, be cleared for development. Most of the cleared areas fit within this limit and the few exceptions may be grandfathered in because they were cleared before the ordinance was effective (Belgrade 1991 and Oakland 1991).

The visual surveys conducted on the watershed revealed no obvious agricultural areas still in use. The Soil Conservation Service of Augusta has no interactions with farmers in the Salmon Lake watershed. Nevertheless, they knew of the same farming activities as Lake Association members (Mitch Michaud pers. comm.).

The first farm is that of Bickford's on Route 8. It used to be a dairy farm but now appears to be land with crops with perhaps a few cows. A study in 1984 concluded one of three problem tributaries drained this dairy farm (Nichols et al. 1984). These tributaries had elevated instream total phosphorus values. The Salmon Lake Association mentioned concerns about a holding pond on this property. The Maine DEP worked with Bickford's in the 1980's to install manure containment pits. The pond was constructed at this time to hold run-off (MDEP 1980). Bickford used to spread paper sludge on the land, but has since stopped because of public concern (Salmon Lake Association pers. comm.). Leighton Farms is a new horse barn used for boarding and as a show facility. It has no visible manure storage facility and is thought to have a number of horses in its large barn. The Zimber property on Town Farm Road has hay harvested on its land.

The towns of Oakland and Belgrade have the same policies regarding agricultural activities. Manure spreading should be done according to the Maine Guidelines for Manure and Sludge Disposal on Land (University of Maine Soil and Water Conservation Commission 1972). Manure is not to be stored or stockpiled within 100 ft of a pond or water body.

Agricultural activities that till more than 40,000 ft^2 of soil, and the spreading, dispersal, or storage of manure within the shoreland zone require a plan to be filed with the Planning Board of the town. No tilling or grazing is allowed within 100 ft of a great pond, 75 ft of other water bodies, or 25 ft of streams and wetlands (Belgrade 1991).

Areas of reverted land were relatively small and did not make up a significant percentage of the watershed of Salmon Lake in the year 1980 or 1991. As is shown in Figure 34, reverted land did comprise a larger percentage of the Salmon Lake watershed in 1991 than in 1980. This is due mainly to an increase in reverted land areas within the Ellis Pond watershed (see Figure 32). Table 13 shows that in 1991, 50.5 ha (7%) of the watershed of Ellis in the town of Belgrade was reverted land. This value is by far the largest percentage of reverted land in the Salmon watershed. Perhaps this large area of reverted land is due to the fact that a large farm that is now closed used to operate in this section of the watershed. Over time, the agricultural fields began to support shrubs and trees due to the process of succession.

Reverted land areas are protected from development in the zoning ordinances of the towns of Belgrade and Oakland. The provision that has been mentioned in the discussion of cleared land above, states that no area more than 25% of the lot size or 10,000 ft^2, whichever is larger, may be cleared. It is difficult to make conclusions, based on the ZIDAS data, as to whether the ordinance is being adhered to or not. More areas of reverted land are apparent in the 1991 aerial photos, so perhaps the land is not being developed and through succession, the forested land will return (Belgrade 1991 and Oakland 1991).

Wetlands

Methods

The area of the wetlands within the watershed of Salmon Lake was calculated by using ZIDAS. In addition to the ZIDAS data, a field reconnaissance was also performed on 27SEP1993. A visual survey was conducted of the wetland areas that border the lake and characteristics such as macrophyte types and development in the area were noted.

Results and Discussion

In the years 1980 and 1991, 1% (approximately 15 ha) of the watersheds of McGrath and Ellis Ponds were wetland areas (Figures 30 and 32). Likewise, the percentage of wetlands within the Salmon Lake watershed remained unchanged. This value does not change because wetland and watershed areas were obtained from the topographical map and the orthophotoquad, respectively. Wetlands and the watershed area were measured this way because digitizing the aerial photos was not precise enough for this study. The water levels at the time of the photos might have been high and this would influence the apparent surface area of the lake.

A visual survey of wetland areas was conducted by car and boat during the field reconnaissance on the date of 27SEP1993. Typical macrophyte growth was observed in the shoreline wetlands. The non-shoreline wetlands were not found so no descriptive data is available. In the shoreline wetlands, emergent vegetation such as pickerelweed, cattail, floating brown leaf, and yellow and white pond lilies were found in the wetland areas around Cold Brook and the smaller tributaries. Buttonbush and other small shrubs were common along the shore of Cold Brook. Development near the wetlands did not seem to infringe upon them.

According to the zoning ordinances of Oakland and Belgrade, development is prohibited on and in close proximity to wetlands. Areas within 250 ft of a freshwater wetland and wetlands associated with great pond or streams are protected by this provision as they are considered a "significant wildlife habitat". No development in either McGrath or Ellis Ponds appears to violate this ordinance (Belgrade 1991, Oakland 1991).

Residential Areas

Methods

The number of homes were counted in two ways. One way was using parcel and tax maps of the towns of Oakland and Belgrade. Also, surveys by car and boat were conducted to count the number of homes and any new homes that have been constructed since the 1975 aerial photos that created the most recent orthophotoquads. These new residences were added to the number of existing homes on the base map and a total count was reached.

ZIDAS digitizing equipment and a 1991 aerial map were used to calculate the length of shoreline occupied by developed lots. ZIDAS was also used to calculate the average lot size of shoreline lots in Oakland and Belgrade. The zoning ordinances of the towns of Oakland and Belgrade of 1991 were referred to for information regarding restrictions and guidelines set for the residents living around Salmon Lake.

Results and Discussion

Counting developed lots with the parcel maps sometimes resulted in higher values than did counting structures by road and boat. Every lot that is developed was counted with the parcel maps, including things other than homes like garages and sheds. The road and boat surveyors only counted homes and came up with smaller numbers. The instance where the visual survey resulted in higher values than the road survey can be explained. More than one home can be constructed on a single lot, according to the Belgrade and Oakland Town Offices (Ginny Joseph and Ellen Bacon pers. comm.). The visual surveyors were counting existing homes even if they were on one lot and came up with higher numbers of developed lots than the parcel maps read. The visual survey results were added to the base map numbers and these numbers are used in calculations of footage and percentage of residential land developed.

Table 14 shows data indicating McGrath having more residences on the Oakland side and Ellis Pond having more residences on the Belgrade side. The totals of McGrath and Ellis are similar in magnitude and both have more shoreline residences than non-shoreline.

Table 14. Number of residences determined by use of the Rome quadrangle of the culture and drainage mylar (USGS 1982) and visual surveys in the Salmon Lake Watershed.

	Belgrade	Oakland	Total
		McGrath	
Non-shoreline	13	83	96
Shoreline	24	116	140
		Ellis	
Non-shoreline	97	34	131
Shoreline	165	28	193

Table 15 shows the data obtained from the ZIDAS digitizing of the parcel maps of Salmon Lake. McGrath Pond is developed about 30% on the Oakland side, but only about 4% on the Belgrade side. This seemingly great difference is explained by the way the town line divides McGrath Pond. Belgrade only contains about 25% of the shoreline. The percentages of the shoreline developed show Ellis Pond is about 18% developed in both Oakland and Belgrade. Combining both ponds and towns, Salmon Lake's shoreline is about 70% developed. This leaves 30% of the shoreline of land for further development, or wetlands and other undevelopable land. Most of the acreage developed on the shoreline is in Oakland on McGrath Pond and in Belgrade on Ellis Pond. The average lot size of developed

Table 15. Length and percentage of shoreline developed on Salmon Lake determined using ZIDAS data and parcel maps, and shoreline development determined from visual survey residences data times the weighted average shoreline lot size of Salmon Lake from ZIDAS data.

	McGrath		Ellis	
	Oakland	Belgrade	Oakland	Belgrade
Developed shoreline (ft)	17,330	2,362	10,340	10,330
Salmon Lake shoreline (%)	30.3	4.1	18.1	18.1
Shoreline development (ha)	80.6	12.6	33.0	94.2

waterfront lots was 1.34 hectares (ha) in Oakland and 0.52 ha in Belgrade. This difference can be explained perhaps because Oakland was developed after Belgrade and the more recent developments have larger lot sizes. The weighted average of the area of Salmon Lake's developed waterfront lots using the visual survey number of residences data is 0.87 ha. The results of ZIDAS digitizing showed McGrath Pond's watershed average non-shoreland lot size of 5.45 ha, Ellis Pond's of 3.15 ha, and Salmon Lake's weighted average of non-shoreline lots using the visual survey number of residences data as 4.12 ha.

The goals of the zoning ordinances of Oakland and Belgrade of 1991 are to assure critical areas are protected from degradation. These areas include wetlands, flood plains, unique natural areas, areas with steep slopes, wildlife habitats and fisheries. The areas are classified into five general categories: Resource Protection, Limited Residential, Limited Commercial, General Development and Resource or Stream Protection District. Most of the ordinances of both towns overlap to assure the same results. Some important policies are described below.

Minimum lot standards are set. In Oakland, for instance, 40,000 ft^2 is the minimum lot area for a residential dwelling unit (Oakland 1991). The minimum shore frontage of a residential per dwelling unit is 200 ft. The amount of development on individual lots is monitored. In Oakland, cluster housing is only permitted if the applicant can convince the planning board the proposed construction will result in four things: 1) Preservation of the open space within the shoreland zone; 2) Continuation of the pattern of development in accord with the natural features of the land; 3) Efficiency of clustering rather than building one residential structure, and 4) Reduction of the amount of impermeable surface on the land.

Set-back limits are established to discourage development too close to critical areas. Setback refers to the nearest horizontal distance form the normal high-water line to the nearest part of a structure, road, parking space, or the regulated object or area (Belgrade 1991 and Oakland 1991). In both towns the Stream Protection District is protected from residential development (Belgrade 1991 and Oakland 1991). This district includes all land areas within 75 ft of the normal high-water line of a stream, exclusive of those areas within 250 ft of the normal high-water line of a great pond or river (Resource Protection

District), or within 250 ft of the upland edge of a freshwater wetland. In Oakland one or two family residences can be constructed in this district provided that a variance from the setback requirement is obtained from the Board of Appeals. Multi-residential units are prohibited. Belgrade prohibits all residential development in this area.

The Resource Protection District is the area in which development would adversely affect water quality, productive habitat, biological ecosystems, or scenic and natural values (Belgrade 1991 and Oakland 1991). These are areas within 250 ft of the upland edge of freshwater wetlands and wetlands associated with great ponds and rivers. A great pond is any inland body of water which in a natural state has a surface area of more than 10 acres, and any inland body of water artificially formed or increased which has a surface area of more than 30 acres. Wetlands associated with great ponds and rivers are those that are contiguous with or adjacent and connected by surface water to the great pond or river. Also included are wetlands which are separated from the great pond or river by a berm, causeway, or similar feature less than 100 ft in width, and which have a surface elevation at or below the normal high water line of the great pond or river. Also included in the Resource Protection District are flood plains along rivers and flood plains along artificially formed great ponds, and areas of two or more contiguous acres with sustained slopes of 20% or greater. No residential development in either town is allowed in this district.

Oakland discourages extensive non-shoreline development in the rural areas by granting no more than three building permits for new housing units for each of their subdivisions yearly (Oakland 1991). They also strive to protect the small town character and preserve view corridors and unique parcels of land. Oakland's Zoning Ordinance calls for the conservation of the ecological integrity and diversity of unique natural areas. Belgrade has areas designated by the federal, state, or municipal governments as natural areas of significance that are protected (Belgrade 1991). It also regulates the development of the town by requiring permits for construction of any type in all zones. These ordinances contain policies affecting existing structures and their repair, maintenance, relocation, and construction.

Commercial Camps

There are three commercial camps on Salmon Lake: Camp Kennebec, Camp Modin, and Camp Tracey. It is in the camps' best interests to help sustain lake water quality. A decrease in Salmon Lake water quality, will detrimentally affect camp enrollments (Carol Montgomery pers. comm.). The camps are sincerely concerned in maintaining high water quality standards (Phil Cromwall pers. comm.). We feel that the camps should play a significant role in ensuring the sustainability of McGrath and Ellis Ponds' water quality.

Methods

Field reconnaissance and personal conversations were used to gather information on the three camps. Some written and video material were obtained from Camp Kennebec and Camp Modin (Carol Montgomery pers. comm.). The information on Camp Modin and Kennebec was prepared solely from personal conversations with Carol Montgomery (Camp Kennebec Director) and Joel Lavenson (owner of Camp Kennebec and Camp Modin). Information regarding Camp Tracey was obtained from personal conversations with Phil Cromwall (Camp Tracey Director).

Results and Discussion

Camp Kennebec

Camp Kennebec is situated on the lower, eastern portion of Ellis Pond. It is primarily a five day, overnight camp and is open approximately three months. The maximum number of people at the camp at any given time is 250. There are 30-35 buildings and most have plumbing. The camp extracts their water from the lake and then treats it with chlorine, which no longer meets Maine health codes (Carol Montgomery pers.comm.). In the near future, the camp will be forced to drill wells for their water usage.

Their septic system is composed of a tank and a filter system with baffles. It is located 500 ft from shore and is pumped out twice a year. All waste water enters their septic system; the camp does not emit gray (wash water) into the lake.

There are seven playing fields located in the camp: one soccer field, two baseball fields, three tennis courts (clay), and a basketball court. The camp is comfortably spaced on the shore of Ellis Pond. There is an extensive waterfront with little or no buffer zone, which may allow introduction of nutrients into the lake.

Camp Kennebec appears to sincerely care about the lake and the camp's impacts. An area of concern is the extensive waterfront. There are many buildings that are close or on the shoreline. The grade of the land is also extremely steep, which may encourage surface run-off. Because there is no extensive buffer zone (area of trees, shrubs, and other vegetation), any erosion or run-off may enter directly into the lake. Another potential problem is the playing fields. The fields are encompassed within large, open areas. There are no physical barriers to impede run-off from this land.

Camp Modin

Camp Modin is located on the southeast side of Ellis Pond. The camp is a day camp with no overnight residents. It sustains anywhere from 45 to 125 people during the summer. The camp has 26 buildings. There are five clay tennis courts, a soccer field, and a baseball field in close proximity to the shoreline. The camp also contains two other baseball fields, a volleyball court, another soccer field, and a lacrosse field.

The septic system is three years old. Because of the stricter zoning laws in place when it was constructed, the tank and leach field is located 1000 ft away from the shore. The septic system is composed of a tank and filter system with baffles. The tank is pumped out twice a year, which should alleviate any contamination that would result from an overfilled and unmanaged tank.

Camp Modin also faces similar problems to Camp Kennebec with concern to developed areas near the shore. Areas close to the shoreline are highly developed with little or no buffer zones. Two clay tennis courts are within eight meters of the lake shore (Figure 36). The tennis courts also slope down towards

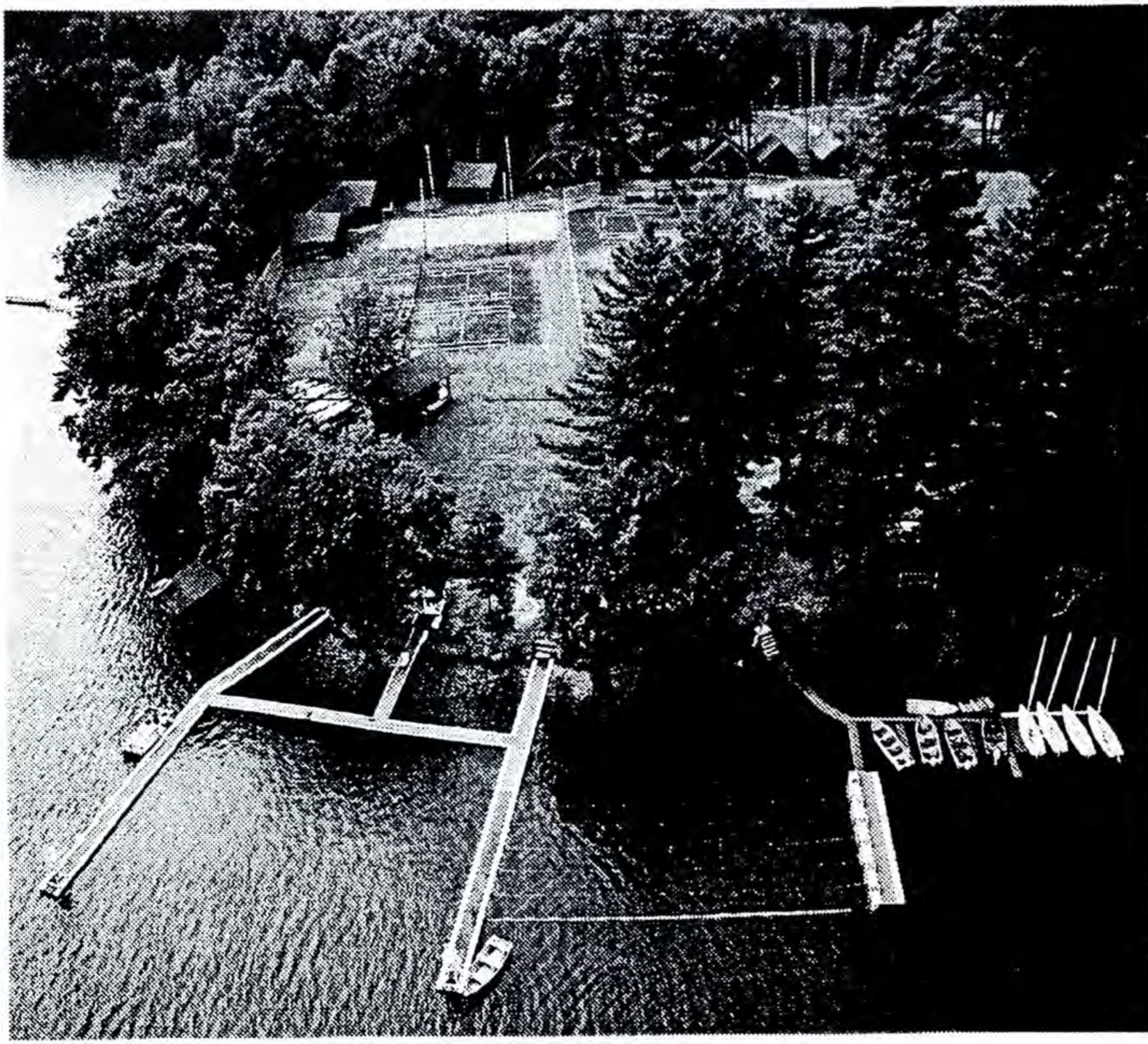


Figure 36. Aerial view of camp Modin. Notice the proximity of the clay tennis courts to the lake and the lack of an extensive buffer zone.

the lake. Again, there is nothing to stop the clay particles from eroding into the lake. Lawns, fields, and tennis courts are not natural environments. These types of human induced environments in close proximity to shorelines may be sources of nutrient loading to Salmon Lake.

Camp Tracy

Camp Tracy is operated by the Y.M.C.A of Waterville, ME. The camp is located on west side of McGrath Pond. The season starts in the last week in June and ends in the last week in August. The camp is a day camp that holds 90-140 people during the season. The camp has a total of 67 acres of which little is developed; two fields and buildings occupy approximately three acres of cleared land (Phil Cromwall pers. comm.). Camp Tracy's shoreline is one-half of a mile long of which 500 ft is devoted to a beach.

The septic system was built in the early 1970's and handles eight toilets and one urinal. This is the only plumbing within the camp. The septic system is approximately 1000 ft from the shoreline and is designed to handle a capacity of 350 people. Neither Phil Cromwall (current camp director) or George Keller (former camp director) remember pumping the septic tank out since it was built.

Camp Tracy had erosion problems along some of the hiking trails near the lake shore. These areas have been closed down and attempts are being made to ratify the problem. Camp Tracy appears to be amply equipped for the small population of people during the summer. We believe that Camp Tracy does not pose a significant threat to the water quality of Salmon Lake, however the septic tank has the potential of creating a problem if it has not pumped out since it was put installed (refer to Septic systems in the Background section).

Residential Subsurface Waste Disposal Systems

Methods

The study of subsurface waste water disposal systems in the Salmon Lake watershed began with a visual field reconnaissance. During September and early October, visual surveys of the waste disposal systems in Oakland and Belgrade were conducted. The size of the buffer zones between the shoreline and residences and location of existing leach fields were observed. In some areas that were heavily settled there were apparently new leach fields that may have been servicing clusters of homes. There are also three commercial summer camps located in the Salmon Lake watershed as mentioned previously.

After the initial reconnaissance was completed on 13SEP1993, a second survey was done on 25OCT1993. The ground truthing surveys used to count the number of residences in the watershed also estimated the number of structures with subsurface waste water disposal systems, by assuming that each home possessed a waste water treatment system. Tax maps, updated in April 1993, for the towns of Oakland and Belgrade were obtained from the respective town offices, and the land parcels that are currently developed were plotted. These maps included the lot size and lot number. In order to accurately map the number of structures in the watershed, indices provided by the Assessors Office in Oakland were used. Alphabetical and map-lot number indexes from which the owner's name and information about the condition of the lot (vacant or developed) were utilized to plot the developed parcels onto the tax maps. Ginny Joseph, in the Assessors Office was helpful in accessing the proper information.

The Plumbing Inspector and Code Enforcement Officer, Paul Lussier and his secretary, Michelle Jandro provided information and insights into the waste water disposal conditions in the town of Oakland. The Oakland town office was able to supply plumbing permit stubs that indicated the number of subsurface waste water disposal systems (holding tanks, or septic systems) issued in the past 10 years. Bob Martin, the part-time Plumbing Inspector for Oakland and full-time inspector for Belgrade, was able to provide similar information for Belgrade from 1989-1993. These data were plotted on the tax maps to give a representation of the distribution of the old and new subsurface waste water disposal systems.

The rules and regulations that determine the design, siting, construction, and inspection of subsurface waste water disposal systems were created by the Maine Department of Human Services-Division of Health Engineering, to ensure the "health, safety and welfare of the citizens of Maine" (MDHS 1980). The state determines a set of minimum regulations that must be observed by home owners. These State mandates are enforced, but they are not meant to be the only code restrictions. Shoreland Zoning Ordinances for individual towns should be passed to complement the state regulations. Belgrade and Oakland both passed Shoreland Zoning Ordinances in November 1991, with amendments added in 1992 and 1993 (Oakland, Town of 1991 and Belgrade, Town of 1991). Currently in Oakland and Belgrade, all state regulations must be followed as well as the following rules: subsurface waste water disposal systems must be at least 100 ft from the high water line and at least 75 ft from streams. If the residences are closer to the shore than is acceptable (grandfathered), the waste can be pumped away from the shoreline into a septic leach field at a higher elevation. However, grandfathered systems are not required to meet current regulations, therefore, some of the shoreline homes do not meet the current standards set by the town and state ordinances.

Results and Discussion

There are three types of waste water disposal systems: pit privies, holding tanks, and septic systems. According to the 1980 Maine census data, approximately half the homes in Maine use septic systems for their waste water disposal (MDEP and MSPO 1990). Although this form of waste treatment is the most popular, properly maintained holding tanks are the ideal form of waste disposal for shoreline areas. They are water tight receptacles that have no impact on the environment if they are pumped out regularly (Paul Lussier pers. comm.). Since the majority of the shoreline residences are only seasonal homes, the pumping costs and maintenance costs of holding tanks would be reasonable. In the Salmon Lake watershed the majority of the subsurface waste water disposal systems are septic systems with treatment tanks and leach fields. The data gathered from the Belgrade Town Office from 1989 to 1993 plumbing permits, revealed only three holding tanks, and one pit privy (Bob Martin pers.comm.). There probably are more holding tanks in the watershed than the number that is represented in this data, since they were only available from Belgrade and not Oakland. Also, after speaking with a seasonal home owner, it seems that holding tanks are popular with the seasonal shoreline residents that spend the summers on the lake shore. This may be because seasonal homes tend to be closer to the shoreline than year long homes, and seasonal usage does not require excessive pumping. Therefore, it is very likely that the data on types of sewage treatment systems is incomplete. In order to obtain a more accurate information about the types of treatment systems, oral surveys could be conducted with the help of the homeowners in the watershed of the Lake Association.

The shoreland lot size in Oakland and Belgrade is highly variable. On the east side of Ellis Pond the lots are large and generally undeveloped. The thickly settled areas consist of small compact lots with clustered buildings. In shoreline areas where the lots are highly developed, septic systems and community leach fields seem to be the prevalent manner of waste disposal. For example, the residences on Birch Point on the shore of Ellis Pond have a community leach field (Paul Lussier pers. comm.). It provides waste water treatment for all the structures on the point referred to as the Wheeler Camp development. The leach field is located uphill from the structures and the pond, and is in compliance with the state of Maine's waste water disposal rules (MDHS 1980).

In order to determine the number of waste water treatment facilities in the watershed, the total number of developed lots and the current number of residences in the watershed were counted. These numbers were calculated from parcel maps obtained from the Belgrade and Oakland town offices, and from visual surveys conducted by car and by boat (refer to Land Use section: Shoreline Residential Areas, Table 14). It was assumed that each residence counted in the ground truthing surveys has one of three common types of waste water disposal systems: holding tanks, septic systems or pit privies. Paul Lussier, Oakland Plumbing Inspector and Code Enforcement Officer considers all septic systems put in after 1974 to be "new" systems. These "new" systems are in accordance with current Maine State regulations and town shoreland zoning restrictions.

The next step was to determine from waste water disposal system permits the number of new systems in the watershed. In Belgrade, plumbing permits were only available from 1989 to 1993. The number of new systems put in during this five year time span was only 30. Therefore, the total percentage of new systems added in that time within the watershed limits of Belgrade is 15%. That leaves 85% as old systems. The number of "new systems" is very small considering that there are 199 residences in watershed within the town limits of Belgrade. This may be because some of the newer systems are servicing more than one home, and also the data on new systems only went back to 1989 in Belgrade's plumbing records, not 1974. Oakland was able to access plumbing permits from 1983-1993. During the past decade, 85 systems have been put in, out of the total number of homes in Oakland's drainage area (261 residences). This equals 33% of all subsurface wastewater disposal systems. This data again leads us to assume that many of the systems in the watershed may be outdated (67%), however, it is important to remember that the data was only available from 1983, while systems as far back as 1974 are considered "new" (Figure 37 and Figure 38).

Paul Lussier feels that the shoreline owners in the Salmon Lake watershed have acceptable waste water disposal systems. He believes that the areas that need to be regulated further are the non-shoreline residences and commercial industries. There are no regulations past 250 ft from the high-water line on

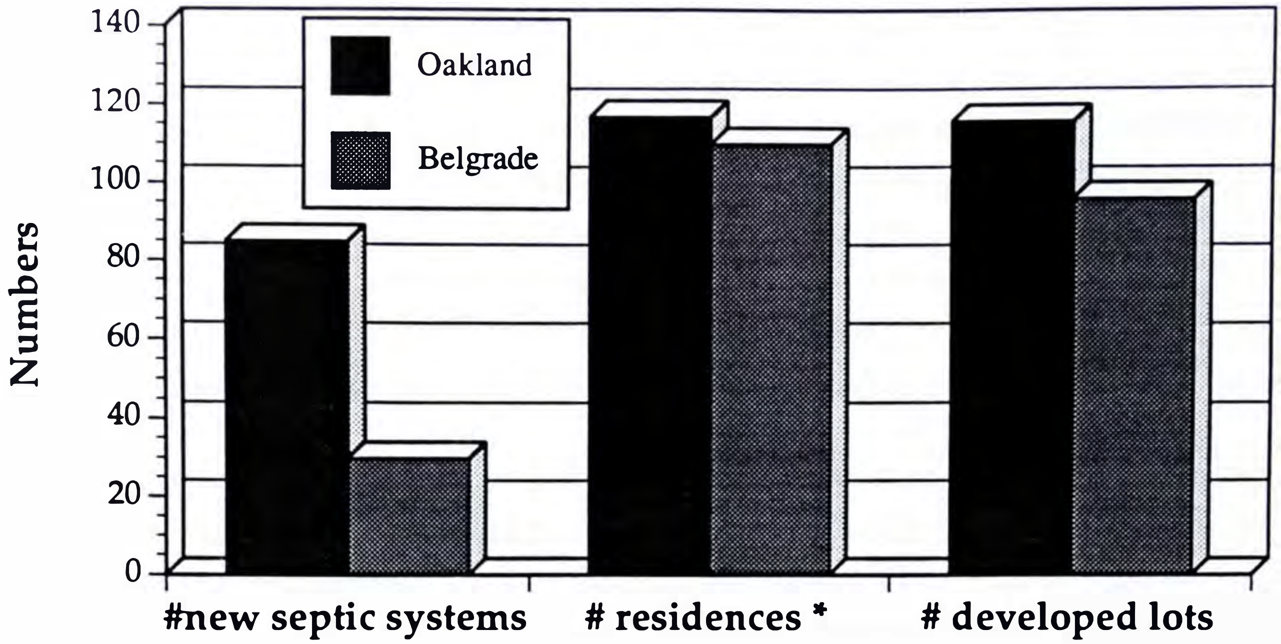


Figure 37. The number of new septic systems compared to number of shoreline residences and the number of developed lots for Oakland and Belgrade shorelines. *It is possible that more than one home exists on one lot.

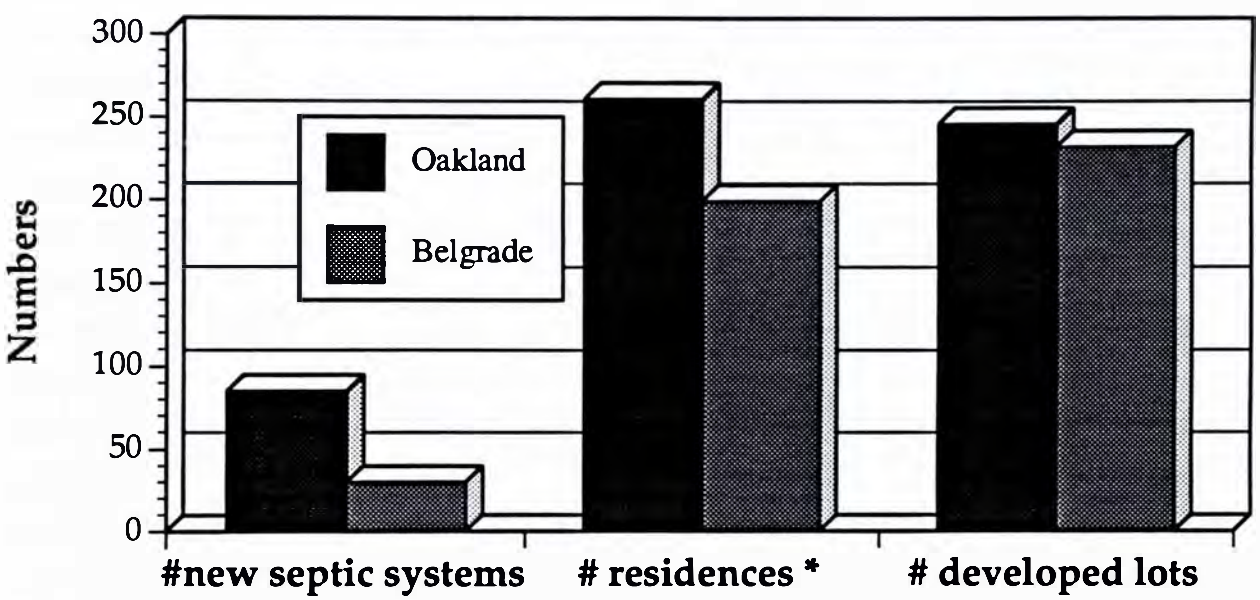


Figure 38. The number of new septic systems compared to the number of residences and the number of developed lots in the Salmon Lake watershed. *It is possible that more than one home exists on one lot.

the shore, and although these areas do not have a high visual impact on the shoreline, they have a large impact on water quality. He would like to see the towns come together, and create shoreline and non-shoreline regulations that both town populations will pass and will enforce. Future development will be positively affected by the cooperation of the towns in the watershed.

Roads

Methods

A comprehensive field survey was conducted on the camp and paved roads contained in the McGrath and Ellis Pond watersheds to evaluate their possible impact on the water quality of Salmon Lake. The survey was conducted by teams on three separate dates: 4OCT1993, 18OCT1993, and 25OCT1993. The camp and paved roads were evaluated by segmenting each road and documenting the characteristics of each segment. Segment length was recorded on foot or by car odometer, and the width of the road was recorded with a metric tape measure. The only exception was the Taylor Woods Road, which was measured on foot and by a 100 m tape measure to be used as the "scale road" for ZIDAS.

The camp road survey was conducted using the "Camp Road Evaluation Form" obtained from the MDEP, enacted and designed by the Kennebec County Soil and Water Conservation District. The form itself was divided into seven sections: surface, ditches, culverts, diversions for water, road total, road segment, and access. The values of each section were weighted by potential phosphorus loading impact.

The road surface index was representative of the overall quality of the road's surface. Criteria used to calculate this index include the quality of the road's crown, surface constituents, edge, base, usage, and an assessment of the overall road surface condition by the evaluator. The quality of the road's surface is an important criterion because of its potential as a nutrient vector into the lake. The most important aspect of the road surface assessment is the crown. Though it is the least costly and time consuming to maintain, it is often the most neglected (Pam Partridge pers. comm.). A properly maintained crown should drain the run-off water as quickly as possible into the ditches, minimizing run-off contact with the road surface. Good crowning decreases the amount of erosion of the road and potential silt loading of the run-off water. The ideal surface should have a crown from which its apex slopes 1/2 in for every foot of width. It should also be hard without dust or berms, and have a base consisting of gravel (KCSWCD 1993). Proper surface constituents and edges allow for drainage of the road with minimal erosion and sedimentation as well. "Usage" reflects seasonal or year-round use by including a measure of "wear and tear" caused by car travel in the index. Finally the general quality of the road's surface was graded by its evaluator.

The ditches index was an evaluation of the condition of the road's ditches. The considerations used to evaluate the ditches were the number present and/or needed, depth, width, whether vegetation lined the ditch, presence of sediments (evidence of erosion), ditch shape, and a summary assessment of overall ditch condition. If properly constructed and maintained, ditches should: collect subsurface water that may cause problems with the road bed, collect road run-off and surface run-off, serve as a storage area for large amounts of rainfall, and collect sediment normally washed into a channel (KCSWCD 1993).

The ideal ditch should have a depth which does not allow the water to come closer than one foot from the edge of the road, and a width that is appropriate for the chosen depth. It should also be parabolic in shape with no sediments and should be lined with established sod or rip-rap, depending on projected water flow (KCSWCD 1993).

The culverts index evaluates the overall condition of the road's culverts. The criteria for the evaluation was number of culverts present and/or needed, weathering (aging) of culvert, size, pitch, cover, and summary assessment of the overall culvert condition. Culverts protect a road from being washed out by natural water flow by allowing water to pass under the road unhindered by the road structure. Culverts are needed in places where streams, brooks or seasonal run-off intersect a road, or if problems with subsurface flow arise and containment is not effectively accomplished by ditches (KCSWCD 1993). The best culvert would not be weathered, would have a pitch free of sediment, and would have at least one foot of cover on top of it. The size of the culvert should be determined by the projected amount of flow to be drained by the culvert with a minimum diameter of 16 in (KCSWCD 1993).

The diversions for water index was used to evaluate the turnouts and outlets for water running off the road. The evaluation was composed of counting the number of diversions present and/or needed, where the water was directed to (woods, fields, etc.), and a summary assessment of the overall diversion condition. Water diversions direct run-off carrying sediment into benign areas, reducing the erosion of the road and nutrient loading to nearby water bodies. A proper diversion would spread the water over a large area following the contours of the land.

The road total index was a cumulative number, composed of surface total, ditches total, culverts total and water diversions total. This index provides a cumulative evaluation of the structure of the road based on these four criteria.

The road segment average index was used to evaluate the potential for erosion from run-off by relating the slope of the road segment to its length. The potential for erosion was calculated by determining slope for a given segment length. A weighted system was used to give the roads with greater erosion potential a higher score (Pam Partridge pers. comm.).

The paved roads were evaluated using an integer scale from 1-5 with 5 being the best possible road (BI 493 1993). The criteria for each of the five categories are listed below:

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.

Results and Discussion

Out of the 25.9 miles of roads surveyed in the Salmon Lake watershed, 12.4 (48% of total) miles consisted of 39 camp roads and one dirt road (Appendix F, Figure 1). The overall condition of these camp roads was fairly good (Figure 39). However, there were eight high scoring roads that seemed to be more problematic than the rest. Five roads are within the McGrath Pond watershed: Elizabeth Street, MP-4, T-5, Ford's Road, and MP-5; Three roads are found in the Ellis Pond watershed: S-16, S-20A, and T-8B.

In the McGrath Pond watershed, Elizabeth Street's high index value for surface total (Appendix F, Figure 2), culverts total (Appendix F, Figure 3), and diversions total (Appendix F, Figure 4) led to its overall high index value (Figure 39). This road had no crown, the surface constituents were loose, and berms were present, preventing proper run-off. The condition of the culverts was not adequate due to siltation, rusting, bent insides and some not working properly. There were no diversions for water present, but one was needed.

The factors contributing to the high index value for MP-4 were problems with culverts, ditches, and diversions (Appendix F, Figures 3-5). The condition of the present culverts was inadequate due to siltation and rust damage. Additional culverts were also needed in places. There was no ditching present along this road, but it was badly needed. A well placed diversion was needed, but one was not present.

The problems leading to T-5's overall high index value were related to surface and diversions for water (Appendix F, Figures 2 and 4). The condition of this surface was insufficient due to poor crowning, loose surface material, and ridging of the edge preventing proper run-off. Although needed, there were no diversions present.

Ford's Road had a high index value because of surface and ditch problems (Appendix F, Figures 2 and 5). The surface had an inadequate crown. No ditching was present on this road, but it was badly needed. Both of these problems allow run-off to flow down the road toward the lake.

The factors contributing to MP-5's high index value involved characteristics related to surface, culverts, ditches, and diversions (Appendix F, Figures 2-5). The condition of the surface was insufficient because of crowning problems. Culverts were needed, but none were present. The road was very steep and needed diversions for water, and there was also no ditching along a large portion of the road.

In the Ellis Pond watershed, S-16 had a high surface index value, which caused it to have a high overall index value. The surface condition was improper due to crowning problems, the presence of ridges along the edge, and some loose surface material.

S-20A had problems with its surface and diversions leading to its high overall index value. The problem areas for the surface total included poor crowning, loose surface material, and the presence of

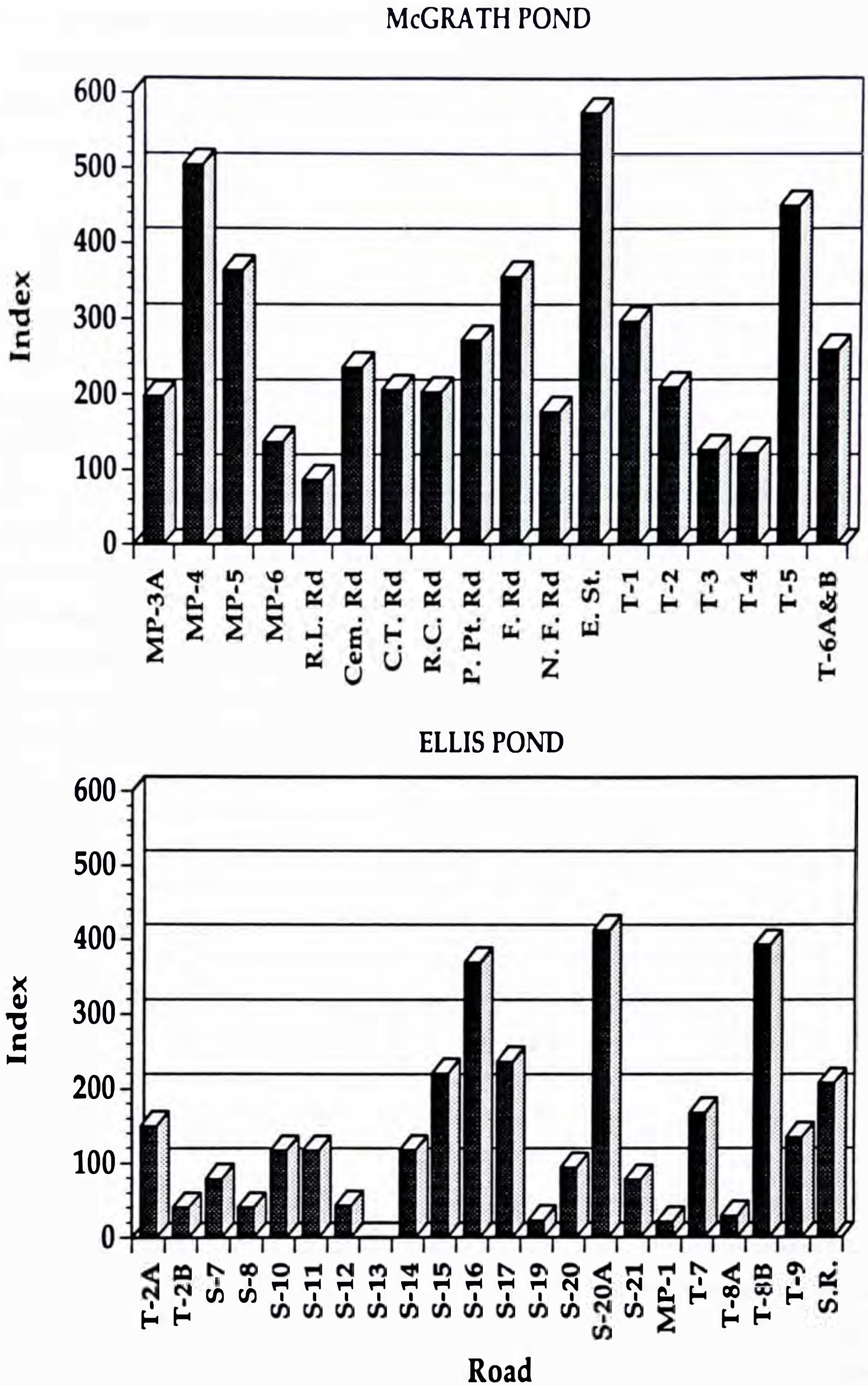


Figure 39. Road total index for the camp roads in the McGrath and Ellis subwatersheds based on surveys conducted on 4OCT1993, 18OCT1993, and 25OCT1993. This index is a measure of surface total, ditches total, culverts total, and diversions for water total (see text for detailed discussion). (R.L. Rd. = Random Lodge Rd., Cem. Rd. = Cemetery Rd., C.T. Rd. = Camp Tracy Rd., R.C. Rd. = Raymond Cottages Rd., P. Pt. Rd. = Pleasant Point Rd., F. Rd. = Ford's Rd., N.F. Rd. = Next to Ford's Rd., E. St. = Elizabeth St., S.R. = Stoney Ridge Development, S-13 was not surveyed.)

berms along the edge. Some diversions for water were needed, and the one present diverted run-off into a stream leading into the lake.

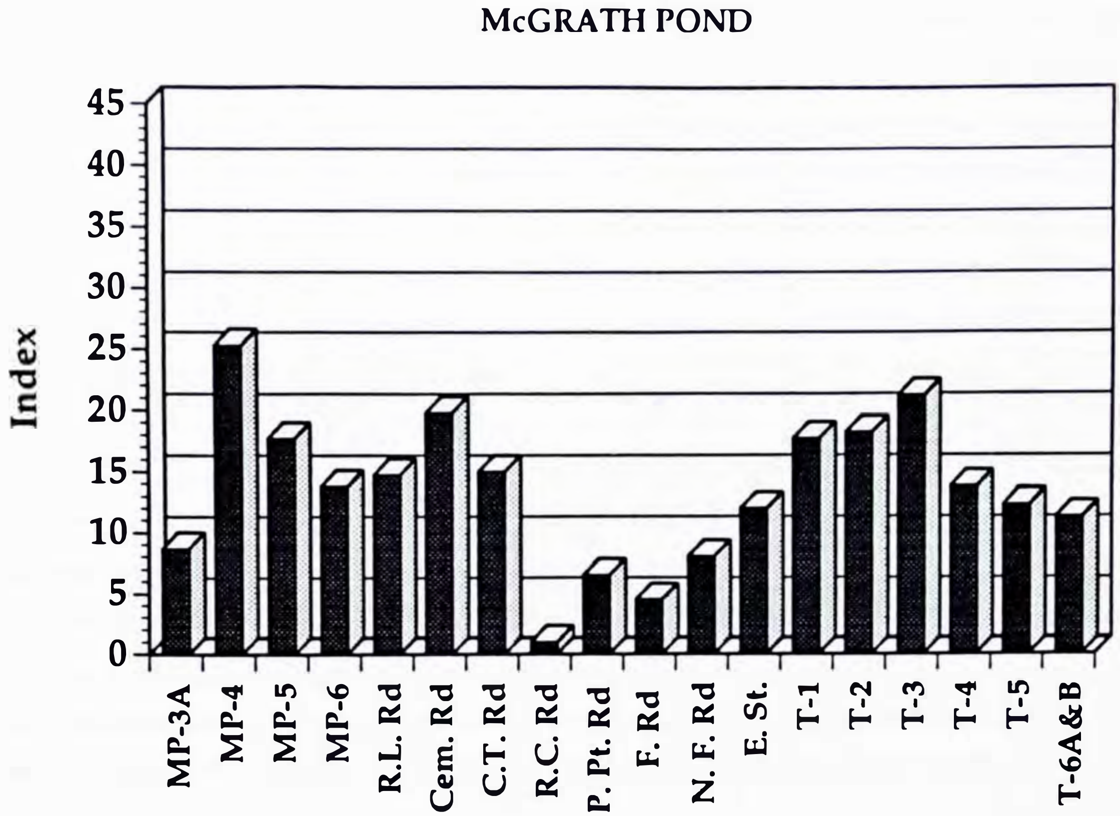
Lastly, T-8B had poor surface and ditches evaluations, causing its overall high index value. The poor surface condition was related to improper crowning and the presence of berms along the edge. There was a need for ditching along this road, but none was present.

In summary, these eight problematic roads showed insufficient crowning, the presence of berms, and the need for diversions. The problems with crowning and the presence of berms can be attributed to the lack of proper maintenance. These conditions can be remedied by properly grading the road periodically (KCSWCD 1993). Construction of diversions for water should be undertaken at sites where surface water can collect from roads and ditches and cannot be immediately drained away (KCSWCD 1993). Also, it was observed that only one of the eight high index roads had a high potential for erosion (Figure 40). There seemed to be little correlation with high total road index and high segment average total index. Meaning that although there was a high potential for erosion for some roads given their segment lengths and slopes (Figure 40), not all of them displayed the effects of such erosion (Figure 39). Although these eight roads had the highest index they were far from having the highest possible total index (Figure 41). Also, on 2DEC1993, these eight high-scoring roads were field checked again for the severity of their condition.

The paved roads that were evaluated included the McGrath Pond Road, Town Farm Road, Route 8, Route 137, Summer Street, Gage Road, Horse Point Road, and Taylor Woods Road, accounting for 13.5 miles (52%) of total roads surveyed. Of the 13.5 miles, 11.1 miles (43% of total roads) consisted of municipal roads and 2.4 miles (9% of total roads) consisted of state roads. Practically all the roads were in excellent condition and received a score of 5, except for a three-tenths of a mile stretch at the town line of Belgrade and Oakland on McGrath Pond Road, which had some surface problems, and was given a score of 3. Also, Route 137 was a good road, having some minor surface problems, and given an evaluation of 4.

It should also be mentioned that a possible problem road was found on the northwest corner of McGrath Pond, off the McGrath Pond Road. The site had a new house being constructed and a parallel dirt road climbing Mutton Hill. Through observation, it was found that the road had a very poor road surface and had neither ditches nor diversions for water. It appeared that the road had a serious erosion and sedimentation problem due to the steep slope and lack of ditching and diversions for the water. Three culverts were observed, at the entrance, 30 ft, and 75 ft from the road entrance. The culvert nearest to the road was partially filled with silt and led to a stream bed on the other side of the McGrath Pond Road. This stream led to the northwest corner of the lake and seemed choked with sediment from the culvert.

Another problem also exists in the Mutton Hill area of McGrath Pond. Specifically, there seems to be a possible problem with the drainage from the paved road leading up to Mutton Hill. The course of the run-off seems unimpeded, as it heads straight to the lake via a clearing leading to the lake's edge. Adding to this potential problem is the fact that the northwest portion of McGrath Pond, which encompasses the above area, has a high expected volume of run-off (with expected run-off determined



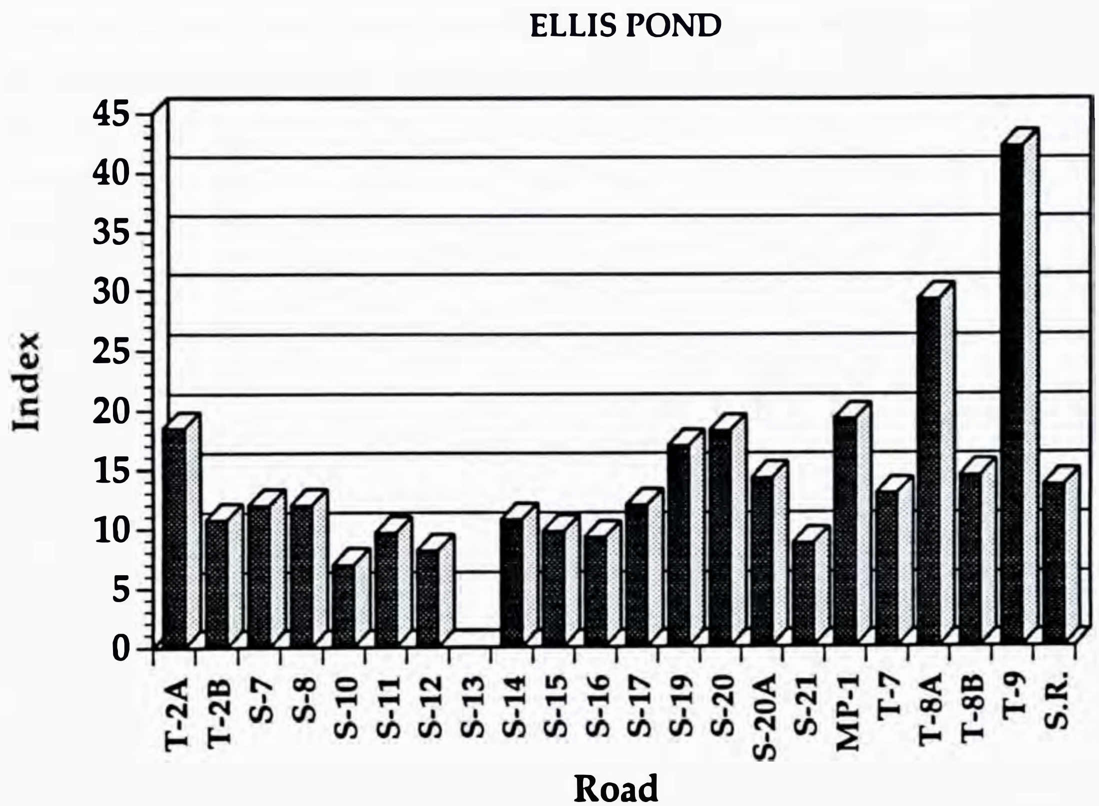


Figure 40. Segment Average Total index for the camp roads in the McGrath and Ellis watersheds based on surveys conducted on 4OCT1993, 18OCT1993, and 25OCT1993. A score of 25 or above indicates high erosion potential. (For road abbreviations see figure 39, S-13 was not surveyed).

as a function of present culvert size).

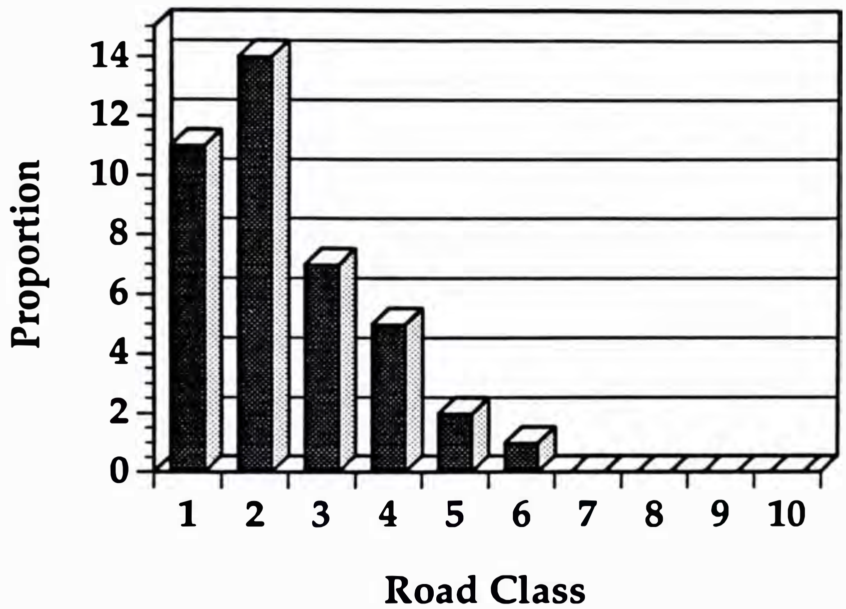


Figure 41. Proportion of camp roads in each road class category based on the road total index. The categories represent ten classes of 100 point intervals ranging from the best possible road total index of 16, to the worst possible road total index of 960.

Industry

Methods

Industrial areas were surveyed by car and plane in the Salmon Lake watershed. Tukey's sawmill was contacted for information regarding its operations. The Zoning Ordinances of the Towns of Oakland and Belgrade of 1991 were referred to for information regarding policies concerning industrial activities. ZIDAS digitizing equipment was used with aerial photographs from 1980 and 1991 to calculate the area in the watershed once or currently used for industrial purposes. The Salmon Lake Association shared its knowledge of industry in the area at their November meeting.

Results and Discussion

The known and visible industries are the old gravel pit on the eastern side of McGrath Pond and Tukey's sawmill located on the western side of Ellis Pond. The gravel pit is no longer in operation. This pit used to be a landfill, and is now used infrequently as a source of sand for the town of Oakland (Bob Quinn pers. comm.). This pit, located on a slope down to McGrath Pond, has had a significant effect on McGrath Pond in the past. Erosion into McGrath Pond carried large amounts of sand and silt down the hill, forming a shallow sandbar near the shore. The fact that the pit previously served as a dump may have significant implications on the amount of phosphorus carried into McGrath Pond through erosion.

In an effort to prevent further erosion, the pit was seeded and Oakland constructed two holding ponds below the gravel pit several years ago. These ponds serve to catch the water draining into the lake, giving the sediment load in the water time to settle out before entering McGrath Pond. Overflow mechanisms in the ponds allow the water to drain out when levels reach a certain height in the holding ponds (Bob Quinn pers. comm.).

Tukey's sawmill has been in operation year round since about 1945 (Bill Tukey pers. comm.). The mill falls under no zoning policies because it is an industry out of the shoreland zone, and the owner has no recollection of any past complaints or problems. A study done in 1984 reported the tributary draining the sawmill section of the watershed having elevated instream total phosphorus levels, because during wet weather, tractors and other vehicles cause erosion of the yard (Nichols et al. 1984). This was one of three tributaries that contributed about 69% of the phosphorus loading and yet drained only 22% of the watershed in 1984.

Table 16. The values and percentages of the gravel pit and sawmill industries in the Salmon Lake watershed based on ZIDAS data from aerial photographs.

	Gravel Pit		Sawmill	
Year	**1980**	**1991**	**1980**	**1991**
Area (ha)	1.47	2.29	2.18	1.95
Watershed area (%)	0.14	0.22	0.26	0.23

Table 16 shows the numbers and percentages of the ZIDAS calculations. Some differences were seen between 1980 and 1991. The gravel pit seems to have grown. This contradicts the idea that since it's closing it should have signs of steady forest regrowth, thus decreasing its area. This discrepancy could be due to the difficulty of reading the aerial maps and accurately delineating the area. The sawmill was measured as occupying about the same percentage of the watershed for both years. In 1991 the sawmill and gravel pit made up less than 1% of the total watershed area. This does not conclude, however, that the effects on water quality are proportional to the size of the area that the industries occupy.

The zoning ordinances of the towns comprising the watershed of Salmon Lake define industrial activity as the assembling, fabrication, finishing, manufacturing, packaging or processing of goods, or the extraction of minerals. The list of commercial and industrial activities they prohibit in the shoreland zone is extensive and includes car-washing and repair facilities, chemical and bacterial labs and storage areas, commercial painting, wood preserving, furniture stripping operations and dry cleaners and laundromats. Also prohibited are electronic circuit assembly operation, metal plating, finishing, and polishing operations, photograph processing centers and printing facilities.

Belgrade goes even further, prohibiting any activity requiring special storage or disposal methods or facilities for chemicals or compounds (other than common household items in common quantities) which are potential pollutants of waters of aquifers in the area (Belgrade 1991).

In Oakland's shoreland zone, mineral extraction is allowed to be done by hand sampling, test boring, or other methods creating minimal disturbance of less than 100 ft^2 of ground. If these standards are not met, a permit is required. These areas must be filled and capped after extraction. Belgrade does not allow any mineral extraction anywhere, yet mineral exploration can occur in the town, outside the Shoreline Protection Zone.

Landfills

Results and Discussion

Landfills can have disastrous effects on regional water quality. Unlined landfills or those in close proximity to the water table have great potential for ground water contamination. Poor landfill management practices can render a town's water supply unfit for use.

The Oakland landfill is located on Rt. 11, on a hill on the eastern side of McGrath Pond, overlooking its central portion. The geology of that area is heterogeneous glacial till composed of semipermeable sand and gravel (USDA 1992). There is a wetland that drains into McGrath Pond just to the north of the landfill. Groundwater monitoring wells have been drilled by the Civil Engineering Services Corp near the landfill to monitor groundwater quality near the dump. The effects of the landfill on the wetland and on the ground water in that area are as yet unknown.

The Oakland landfill is classified as "insecure" by the state, as it has no rubber liner to prevent waste seepage into underlying groundwater (Bob Quinn pers. comm.). Due to the state mandate closing all unlined municipal dump sites, the Oakland landfill will be closed to public use on 1DEC1993, and will become a transfer station. Waste will be sent to the Lewiston-Auburn landfill. Though this will end the accumulation of waste in the landfill, seepage of nutrients and pollutants into groundwater can still occur as waste decomposition occurs in the soil and leaching through the soil liberates and carries nutrients into the groundwater system. This groundwater, following the slope of the watershed, flows toward Salmon Lake and may therefore be adding nutrients and pollutants to the lake via subsurface flow.

Phosphorus Loading Model

Methods

A model for the total external phosphorus loading based on land use and atmospheric input for the surrounding watershed into Salmon Lake was developed. It included export coefficients defined by Reckhow and Chapra (1983) and other coefficients that were modified using two case studies: Higgins Lake (Reckhow and Chapra 1983) and East Pond (BI 493 1993). The equation that resulted is as follows:

$$W = (Ec_a \times A_s) + (Ec_f \times Area_f) + (Ec_w \times Area_w) + (Ec_c \times Area_c) + (Ec_r \times Area_r) + (Ec_s \times Area_s) + (Ec_n \times Area_n) + ((Ec_{ss} \times \#\ of\ capita\ years_1 \times (1-SR_1)) + (Ec_{ns} \times \#\ of\ capita\ years_2 \times (1-SR_2)) + Ec_{cs} \times (1-SR_3)) + PSI$$

W is the total mass phosphorus loading into McGrath and Ellis Ponds. Ec is the export loading coefficient of each category (a = atmospheric input, f = forests, w = wetlands, c = cleared land, r = roads, s = shoreline development, n = non-shoreline development, ss = shoreline septic tank, ns = non-shoreline septic tank, cs = commercial summer camps) and is multiplied by the area corresponding to each category (As = area of the lake, SR = soil retention, PSI = point source input). A more detailed explanation of the model and how the export loading coefficients were chosen can be found in Appendix D.

Low and high export coefficients were selected from the Higgins Lake case study of Reckhow and

Chapra (1983) and modified based on information from MDEP and conditions observed at Salmon Lake as a reference for the phosphorus input categories. These numbers were used to calculate low and high total loading estimates. The difference between the low and high export coefficients represents the uncertainty in the estimates. If the model is constructed properly, the low and high estimates should fall on either side of the actual phosphorus concentrations in the lake.

Reckhow and Chapra (1983) explain that uncertainty in the estimates may be caused by either variability or bias. Variability may result from natural fluctuations such as changes in stream flow or stream phosphorus concentration, or may rise due to uncertainty in statistical analysis. Bias may result because the estimates may not be accurate in their representation of the category. In other words, export coefficients derived for use in one watershed may not be accurate measures in another.

The area for each land use in the watersheds was obtained from ZIDAS data. Total shoreline and non-shoreline developed lot area for each watershed was used to calculate average lot sizes. To represent the actual number of residents contributing to the septic tanks in either watershed, we used an average of 3.5 people per household. Fifty days/yr for each seasonal residence was used in calculating the number of capita years. A more detailed explanation of the model and the calculations is described in Appendix E.

Using the phosphorus loading coefficient calculated above and the results from the water budget, low and high-range predictions of the phosphorus concentration in McGrath and Ellis Ponds were made using the following equations from Reckhow and Chapra (1983):

$$P = \frac{L}{11.6+1.2qs} \qquad qs=\frac{Q}{A_S}$$

P is the predicted phosphorus concentration for the pond being modeled. 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). When calculating these values for Ellis Pond, we added W and inflow water volume from McGrath to W from Ellis because the water from McGrath flows into Ellis. The q_S of the above equation 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 value for Ellis Pond is equal to the total I_{net} of the water budget which includes the inflow from McGrath Pond (15,621,924 m^3).

We used the phosphorus concentration estimates, to project loading changes based on an increase in shoreline development and a decrease in forested land over the course of 20 years. Population growth in the area is approximately 23% every ten years (refer to Futrue Trends section: Population trends). Thus, assuming the same growth rate, the 20 year projection predicts a 46% increase in the shoreline development which results in higher phosphorus concentrations in both ponds.

Results and Discussion

The McGrath Pond watershed encompasses a total area of 1200 ha. In this area, forests cover 73%, shoreline and non-shoreline developed lots cover 13%, and cleared land, roads, and wetlands together cover 14%.

Land use in the Ellis Pond watershed (1113 ha) is proportioned a little differently from that in the McGrath watershed. Forests cover approximately 63% of the watershed, while 15% is covered by shoreline and non-shoreline developed lots. The remaining 22% is covered by cleared land, roads, and wetlands.

Results of the phosphorus loading model indicate that both ponds have phosphorus levels on the low end of the range we would expect using our estimates. Because the actual values we found are very close to the low estimate, the relative amounts of phosphorus contributed by each land use are probably fairly accurate. In general, the estimated phosphorus levels in Ellis were higher than those in McGrath, which is consistent with the data we collected. This is probably due to the fact that McGrath drains into Ellis, adding any dissolved phosphorus that is in the water to Ellis Pond. The estimated phosphorus concentration in McGrath Pond using our equation gave a range of 6.7 ppb to 25.3 ppb. Actual levels measured in the pond this fall were between 8 and 9 ppb. The estimated range for Ellis is 9.2 ppb and 33.6 ppb, with actual values measured in the pond being 10 to 12 ppb.

From the phosphorus export loading model for McGrath Pond, a projection ranging from 218.12 kg/yr to 812.88 kg/yr was predicted for the total amount of phosphorus entering McGrath Pond each year. The forested area contributed the greatest amount of phosphorus in these estimations, 24% in the low estimate and 22% in the high estimate (Figure 42). This is not surprising as forests cover the majority of the watershed. The decrease in the high estimate is due to an increase in the relative importance of other coefficients.

Shoreline and non-shoreline development contribute the next largest amount of phosphorus each year, each adding 18% to McGrath Pond in the low estimate, 19% and 21% in the high estimate, respectively. Shoreline and non-shoreline septic inputs to McGrath together comprise 14% of the total phosphorus contribution in the low estimate and 8% in the high estimate. From our estimates, more phosphorus is coming from development in the watershed than from septic tanks.

The wetlands in McGrath Pond contribute less than 1% of the total phosphorus loading in both low and high estimations. Cleared land and roads contribute relatively little as well. In the low estimate, together, only 6% of the total phosphorus entering the pond is contributed by these sources. This contribution rises to 12% in the high estimate.

Camp Tracey, the summer camp on McGrath Pond, is a potential source of phosphorus because it is close to the lake shore and houses up to 140 people during the summer. Our estimates show that Camp Tracey contributes 7% of the total loading to the pond in the low estimate and 6% in the high estimate.

From the phosphorus equation for Ellis Pond, total phosphorus loading values were 250.06 kg/yr in the low estimate and 889.22 kg/yr in the high estimate (Figure 43). As expected, these ranges are higher than those for McGrath Pond. Forest, comprising 63% of the watershed, is not the main contributor as

McGrath Pond

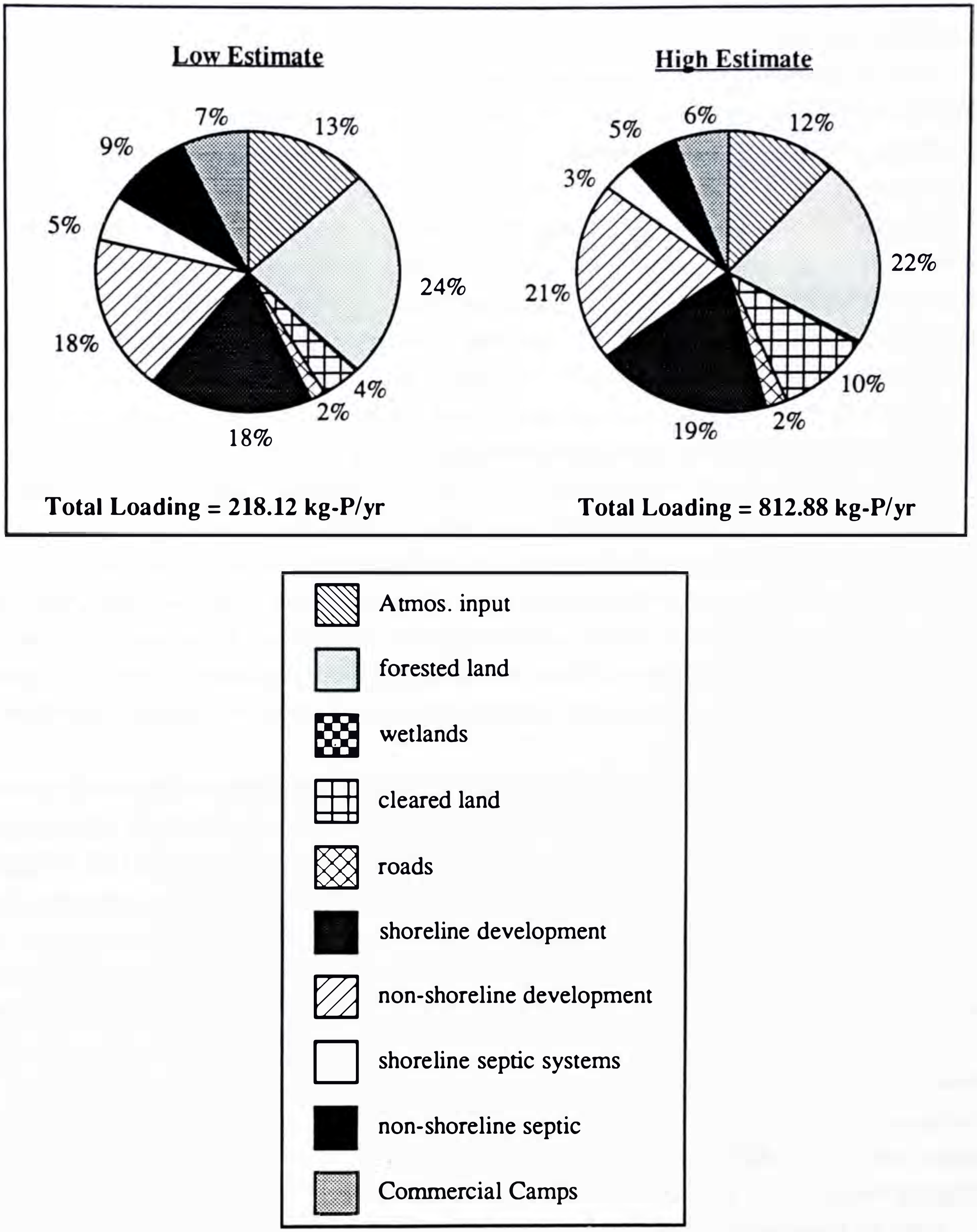


Figure 42. Low and high estimates of total Phosphorus export loading from each land use within the McGrath Pond watershed.

Ellis Pond

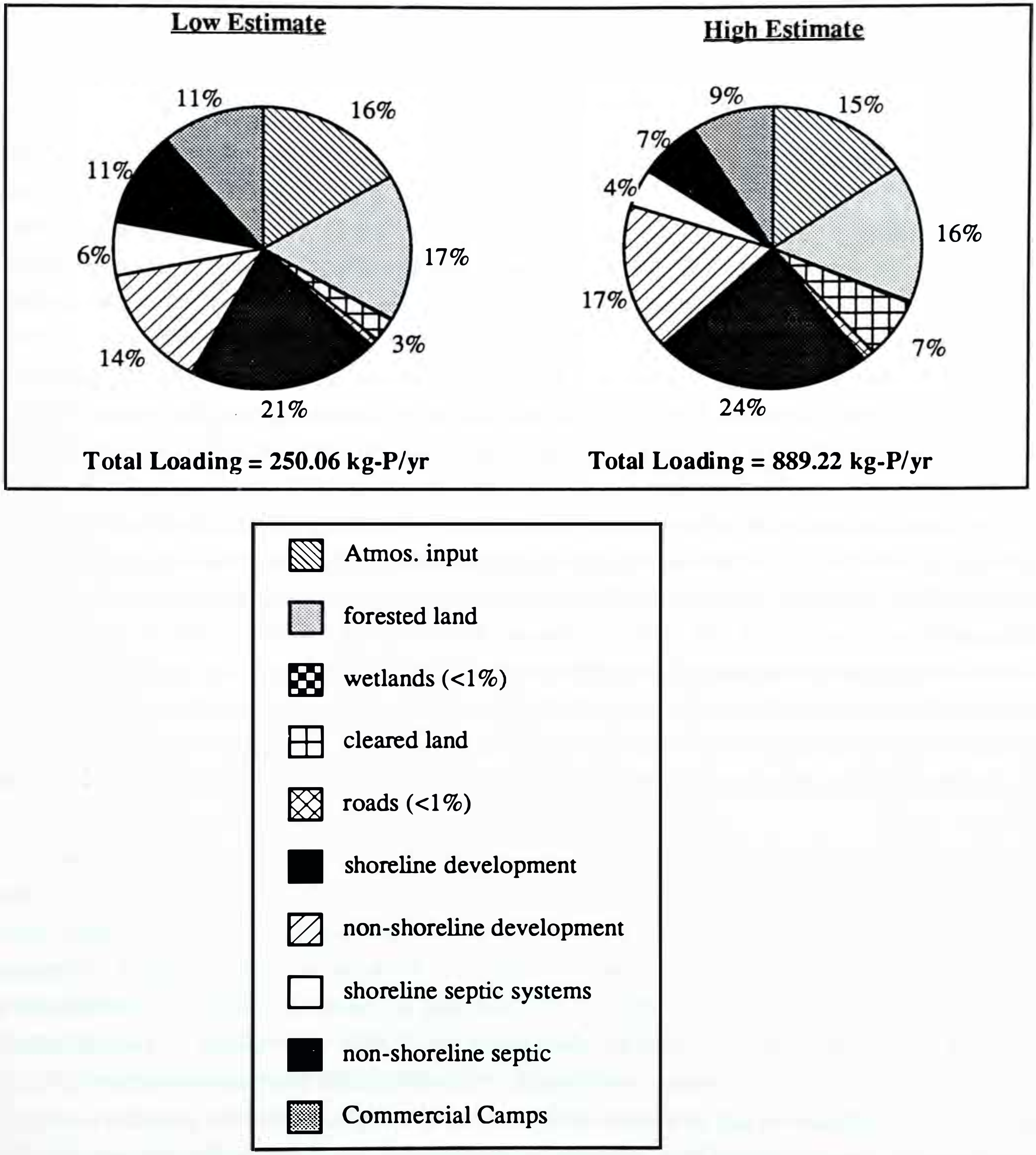


Figure 43. Low and high estimates of total phosphorus export loading from each land use within the Ellis Pond watershed.

in the McGrath watershed. In the Ellis watershed, forests contribute 17% in the low estimate of phosphorus loading and 16% in the high estimate. The main contributor is shoreline development, with a low estimate of 21% and a high value 24%. We estimated that there are 131 lots on the shoreline of Ellis Pond, with an average lot size of 0.5 ha. Combined shoreline and non-shoreline development is comparable to that of McGrath, with a low phosphorus loading estimate for Ellis being 87.4 kg/yr combined, and an estimate for McGrath of 77.2 kg/yr (compare Figures 42 and 43).

Atmospheric input contributes the next highest amount to Ellis Pond as 16% in the low and 15% in the high estimate. The numerical values of 41.2 kg/yr and 137.4 kg/yr are greater that those in McGrath because Ellis Pond has a greater surface area. The 22% of the watershed that is covered by cleared land, roads, and wetlands contributes less than 5% of the total phosphorus loading, according to our estimates. The 15% comprised of shoreline and non-shoreline lots adds 35%, and when combined with the septic systems on those lots accounts for 50% of the loading.

The summer camps on Ellis Pond, Camp Kennebec and Camp Modin (refer to Land Use section: Commercial camps), contribute 11% in the low estimate, and 9% in the high estimate, about the same amounts as non-shoreline septic systems. This value may, in fact, be a conservative estimate, as we don't know exactly the impact these summer camps may have on the ponds. Uninformed children may be having more of a deleterious effect than we can predict. Up to 250 children can be found at Camp Kennebec at one time, and 140 at Camp Modin. Clay tennis courts sloped toward the water, a vast amount of cleared land directly on the lake shore, and a lack of buffer strips, could have more input than we are estimating.

We believe the low estimates are close to the actual amounts each land use is contributing to each pond because measured phosphorus levels came close to those estimates. The low estimates give an approximate level of importance to each type of land use in terms of phosphorus loading and lake water quality and can also help determine which land use practices need monitoring and perhaps control in the future.

In addition to giving estimates of current loading relationships, the phosphorus model allows us to project these current trends into the future to see the effects different land uses can have on phosphorus levels in the pond. From current population growth trends, we could predict the amount of development and phosphorus loading twenty years hence. Two decades is a reasonable time period for which to plan future development without spurious predictions. Projecting too far into the future reduces the validity of this type of model. With an average ten-year growth rate of 23%, we predicted the state of Salmon Lake with a 50% increase in shoreline development. This corresponds to an increase in the # of capita years for septic calculations <u>and</u> an increase in the number of hectares allocated to shoreline lots with a concomitant decrease in forested land. Although development will occur in shoreline and non-shoreline areas, we chose to project using shoreline development and septic increases only because they would have the greatest influence on lake phosphorus levels.

The results of the growth projection on the McGrath Pond watershed show that total loading into McGrath Pond 20 years from now is predicted to be 266.88 kg-P/yr to 992.28 kg-P/yr. The predicted phosphorus concentrations in McGrath Pond are between 8.3 ppb to 30.9 ppb. Shoreline lots contribute 29% to 32% of the total loading, and combined shoreline, non-shoreline, and septic contributions are 60% in both the low and high estimates (Figure 44). The loading from forested land decreased because of the decrease in amount of forested land (it was developed).

The twenty-year projections done on Ellis Pond are summarized in Figure 45. Total loading is again higher than in McGrath Pond, estimated at 289.57 kg-P/yr to 1067.99 kg-P/yr. There are other interesting characteristics in the data, however. With the same percentage increase in shoreline lots and # capita years (shoreline septic contribution), combined shoreline and non-shoreline development estimated loading values equal 61% of the total loading, in the low and in the high projections. Though the actual loading values are greater in the Ellis projection, they are allocated in the same proportions as in the McGrath projection. This is to say that the same amount of shoreline development in the next twenty years on both ponds will add proportionately the same amounts of phosphorus from each land use. However, total phosphorus amounts will be greater in Ellis, and this will be reflected in higher phosphorus concentrations, estimated to be 10.2 to 37.1 ppb.

The MDEP (1992) produced a manual called *Phosphorus Control in Lake Watersheds: A Technical Guide to Evaluating New Development* in which the ramifications of development on lake water quality are discussed. Using techniques outlined in the manual, they have classified the water quality of McGrath and Ellis Pond as moderate/sensitive (Mary-Ellen Dennis, pers. comm.). The manual also gives a description of an F value which can be obtained from the MDEP for many ponds and lakes. The F value is a measure of the amount of phosphorus in pounds per year, that would raise the phosphorus concentration of the lake 1 ppb. This F value is important for towns planning development because it gives an estimate of the amount of phosphorus it will take to subsequently change the phosphorus concentration in the lake 1 ppb. This number can be helpful when planning development in the watershed because a town can contact the MDEP and get an estimate of the loading that will result from a certain type of development, and the subsequent effect it can have on the lake.

The F values for McGrath and Ellis Ponds, given by the MDEP, are 27.14 lbs/ppb/yr and 36.39 lbs/ppb/yr respectively (Mary-Ellen Dennis, pers. comm.). Using more recent values of precipitation, net water volume, and flushing rate, we calculated the F values for McGrath and Ellis Ponds. We found consistently higher F values: 32.12 lbs/ppb/yr for McGrath and 47.3 lbs/ppb/yr for Ellis. Our values are higher because of the higher values for flushing rates of both ponds (refer to Quantitative Water Measurements and Calculations section: Water budget). The faster flushing rate results in more phosphorus needed to raise the lake concentration by 1 ppb.

20 Year Projection
McGrath Pond

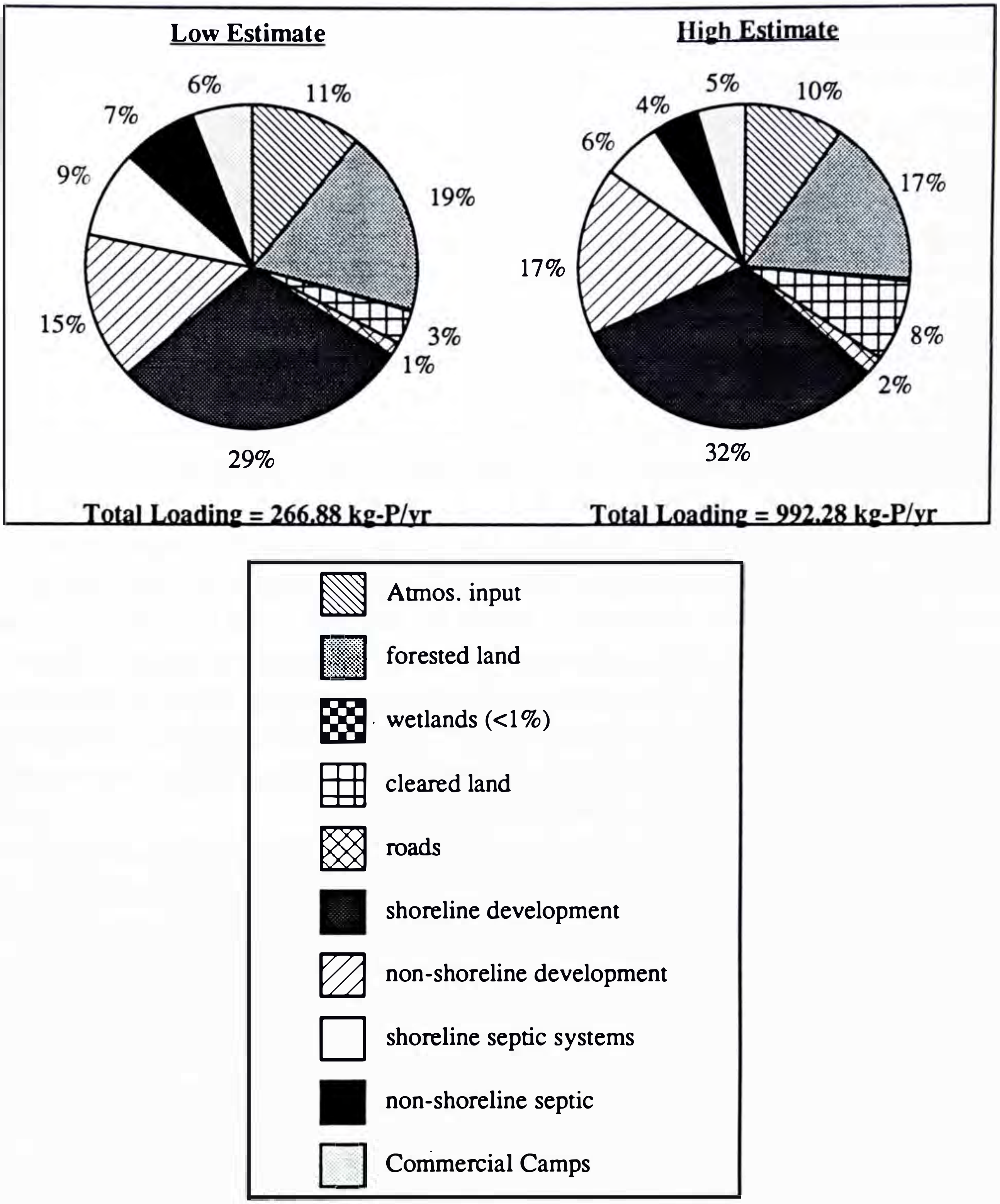


Figure 44. Projected high and low estimates of total phosphorus export from each land use in the McGrath Pond watershed.

20 Year Projection
Ellis Pond

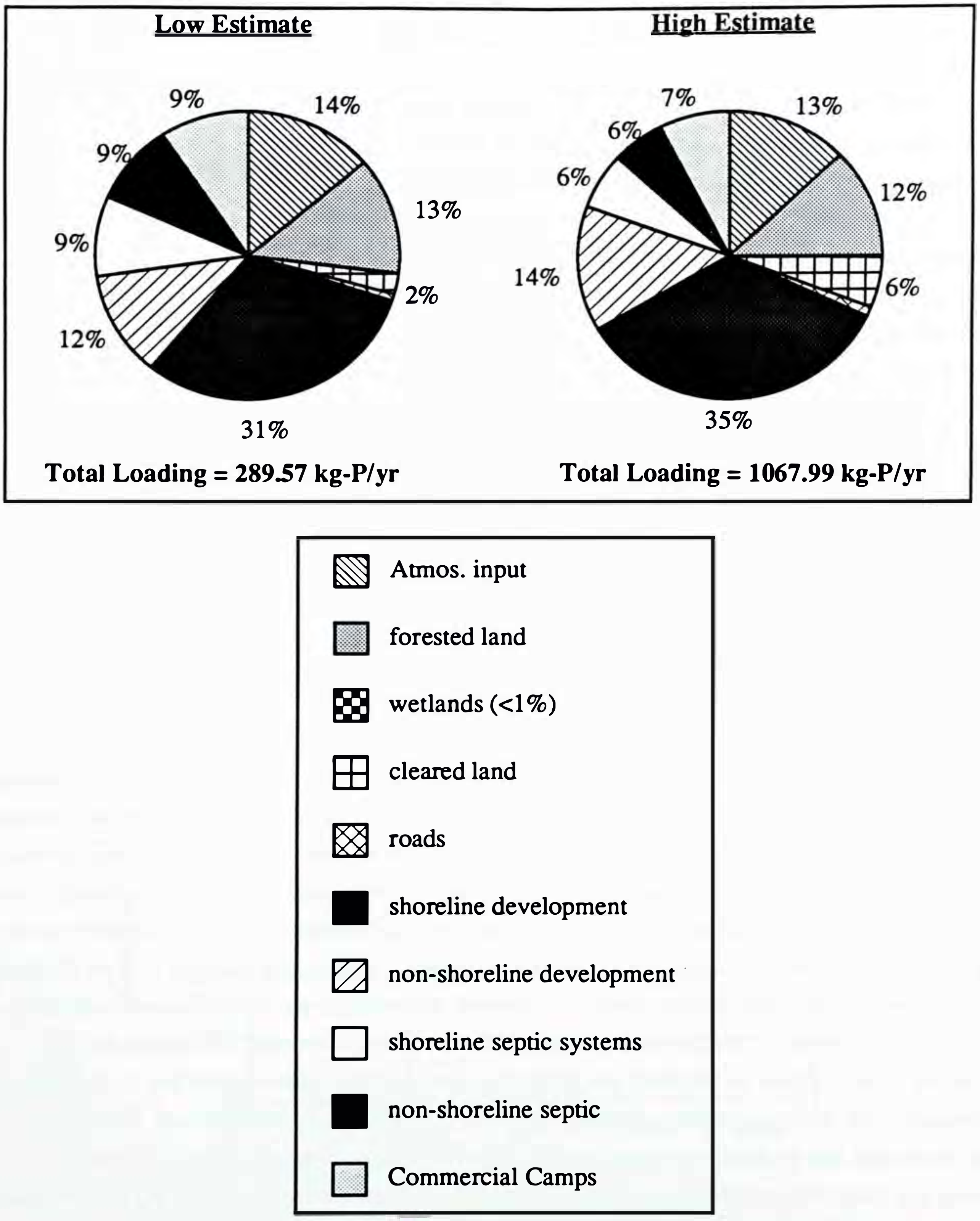


Figure 45. Projected Phosphorus export loading from each land use within the Ellis Pond watershed.

FUTURE PROJECTIONS

POPULATION TRENDS

The census information for Belgrade and Oakland from 1950-1990 shows that population has grown extensively in these two townships (Figures 46 and 47). There have been constant increases in population every ten years in both towns with no declines (NKRPC pers. comm.). The average increase in the total population for Belgrade over this time period is 23% while that for Oakland is approximately 22%. Population is predicted to continue growing at this rate (Brenda Corkum pers. comm.). Part of the reason for continued population growth is the proximity of these towns to the Augusta and Waterville job markets (Hunter and Bickford-Caret 1990). There has been an increase in employment opportunities in both of these areas over the past twenty years. In addition to being close to the Augusta - Waterville employment centers, Oakland and Belgrade are also very attractive rural communities. The towns are ideal locations for people who want to build retirement and pre-retirement seasonal and year round homes. The coastline in Maine is generally the first place that experiences population increases due to retirement and summer vacation homes, but recent economic declines and increased real estate costs have caused people to move to inland communities like those in the Belgrade Lakes region. It is expected that Oakland and Belgrade will continue to experience population increases due to these two trends (Hunter and Bickford-Caret 1990).

DEVELOPMENT TRENDS

Future development in Oakland and Belgrade will be affected by a number of factors, including economic, political, and environmental pressures. These influences often conflict from a developmental standpoint. Regional development that is economically practical is often detrimental environmentally, and vice versa. Past development in Oakland and Belgrade has been mostly residential, although some industrial development has occurred as well. Residential development has in the past been fairly strong, but all development is now "on hold" due to the poor economic situation now existing in New England (Mid State Economic Corporation pers. comm.). However, according to the 1990 Comprehensive Plan, the residential development is the type of development that is likely to increase. According to the parcel maps from the Town Offices of Oakland and Belgrade, there are 144 undeveloped lots in the Salmon Lake watershed; 35% of the vacant lots are shoreline lots and 65% are non-shoreline lots. These lots will not all be developed due to development constraints like soil characteristics and septic suitability.

Zoning and Code Enforcement issues are also important to consider with increasing development and population. Paul Lussier, the Plumbing Inspector and Code Enforcement Officer for Oakland, believes that 98% of shoreline land owners break state and town mandated development regulations. These violations include not applying for a permit before building a sunporch, or creating beaches for their children to play on. These codes are difficult to enforce and difficult to prove that they have been

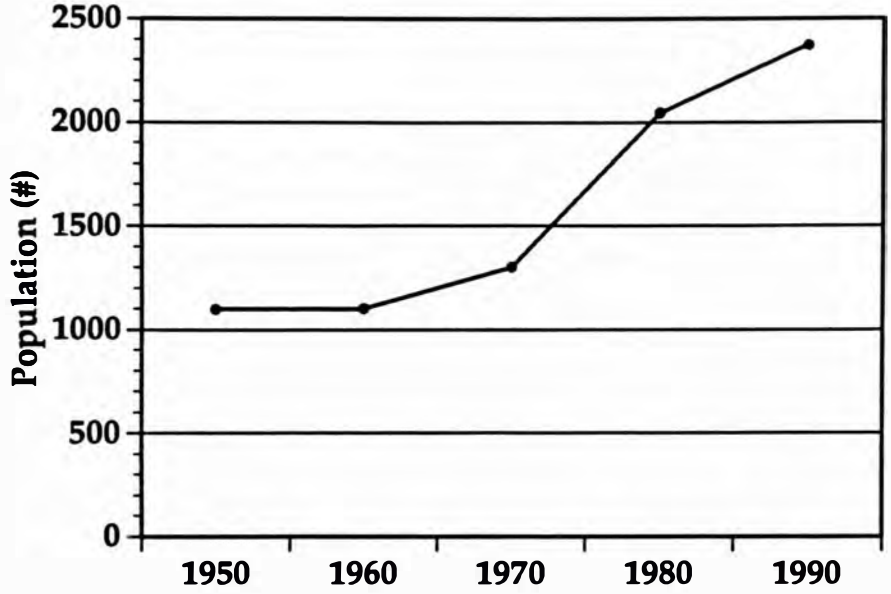


Figure 46. Total population counts from 1950-1990 census information for the town of Belgrade (North Kennebec Regional Planning Commission).

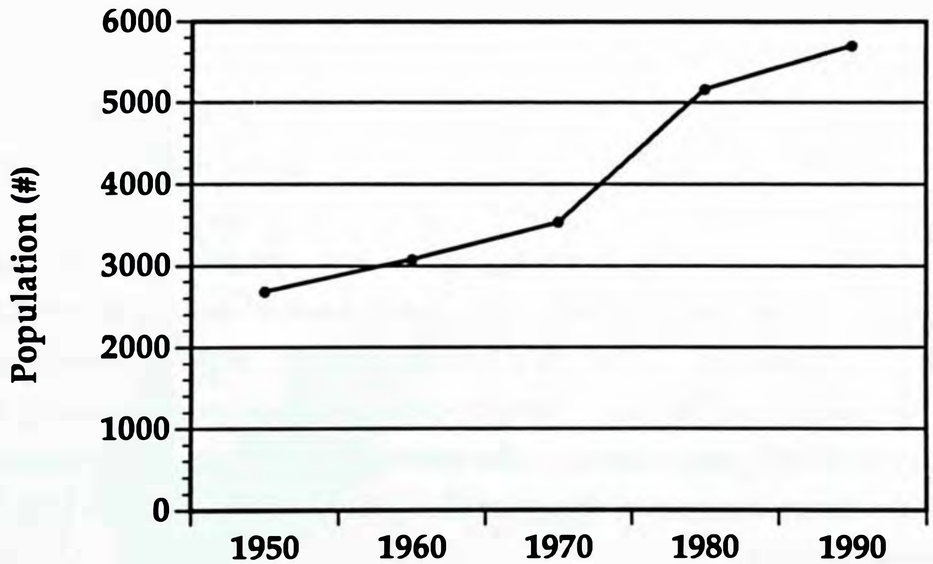


Figure 47. Total population counts from 1950-1990 census information for the town of Oakland (North Kennebec Regional Planning Commission).

violated. It would be helpful to increase the enforcement of state and town mandated regulations with the help of the Lake Association. Despite the restrictions, residential development accounts for about 80% of the tax base in Oakland (Hunter and Bickford-Caret 1990). As residential development increases, more utilities such as sewage systems and sources of electricity must be created to accommodate the new homes.

From an economic point of view, development will occur where it is least costly. Environmental pressures aside, people will prefer to clear and develop land and construct buildings and houses in areas that will give them the most use, but cost them the least amount of money. Keeping this in mind, we constructed a map, using GIS, that shows the network of roads in the Salmon Lake watershed. Central Maine Power will install power lines free of charge to structures within 300 feet or one additional pole of primary power lines. Past 300 feet, homeowners must pay per foot of line (this includes poles) (Central Maine Power and David Sanderson pers. comm.).

Figure 48 shows the land within 500 ft of roads in the watershed. We assumed that development will not be specifically limited to 300 ft of existing lines, but will be some what limited by this added cost imposed on developers farther away from power lines. Assuming no new road construction over the next ten years, we chose the distance of 500 ft as a reasonable limit to new development.

The majority of homes in both townships use septic systems as the main form of subsurface wastewater treatment as opposed to public sewers. Although the number of these systems has been seen to increase with past residential development, these numbers are now on the decline. This may be because development is projected to remain low until the economic situation of the area improves. Another reason for a decline in the construction of new septic systems is that developers are choosing to build large communal waste treatment facilities that will service a cluster of homes (e.g., Mutton Hill development on McGrath Pond and Wheeler Camps on Ellis Pond). If these systems are maintained properly they should have minimal impact on the Salmon Lake watershed and other lake watersheds in the Belgrade Lakes Region.

Industry is another area that has shown a marked increase in development in the past. Figures show that the majority of people in Belgrade are employed in wholesale trade while people from Oakland are primarily employed in manufacturing of nondurable goods (Figure 49). Wholesale trade employs the second largest number of people in Oakland. Employment in education and health services is comparable for both towns (NKRPC pers. comm.). Like residential areas, though, industrial development will be slowed in the future because of the general economic attitude in the area (Mid State Economic Corporation pers. comm.).

Agriculture is declining in the Salmon Lake watershed and in Oakland and Belgrade. In general, traditional agriculture, like growing crops and raising livestock, makes up a small percentage of land use in the watershed. However, other types of agriculture are gaining popularity. For example, in Oakland, there are thirty-five parcels of land that are registered under the Tree Growth Tax Law. This law offers a reduction on taxes if the land is managed for tree growth. The majority of these parcels are undeveloped (Hunter and Bickford-Cater 1990). In general, it is assumed that starting a farm is not profitable at this

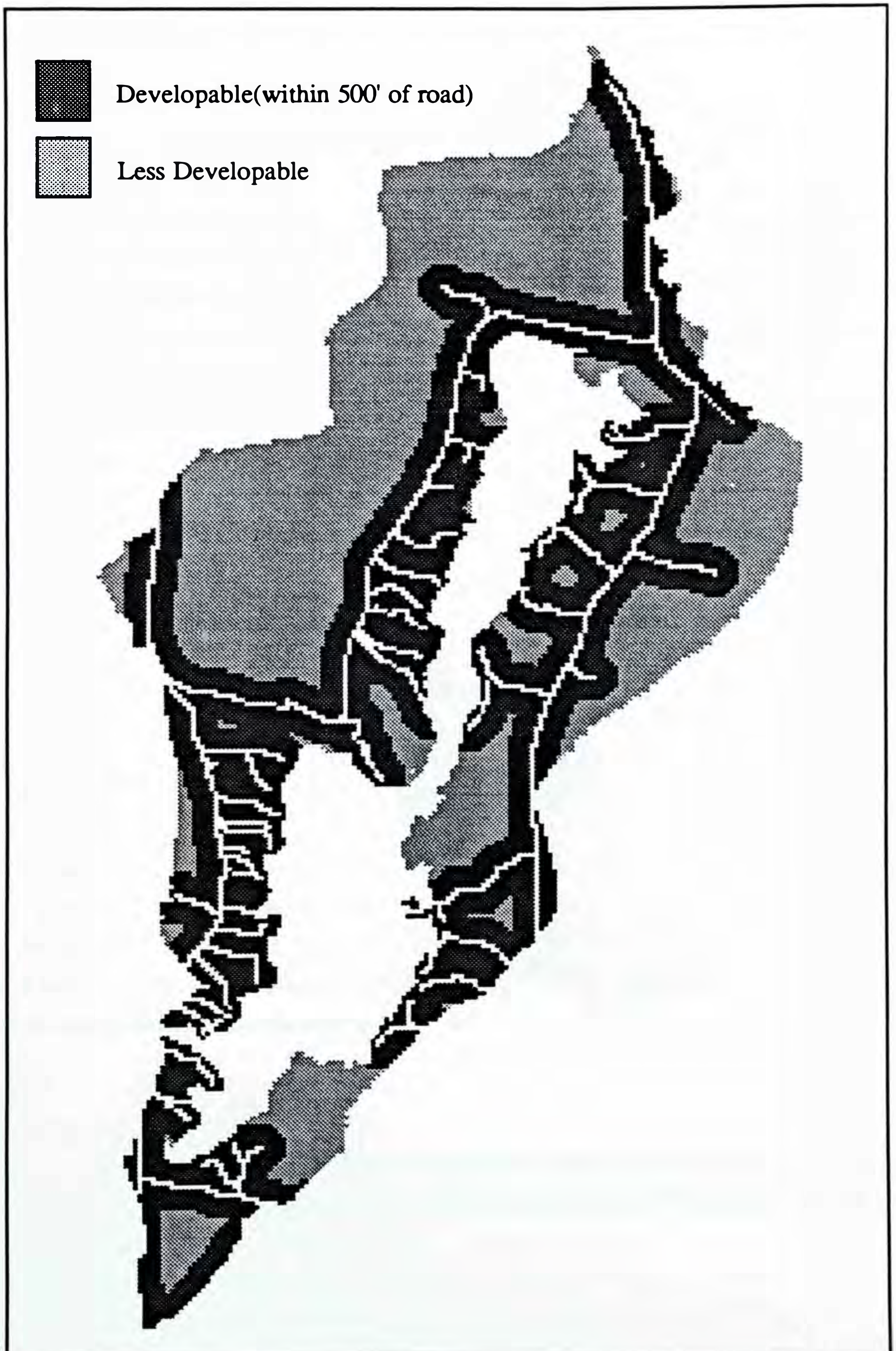


Figure 48. Future Development Possibilities in the Salmon Lake Watershed

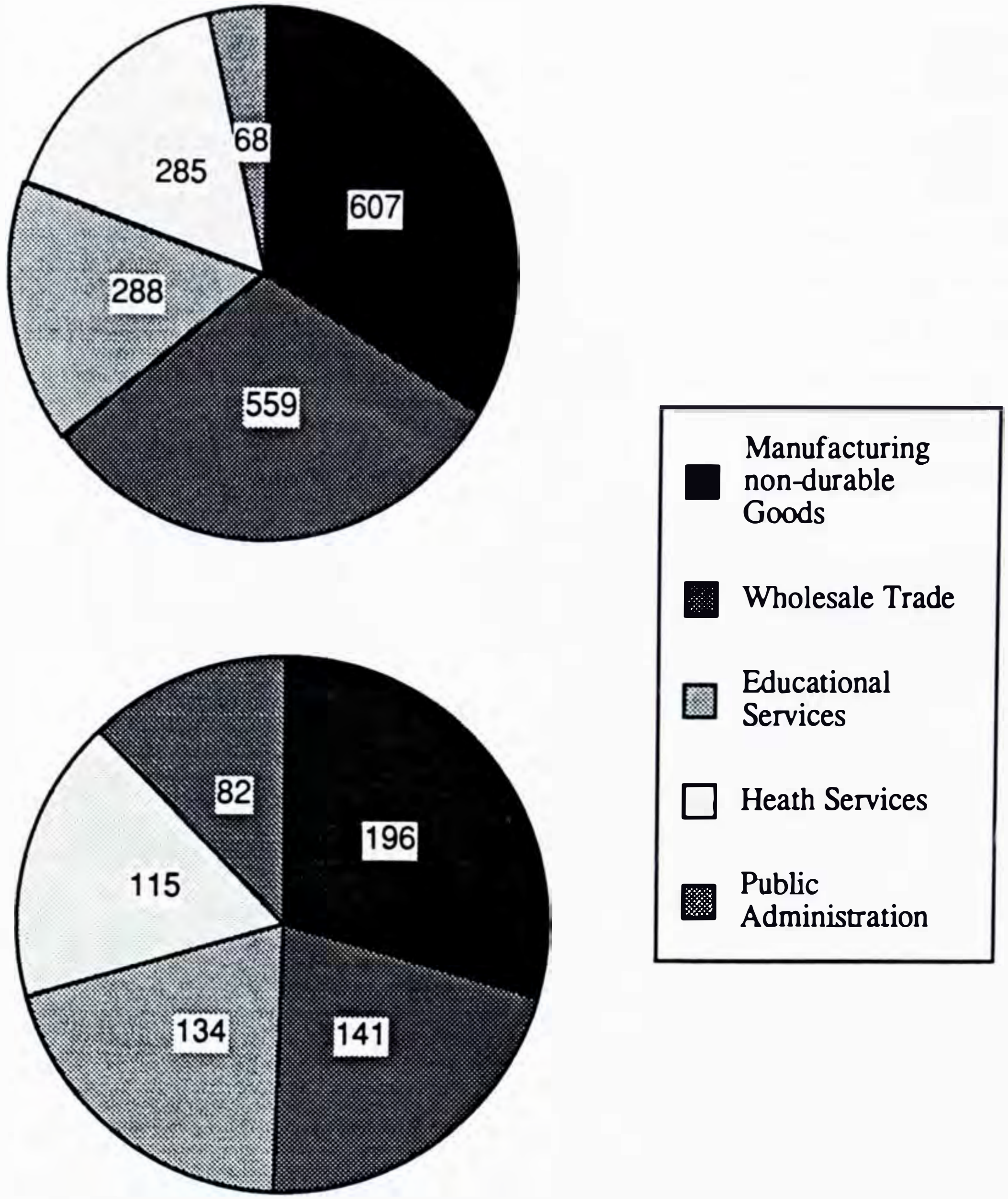


Figure 49. Division of five common industrial occupations within the towns of Belgrade and Oakland (North Kennebec Regional Planning Commision).

time and it is unlikely that new farms will be opened in either of the two towns (Paul Lussier pers. comm.).

RAMIFICATIONS FOR PHOSPHORUS LOADING

Future increases in development and population will ultimately increase the amount of phosphorus loading to the water body from the watershed. People and developed land add stress to the simple balance that exists in a fragile freshwater ecosystem. In order to maintain good water quality and aesthetically pleasing lakefront property, the impact of human land uses must be monitored and restricted.

Results of the phosphorus loading model indicate that currently both ponds have phosphorus levels on the low end of the range we would expect using our estimates of land use in the watershed. The phosphorus model allows us to project these current trends into the future to see the effects different land uses can have on phosphorus levels in the pond. From current population growth trends, we predict that total loading into McGrath Pond 20 years from now is predicted to be 266.88 kg-P/yr to 992.28 kg-P/yr. The predicted phosphorus concentrations in McGrath Pond are between 8.3 ppb to 30.9 ppb. Shoreline lots will contribute 29% to 32% of the total loading, and combined shoreline, non-shoreline, and septic contributions are 60% in both the low and high estimates. The 20 year projections done on Ellis Pond indicate that total loading is higher than in McGrath Pond, estimated at 289.57 kg-P/yr to 1067.99 kg-P/yr. With the same percentage increase in shoreline lots and # capita years (shoreline septic contribution), combined shoreline and non-shoreline development estimated loading values equal 61% of the total loading, in the low and in the high projections. Though the actual loading values are greater in the Ellis projection, they are allocated in the same proportions as in the McGrath projection. This is to say that the same amount of shoreline development in the next 20 years on both ponds will add proportionately the same amounts of phosphorus from each land use. However, total phosphorus amounts will be greater in Ellis, and this will be reflected in higher phosphorus concentrations, estimated to be 10.2 to 37.1 ppb.

SUMMARY

WATER QUALITY OF SALMON LAKE AND TRIBUTARIES

Based on the data collected over the summer and fall, the overall lake water quality seems to not be threatened and in fact appears to have been improving over past years. The phosphorus measurements and other indicators of excessive nutrients indicated that both lakes are moderately productive. Nitrogen, the other major plant nutrient, in the form of nitrates and nitrites, existed in negligible concentrations throughout both lakes. The only exceptional feature of the water was the relatively high pH values, but even these were within acceptable standards. Due to the resonable quality of the water, by following the recommendations outlined in this report to limit nutrient loading, it should be possible to maintain the current healthy status of Salmon Lake.

The results of the tributary analysis indicated that there do not appear to be any tributaries with severe impacts on the water quality of the lake. However, our study occurred over such a limited period of time that it was impossible to do a thorough study of each tributary, including their flow and inputs to the lake over extended periods of time. For example, the small number of streams that had excessive phosphorus concentrations (15, 21a and b, and 22) seemed to have very low flow into the lake and thus they may not have a significant impact on the water quality. To conclusively quantify the impact of these and other tributaries, further study must be done.

LAND USE

Residential Development

Residential development is the main type of development occurring in the Salmon Lake watershed. However, there is very little development occurring at the present time due to the current economic situation in Maine. In the watershed, only 30% of the land is left undeveloped. Some of the land, such as wetlands, is undevelopable because it is protected by the Natural Resource Protection Act. Other vacant lots will never be developed due to the unsuitability of the soil for subsurface wastewater disposal, or other development constraints regulated by state zoning ordinances and town zoning laws. The non-shoreline areas are less protected by existing ordinances, but they also affect lake water quality. In the future, it will be important for the towns that overlap in the watershed to create some regulations and legislation that will limit the amount of non-shoreline development.

Septic systems in the watershed are in fairly good condition. Most people will address their wastewater treatment facilities first , because they are the most visible land use issues. Therefore, the systems appear to be in good shape and the towns should maintain the current level of regulation.

The camp roads in the Salmon Lake watershed are in relatively good condition as well. There are 40 camp roads that were rated in good condition by our study. Eight roads in the watershed were categorized as problem roads and could use some attention. The landowners should take responsibility of maintaining their own camp roads regularly, so that no major reconstruction projects will need to be undertaken. The paved roads were all in good condition except for 0.2 miles between the town lines that are currently under construction.

Commercial summer camps are another seasonal residential area. The camps are responsible about following state and town regulations, as well as regulations designed especially for summer camps. The economic success of the camps is dependent on the water quality of Salmon Lake; parents will not send their children to a camp with bad water quality. The main area that the camps need to improve on is increasing the buffer strips around the shoreline, and any large athletic fields. They also must follow guidelines in maintaining septic systems.

Non-Residential

There are a few industries in operation in the Salmon Lake watershed. There are no separate regulations for these non-residential structures in the watershed. Industry may put added stress on an ecosystem if it is not properly regulated. The major industry in the watershed is the Tukey Brothers Sawmill. So far, no major water quality issues have been created by the sawmill, but it would be worthwhile in the long run to have separate legislation for industries. The other industry in the watershed is the old gravel pit located in Oakland, though no longer in operation. It has been seeded and two holding ponds were created to catch run-off flow. However, the residents of Oakland, and the Lake Association are still concerned about the amount of run-off flowing in to the lake (refer to Recommendations section: Land use).

The Oakland landfill is another important non-residential area in the watershed. It was closed 1DEC1993, and labeled insecure because it was unlined. The landfill area will now be used only as a transfer station, and the town's solid waste must go to the Lewiston-Auburn landfill. According to state, law the Oakland landfill should never be reopened.

Managed (Agriculture and Cleared) Land

The Salmon Lake Association has expressed concern over three areas that can be classified under agriculture. One of these is Bickford's farm, a former dairy farm which now seems to be cropland. Paper sludge was spread here in the past but this practice has stopped due to public concern. The Zimber property has hay harvested on its land and can therefore be defined as a cleared land area. Although these agricultural areas still exist within the watershed and are likely to contribute to phosphorous levels of the lake, there has been a marked decline in agricultural practices within the watershed. This has most likely resulted in a decrease of phosphorous entering the lake. Recently, a new horse farm (Leighton farms) has been opened in the McGrath Pond watershed. It is believed that this farm houses a number of horses. Manure disposal is an important consideration that these types of farms must deal with. It may be necessary for the towns to agree on a way to regulate such livestock farms that are not located directly on the shoreline.

It was concluded that the amount of cleared land in the watershed of Salmon Lake has not changed drastically over this period of time. In fact, it seems that the amount of cleared land has decreased by

1.17%. It was also seen that cleared land practices seem to follow the zoning ordinances set forth by the towns of Oakland and Belgrade.

Natural (Forests and Wetlands)

There has been a 1.18% reduction in the area of land covered by forest. Active logging areas were seen near camp roads MP1 and T8b. It seems that these areas are complying with town zoning regulations, but both areas should undergo an extensive inspection and evaluation to assure compliance. It was observed that small tributaries run close to these areas and may allow for easy entrance of nutrients and debris into the lake.

Typical emergent vegetation was seen to grow in wetland areas as well as small shrubs. Development near these wetland areas has not seemed to disturb the wetland itself, probably because of the prohibition of development on or in close proximity to wetlands. The zoning ordinances of Belgrade and Oakland therefore seem to be followed.

Future Trends

The future trends that we focused on in our report dealt with population and development. Development is increasing at a rate of about 22% every ten years (NKRPC pers. comm.). Population is expected to continue to increase in the future. Oakland and Belgrade are located between the employment centers of Augusta and Waterville. The employment opportunities in these market centers have been increasing as well. Oakland and Belgrade are also attractive rural communities that draw a number of vacationers and retirees.

Development in the watershed is currently "on hold" and future development is dependent on the economic condition of the state. This developmental stand still refers to both residential and industrial development.

Overall, we predict that if development increases with out proper regulation, it will led to increasing levels of stress on the natural cycles of the lake.

RECOMMENDATIONS

One of the things we would like to offer at this point in our study are a set of recommendations that will help maintain the water quality of Salmon Lake, and will allow it continue to improve in the future. There are two major categories in which our recommendations are divided: water quality, and land use.

WATER QUALITY

•Monitor phosphorus concentrations annually.

Although the water quality of Salmon Lake appears to be improving, it will be important to monitor the phosphorus levels of the lake. This will be helpful in assessing the changes in water quality over time as the development in the Salmon Lake watershed changes.

•Monitor changes in macrophyte growth.

Increases in the number of emergent plants in the lake are an indication of increased nutrient levels, often associated with sediment loading. Macrophyte growth is easily monitored through visual surveys. Visual surveys should be conducted at least once a year.

•Monitor tributary water quality.

Our study indicated that the tributaries had very little impact on lake water quality during the time period of our sampling. However, the tributaries are areas that need to be monitored regularly to assess the amount of phosphorus entering the lake. It is possible that as development increases, tributary phosphorus inputs will increase as well. The tributary sites that we identified in our study (Sites 15,16,17,25, 21a, 22, 23, and 24) should be monitored regularly for flow, during the early spring and fall. Water samples should also be taken to measure phosphorus concentrations.

•Monitor run-off from the Mutton Hill area.

The Mutton Hill development area has a steep road running directly down to the lake shore. This area will be an important place to monitor phosphorus loading during the spring when seasonal run-off is at its peak.

LAND USE

•Ordinances mandated by the state and the towns should be strictly followed in relation to forest, cleared land, and wetlands.

The majority of the watershed is forested. Forestry and cleared land are areas in which the towns and the state both have official ordinances regulating their use. We heard rumors about illegal logging occurring on the east side of Ellis Pond, but we were unable to locate any evidence of extensive logging practices in that area. However, to ensure that logging only occurs in specified areas, the current regulations must be strictly enforced.

Wetlands make up a small percentage of the land area in the Salmon Lake watershed. They are also protected by town and state regulations. These regulations seem to be accepted, and enforced by residents of the towns and developers. One thing that may be helpful to ensure proper protection of the wetlands, is to create an education program that explains how and why wetlands are protected.

•Agricultural land with active farms should implement monitoring plans and programs supplied by the Soil Conservation Service.

•Separate zoning ordinances should be implemented for agriculture following the NaturalResource Act Regulations.

There are very few active farms in the watershed. However, they are potentially large contributors of phosphorus in the lake ecosystem. It is important to regulate these farms to ensure that minimal amounts of phosphorus enter the lake. Currently, the farms are under the same regulations as residential homes. In the future, they should be regulated separately.

•Industry should have separate zoning ordinances, different from residential development, that apply to shoreline and non-shoreline industry.

Industry is another potential source of phosphorus loading. Therefore, it should also be regulated more stringently than residential development. It is important to regulate the non-shoreline industries that are not as visible as shoreline industries, but have major effects on lake water quality as well. The regulations should be made in accordance with the Natural Resource Act.

•The old gravel pit in Oakland should continue to be regulated by the present sediment control practices.

• If run-off continues to be a problem a buffer zone could be created by planting vegetation.

The old gravel pit has been closed down, but residents on the shoreline and the Lake Association are concerned that large amounts of sediments are washing down into the lake. The present controls placed on the pit should continue to be followed. If sediments continue to wash down to the lake shore, it may be beneficial to create a buffer zone of trees and shrubs to slow the rate of the sedimentary run-off.

•Camp roads should be maintained regularly, following the guidelines in the Camp Road Maintenance Manual: A Guide for Landowners written by the Maine Department of Environmental Protection.

The camp roads in the watershed should be maintained regularly to avoid deterioration and costly repairs. The state of Maine has a manual for landowners that explains the types of maintenance that should be done. In general, the roads were in good condition. However, some attention should be paid to the eight roads singled out in the report.

•Increase/create zoning regulations for non-shoreline development.

Currently, there are no zoning ordinances in place for development further than 250 ft from the shoreline. Although the shoreline is in direct contact with the lake, non-shoreline development also has an impact on the water quality. As development in the watershed increases, non-shoreline regulations will be important in maintaining current levels of water quality.

• Increase enforcement of current zoning regulations.

Enforcement of current legislation is very important. The code enforcement officer of Oakland is interested in installing Lake Association members as Assistant Code Enforcement Officers. The members of the Lake Association have incentives to enforce the zoning regulations because they want to keep the lakes clean. The assistants would allow more area to be covered at one time, making enforcement more efficient.

•Video of shoreline done by the Lake Association to make sure that there are no code violations. The video should be updated every ten years.

A video taken by boat, of the shoreline homes would be helpful in enforcing zoning regulations. The video should be updated every ten years to ensure that no code violations have occurred. Some violations that will be able to be seen on a video are: construction of man-made beaches and violations of buffer zone regulations. Violations should be reported to the proper authorities.

•Adoption of Phosphorus-Loading Ordinances for Belgrade and Oakland.

Belgrade and Oakland need to cooperate and agree on one Phosphorus-loading plan, that both towns accept and will enforce.

•Septic Systems installed before 1974 should be inspected within the next 5 years.

Wastewater disposal systems installed before 1974 are regulated under a different set of ordinances than today's treatment systems. Therefore, the "old" systems should be inspected and evaluated to see if the system needs to be replaced.

•Septic Systems should be pumped every 3-5 years to ensure proper maintenance.

Septic systems are popular forms of wastewater treatment in Maine. They are effective, but must be pumped every 3-5 years to make sure that the system will not become overloaded.

•Holding Tanks should be pumped when full, dependent on use.

Holding Tanks are popular wastewater treatment systems for shoreline landowners, because maintained correctly they have no impact on the environment. The tanks must be pumped out when they are full, or they will the wastewater will seep out into the ground, and pollute the surface and the ground water.

•Oral surveys of all homeowners in the watershed to determine: the type of system in use, when it was installed, and how often it is pumped.

The most accurate way to determine the status of the wastewater treatment systems in the watershed is through oral surveys of homeowners. This information may require a lot of time to gather, but it would be very beneficial to have the data.

• Commercial summer camps need to create larger buffer zones between shoreline structures and the lake, and around the large fields on the camp property

The camps on Salmon Lake should create larger buffer zones between the shoreline areas and the lake, and around their large fields. This may be a project that the campers could be involved in, to teach them about water quality and to keep the camp waterfront clean.

• Future development should be done only in areas which have no severe development constraints.

Future development should occur in areas where the soil is suitable for development. Aerial photographs, constraint maps, and the Geological Information Service are important resources that can be used to determine appropriate areas for future development.

•Phosphorus-loading will increase as development increases, strict legislation is needed for future development.

In our report we projected the amount of phosphorus-loading that will be occurring in 20 years. This estimate was calculated using a theoretical phosphorus model. It appears that development has the greatest effect on phosphorus levels in the lake system. It is important that laws and ordinances are written to carefully monitor future development and its effect on water quality.

The most important recommendation is that the towns of Belgrade and Oakland need to work together to create legislation that is acceptable and enforceable for both towns. The phosphorus-loading ordinance that Oakland is currently working on may be an ideal place for both town governments to begin joint legislation. It will also be important for Belgrade to create a comprehensive plan in the near future, so that the long range plans for both towns are stated clearly. We hope that our recommendations will be helpful in the maintenence of high water quality of Salmon Lake.

ACKNOWLEDGEMENTS

We would like to thank the following people without whose direction, logistical support, and advice, this report would not have been possible. Although this study has been an incredibly difficult, yet satisfying task, it has been the patience, energy, and efforts of these people that have kept us going. Perhaps the most rewarding part of this study has been that it has put us in touch with such knowledgable people. In addition to the following people, we would also like to thank the Salmon Lake Association and the Nothern Kennebec Regional Planning Committee for their generous assistance with this project.

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King Payne

Len Reich

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LITERATURE CITED

Belgrade, Town of. 1991. Town of Belgrade Shoreland Zoning Ordinance. Town Office of Belgrade. Belgrade, ME. November 5, 1991.

BI493. 1989. An Analysis of the Factors Influencing Eutrophication Within the China Lake Water shed. Department of Biology, Colby College. Waterville, ME.

BI493. 1991. An Analysis of East Pond and The Serpentine Watersheds in Relation to Water Quality. Department of Biology, Colby College. Waterville, ME.

BI493. 1993a. An Analysis of the Pattee Pond Watershed in Relation to Lake Water Quality. Department of Biology, Colby College. Waterville, ME.

BI493. 1993b. Quality Assurance Plan for Clean Lakes Program: Adapted for Salmon Lake. Department of Biology, Colby College. Waterville, ME.

Bouchard, R. 1988. Alum Treatment as a Lake Restoration Alternative for China and Chicawaukie Lakes. Maine Department of Environmental Protection. Augusta, ME.

Bradbury, D. 1993. Wildlands Popularity Concerns Officials. Maine Sunday Telegram. Portland, ME. October 31, 1993. 1A and 4A.

Bunce, N.J. 1990. Environmental Chemistry. Wuerz Publishing Limited. Winnipeg, Canada.

Burgis, M.J. and P. Morris. 1987. The Natural History of Lakes. Press Syndicate Cambridge University Press. New York, NY.

Canter, L.W., and R. C. Knox. 1985. Septic Tank System Effects on Ground Water Quality. Lewis Publishing. Chelsea, MI.

Cashat, J.P. 1984. Design and Maintenance of Unpaved Roads. Public works. Maine Department of Environmental Protection, pp.154-158.

Chapman, D. 1992. Water Quality Assessments: A Guide to the Use of Biota, Sediments and Water in Environmental Monitoring. Chapman & Hall. New York, NY.

Charles, D. F. 1991. Regional Case Studies, in Acid Deposition and Aquatic Ecosystems, Chapter 7. Springer-Verlag, Inc. New York, NY.

COLA (Congress of Lake Associations). 1991. The Lake Book: Actions You Can Take To Protect Your Lake. Second edition. Congress of Lake Associations. Yarmouth, ME.

COLA (Congress of Lake Associations). 1992. A Citizen's Guide to Lake Watershed Surveys: How to Conduct a Nonpoint Source Phosphorus Survey. Congress of Lake Associations and Maine Department of Environmental Protection. Yarmouth, ME.

Cooke, G.D. 1986. Lake and Reservoir Restoration. Butterworth. Boston, MA.

Davis, R.B., J.H. Bailey, M. Scott, G. Hunt, and S.A. Norton. 1978. Descriptive and Comparative Studies of Maine Lakes. Life Sciences and Agriculture Experimental Station. Technical Bulletin 88. University of Maine-Orono. Orono, ME.

Dennis, J. 1975. Those Blooming Algae. Maine Fish and Wildlife. Summer 1975. Photocopy.

Dennis, J. 1986. Phosphorus Export From a Low Density Residential Watershed and An Adjacent Forested Watershed. Maine Department of Environmental Protection. Augusta, ME.

Dennis, J. 1986. Nutrient Loading Impacts: Lake and Reservoir Management. Maine Department of Environmental Protection. Augusta, ME.

Dominie, H. and J. Scudder. 1987. Land Use Impacts of Development: A Study Summary. Maine State Planning Office. Augusta, ME.

EPA (United States Department of Environmental Protection). 1980. Design Manual- On Site Waste Water Treatment And Disposal Systems. United States Environmental Protection Agency- Office of Water Program Operations Municipal Environmental Research Laboratory.

EPA (United States Department of Environmental Protection). 1990. Predicting Lake Water Quality, in The Lake and Reservoir Restoration Manual, Chapter 4. United States Department of Environmental Protection.

Fernandez, I.J., J.S. Kahl, and D.P. Nieratko. 1992. Evaluation of Natural Factors Controlling Phosphorus Loading to Maine Lakes. University of Maine Orono, Orono, ME.

Finayson, M. and M. Mosar. 1991. Wetlands. International Waterfowl and Wetlands Research Bureau (IWRB). New York, NY.

Frey, D.G. 1963. Limnology in North America. University of Wisconsin Press. Madison, WI.

Godfrey, P. J., E. R. Kaynor, S. Pelczarski, and J. Benforado. 1985. Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Van Nostrand Reinhold. New York, NY.

Goldman, C. and A.J. Home. 1983. Limnology. McGraw-Hill Inc. New York, NY.

Gore, A. 1983. Ecosystems of the World. Volume 4A. Elsevier Publishing Co. New York, NY.

Greenberg, A. E., L. S. Clesceri, and A.D. Eaton. 1992. Standard Methods for the Examination of Water and Wastewater. Eighteenth Edition. American Public Health Association. Washington D.C.

Hach. 1991. D/R 3000 Spectrophotometer Instrument Manual. Hach Company. Loveland, CO.

Henderson-Sellers, B. and H.R. Markland. 1987. Decaying Lakes. John Wiley and Sons. NY.

Hendler, B. 1973. Subdividing in the Wetlands of Maine. Maine Land Use Regulation Commision. Augusta, ME.

Hunter, R. and R.Bickford-Caret. 1990. Oakland Comprehensive Land Use Plan. Oakland Town Office and Planning Commission. Oakland, ME.

Jorgensen. 1978. Southern New England. Sierra Club Books. San Fransisco, CA.

KCSWCD (Kennebec County Soil and Water Conservation District). 1993. Camp Road Maintenance Manual: A Guide For Landowners. Kennebec County Soil and Water Conservation District. Augusta, ME.

KCSWCD (Kennebec County Soil and Water Conservation District). 1991. Maintenance Guidelines for Secondary Gravel Roads. Kennebec County Soil and Water Conservation District.

Lea, F., T. Landry, and B. Fortier. 1990. Comprehensive Planning For Lake Watersheds. Androscoggin Valley Council of Governments.

Lerman, A. 1978. Lakes- Chemistry, Geology, Physics. Springer-Verlag. New York, NY.

Lyon, J.G. 1993. Practical Handbook for Wetland Identification and Delineation. Lewis Publishers. Ann Arbor, MI.

Maitland, P.S. 1990. Biology of Fresh Waters. Chapman & Hall. New York, NY.

McKee, J. E. and H.W. Wolf. 1963. Water Quality Criteria. Second Edition. The Resources Agency of California State Water Quality Control Board Publication No. 3-A. Sacramento, CA.

MDC (Maine Department of Conservation). 1983. Land Use Plan. Land Use Regulation Commission. Augusta, ME.

MDC (Maine Department of Conservation). 1990. Amendment of the Comprehensive Land Use Plan, Regarding the Development and Conservation of Lakes in Maine's Unorganized Areas. Maine Department of Conservation Augusta, ME.

MDEP (Maine Department of Environmental Protection). 1980. Salmon Lake Restoration Grant Application. MDEP (Maine Department of Environmental Protection) Bureau of Water Quality Control Division of Lakes and Biological Studies. Augusta, ME.

MDEP (Maine Department of Environmental Protection). 1987. The Restoration of Salmon Lake. Maine Department of Environmental Protection. Augusta, ME.

MDEP (Maine Department of Environmental Protection). 1990. State of Maine Guidelines for Municipal Shoreland Zoning Ordinances. Maine Department of Environmental Protection. Augusta, ME.

MDEP (Maine Department of Environmental Protection). 1991. Proposed Amendments to the Subdivision Ordinance for the Town of Dedham. Maine Department of Environmental Protection. September 21, 1991. Augusta, ME.

MDEP (Maine Department of Environmental Protection). 1992a. Phosphorus Control in Lake Watersheds: A Technical Guide to Evaluating New Developement. Maine Department of Environmental Protection. Augusta, ME.

MDEP (Maine Department of Environmental Protection). 1992b. State of Maine Guidlines for Municipal Shoreline Zoning Ordinances. Maine Department of Environmental Protection, Augusta, ME.

MDEP (Maine Department of Environmental Protection). 1993. Water Quality Computer Data for Salmon Lake. Maine Department of Environmental Protection. Augusta, ME.

MDEP and MSPO (Maine Department of Environmental Protection and the Maine State Planning Office). 1990. Watershed: An Action Guide to Improving Maine Waters. Maine State Offices. Augusta, ME.

MDHS (Maine Department of Human Services, Division of Engineering). 1980. State of Maine Subsurface Wastewater Disposal Rules-Chapter 241. Department of Human Services. Augusta, ME.

MDHS (Maine Department of Human Services). 1983. Site Evaluation for Subsurface Wastewater Disposal Design in Maine Second Edition. No. Maine Department of Human Services, Division of Health Engineering. Second Edition. Augusta, ME.

MDHS (Maine Department of Human Services). 1988. State of Maine Subsurface Wastewater Disposal Rules. Augusta, ME.

MDHS (Maine Department of Human Services-Division of Health Engineering). 1993. Subsurface Wastewater Disposal System Application. Maine Department of Human Services. Augusta, ME.

MDOT (Maine Department of Transportation). 1986. Roadway Fundamentals for Municipal Officials. Maine Department of Transportation. Augusta, ME.

Miller, D.W. 1980. Waste Water Disposal Effects on Ground Water. Premier Press. Berkeley, CA.

Mitchell, R. 1974. Introduction to Environmental Microbiology. Prentiss-Hill. Englewood Cliffs, NJ.

Mitsch, W.J. and J.G. Gosselink. 1993. Wetlands. Second Edition. Van Nostrand Reinhold Co. New York, NY.

MLURC (Maine Land Use Regulation Commission). 1977. Land Use Districts and Standards for Areas within Jurisdiction of the Maine Land Use Regulation Commission. Department of Conservation. Augusta, ME.

Montgomery, C. W. 1989. Environmental Geology. Wm. C. Brown. Dubuque, IA.

Nebel, B.J. 1987. Environmental Science: The Way The World Works. Prentice-Hall, Inc. Englewood Cliffs, NJ.

Nichols, W., J.W. Sowles, and J.J. Lobao. 1984. Phosphorus Loading to McGrath and Ellis Pond, Kennebec County, Maine. Maine Department of Environmental Protection (U. S. Geological Survey). Water Resources Investigation Report no. 84-4177. Augusta, ME.

Niering, W.A. 1985. Wetlands. Alfred A. Knopf, Inc. New York, NY.

NKRPC (North Kennebec Regional Planning Commission). 1993. Salmon and McGrath Data. North Kennebec Regional Planning Commision. Winslow, ME.

Oakland, Town of. 1991. Shoreland Zoning Ordinances for the Municipality of Oakland. Town Office of Oakland, Code Enforcement Officer,(Paul Lussier) and Town Planning Board. November 26, 1991. Oakland, ME.

Pearsall, W. 1991. Understanding Maine's Lakes and Ponds: A Guide For the Volunteer Monitoring Program. Maine Department of Environmental Protection- Division of Environmental Evaluation and Lakes Studies. Augusta, ME.

Prescott G. C. Jr. 1969. Ground-water Favorability Areas and Surficial Geology of the lower Kennebec River Basin, Maine. Hydrologic Investigations Atlas HA-337. U.S. Dept. of Interior, U.S. Geological Survey, Washington, D.C.

Reckhow, K. H and S. Chapra. 1983. Engineering Approaches for Lake Management. Butterworth. Boston.

Reid, G. K. 1961. Ecology of Inland Waters and Estuaries. Reinhold Publishing Corporation. New York, NY.

Reid, G.K. 1987. Pond Life. Golden Guides. Western Publishing Company. New York, NY.

Shroeder, D.C. 1979. Phosphorous Export from Rural Maine Watersheds. Land and Water Re sources Center, University of Maine-Orono. Orono, ME.

Smith, R.L. 1990. Ecology and Field Biology. Fourth Edition. Harper Collins Publishers. New York, NY.

Smith, R.L. 1992. Elements of Ecology. Harper Collins Publishers. Third Edition. New York, NY.

Stauffer, R.E. 1990. Alkalinities of Maine Lakes: Are They Really Changing? Limnology and Oceanography. 35. 1238-57.

University of Maine Soil and Water Conservation Commission. 1972. Maine Guidelines for Manure and Manure Sludge Disposal on Land. University of Maine Soil and Water Conservation Commission.

USDA (United States Department of Agriculture-Soil Conservation Service). 1978. Soil Survey of Kennebec County, Maine.

USDA (United States Department of Agriculture-Soil Conservation Service). 1992. Engineering Criteria for Soil Series Mapped in Maine.

USGS (United States Geological Survey). 1979. Water Resources Data for Maine.

USGS (United States Geological Survey). 1980. Water Resources Data for Maine.

Woodard, S.E. 1989. The Effectiveness of Buffer Strips to Protect Water Quality. University of Maine Orono, Orono, ME.

APPENDICES

A. On-site and Laboratory Water Quality Tests

B. Quality Assurance

C. Results of Samon Lake Water Quality Tests

D. Phophorus Loading Model

E. Predictions for Annual Mass Rate of Phosphorus Inflow

F. Road Index

G. Personal Communications

Appendix A. Table 1. Summary of the water quality test results for the lake sites of McGrath and Ellis Ponds. All samples collected are core samples on 27SEP1993, unless otherwise noted. See Figure 12 in the text for location of sites.

Site	P (ppb)	Nitrates/nitrites (ppm)	Hardness (mg/l)	Color (SPU)	Turbidity (FTU)	Conductivity (µmhoms/cm²)	Transp. (m)	pH	Chlorophyll a (ppb)	Surface DO(ppm)
1	8.9t	0.01‡	26.5	10	3	54	-	-	-	-
2	8.3t	0.00‡	-	-	2	55	-	-	-	-
3	13.6t	0.00t	-	-	1	79	-	-	-	-
4	9.5	0.00‡	26.6	9	2	140	2.5	7.6	2.2	9.2
5	8.9	0.00	26.8‡	13	2	58	-	-	-	9.2
6	14.9t	0.00	23.3	13	2	46	-	-	-	9.0
7	14.3t	0.04t	-	-	3	-	-	-	-	-
8	11.5(147)	0.00‡	23.7(28.8)	18	2	48	3.25	7.5	4.2	8.8
9	16.2	0.00	-	-	3	46	-	-	-	-
10a	7.9	0.00	-	-	2	170	-	-	-	-
11	10	0.00	-	-	3	50	-	-	-	-
12	9.8	0.00	-	-	2	45	-	8.0	-	-
13^	9.0	0.00	-	-	2	46	-	8.0	-	-

Key: ( ) indicates value from bottom sample
^ indicates duplicate samples taken, average is reported
‡ indicates sample taken 4OCT1993
t indicates sample taken from surface as opposed to a core sample

Appendix A. Table 2. Summary of the water quality test results for the tributary sites of the McGrath and Ellis Pond watersheds. See Figure 12 in the text for locations of sites.

Site	P (ppb)	Nitrates/nitrites (ppm)	Turbidity (FTU)	Conductivity (μmhoms/cm2)	pH	Surface DO(ppm)	Flow (L/min)
14	10.7	0.00	6	60	6.13	8.9	0
15	17.7	0.00	17	480	6.11	3.8	0
16	7.0	0.00	12	150	6.45	5.0	0
17	1.8^	0.19‡	3	229^	6.73	10.1	11.7
20	10.8	0.00	3	96	7.30	-	-
21a	39	0.00	28	390	6.86	7.7	-
21b	31.5	0.02	-	-	-	-	-
22	18.0	0.03	11	142	6.90	-	-
23	9.2^	0.00	13	157^	6.97	6.8	392.0
24	8.8‡	0.00	30	51^	6.83	-	283.0
25	7.0‡	0.05	20	45^	5.70	7.7	134.3

Key: ^ indicates value reported is an average of samples collected on 27SEP1993 and 4OCT1993
‡ indicates sample taken 4OCT1993

Appendix B. On-site and laboratory water quality tests conducted on Salmon Lake and selected tributaries. Sample sites and dates of sampling and analysis are indicated. Refer to site map in text for locations of sites.

Test	Sampling Date	Date of Analysis	Sites Tested
Physical Factors			
Depth	27SEP1993	27SEP1993*	1-6,8,12,13
Temperature	27SEP1993	27SEP1993*	4-6,8,10b,14-17,20,21a,22-25
Dissolved Oxygen	27SEP1993	27SEP1993*	4-6,8,14-17,21a,23-25
Transparency	27SEP1993	27SEP1993*	4,8
Turbidity	27SEP1993	28SEP1993	1-8,9-17,20,21a,22-25
	4OCT1993	5OCT1993	17,23-25
Conductivity	27SEP1993	3OCT1993	1-6,8,9-17,20,21a,22-25
	4OCT1993	11OCT1993	17,23-25
Chemical Factors			
Total Phosphorus	27SEP1993	29SEP1993	1-8,9-17,20-25
	4OCT1993	14OCT1993	17,23-25
Nitrates/Nitrites	27SEP1993	28SEP1993	3,5-7,9-17,20-25
	4OCT1993	5OCT1993	1,2,4,6,8,17
Hardness	27SEP1993	3OCT1993	1,4,6,8
	4OCT1993	11OCT1993	5,23
Color	27SEP1993	27SEP1993	1,4-6,8
pH	27SEP1993	27SEP1993*	4,8,13-17,20,21a,22-25
Biotic Factors			
Chlorophyll a	4 Oct 93	18OCT1993**	4,8

*These parameters were determined on-site. **Analyzed by Northeast Laboratory, Winslow, ME.

Appendix C: Quality Assurance Package

Secchi Disk

The secchi disk was lowered until it was out of site. Then the depth was recorded. The disk was then lowered an extra meter and then brought back into sight. This depth was also recorded. The average of these two values is the transparency. This process was repeated two more times and the average of all three trials was averaged for the final transparency value.

Depth Line

The depth line was dropped into the water until slack was felt. The slack was gently pulled out of the line while being careful not too lift to hard and pull the sinker out of the bottom. This depth was recorded. This process was repeated one more time and an average was taken of the two values.

pH

Before any testing, the pH meter was calibrated using a 3 point calibration method with standards for pH 4, 7, and 10. This was only done once during the testing day, unless the meter's calibration was inadvertently deleted.

Dissolved Oxygen Meter

The electrode was calibrated using a saturated water solution. To measure DO the electrode was placed in the water and the DO was recorded once the reading stabilized. At lake sites the electrode was moved up and down to create a flow around the electrode to obtain a more accurate reading.

Water Sampling

The water samples were taken from boats on the lake. When approaching a site, the boat sped up, turned off the engine, and then drifted into the site. Sampling was done from the bow of the boat and into the wind. When surface sampling, the bottle was held upside down and filled with water by pushing horizontally away from the boat to 0.5 m below the surface. The bottle was then lifted out of the water and capped. There was no contact between the hands and the sampled water. Bottle lids, if contaminated, were rinsed with distilled water. All bottles were washed and rinsed with 1:1 HCl prior to use. Bottles used for most sampling were polyethylene, and those used for phosphorus were polymethylpentene. Core samples were taken by slowly lowering plastic tubing into the water to the desired depth. The top was pinched to hold the sample in the tube while being raised out of the water and it was then emptied into the appropriate sampling container.

Maximum Holding Times

The maximum holding time allowed prior to testing varied by test. Most of the tests were conducted well before the maximum holding time was reached. The maximum holding times for the tests that we conducted are listed in Table 1.

Table 1. Maximum holding time of the water samples to ensure accuracy for the tests performed (Greenberg et al. 1992).

Test	Maximum Holding Time
Turbidity	48 Hours
Conductivity	28 Days
Total Phosphorus	28 Days
Nitrates/ Nitrites	48 Hours
Hardness	6 Months
Color	48 Hours
Chlorophyll a	30 Days in Dark

Preservation of Nitrate and Hardness Samples

To prepare water samples for analysis of hardness, nitric acid was added drop by drop to the sample. To prepare samples for nitrate analysis, sulfuric acid was added in a similar manner. To do this the bottle lids were rinsed with distilled water, then a small amount of the sample was added to the lid. The pH of the water in the lid pH was then tested. If the pH was lower than 2, then the bottle was capped. If the pH was not lower than 2, the appropriate acid was added drop by drop until it was. The same number of drops of acid were then added to all of the other bottles of the same size and same test.

Laboratory Testing

To ensure accuracy of laboratory and sampling procedures several steps were taken. Duplicate samples were taken once for every test. Also, one split, one spike, one blank, and one standard were run for each test when possible.

Appendix D: Phosphorus Loading Model

This was applied to McGrath and Ellis Ponds, using the same coefficients in both ponds.

$W = (Ec_a \times A_{s1}) + (Ec_f \times Area_f) + (Ec_w \times Area_w) + (Ec_c \times Area_c) + (Ec_r \times Area_r) + (Ec_s \times Area_s) + (Ec_n \times Area_n) + ((Ec_{ss} \times \text{\# of capita years}_1 \times (1-SR_1)) + (Ec_{ns} \times \text{\# of capita years}_2 \times (1-SR_2)) + Ec_{cs} \times (1-SR_3)) + PSI$

Ec_a= export coefficient for atmoshperic input [ka/ha-yr]

0.15-0.5 The general range is 0.15-0.6. Salmon Lake is similar to the description of the Higgins Lake case study where little agricultural and industrial activity takes place, which probably result in small quantities of airborne phosphorus. (The export coefficient is multiplied by the area of the pond As1).

Ec_f= export coefficient for forested land [ka/ha-yr]

0.06-0.2 The general range is 0.02 to 0.45, and the values used for Higgins Lake were 0.10 to 0.30, which was mostly coniferous forest. The forest surrounding McGrath and Ellis Ponds extends quite a distance away from the lake, the distant portions not contributing much phosphorus at all. Therefore, our values are slightly lower.

Ec_w= export coefficient for wetlands [ka/ha-yr]

0.03-0.2 This coefficient is from the Pattee Pond (1993) and East Pond study (1991).

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

0.1-0.9 Reckow and Chapra (1983) have agricultural land coefficients ranging from 0.1 to 3.0, with Higgins Lake ranging from 0.2 to 1.3. This is the equivalent of cleared land in the Salmon Lake watershed, as there is little active agriculture. Therefore, the cleared land in the Salmon Lake watershed has lower coefficients. Pattee Pond study gave a range from 0.1-1.0, and East Pond used 0.25-0.6. Salmon Lake does not have as much cleared agricultural land as East Pond.

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

0.3-1.5 Values from the Pattee Pond study are 0.8-4.0, reflecting many poorly maintained and eroding roads. Roads in the watershed surrounding Salmon Lake are fairly good, with occasional areas of s in small quantities of airborne phosphorus. (The export coefficient is multiplied by the area of the pond A_{s1}).

Ec_f= export coefficient for forested land [ka/ha-yr]

0.06-0.2 The general range is 0.02 to 0.45, and the values used for Higgins Lake were 0.10 to 0.30, which was mostly coniferous forest. The forest surrounding McGrath and Ellis Ponds extends quite a distance away from the lake, the distant portions not contributing much phosphorus at all. Therefore, our values are slightly lower.

Ec_w= export coefficient for wetlands [ka/ha-yr]

0.03-0.2 This coefficient is from the Pattee Pond (1993) and East Pond study (1991).

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

0.1-0.9 Reckow and Chapra (1983) have agricultural land coefficients ranging from 0.1 to 3.0, with Higgins Lake ranging from 0.2 to 1.3. This is the equivalent of cleared land in the Salmon Lake watershed, as there is little active agriculture. Therefore, the cleared land in the Salmon Lake watershed has lower coefficients. Pattee Pond study gave a range from 0.1-1.0, and East Pond used 0.25-0.6. Salmon Lake doesn't have as much cleared agricultural land as East Pond.

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

0.3-1.5 Values from the Pattee Pond study are 0.8-4.0, reflecting many poorly maintained and eroding roads. Roads in the watershed surrounding Salmon Lake are fairly good, with occasional areas of erosion. Coefficients are consequently lower.

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

0.8-3.2 The general range given by Reckhow and Chapra was 0.5-5.0. The Higgins Lake case study was described as mostly residential/recreational with all units served by septic systems. The range was 0.35-2.7. Pattee Pond has equal amount of septic and holding tanks and many privies, giving a higher estimate of 1.5-5.0. Salmon Lake is probably in the middle of these two examples.

Ec_n= export coefficient for non-shoreline development [ka/ha-yr]

0.35-1.5 Non-shoreline structures have less impact in general than shoreline homes, and therefore the coefficients are lower. In addition, many houses in the watershed are quite far from the lake shore and probably contribute very little phosphorus.

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

0.4-1.0 The general range is 0.3-1.8. The coefficients used in the Higgins Lake study were 0.3-1.0, and in Pattee Pond, 0.6-1.8. Salmon Lake septic characteristics were closer to those of Higgins Lake.

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

An estimate of 3.5 persons per living unit was used in the Higgins Lake study. As in the Pattee Pond study, the time spent at living units for seasonal residents for our study is estimated at 50 days/yr. The number of units considered for permanent versus seasonal residence was determined using both the structure map and the on site survey. There are 96 shoreline homes on McGrath Pond and 131 on Ellis. The phosphorus contribution from shoreline homes for McGrath is 47.04 kg/yr and for Ellis it is 62.81 kg/yr.

SR_1=soil retention coefficient for shoreline development

0.4 This is an estimate of how well the soil is able to immobilize phosphorus ranging from 0 to 1. A value of 1 indicates that the soil is able to tie up all the phosphorus (none of it will reach the lake) and a value of 0 indicates that all the phosphorus entering the soil eventually reaches the lake (Reckhow and Chapra 1983). Pattee Pond used a value of 0.6, and has soils with better retention than the glacial till surrounding Salmon Lake. Therefore, our retention is lower.

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

0.4-0.9 The Pattee Pond report (Colby BI493 1993) uses 0.4-1.8. The general range is 0.3-1.8. The condition of the septic tanks around McGrath and Ellis Ponds is better than those around Pattee Pond. Therefore, the high estimate is lower than that of Pattee Pond.

# of capita $years_2$ = # of persons contributing to septic systems (non-shoreline residents)

An estimate of 3.5 people per living unit was used, with the time spent in each unit at 365 days per year. There are 140 non-shoreline units in the McGrath Pond watershed and 193 in the Ellis watershed. Values obtained for non-shoreline phosphorus contributions are 490 kg/yr for McGrath and 675.5 kg/yr for Ellis.

SR_2 = soil retention coefficient for non-shoreline development [dimensionless]

0.8 As phosphorus exported from non-shoreline areas has a greater chance of being absorbed, a larger soil retention coefficient was used. Many non-shoreline lots are a great distance from the ponds, and probably do not contribute much, if any, phosphorus to McGrath and Ellis Ponds.

Ec_{cs}= combined export coefficient and # capita years for Camp Modin, Camp Kennebec, and Camp Tracy.

These numbers were calculated by using the design manual by the U.S. Environmental Protection Agency (1980) which lists numbers for pollutant concentrations of major residential wastewater fractions (23 mg/l) and typical wastewater flow from institutional sources (52.8-106 gal day/

unit). The Camps are treated as seasonal residences (90 days/yr). Camp Modin, and Camp Kennebec have approximately 100 and 250 people, respectively. Camp Tracey has 120 people. McGrath Pond, with Camp Tracey, has a value between 38.6-77.5 kg/yr. Ellis Pond, with both Modin and Kennebec, has a value between 140.6-400 kg/yr.

SR_3 = soil retention coefficient used for the Commercial Camps [dimensionless]

0.7 As the septic systems for the summer camps are located far from the lake shore (500-1000 feet), a larger soil retention coefficient than normal shoreline development was used.

As1=area of the ponds

McGrath = 190.78 ha

Ellis = 274.97 ha

PSI=point source input [ka/ha-yr]

At present, there are no known point sources of phosphorus in the Salmon Lake watershed, therefore PSI = 0 kg/yr.

Appendix E: Predictions For Annual Mass Rate Of Phosphorus Inflow

Equations

$$L = W/A_S$$

where, L = areal phosphorus loading (kg/m^2yr)
W = annual mass rate of phosphorus inflow (kg/yr)
A_S = surface area of the lake (m^2)

$$q_S = Q/A_S$$

where, q_S = areal water loading (m/yr)
Q = inflow water volume (m3/yr)

$$P = L/(11.6+1.2q_S)^*$$

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

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

Constants for both predictions for McGrath Pond

As = 1,907,800 m^2

Q = 8,322,883 m^3/yr

qs = 4.3625 m/yr

Low Prediction

WL= 218.12 kg/yr
LL= 1.114×10^{-4} $kg/m^2/yr$
PL =1.114 x $kg/m^2/yr/[11.6+1.2(4.3625\ m/yr)]$
= $6.79 \times 10^{-6}\ kg/m^3)(10^6\ mg/kg)(m^3/L^3)(10^3\ ppb/ppm)$
= 6.79 ppb

High Prediction

WH =812.88 kg/yr
LH = 4.26×10^{-4} $kg/m^2/yr$
PH = $4.26 \times 10^{-4}\ kg/m^2/yr)[(11.6+1.2(4.362)]$
= $25.3 \times 10^{-6}\ kg/m^3)(10^6\ mg/kg)(m^3/L^3)(10^3\ ppb/ppm)$
= 25.31 ppb

Constants for both predictions for Ellis Pond

$As = 2,749,700\ m^2$

$Q = 15,621,924\ m^3/yr$ (equal to the inflow volume of McGrath+Ellis)

$qs = 5.68\ m/yr$

Low Prediction

$WL = 250.1\ kg/yr$
$LL = 1.70 \times 10^{-4}\ kg/m^2/yr$
$PL = 1.07 \times kg/m^2/yr/[11.6+1.2(5.68\ m/yr)]$
$= 9.2 \times 10^{-6}\ kg/m^3)(10^6\ mg/kg)(m^3/L^3)(10^3\ ppb/ppm)$
= 9.2 ppb

High Prediction

$WH = 889.2\ kg/yr$
$LH = 6.19 \times 10\text{-}4\ kg/m^2/yr^{\dagger}$
$PH = 6.19 \times 10\text{-}4\ kg/m^2/yr/(11.6+1.2(5.68)]$
$= 33.6 \times 10\text{-}6\ kg/m^3)(10^6\ mg/kg)(m^3/L^3)(10^3\ ppb/ppm)$
= 33.6 ppb

*Equations obtained from Reckow and Chapra (1983).
†(equal to the mass loading of McGrath + mass loading of Ellis).

Note: An important change in the equation involves the flow from McGrath Pond into Ellis Pond. To approximate this addition of phosphorus into Ellis Pond, we used the flushing rate of McGrath. Because 99% of McGrath Pond flushes into Ellis, we took 99% of the total mass loading from McGrath and added it to the total mass loading of Ellis.

Appendix F: Components of Road Total Index

The camp road survey was conducted using the "Camp Road Evaluation Form" obtained from the Maine DEP and designed by the Kennebec County Soil and Water Conservation District. All 39 camp roads and the dirt road, Elizabeth Street, in the watershed were surveyed (Figure 1). The roads were evaluated for surface, culverts, diversions, and ditches characteristics; The summation of these individual index values equaled the road total index reported in the "roads" part of the Land Use section of this paper. Each road was individually surveyed for all criteria. Values that were given to each section were weighted by their potential phosphorus loading impact. Each of the categories comprising the road total index had their own high scoring roads. The eight high scoring roads based on the road total index were field checked again.

The criteria used to calculate the road surface index included the quality of the road's crown, surface constituents, edge, base, usage, and an assessment of the overall road surface condition. The high scoring roads in this category were Elizabeth Street and T-5 from the McGrath Pond watershed, and S-16, S-20A, and T-8B from the Ellis Pond watershed (Figure 2). In general, these five roads displayed poor crowning, the presence of berms, and poor surface materials.

The criteria used to calculate the culverts index included the number of culverts present and/or needed, weathering (aging) of culverts, size, pitch, cover, and summary assessment of the overall culvert condition. Roads that scored high in this category included MP-4 and Random Lodge Road from the McGrath Pond watershed, and T-7 from the Ellis Pond watershed (Figure 3). Overall, the culverts in these high scoring roads required maintenance and/or more culverts were necessary.

The criteria for the diversions for water index included the number of diversions present and/or needed, where the water was directed, and a summary assessment of the overall diversion condition. The high scoring roads in this category included MP-5 from the McGrath Pond watershed, and S-20A from the Ellis Pond watershed (Figure 4). The largest problem we observed was the need for diversions for water on slopes.

The criteria used to calculate the ditches index included the number of diversions present and/or needed, depth, width, whether vegetation was lining the ditch, presence of sediments (evidence of erosion), ditch shape, and a summary assessment of overall ditch condition. The high scoring roads in this category included MP-4, Cemetery Road, Camp Tracy Road, Pleasant Point Road, Ford's Road, next to Ford's Road and T-2 in the McGrath Pond watershed, and S-17 in the Ellis Pond watershed (Figure 5). The common problems seemed to be a need for ditches, the presence of silt, and incorrect shape.

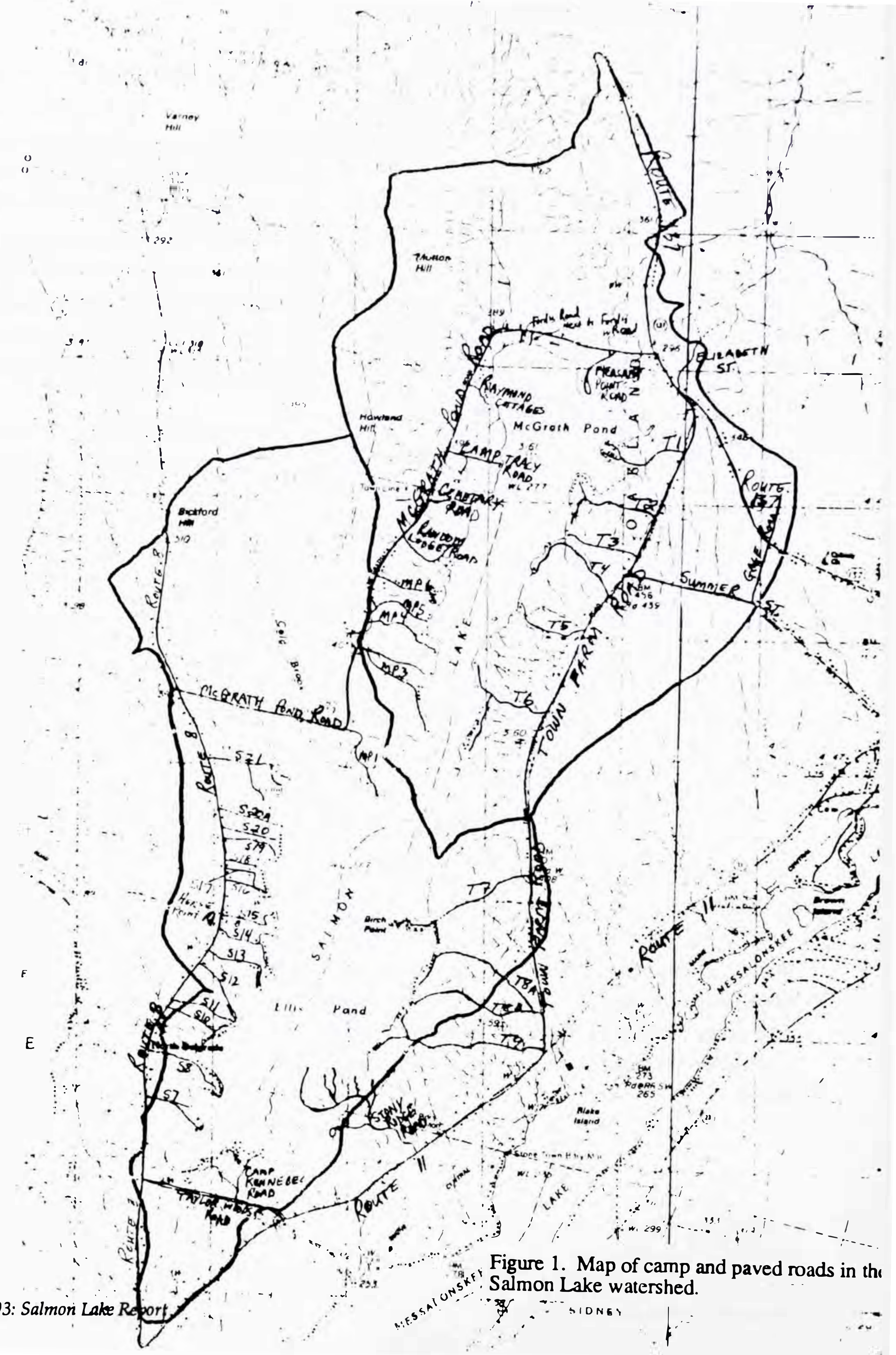
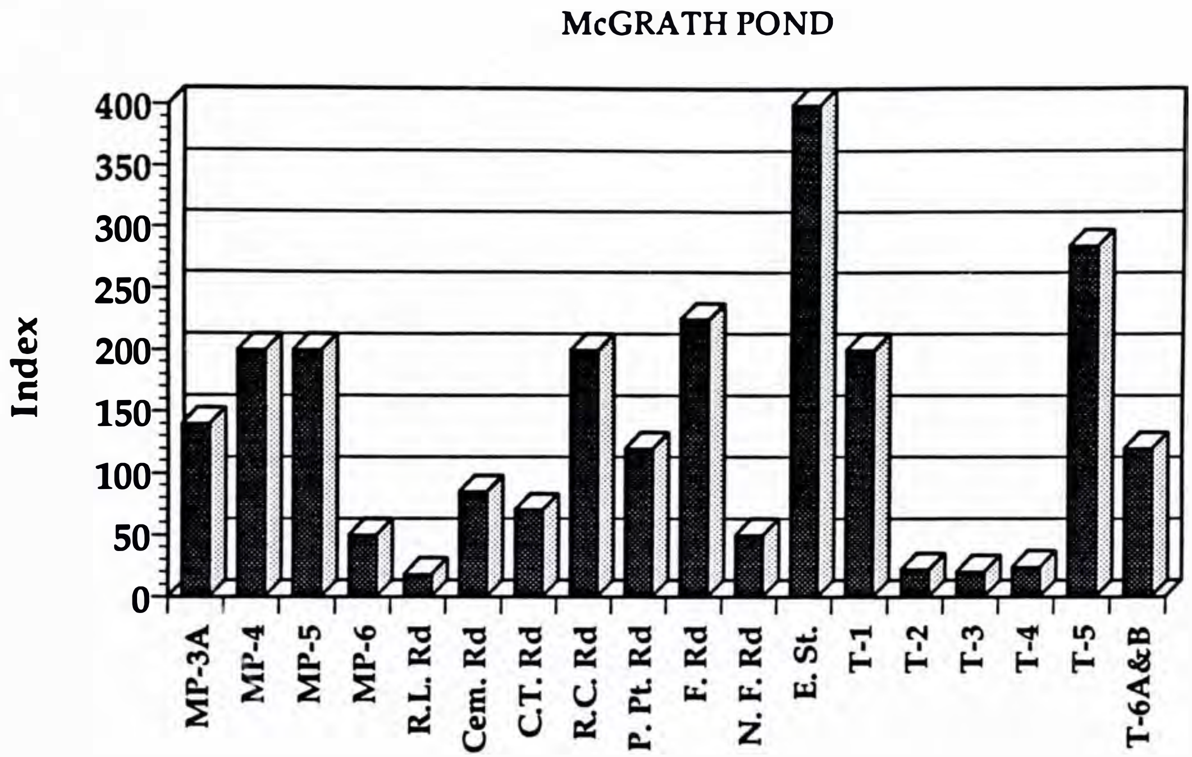


Figure 1. Map of camp and paved roads in the Salmon Lake watershed.



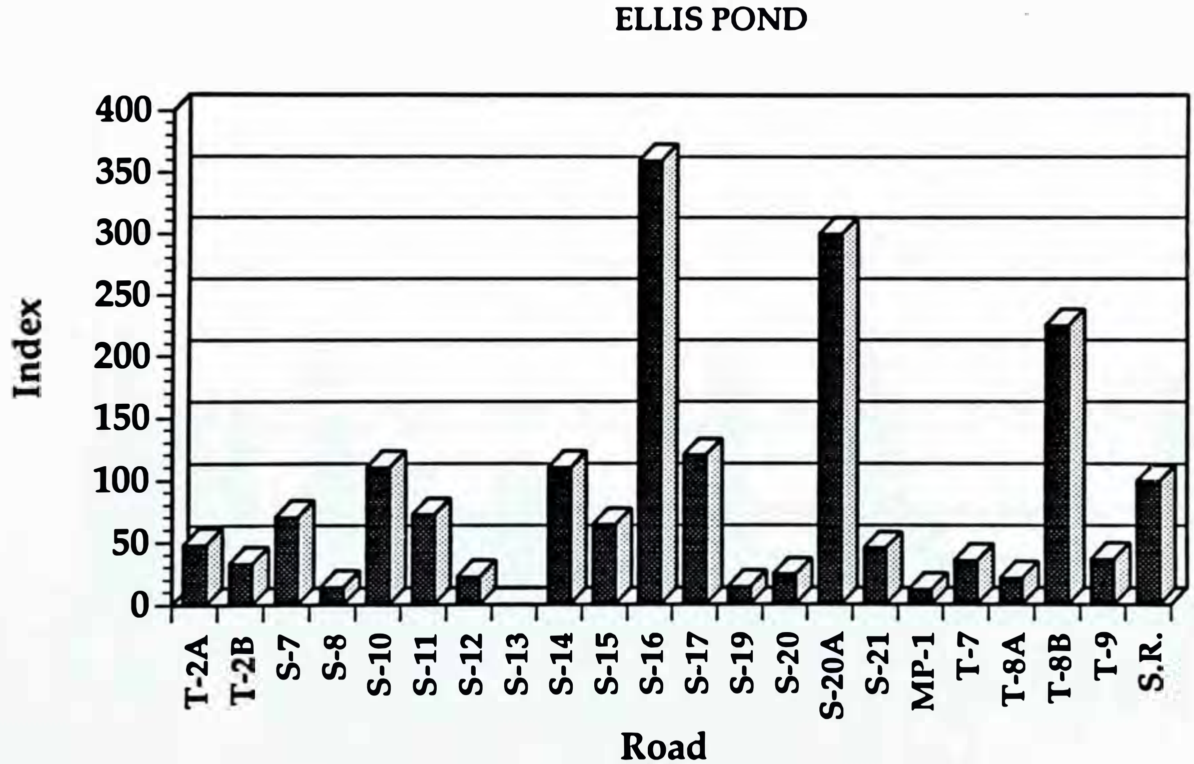


Figure 2. Surface index for the camp roads in the McGrath and Ellis subwatersheds based on surveys conducted on 4OCT93, 18OCT93, and 25OCT93. (R.L. Rd. = Random Lodge Rd., Cem. Rd. = Cemetery Rd., C.T. Rd. = Camp Tracy Rd., R.C. Rd. = Raymond Cottages Rd., P. Pt. Rd. = Pleasant Point Rd., F. Rd. = Ford's Rd., N.F. Rd. = Next to Ford's Rd., E. St. = Elizabeth St., S.R. = Stoney Ridge Development. S-13 was not surveyed.)

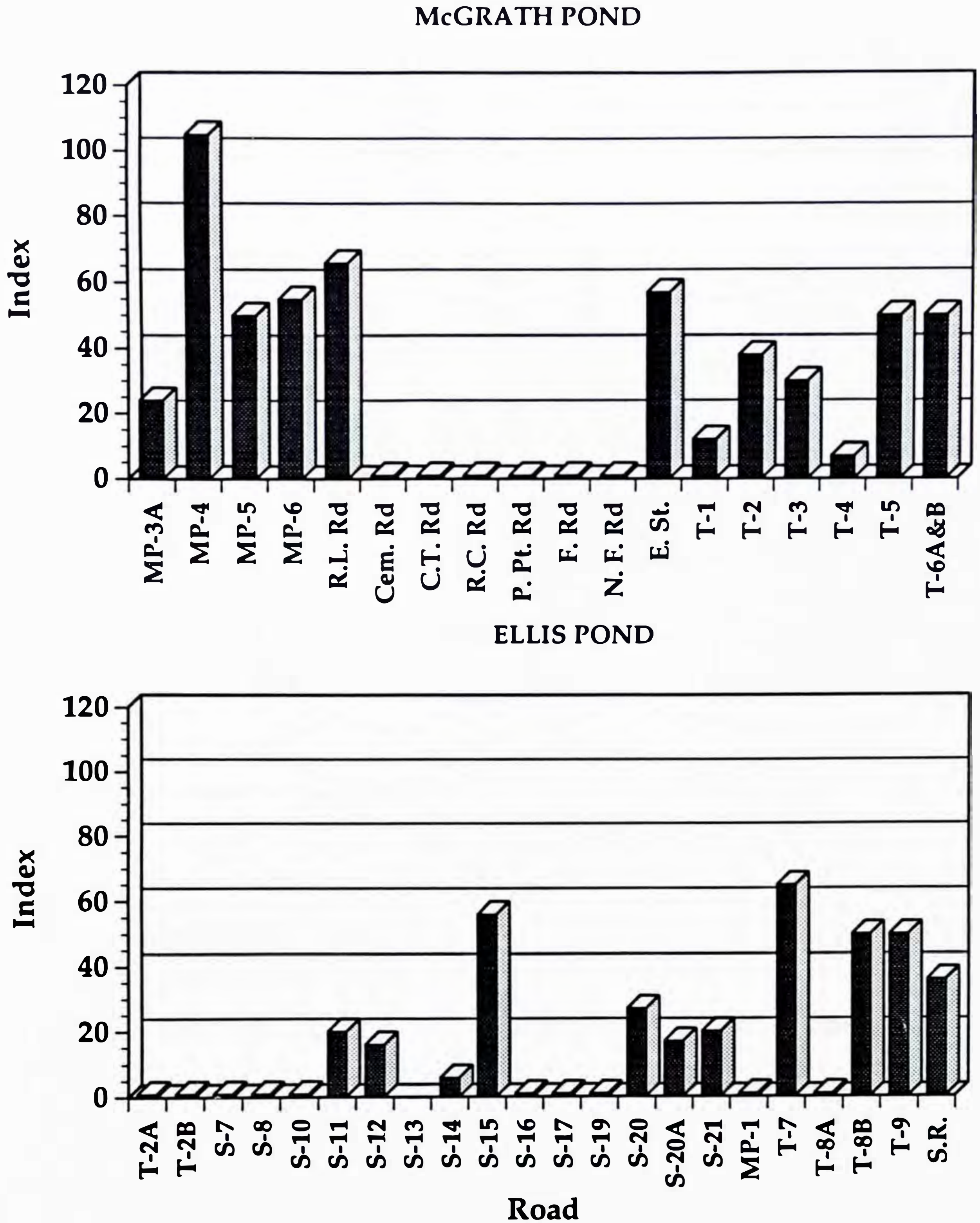


Figure 3. Culverts index for the camp roads in the McGrath and Ellis subwatersheds based on surveys conducted on 4OCT93, 18OCT93, and 25OCT93. (For road abbreviations see figure 2, S-13 was not surveyed).

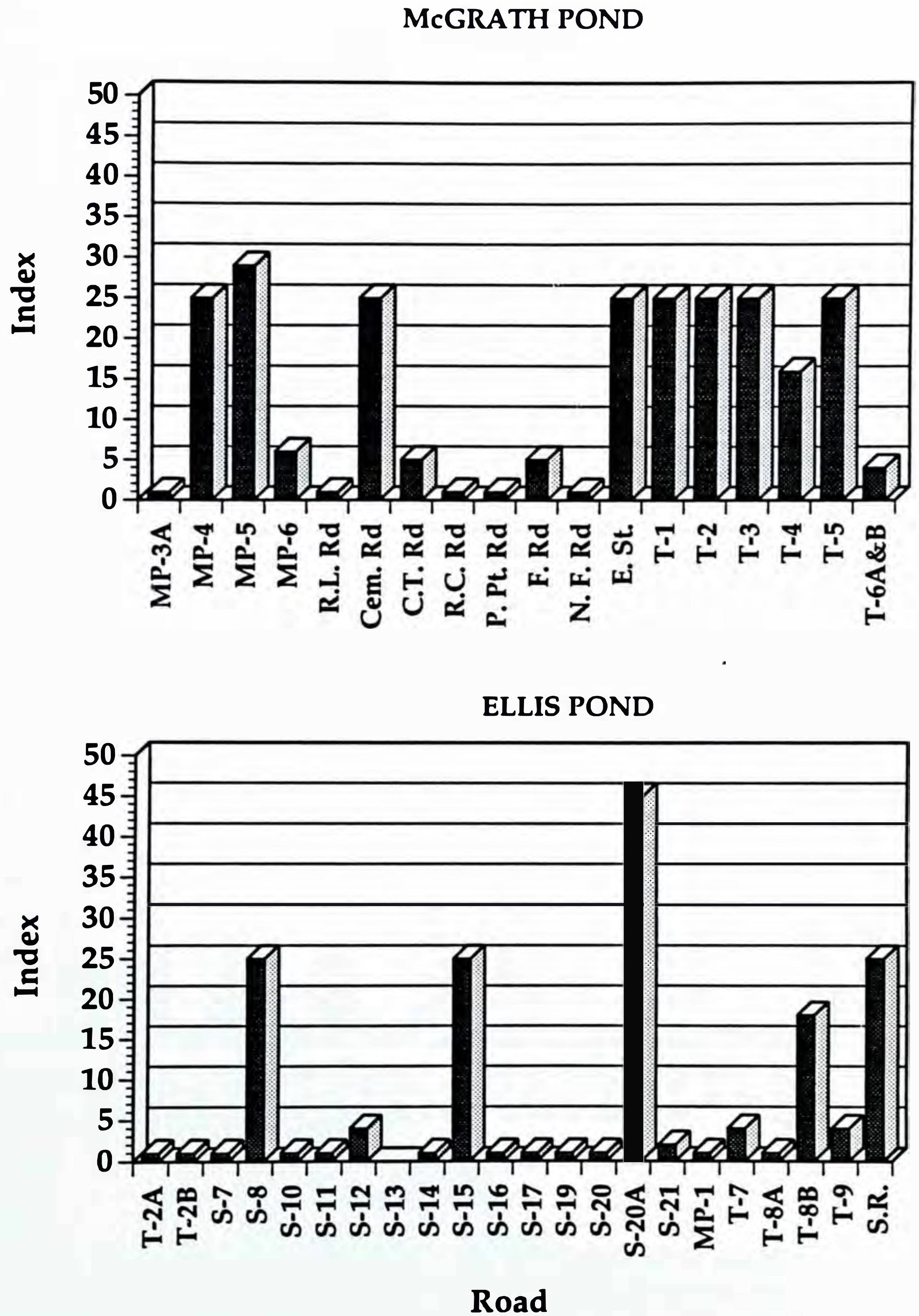
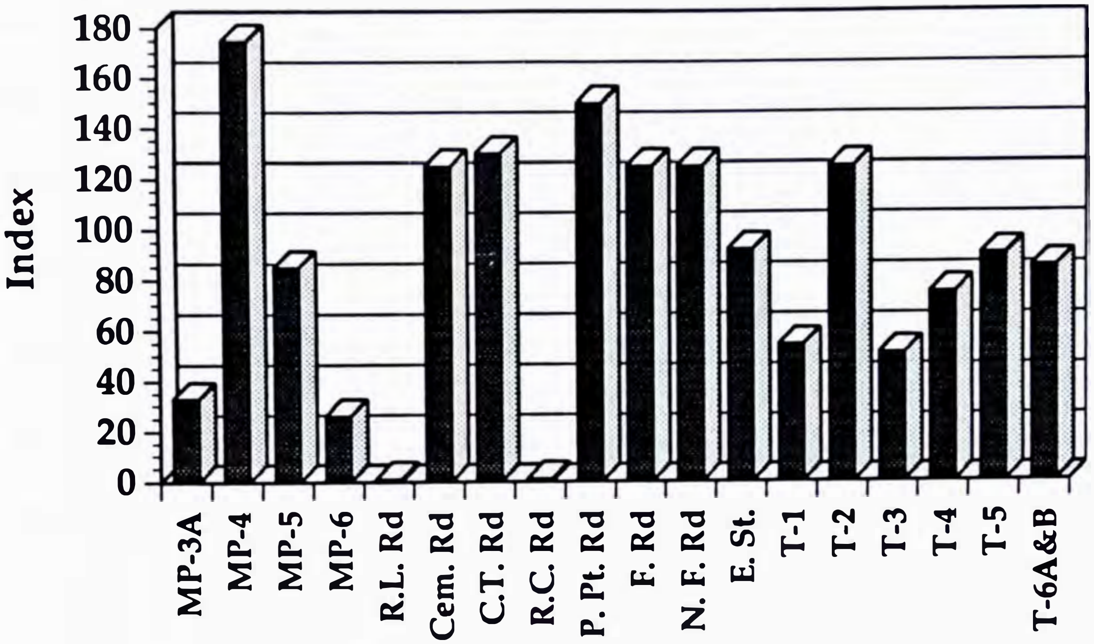


Figure 4. Diversions index for the camp roads in the McGrath and Ellis subwatersheds based on surveys conducted on 4OCT93, 18OCT93, and 25OCT93. (For road abbreviations see figure 2, S-13 was not surveyed).

McGRATH POND



ELLIS POND

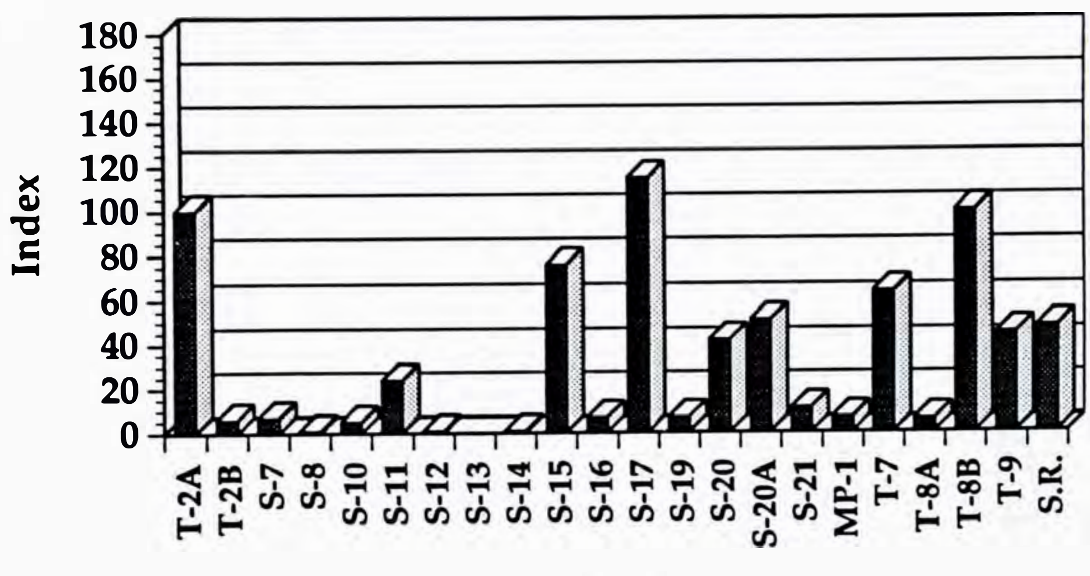


Figure 5. Ditches index for the camp roads in the McGrath and Ellis subwatersheds based on surveys conducted on 4OCT93, 18OCT93, and 25OCT93. (For road abbreviations see figure 2, S-13 was not surveyed.)

Appendix G: Personal Communications

Name	Affiliation
Ellen Bacon	Town of Belgrade, Clerk
Roy Bouchard	Maine Department of Environmental Protection
Central Maine Power	
Tim Christensen	Colby College
F. Russell Cole	Colby College
Brenda Corkum	Department of Human Services-Vital Statistics
Phil Cronwall	Camp Tracey
Paul Doss	Colby College
Charles Elvin	MDEP
David Firmage	Colby College
Tom Gordon	Formerly with the Cobbossee Water District
Gardner Hunt	MDEP
Chris Huck	Works on Oakland Dump situation, NKRPC
Michelle Jandro	Town of Oakland, Secretary
Ginny Joseph	Town of Oakland, Assessors Office
Elery Keene	Director, NKRPC
Phil Joel Lavenson	Camp Modin owner
George Lord	Town Office, China
Paul Lussier	Plumbing Inspector/Code Enforcement Officer, Oakland
Bob Martin	Part-time Plumming Inspector, Oakland (also Full-time Inspector for Belgrade)
Mitch Michaud	Soil Conservation
Carol Montgomery	Camp Kennebec
North Kennebec Regional Planning Committe	
Pam Partridge	Developer of Road Survey
Janice Porter	Town of Oakland Clerk
Bob Quinn	Town of Oakland, Manager
Len Reich	Salmon Lake watershed resident
David Sanderson	Maine Resident
Secretary	Mid-State Economics Corporation
Paula Thompson	Colby Grad, NKRPC
Mary-Ellen Dennis	MDEP-Division of Environmental Evaluations