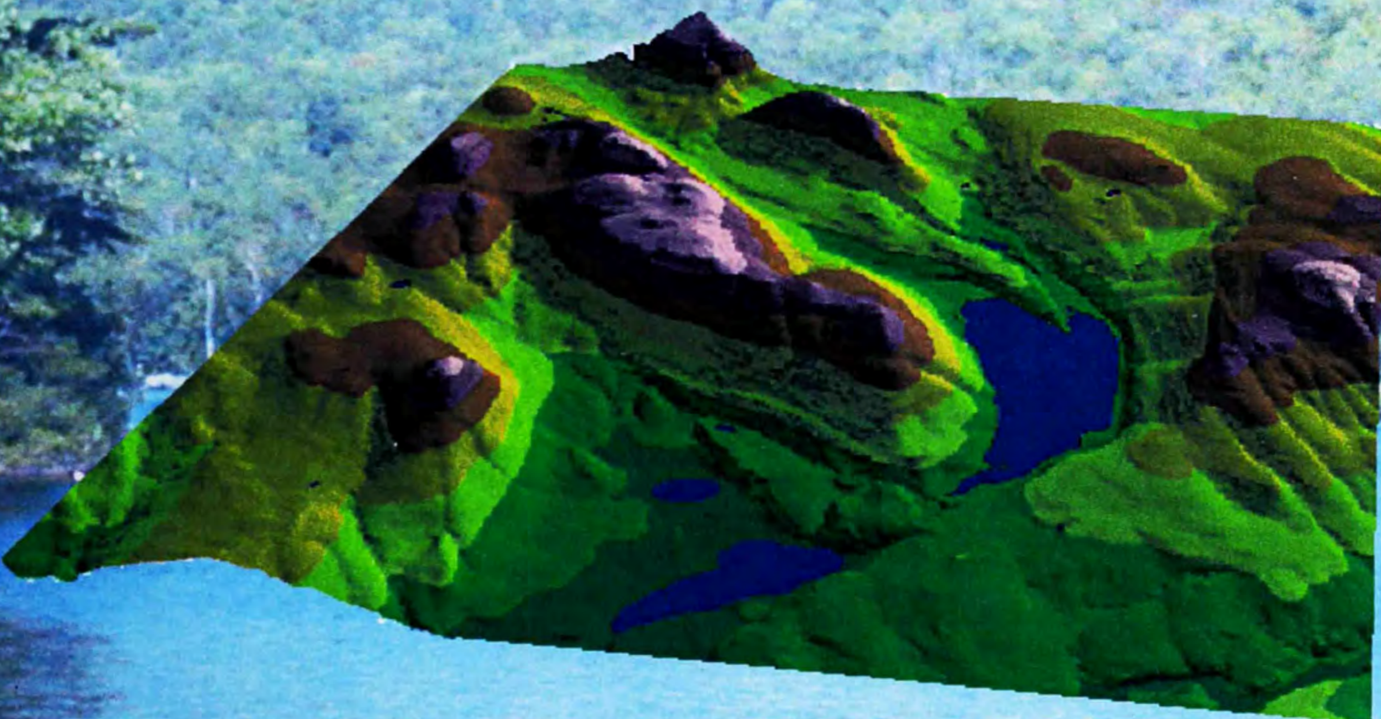
2001

Land Use Patterns in Relation to Lake Water Quality in the Lake George and Oaks Pond Watersheds

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

Colby Environmental Assessment Team, Colby College

LAND USE PATTERNS IN RELATION TO LAKE WATER QUALITY IN THE LAKE GEORGE AND OAKS POND WATERSHEDS



BI 493
Problems in Environmental Science
Colby College
Waterville, ME 04901
2001

Colby College
5720 Mayflower Hill
Waterville, ME 04901-8857

Department of Biology
phone 207-872-3322
fax 207-872-3731

May 14, 2002

To: **Report Recipients**
From: **Professor Russell Cole and Daniel Tierney**
Re: **Class Report on Lake George and Oaks Pond**

We have very much enjoyed working with the people concerned with the water quality of Lake George and Oaks Pond. We hope that the work done by Colby students and presented in this report will be of value to them and to other interested parties. We realize that some areas of the study could and perhaps should be expanded. We feel confident in the quality of the work done and only wish that more time had been available 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 2001. This course is taken by seniors who are majoring in Biology, most with a concentration in Environmental Science. The students work as though they were an environmental consulting firm. The object of the course is to teach the students how to approach a problem, how to develop a work plan, 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 other methodology as needed. Standard methods of analysis are used as well as state of the art instrumentation for any of the original analysis conducted. The methods used were those approved by EPA and/or 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 some of the new data can only be gathered in the months of September through early November and, typically, that extensive analysis can not be done. Some of the water quality data were gathered during the previous summer and made available to the class for analysis in addition to their fall sampling. 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 ways we sacrifice depth for more breadth.

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

The first section of the report provides background material, somewhat general in nature, which will help readers who are not familiar with some basic concepts concerning lakes and their watersheds. There is also a small section discussing the general features of the lake itself. The majority of the report consists of the analysis done by students during the fall semester class.

Authors

The analysis of the Lake George and Oaks Pond watersheds was conducted by the students of the Biology 493: Problems in Environmental Science class at Colby College, Waterville, Maine.

Catherine Benson
Sarah Bostick
Deandra Brassard
Matthew Goehring
Meghan Kreider
Sharon Lee
Maria Mensching
Kirsten Ness
Michael Rogalus
Melissa Sternlieb
Austin Stonebraker
Jonathan Weber

The advisors for this study were Professor F. Russell Cole and Daniel Tierney

PROJECT SUMMARY

The water quality of Lake George and Oaks Pond is currently below the critical range for phosphorus (12 to 15 ppb), which is the primary cause of algal blooms. These low levels of phosphorus are one of several characteristics that classify both lakes as mesotrophic. The results of other physical and chemical tests were also within acceptable ranges for healthy lakes with the exception of dissolved oxygen and alkalinity. Oxygen depletion is occurring in deep areas of both lakes, which can affect the cold water fisheries negatively and is an early warning sign of eutrophication. Alkalinity helps to buffer a lake by mitigating the effects of acid deposition. Our study indicates low alkalinity for both lakes and a resulting sensitivity to acid inputs. We calculated a water budget and annual flushing rate for both lakes. The flushing rate is a measure of how fast water is replaced within the lake and reflects the nutrient/pollution cleansing ability of the lake. The flushing rate for Oaks Pond is more than five times faster then that of Lake George. Consequently, Lake George has a higher sensitivity to nutrient loading than Oaks Pond. However the water quality of Lake George and Oaks Pond are closely related because Lake George drains into Oaks Pond.

A primary objective of our study was to identify land use patterns within the watersheds and document their effects on water quality because land use influences the magnitude of phosphorus inputs into the lakes. A Geographic Information System (ArcView) was an invaluable tool for analyzing land use and development trends, through the construction of composite maps and models. Land use in the watersheds changed dramatically over the 42-year period studied. A comparison of 1955 and 1997 land use patterns, made possible from aerial photographs, showed a major increase in mature forests in the Lake George watershed and a drastic decrease in agricultural land in both watersheds. The mature forests help to mitigate erosion and phosphorus loading that can affect water quality.

Active logging of these mature forests within the Lake George watershed, particularly, is a concern and use of best management practices is recommended. Compliance with the Natural Resources Protection Act is also important. Future logging is more likely but less suitable in the Lake George watershed and more suitable but less likely in the Oaks Pond watershed as determined by the logging suitability model. The model integrates soil types and slope of the land to project areas that could support logging with minimal detrimental effects on lake water quality.

Shoreline residential land increased from very few residences in 1955 to approximately 34 houses today. Oaks Pond has experienced a similar increase in the number of shoreline residences. This land use type is of particular concern because of the greater potential for nutrient loading from shoreline development and septic systems than from these activities in non-shoreline areas of the watershed. Shoreline development may cause increased erosion and phosphorus loading caused by the presence of impervious surfaces and by disturbance of shoreline vegetation. Oaks Pond is at a higher risk for these problems because of the high number of shoreline camps and the potential for conversion of camps from seasonal to year round use. Lake George is at less risk due to the Lake George Regional Park, which owns a substantial portion of the lake shoreline and subsequently reduces the potential for problems related to shoreline development. Installation of adequate shoreline buffer strips in front of residences is an economical and effective way to mitigate erosion and subsequent nutrient loading. Based on our analysis, 69 percent of buffer strips on Lake George and 33 percent of buffer strips on Oaks Pond were adequately buffered.

Roads are significant pathways for nutrients to enter the lakes. Most of the roads surrounding Oaks Pond run in close proximity to the shoreline and are an immediate threat to water quality. Two of these roads are classified as high risk. The majority of all roads in the combined Lake George and Oaks Pond watershed were classified as being a risk to lake water quality. There is one high-risk road in proximity to Lake George.

We believe that the Lake George Regional Park has been practicing ecologically sound stewardship of the land under its control. However, the public boat launch, gravel parking lots, and the east side access road are of particular concern for water quality management. These areas all contribute to erosion and potential nutrient loading. The Regional Park can play an important role in protecting Lake George by working to enhance buffering around the boat launch, parking areas, and along the park access roads. The park septic systems on the east and west sides of the park are under their projected capacity. However, increased park visitation could threaten their ability to function optimally and result in a negative impact on lake water quality. This issue is especially of concern on the east side where visitation rates are highest and the septic field is located close to the shoreline.

The Colby Environmental Assessment Team developed a phosphorus model as part of our study to project current and future phosphorus inputs into Lake George and Oaks Pond. Current projections were approximately equal to the values determined by our chemical analysis. The greatest contributors of phosphorus to the lakes determined by the model were roads, shoreline and non-shoreline residences, commercial/municipal lands, and the park. Our phosphorus model showed current inputs to be below the critical value of 12 to 15 ppb, which is the threshold for potential algal blooms. Future predictions from our model for several development and logging scenarios suggest that resulting phosphorus inputs are not likely to exceed this critical value.

Invasive plant species are not present in either lake. However, there is the potential for accidental introduction through the launching of contaminated boats. Invasive aquatic plant species can cause serious economic and ecological damage to lake communities and to the recreational resources of the lakes. Education of boat owners is an important preventative measure that should be undertaken to address this potential threat.

In summary, Lake George and Oaks Pond are presently within acceptable ranges of good water quality as defined by the study. To maintain present levels, appropriate actions to limit erosion and nutrient loading should be taken. Community awareness through educational initiatives will help lake stakeholders prevent future degradation of water quality.

Table of Contents

Figures

Tables

Appendices

INTRODUCTION

GENERAL NATURE OF STUDY

There has always been an inexplicable wonder associated with the beauty of Maine lakes. In addition to their aesthetic value, lakes and ponds provide important habitats for aquatic and terrestrial wildlife. The attraction of the lake's natural beauty, however, can increase recreational pressures that may lead to human induced eutrophication.

Eutrophication is a natural aging process of lakes and ponds. This process causes young, oligotrophic lakes (lakes that have low primary productivity and biomass due to low concentrations of nutrients) to mature through the addition of nutrients from natural activities such as the decay of organic matter (Chapman 1996). Higher concentrations of nutrients lead to increased productivity of plants. Human activities can accelerate eutrophication through nutrient loading. When nutrient levels become too high, algal blooms occur. Algal blooms are not only aesthetically unappealing but are also ecologically detrimental. Algal blooms can deplete dissolved oxygen levels that in turn decrease biodiversity (Smith and Smith 2001).

Lake George and Oaks Pond were chosen as the Colby Environmental Assessment Team's (CEAT) study sites due to the concern about potential human induced eutrophication of both water bodies. Lake George and Oaks Pond are situated in southern Somerset County, Maine, and experience heavy recreational and developmental uses. Neither water body has experienced algal blooms, but both are vulnerable because of potential nutrient loading from human activities.

The purpose of this study was to evaluate the impacts of land use patterns and development on the water quality of Lake George and Oaks Pond. The physical and chemical parameters of both lakes were measured in order to determine the present water quality. Development within the watersheds was documented through the assessment of residences, septic systems, and roads. Water quality and land use assessments were conducted by CEAT during the summer and fall of 2001. These results were then used to construct a phosphorus model to predict present and future phosphorus loading. A Geographic Information System (GIS) was used to construct models of land use and soil characteristics in the Lake George and Oaks Pond watersheds. The results obtained from the lake and watershed analyses were used to make recommendations concerning the future ecological health of Lake George and Oaks Pond.

BACKGROUND

Lake Characteristics

Differences Between a Lake and a Pond

Lakes and ponds are inland bodies of standing water created either naturally through geological processes or artificially through human intervention (Smith and Smith 2001). Lakes and ponds differ in their size and depth profiles. Lakes most often have greater surface area and are deeper than ponds. Lakes generally develop both vertical and horizontal stratification. However, ponds do not stratify because of their shallow depth. Horizontal stratification in a lake divides the lake into zones based on sunlight penetration and the growth of vegetation. The littoral zone is the shallow-water zone in which sunlight can penetrate to the bottom allowing vegetation to grow from the substrate. The limnetic and profundal zones make up the deep-water area where sunlight cannot reach the bottom and rooted plants are not able to grow. A pond does not have this zonation and it is shallow enough that vegetation can be rooted throughout (Smith and Smith 2001).

The vertical zonation found in a lake is dependent on density and water temperature. Deep lakes stratify with the cold, denser water on the bottom and the warm, less dense water on the surface. Ponds and shallow lakes do not stratify because disturbance of wind and waves causes constant mixing and temperature distribution.

General Characteristics of Maine Lakes

Lakes are a vital natural resource in Maine (Davis et al. 1978). They provide fresh water for swimming, fishing, drinking, livestock, and agriculture. Maine's beautiful lakes draw many tourists throughout the year and serve as important habitats for wildlife.

The majority of Maine lakes were formed during the Wisconsonian glaciation of the Pleistocene period, which occurred approximately 10,000 years ago (Davis et al. 1978). As a result of glacial activity in Maine, glacial till, bedrock, and glaciomarine clay-silt dominate most lake basin substrates. Generally, these deposits and the underlying granitic bedrock are infertile, making most of Maine's lakes poor in nutrients. The movement of glaciers in Maine was predominantly southeasterly, carving out Maine lakes in a northwest to southeast direction (Davis et al. 1978). This unique orientation along with lake surface area and shape play a fundamental role in the effect of wind on the water body. Wind is an important factor in lake turnover, the mixing of thermal layers.

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

In Maine, many factors influence lake water quality: proximity to the ocean, location within the state, residence time of water within the soil, wetland influences, and bedrock chemistry (Davis et al. 1978). Besides these factors, terrestrial and aquatic vegetation as well as unique habitat types may affect the water quality. Depth and surface area can affect temperature and turnover in the lake.

Annual Lake Cycles

Stratification, created by the different densities due to variations in temperature with depth, is an important component in the lake ecosystem. Water has the unique physical property of being most dense at 4° C (Smith and Smith 2001). Water decreases in density at temperatures above and below 4° C, allowing ice to float on the surface of lakes and ponds because it is less dense than the warmer water below it.

In the summer, direct radiation warms the upper levels of the water column forming a layer called the epilimnion, which hosts the most abundant floral communities (Davis et al. 1978). The photosynthetic capacities of the plants create an oxygen rich stratum. However, available nutrients in the epilimnion can be depleted by algal populations growing in the water column and may remain depleted until the turnover of early fall (Smith and Smith 2001). The process of lake cycling is summarized in Figure 1.

Below the epilimnion is the metalimnion, a layer of sharp temperature decline (Smith and Smith 2001). Within this stratum is the greatest temperature gradient in the lake called the thermocline. This thermocline separates the epilimnion from the hypolimnion, the lowest stratum of a lake. The hypolimnion, only found in the deepest lakes, is beyond the depth to which sufficient light can penetrate in order to facilitate effective photosynthesis (Figure 1). It is in the substrate of the hypolimnion where most decomposition of organic material takes place through aerobic and anaerobic biological processes. Aerobic bacteria break down organic matter quicker than anaerobic bacteria, but they also significantly deplete the oxygen at these depths (Davis et al. 1978).

When the temperature becomes colder, water temperature decreases and wind facilitates thermal mixing until the vertical profile of the water column is uniform in temperature. This event, known as turnover, reoxygenates the lower depths and mixes nutrients throughout the strata. The cold water near the surface can hold increased levels of oxygen, which is redistributed to lower depths with turnover. Through this process, organisms in the hypolimnion receive oxygenated water. A similar turnover event also occurs in the spring (Smith and Smith 2001).

Lakes in Maine are classified as dimictic lakes because they experience overturn twice a year, once in the spring and once in the fall. The summer stratification is reversed during the fall when the coldest water is on the surface and the warmer water (4° C) is at depth. During the winter, significant snow cover on the ice may affect the photosynthetic processes under the ice by blocking some of the incoming solar radiation. Without oxygen replacement by photosynthesis, organisms can deplete oxygen levels enough to cause significant fishkills (Smith and Smith 2001).

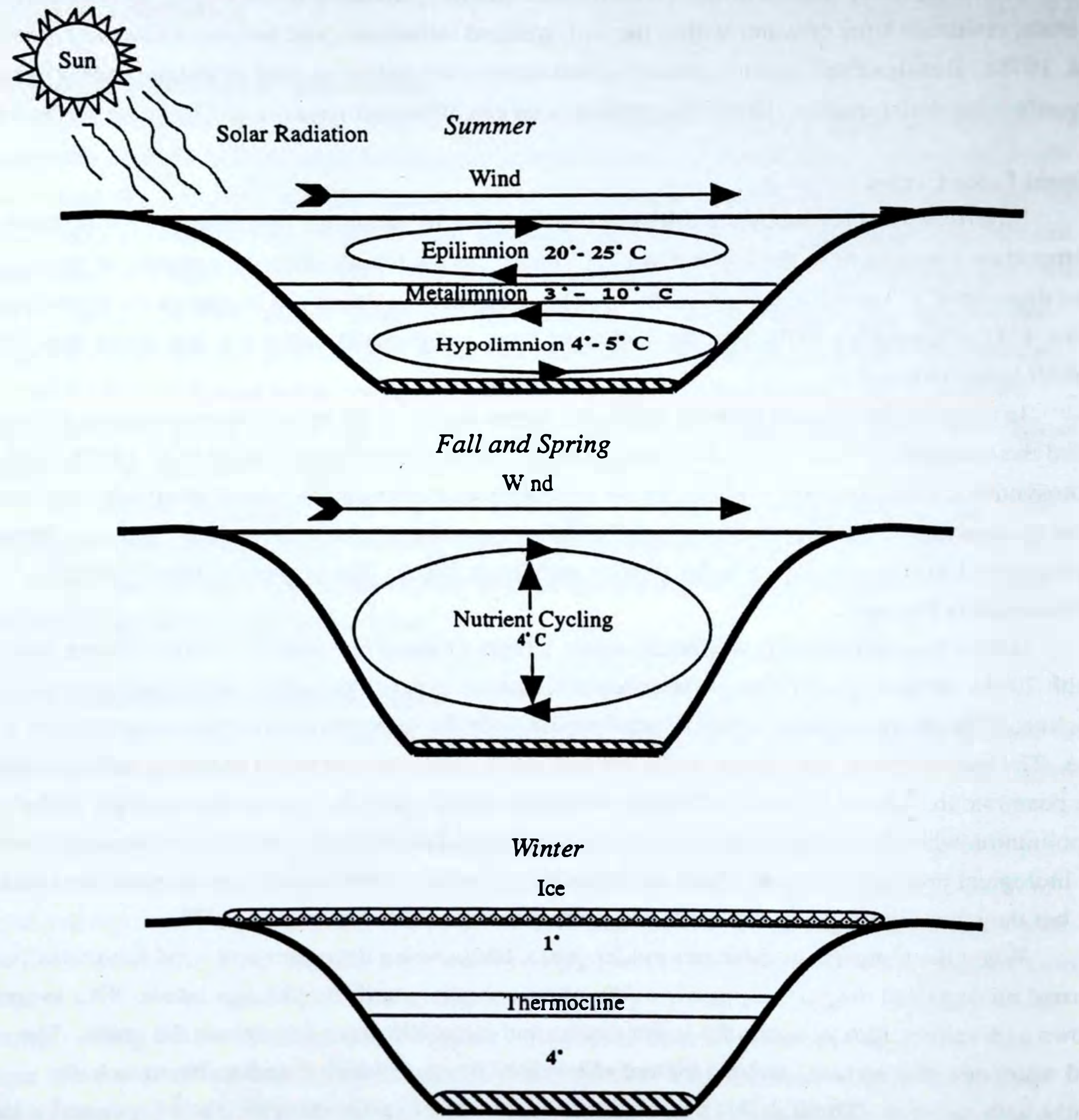


Figure 1. Mixing by means of lake turnover in dimictic lakes. During the summer, lakes are stratified into three layers (epilimnion, metalimnion, and hypolimnion). During the fall and spring, the isothermal temperature and density facilitate the lake turnover and redistribution of nutrients. In the winter,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

In the spring, solar radiation warms the upper stratum of the lake causing the colder surface water to sink, which combined with wind, overturns the lake. Once the temperature in the water column is uniform, oxygen and nutrients are again mixed throughout. As late spring approaches, solar radiation increases, stratification becomes evident and temperature profiles return to those of the summer (Smith and Smith 2001).

Trophic Status of Lakes

Lakes are divided into four major categories based on nutrient levels: oligotrophic, mesotrophic, eutrophic, and dystrophic (Appendix A; Maitland 1990). The mesotrophic characterization is not included in Appendix A, because it is referred to as a transitional stage between oligotrophic and eutrophic states (Chapman 1996). Young or oligotrophic lakes are lacking in nutrients, and eutrophic lakes are nutrient rich (Niering 1985). Oligotrophic lakes tend to be deep and oxygen rich with steep-sided basins creating a low surface to volume ratio. These lakes contain high levels of nitrate and low levels of phosphorus, the limiting nutrient for plant productivity in most freshwater ecosystems. The shape of a lake can also influence its productivity. Steep-sided oligotrophic lakes are not conducive to extensive growth of rooted vegetation because there is no shallow margin for attachment.

Eutrophic lakes are nutrient rich (Chapman 1996) and have a relatively high surface to volume ratio (Maitland 1990). These lakes have a large phytoplankton population supported by the increased availability of dissolved nutrients (Appendix A). Low dissolved oxygen levels at the bottom of a eutrophic lake are a result of high decomposition activity. This activity leads to the release of phosphorus and other nutrients from the bottom sediments, resulting in their eventual recycling through the water column (Chapman 1996). This nutrient release stimulates further growth of phytoplankton populations such as algae (Smith and Smith 2001). Due to sediment loading over the years, eutrophic lakes tend to be shallow and bowl-shaped, which allows for the establishment of rooted plants.

Dystrophic lakes receive large amounts of organic matter from the surrounding land, particularly in the form of humic (dead organic) materials (Smith and Smith 2001). The large quantity of humic materials stains the water brown. Dystrophic lakes have highly productive littoral zones, high oxygen levels, high macrophyte productivity, and low phytoplankton numbers (Appendix A). Eventually, the invasion of rooted aquatic macrophytes chokes the habitat with plant growth. The lake basin is filled in, resulting in the development of a terrestrial ecosystem (Goldman and Home 1983).

The natural aging process of a lake begins as oligotrophic and progresses through eutrophication, eventually becoming a terrestrial landscape (Niering 1985). This process can be greatly accelerated by anthropogenic activities, which increase nutrient loading. The United States Environmental Protection Agency (USEPA) characterizes the process of eutrophication by the following criteria:

1) Decreasing hypolimnetic dissolved oxygen concentrations
2) Increasing nutrient concentrations in the water column

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

As a lake ages, it fills with dead organic matter and sediment from various inputs that settle to the bottom. Lakes may receive mineral nutrients from streams, groundwater, runoff, and precipitation. The increase in nutrient availability promotes primary productivity. Increased productivity leads to more dead organic material that accumulates as sediment in lentic ecosystems (standing bodies of water such as lakes and ponds). Over time lakes will fill in, decrease in size, and be replaced by a terrestrial community (Chiras 1994).

Phosphorus and Nitrogen

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

Phosphorus is considered the most important nutrient in lakes because it is the limiting nutrient for plant growth in freshwater systems (Maitland 1990). Phosphorus naturally occurs in lakes in minute quantities measured in parts per billion (ppb). This concentration is sufficient for plant growth, due to the high efficiency with which plants can assimilate phosphorus (Maitland 1990). There are multiple external sources of phosphorus (Williams 1992), but a large supply is also found in the lake sediments (Henderson-Sellers and Markland 1987). The cycle of phosphorus in a lake is complex; some models include up to seven different forms of phosphorus (Frey 1963). Typically, two broad categories of phosphorus exist in lakes: dissolved phosphorus (DP), and particulate phosphorus (PP). The phosphorus cycle of a stratified lake is summarized in Figure 2. DP is an inorganic form of phosphorus readily available for plant use in primary production. It is this form of phosphorus that is limiting to plant growth. PP is a form of phosphorus incorporated into organic matter such as plant and animal tissues. DP is converted to PP through the process of primary production. PP then gradually settles into the hypolimnion in the form of dead organic matter. PP can be converted to DP through aerobic and anaerobic processes. In the presence of oxygen, PP will be converted to DP through decomposition by aerobic bacteria. In anoxic conditions, less efficient anaerobic decomposition occurs (Lerman 1978).

An important reaction occurs in oxygenated water, which involves DP and the oxidized form of iron, Fe (III) (Chapman 1996). This form of iron can bind with DP to form an insoluble complex, ferric phosphate, which can effectively tie up large amounts of phosphorus as it settles into the

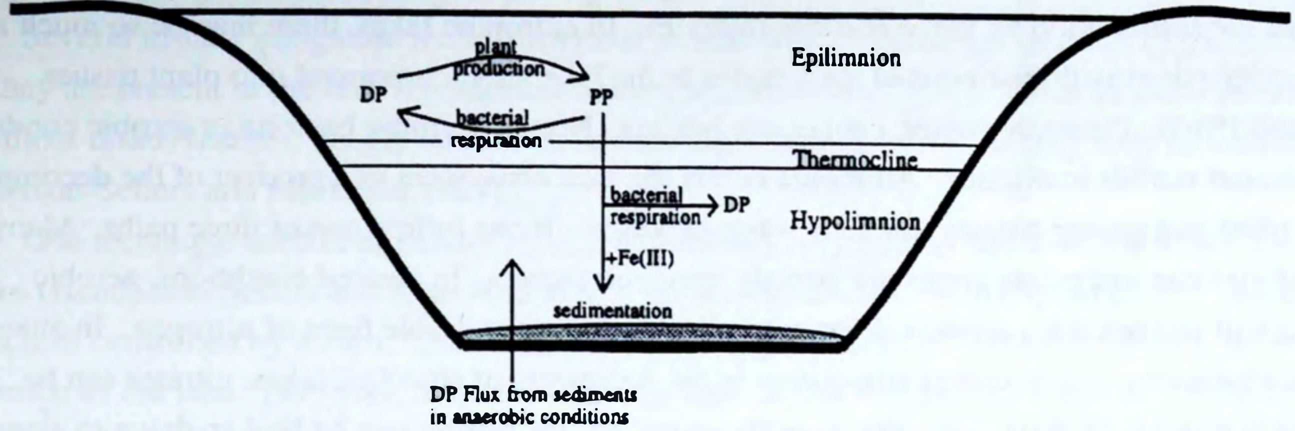


Figure 2. A model of the cycle of the major forms of phosphorus, dissolved (DP) and particulate (PP), within a lake ecosystem. The sedimentation of DP through complexation with Fe (III) contributes to the build-up of DP in the sediments. Note the production of DP in the hypolimnion due to bacterial decomposition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

bottom sediments. Fe (III) is reduced to Fe (II) in the presence of decreased oxygen levels at the sediment water interface, resulting in the release of DP. The ferric phosphate complex, combined with the anaerobic bacterial conversion of PP to DP, can lead to a significant build-up of DP in anoxic sediments. The sediments of a lake can have phosphorus concentrations of 50 to 500 times the concentration of phosphorus in the water (Henderson-Sellers and Markland 1987). Sediments can be an even larger source of phosphorus than external inputs. DP concentrations build up in the lower hypolimnion until fall turnover because nutrients are inhibited from mixing into the epilimnion during the summer by stratification.

The fall turnover results in a large flux of nutrients, creating the potential for algal blooms. Algal blooms can occur when phosphorus levels rise above 12 to 15 ppb. If an algal bloom does occur, DP will be converted to PP in the form of algal tissues. The algae die as winter approaches and the dead organic matter settles to the bottom where PP is converted back to DP and builds up again, allowing for another large nutrient input to surface waters during spring overturn (Chapman 1996).

Nitrogen, the other major plant nutrient, is not usually a limiting factor for plant growth in lakes (Chapman 1996). However, it is still important to understand its cycle because high concentrations can lead to algal blooms in the presence of phosphorus.

Available nitrogen exists in lakes in three major chemical forms: nitrate (NO_3^-), nitrite (NO_2^-), and ammonia (NH_3). The nitrogen cycle is summarized in Figure 3. The majority of free nitrogen in a lake exists in the form of nitrates (Maitland 1990). This form of nitrogen is directly available for assimilation by algae and macrophytes. In eutrophic lakes, there may be so much algae and macrophyte growth that most of the nitrates in the lake are incorporated into plant tissues (Maitland 1990). Plants, however, cannot use nitrites. Nitrate-forming bacteria in aerobic conditions convert nitrites to nitrates. Ammonia enters the lake ecosystem as a product of the decomposition of plant and animal tissues and their waste products. It can follow one of three paths. Many macrophytes can assimilate ammonia directly into their tissues. In aerated conditions, aerobic bacteria will convert the ammonia directly to nitrates, the more usable form of nitrogen. In 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 broken down to elemental nitrogen (N_2). This form is not available to any plants without the aid of nitrogen-fixing bacteria. Plants depend on these bacteria to convert nitrogen to nitrates through the process of nitrogen fixation (Overcash and Davidson 1980).

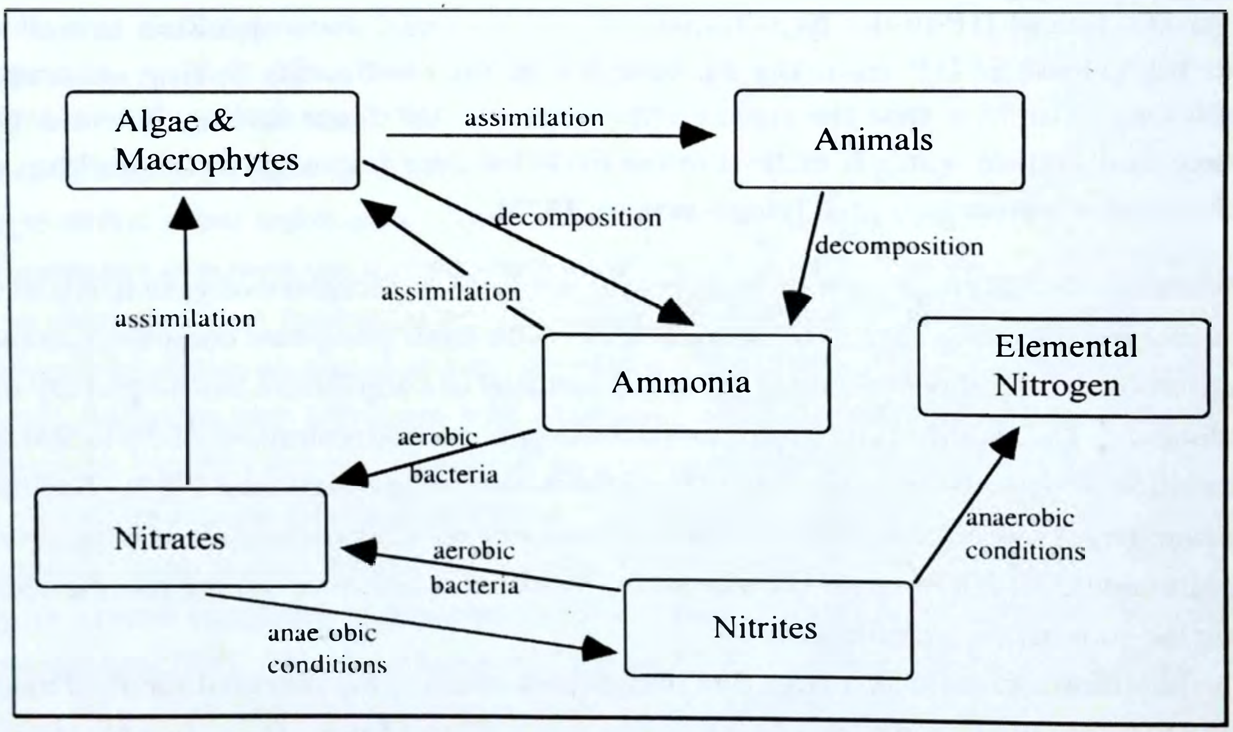


Figure 3. A diagram of the various forms of nitrogen that occur in the nitrogen cycle within a lake ecosystem. It is important to note that in aerobic conditions both ammonia and nitrites are converted to nitrates which are available for use by plants.

The underlying pattern evident from this cycle is that all forms of nitrogen added to the lake will eventually become available for plant use. The various forms of nitrogen as well as the oxygen concentrations (aerobic and anaerobic conditions) of the water must be considered in order to understand the availability of this nutrient for plant growth.

Several in-lake mitigation techniques exist to deal with the problem of excessive nutrients once they are present in the lake (Henderson-Sellers and Markland 1987). 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 technique used to eliminate excessive nutrients is to rapidly decrease the water level of the lake (Henderson-Sellers and Markland 1987). Releasing a large volume of water can quickly flush a lake controlled by a dam. The result may be the rapid export of many nutrients from the epilimnion of the lake. However, in cases where the lake drains into another lake or significant water body, the problem may not be eliminated, but simply shifted to another site. Flushing out a lake may only be a temporary solution because if the nutrient source is not eliminated it will continue to supply nutrients to the lake.

Another approach to nutrient reduction involves removing the nutrient rich hypolimnetic water. Nutrient levels in the water would be reduced by inserting a large pipe into the hypolimnion and pumping the water out in such a way that it would not flow directly back into the lake (Henderson-Sellers and Markland 1987).

Chemical precipitation is based on the natural affinity of iron to complex with phosphorus. Adding salt, such as iron or aluminum, to the water will complex the DP to form an insoluble compound that will immobilize the phosphorus (Henderson-Sellers and Markland 1987). This technique is effective but is not practical for very large lakes due to the cost. Furthermore, the phosphorus will eventually be released from this complex, requiring reapplication after several years.

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

Another approach in lakes with large macrophyte production is to harvest the plants. This method can be expensive due to the cost of equipment used and the frequency with which the harvesting must be performed. This procedure removes all the nutrients tied up in the plants at the time of harvest, preventing them from re-entering the lake cycle. It is important that harvested plants are not left along the shore, allowing nutrients from decomposing plants to leach into the lake. There is some debate over the effectiveness of this method because macrophytes also act as a sink for nutrients. At the time of removal, the nutrients that would normally have been taken up by the macrophytes will be available to algae, perhaps resulting in an algal bloom (Chapman 1996). On the other hand, if only the foliage of the plants is harvested, then the plants will still be able to take up nutrients via the roots.

One final management option is dredging. This process extracts the nutrients from the sediments by removing the sediments themselves. Although dredging is effective, it is extremely expensive due to the large amount of labor and equipment cost needed (Henderson-Sellers and Markland 1987). There are concerns of possible ecological disruption that these actions may have on the lake ecosystem.

Eliminating nutrients once they have built up in a lake is a challenging task. The ideal method for controlling nutrients in a lake is to regulate and monitor the input sources. This regulation allows the natural processes of nutrient cycling and uptake by flora and fauna to compensate for nutrient inputs without accelerated eutrophication of the lake.

Freshwater Wetlands

Wetlands are important transitional areas between lakes and terrestrial ecosystems that typically support a wide range of biotic species (MLURC 1976). Wetland soil is periodically or perpetually saturated and contains non-mineral substrates such as peat. Wetlands also contain hydrophylic vegetation that is adapted for life in saturated and anaerobic soils. They usually have a water table at or above the level of the land (Chiras 1994). Table 1 gives descriptions of freshwater inland wetlands. They also help maintain lower nutrient levels in an aquatic ecosystem because of the efficiency in nutrient uptake by their vegetation (Smith and Smith 2001). Wetlands have the potential to absorb heavy metals and nutrients from various sources including mine drainage, sewage, industrial wastes, and agriculture (Chiras 1994). Wetlands improve the overall water quality by absorbing and storing nutrients in organic plant tissues (Niering 1985).

Invasive Species

Invasive species are biota that are non-native to an area and have been introduced intentionally or unintentionally by humans (Smith and Smith 1998). These species are usually highly adaptive to the new environments to which they are introduced. The ability to adapt results from evolution within the species, genetically and phenotypically. These physical and genetic changes alter characteristics of the organism's body so that it may better survive. Invasive species tend to be better competitors than native species because of their ability to adapt and their aggressive survival tactics. As a result, invasive species harm native ones through predation, competitive exclusion, or their ability to reproduce faster than native organisms (Cole, pers. comm.).

Invasive species have serious implications for lake quality and biodiversity. Invasive plant species are commonly introduced into new lakes by boats and trailers (Bouchard, pers. comm.). Boats are the largest contributors to unintentional plant introduction. Invasive plant species such as, Eurasian milfoil (*Myriophyllum spicatum)* and variable milfoil (*Myriophyllum heterophyllum)* are two aquatic species whose populations have spread swiftly northward in lakes along the east coast. Both species grow up from the bottom and form mats at the lake surface. These mats can cover the surface or spread under the surface throughout the shallow areas of the water column and depths of 20 ft. These species are especially dangerous to water quality in lakes because they are prolific and grow very rapidly as compared to most native species. They reproduce effectively by fragmentation

Table 1. Descriptions of site characteristics and plant populations of different types of freshwater inland wetlands (Smith and Smith 2001).

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

of the stalk and also by the spread of seeds. Rapid growth increases their capacity to absorb sunlight along the surface, which then blocks out the light for native submergent plant species (Bouchard, pers. comm.). For example, Eurasian milfoil is adept at choking out other floating and emergent species because of its rapid growth.

Eurasian and variable milfoil species are capable of changing the chemical properties of a lake. Rapid growth quickly takes up nutrients, and is followed by massive biomass death, which causes pH swings because of the flux of nutrients in the water column. When a large population dies off, producing a large dead organic mass that must be degraded by aerobic decomposers, the decomposers can change the dissolved oxygen (DO) levels in a lake (Firmage, pers. comm.). The aerobic decomposers then consume much of the DO in the water column to complete the breakdown of the dead plant biomass. The low DO levels can be detrimental to other native biota of the lake including fish. In addition to affecting lake quality, milfoils can harm the economic, recreational, and aesthetic values of lakefront property by forming mats of biomass that cover the shallow areas of the lake (See The Economic Impact of Lake Use and Water Quality).

Currently Maine lakes do not harbor Eurasian milfoil although some experts speculate that the species has arrived, but has not developed a large enough population to be observable (Bouchard, pers. comm.). Experts also agree that if it is not already present, it is only a matter of time before Eurasian milfoil begins to populate Maine lakes. Variable milfoil has been found in seven Maine lakes, including Messalonskee Lake, most of which are in the southwestern portion of the state. Another milfoil that resides in Maine lakes is slender water milfoil *(Mryriophyllum tenellum).* This species is native to Maine and is acceptable aquatic vegetation. The slender water milfoil does not cause the ecological problems associated with the invasive milfoils. This species has evolved with neighboring native plant species and does not interfere with their growth. Lake George and Oaks Pond have neither of the invasive milfoil species and can remain that way if proper considerations are taken in regard to boating activities.

It is important to prevent the introduction of invasive aquatic plant species to preserve the water quality and beauty of Maine lakes. A simple boat and trailer check by the owner, after removing the boat from the water, will prevent plant species traveling from one lake to another. Public awareness and responsibility for eliminating the possibility of plant introductions will be the most effective means of preventing unwanted species in Maine lakes.

Fish species are common invasive species that are more often intentionally brought in by "bucket biologists", locals that try to improve fishing in their favorite lake or pond, but do so without first consulting proper authorities (Bouchard, pers. comm.). The largemouth bass and the black crappie are two unauthorized species introductions to Oaks Pond. These species may harm cold water fisheries within the pond through competitive exclusion.

Tributary Characteristics

Tributaries are streams that drain a watershed, bringing water, nutrients, dissolved particles, sediments, and potential pollutants into a lake (Wetzel and Likens 1991). Geology, climate, and vegetation in the surrounding watershed define the chemical and physical characteristics of a tributary. The amount of dissolved solids and sediments increase with greater flow rates and turbulence in a tributary (Chapman 1996). Storms and spring runoff result in episodic influxes of sediments and phosphorus into a lake from the tributaries. Water quality of tributaries is important to assess because tributaries with high flow rates can have considerable impact on the amount of nutrients and sediments deposited into a lake.

Watershed Land Use

Nutrient Loading

Natural and anthropogenic processes affect nutrient loading into a lake (Hem 1970). Human activity accelerates the loading of nutrients and sediments into a lake, which can adversely affect the water quality in a short period of time. Clearing forests to construct roads and buildings with impervious surfaces increases runoff, carrying nutrients from agricultural, residential, and industrial products (such as detergent, fertilizer, and sewage) into the lake. Since phosphorus and nitrogen are the limiting nutrients to algal growth, and algal growth affects the trophic state of a lake, increases of phosphorus and nitrogen from these sources can lead to a decrease in lake water quality and eventual eutrophication.

Total phosphorus loading into a lake can be determined using a phosphorus loading model. This model takes into account the various aspects upon which the phosphorus concentration in the lake basin is dependent, such as lake size, volume, flushing rate, and land use patterns within the watershed (Cooke et al. 1986). The model allows for the projection of the impact that various factors may have on phosphorus loading and generates predictions of lake responses to changes in land use. The accuracy of the predictions is determined by the accuracy of the assumptions (USEPA 1990).

Soil Types

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

Land Use Types

A watershed is the total land area that contributes a flow of water to a particular basin (Smith and Smith 2001). The highest points of land that surround a lake or pond and its tributaries define the boundary of a watershed. Any water introduced to a watershed will be absorbed, evaporated, or run into the basin of the watershed.

Nutrients bind to soil particles. If eroded, nutrient-rich soil will add to the nutrient load of a lake, hastening the eutrophication process and leading to algal blooms (USEPA 1990). Different types of land use have distinct effects on nutrient loading in lakes as a result of erosion and runoff. Assessment of land use within a watershed is essential in the determination of factors that affect lake water quality.

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

Naturally vegetated areas offer protection against soil erosion and surface runoff (Hardesty and Kunhs 1998). The forest canopy reduces erosion by diminishing the direct physical impact of rain on soil. The root systems of trees and shrubs reduce soil erosion by decreasing the rate of runoff, allowing water to percolate into the soil. Roots decrease the nutrient load in runoff through direct absorption of nutrients for use in plant structure and function. Due to these features, a forested area acts as a buffering system by decreasing surface runoff and absorbing nutrients before they enter water bodies.

Residential areas are a significant threat to lake water quality for a number of reasons. These areas generally contain lawns, driveways, parking spaces, rooftops, and other impervious surfaces that reduce percolation and increase surface runoff. Shoreline residences are often direct sources of nutrients to the water body due to their proximity to lakes.

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

The use of chemicals in and around houses is potentially harmful to water quality. Products associated with cleared and residential land include fertilizers, pesticides, herbicides, and detergents that often contain nitrogen, phosphorous, other plant nutrients and miscellaneous chemicals (MDEP 1992a). These products can enter a lake by leaching directly into ground water or traveling with

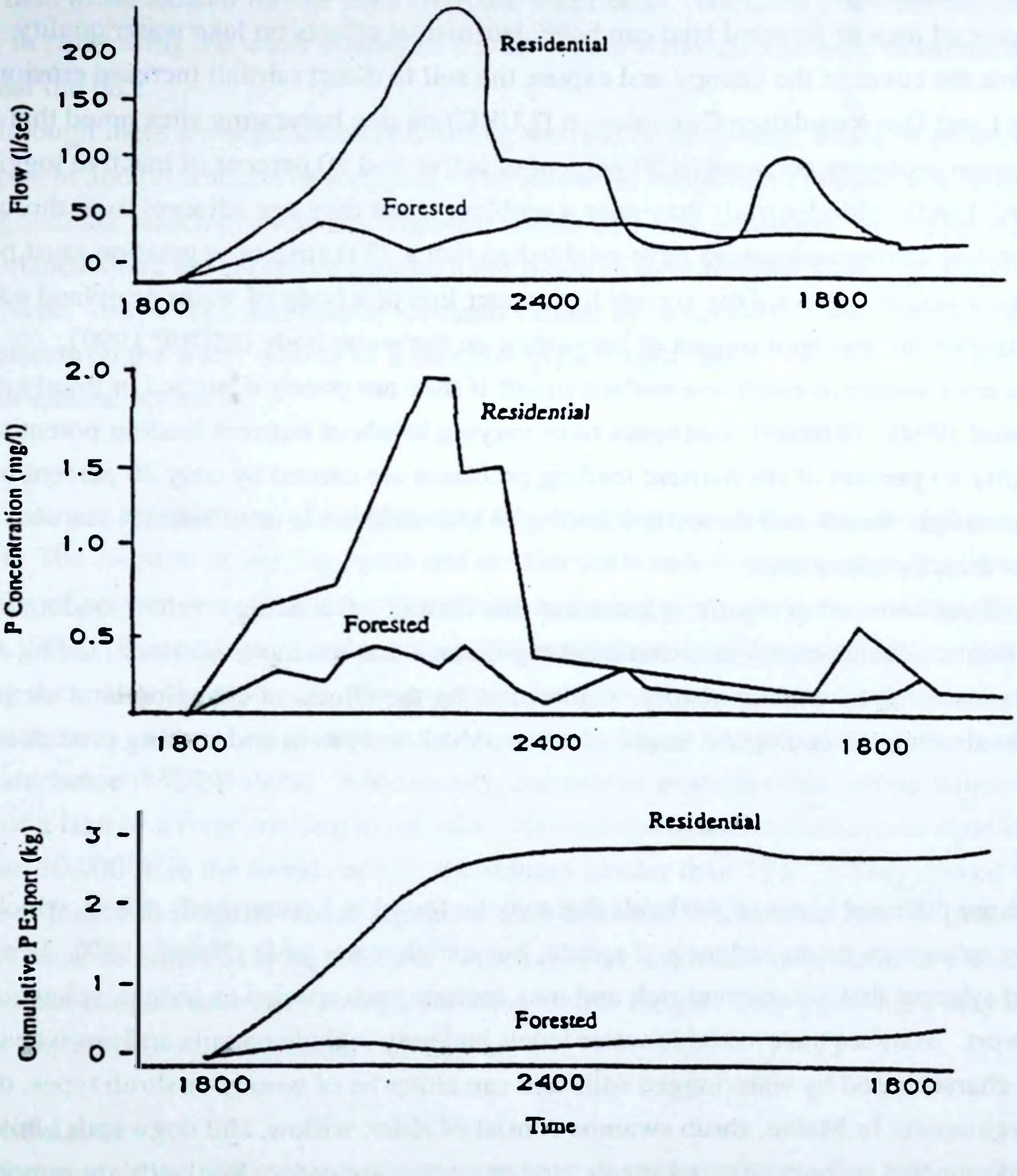


Figure 4. Comparisons of runoff after an April rain storm in two neighboring watersheds near Augusta, ME. Top: volume of immediate runoff over a 12 hour period; Middle: phosphorus concentration in the runoff; Bottom: total amount of phosphorus exported into local streams and lakes from the storm (Dennis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

eroded sediments. Heavy precipitation aids the transport of these high nutrient products due to increased surface runoff near residences (Dennis 1986). Upon entering a lake, these wastes have adverse effects on water quality.

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

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

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

As land use conversion occurs, it is critical that factors influencing nutrient loading are considered. Public education and state and local regulations that moderate nutrient loading are essential in maintaining lake water quality. Understanding the effects of changing land use practices is critical in evaluating the ecological health of a watershed ecosystem and making predictions about its future.

Wetlands

There are different types of wetlands that may be found in a watershed. A bog, which is dominated by sphagnum moss, sedges and spruce, has a high water table (Nebel 1987). Fens are open wetland systems that are nutrient rich and may include such species as sedges, sphagnum moss, and bladderwort. Marshes have variable water levels and may include cattails and arrowheads. Swamps are characterized by waterlogged soils and can either be of woody or shrub types, depending on the vegetation. In Maine, shrub swamps consist of alder, willow, and dogwoods while woody swamps are dominated by hemlock, red maple, and eastern white cedar. Wetlands are important because they provide habitat for numerous organisms, such as waterfowl and invertebrates (Nebel 1987).

The type of wetland and its location in a watershed are important factors when determining whether the wetland is a nutrient sink or source, either preventing nutrients from entering a lake or contributing nutrients to a lake. It is also important to note that one wetland may be both a source and a sink for different nutrients. This characteristic may vary with the season, depending on the amount of input to the wetland. Vegetation type within a wetland is important because different flora absorb different nutrients. For example, willow and birch assimilate more nitrogen and phosphorus than sedges and leatherleaf (Nebel 1987). Shrub swamps are better nutrient sinks than many other types of wetlands. When nutrient sink wetlands are located closer to the lake, the buffering capacity is greater than those located further back from the water body. Wetlands that filter out nutrients are important in controlling the water quality of a lake. These wetlands also help moderate the impact of erosion near the lake.

Although there are regulations controlling wetland development, a lack of enforcement leads to development and destruction of wetlands. The Resource Protection Districts and other environmental regulations, which prohibit development within 250 ft of a wetland, should protect these areas. Wetlands along the shoreline may be more prone to development due to the nature of their location (Nebel 1987). The decrease of wetlands caused by development will most likely have negative effects on the water quality of a lake due to increased runoff, and erosion as well as a decrease of natural buffering.

Forestry

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

Transitional Land

Succession is the replacement of one vegetative community by another that results in a mature and stable community referred to as a climax community (Smith and Smith 2001). An open field ecosystem progresses through various successional stages before it develops into a mature forest. The earliest stages of open field succession involve the establishment of smaller trees and shrubs throughout a field (reverting land). Intermediate and later successional stages involve the growth of larger, more mature tree species. The canopy of this forest is more developed, resulting in less light reaching the forest floor. Regenerating land is referred to as a forest that is nearing maturity and contains over 50 percent mature trees.

Cleared Land

Cleared land, frequently generated by logging activities, also presents potential problems of erosion and nutrient runoff especially when large areas are cleared of trees and vegetation that once acted as natural filters. Sediments from these cleared areas create potential problems if they carry large amounts of nitrogen, phosphorus, other plant nutrients, and chemicals to a lake. Without vegetation acting as a buffer, problems are exacerbated.

The MDEP (1990) has established specific guidelines for cleared land. There can be no cleared openings greater than 250 ft^2 in the forest canopy within 100 ft of a lake or river. Where there are cleared lands, some solutions to minimize erosion include construction of terraces and plowing parallel to the contour lines. Both techniques decrease the flow of storm water down a slope, allowing the nutrients to settle out before they reach the lake. These two solutions also may prevent erosion by breaking up large areas of tilled soil.

Agriculture and Livestock

Agriculture within a watershed contributes to nutrient loading in a lake. Plowed fields and livestock grazing areas are potential sources of erosion and can carry sediments and nutrients to a lake (Williams 1992). Animal wastes are also sources of excess nutrients. There are ordinances to minimize these problems that prohibit new tilling of soil and new grazing areas within 100 ft of a lake or river. However, problems can still exist in areas that were utilized for agriculture prior to the enactment of these ordinances by the State of Maine in 1990. The Shoreland Zoning Act enables these areas to be maintained as they presently exist, which may result in relatively high levels of erosion and decreased water quality (MDEP 1990). Some methods to reduce erosion are plowing with the contour lines (across as opposed to up and down a slope), and strip cropping. Both solutions will reduce soil erosion and sediment deposition in the lake.

Livestock manure is another potential agricultural impact on water quality. Improper storage of manure may result in excess nutrient loading. Manure also becomes a problem when it is spread on fields as a fertilizer, a common agricultural practice. Manure spreading can lead to nutrient loading, especially in winter when the ground is frozen and nutrients do not have a chance to filter into the soil. These problems are aggravated by the tendency to over-fertilize. To prevent these problems the state passed zoning ordinances, prohibiting the storage of manure within 100 ft of a lake or river (MDEP 1990). Another solution is to avoid spreading manure in the winter. These solutions, however, do not address the problem of livestock that defecate close to water bodies. One solution may be to put up fences to keep the cattle away from the water.

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

Roads

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

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

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

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

It is crucial to design a road with its future uses in mind. For instance, a road should be constructed no longer than is absolutely necessary. A particular road should not be extended past the last structure that is to be serviced by that road. The width of a road, which is often based upon the maintenance capabilities of the area, must also be considered (Cashat 1984).

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

The road cross section is another important factor to consider when planning road construction. A crowned road, a road that slopes downward from the middle towards the outer edges when viewed as a cross section, allows for proper drainage and helps in preventing deterioration of the road surface (MDOT 1986). The crown should have a slope of 1/8 to 1/4 inches per foot of width for asphalt and 1/2 in to 3/4 in per foot of width for gravel roads (Michaud 1992). This slope allows the surface water to run off down either side of the road as opposed to running along its whole length. Road shoulders should also have a slightly steeper cross slope than the road itself so that runoff can flow into a ditch or buffer zone (Michaud 1992).

The drainage of a road and the land that surrounds it must also be considered during construction or maintenance projects. Ditches and culverts are used to help drain roads into buffer zones where nutrient loads from the road can be absorbed by vegetation. These measures are also used for handling runoff that may be blocked by road construction. Ditches are necessary along wide or steep stretches of road to divert water flow off the road and away from a body of water. They are ideally parabolic in shape with a rounded bottom, are of a sufficient depth, and do not exceed a depth to width ratio of 2:1. The ditch should be free of debris and covered with abundant vegetation to reduce erosion (Michaud 1992). Ditches must also be constructed of a proper soil that will not be easily eroded by the water flowing through them.

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

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

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

The Economic Impact of Lake Use and Water Quality

Clean lakes not only offer intrinsic, aesthetic value for recreation, but also help maintain lakeshore property values and contribute to the economic status of communities. Determining the monetary value of lakes allows for an assessment of the risk associated with degrading lake water quality thereby putting the cost of protecting these lakes into perspective. The University of Maine and the MDEP have conducted studies on various lakes in Maine to better understand the economic value of Maine lakes (Bouchard 2000).

Eutrophication of lakes, the primary cause of diminished water quality in Maine, not only reduces the desirability of a lake for recreational activities, but also decreases the likelihood of people establishing residency in the area. The MDEP study reported that lakes with compromised water quality reflected lower net economic values, lower use rates, and a decrease in both direct (dollars spent on gasoline, fishing tackle, food, etc.) and indirect expenditures (dollars spent on services to maintain lake-related business) (Boyle, Scheutz, and Kahl 1997). It is important for users of Maine lakes, both residents and non-residents alike, to protect water quality because deterioration decreases the value of their property. Town officials should also take note that lower water quality leads to fewer dollars spent in the community, which can decrease the tax revenue for the entire town. Again, a decline in lake water quality lowers property values, which lowers the tax base, and finally the revenue for the towns that harbor them.

The value of lakes to the Maine economy and the value that transient visitors place on Maine lakes were also investigated in the MDEP study. Recreational use of Maine lakes provides nearly $1.1 billion each year to the state's economy, 15 percent of which is attributed to nonresidents (Boyle, Scheutz, and Kahl 1997). Other uses of lake water include drinking water, youth camps, and commercial uses, which are worth approximately $400 million. Shoreline property owners also contribute to the state's economy through taxes and the investments they make in their property. These costs total $349 million in economic activity annually, 25 percent of which comes from nonresident property owners. As shown by these figures, large proportions of the local economic activity and a number of employment opportunities (e.g., park rangers, marina attendants) are generated as a result of having a desirable lake in the locality. A decline in water quality will have the opposite effect; fewer dollars will be spent in the community, which could result in the loss of jobs.

The results of the MDEP study indicate that it is important to maintain water quality levels because each increment of decline in quality results in increasing economic losses to the community. In addition, it is increasingly difficult and more costly to restore water quality conditions that have deteriorated below acceptable conditions. By maintaining current water quality levels or improving the standards, community members enhance both their local economy and benefit the environment.

Zoning and Development

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

Buffer Strips

Buffer strips play an important role in absorbing runoff by helping to control the amount of nutrients entering a lake (MDEP 1990). Excess amounts of nutrients such as phosphorus and nitrogen can promote algal growth and increase the eutrophication rate of a lake. A good buffer should have several vegetation layers and a variety of plants and trees to maximize the benefit of each layer (MDEP 1990). Naturally occurring vegetation forms the most effective buffer. Trees and their canopy layer provide the first defense against erosion by mitigating the impact of rain and wind on the soil. Their deep root systems absorb water and nutrients while maintaining the topographical structure of the land. The shallow root systems of the shrub layer also aid in absorbing water and nutrients and help to hold the soil in place. The groundcover layer, including vines, ornamental grasses, and flowers, slows down surface water flow and traps sediment and organic debris. The duff layer, consisting of accumulated leaves, needles, and other plant matter on the forest floor, acts like a sponge to absorb water and trap sediment. Duff also provides a habitat for many microorganisms that break down plant material and recycle nutrients (MDEP 1990).

An example of an ideally buffered home is shown in Figure 5. This home has a winding path

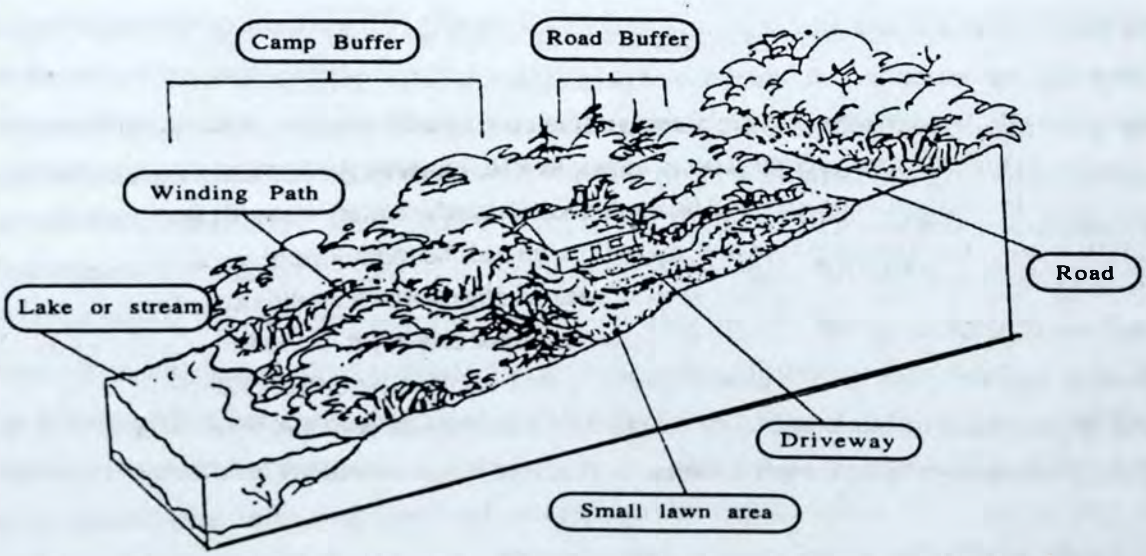


Figure 5. Diagram of an ideally buffered home.

down to the shoreline. Runoff is diverted into the woods where it can be absorbed in the forest litter. The house itself is set back from the shoreline 100 ft, and has a dense buffer strip between it and the water. The buffer is composed of a combination of canopy trees, understory shrubs, and groundcover. In addition, the driveway is curved, allowing for runoff accumulating on these surfaces to be deposited into a number of diversions along its path down the slope of the land. As opposed to a steep, straight, and paved path that leads directly into the water, a curved driveway can be a very effective deterrent to runoff. Slopes within a buffer strip that are less than two percent are most effective at slowing down the surface flow and increasing absorption of runoff (MDEP 1998b). Steep slopes are susceptible to heavy erosion and will render buffer strips ineffective.

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

Shoreline Residential Areas

Shoreline residential areas are of critical importance to water quality due to their proximity to the lake. This study considered houses less than 200 ft from the shoreline to be shoreline residences. Any nutrient additives from these residences have only a short distance to travel to reach the lake.

Seasonal residences, especially older ones located on or near the shoreline in a cluster, can contribute disproportionately to phosphorus loading into the lake ecosystem. Such clusters of camps usually exist because they were installed before the passage of current regulations, and do not follow shoreland zoning laws. Although seasonal, they may involve large numbers of people, and phosphorus exported from these areas is likely to increase during periods of heavy use. The location and condition of septic systems also affects the nutrient loading from these plots (See Sewage Disposal Systems).

Non-Shoreline Residential Areas

Non-shoreline residential areas (greater than 200 ft from the shoreline) also have an impact on nutrient loading, although generally less than that of shoreline residential areas. Runoff, carrying fertilizers and possibly phosphorus-containing soaps and detergents, usually filters through buffer strips consisting of forested areas several acres wide rather than a few feet wide (as with shoreline buffers). In these cases, phosphorus has the opportunity to be absorbed into the soils and vegetation. The majority will not reach the lake, but will simply enter the forest's nutrient cycle.

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

Non-buffered, non-shoreline residences can also contribute to nutrient loading. Phosphorus washed from residential lawns without buffer strips can enter into a stream and eventually into the lake. Similar restrictions and regulations for shoreline residences apply to non-shoreline homes that are located along streams.

Sewage Disposal Systems

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

Pit Privy

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

Holding Tank

Holding tanks are watertight, airtight chambers, usually with an alarm, which hold waste for periods of time. The tanks are durable and made of either concrete or fiberglass (MDHS 1988). The minimum capacity for a holding tank is 1500 gallons. These must be pumped to prevent backup or leakage of contaminants. Although purchasing a holding tank is inexpensive, the owner is then required to pay to have the holding tank pumped on a regular basis (EPA 1980).

Septic System

Septic systems are a waste disposal unit that includes a building sewer, treatment tank, effluent line, disposal area, distribution box, and often a pump. The pump enables the effluent to be moved to a more suitable leach field location if the location of the treatment tank is unsuitable for a leaching field (MDHS 1983). Figure 6 shows the basic layout of the components of a typical septic system. Septic systems are an efficient and economical alternative to a sewer system, provided they are properly installed, located, and maintained. Unfortunately, septic systems that are not installed or located properly may lead to nutrient loading and groundwater contamination. Both septic placement and soil characteristics determine the effectiveness of the system.

The distance between a septic system and a body of water should be sufficient to prevent contamination of the water by untreated septic waste. Unfortunately, many septic systems were installed prior to current regulations and are sited closer to the shore than is currently permitted.

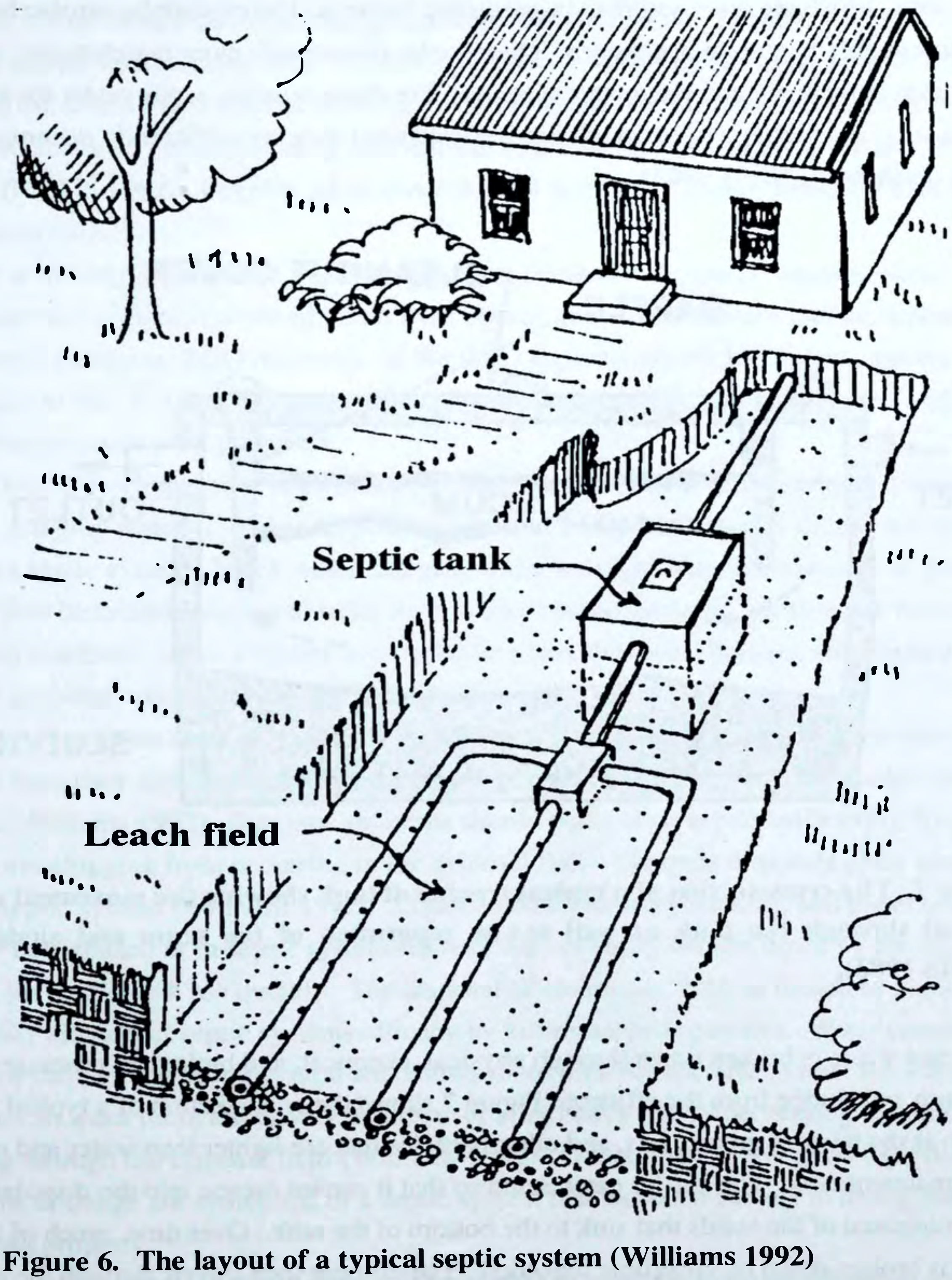


Figure 6. The layout of a typical septic system (Williams 1992)

However, new systems and those that need to be replaced must reflect the new regulations. Replacement systems can either be completely relocated, or an effluent pump, installed on the outside of the existing treatment tank, can be used to move the sewage uphill to an alternative disposal area further from the water body (MDHS 1983).

Human waste and gray water are transferred from a residence through the building sewer to the treatment tank. There are two kinds of treatment tanks, aerobic and septic, both of which are tight, durable, and usually made of concrete or fiberglass (MDHS 1983). Aerobic tanks rely on aerobic bacteria, which are more active than anaerobic bacteria. Unfortunately, aerobic bacteria are also more susceptible to condition changes. These tanks also require more maintenance, more energy to pump in fresh air, and are more expensive. For these reasons, septic tanks are preferable. Septic tanks rely on anaerobic bacteria. Solids are held until they are sufficiently decomposed and suitable for discharge (MDHS 1983).

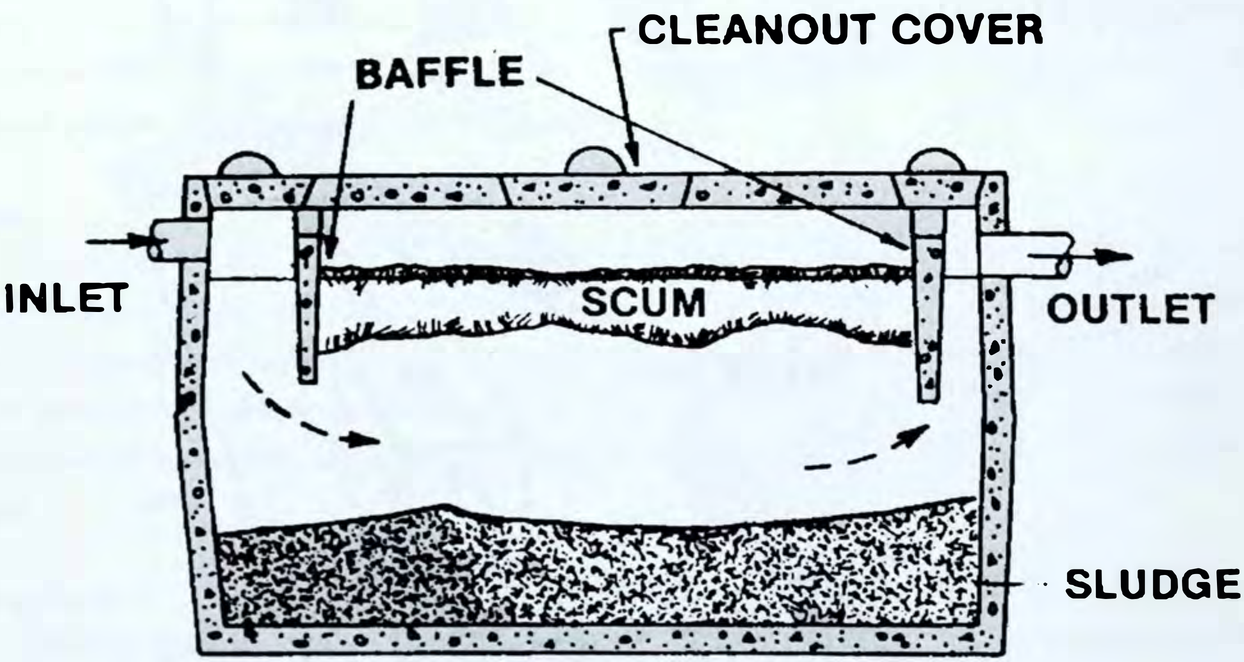


Figure 7. The cross-section of a typical treatment tank showing the movement of effluent through the tank as well as the separation of the scum and sludge (MDHS 1983).

Human waste is broken down through physical, chemical, and biological processes which separate scum and sludge from the effluent. Figure 7 shows the cross section of a typical treatment tank. Scum is the layer of grease, fats, and other particles that are lighter than water and move to the top of the treatment tank. The baffles catch scum so that it cannot escape into the disposal area. Sludge is composed of the solids that sink to the bottom of the tank. Over time, much of the scum and sludge is broken down by anaerobic digestion. The effluent then travels through the effluent line to the disposal area.

The purpose of a disposal area is to provide additional treatment of the wastewater. The disposal area can be one of three types: bed, trench, or chamber (MDHS 1983). Beds are wider than trenches, and usually require more than one distribution line; typically, beds need a distribution box. Chambers are made of pre-cast concrete. The size of the disposal area depends on the volume of water and soil characteristics. The soils in the disposal area serve to distribute and absorb effluent, provide microorganisms and oxygen for treatment of bacteria, and remove nutrients from the wastewater through chemical and cation exchange reactions (MDHS 1983). Effluent contains anaerobic bacteria as it leaves the treatment tank. Treatment is considered complete when aerobic action in the disposal field has killed the anaerobic bacteria. Incomplete effluent treatment is harmful to groundwater and contributes to nutrient loading and water contamination through the addition of viruses and bacteria (MDHS 1983). Organic particulates present in effluent also increase the biological oxygen demand (BOD).

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

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

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

When constructing a septic system, it is important to consider soil characteristics and topography to determine the best location. An area with a gradual slope (10 to 20 percent) that allows for gravitational pull is necessary for proper sewage treatment (MDHS 1988). Level slopes cause stagnation, and steep slopes drain the soil too quickly for proper treatment to take place. Adding or removing soils to decrease or increase the slope is one solution to this problem.

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

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

Since 1974, state mandates have prevented septic systems from being installed without a site evaluation or within 100 ft from the high water mark. Other regulations state that there must be no less than 300 ft between a septic system disposal field and a well that uses more than 2000 gallons per day (MDHS 1988). The maximum slope of the original land that can support a septic system is 20 percent.

Regional Land Use Trends

Similarities can be found in land use trends of the different watersheds in the central Maine region. Since the 1950s, a marked decrease in agriculture has been observed. This pattern has been observed in many of the Belgrade lake watersheds (BI493 1991, 1994 – 2000) and the Lake Wesserunsett watershed (BI493 2001). In contrast, there has been a corresponding overall increase in the percentages of mature forest for all of these previously studied watersheds. This increase in forested land could be attributed to the decrease in land used for agriculture and logged land. Another notable trend is an increase in shoreline residential land as shoreline lots have been developed. As the population has increased, the areas of nonshoreline residential land and roads have also increased. An increase in forested land and a decrease in agriculture are beneficial to the overall water quality in lakes, while an increase in shoreline residential land, nonshoreline residential land, and roads can have detrimental effects (See Analytical Procedures and Findings: Land Use Assessment: Land Use Patterns).

Park Recreational Uses

Lake George Regional Park (LGRP) provides both recreational and educational opportunities for the public. Boating, fishing, and swimming occur during the spring, summer, and fall, and ice fishing and snowmobiling are popular activities during the winter. LGRP has two trail networks, one on the east side of Lake George and one on the west side, which offer opportunities for hiking and cross-country skiing. Educational opportunities exist within LGRP as well, including, but not limited to, the study of lake ecology, forest succession, vernal pool ecology, and archaeology.

LGRP has identified two vernal pools, one on each side of the lake, which are easily accessible to visitors. An educational kiosk exists near the vernal pool located on the west side of Lake George. Vernal pools are ephemeral wetlands that support water primarily during the springtime and lack a permanent outflow (MacCallum 2001). Vernal pools dry up for many months during the year and are unable to support fish populations. There are some species that inhabit vernal pools whose lifecycles depend on the absence of fish predation. Mole salamanders (*Ambystoma* spp.), wood frogs (*Rana sylvatica)*, and fairy shrimp (*Eubranchipus* spp.) are all obligate vernal pool species. Facultative species that take advantage of vernal pools but do not depend on them exclusively include the American toad (*Bufo americanus)*, the green frog (*Rana clamitans),* and the red spotted newt (*Notophthalamus viridescens*). Vernal pools are considered by many to be endangered ecosystems, largely due to the lack of public awareness concerning their important ecological roles and the need for their protection (MacCallum 2001).

All recreational activities that occur in LGRP can potentially have adverse effects on the surrounding environment. Surface uses on Lake George can be especially problematic due to their direct influence on lake water quality. The main concerns with motor boating include: air and noise pollution, the potential introduction of exotic species, increased erosion and sedimentation, and threats to public safety. Ice fishing can also lead to lake pollution when huts, stoves, and other equipment are brought onto the lake. Oil, gas, or other chemicals that are spilled on the ice will enter the lake when the ice melts in the spring. Trash left on the surface of the ice will inevitably be deposited into the water when the ice melts, resulting in lake contamination (Hubbard, pers. comm.). In addition, intense ice fishing as well as spring and summer fishing can result in the depletion of prominently fished stocks.

Recreational trail uses raise additional concerns for LGRP. Snowmobiling poses safety hazards to cross-country skiers, and raises concerns about noise and lake pollution. Although snowmobiling is only permitted on marked snowmobile trails, occasional use does occur on the ski trails (Hubbard, pers. comm.). The main concern with non-winter trail use is the degradation and subsequent erosion of trails that can enhance nutrient loading into Lake George, diminishing the park's aesthetic value. While hiking results in some trail damage, the use of all terrain vehicles (ATVs) contributes the most impact through trail compaction and widening. Although ATVs are prohibited on park property, occasional ATV use does occur due to the difficulty in enforcing park rules (Hubbard, pers. comm.).

Regulations and appropriate management strategies are necessary to minimize the impact of recreational uses within LGRP on lake water quality. A Great Ponds Task Force was established in 1994 to address people's concerns pertaining to the diminishing quality of Maine lakes due to human impacts (Tyler 1999). The task force proposed several management strategies that apply directly to the regulation of recreational surface uses (See Analytical Procedures and Findings: Regional Park: Lake Uses). Fourteen of the thirty-four recommendations have already been passed into law. The remaining park uses must be regulated under the discretion of park managers. Trail maintenance strategies are also important in LGRP to minimize erosion and runoff into Lake George and to preserve the aesthetic quality of the trails.

Boat Launch

Lake George has a public boat launch at the southern end of the lake. Oaks Pond has no public access. A survey of the shoreline indicates that residents of Oaks Pond are using their own property to launch their boats.

Boat launches can have serious effects on the overall quality of lake water and the beauty of the surroundings. Like roads, boat launches provide easy access for runoff and sediment to enter a water body. However, unlike most roads, boat launches lead directly into water bodies. This direct access creates an easy route for phosphorus entry to the lake (Powell, pers. comm.). This level of phosphorus could be reduced if runoff sediment was first filtered through a buffer. Boat launches can have enormous effects on the lake depending on their location and number.

A public boat launch might seem like the ideal solution to reduce the number of private boat launches. Public boat launches reduce on the number of private boat launches, which lowers the number of points of entry of phosphorus to the water body (Powell, pers. comm.). Unfortunately, a variety of disadvantages are associated with public launches. Boats launched in public areas are more likely to have visited many other water bodies, which may be contaminated with exotic species. Many exotic species have been introduced to lake ecosystems via boats. For example, Eurasian milfoil (*Myriophyllum spicatum*) has been introduced to small freshwater lakes and streams on boat propellers and zebra mussels (*Dreissena polymorpha*) have invaded the Great Lakes region by being dumped with ballast water from international ships (Bouchard, pers. comm.). The introduction of Eurasian milfoil to the watershed could quickly take over the edges of the lake and ruin its aesthetic value. Swimming and boating would still be possible because these lakes are deep, but the shoreline would be lined with weeds. This could lower property values along the lake as well as the tax base for the town (Bouchard 2000).

Public and private boat launches can also add pollutants other than phosphorus. Oil and gasoline are often spilled into the lake through boat use, which is detrimental to the overall lake quality. Many small spills, or one large spill, could greatly affect the wildlife around the lake.

Aquatic plants, waterfowl, and larger mammals would be at risk (Firmage, pers. comm.).

The effects of nutrient loading on lake water quality are widespread with private boat launches, but could be better contained with one public boat launch. A reduced number of boat launches may increase overall lake water quality.

STUDY AREA: LAKE GEORGE AND OAKS POND

Lake George and Oaks Pond Characteristics

Historical Perspective

Land use patterns in the Canaan and Skowhegan area have changed drastically over the last 200 years (Skowhegan 1995. Canaan 1997). In the early 1800s, land was cleared by an influx of small family farmers. As small farms in the rocky soils of Maine became less viable and the war-time economy of the Civil War created jobs in large cities, small farmers sold their land to a few large landholders and left the region for more stable employment elsewhere. Large landowners created a thriving dairy and poultry industry in the Canaan and Skowhegan region (Skowhegan 1995, Canaan 1997). In the from the late 1800s to the mid 1900s, following a general trend in Maine, many of the farms became economically unviable and were abandoned, allowing for the natural succession of the fields to forests. Over the past 40 years, forests have replaced thousands of acres of crop and pasture land in the region. There has recently been a significant increase in residential areas due to a rise in the human population in the area, especially in Canaan (Skowhegan 1995, Canaan 1997).

A 1994 archaeological dig on the east beach shore of Lake George uncovered remnants of an 8000 year old Paleo-Indian archaeological site (site #70.28) (Warren, pers. comm.). Artifacts found at the site include split cobble, chopper and hammer stones, gray rhyolite cobble stones, and kineo hammer stones. The artifacts suggest that multiple cultural groups briefly inhabited the site between the Early to Mid-Archaic and the Middle Ceramic periods (8000 BC to 1500 AD). Due to limited funding for the excavation, the entire site was not fully exhumed, leaving significant amounts of artifacts still buried in the grassy area above the east beach (Warren, pers. comm.).

In the early 1890s, George Washburn, a local entrepreneur, built Mohican Lodge on the east beach of Lake George (Warren, pers. comm.). The foundations of the lodge can still be seen in the water a few meters out from the shore. He was able to attract wealthy people from the cities of New England to visit the lodge with the help of the train system that had recently been extended into Maine. The city patrons were attracted by the quiet pristineness of the lake, the good company and food, and the excellent fishing and boating. World War I put an end to the profits for Mohican Lodge. Consequently, in 1922, the lodge and its land was sold to Camp Modin, a summer camp for boys from the metropolitan areas of New York and New England. A few years later, a girls' camp was built across the lake from the boys' camp. For 70 years, the primary inhabitants of Lake George were the residents of Camp Modin, although a few private cottages were built on the northern shoreline of the lake (Warren, pers. comm.).

Funded by the Bureau of Parks and Recreation of the Department of Conservation and the Land for Maine's Future Board, the State of Maine purchased the 275-acre camp in 1992 for $850,000 for the purpose of becoming a Central Maine swimming park (Hubbard, unpublished document). Five months after the purchase, the State of Maine leased the land to the towns of Skowhegan and Canaan in an interlocal agreement to jointly manage Lake George Regional Park. The park is managed by ten volunteer directors who are appointed for three-year terms by the selectmen of Canaan and Skowhegan. The park officially opened in July 1993, when the construction of the public recreational area on the west side of the lake was completed. The public boat launch was completed in November 1993, and the east beach and facilities were completed in July 1995. In 1994, over 5,000 people visited Lake George. By the summer of 2001 the number of visitors had increased to 25,000 (Hubbard, unpublished document).

The history of Oaks Pond is less well documented than the history of Lake George. Oral historical accounts indicate that the first camps on Oaks Pond were built in the 1930s along a narrow span of shoreline (Dionne, pers. comm.). The remainder of the shoreline and much of the subwatershed immediately surrounding Oaks Pond were owned by a large dairy farm. In the mid-1900s the farm was sold and the grazing land reverted to forest. Throughout the twentieth century, many seasonal camps were built on the shore of Oaks Pond. In the past decade a small number of seasonal camps on Oaks Pond were converted to year round residences (Dionne, pers. comm.).

Biological Perspective

Lake George and Oaks Pond are part of the Lower Kennebec River watershed. The watershed encompasses 3484 square miles, 50 percent of which is agrarian or urban riparian (EPA 2001). The urban riparian classification is indicative of a town or city settlement along a flowing water body. The Lower Kennebec River watershed extends from north of Skowhegan to just south of Gardiner. The entire area drains into the Kennebec River, which ultimately flows into the Atlantic Ocean. Within the watershed are 2918 total river miles (EPA 2001).

Lake George is located within the towns of Canaan and Skowhegan (80 percent of the lake lies in Canaan). It covers an area of 335 acres, making it more than three times the size of Oaks Pond. Lake George receives flow from two unnamed tributaries and drains into Oaks Pond.

Oaks Pond lies entirely within Skowhegan and covers an area of 102 acres. Lambert Stream flows out of Round Pond and drains much of the Oaks Pond watershed. Oak Stream is the outlet of Oaks Pond and flows into the Little Carrabassett River, which in turn flows into the Kennebec River. A schematic representation of the flow of water within the two watersheds is shown in Figure 8.

Each lake experiences turnover of the water column twice a year, when the water temperature changes with seasons; as a result, they are classified as dimictic lakes (See Figure 1). Both water bodies support large fisheries and a variety of wildlife and aquatic macrophytic vegetation. This

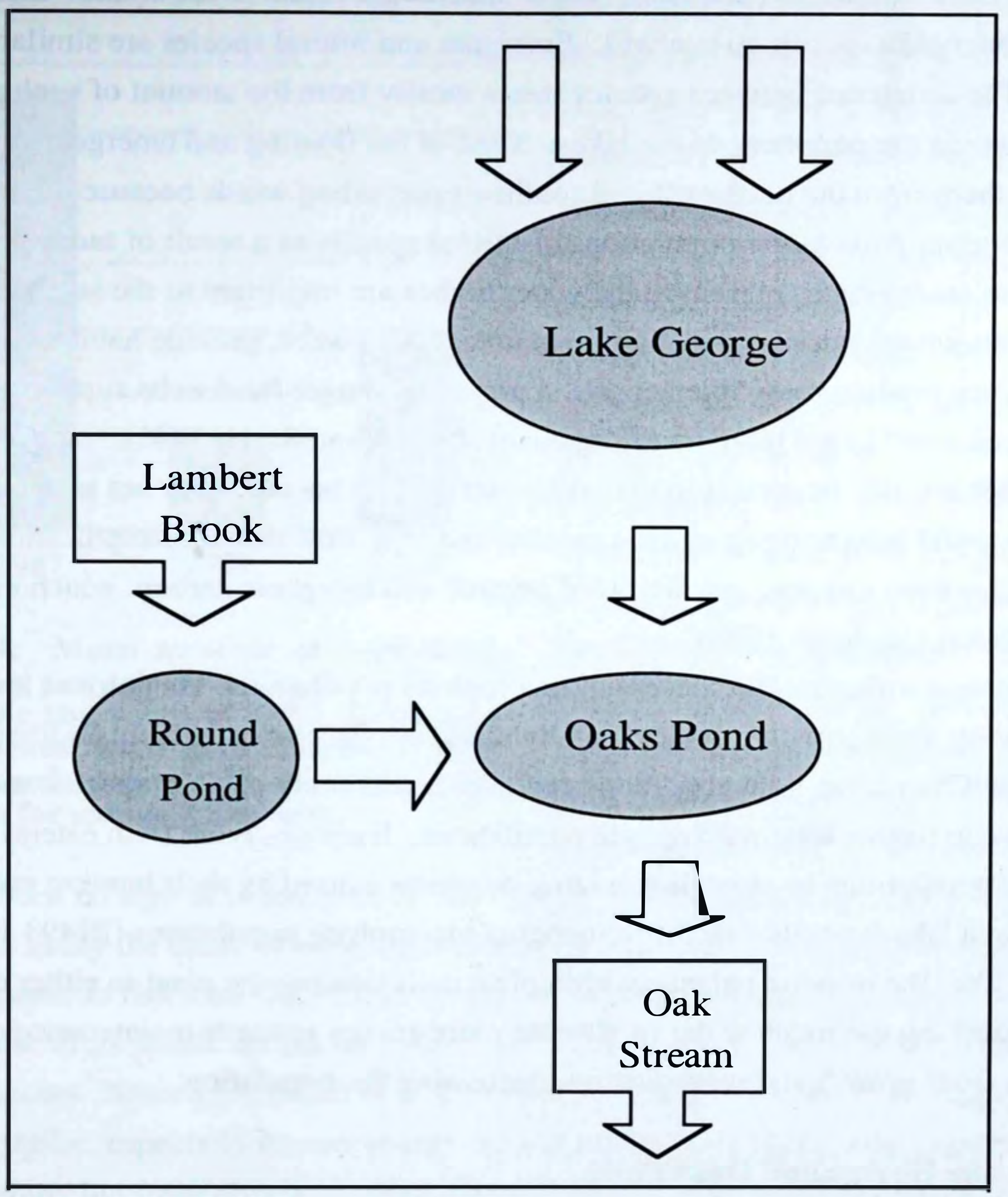


Figure 8. A schematic representation of the inflow and outflow of Lake George and Oaks Pond. Unlabeled sources have no name.

biological diversity is important to the people who live in the area who enjoy its aesthetic qualities and ecological contributions that help to preserve the quality of both watersheds.

Flora of Lake George and Oaks Pond

There is little difference in macrophytic plant species between Lake George and Oaks Pond. Macrophytes are defined as large, visible, rooted aquatic plants (Smith and Smith 2001). Both lakes support multiple emergent and floating species including pickerel weed (*Pontederia cordata*), arrowhead (*Sagittaria spp.*), watershield (*Brasnia schreberi*), yellow pond lily (*Nuphar variegatum*), scented pond lily (*Nymphaea odorata*), coontail (*Ceratophyllum spp.*), pipewort (*Eriocaulon* *aquaticum*), and elodea (*Elodea canadensis*). These species are found in the shallow shoreline areas where they have the most exposure to sunlight. Emergent and littoral species are similar for both bodies of water. The difference between species stems mostly from the amount of sunlight available and space for growth in the periphery of the lakes. Most of the floating and emergent species inhabit coves that protect them from the northwest and southeast prevailing winds because there is less wave action. Lake George supports larger populations of littoral species as a result of more shallow shoreline area. The macrophytes present in the water bodies are important to the aquatic ecosystems and lifecycles of other biota because they help to maintain food webs, provide habitats for aquatic species, and influence predator/prey interactions. Larger and longer food webs support more stable populations of species and larger biomass of organisms (Smith and Smith 1998).

Macrophytes are also important to the lake water quality because they act as sponges and buffers for nutrients and help mitigate against erosion and may slow down eutrophication. They also affect pH levels, dissolved oxygen, and dissolved organic and inorganic carbon, which are important to the ecology of lakes (Jeppesen 1998).

Multiple factors influence the success of macrophyte populations. As nutrient levels increase, corresponding algal growth can block sunlight and inhibit photosynthetic abilities of submergent plants. Changes in light conditions can alter biodiversity of plant species and lake conditions, which can further alter macrophyte populations. Even piscivore (fish eaters) density can affect macrophyte populations by changing grazing pressures caused by their hunting pressure on the grazers. The pH in a lake is another factor influencing macrophyte populations (BI493 1999). A change in pH can alter the osmotic balance within plant cells causing the plant to either die when its cells lyse from absorbing too much water or allocate more energy towards maintenance of osmotic balance and away from growth and reproduction, decreasing the population.

Fish Species of Lake George and Oaks Pond

Both waterbodies are classified as warm/coldwater fisheries and contain similar species. The six principle game fish for the lakes are: brown trout (*Salmo trutta*), largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieui*), yellow perch (*Perca flavescens*), chain pickerel (*Esox niger*), and rainbow trout (*Salmo gairdneri*) (Lake George only) (IF&W, unpublished document). Lake George is best known for its ideal smallmouth habitat and stable brown trout fishery, Oaks Pond is known for brown trout, smallmouth bass, and perch (IF&W, unpublished document). The brown trout is one of the most popular and sought after game fish. This species is part of the coldwater fishery that is stocked and able to be maintained because of the depth of the lakes and the good water quality. A list of species found in Lake George and Oaks Pond is found in Appendix B.

There is no public landing around Oaks Pond because most of the shoreline is privately owned. The lack of easy public access limits fishing during most of the year except during the winter. Oaks Pond is more easily accessed in the winter by snowmobile or ATVs when it is possible

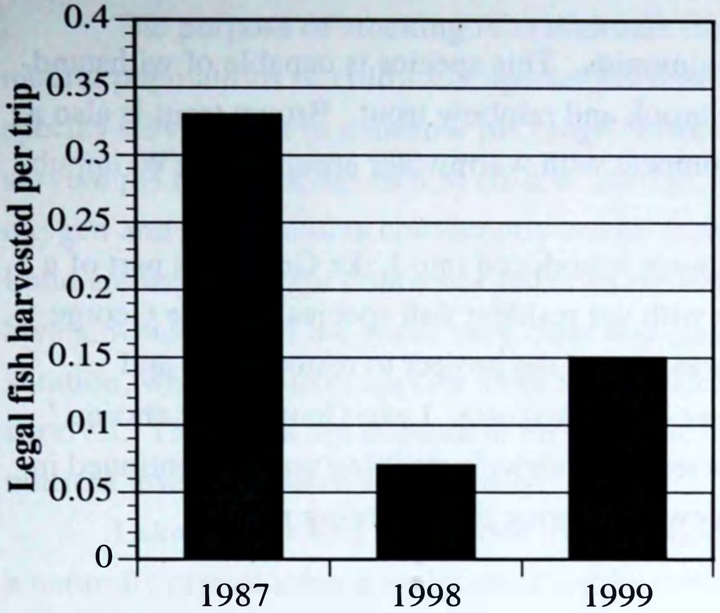


Figure 9. Mean number of legal-sized fish taken per trip to Oaks Pond in the winter for the years of 1987, 1998, and 1999. Means were provided by IF&W unpublished document. No data are available for summer harvests.

to drive out onto the pond by snowmobile and not trespass on private property. There is considerably more fishing in the winter on both lakes because of the accessibility afforded by snowmobile (Hubbard, pers. comm.).

Information on catch rates of both lakes is limited. No data exist for Lake George and data for Oaks Pond are provided by personal communication and one unpublished IF&W document. Past data on Oaks Pond show an overall decline in the number of legal-sized brown trout taken per trip in the last decade (Figure 9). Supporting information revealed that 30 years ago one could catch a bucket of white perch within a few hours; now it takes a few hours just to catch two or three perch (Dionne, pers. comm.). In the early 1970s, it was possible to catch brook trout in the tributaries and inlets but there has been no sign of brook trout in these locations for a number of years. Intense winter fishing is most likely the cause of unsuccessful fishing at other times during the year. Lake George is ultimately easier to fish than Oaks Pond during all seasons, especially during the non-winter months, because of its public access. It also accommodates intense winter fishing because of its snowmobile access. More people fish on Lake George in the winter than in the summer because the high summer traffic, especially in swimming areas, disturbs the fish and other recreational users who may not be fishing but must also be avoided (Hubbard, pers. comm.). Throughout the warmer months, fishing is better in the early morning and evening when the crowds of other recreational users are not there and the fish are more active (Hubbard, pers. comm.).

Stocking in Lake George and Oaks Pond

The IF&W stocks both lakes with coldwater fish including brown trout, brook trout, rainbow trout, and splake. Splake have only been introduced since the fall of 1999 in Lake George and in the fall of 2000 in Oaks Pond. More recently, stocking has changed almost exclusively to brown trout and splake (IF&W, unpublished document). Splake is stocked to increase catch rates and provide the public with a successful fishery. Splake is a hybrid resulting from lake trout sperm fertilizing brook trout eggs. These fish possess a "hybrid vigor" that permits them to grow faster and live longer, providing a consistent and productive fishery (IF&W 2001c). Exclusive stocking of only brown trout in Oaks Pond occurred from 1959 until 1998. IF&W management will continue the stocking of brown trout in both lakes provided that their populations and harvest rates remain high (IF&W,

unpublished document).

Brown trout is one of the hardiest species of salmonids. This species is capable of withstanding higher temperatures and lower water quality than brook and rainbow trout. Brown trout is also a popular coldwater fish to stock because it is able to compete with warmwater species (IF&W, unpublished document).

Additionally, in 1991, 2,030 sea-run alewives were introduced into Lake George as part of a four-year study to observe the interaction of alewives with the resident fish species of Lake George and their indirect effect on water quality. The study was part of the project to restore shad and anadromous alewife populations in the Kennebec River above Augusta. Lake George was chosen because of its size, accessibility, and resident fish species. The alewife stocking was discontinued in 1993 as the result of lack of manpower for trapping alewives during the recording periods (Stahlnecker, Robilland, and Squiers 1992).

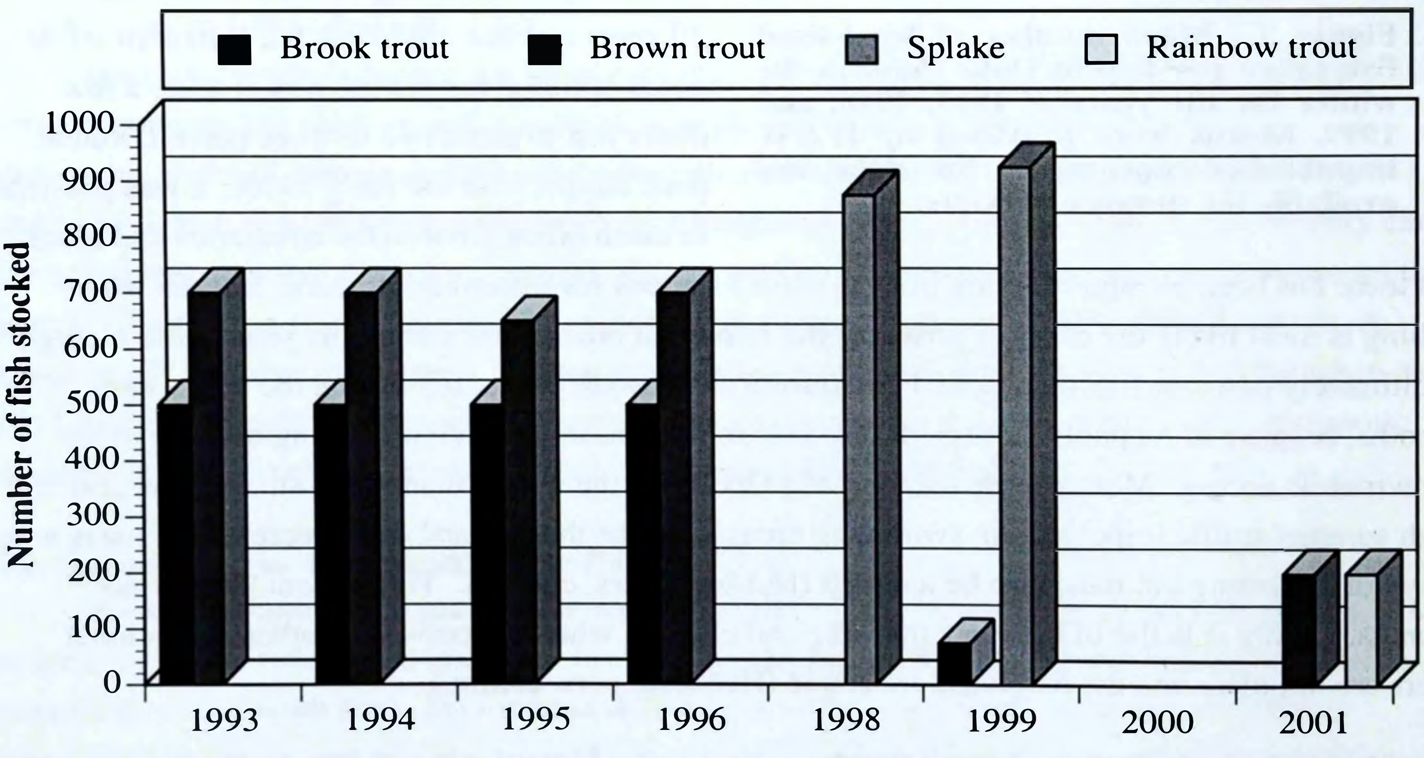


Figure 10. Comparison of the number of four species of fish stocked in Lake George between the years of 1993 and 2001 (IF&W, unpublished data). Stocking for 2001 represents fall study begun by IF&W.

In fall 2001, the IF&W conducted a study, in which they stocked Lake George with 200 brown and 200 rainbow trout to determine the interactions between these two species and their success in a warm/coldwater fishery (Figure 10; IF&W, unpublished document). This study represents the first time that rainbow trout have been introduced into Lake George. No data have yet been obtained from this study; however, the hope is that both species will coexist successfully and Lake George will be able to support this additional coldwater species.

The purpose of stocking is to maintain the popular coldwater fishery. Very few lakes support natural populations of coldwater species because of their requirements for survival. Coldwater species survive best in a narrow pH range between 6.5 to 8.5 (warmwater species such as perch can survive pH ranges of 4.5 to 8.5) (IF&W 2001a). Coldwater species require high levels of dissolved oxygen and temperatures consistently colder than 68°F. Deep lakes like Lake George and Oaks Pond are important for coldwater fisheries (IF&W 2001a). Waters must also have low nutrient levels, which makes the water very clear and clean. Coldwater fish species are also very sensitive to siltation, which actually applies more to the success of spawning and egg-hatching than to adult survival. These fish are dependent on clear, clean streams that have very little siltation and low nutrient levels to spawn successfully.

Lake George and Oaks Pond must be stocked because they do not meet all criteria to support a naturally reproducing population of coldwater species. Both lakes also lack proper spawning and nursery grounds. Additionally, competition with warmwater species is specifically detrimental to the success of the young of coldwater species (IF&W, unpublished document). Many warmwater species, especially bass, crappie, and pickerel are piscivores; they are influential in limiting the success of the less competitive and more water quality sensitive coldwater species.

Lake George and Oaks Pond are able to support stocked populations of coldwater species because these lakes are cold enough at deeper levels and also have low nutrient content. Early in the twentieth century, Lake George supported a successful naturally reproducing brook trout population that attracted vacationers from the cities, but there is now no natural population. Stocking of brook trout has been discontinued because of the low population levels and minimum success of the species (IF&W, unpublished document).

Species that were not stocked but have been caught or observed in Oaks Pond are the largemouth bass, black crappie, and the sea-run alewives (IF&W, unpublished document). These species were either unauthorized introductions or, as in the case of the black crappie, entered Oaks Pond through the outlet leading into Oak Stream. Alewives appeared in Oaks Pond only after intense rains and spring melt apparently carried them over the fish weirs of Lake George and into the tributary connecting the two lakes (Dionne, pers. comm.). The bass and crappie species are very hardy and competitive, which indicates that they may be a long-term problem in the attempt to maintain a coldwater fishery in Oaks Pond.

Recommendations for the Fisheries

The IF&W recommends that the outlets and tributaries of both lakes be kept free of obstacles to allow for movement of resident and stocked fish to occur. By keeping outlets and tributaries open, lake levels will bemore consistent, allowing fish species to move between lakes and reproduce with other populations (IF&W 2001a). In addition, movement of coldwater species out of Oaks Pond towards the Kennebec River will also support fisheries in the Lower Kennebec River watershed. Brook trout stocking is expected to cease in both lakes because of failing returns and minimum catch rates (IF&W, unpublished document). There will be continued stocking of brown trout on both lakes and perhaps of splake and rainbow trout in Lake George only if follow-up data regarding their population success are encouraging.

Wildlife in the Lake George/Oaks Pond Watershed

Both lakes support a large variety of other aquatic and terrestrial animals within the watershed because of the multiple habitats available in the area. There are two marshy areas to the north of Lake George that provide cover for nesting birds and ducks. They are also excellent foraging areas for wading birds including the great blue heron (*Ardea herodias*) and open water fowl such as the common loon (*Gavia immer*). These areas are frequented by beavers (*Castor canadensis*), as evidenced by several dams, and also by muskrats (*Ondatra zibethicus*). Lake George and Oaks Pond both support at least one mating pair of loons, and great blue herons have been sighted every year (IF&W, unpublished document). The presence of the loons and herons is an indicator of good water quality because each species requires healthy fisheries to survive. Birds of prey such as the bald eagle (*Haliaeetus leucocephalus*) and the osprey (*Pandion haliaeetus*) have been seen recently at both lakes. Although these species are not endangered, they are still threatened and their populations have yet to reach a stable density. Consequently it is important to maintain the habitat quality of both lakes to retain these species in the Lake George and Oaks Pond watersheds (IF&W 1998). The IF&W has recognized one waterfowl/wading bird habitat on Oaks Pond (IF&W, unpublished document).

The forests around the lakes are more abundant now than they were five decades ago (See Figures 31 & 32). A mix of climax and secondary forests, and some transitional forest areas provide diverse animal habitats. The hemlock climax forests provide good wintering areas for deer because they accumulate less snow beneath them. The transitional areas next to fields provide good edge habitat for animals such as snowshoe hare (*Lepus americanus*), coyote (*Canis latrans*), deer (*Odocoileus virginianus*), and a variety of rodent species. Mixed forests of the upper hillside regions surrounding the lakes offer prime habitat for bird species, as well as for rodents and mid-sized mammals such as porcupine (*Erethizon dorsatum*), striped skunk (*Mephitis mephitis*), red fox (*Vulpes vulpes*), and raccoon (*Procyon lotor*).

Many animals in the combined watersheds rely on the quality of the water and the habitats of Lake George and Oaks Pond. It is important to maintain good water quality and preserve a diverse range of terrestrial habitats because these important ecological factors will benefit all the species within the watershed.

Geological and Hydrological Perspective

Geological activity that occurred more than 10,000 years ago helped to form the watersheds of Lake George and Oaks Pond. The orientation of the lakes, the types and depth of soils, and the proximity of the bedrock are results of the movement of material and the scouring abilities of the glacier that shaped the landscape of the area.

The predominant surficial geology around the watersheds is glacial till (MDC 1996). This soil layer was deposited directly by the most recent glacier as it receded almost 12,000 years ago. Maine experienced multiple glacial periods during the Pleistocene Epoch, which lasted 1.5 million to 10,000 years ago during the Wisconsin glaciation (BI493 2000). The glacier was higher than Mt. Katahdin in Baxter State Park and was heavy enough to depress the Earth's crust by 790 ft, allowing the ocean to advance inland and cover areas that are today at elevations of approximately 400 ft (MDC 1996). The inundation was the result of the rapid rise in sea level over slow terrestrial rebound. This depression of the crust helped to create basins that would later fill up with water from the melting and receding glacier. This wall of ice moved slowly southeast, gouging out the landscape as it progressed and deposited materials along the way. The finer-grained sediments originated from erosional surfaces and the mascerating of larger material caused by the grinding and weight of the glacier. The fine sediments remained suspended in the moving water and did not settle out quickly due to their light weight. The glacial streams and rivers followed the gouged valleys left by the receding glacier and deposited their payloads along the margins of the valleys with the heaviest particles being deposited first.

The Kennebec River Valley was created by this movement of glaciers. A surficial geology map of this waterway reveals the carved bedrock and the varying depositional layers proceeding northward to the river's source (MDC 1996). Much of the Lower Kennebec drainage is underlain by a fine-grained Presumpscot formation. This formation is composed of silts and clays, a result of marine deltas, which are areas where the water fanned out over a shallow water body (the coast, or what was coast when sea level began to rise after the glacier receded) and slowed enough that these lighter particles fell out of suspension. However, in the northern half of the Lower Kennebec region drainage, the surface is covered with large boulders left by the glacier.

Lake George and Oaks Pond lie in the northern region of the Lower Kennebec watershed. Their narrow basins were carved out of the bedrock in a north-south direction. They are deep lakes for their small size, both averaging 25 ft deep, in comparison to nearby Lake Wesserunsett, which is approximately 22 ft deep at its deepest point and approximately five times larger in area. Thorndike and Plaisted soil types are common around Lake George and Oaks Pond. These soil types are characteristic of shallow soils on top of shale bedrock. They are highly permeable because of their larger grain size, which results in the soils retaining little water. Water percolates through the soils, rapidly reaching the water table, but takes much longer to percolate down through cracks and pores in the bedrock. The water table is very shallow in Thorndike and Plaisted soils because of the proximity of bedrock to the surface. Such soils result in enhancing runoff into the lakes, which can help to recharge lake levels. Lake George has moderate to steep slopes on the east and west sides that are predominantly Thorndike soils, which suggests that the water table recharges Lake George quickly (See Analytical Procedures and Findings: GIS Assessment: Soils). The basins of both lakes have areas of bedrock outcroppings, especially the east shore of Oaks Pond, which suggests the likelihood of replenishment of the lakes by groundwater in these areas. Water found within the saturation zone, the lithology between the soil surface and the bedrock, is defined as groundwater. Unconsolidated material conducts a greater volume of groundwater than areas of fractured bedrock (Caswell 1987). Consequently the recharge of Oaks Pond will occur as a result of the shallow saturation zone. The term recharge depicts the water that has seeped into the upper saturation zone and represents a potential source of replenishment for the watertable and surficial water bodies such as streams and lakes if the water reaches the surface (Caswell 1987). The water will stay within the water table and be directed by gravity until it can reach the surface through unconsolidated material or it can reach the exposed bedrock around the Oaks Pond shoreline. Lake George would most likely have similar hydrologic processes; the steeper surrounding hills are good recharge areas.

Artesian wells within the park were drilled to a depth of 190 ft and are naturally under high pressure resulting in the wells overflowing 24 hours a day (Hubbard, pers. comm.). Artesian aquifers are those with confined ground water under pressure. The aquifers in the park are the spaces in fractured bedrock that are confining water. The restriction of the upward flow of water by the bedrock results in hydrostatic pressure leading to overflow of the well heads (Caswell 1987).

Watershed Description

The CEAT lake water quality assessment investigated both the Lake George and Oaks Pond watersheds, which are located in southern Somerset County, Maine (Figure 11). The watershed boundaries used in this study were acquired from the Maine Office of GIS (MEGIS 2001). In this study, the Lake George watershed refers to the larger watershed area, including Lake George. The Oaks Pond watershed is comprised of three sub-watersheds including the one in which Oaks Pond is located (Figure 12).

There are small differences between the watershed boundaries acquired from the Maine Office of GIS (MEGIS 2001) and those used by the MDEP. These differences between the MEGIS and MDEP boundaries were found in the northern portion of the Lake George watershed, as well as on the southern and western portions of the Oaks Pond watershed. The MEGIS schematic of the Lake George watershed area differs from the MDEP watershed area by 0.2 percent. Similarly, the MEGIS representation of the Oaks Pond watershed area differs from the MDEP figure by 0.6 percent. In total, the MEGIS Lake George and Oaks Pond watershed areas overlap 99.2 percent with the MDEP watershed areas for these lakes. Based on a conversation with Roy Bouchard, CEAT decided that the MEGIS watershed boundaries would be used for our study (Bouchard, pers. comm.).

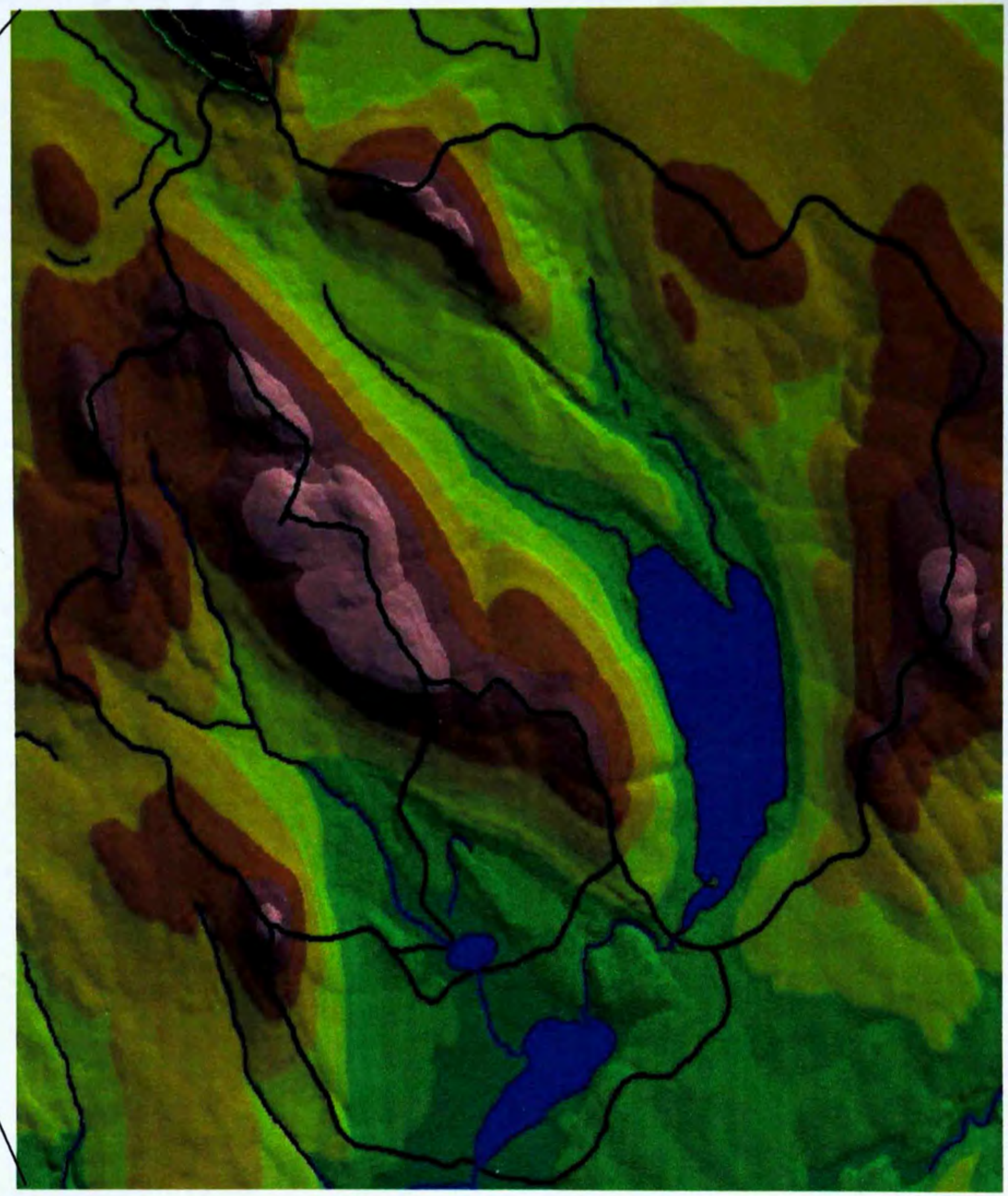



Figure 11. The location of Lake George and Oaks Pond watersheds in the State of Maine. The watershed boundaries are outlined in black. Data adapted from the Maine Office of GIS (MEGIS 2001).

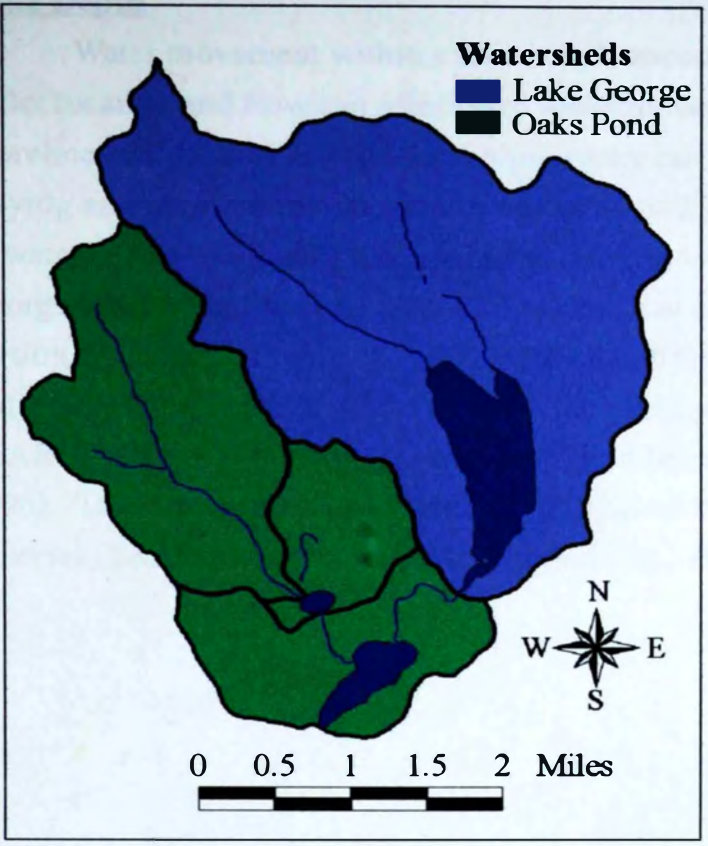


Figure 12. The Lake George watershed is comprised of the single watershed that includes Lake George. The Oaks Pond watershed is composed of three sub-watersheds. Watersheds are outlined in black (MEGIS 2001).

Lake Depth

Water movement within a lake is influenced by many factors. Near shore, tributary and outlet location and flow can affect lake water movement. Lake depth, prevailing winds, shape of the shoreline and lake basin, and local topography can also affect lake water movement. Besides playing an important role in water movement, bathymetry (the measurement of the depth of bodies of water) helps to identify the organisms that can inhabit the lake basin (Chapman 1996). Lake George has a mean depth of 24 ft (7.3 m) and a maximum depth of 68 ft (21 m) in the east central portion of the lake (Figure 13; MDEP PEARL 2001). Oaks Pond has a mean depth of 25 ft (7.6 m) and a maximum depth of 53 ft (16 m) in the north central portion of the lake (Figure 14; MDEP PEARL 2001). Both lakes are deep enough to become stratified during the summer (Chapman 1996). The deep water in both basins remains cold enough during the summer to support coldwater fisheries (See Study Area: Lake George and Oaks Pond: Biological Perspective).

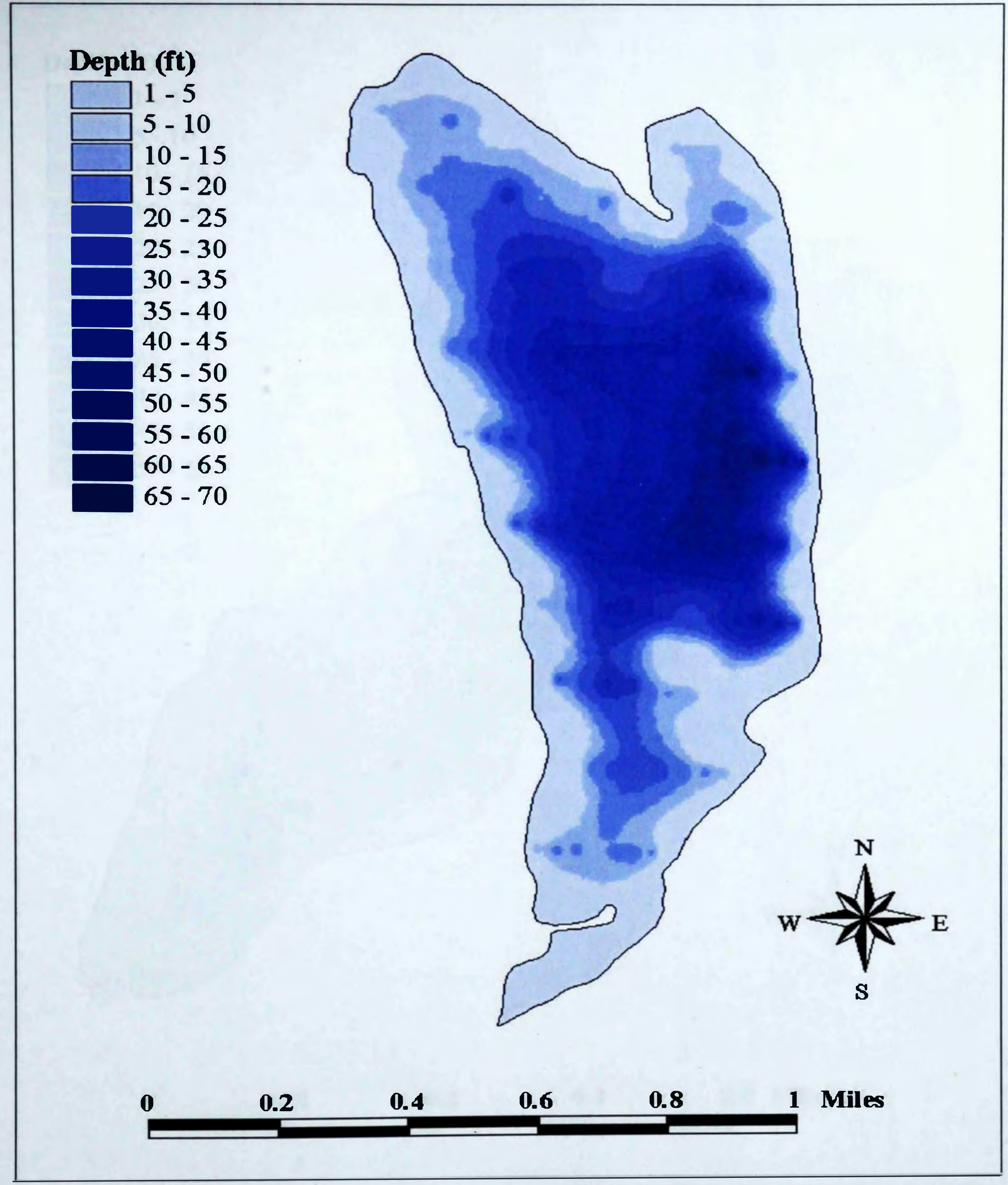


Figure 13. Bathymetric map of Lake George. Data adapted from the Maine Department of Environmental Protection PEARL website (MDEP PEARL 2001).

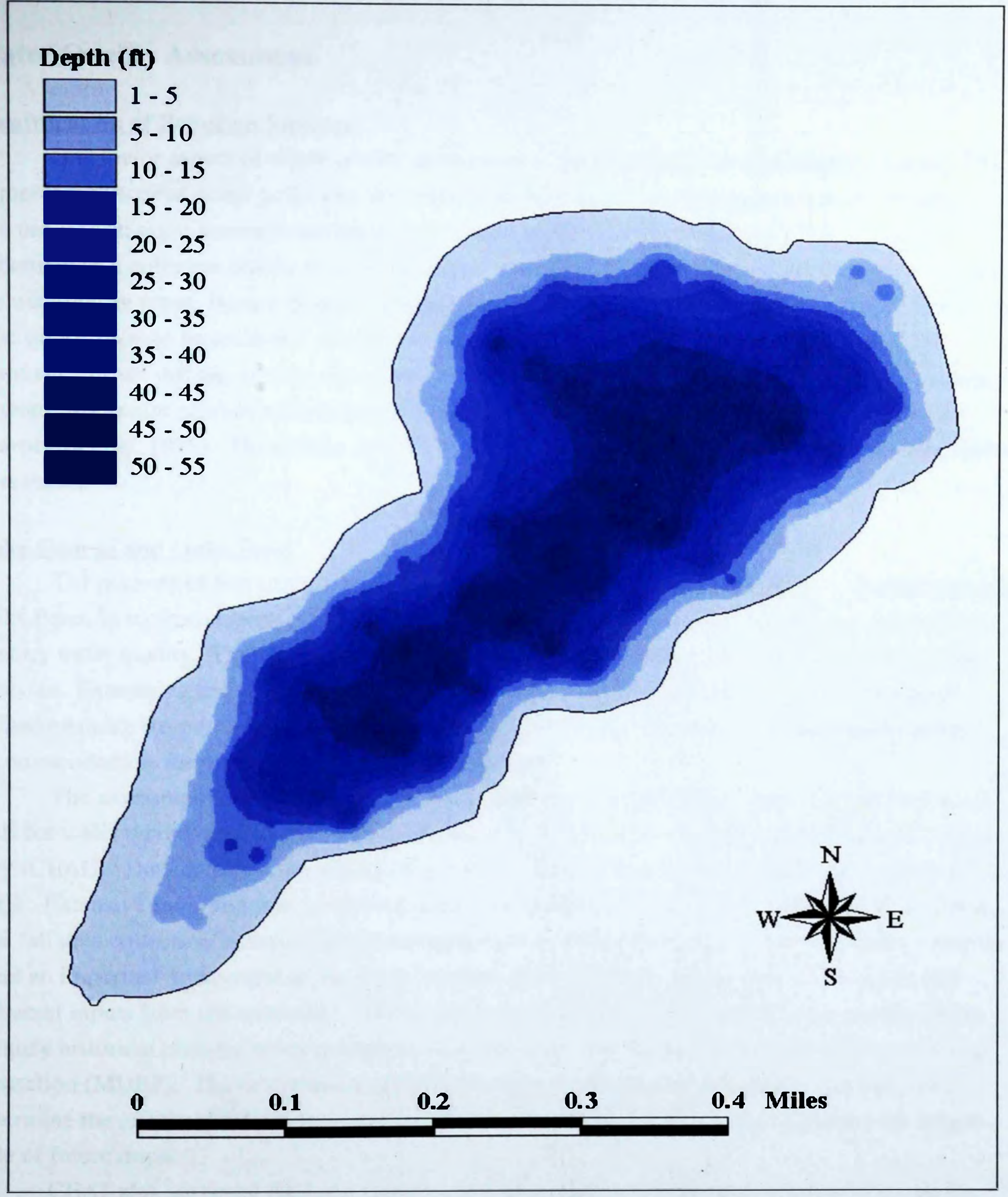


Figure 14. Bathymetric map of Oaks Pond. Depth obtained from the Maine Department of Environmental Protection PEARL website (MDEP PEARL 2001).

STUDY OBJECTIVES

Water Quality Assessment

Identification of Pollution Sources

One major aspect of water quality assessment is the identification of pollution sources. The numerous sources of water pollution, including both natural and anthropogenic, can be divided into two categories: point source pollution and non-point source pollution (Chiras 1994). A point source is defined as a pollution source that can be linked to a single output (Chapman 1996). Point sources include sewage pipes, factory outputs, and certain agricultural activities. The fixed outlet allows this type of pollution to be collected, treated, or controlled more easily than non-point sources. Non-point sources are diffuse sources that cannot be attributed to a fixed point or an activity by a single human. Non-point sources include runoff from farms, lawns, roads, and atmospheric deposition (Carpenter et al. 1998). The diffuse sources cause this type of pollution to be less distinct and harder to regulate.

Lake George and Oaks Pond

The purpose of this study was to determine the current ecological health of Lake George and Oaks Pond, to recognize possible pollution sources, and to recommend techniques for maintaining healthy water quality. The current ecological health of the lakes was determined by water quality analysis. Examining residential areas, roads, and the recreational park including the boat launch helped evaluate the possible pollution sources. The results from the study will provide insight to recommendations for maintaining healthy water quality.

The assessment of Lake George and Oaks Pond includes physical, chemical, and biological tests for water quality conducted both in the field and in the Colby Environmental Analysis Laboratory (CEAL). Data collection by CEAT at selected sites on Lake George began in the summer of 2001. Extensive sampling was conducted in the fall of 2001 for both Lake George and Oaks Pond. The fall data collection included samples from the tributaries of both lakes. These tributary samples were an important component of the study because tributaries are a direct source of nutrient and pollutant inputs from the watershed. These data were used to characterize the water quality and to identify historical changes when compared with data from the Maine Department of Environmental Protection (MDEP). The information gathered from the water quality assessment was used to determine the effects of human activities on Lake George and Oaks Pond and to predict the magnitude of future impacts.

CEAT also surveyed the Lake George and Oaks Pond combined watershed to examine the potential effects of shoreline and non-shoreline residences, roads, and the Lake George Regional Park on water quality. In addition, CEAT assessed the effects of other land uses within the watersheds, such as agriculture and forestry practices on the ecological health of Lake George and Oaks

Pond. It is necessary to assess all of these parameters to affirm and recommend healthy watershed management practices to minimize pollution and human induced eutrophication.

ANALYTICAL PROCEDURES AND FINDINGS

WATER QUALITY STUDY SITES

Twelve sites were selected for water testing on Lake George and eight sites were chosen for Oaks Pond. Three types of sample sites are included in CEAT's study: characterization, spot, and tributary. Characterization sites were chosen to help classify the entire lake's physical and chemical characteristics, which could then be compared to historical data provided by the MDEP taken at approximately the same locations. Spot site testing occurred at sites on Lake George and Oaks Pond where the potential threat to water quality by non-point pollution introduction was perceived. For example, the water bordering the shoreline where the LGRP septic systems are located was tested for *Escherichia coli*. Tributary sites were chosen within inlets of Lake George and Oaks Pond to assess possible point-source inputs into the lake and the outlets were also sampled.

A Garmin® Global Positioning Systems (GPS) 12CX was used to record coordinates at each site, which are presented in Universal Transverse Mercator (UTM) units. These units give location in the form of a coordinate pair that is first signified by an east-west distance or *easting*, followed by the north-south distance or *northing* (Clarke 2001). These coordinates correspond with a global grid that is designed to give position in meters from a Central Meridian (easting coordinate), which is significant to a single zone distinguished from others around the world, and the Equator (northing coordinate). Both lakes fall within zone 19 on the global grid. The approximate locations of sample sites for Lake George (Figure 15) and Oaks Pond (Figure 16) are described in the following text .

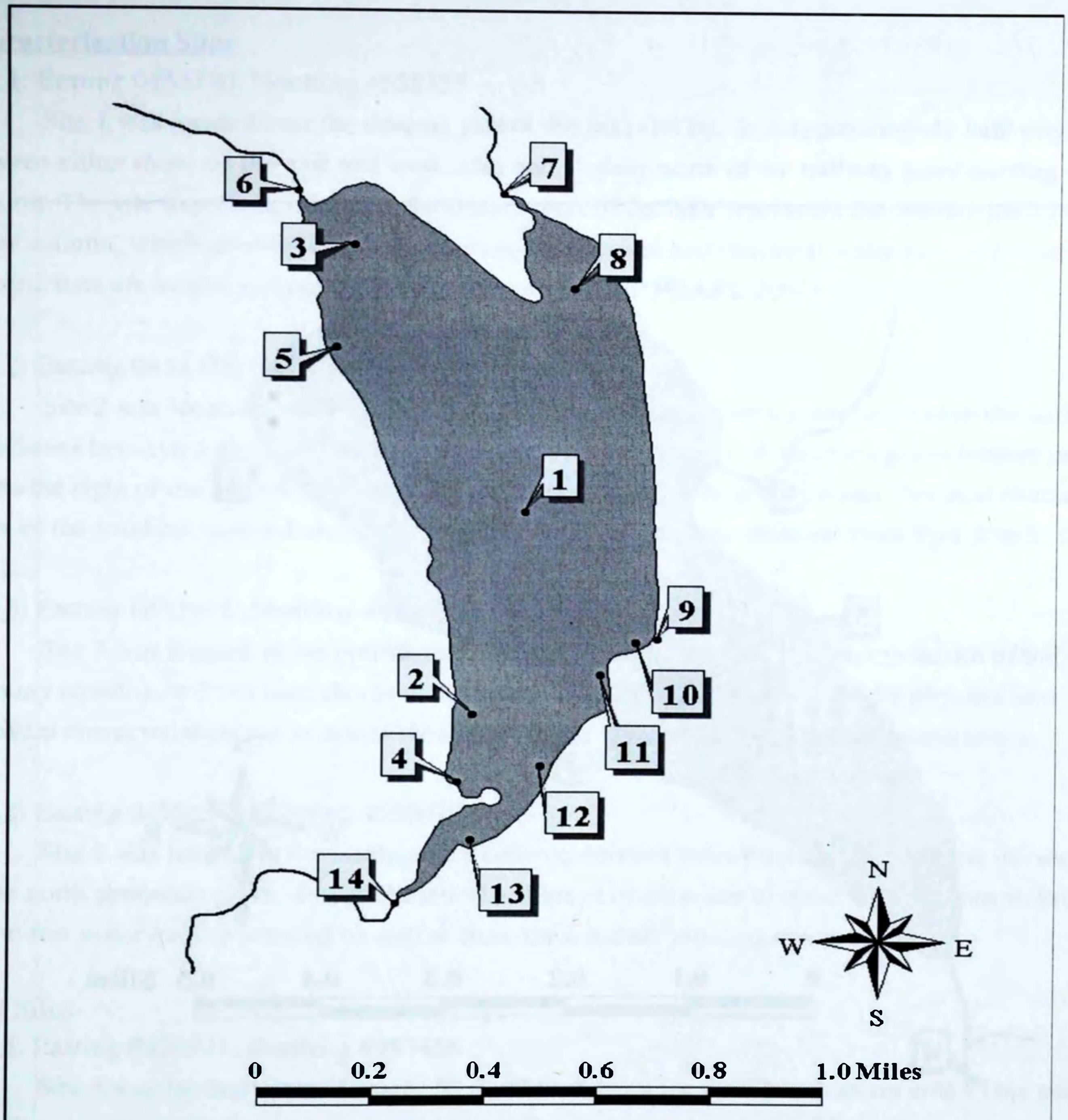


Figure 15. Lake George sampling sites tested during water quality analysis by CEAT on 19-Jul-01, 7-Aug-01, 28-Aug-01, and 12-Sep-01. Sites 1, 2, 3, and 8 are Characterization Sites, Sites 4, 5, and 9-13 are Spot Sites, and Site 14 is the outlet site for Lake George. Tributary Sites 6 and 7 were not sampled because no flow was observed at these sites.

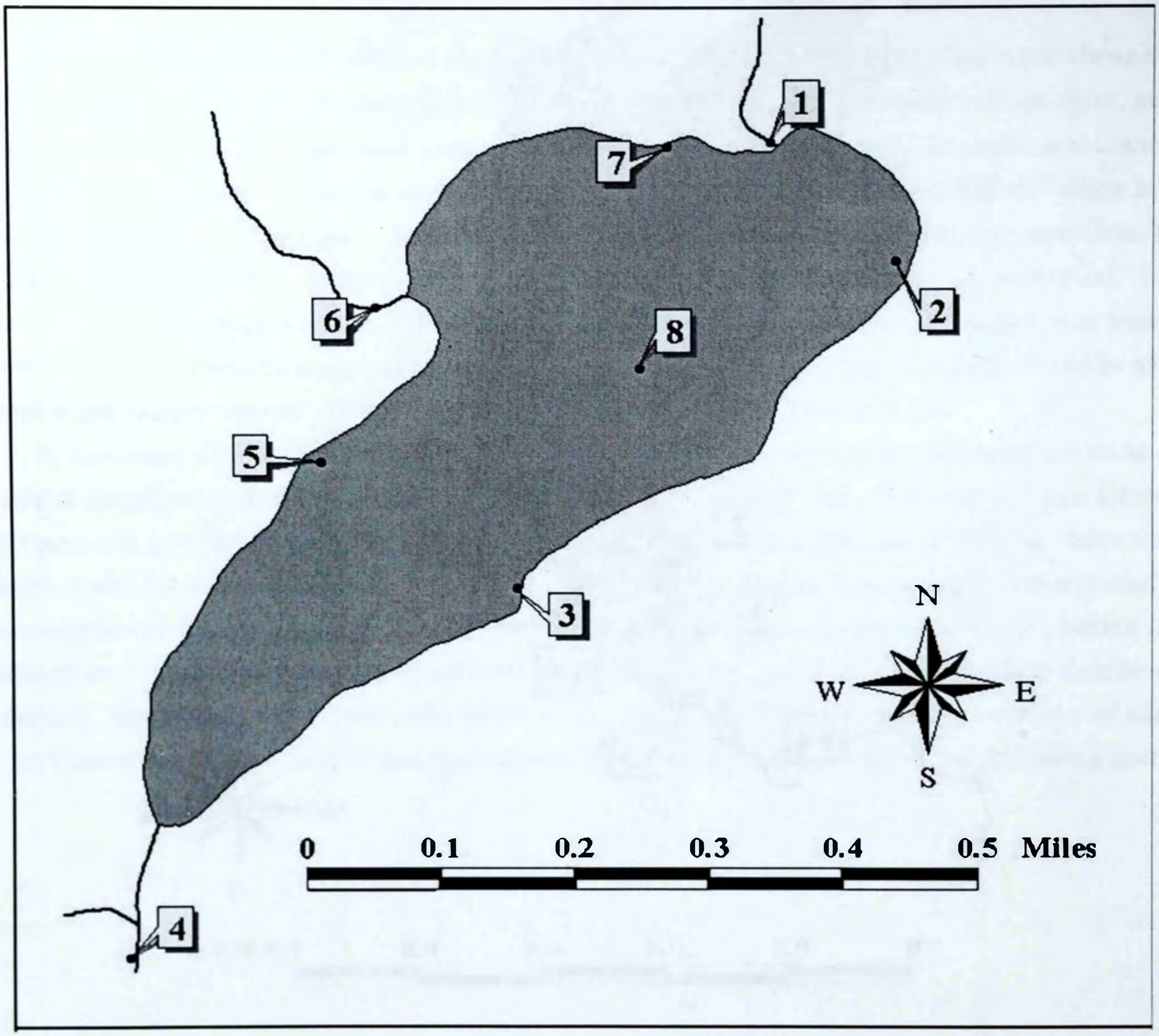


Figure 16. Oaks Pond sampling sites tested during water quality analysis by CEAT on 17-Sep-01. Site 8 is the Characterization Site, Sites 2, 3, 5, and 7 are Spot Sites, and Sites 1, 4, and 6 are the Tributary Sites of Oaks Pond. Tributary Site 6 was not sampled because no flow was observed at this site.

Lake George

Characterization Sites

Site 1: Easting 0453210; Northing 4958335

Site 1 was located near the deepest part of the lake (68 ft). It is approximately half way between either shore on the east and west sides and slightly north of the halfway point moving south to north. The site was chosen because the deepest part of the lake represents the overall quality of the water column, which allowed CEAT to measure the physical and chemical water quality parameters. Historic data are available from MDEP for this site (MDEP PEARL 2001).

Site 2: Easting 0453375; Northing 4957659

Site 2 was located approximately 100 ft offshore of the western shoreline within the park boundaries between a gray house and a long tree trunk in the water. A large snag was located on the hill to the right of the houses. This site was chosen to measure the physical and chemical characteristics of the southern end of Lake George and to compare to values obtained from Spot Site 5.

Site 3: Easting 0453035; Northing 4959223

Site 3 was located in the northwestern cove approximately 250 ft from the mouth of the tributary equidistant from both shores of the cove. This site was chosen to test its physical and chemical characteristics and to assess the impact of the tributary on water quality parameters.

Site 8: Easting 0453657; Northing 4959078

Site 8 was located in the northeastern cove equidistant from the eastern shore and the shore of the north peninsula point. It was chosen as a characterization site to make comparisons to Site 3 and to test water quality affected by inflow from the tributary entering the cove.

Spot Sites

Site 4: Easting 0453331; Northing 4957436

Site 4 was located approximately 50 ft offshore from the west beach swim area. This site was chosen to investigate problems linked to erosion and human activity. There is a septic system located approximately 300 ft uphill from the shoreline. The presence of nitrates and *E. coli* was tested to investigate the function of the septic systems. This site was also chosen to make comparisons to the septic facility of the east side, which receives more park patrons.

Site 5: Easting 0452985; Northing 4958882

Site 5 was located along the western shoreline approximately 50 ft offshore from the red house. It was located to the right of the yellow-marked rock in the middle of the line of summer camps. This site was chosen to test for potential problems stemming from camp septic systems and erosion.

Site 9: Easting 0453901; Northing 4957910

Site 9 was located at a land based culvert at the end of the east side swim area. Samples were taken onshore below the path and five feet above where the stream forks before running down a slight slope into the water. This site was chosen to measure arsenic levels (mentioned as a potential issue by park personnel) from the overflow of wells used for park services and for potential nutrient loading stemming from erosion.

Site 10: Easting 0453839; Northing 4957898

Site10 was located approximately 50 ft offshore from the middle of the east side beach area. This site was chosen to test for problems associated with intense swimming activity and runoff from the parking lot located approximately 200 ft from the water's edge.

Site 11: Easting 0453738; Northing 4957789

Site 11 was located approximately 50 ft offshore from the west facing leach bed and septic system of the east side portion of the park. The samples were collected across from the large boulder adjacent to the white birch below the leach bed. This site was chosen to test for problems caused by high use of restroom facilities and the related septic system.

Site 12: Easting 0453568; Northing 4957487

Site 12 was located approximately 50 ft offshore of the eastern shoreline in the middle of the line of apparently abandoned camps. Samples were taken across from the garage-like shed with tan shingles nearest to the east side access road. This site was chosen to examine the impacts on water quality that could be linked to improper disposal or storage of chemicals within the abandoned camps.

Site 13: Easting 0453372; Northing 4957240

Site 13 was located 50 ft offshore of the boat ramp (so as not to stir up any sediment). This site was chosen to examine nutrient loading associated with runoff from the adjacent parking lot and the boat launch area.

Tributary Sites

Site 14: Easting 0453157; Northing 4957027

Site 14 was located in the outlet of Lake George on the southern (downstream) side of Route 2 next to the bridge. This site was chosen to test the quality of water leaving the lake and to assess the possible implications this water might have as a point source for Oaks Pond.

Sites 6 and 7:

These sites were in the tributaries at the northern end of Lake George. CEAT was unable to test or collect samples because there was no water flow.

Oaks Pond

Characterization Sites

Site 8: Easting 0452450; Northing 4956251

Site 8 was located near the deepest point of Oaks Pond (53 ft) and near the sampling site of MDEP. It is located approximately one-third the length of Oaks Pond from the north shore near Steve Dionne's house. This site is approximately where Steve Dionne, the Volunteer Lake Monitoring Program participant for Oaks Pond, takes secchi disk readings. This site was chosen to measure the overall physical and chemical water quality parameters of Oaks Pond. The site was also chosen by the CEAT to make comparisons with historical MDEP data.

Spot Sites

Site 2: Easting 0452757; Northing 4956388

Site 2 was located approximately 50 ft offshore from the cluster of houses in the northeastern cove along Blue Heron Road (Fire Lane #2). This site was chosen to assess for any potential problems related to runoff and septic systems.

Site 3: Easting 0452304; Northing 4955965

Site 3 was located approximately 50 ft offshore on the eastern side of the lake centered along the row of houses on Woodcock Lane (Fire Lane #4). This site was chosen to test for any problems related to runoff, erosion, and faulty/inadequate septic systems.

Site 5: Easting 0452070; Northing 4956128

Site 5 was located approximately 50 ft offshore from where there are no houses and centered along the western shoreline opposite of Site 3. This site was chosen to provide a comparison of water quality between a site with no houses and Site 3, which has many camps nearby.

Site 7: Easting 0452484; Northing 4956536

Site 7 was located approximately 50 ft offshore from the group of houses on the northwestern side of Oaks Pond. This site was chosen to determine any effects on water quality from runoff and septic systems in this area.

Tributary Sites

Site 1: Easting 0452608; Northing 4956541

Site 1 was located in the tributary draining into Oaks Pond from Lake George bordering Steve Dionne's property. This site was chosen to determine the water quality flowing into the pond as a possible point source for nutrients and sediments.

Site 4: Easting 0451839; Northing 4955481

Site 4 was located approximately 20 ft downstream of the snowmobile bridge crossing the outlet for Oaks Pond. This site was chosen to determine the quality of the water leaving the lake and to compare the values to those of the water entering the northern end of the pond and the overall lake quality.

Site 6: Easting 0452136; Northing 4956329

Site 6 was located approximately 15 ft on the east on the lake side of the beaver dam, in a very marshy area that is part of Lambert Stream. CEAT did not sample here because there was no flowing water.

WATER QUALITY METHODOLOGY

CEAT conducted its assessment of the water quality of Lake George and Oaks Pond in the field and in the Colby Environmental Analysis Laboratory (CEAL). Water sample collection and field measurements were conducted on 12-Sep-01 for Lake George and 17-Sep-01 for Oaks Pond. Open water sampling sites were accessed using boats, canoes, and a kayak. Tributary sites were accessed using a canoe or on foot.

Physical measurements performed in the field included depth, dissolved oxygen, temperature, turbidity, and tributary flow. Depth measurements were taken using a HONDEX™ Model PS-7 depth finder with a LCD™ Digital Sounder or a Humminbird™ depth finder. Dissolved oxygen and temperature readings were collected using a YSI™ Dissolved Oxygen/Temperature meter or an Orion™ Dissolved Oxygen/Temperature meter (Orion Research Inc. 1999). The dissolved oxygen meters were calibrated in the laboratory prior to use. Turbidity was measured in the field using a Hach™ 2100N Turbidimeter. An Aqua Scope™ and a Secchi disk were used to measure transparency. Flow in the tributaries was measured using the Flo-mate™ Flow Meter (Marsh-McBirney Inc. 1990). A HORIBA™ Twin pH meter was used to measure pH and was calibrated in the field before use.

Physical measurements taken in the laboratory included true color, conductivity, and turbidity. Chemical analyses performed in the laboratory included total phosphorus, nitrates, hardness, and alkalinity. Northeast Laboratory Services in Winslow, Maine conducted tests for coliform bacteria, heavy metals, and volatile organics for Lake George. Northeast Laboratory Services also tested coliform bacteria for Oaks Pond. Northeast Laboratory Services used EPA method 600-R-00-013 for total coliform and *E. coli* analysis, EPA method 6010B for heavy metal analysis, and EPA method

8260B for volatile organics analysis. The methods for physical and chemical testing are described in the Lake George and Oaks Pond Water Quality Measurements and Analysis section of this report and Appendix C.

Water samples for each test were collected in appropriately sized and labeled plastic Nalgene® water bottles. Bottles used for phosphorus testing were rinsed three times with 1:1 hydrochloric acid and then rinsed three times with E-pure water. Bottles used for the other physical and chemical tests were rinsed three times with RO pure water.

Four types of water samples were collected: surface grab, mid-depth grab, bottom grab, and epicore. Surface grabs were collected for all tests at all sites, and mid-depth grabs, bottom grabs, and epicore samples were taken at the characterization sites on both lakes. Epicore samples were collected using a 1/2-inch flexible clear tube that was rinsed three times with lake water prior to sample collection. The tube was lowered into the water column to 1 m below the epilimnion to collect a representative sample of that part of the water column. The tube was then emptied into a 1 L Nalgene® bottle for mixing; this process was repeated two more times. The epicore sample represents a composite of the three tube samples. A Wildco™ water sampler was used to collect mid-depth and bottom grab samples, with bottom grab samples being taken 1 m above the bottom of the lake.

Water samples collected in the field were stored on ice in coolers until they were placed in the refrigeration unit in the CEAL. Samples remained in the refrigerator at 4° C until chemical analysis. Water samples used for nitrates and hardness testing were preserved by acidifying the samples to a pH of less than two. Chemical tests were then performed within the holding time for the samples (Appendix C).

Adherence to Quality Assurance protocol ensured the accuracy of the sampling and testing performed by CEAT (Appendix C). Samples collected for laboratory testing included a duplicate and a split sample for every ten samples collected. Duplicate samples were collected in two separate bottles to test field sampling accuracy. Split samples were collected in one water bottle and split into two bottles upon return to the laboratory to test the accuracy of laboratory analysis.

Lake George and Oaks Pond Water Quality Assessment

Lake Water Quality

Physical Measurements

Physical characteristics, unique to individual lakes, influence the biological activity and amount of suspended material in the water column (Chapman 1996). The physical measurements made on Lake George and Oaks Pond included dissolved oxygen (DO), temperature, transparency, turbidity, conductivity, and color.

Dissolved Oxygen and Temperature

DO is a measure of the oxygen concentration in the water column, and temperature is a measure of heat energy (Reid 1961). DO and temperature affect the biological activity of the lake, resulting in greater levels of productivity and activity at higher temperatures (Chapman 1996). DO is directly related to temperature because colder water can hold more dissolved oxygen than warmer water (Reid 1961). Low oxygen concentrations in the water column can have negative effects on fish, especially if oxygen depletion occurs in the deep waters of the hypolimnion (Pearsall 1993). DO concentrations vary throughout the water column daily and seasonally due to changes in temperature and biological activity. DO is one of the most important parameters to consider when assessing the water quality of a lake (Chapman 1996).

Methods

DO and temperature measurements were recorded by CEAT on 12-Sep-01 on Lake George and 17-Sep-01 on Oaks Ponds using the Orion™ DO/Temperature and YSI™ DO/Temperature meters. DO and temperature readings were recorded in one-meter increments from the surface to the bottom to create a profile. CEAT collected the readings at Characterization Sites 1, 2, 3, and 8 on Lake George and Characterization Site 8 on Oaks Pond. DO was measured in parts per million (ppm), and temperature was measured in degrees Celsius (° C). Historical data were obtained from the MDEP (MDEP PEARL 2001).

Results and Discussion

Historical MDEP DO data for Lake George showed stratified profiles for the years 1985, 1990, 1995, and 2001 (Figure 17). The MDEP sample site is near CEAT Characterization Site 1. The historical DO values ranged from 8.5 ppm in 1985 to 8.7 ppm in 1995 at the surface for the years sampled (MDEP PEARL 2001). The historical values ranged from 1.2 ppm in 1985 to 0.8 ppm in 1995 at the bottom of the lake. The oxygen levels in the hypolimnion are lower in 1995 than in 1985, suggesting that the oxygen depletion in the deep areas of the lake has been occurring for some time. A lack of oxygen could have potential negative impacts for the coldwater fisheries in the future. The lake may not be able to support the coldwater fisheries if oxygen levels remain below the critical level of 5 ppm to 6 ppm (Boyd 2000).

DO and temperature measurements were collected by CEAT on 19-Jul-01, 7-Aug-01, 28-Aug-01, and 12-Sep-01 at Characterization Site 1 on Lake George (Figure 17). Lake George Characterization Site 1 is the only site sampled on Lake George that was sufficiently deep enough to show clear stratification in the water column. The values of DO at the surface ranged from 8.0 ppm to 9.4 ppm during the summer and fall of 2001. DO readings are highest in the epilimnion where oxygen is replenished from the atmosphere. The temperature profile is similar to the DO profile, with the highest temperature levels occurring in the epilimnion and the lowest in the hypolimnion. Temperature of the lake water ranged from 22.4° C at the surface to 6.2° C at the bottom on 12-Sep-

01. The layers are separated by a thermocline, which is a stratum of rapidly decreasing temperature between the epilimnion and the hypolimnion.

DO concentrations are fairly constant in the profile until a depth of about 6 m where the oxycline is present. The oxycline is approximately 2 m thick and is the layer of water where the DO concentration falls sharply between the epilimnion and the hypolimnion (Henderson-Sellers and Markland 1987). The DO concentration in the hypolimnion at Characterization Site 1 ranged from 0.1 ppm to 4.5 ppm in the summer of 2001; the value in the fall of 2001 was 3.5 ppm. The concentrations of DO at the bottom of the lake were lower in the late summer and early fall than in the mid summer. DO concentrations decrease over the summer months into the early fall because the oxygen is used by fish and decomposition processes (Boyd 2000). The data collected by CEAT support the MDEP records, showing oxygen depletion in the deep areas of Lake George. These low levels of oxygen could result in future declines in the fish populations of Lake George (MDEP PEARL 2001).

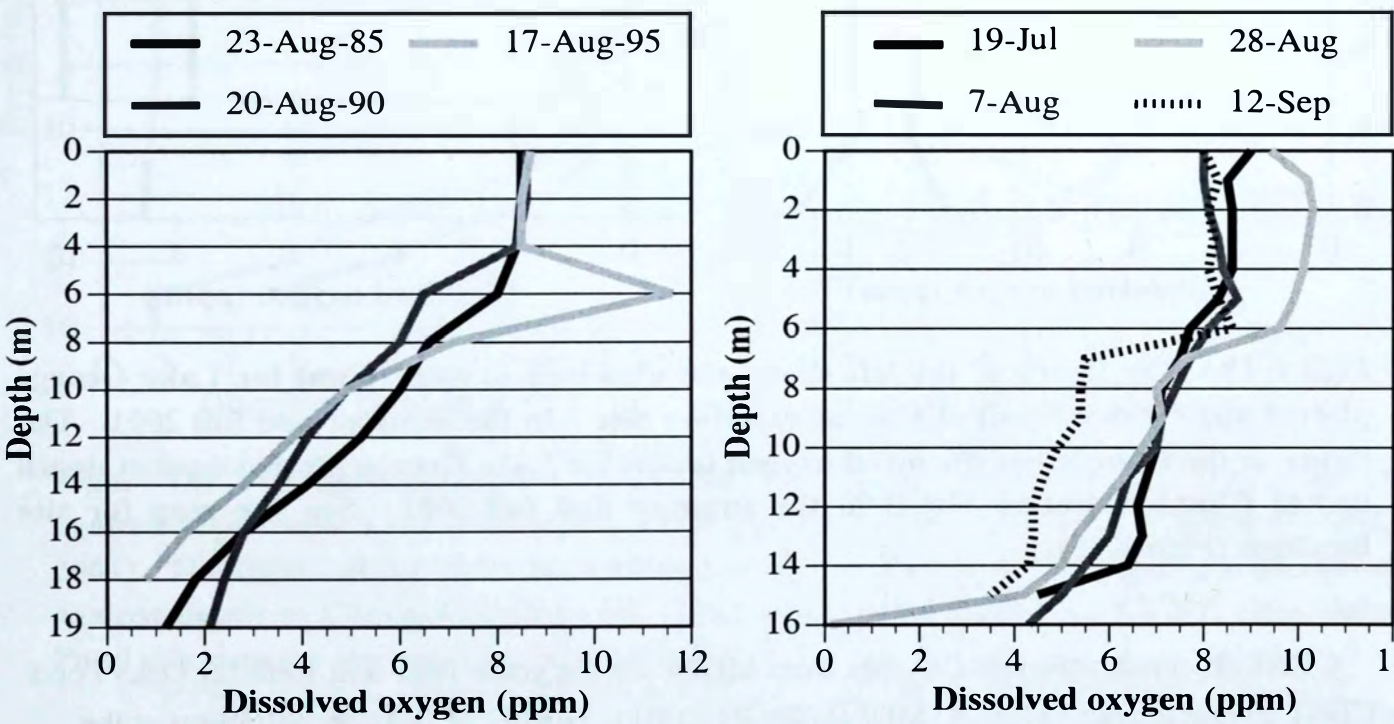


Figure 17. The figure at the left shows dissolved oxygen (ppm) for Lake George near CEAT Characterization Site 1 plotted against depth (m) from 1985, 1990, 1995, and 2001 (MDEP PEARL 2001). The figure at the right shows dissolved oxygen (ppm) for Lake George collected by CEAT plotted against depth (m) at Characterization Site 1 on 19-Jul-01, 7-Aug-01, 28-Aug-01, and 12-Sep-01. See Lake George site map for site location (Figure 15).

CEAT also measured DO at Characterization Sites 2, 3, and 8 in the summer and fall of 2001 (Figure 18). The DO concentrations are constant throughout the water column because the sites are not deep enough for stratification to occur. Characterization Sites 2, 3, and 8 are shallower than the depth of the oxycline at Characterization Site 1. The DO concentrations fall into the 8 ppm to 10 ppm range, a similar range as the epilimnion for the stratified Characterization Site 1. The DO at these shallower sites can be replenished due to diffusion and constant mixing in the water column from wind action.

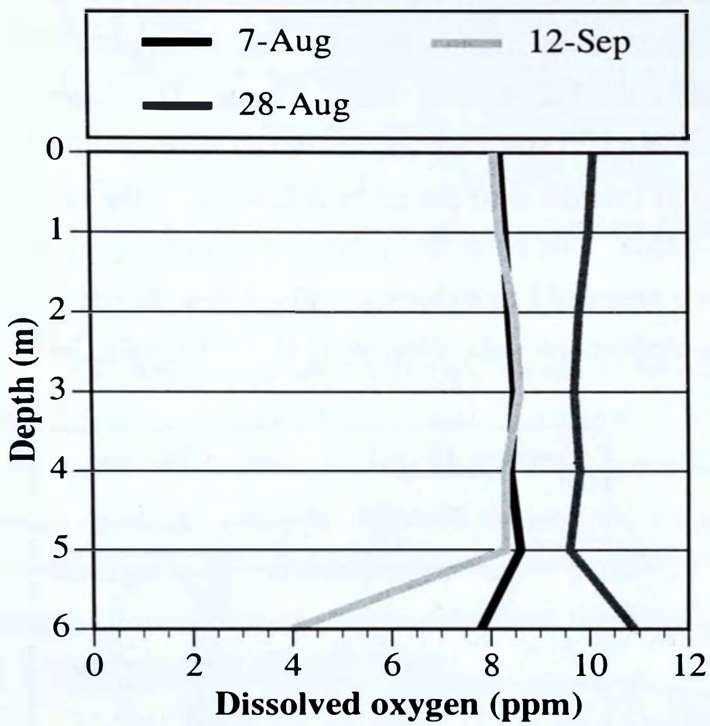


Figure 18. The figure at the left shows the dissolved oxygen (ppm) for Lake George plotted against depth (m) at Characterization Site 2 in the summer and fall 2001. The figure at the right shows dissolved oxygen (ppm) for Lake George plotted against depth (m) at Characterization Site 3 in the summer and fall 2001. See site map for site locations (Figure 15).

CEAT obtained historical DO data from MDEP for the years 1987 and 1998 for Oaks Pond near CEAT Characterization Site 8 (MDEP PEARL 2001). Historical DO concentrations at the surface were 8.1 ppm on 18-Aug-87 and 7.9 ppm on 14-Aug-98 (Figure 19). Like Lake George, Oaks Pond is stratified at the deep areas of the lake. The DO concentration is lower in the hypolimnion than the epilimnion. The historical DO concentrations, measured in the hypolimnion, were 2.3 ppm on 18-Aug-87 and 0.7 ppm on 14-Aug-98. Oxygen depletion in the hypolimnion may be increasing because the value of DO was much lower in 1998 than in 1987. More study is necessary to document this change. Low values of DO may result in a decline in the coldwater fisheries in Oaks Pond (MDEP 2000).

CEAT measured DO and temperature on 17-Sep-01 at Characterization Site 8. The lake water temperature ranged from 20.8° C at the surface to 4.6° C at the bottom on 17-Sep-01. The DO concentration at the surface was 8.3 ppm and 0.2 ppm at the bottom of the lake (Figure 18). The oxycline was located at approximately 5 m depth in the water column. The low DO concentration at the bottom of the lake is of concern for the coldwater fisheries in Oaks Pond. The DO concentration on 17-Sep-01 (0.2 ppm) was lower than the concentration found by the MDEP on 14-Aug-98 (0.7 ppm), suggesting that oxygen depletion is increasing. The DO concentrations drop more rapidly below the oxycline in Oaks Pond as compared to Lake George, suggesting that oxygen depletion is of greater concern in Oaks Pond. Continued monitoring is important because of the potential negative impacts of low DO levels for the coldwater fisheries in both lakes in the coming years.

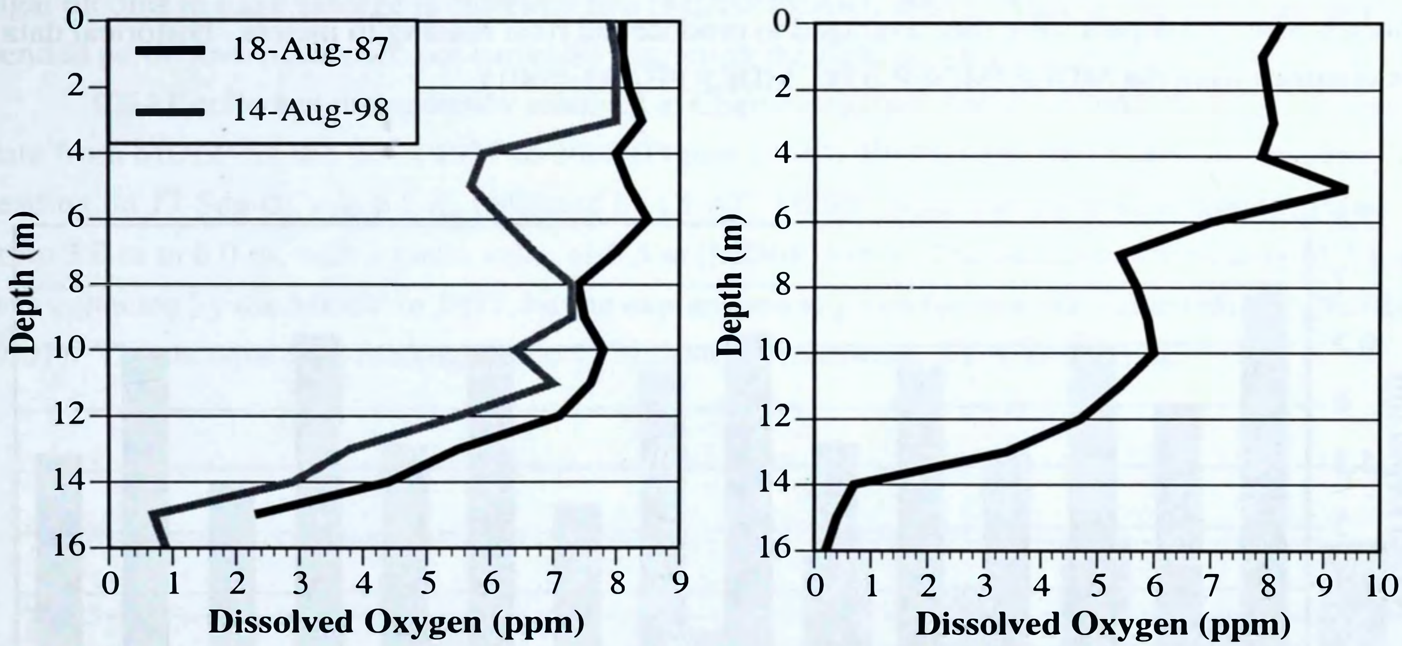


Figure 19. The figure at the left shows dissolved oxygen (ppm) for Oaks Pond plotted against depth near CEAT Characterization Site 8 in 1987 and 1998 (MDEP PEARL 2001). The figure at the right shows the dissolved oxygen (ppm) for Oaks Pond plotted against depth at Characterization Site 8 on 17-Sep-01 collected by CEAT. See Oaks Pond site map for site location (Figure 16).

Transparency

Transparency is the basic measurement used by the MDEP and the Volunteer Lake Monitoring Program to assess the water quality, primary productivity, and trophic state of Maine's lakes. Transparency measures the clarity of water in a lake and is influenced by the amount of suspended particulate matter and the penetration of light into the water column (Pearsall 1993). Transparency is primarily reduced by high levels of primary productivity, especially algae. As waters become more eutrophic, transparency readings decrease (Henderson-Sellers and Markland 1987, Pearsall 1993). Productivity is categorized, in meters of transparency depth, as oligotrophic (>7 m), mesotrophic (4 m to 7 m), and eutrophic (0 m to 4 m) (Pearsall 1993). Weather, location of sampling site, amount of suspended particulate matter, and density of algal populations contribute to daily and seasonal fluctuations in transparency readings in lakes (Pearsall 1993).

Methods

Transparency measurements were collected using an Aqua Scope and a black and white Secchi disk at Characterization Site 1 on Lake George on 12-Sep-01 and at Characterization Site 8 on Oaks Pond on 17-Sep-01. One person lowered the disk over the side of the boat, while a second person observed the sinking disk through the Aqua Scope™. When the disk disappeared from view, the depth was recorded. The disk was then lowered and raised back into view, and the depth was recorded. The two depths were then averaged to produce the final reading in meters. Historical data were obtained from the MDEP (MDEP 2000, MDEP PEARL 2001).

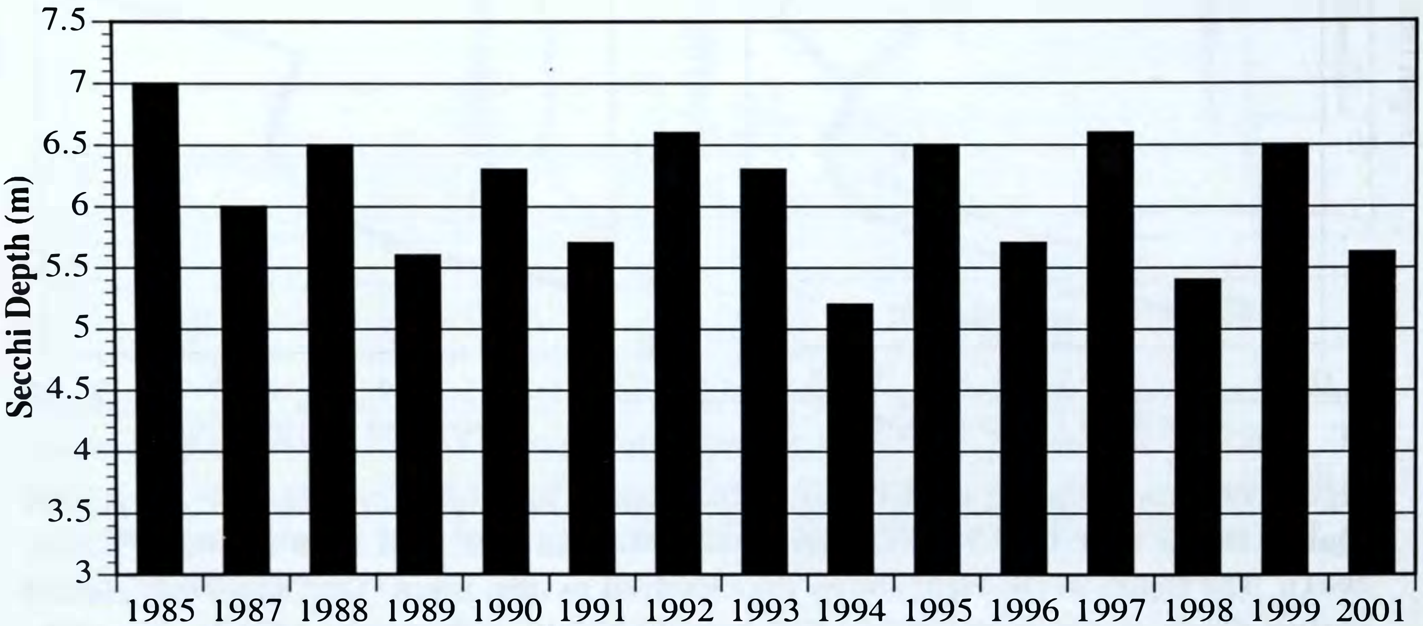


Figure 20. Mean secchi disk transparency depths reported by MDEP for Lake George near CEAT Characterization Site 1 for selected years from 1985 to 1999 (MDEP PEARL 2001). Year 2001 data were collected at Characterization Site 1 by CEAT on 12-Sep-01. See Lake George site map for location of Characterization Site 1 (Figure 15).

Results and Discussion

Transparency readings were collected by CEAT at Characterization Site 1 on Lake George on 19-Jul-01, 7-Aug-01, 28-Aug-01, and 12-Sep-01. The mean transparency reading for Lake George, collected by CEAT, was 5.8±0.4 m (n=4) for the summer and fall 2001. Historical data were obtained from the MDEP for the years 1985 and 1987 to 2000 (Figure 20; MDEP PEARL 2001). Over the 16-year period, the transparency readings oscillated between 5.2 m and 7.0 m, with a mean value of 6.1 m (MDEP 2000, MDEP PEARL 2001).

Annual fluctuations in transparency are evident in Lake George, but there are no apparent increasing or decreasing trends in the data. The mean value calculated by CEAT for the year 2001 is similar to the mean value calculated by the MDEP for the years 1985 to 2000. Transparency readings for Lake George are similar to those recorded by CEAT for Lake Wesserunsett and Great Pond. These readings are higher than Messalonskee Lake, North Pond, and Salmon Lake (Table 2).

According to the productivity categories proposed by Pearsall (1993), Lake George is considered a mesotrophic lake with moderate productivity. MDEP reports that the potential for harmful algal blooms in Lake George is currently low (MDEP PEARL 2001). Algal populations and suspended particulate matter are not currently restricting the light penetration into the water column.

CEAT collected transparency readings at Characterization Site 8 on Oaks Pond and historical data from MDEP for the years 1977 to 2000 (Figure 21; MDEP PEARL 2001). The transparency reading on 17-Sep-01 was 6.0 m, collected by CEAT. MDEP mean transparency readings ranged from 3.8 m to 6.0 m, with a mean value of 5.3 m (MDEP 2000). The transparency reading of 3.8 m was collected by the MDEP in 1977, but no explanation is given for this low value (MDEP PEARL 2001). The transparency readings since 1978 have been between 5.1 m and 6.0 m.

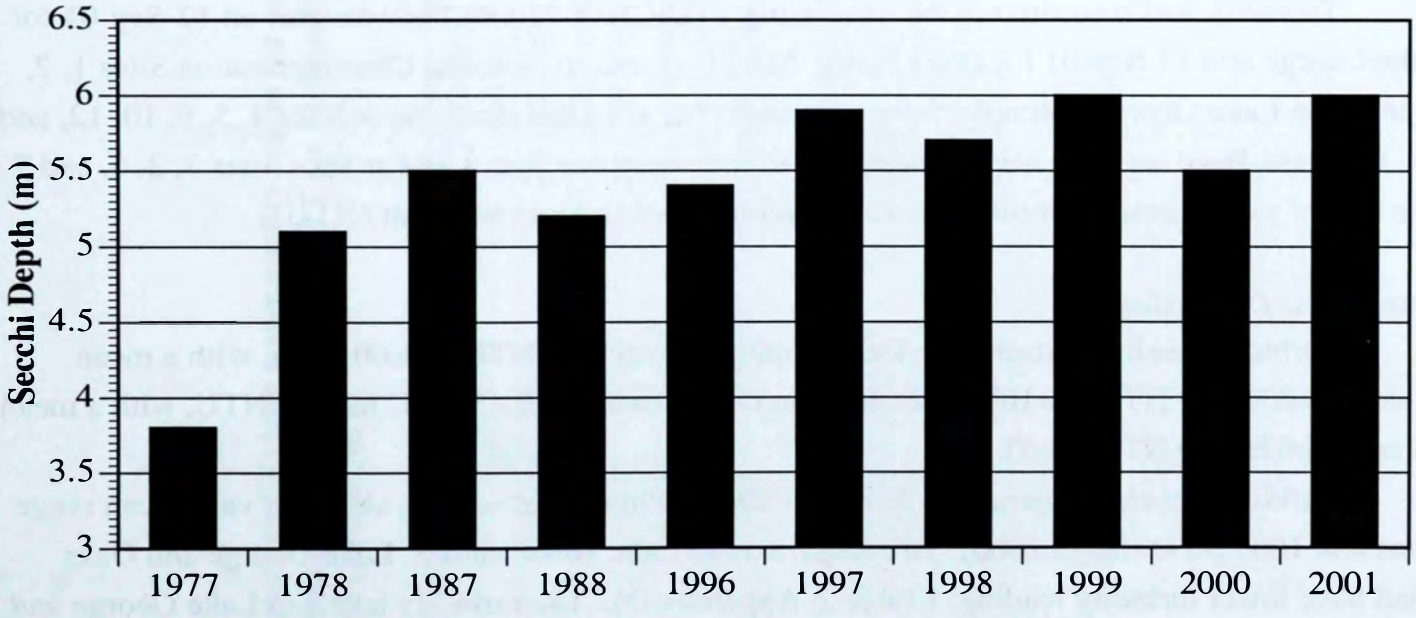


Figure 21. Mean secchi disk transparency depths reported by MDEP for Oaks Pond near CEAT Characterization Site 8 for selected years from 1977 to 2000 (MDEP PEARL 2001). Year 2001 data were collected at Characterization Site 8 by CEAT on 17-Sep-01. See Oaks Pond site map for location of Characterization Site 8 (Figure 16).

The transparency data collected by CEAT might suggest that transparency is higher in Oaks Pond because the value was higher than the mean value for Lake George in 2001. However, the transparency reading for Oaks Pond was only one sample, and it is difficult to draw conclusions from the 2001 value because transparency readings vary daily. Historical data from the MDEP show that the clarity on Oaks Pond is significantly lower than Lake George (unpaired t-test; $df = 2$; $p = 0.0079$). Lower transparency readings suggest that the amount of particulate matter in the form of algal biomass and suspended solids is higher in Oaks Pond than Lake George.

Although transparency is significantly lower in Oaks Pond as compared to Lake George, it is classified as a mesotrophic lake under the categories proposed by Pearsall (1993). The MDEP reports that the potential for harmful algal blooms in both Oaks Pond and Lake George is currently low (MDEP PEARL 2001).

Turbidity

Turbidity is a measure of the scattering and absorption of light by suspended particulate matter in the water column (Chapman 1996). Like transparency, turbidity can vary daily and seasonally due to strong winds or heavy rainfalls that may stir up bottom sediments in shallow areas. Turbidity, along with transparency and color determine the depth of light penetration into the water column. Light penetration and nutrient concentration determine the rate of photosynthesis and the level of primary productivity in a lake (Chapman 1996).

Methods

Turbidity was measured in the field using a HACH™ 2100N Turbidimeter on 12-Sep-01 for Lake George and 17-Sep-01 for Oaks Pond. Samples were collected at Characterization Sites 1, 2, 3, and 8 on Lake George. Samples were also collected at Lake George Spot Sites 4, 5, 9, 10, 12, and 13. On Oaks Pond samples were collected at Characterization Site 8 and at Spot Sites 2, 3, 5, and 7. The unit of measurement for turbidity is the Nephelometric Turbidity Unit (NTU).

Results and Discussion

Turbidity readings from Lake George ranged from 0.40 NTU to 1.00 NTU, with a mean value of 0.63±0.10 NTU (n=10). The range on Oaks Pond was 0.45 NTU to 0.98 NTU, with a mean value of 0.67±0.10 NTU (n=5).

Turbidity levels are generally less than 50 NTU in natural waters, although values can range from 1 to 1000 NTU (Boyd 2000). In comparison to Lake Wesserunsett, Lake George and Oaks Pond have lower turbidity readings (Table 2, Appendix D). The turbidity levels in Lake George and Oaks Pond are very similar due to low levels of suspended particles and the absence of algal blooms.

Conductivity

Conductivity measures the ability of a body of water to conduct an electrical current. Conductivity, along with transparency and turbidity, indicates the amount of dissolved solids in the water column (Chapman 1996). Conductivity is measured in micromhos per centimeter (μMHOs/cm) and is influenced by the degree of dissociation of mineral salts into ions, the electrical charge of ions, mobility of ions, and temperature. Estimates of mineral content and areas of pollution may also be

Table 2. Comparison of mean (± SE) lake water quality values for physical characteristics at sites in selected area lakes. Data for Lake George and for Oaks Pond collected by CEAT on 12-Sep-01 and on 17-Sep-01, respectively. Other data collected by CEAT from 1994-2001 (BI493 1994-2001).

Lake	Transparency (m)	Turbidity (NTU)	Color (SPU)	Conductivity (μMHOs/cm)
Lake George	5.8±0.4 (n=4)	0.63±0.10 (n=10)	23±3 (n=5)	25.6±0.2 (n=10)
Oaks Pond	6.0 (n=1)	0.67±0.10 (n=5)	21 (n=1)	35.1±0.4 (n=4)
Lake Wesserunsett	5.4±0.1 (n=9)	0.97±0.09 (n=11)	10±3 (n=8)	39.8±0.8 (n=6)
Great Pond	5.9±0.2 (n=13)	4.34±1.84 (n=10)	13±2 (n=15)	32.2±1.0 (n=10)
Messalonskee Lake	4.6±0.4 (n=14)	5.93±1.58 (n=14)	50±4 (n=3)	34.3±3.1 (n=6)
North Pond	3.8±0.3 (n=5)	2.79±0.28 (n=6)	17±2 (n=7)	27.3±1.9 (n=7)
Long Pond				
North Basin	6.2±0.4 (n=14)	3.33±0.17 (n=9)	12±1 (n=9)	28.9±0.7 (n=5)
South Basin	6.5±0.003 (n=2)	2.32±0.35 (n=11)	8±1 (n=11)	34.5±1.9 (n=12)
Salmon Lake	2.9±0.4 (n=2)	2.23±0.17 (n=13)	13±2 (n=5)	69.8±11.9 (n=12)

indicated by measurements of conductivity.

Methods

CEAT collected samples on 12-Sep-01 at Characterization Sites 1, 2, 3, and 8. Samples were also collected at Spot Sites 4, 5, 9, 10, 12, and 13 on Lake George on 12-Sep-01. On Oaks Pond, samples were taken at Characterization Site 8 and at Spot Sites 2, 3, and 5 on 17-Sep-01. Samples were placed in a cooler and analyzed in the CEAL using a YSI™ Model 31A Conductance Bridge. Historical data were obtained from MDEP for the years 1985, 1987, 1989, and 1991 to 1996 for Lake George and for the years 1987 and 1998 for Oaks Pond (MDEP 2000).

Results and Discussion

Conductivity measurements on Lake George ranged from 25 μMHOs/cm to 27 μMHOs/cm, with a mean value of 25.6±0.2 μMHOs/cm (n=10) (Table 2, Appendix D). Historical conductivity data for Lake George ranged from 30 μMHOs/cm to 38 μMHOs/cm, with a mean value of 34 μMHOs/cm (Appendix E; MDEP 2000).

Conductivity measurements on Oaks Pond ranged from 34 μMHOs/cm to 36 μMHOs/cm, with a mean value of 35.1±0.4 μMHOs/cm (n=4) (Table 2). Historical conductivity data for Oaks Pond were 55 μMHOs/cm in 1987 and 60 μMHOs/cm in 1998, with a mean value of 58 μMHOs/cm (Appendix E; MDEP 2000). The historical conductivity for Oaks Pond is lower than the historical conductivity for Lake George (unpaired t-test; df = 9; $p < 0.0001$).

The majority of Maine lakes range in conductivity values from 20.0 μMHOs/cm to 40.0 μMHOs/cm, and the conductivity values on Lake George are on the lower end of the range (Pearsall 1993). Rainwater generally has a conductivity level of 10.0 μMHOs/cm to 20.0 μMHOs/cm (Boyd 2000).

The low level of conductivity in Lake George can most likely be attributed to a low mineral content of the water and minimal contribution of dissolved solids overall from runoff into the lake (See Lake George and Oaks Pond Water Quality Assessment: Hardness). The conductivity level determined by CEAT (25.6 μMHOs/cm) is lower than the conductivity value found by the MDEP (34 μMHOs/cm).

Oaks Pond has a slightly higher mean conductivity value than Lake George and is on the higher end of the mean range for Maine lakes. The conductivity value for Oaks Pond suggests that the amount of dissolved solids is greater in Oaks Pond than Lake George. The conductivity level found by CEAT (35.1 μMHOs/cm) is considerably lower than the mean determined by MDEP (58 μMHOs/cm). Lake George and Oaks Pond have similar conductivity readings to area lakes, with the exception of Salmon Lake with a mean conductivity value of 69.8±11.9 (n=12) (Table 2).

Color

Color can be measured as true or apparent color. True color is a measure of the natural minerals and organic acids dissolved in a body of water (Chapman 1996). Apparent color results from the scattering of light by suspended particles and dissolved organic matter in the water column (Wetzel and Likens 1991). Color is measured in Standard Platinum Units (SPU). High levels of color in a water body can reduce the clarity of the water, resulting in lower the transparency readings (Pearsall 1993). Lakes are considered uncolored if the color measurement is 30 SPU or less (MDEP 2000).

Methods

CEAT collected water samples at Characterization Sites 1, 2, 3, and 8 on 12-Sep-01 on Lake George and at Characterization Site 8 on 17-Sep-01 on Oaks Pond. Appropriately sized and labeled bottles were filled with water and placed in a cooler until they were analyzed. Samples were filtered and analyzed for true color at room temperature using a HACH™ 4000 DR Spectrophotometer within 24 hours of sample collection (HACH 1997).

Results and Discussion

True color values for Lake George ranged from 14 SPU to 29 SPU, with a mean value of 23±3 SPU (n=5). The Oaks Pond true color was 21 SPU (n=1) at Characterization Site 8.

Lake George and Oaks Pond are both considered uncolored lakes because the mean values for both lakes are less than 30 SPU. MDEP historical data also classify both lakes as uncolored (MDEP 2000). Lake George has a historical mean color value of 16 SPU, and Oaks Pond has an average color reading of 18 SPU (Appendix E; MDEP PEARL 2001). The mean color values for Lake George and Oaks Pond are higher than for other area lakes. These higher values might be attributed to the wetlands in the area contributing organic acids to the tributaries flowing into the lakes (Table 2, Appendix D).

Wetland areas may add high levels of color to adjacent lakes due to the higher concentrations of organic material in the water (Brönmark and Hansson 1998). If this highly colored water flows into the lake from the tributaries, some areas near these inlets can be expected to have elevated color levels. The overall color levels in both lakes, however, indicate that light penetration is not currently being affected.

Chemical Analyses

pH

The pH of a body of water is a measure of the free hydrogen ion concentration and determines whether a lake is acidic or basic (Boyd 2000). The pH scale ranges from 0 to 14 with values less than 7 indicating acidic conditions and greater than 7 indicating basic conditions. Aquatic organisms are sensitive to changes in pH, which results in a distribution of species along an acidity gradient (Pearsall 1993). The pH range for most Maine lakes is 6.1 to 6.8. Lakes can become acidic as a result of acid precipitation or naturally occurring organic acids, which can cause stressful conditions for aquatic organisms (Pearsall 1993).

Methods

CEAT measured the pH at Characterization Sites 1, 2, 3, and 8 on 12-Sep-01. Samples were also taken at Spot Sites 4, 5, 8, 9, 10, 12, and 13 on 12-Sep-01 on Lake George. On Oaks Pond samples were taken at Characterization Site 8 and at Spot Sites 2, 3, 5, and 7 on 17-Sep-01. The pH was measured in the field using a HORIBA™ Twin pH meter. Historical data were obtained from MDEP for the years 1985, 1987, and 1988 to 1995 for Lake George and for the year 1987 for Oaks Pond (MDEP 2000).

Results and Discussion

The pH values for Lake George ranged from 6.54 to 7.37, with a mean value of 7.14±0.10 (n=10) (Table 3, Appendix F). MDEP historical pH data ranged from 6.24 to 7.30 for the years 1985 and 1987 to 1995, with a mean value of 6.78 (Appendix E; MDEP 2000). The pH values for Oaks Pond ranged from 6.62 to 7.33, with a mean value of 7.06±0.12 (n=5). MDEP measured a pH of 7.10 on Oaks Pond in 1987 (Appendix E; MDEP 2000).

Lake George and Oaks Pond have mean pH values close to neutral (pH=7). The pH range of most natural waters is 6.0 to 8.5 (Chapman 1996). The mean pH values of Lake George and Oaks Pond are similar to other lakes in the region (Table 3). The pH of Lake George, collected by CEAT, is higher than the mean calculated by the MDEP for the historical data. The value falls within the range of pH values collected by the MDEP, suggesting that the pH is relatively stable. The mean pH value calculated by CEAT for Oaks Pond is similar to the historical data reported by the MDEP.

Hardness

Hardness is defined as the concentration of magnesium (Mg^{+2}) and calcium (Ca^{+2}) ions present in water (Chapman 1996). Hardness arises from the dissolution of minerals, primarily calcium and magnesium carbonate, in the water column. Measurements of hardness are expressed in mg/L calcium carbonate ($CaCO_3$), although total hardness may not be due solely to calcium carbonate (NREPC 2001a). The USGS provides a classification system for the hardness levels of water: measurements between 0 mg/L and 60 mg/L are classified as soft waters, 60 mg/L to 120 mg/L are moderately hard, 120 mg/L to 180 mg/L hard, and greater than 180 mg/L are classified as very hard waters (USGS 2001). In a biological context, higher hardness values limit the algal productivity of a lake because high concentrations of calcium can increase phosphorus sedimentation (Mairs 1966).

Methods

Samples were collected to test for hardness on 12-Sep-01 at Characterization Sites 1, 2, 3, and 8 on Lake George and collected on 17-Sep-01 at Characterization Site 8 on Oaks Pond. Water

Table 3. Comparison of mean (± SE) lake water quality chemical tests at sites in selected area lakes. Data for Lake George and for Oaks Pond collected by CEAT on 12-Sep-01 and on 17-Sep-01, respectively. Data for other area lakes collected by CEAT from 1994-2001 (BI493 1994-2001).

Lake	pH	Hardness (mg/l)	Nitrates (ppm)	Alkalinity (ppm)
Lake George	7.14±0.10 (n=10)	4.17±0.03 (n=8)	0.06±0.01 (n=12)	8.7±1.0 (n=4)
Oaks Pond	7.06±0.12 (n=5)	3.76±0.09 (n=3)	0.06±0.01 (n=5)	3.7 (n=1)
Lake Wesserunsett	7.28±0.06 (n=14)	3.24±0.03 (n=4)	0.04±0.004 (n=12)	13.7±0.4 (n=2)
Great Pond	6.98±0.09 (n=10)	3.00±0.03 (n=2)	a	8.7±0.3 (n=6)
Messalonskee Lake	6.92±0.17 (n=9)	14.91±0.26 (n=6)	0.10±0.00 (n=3)	16.2±1.8 (n=6)
North Pond	6.99±0.09 (n=4)	10.11±0.40 (n=6)	0.05±0.01 (n=9)	12.4±0.2 (n=8)
Long Pond				
North Basin	6.85±0.21 (n=4)	12.40±0.22 (n=8)	0.03±0.002 (n=13)	9
South Basin	6.59±0.11 (n=12)	3.42±0.21 (n=9)	0.04±0.003 (n=5)	8.6±0.3 (n=7)
Salmon Lake	7.78±0.13 (n=4)	25.90±0.74 (n=4)	0.00±0.01 (n=13)	-

[a] Below the limit of detection

was sampled from the surface at Lake George, and the water for hardness analysis from Oaks Pond was obtained from epicore samples. Water samples were acidified to a pH of 2 with concentrated nitric acid immediately after collection and then stored at 4° C prior to testing. Before analysis of the samples in the CEAL, pH was adjusted to a level between 3 and 8 with 5.0 N sodium hydroxide (NaOH). The samples were then analyzed using the calmagite colorimetric method and a HACH™ DR/4000 spectrophotometer (HACH 1997).

Results and Discussion

The mean (± SE) hardness for Lake George was 4.17 ± 0.03 mg/L $CaCO_3$ (n = 8), compared to 3.78 ± 0.10 mg/L $CaCO_3$ (n = 3) in Oaks Pond (Table 3, Appendix F). The Lake George value was significantly higher than that of Oaks Pond (unpaired t-test, df = 9, p=0.0007). However, these results may not be directly comparable because of the difference in sampling techniques used in each lake. The data indicate that both Lake George and Oaks Pond should be classified as soft water lakes by USGS standards.

Soft water lakes are typical of central Maine, as indicated by the results of past studies (BI493 1994 - 2001). A study on Lake Wesserunsett water quality reported a similar mean hardness value of 3.24 ± 0.03 mg/L (Table 3; BI493 2001). Research in the Belgrade Lakes area conducted by CEAT reported mean hardness values ranging from 3.00 ± 0.03 mg/L for Great Pond to 25.38 ± 0.77 mg/L for Salmon Lake (Table 3; BI493 1994 and 1999). These low hardness values indicate that the bedrock of this area of Maine contains low levels of calcium carbonate or is highly resistant to weathering. High hardness values also have beneficial implications for the aquatic life such as mitigating the effects of heavy metals entering the ecosystem. The calcium and magnesium ions complex with metals in the water, converting them to a form unable to be taken up by aquatic organisms (NREPC 2001a). If heavy metals were added to Lake George or Oaks Pond by a pollution source, there would be little complexing protection offered to aquatic organisms. In addition to complexing with metals, hardness has been associated with higher fish productivity levels (Mairs 1966). The data for Lake George and Oaks Pond may suggest that these lakes are not optimal fisheries because the low hardness of the waters may limit fish productivity.

Alkalinity

Alkalinity is commonly referred to as the acid neutralizing capacity of a lake because it reflects the ability of lake water to buffer the effects of strong acids (Wetzel and Likens 1991). It is a measure of the concentration of carbonate, bicarbonate, hydroxide, and other basic ions in water (Chapman 1996). These anions act as a buffer by neutralizing excess hydrogen ions and preventing drastic changes in pH (Maitland 1990). A high alkalinity lake is better able to neutralize a sudden increase in acid and maintain constant pH levels than one with a lower alklainity level. A decline in alkalinity serves as an indicator of acid deposition to a lake before adverse effects on aquatic life are observable, because a drop in alkalinity will occur before a decrease in pH of the lake.

Methods

Epicore samples were obtained from Characterization Sites 1, 2, 3, and 8 at Lake George on 12-Sep-01 and from Oaks Pond Characterization Site 8 on 17-Sep-01. The samples were stored at 4° C and analyzed within 24 hours of collection. Each sample was titrated using the potentiometric titration method with 0.02 N sulfuric acid (H_2SO_4) and then entered into a formula to determine the concentration of calcium carbonate ($CaCO_3$) in parts per million (ppm) (Clesceri, Greenberg, and Trussell 1989).

Results and Discussion

The mean (± SE) alkalinity of the characterization sites on Lake George was 8.73 ± 0.97 ppm (Table 3, Appendix F), compared to a historical mean of 10.9 ppm reported by MDEP (Appendix E; MDEP 2000). The value obtained by CEAT is similar to the historical data, which suggests that there has been no recent influx of hydrogen ions to Lake George and the buffering capacity is fairly stable. The alkalinity value obtained from Characterization Site 8 on Oaks Pond was 3.73 ppm (Appendix F), compared to a historical mean of 12.5 ppm reported by MDEP (Appendix E). The difference in these values may suggest that acidic deposition to the lake has lowered the buffering capacity of Oaks Pond. The low value obtained by CEAT may also have resulted from sampling error, especially considering only one sample was collected at Oaks Pond for analysis of alkalinity.

These data suggest that Oaks Pond has a lower buffering capacity than Lake George. Surface waters with alkalinity values less than 24 ppm $CaCO_3$ are considered to have low alkalinity values and are more susceptible to changes in pH from acidic additions (Chapman 1996). Recent research indicates that, similar to hardness, alkalinity values are low for this region of Maine (BI493 1994 – 2001). Studies of the Belgrade Lakes report mean alkalinity values from 9 ± 0.03 ppm in Long Pond to 18 ± 1.0 ppm in Messalonskee Lake (Table 3). Alkalinity values are largely derived from $CaCO_3$ concentrations in the water; softer waters tend to have lower alkalinity values (NREPC 2001b). The low alkalinity values for Lake George and Oaks Pond are consistent with their ratings as soft lakes. The majority of lakes in Maine (67 percent) have low alkalinity values of less than 10 ppm (Norton et al. 1989). The low historical values for Lake George and Oaks Pond may not be indicative of acidic deposition into the lakes and are more likely to represent the natural condition of low carbonate levels present in Maine. These lakes may not yet be affected by acidic deposition as indicated by their neutral pH levels, however, they may be considered highly susceptible to any input of hydrogen ions.

<u>Nitrates</u>

Nitrogen is an important nutrient for life because it is a major constituent of proteins (Boyd 2000, Smith and Smith 2001). Nitrates are rarely found in concentrations above 1 ppm, and levels above 5 ppm are considered to be indicative of pollution by human or animal waste (Chapman 1996). Nitrates are not the sole determinants of a eutrophic lake because they tend to be the more limiting nutrient in marine environments (Carpenter et al. 1998), whereas phosphorus is usually the primary limiting nutrient of freshwater systems (Boyd 2000).

Methods

Epicore samples were obtained at Characterization Sites 1, 2, 3, and 8, and surface grabs were collected at Spot Sites 4, 5, and 11 on Lake George. On Oaks Pond, an epicore and surface sample were taken at Characterization Site 8, and only surface grabs were taken at Spot Sites 2, 3, and 7 and Tributary Sites 4 and 6. Samples were acidified in the field to a pH less than 2 with concentrated sulfuric acid (H_2SO_4) and stored at 4° C following collection. The samples were analyzed within 48 hours by the low nitrate cadmium reduction method utilizing a HACH™ DR/4000 spectrophotometer (HACH 1997).

Results and Discussion

The mean (± SE) nitrate level for Lake George was 0.06 ± 0.01 ppm (n = 12). Spot Site 5, located 50 ft offshore from houses on the west side of Lake George, had a nitrate reading of 0.12 ppm, twice that of the mean value, which may suggest that slightly higher levels of nitrates are leaching into the lake from this area of shore (Appendix G). The mean (± SE) level for surface samples on Oaks Pond was 0.06 ± 0.01 ppm (n = 5). An epicore sample from Characterization Site 8 produced a similar value of 0.05 ppm (Appendix G). The nitrate values for all of the other sites on both lakes ranged from 0.04 to 0.08 ppm. Although these nitrate values are slightly higher than the mean values of other lakes in Central Maine, all of the values obtained from these lakes, including Lake George Spot Site 5, are well within the limits of a natural system and do not suggest pollution from human or livestock sources (Table 3; Chapman 1996).

Total Phosphorus

Phosphorus is necessary to all forms of life because it is a major element in DNA and in ATP, the energy source of cells (Brönmark and Hansson 1998). Phosphorus is also the primary limiting nutrient of aquatic plants in freshwater systems (Brönmark and Hansson 1998). Macrophytes and phytoplankton are efficient at extracting large quantities of phosphorus from water containing minute concentrations (Maitland 1990). Consequently, phosphorus concentrations in surface waters are generally low, with typically ten percent or less of total phosphorus concentrations in a form readily usable by plants (Maitland 1990, Boyd 2000). Most unpolluted lakes range in total phosphorus levels from 10 to 30 ppb (Reid 1961). The critical phosphorus level used by MDEP to indicate water with the imminent potential of algal blooms is between 12 and 15 ppb (See Introduction: Phosphorus and Nitrates).

Methods

Samples were obtained on 12-Sep-01 from 12 sites on Lake George including the outlet site.

Characterization Sites 1 through 3 were also sampled on 19-Jul-01, 07-Aug-01, and 28-Aug-01. Samples were collected on 17-Sep-01 from five sites on Oaks Pond, two tributaries, and the outlet site. At the characterization sites for both lakes, samples were obtained by surface, mid-depth, and bottom grabs as well as by epicore; the spot and tributary sites samples were collected only by surface grabs.

The water samples were chilled on ice until they were brought to the Colby Environmental Analysis Laboratory (CEAL) where they were stored at 4° C. All samples were separated into two containers, each containing 50 ml. The second containers were implemented as a safety precaution against possible errors in the testing. Duplicates and splits were made for ten percent of all samples to ensure accuracy. Standards of known phosphorus concentrations ranging from 0 to 50 ppb were used to calibrate the spectrophotometer and test analytical accuracy. Within 24 hours after collection, the 50-ml samples and standards were digested by the addition of 1.0 ml of 11 N sulfuric acid and 1.0 ml 1.75 N ammonium peroxydisulfate and placed in an autoclave at 15 pounds per square inch at 120° C for 30 minutes. This digestion process both sterilized the samples and converted the particulate organic phosphorus into the dissolved form.

Digested samples were stored in refrigeration until analysis. Immediately prior to analysis, the pH of the samples was raised to approximately 8.2 by titrating with 11 N NaOH. The sample was treated with 8 ml of combined reagent composed of 5.0 N sulfuric acid, potassium antimonyl tartrate, ammonium molybdate, and ascorbic acid. After a reaction time of ten minutes, the concentration of phosphorus was measured using a HACH™ DR/4000 spectrophotometer. The methods for total phosphorus analysis that we employed were outlined by Eaton, Clesceri, and Greenberg (1995), with modification by G. Hunt and C. Elvin of the MDEP.

Results and Discussion

Characterization Site History

The MDEP began monitoring phosphorus concentrations near our Characterization Site 1, the deepest location on Lake George, in August of 1985 and monitored the concentration throughout the summer (mid-June to mid-August) and early fall (late August to mid-October) with epicore and bottom samples until 1996 (MDEP PEARL 2001). Data from 1996 to 2000 were not collected (MDEP PEARL 2001). The mean value from epicore samples in the summer and fall from 1987 to 1990 was approximately 8 ppb. The levels of phosphorus in summer and fall decreased between 1990 and 1993. From 1994 to 1996, the mean total phosphorus levels increased, with a summer mean of approximately 9 ppb and a mean slightly below 8 ppb for the fall concentrations (Figure 22). The occurrence of higher mean values in the summer months may be indicative of populations of phytoplankton and zooplankton present in the upper section of the water column in the summer. The lower mean concentrations in the early fall measurements likely reflect the death of some phytoplankton and zooplankton, which then sank to the sediments on the lake bottom. The lower concentrations also suggest that sampling occurred prior to turnover, which could elevate phosphorus levels in surface waters (Reid 1961). All of these values are well below the threshold level for algal blooms (12 to 15 ppb), and the consistency of the values suggests that Lake George has not suffered from algal blooms in the past (See Introduction: Phosphorus and Nitrates).

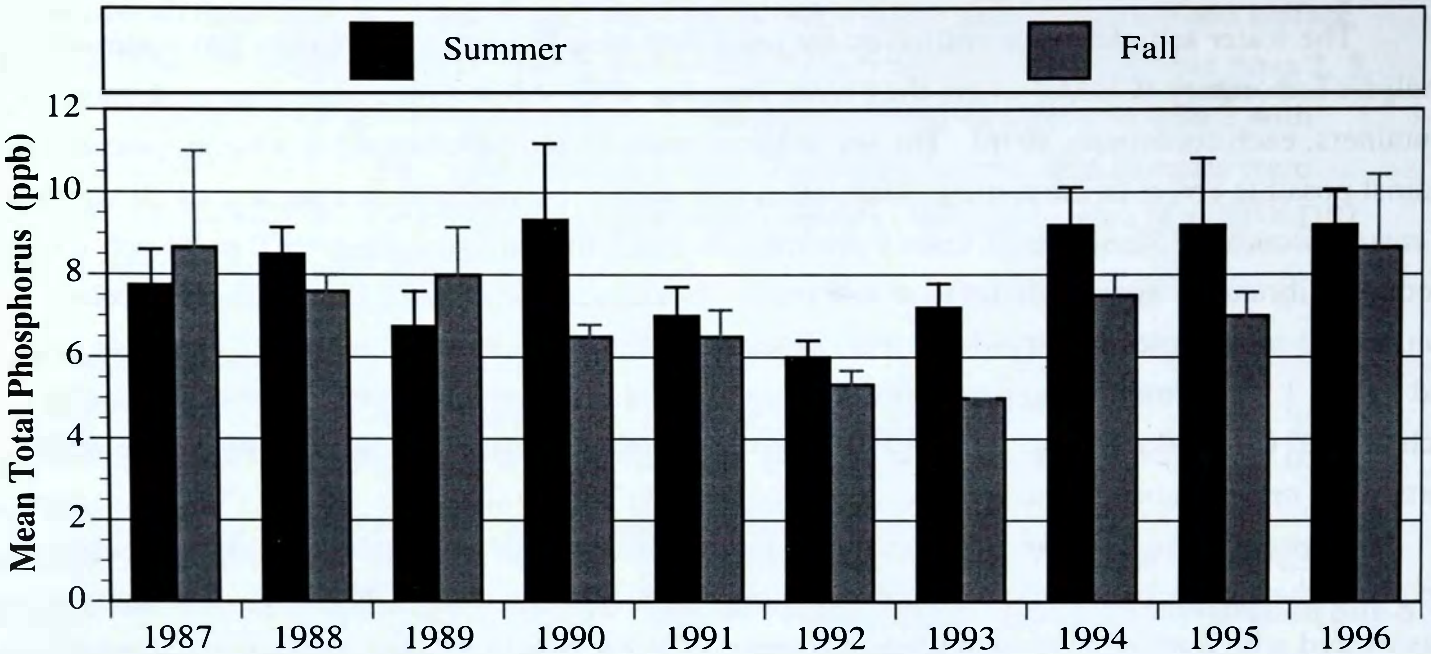


Figure 22. Mean (± SE) total phosphorus concentrations for Lake George determined from summer and fall epicore samples taken near Characterization Site 1 over a 9-year period from 1987 to 1996 (MDEP PEARL 2001). See Lake George site map for location of Characterization Site 1 (Figure 15).

The MDEP has monitored total phosphorus levels in Oaks Pond three times: in 1977, 1987, and 1998. The samples from 1987 and 1998 were collected in late August, whereas the bottom sample from 1977 was obtained in mid-May (MDEP PEARL 2001). The phosphorus levels of epicore samples from 1987 and 1998 were 8 and 9 ppb, respectively (Figure 23), and these levels have remained relatively constant over a ten-year period. However, the bottom grabs of these two years are strikingly different, increasing by 50 percent within a decade (Figure 23). In addition to the discrepancy between these two bottom values, there was also an increase from 6 to 12 ppb in phosphorus of bottom samples taken between 1977 and 1987. These data may suggest that anoxic conditions in the hypolimnion initiated phosphorus release from the sediment, resulting in a continual increase in phosphorus in bottom samples. The measurement from 1977 was taken in May, which may be another cause for the difference in values between the bottom sample from this period and the other two bottom samples. This sample was likely collected shortly after spring overturn, decreasing relative phosphorus levels in the hypolimnion and equalizing concentrations throughout the water column. The trend of oxygen depletion corresponding to the increasing phosphorus sug-

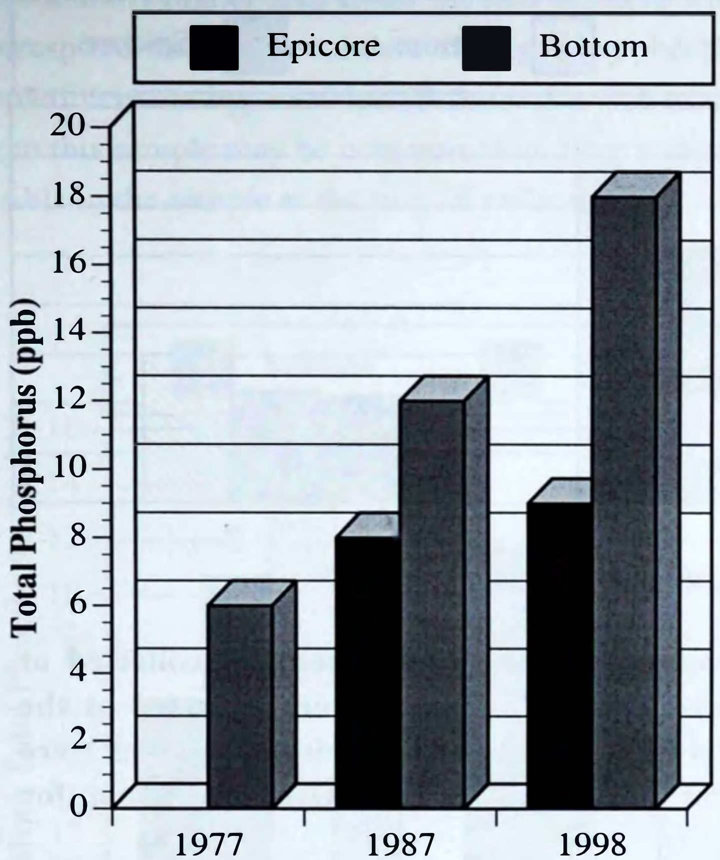


Figure 23. Total phosphorus concentration reported by MDEP for Oaks Pond sampled near CEAT Characterization Site 8 for selected years from 1977 to 1998 (MDEP PEARL 2001). Samples were taken as an epicore and at the bottom. See Oaks Pond site map for location of Characterization Site 8 (Figure 16).

gests that phosphorus is being released from the sediment, increasing the potential for internal recycling when water is disturbed. The water with high concentrations of dissolved nutrients then rises to the surface, making the nutrients available to phytoplankton. If the increase in phosphorus levels continues in Oaks Pond and the possible internal recycling persists, an algal bloom could occur in a few years. Because phosphorus levels are characterized by fluctuations overtime and the historical data are rather sparse, more frequent investigations of phosphorus levels should be conducted on Oaks Pond to conclude if the overall concentrations exhibit an increasing trend (Lampert and Sommer 1997).

Characterization Sites- Summer

The summer sampling was performed only on Lake George on 19-Jul-01 and 7-Aug-01 at Characterization Sites 1, 2, and 3. Surface, mid-depth, and bottom samples were taken at all three sites, and epicore samples were taken at Characterization Site 1 (Appendix H). The data indicate a stratification of phosphate, with lower values at the surface than at the bottom at Characterization Site 1 (Figure 24). The similarity of phosphorus concentrations throughout the water column at Characterization Sites 2 and 3 suggest that circulation of the water column in these more shallow areas of the lake resulted in the uniform values, although the values were slightly higher at the bottom (Figure 24). The mean (± SE) of the surface and epicore samples of Characterization Sites 1, 2, and 3 was 8.7 ± 1.1 ppb; (n = 13). The mean (± SE) of the bottom samples of Characterization Sites 1, 2, and 3 was 12.9 ± 1.4 ppb (n=13) and was significantly higher than the surface samples (unpaired t-test, df = 24, p=0.03). This surface value is below the critical phosphorus limit of 12 to15 ppb (See Introduction: Phosphorus and Nitrates), which suggests that Lake George is unlikely to have algal blooms in the summer months in the near future.

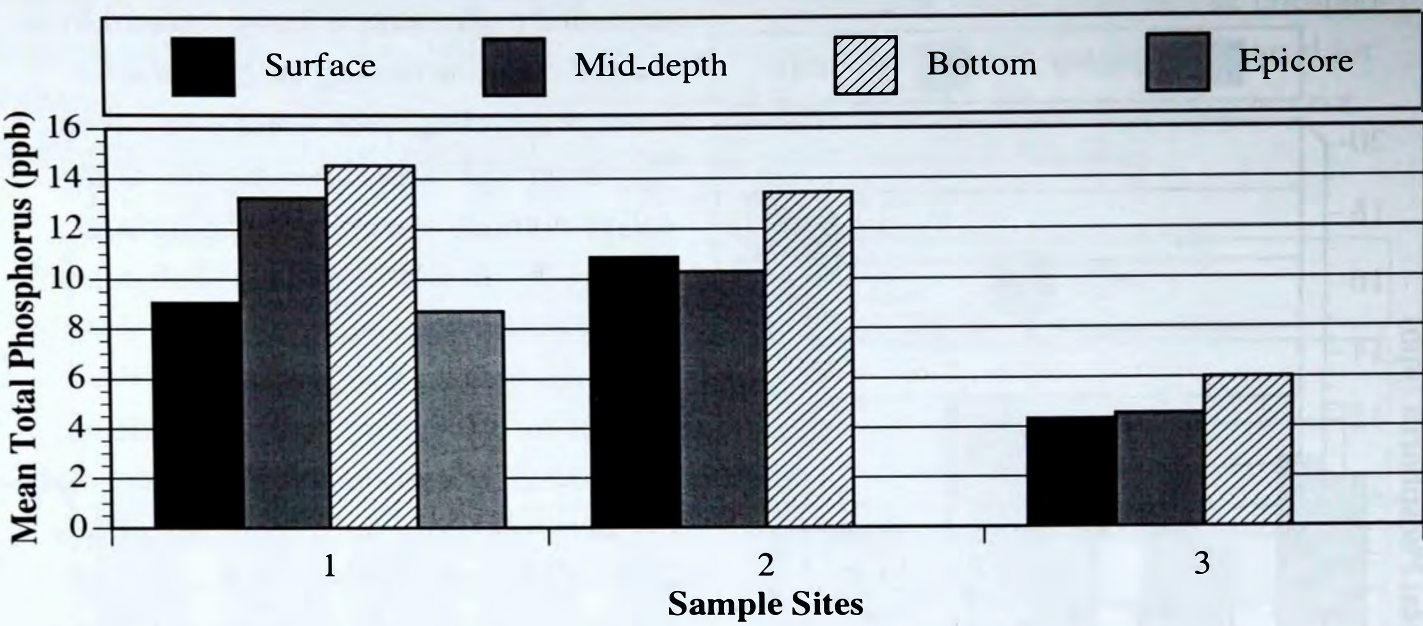


Figure 24. Mean total phosphorus concentration for summer samples collected at Characterization Sites 1, 2, and 3 on Lake George. Samples were collected at the surface, mid-depth, and bottom on 19-Jul-01 and 7-Aug-01. Epicore samples were also obtained at Characterization Site 1 on 7-Aug-01. See Lake George site map for site locations (Figure 15).

Characterization Sites- Fall

The mean (± SE) total phosphorus level from the surface and epicore samples of Lake George at Characterization Sites 1 through 3 on 28-Aug-01 and Characterization Sites 1, 2, 3, and 8 on 12-Sep-01 was 9.0 ± 0.7 ppb (n = 21; Appendix I). These data correspond with the summer data from the characterization sites of this lake. The mean (± SE) for the bottom samples at the characterization sites was 11.3 ± 1.0 ppb (n = 9), slightly lower than the summer bottom sample mean (12.9 ppb). The difference between the surface and epicore samples and bottom samples was insignificant but did show a trend (unpaired t-test, df = 28, p=0.07), suggesting that stratification occurred but was not as pronounced as it had been in the summer. With the exception of Characterization Site 2, phosphate was stratified in the water column, with lower concentrations of phosphorus measured at the surface and higher concentrations measured in the hypolimnion (Figure 25). Characterization Site 3 showed a greater degree of stratification compared to the summer data during this sampling period. The unexpected higher level of stratification in the fall may have resulted from decreased turbulence because of lower levels of boat traffic and swimming with the onset of fall.

The sample data from the Oaks Pond Characterization Site 8 indicate that stratification of phosphorus occurred, with lowest concentrations at the surface and the highest concentrations at the bottom (Figure 26, Appendix J). The mean phosphorus concentration for the surface and epicore samples from the Oaks Pond characterization site was 8.7 ± 2.2 ppb (n = 3). The concentration of the bottom sample from Characterization Site 8 was of 40.5 ppb (Appendix J). This measurement is substantially higher than either the mid-depth (6.8 ppb) or epicore (11.0 ppb) samples and may correspond with historical data in suggesting phosphorus recycling from the sediment due to oxygen depletion in the hypolimnion (Brönmark and Hansson 1998). Another explanation for the high value from this sample may be contamination from sediment obtained during sampling, although none was visible in the sample at the time of collection.

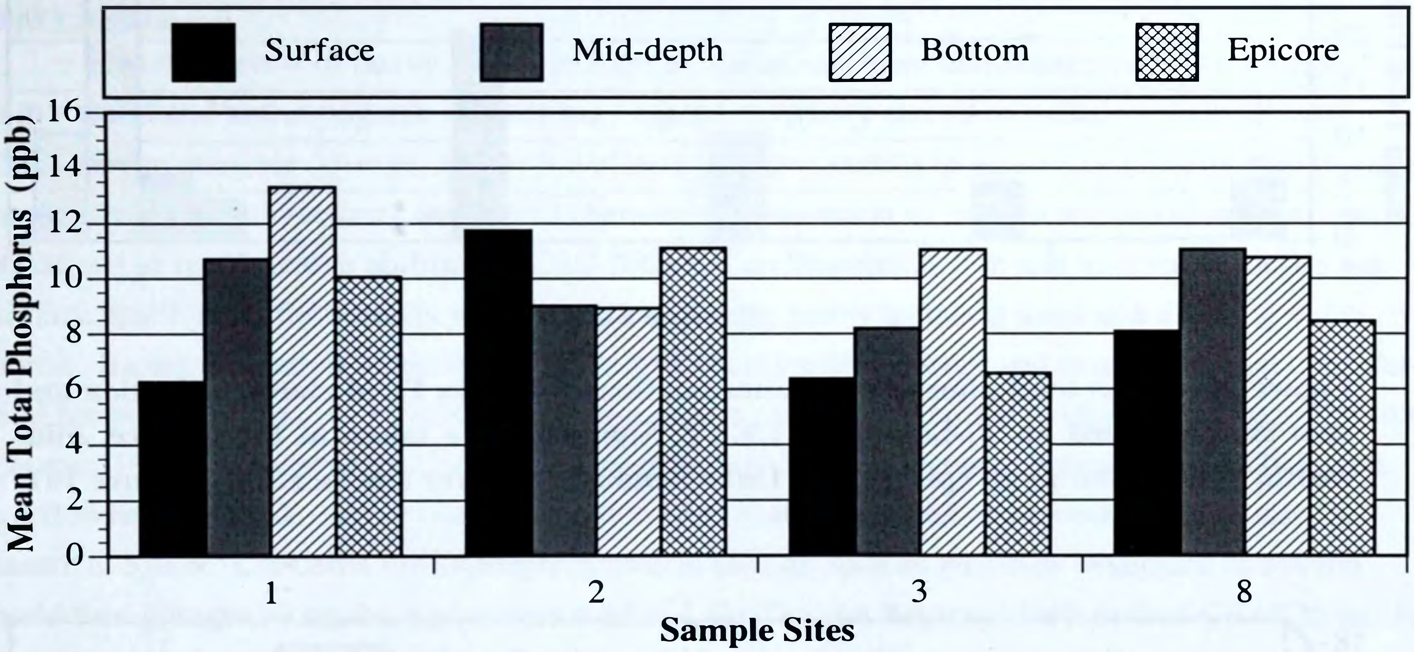


Figure 25. Mean total phosphorus concentration for fall samples collected at the four characterization sites on Lake George. Samples were collected at the surface, mid-depth, bottom or as an epicore on 28-Aug-01 and 12-Sep-01 by CEAT. See Lake George site map for site locations (Figure 15).

Spot Sites

The spot sites for Lake George were sampled on 12-Sep-01. The mean total phosphorus concentration for Spot Sites 4, 5, 9, 10, 12, and 13 was 11.2 ± 1.6 ppb (n = 8). Most of the spot sites showed similar concentrations of phosphorus to the surface samples from the characterization sites collected on the same day. Two exceptions were Site 5, which was slightly higher at 11.7 ppb, and Site 12 with a value of 17.3 ppb (Figure 27, Appendix I). Both of these sites were located 50 ft offshore from shoreline houses. These high values could indicate that waves in these shallow areas stirred up sediments or that low level phosphorus loading is occurring from these locations. Site 12 is also located near the east beach and was highly populated by aquatic plants at the time of sampling. Increased disturbance of sediment in this area or increased phosphorus release from decaying matter may also contribute to the higher phosphorus concentration.

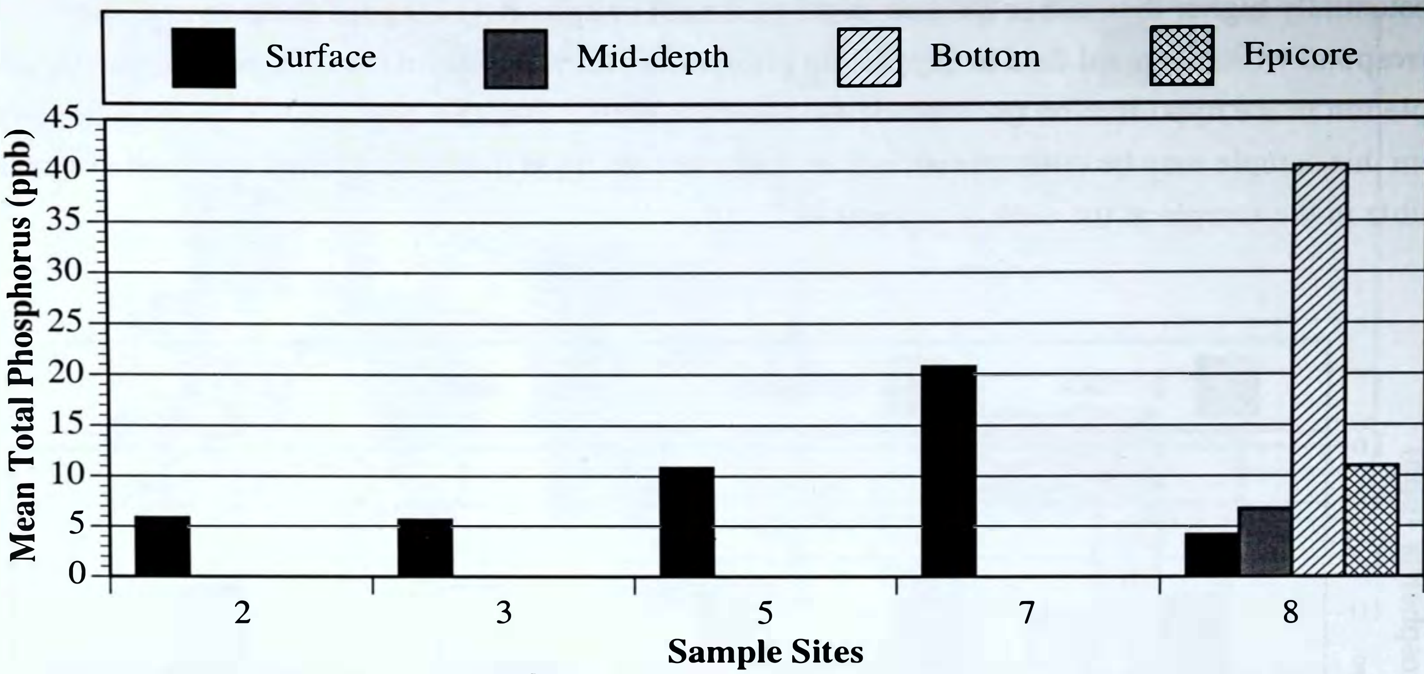


Figure 26. Mean total phosphorus concentrations for Oaks Pond characterization and spot sites sampled on 17-Sep-01 by CEAT. Samples were taken at the surface, mid-depth, bottom and as an epicore. See Oaks Pond site map for site locations (Figure 16).

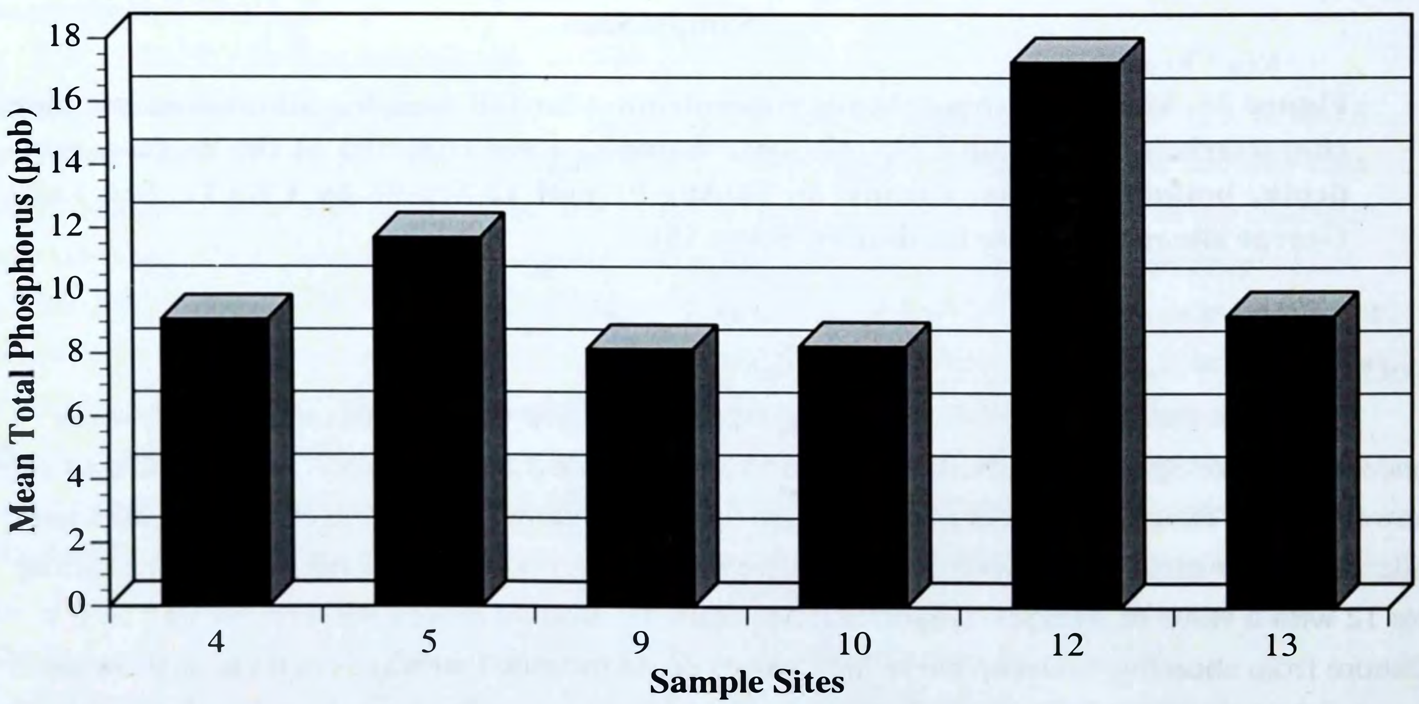


Figure 27. Mean total phosphorus concentration for six spot sites on Lake George. Samples were collected as surface samples on 12-Sep-01 by CEAT. See Lake George site map for site locations (Figure 15).

Spot sites on Oaks Pond were sampled on 17-Sep-01. The mean total phosphorus level for Spot Sites 2, 3, 5, and 7 was 11.3 ± 2.2 ppb (n = 8). These values are all higher than the surface mean from Site 8 on the same date (Figure 26). Spot Site 7 was exceptionally higher with a mean value of approximately 20.8 ppb (Appendix J). This value is approximately double that of the mean for the other spot sites and suggests a high degree of phosphorus loading in this area. Another explanation for this value is possible contamination during sampling.

Heavy Metals

Elevated levels of heavy metals in natural waters can have detrimental effects on aquatic life. Both natural and anthropogenic sources may contribute heavy metals to surface waters (NCSU 2001). Some possible adverse, non-lethal effects of heavy metals to aquatic organisms may include changes in enzymatic activity and blood chemistry, suppression of growth and development, and alterations in reproductive abilities (NCSU 2001). Carcinogenic action and toxicity of metals are primary health risks for humans when water containing heavy metals is used as a drinking water source. Bioaccumulation of heavy metals in fish occurs with mercury and is an additional consideration for possible negative effects because the metals can be transmitted to those who ingest the fish (Lerman 1978). Concerns that naturally occurring high arsenic levels in water from a LGRP well overflowing into Lake George were possibly contaminating the lake prompted CEAT to test for arsenic at Site 9. Concerns for improper chemical storage such as paints or pesticides in several abandoned garages along the east access road of Lake George Regional Park caused CEAT to test for lead, chromium, and arsenic at Spot Site 12 on Lake George. High arsenic levels have been found in well water of residences along the East Ridge Rd., west of Lake George (Reid, pers. comm.).

Methods

A surface sample was obtained for analysis for arsenic Spot Site 9 on Lake George on 17-Sep-01. Surface samples were collected from Spot Site 12 on Lake George on 17-Sep-01 and tested for the presence of arsenic, chromium, and lead. Analysis for the heavy metals was conducted by Northeast Laboratory Services in Winslow. Inductively coupled plasma-atomic emission spectroscopy was used to quantify the concentrations of these metals.

Results and Discussion

Northeast Laboratory Services found no arsenic, chromium, or lead present above the detection limit of 0.01 mg/L in their analysis of samples from Spot Site 12. However, arsenic was present in the sample water at Spot Site 9 at a concentration of 0.02 mg/L. This level of arsenic is below the current EPA maximum levels for drinking water of 0.05 mg/L (DWP 2001); however, these levels are under revision due to recent studies on arsenic's role as a carcinogen (NRC 1999). The maximum arsenic concentration recently recommended by the EPA for drinking water is 0.005 mg/L, and this level is under consideration as a new legislative standard (DWP 2001). The Spot Site 9 arsenic concentration is four times higher than this newly recommended standard, indicating it should not be used for a drinking water source. Arsenic in the lake does not appear to pose a great threat to human health standards because it has not been demonstrated that arsenic bioaccumulates in the tissues of fish and the concentration of arsenic is diluted upon entry to the lake (NCSU 2001).

Volatile Organics

Volatile organic compounds are components of petroleum products, paints, and solvents (ATSDR 2001). These types of chemicals were included in a broad list of potentially toxic chemicals to both humans and other organisms by Boyd (2000). The potential entry of these chemicals into surface waters is an issue of concern because of their potential harmful effects on aquatic organisms and human health. Volatile organic compounds can be introduced to the water via boat traffic or improper chemical storage. CEAT tested for volatile organic compounds at Spot Site 12 on Lake George because of a concern for improper chemical disposal and poor maintenance of apparently abandoned garages in the shoreline camps neighboring the site.

Methods

A surface sample was collected from Spot Site 12 on 17-Sep-01 by CEAT and was analyzed for the presence of a broad spectrum of volatile organic compounds by Northeast Laboratory Services in Winslow (Appendix K). The analysis followed the procedures outlined in EPA-approved method 8260B.

Results and Discussion

The analysis by Northeast Laboratory Services for volatile organic compounds yielded no detectable evidence of organic compounds in the water. However, these results do not imply that no gasoline is entering the water. Detectable levels of volatile organic compounds in the water column would have to have been emitted just prior to sampling because these chemicals do not remain in the environment for long periods of time (Parker, pers. comm.). This analysis suggests that no prolonged seepage of volatile organic compounds from shore point sources is occurring near Spot Site 12 at Lake George. However, pollution from outboard motors of boats is likely to occur on some level due to boat traffic on the lake. The sampling by CEAT is not indicative of the potential effects of motorboats on the levels of organic compounds in the water because only one sample was taken at a time of the year with low boat traffic.

Biotic Measurements

Two common biotic measurements used to assess lake water quality are coliform bacteria and chlorophyll *a*. Coliform bacteria are indicators of possible fecal pollution from faulty septic systems. Chlorophyll *a* is an indirect measure of the photosynthetic activity in a lake.

Coliform

Coliform bacteria are facultative anaerobic bacteria, meaning that they are able to survive and reproduce if oxygen is not present but will grow more readily if oxygen is abundant (Prescott, Harley, and Klein 2002). These bacteria can be found in solids, plant matter, and most importantly, in the intestinal tract of organisms (Fekete, pers. comm.). Total coliform and *Escherichia coli* testing are necessary if a source of water is to be used as a drinking water supply, because these bacteria are naturally occurring in the environment from wild animals and decaying organic matter (Fekete, pers. comm.). Total coliform bacteria could also be present in beach areas as a result of people swimming in the area. *E. coli* is the primary indicator of fecal contamination and can cause severe illness or death if ingested. Fecal coliform testing is important in determining the levels of possible disease causing agents in the water due to fecal contamination.

Methods

CEAT collected water samples to be tested for coliform bacteria in sterile bottles provided by Northeast Laboratory Services. Water samples were collected at Spot Sites 4, 5, and 11 on 12-Sep-01 on Lake George and at Spot Sites 2, 3, 5, and 7 on 17-Sep-01 on Oaks Pond. Spot Sites 4 and 11 on Lake George were sampled to test the function of the park septic systems. Spot Site 5 on Lake George was sampled near a cluster of old camps as an indicator of possibly malfunctioning septic systems. The spot sites on Oaks Pond were sampled as indicators for possible problems with septic systems on the shoreline properties. The samples were refrigerated after collection until they were taken to Northeast Laboratory Services the following morning for analysis. The method used to analyze the samples was EPA 600-R-00-013.

Results and Discussion

Total coliform bacteria were present at all three sites on Lake George, which is common due to fecal matter from wild animals (Figure 28). Total coliform levels were highest at Spot Site 4 of the sites sampled on Lake George. This site was located off the west beach of the park. Further testing is recommended during peak use of the park to monitor the level of total coliform at Spot Site 4. The higher levels of total coliform bacteria in the area could be due to the presence of fecal matter from wild animals. *E. coli* was not found at any of the sites on Lake George.

Total coliform bacteria and *E. coli* were found at all four spot sites on Oaks Pond (Figure 29). The higher levels of total coliform and the presence of *E. coli* on Oaks Pond may suggest that septic systems near the areas of testing could be malfunctioning. However, further testing is necessary because the contamination could also be the result of fecal matter from wild animals.

The levels of total coliform bacteria and *E. coli* in both Lake George and Oaks Pond indicate that neither body of water is safe for drinking without treatment. The source of bacteria at the spot sites is difficult to determine because sampling only occurred once at each spot site. The presence of *E. coli* indicates recent fecal contamination in the area, but the source is hard to determine (Fekete, pers. comm.). The presence of these bacteria is not directly harmful to lake users at these levels as long as the water is not used for drinking. Further testing is recommended to monitor the total coliform and *E. coli* levels at each of the sites. This testing should occur during periods of peak use for each of the lakes.

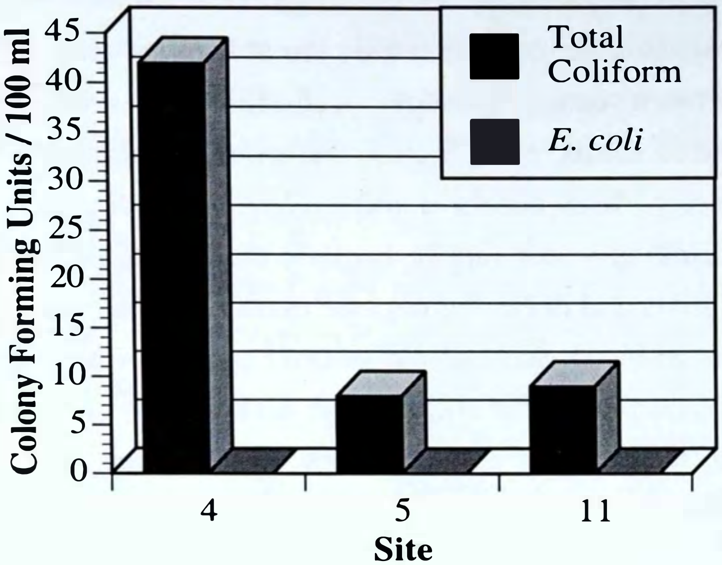


Figure 28. Total coliform and *E. coli* readings for Lake George at Spot Sites 4, 5, and 11 on 12-Sep-01. Spot Sites 4 and 11 were sampled to test for possible septic system problems with the park facilities. Spot Site 5 was sampled off shore from camps as a spot site for possible septic system problems. See Lake George site map for site locations (Figure 15).

Chlorophyll

Chlorophyll is a green pigment present in the majority of photosynthetic organisms in the forms chlorophyll *a*, *b*, and *c* (Chapman 1996). Chlorophyll *a* indirectly measures algal biomass and helps determine the trophic state of a lake because it is a relative measure of primary productivity. The amount of chlorophyll *a* in a lake increases with higher primary productivity and the progression of eutrophication. The best time of year to measure chlorophyll *a* concentration is during the summer months at the peak of the growing season when the algal concentration is highest (Chapman 1996).

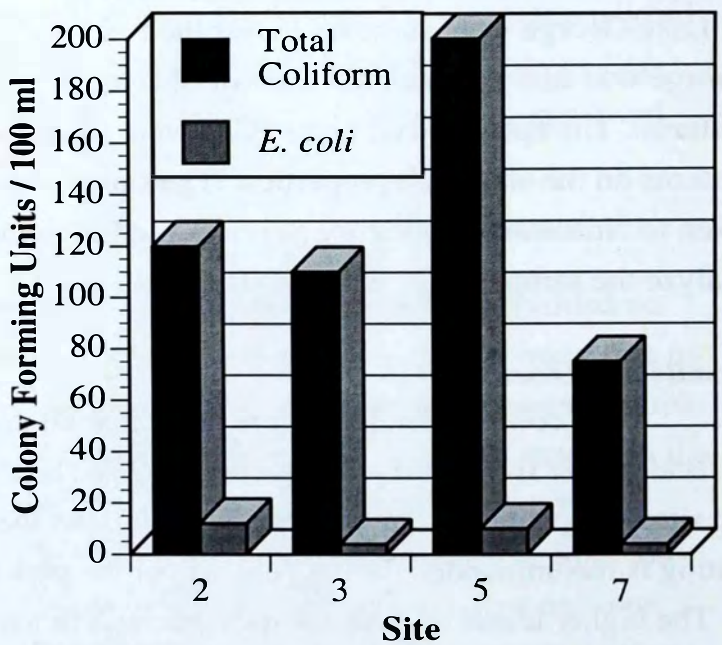


Figure 29. Total coliform and *E. coli* readings for Oaks Pond at Spot Sites 2, 3, 5, and 7 sampled on 17-Sep-01. These sites were established as spot sites to test for possible septic system problems. Total coliform at Spot Site 5 is recorded as 200 on the graph, but the actual value is >200 CFU/100 ml. See Oaks Pond site map for site locations (Figure 16).

Methods

CEAT did not measure chlorophyll *a* concentrations for Lake George or Oaks Pond because chlorophyll *a* levels are more effectively studied in the summer months when peaks in algal production result in higher levels of chlorophyll *a* (Chapman 1996). During the fall months, the concentrations of chlorophyll *a* are low and do not accurately represent the biological activity within the lake during the most productive months. Algal concentrations are low in the fall months because the summer algae die and settle to the bottom of the lake. CEAT obtained historical chlorophyll *a* data from the MDEP for the years 1987 to 1994 and 1996 for Lake George and 1998 for Oaks Pond (MDEP 2000).

Results and Discussion

The mean chlorophyll *a* values for Lake George ranged from 2.7 ppb to 5.0 ppb for the years 1987 to 1994 and 1996 (Appendix E; MDEP 2000). The MDEP sampled the chlorophyll *a* level for Oaks Pond in 1998 and reported a value of 2.3 ppb (Appendix E; MDEP 2000).

Oligotrophic lakes generally have chlorophyll *a* levels of less than 2.5 ppb, and eutrophic lakes have chlorophyll *a* levels ranging from 5 ppb to 140 ppb (Chapman 1996). The fairly low chlorophyll *a* level of Lake George classifies the lake as mesotrophic. The data indicate that algal production Lake George is low because all but one of the mean values are below the chlorophyll *a* concentration for eutrophic lakes. The chlorophyll *a* concentration on Oaks Pond is similar to the concentration on Lake George. These data suggest that the potential for harmful algal blooms is low for both lakes.

Tributary Water Quality

Tributary Sites

Lake George has two primary inlets and one outlet that eventually empties into Oaks Pond. The distance the stream travels between Lake George and Oaks Pond is approximately 1277 meters. The tributaries at the northern end of Lake George were each chosen for sample sites because they drain the northern region of the watershed. CEAT planned to sample at Sites 6 and 7, but they were not sampled because no flow was detected (see Lake George site map for tributary site locations: Figure 15). CEAT sampled at the outlet of Lake George at Tributary Site 14 on 12-Sep-01.

Two tributaries carry water into Oaks Pond: the outlet of Lake George and Lambert Brook from Round Pond. CEAT sampled the tributary from Lake George at Tributary Site 1, located approximately 50 ft from the entry point of the tributary into the lake to avoid any influence from the lake on the water in the tributary. Tributary Site 6 on Lambert Brook was not sampled because the tributary was stagnant. The outlet of Oaks Pond was also sampled on 17-Sep-01 at Tributary Site 4 to assess the quality of the water flowing out of Oaks Pond (see Oaks Pond site map for tributary site locations: Figure 16).

Tributaries are important in contributing nutrients to a lake, but this input is often episodic as a result of storm events (Boyd 2000). Increased flow from storms can contribute to phosphorus loading in a lake. Seasonal flows of water from snowmelt in the spring can also contribute high inputs of phosphorus and sediments. Phosphorus and other ions are often associated with sediments that are stirred up by turbulence and deposited into the lake.

Physical measurements made on the tributaries included flow rate, turbidity, conductivity, and color. Chemical tests performed included pH, nitrates, and total phosphorus (Appendix C). Water quality assessment of these sites is important because tributaries drain the surrounding watershed, reflecting the conditions and land use patterns of the watershed (Chapman 1996).

Physical Measurements

The methods used for tributary sampling and testing were the same methods used for lake sampling and testing (See Lake George and Oaks Pond Water Quality Assessment). Adherence to Quality Assurance protocol ensured the accuracy of the sampling and testing performed (Appendix C).

Flow

Flow measures the rate of water movement in a tributary or outlet. Flow can have a strong influence on water quality because it influences the amount of dissolved solids and possible pollutants that are introduced into a lake from upstream areas (Chapman 1996). The greater the flow in a tributary, the more turbulence is created and the greater chance that more particles and dissolved solids will be disturbed and transported in the stream.

Methods

The flow rate of water was measured at Site 14 on 12-Sep-01 in the outlet of Lake George using the Flo-mate™ Flow Meter. Flow was not measured at Tributary Sites 6 and 7 leading into Lake George because there was not water. The flow rate of water was measured at Oaks Pond Tributary Sites 1 and 4 on 17-Sep-01. Flow was not measured at Tributary Site 6 leading into Oaks Pond because the tributary was stagnant.

Results and Discussion

The flow rate at Tributary Site 14 in the outlet of Lake George was 0.07 m/s. The flow of water in the tributary leading into Oaks Pond from Lake George was 0.06 m/s at Tributary Site 1, and the rate was 0.02 m/s at Tributary Site 4 in the outlet of Oaks Pond (Table 4).

One of the primary tributaries (Tributary Site 6) that leads into Lake George drains the northwest corner of the watershed, and a second primary tributary (Tributary Site 7) drains the northeast portion of the watershed. At the time of sampling, these tributaries were not flowing, but they have the potential to contribute considerable water to the lake when they are flowing.

The tributary that flows from Lake George to Oaks Pond drains the eastern portion of the Oaks Pond watershed. Lambert Brook drains the northwestern portion of the Oaks Pond watershed. This tributary passes through wetlands between Round Pond and Oaks Pond. Lambert Brook was not flowing during the time of sampling, but it has the potential to contribute water and dissolved solids to Oaks Pond when it is flowing.

The tributary flow values are fairly low, which can be attributed to the low levels of precipitation and dry conditions during the summer and early fall months of 2001. Sediments and possible pollutants are not carried quickly into the lake with low flow rates.

Turbidity

Results and Discussion

The turbidity value was 1.00 NTU at Tributary Site 14 in the outlet of Lake George. The values of turbidity were 0.27 NTU at Tributary Site 1 in the tributary leading into Oaks Pond and 0.80 NTU at Tributary Site 4 in the outlet of the lake (Table 4).

The low turbidity value at Tributary Site 1 on Oaks Pond indicates that there was very little suspended material entering the lake from this tributary during September 2001. This low level input of suspended material into the lake can be attributed to the lack of precipitation and the resulting low flow. This tributary originates at the outlet of Lake George, meaning that the water quality of Lake George has some impact on Oaks Pond. The water in the tributary takes up particulate matter and runoff from the land between the two lakes in the eastern portion of the Oaks Pond watershed and deposits them into Oaks Pond.

Conductivity

Results and Discussion

The conductivity value in the outlet of Lake George at Tributary Site 14 was 26.2 μMHOs/cm. The conductivity value at Tributary Site 1 in the tributary leading into Oaks Pond was 37.5 μMHOs/cm, and the value at Tributary Site 4 in the outlet of Oaks Pond was 36.5 μMHOs/cm (Table 4).

The outlet of Lake George becomes the inlet of Oaks Pond, and the conductivity value was higher at Tributary Site 1 leading into Oaks Pond than at Tributary Site 14 leaving the outlet of Lake George. Higher conductivity readings indicate higher levels of dissolved solids, which were probably stirred up by the flowing water in the stream between the two lakes. The conductivity at the outlet of Lake George is comparable to the mean value of 25.6 μMHOs/cm for the open water sites on the lake and is on the lower end of the range of values of 20 μMHOs/cm to 40 μMHOs/cm for the majority of Maine lakes (Pearsall 1993).

Conductivity measurement is also an index of phosphorus and ion loading into a lake from a tributary. The conductivity levels from the outlet of Lake George and the inlet of Oaks Pond indicate that more dissolved solids and ions are entering Oaks Pond than are leaving Lake George.

Table 4. Selected physical and chemical characteristics for the tributaries around Lake George and Oaks Pond. Data collected by CEAT on 12-Sep-01 for Tributary Site 14 (outlet) on Lake George and 17-Sep-01 for Tributary Sites 1 and 4 (outlet) on Oaks Pond. Tributary Sites 6 and 7 leading into Lake George were not sampled because the tributaries were not flowing. Tributary Site 6 leading into Oaks Pond was not sampled because the tributary was not flowing. See site maps for site locations: Lake George (Figure 15) and Oaks Pond (Figure 16).

	Physical				Chemical		
Site	Flow (m/s)	Turbidity (NTU)	Conductivity (μMHOs/cm)	Color (SPU)	pH	Nitrate (ppm)	Total Phosphorus (ppb)
LG 6	-	-	-	-	-	-	-
LG 7	-	-	-	-	-	-	-
LG 14	0.07	1.00	26.2	45	6.80	-	10.0
OP 1	0.06	0.27	37.5	39	7.09	-	13.9
OP 4	0.02	0.80	36.5	30	6.48	0.04	9.3[a]
OP 6	-	-	-	-	-	-	-

[a] The value of total phosphorus (ppb) at this site is the mean of two values.

Color

Results and Discussion

The color value was 45 SPU at Tributary Site 14 in the outlet of Lake George. The color values were 39 SPU at Tributary Site 1 leading into Oaks Pond and 30 SPU at Tributary Site 4 in the outlet of Oaks Pond (Table 4).

The color values for the tributaries were higher than the mean values for each of the lakes. The classification of an uncolored body of water is a reading of less than or equal to 30 SPU, classifying the outlet of Lake George and the tributary leading into Oaks Pond as colored (MDEP 2000). The color value for the inlet of Oaks Pond is lower than the color value for the outlet of Lake George. The lower color reading in the inlet of Oaks Pond could be attributed to the presence of wetlands around the stream between Lake George and Oaks Pond. Oxidation of organic compounds in the stream may have caused the difference of color readings (Firmage, pers. comm.).

Chemical Analyses

pH

Results and Discussion

Tributary Site 14, in the outlet of Lake George, had a pH of 6.80. The pH value at Tributary Site 1 in the tributary leading into Oaks Pond was 7.09, and the value in the outlet of Oaks Pond at Tributary Site 4 was 6.48 (Table 4).

The tributary sites fall in a comparable range to the open water sites, indicating that overall pH is near neutral in the lakes and the associated tributary and outlets. The pH at Tributary Site 4 on Oaks Pond in the outlet is more acidic than the other sites, most likely due to the wetlands in the area contributing organic acids to the water.

Nitrates

Results and Discussion

The nitrate level at the outlet of Oaks Pond at Tributary Site 4 was 0.04 ppm (Table 4). Samples were not taken for nitrate testing at the outlet for Lake George nor were they taken at the tributary leading into Oaks Pond. The critical level for nitrate pollution from fertilizers and animal waste is 5 ppm (Chapman 1996). The nitrate level at Tributary Site 4 does not indicate problematic levels of human pollution in the area because the nitrate level was very low. The farm located near the outlet of Oaks Pond does not appear to be contributing high levels of nitrates to the outlet.

Total Phosphorus

Results and Discussion

The total phosphorus concentration at Tributary Site 14 in the outlet of Lake George was 10.0 ppb. The total phosphorus concentration at Tributary Site 1 in the tributary leading into Oaks Pond was 13.9 ppb, and the concentration at Tributary Site 4 in the outlet of Oaks Pond was 9.3 ppb (Table 4).

The levels of total phosphorus in the outlets are similar to those values obtained from the open water sites on both Lake George and Oaks Pond. The concentration at Tributary Site 1 leading into Oaks Pond is slightly higher than the open water values for the lake. Tributary Site 14 in the outlet of Lake George and Tributary Site 4 in the outlet of Oaks Pond are below the critical level of phosphorus of 12 to 15 ppb. Tributary Site 1 in the tributary leading into Oaks Pond is within the critical range of phosphorus. Inputs may be higher during spring runoff and storm events because the input of phosphorus is episodic (See Introduction: Phosphorus and Nitrates). CEAT sampled when the flow rates were low in the fall of 2001. High levels of precipitation increase the flow in the tributary, resulting in possible influxes of phosphorus into Oaks Pond from the tributary leading from Lake George.

LAND USE ASSESSMENT

Land Use Patterns

The different land uses in a watershed can affect the amounts of nutrient loading and water quality. Various land use types in a watershed have different types and density of vegetative cover. Vegetation provides protection from runoff, controls the amount of erosion in an area, and stabilizes the soil. Different land use types affect the watershed in distinctive ways. For example, an area of cleared land has limited vegetation cover, making erosion much more likely than in a forested area with a greater amount of cover. Erosion can result in each hectare of undisturbed land losing between 0.004 and 0.05 tons of soil per year under normal conditions (Abramovitz 1997). When land is converted to cropland or pasture, or is logged, the soil erosion rate can be many times the rate of undisturbed land. The primary goal of the land use study was to identify and classify the different land use types in the watershed, to determine relative importance of land use types to phosphorus loading, and to gain a greater understanding of the ecological health of the Lake George and Oaks Pond watersheds. Land use maps were created to examine land use trends and determine the influences of these uses on the watershed over time.

Methodology

Land use patterns in the Lake George and Oaks Pond watersheds were determined by analyzing 1955 and 1997 Digital Orthophoto Quads obtained from the James W. Sewall Company in Old Town, Maine. Watershed boundaries were obtained from the Maine Office of GIS in Augusta, Maine. Infrared photographs obtained from the National Aerial Photography Program (NAPP) also helped to identify land use patterns in the 1997 map (Light 1995). The photographs used for this study site were flown in 1997. The photographs were received as 9" by 9" photographic prints with a scale of 1 in: 1000 ft. Photographs were converted to a format that could be recognized and manipulated by Environmental Science Research Institute's ArcView ® 3.2. The photographs were first scanned and converted to digital JPEG images using a flatbed scanner and Adobe Photoshop™ 5.5. These photographs were then aligned with features on the base map (See GIS Assessment: Methodology). The following classifications were used in determining land use patterns within the watersheds: mature forest, transitional forest, regenerating land, reverting land, wetlands, residential lands (both shoreline and non-shoreline), roads, municipal/commercial lands (includes businesses, gravel pits, Lake George Regional Park, and Eaton Mountain ski slope), agricultural land (includes crop and pasture), and cleared land.

ArcView 3.2 was used to create the land use map by tracing the identified areas and creating polygons. The area of each land use type was summarized by using the sum program in ArcView 3.2. Total area of each land use cover type was calculated in square meters. These total areas were then used to analyze the land use trends in the watershed over time.

Wetlands

Depending on type, location, and season, the presence of wetlands can greatly influence the water quality of surrounding areas because they may serve as both sources and sinks for nutrients (Mitsch and Gosselink 1993). Wetlands experiencing growth typically act as sinks by taking up nutrients while the vegetation grows. Decomposing plant species in wetlands, especially in the fall, act as sources for nutrients (See Background: Wetlands). Wetlands are one of the most productive types of ecosystems because of their high content of organic matter (Patrick 1994). Additionally, they provide ecosystem services such as flood control, sediment trapping, and nutrient retention (Niering 1985). Buffering potential is greatest in those wetlands found closest to the edge of water bodies. Shoreline wetlands are particularly useful for controlling water quality of the lake and for minimizing the impacts of erosion (BI493 2000).

Methods

The wetlands in the Lake George and Oaks Pond watersheds are all freshwater; consequently, all wetlands fall into one land use classification category. This classification includes all forms of freshwater wetlands such as swamps and marshes (See Introduction: Wetlands). Vernal pools in the area do not appear in the aerial photos, so they are not included on the land use map. Instead, they were included on park trail maps (See Land Use Patterns: Park).

Results and Discussion

Wetlands composed approximately 1.8 percent of total land use in the Lake George watershed and 2.9 percent of total land use in the Oaks Pond watershed in 1997 (Figure 30, Table 5). There is a posibility that relying on digital photographs may lead to an underestimation of the total area of wetlands in the watersheds. The visible wetlands are located primarily on the northern end of Lake George near the tributaries, on the southern tip of Lake George, on the western side of Oaks Pond, on all edges surrounding Round Pond, on some areas slightly north of Round Pond, and also on the Northern edges of Lake George (Figure 31). Studies of wetlands have shown that watersheds composed of five to ten percent wetlands can reduce peak flooding volumes by up to 50 percent, which helps buffer nutrient loading into lakes (Abramovitz 1997). The wetlands in the Lake George and Oaks Pond watersheds do not meet these criteria, making it likely that their effectiveness is not optimal. Compliance with laws requiring that the total land area of wetlands must be maintained is essential to ensure optimal water quality.

Distances between the logging areas and the wetlands were calculated using GIS. The Natural Resources Protection Act regulates areas within 100 ft of a wetland (MDEP 2001). The act states that permits are required for activities that might cause material from adjacent land to be washed into a wetland area (MDEP 2001). Activities requiring a permit include dredging; removing vegetation or soil; draining or filling land; and contructing, repairing, or altering any permanent

Table 5. Land use areas for Lake George and Oaks Pond for both 1955 and 1997. Data were unavailable for the northern portion of the Lake George watershed in 1955; consequently, these 84.5 hectares are not included in 1955 areas. Hectares were obtained from land use maps with the exception of residential areas and roads which were obtained from the development group. Data are presented in hectares with the percentage for each land use type in the adjacent column.

Land Use Types	Lake George 1955	Percentage	Lake George 1997	Percentage	Oaks Pond 1955	Percentage	Oaks Pond 1997	Percentage
Mature Forest	79.70	5.79	682.20	49.57	68.61	6.62	754.24	72.80
Transitional	349.37	25.39	557.39	40.50	241.04	23.27	39.54	3.82
Regenerating	226.32	16.44	13.17	0.96	16.75	1.62	19.06	1.84
Reverting	202.83	14.74	50.69	3.68	297.54	28.72	19.41	1.87
Wetland	15.94	1.16	27.16	1.97	20.62	1.99	32.92	3.18
Residential	2.83	0.21	15.58	1.13	15.99	1.54	46.14	4.45
Road	4.07	0.30	4.18	0.30	7.18	.69	9.56	0.92
Commercial/ Municipal	5.20	0.38	4.24	0.31	0.15	0.01	34.06	3.29
Agricultural Land	188.98	13.73	14.07	1.02	349.59	33.74	76.85	7.32
Cleared Land	301.03	21.87	7.59	0.55	18.58	1.79	4.27	0.41
Total Hectares	1376.27		1460.77		1035.05		1036.05	

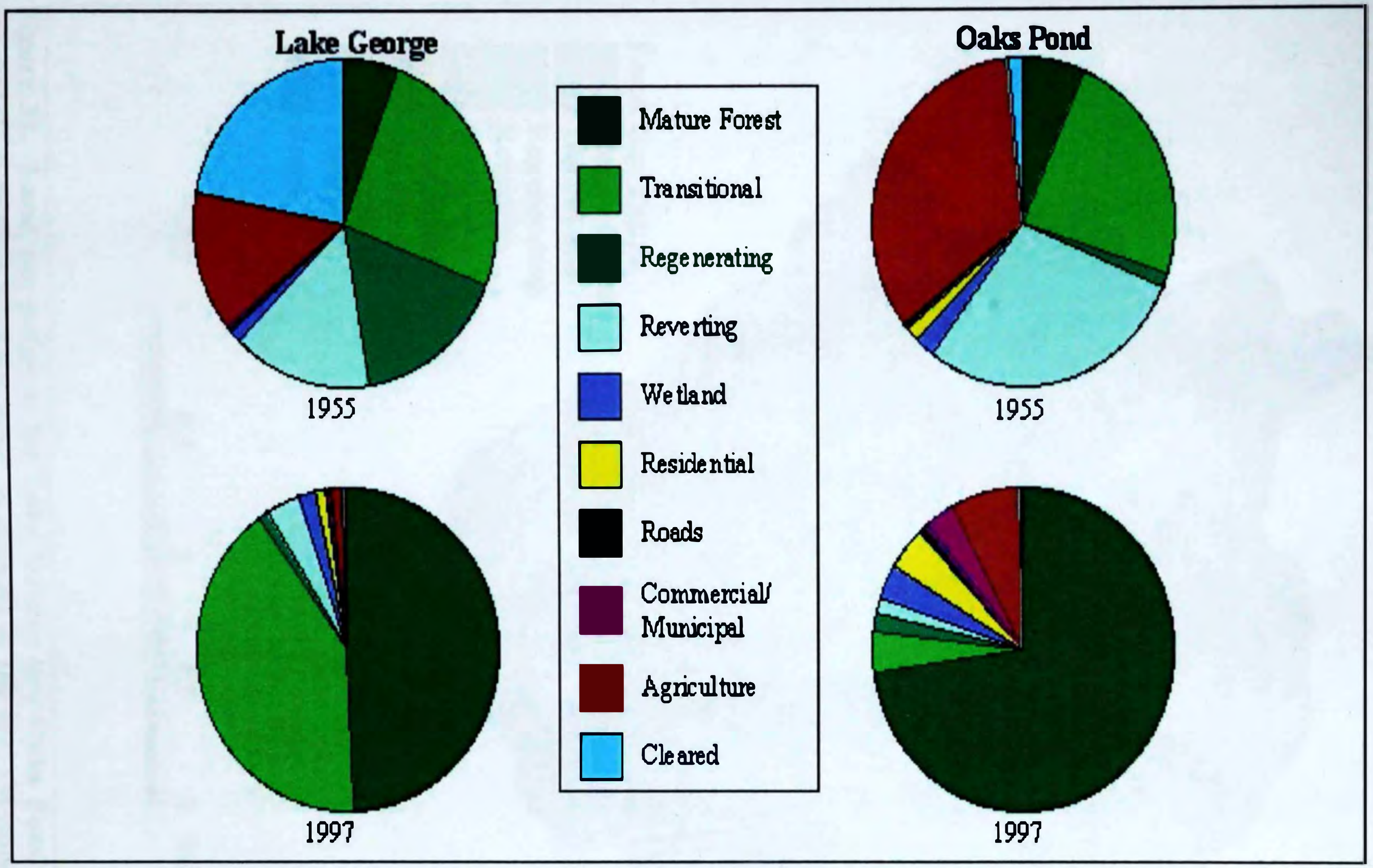


Figure 30. Land use patterns for Lake George and Oaks Pond watersheds for 1955 and 1997. Data show the percent of each land use type in the watersheds. A small portion of the 1955 Lake George watershed was not available; this area was also excluded in calculations for the 1997 chart. Data obtained from Digital Orthophoto Quads (USGS 1997), the James W. Sewall Company, and Maine Office of GIS (MEGIS 2001).

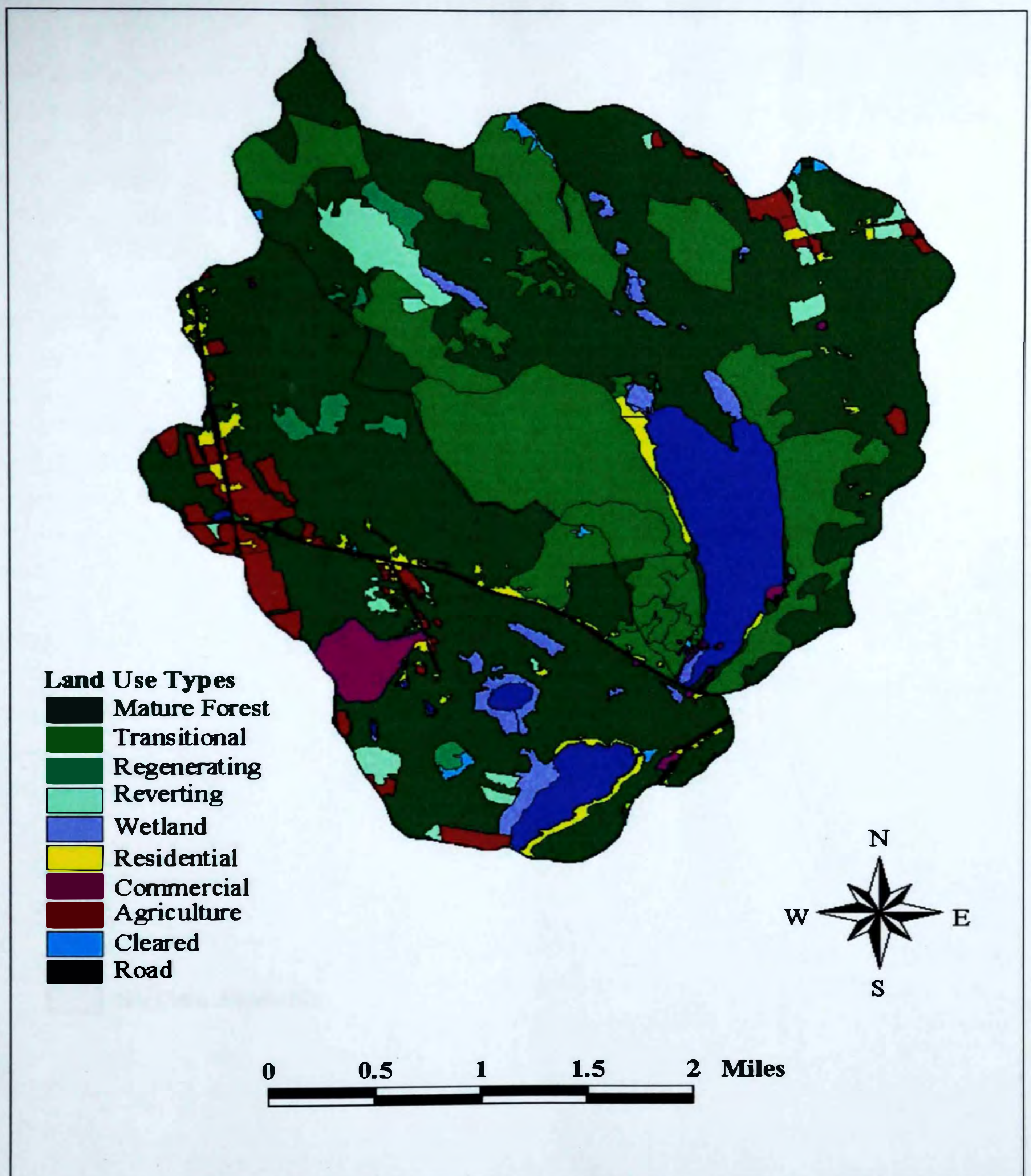


Figure 31. Land use patterns for Lake George and Oaks Pond Watershed. Each color represents a distinct land use type, as defined in the text (Methods: Watershed Landuse). Data acquired from United States Geological Survey Digital Orthophoto Quadrangle (DOQ) Data (USGS 1997) and Maine Office of GIS (MEGIS 2001).

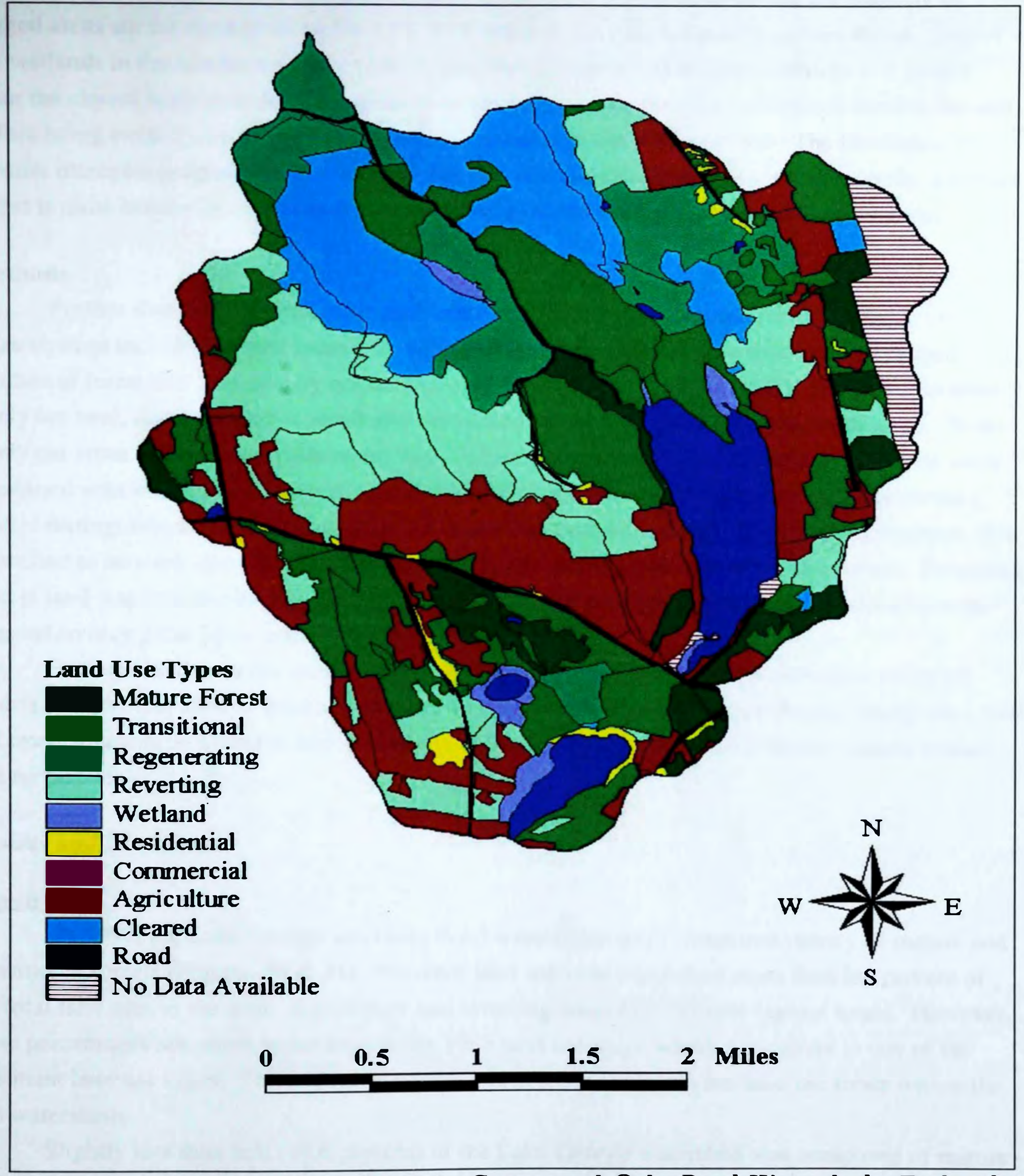


Figure 32. Land use patterns for Lake George and Oaks Pond Watershed. Each color represents a distinct land use type, as defined in the text (Methods: Watershed Landuse). The historical aerial photographs on which this analysis is based were acquired from the James W. Sewall Company in Old Town, Maine.

structure on land adjacent to a wetland. Loggers must have a permit; however, the majority of logged areas are far enough away from the wetlands that they do not pose a serious threat. One of the wetlands in the northern portion of the Lake George watershed is approximately 118 meters from the closest logging road. This distance provides adequate time for nutrients to bind to the soil before being eroded into the wetland or lake (Lea, Landry, and Fortier 1990). The likelihood of erosion increases proportionally as the number of trees harvested increases. Consequently, a mature forest is most beneficial in preventing erosion and a recently logged area is most detrimental.

Methods

Further distinctions were made between forests and logging categories. The logged land classification includes cleared areas and regenerating areas. Cleared land is defined as cleared patches of forest that may or may not contain skidder trails or logging roads. It also includes selectively cut land, distinguished as small patches of cutting, intermingled within forested areas. Selectively cut areas and logging roads comprised a small percentage of the total land uses so they were combined with cleared land to create one category that includes all disturbed land. Regenerating land is distinguished as an early successional stage that follows logging, rather than agriculture. It is identified as an even-aged stand of vegetation with the entire patch regrowing as a cohort. Reverting land is land that was previously used for agriculture and is now undergoing a successional change. Vegetation may grow up in uneven patches in these areas.

Forested land includes transitional forests and mature forests. CEAT defined transitional forests as areas that have at least a 50 percent forest cover, with a mixture of shrubs, young trees, and old trees, resulting in a patchy, uneven canopy. Mature forest is land with a distinct closed canopy and no patches.

Results and Discussion

Forestry

In 1997, the Lake George and Oaks Pond watersheds were composed mainly of mature and transitional forests (Figures 30 & 31). No other land use type comprised more than ten percent of the total land uses in the area. Agriculture and reverting areas had the next highest totals. However, these percentages are much lower than in the 1955 land use maps where agriculture is one of the dominant land use types. There are some distinct differences between the land use totals within the two watersheds.

Slightly less than half (49.6 percent) of the Lake George watershed was composed of mature forest. Transitional forest areas made up 40.5 percent of the watershed. Regenerating areas accounted for one percent of the watershed. The Oaks Pond watershed has less total forest cover than the Lake George watershed (78.5 percent versus 91.0 percent), but more of the forest cover is mature forest (72.8 percent compared to 49.6 percent). Mature forest comprises 72.8 percent of the total land uses and transitional land accounts for only 3.8 percent of all land uses in the Oaks Pond watershed. Regenerating areas in Oaks Pond make up a slightly larger percent than in Lake George (1.8 percent vs. 1.0 percent).

A comparison of the 1955 and 1997 land use maps (Figures 30, 31 & 32) demonstrates that a much larger percent of the land use in the Lake George watershed in 1955 was agriculture. A portion of the 1955 land use was unavailable; consequently, when comparing percentages between the two watersheds this portion in the 1997 map is also omitted. As a result, percentages from the 1997 map and the 1997 clipped map described below will be slightly different. The clipped 1997 map shows that agriculture made up 0.96 percent of total land uses in 1997 compared to 12.94 percent in 1955. Much of the land that was classified as agriculture on the 1955 map became transitional land by 1997. Consequently, these percentages help to explain why there is a larger amount of transitional land in the 1997 Lake George watershed.

The data are consistent with past data on Maine watersheds. Previous CEAT studies reported that mature forest made up the greatest percentage of land use types within the respective watersheds (BI493 2000). Transitional percentages varied from watershed to watershed, with the lowest percentage being 2.0 percent in both North Pond and East Pond. The largest percentage of transitional land was 27 percent in the Long Pond watershed. Part of the reason for variation in results arises from differences in defining transitional forest. The Great Pond study combined reverting and regenerating categories into the transitional category while the East Pond report classified all forested areas as one category. The amount of transitional land within the Oaks Pond watershed is low, but it is still within the range of past data. The transitional land in Lake George was the highest percentage to date, which suggests that in the future Lake George will have a much larger amount of mature forest than other watersheds in the area. This amount of forest coverage will be beneficial for its potential to increase nutrient absorption and prevent erosion; however, it may also result in increased interests in logging in the area (BI493 2000).

The amount of forested areas in the watersheds has increased over time. The Lake George data (Figure 30) indicate that mature forest increased from 5.9 percent to 49.6 percent and transitional forest increased from 25.4 percent to 40.5 percent. Regenerating and reverting areas both decreased from 16.4 percent to 1.0 percent and from 14.7 percent to 3.7 percent, respectively. This change constitutes an increase in natural buffers, making runoff erosion a less serious threat to the lakes. Continued efforts to minimize erosion within the watershed are important for maintaining water quality. As the populations of Canaan and Skowhegan continue to grow, it is imperative that forested areas in the watershed do not drastically decrease in the future from either logging or development.

Logging

Cleared areas in Lake George only represent 0.6 percent of the watershed. As mentioned earlier, this category is composed of cleared land, selectively cut land, and logging roads. In the

Oaks Pond watershed cleared areas make up 0.4 percent. The amount of cleared land surrounding Lake George is only slightly larger than in Oaks Pond. One possible reason for the slight difference in the amount of cleared land may be that Plum Creek Timber Company, Inc. owns land in the northern portion of the watershed. No logging company currently owns land in the Oaks Pond watershed. Cleared areas in the watersheds are not concentrated in one specific area but rather are scattered throughout each of the watersheds. Most of the logging takes place in the northern portion of the watershed near the one logging road that was identified on the 1997 land use map. This area is more than the minimum 250 ft away from the lake, making it less of an immediate threat to water quality. It is extremely likely that more logging roads exist in both the Lake George and Oaks Pond watersheds, but were obscured by vegetation in the DOQs.

Cleared areas in the Lake George watershed have decreased: in 1955 cleared land represented 21.9 percent of total land uses compared to 0.6 percent in 1997. This trend was consistent in the Oaks Pond watershed, although decreases were not as drastic. Cleared land decreased from 1.8 percent in 1955 to 0.4 percent in 1997. These data suggest that logging does not pose the same threat it posed 42 years ago,although impact depends on when, where, and how logging takes place. The Lake George and Oaks Ponds combined watershed has less cleared land than any watershed previously surveyed by CEAT. In past CEAT studies, cleared land has been defined as any land not covered by trees or shrubs, which included agricultural tillage, fallow fields, and golf courses. The CEAT study of the Lake George and Oaks Pond watershed defines cleared land as cleared patches of forest resulting from logging,, including selection cutting. The definition of agriculture for the study of the Lake George and Oaks Pond watershed includes areas of fallow fields, agricultural tillage, cropland, and pasture. The variation in the definition for cleared land may partially account for the small percentages in this year's study, especially when compared to percentages from the CEAT Lake Wesserunsett study in 2001. However, runoff and sediment erosion resulting from logging may still impact the Lake George and Oaks Pond watershed less than other lakes previously studied by CEAT.

Agriculture

Agriculture is the leading source of pollution in rivers and lakes due to nutrient laden runoff associated with livestock, manure, and fertilizers applied to cropland entering the surface waters (See Introduction: Agriculture). The degradation of 30 percent of the nation's impaired lakes and 57 percent of impaired rivers can be attributed to agriculture (USDA 2000). Due to the potential threat that agriculture poses to water quality, careful monitoring and best management practices such as riparian buffer strip implementation and proper manure disposal are necessary.

Methods

Agriculture was divided into two categories: cropland and pasture. Cropland was defined by areas of cleared land that had even rows indicative of planting. Pasture land was defined by large areas of cleared land that did not have the row-like pattern of cropland. This was distinguished from cleared land associated with logging because it was typically in an area near roads, cropland, and houses. Cleared land associated with logging is typically surrounded by forest.

Results and Discussion

In 1955, agriculture represented 13.7 percent of the Lake George watershed and 33.7 percent of the Oaks Pond watershed (Figure 32). In 1997, the Lake George watershed was composed of 1.0 percent agriculture and the Oaks Pond watershed was composed of 7.3 percent (Figure 31). This decrease in agricultural land is a trend observed in many watersheds throughout the central Maine region (See Introduction: Regional Trends).

The 1997 agricultural land use percentage represents a small portion of the total area of the watershed for Lake George (1.0 percent), indicating that the effect of agriculture on water quality is likely to be minimal. In the Oaks Pond watershed, agriculture has a greater potential for negative impacts on water quality but it is still a relatively small area (7.3 percent).

Commercial and Municipal

Commercial and municipal land can have a high potential for runoff and phosphorus loading. These land uses often contain impervious surfaces such as roof- tops and pavement that can enhance runoff. Businesses have the potential to enhance the amount of toxic chemicals and wastewater that enters into a watershed (BI493 2000). Gravel pits can contribute to poor water quality in a lake by increasing erosion through the exposure of sediments. Gravel pits also allow greater penetration into the water table of substances contained in runoff, which can also lead to adverse lake water conditions (BI493 2000).

Methods

CEAT grouped municipal and commercial land within the Lake George and Oaks Pond watersheds into one land use category entitled, “commercial/municipal.” This land use category was defined to include industries, businesses, gravel pits, schools, hospitals, and other public facilities.

Results and Discussion

In 1955, commercial/municipal land made up a total of 0.4 percent of the land in the Lake George watershed, and 0.01 percent of the land in the Oaks Pond watershed (Figure 32). Camp Modin was the major source of commercial/municipal land in 1955 prior to the creation of Lake George Regional Park. In 1997, commercial/municipal land made up a total of 0.3 percent of the Lake George watershed and 3.3 percent of the Oaks Pond watershed (Figure 31). CEAT collected some of this data through direct observation of land use types, and therefore a more detailed description of commercial/municipal land is available for the more current 1997 data. The Lake George Regional Park was the largest source of commercial/municipal land in the Lake George watershed in

1997, including parking lots, roads and park buildings. There are also several small businesses along Route 2, many of which are either attached or adjacent to personal residences. The increase in commercial/municipal land between 1955 and 1997 in the Oaks Pond watershed is largely due to the construction of the Eaton Mountain ski area.

Residential Survey

Shoreland zoning

Regulations

Development too close to the shore of a water body may result in a decline in water quality. Shoreline development can lead to increased soil erosion and potentially the addition of contaminants from septic systems. The Maine Department of Environmental Protection (MDEP), with the assistance of the United States Environmental Protection Agency (USEPA), has constructed Maine's Mandatory Shoreland Zoning Act to encourage responsible development, protect water quality, limit erosion, and conserve wildlife and vegetation (MDEP 1998a). This act establishes minimum requirements that all towns must abide by when developing their local ordinances. However, towns are allowed to implement more stringent standards if they deem such regulations necessary. Both Canaan and Skowhegan have adopted the State of Maine's regulations to implement in their towns with some adaptations. The regulations put forth in this act apply to land uses within 250 ft (horizontal distance) of the normal high watermark of any pond over ten acres, and any river that drains at least 25 mi^2. These regulations also apply to land uses within 250 ft of a freshwater wetland over ten acres, and within 75 ft of any stream (MDEP 1998a). Unfortunately, at this time, wetland areas under ten acres, such as vernal pools, are not protected by such regulations.

Residential units proposed in the shoreland zone are subject to the following zoning regulations (Canaan Town Office 2001, Skowhegan Planning Office 2001):

- Structures are required to be set back a minimum of 100 ft (horizontal distance) from the shoreline.
- Structures are allowed a maximum height of 35 ft, measured from the downhill side of the building.
- The minimum shore frontage for a proposed lot is 200 ft
- The minimum area for a proposed lot is 40,000 ft^2.

Proper set back is important to provide space for an adequate buffer and to limit the amount of erosion along the shoreline. Certain areas within the watershed are designated by the towns as Resource Protection Districts; these include: areas with two or more acres of steep slopes (greater than 20 percent), areas with two or more acres of wetland vegetation not part of the water body, and 100-year floodplains on rivers. New development is prohibited within the shoreland zone of Resource Protection Districts; that is, new development must be set back more than 250 ft from the shoreline in these areas. Nutrient loading is further minimized by shoreline ordinances that regulate driveway placement, septic system placement, the clearing of vegetation, and the expansion of existing buildings.

Non-conformance describes buildings, lots, and uses that do not meet the current ordinance standards. These structures are usually buildings that predate the existence of the ordinance and, as a result, are sited too close to the water. Non-conformities exist because houses built prior to 1989 were only required to be set back 75 ft, and prior to 1974 no setback from the shore was required (Gray, pers. comm.). Ordinances typically contain provisions to help reduce the number of non-conformities over time. For example, a non-conforming structure that existed prior to 1989 must not be expanded more than 30 percent during the remainder of its lifetime. If a non-conforming structure is damaged or destroyed and loses more than 50 percent of its value, the structure may be reconstructed provided that a few requirements are met. A permit must be obtained within one year, and the reconstruction should meet the current shoreline setback requirements to the greatest practical extent as determined by the code enforcement officer.

Results and Discussion

Meetings were held with Randy Gray, the Code Enforcement Officer for the towns of Canaan and Skowhegan, to discuss the compliance and enforcement of the zoning regulations. Residents who wish to expand, change, or replace an existing use or structure must apply for a permit. The Planning Board decides, within the context of the regulations, whether or not to approve the permit (Marcotte, pers. comm.). Neither Canaan nor Skowhegan keeps a formal record of the number of non-conforming structures along the shoreline. It is probable however, that the vast majority of the homes in the shoreland zone of both the Lake George and Oaks Pond watersheds are non-conforming (Gray, pers. comm.). Gray expressed his belief that the reason so many non-conforming houses exist along the shoreline is because they were established before the 1974 zoning ordinance was enacted. It is important to attempt to reduce the number of non-conformities over time by increasing the setback of homes that need to be replaced. This improvement will help to decrease the potential for run off and septic contamination because homes and their septic systems will be further away from the water. Increased setback allows more time for nutrients to be absorbed by the soil before reaching the lake. If the lot is too small or some other obstacle prevents proper setback, the lot owner can petition the town to allow replacement of the structure based on a practical proposal by the property owner. In addition to these concerns, many homes along the shoreline are currently too small or are encroaching upon the 200 ft minimum shoreline frontage. This has implications for future development potential as discussed later (See Future Projections: Development Projections).

House counts

The existence of residences in the Lake George and Oaks Pond watersheds represent potential impacts on the water quality of these two lakes. Shoreline properties may increase the runoff of sediment and chemicals into these lakes, which then increases phosphorus loading. In addition, the septic systems of shoreline homes are located in close proximity to the water's edge and have the potential to contribute additional contaminants. Nutrients and pollutants from non-shoreline homes however, have more time to be absorbed and filtered through the soil before reaching the water's edge. It is also important to consider the percentage of seasonal versus year round properties because their respective impacts on runoff and septic leaching can vary significantly. The increased use of septic systems, roads, and activity of year round homes, tends to increase the potential for further nutrient loading. Residences located along streams and tributaries that flow into Lake George and Oaks Pond also present potential problems.

Methods

The houses in the watershed were counted using two methods. Shoreline houses (those within 200 ft of the water's edge) were counted by boat during the buffer strip survey conducted on 24-Sep-01. CEAT chose 200 ft as a cutoff point to be consistent with past reports completed by the CEAT and to allow for comparison with other lakes. Non-shoreline homes were counted in conjunction with the road survey conducted on 3-Oct-01 and 9-Oct-01 (Appendix L). Surveyors determined whether the homes were seasonal or year round by examining certain characteristics. Features suggesting year round residency included an enclosed foundation, an external oil tank, or a paved driveway because they help equip a home for winterization. An open foundation, the absence of a chimney, the presence of pit privies, and dirt driveways often indicate that a residence is seasonal. In addition to the data collected in the field, the tax maps from both Skowhegan and Canaan were obtained from the respective town offices. Tax maps provided information on lot divisions within the watershed and were also helpful in confirming the number of shoreline versus non-shoreline homes.

Results and Discussion

There are 197 houses in the Lake George and Oaks Pond combined watershed, 60 percent (119 houses) of which are year round, and 40 percent (78 houses) of which are seasonal. More than half of the homes in the watershed are year round indicating that these residences potentially affect the watershed on a regular basis. This result has implications for the phosphorus budget because year round homes generally contribute larger amounts of nutrients due to year round septic use and increased human activity (See Land Use Assessment: Phosphorus Loading).

Of the 197 houses in the combined watershed, 55 percent (109 houses) are non-shoreline while 45 percent (88 houses) are designated as shoreline. Approximately half of the homes are located on the shoreline and many of them do not conform to the shoreland zoning regulations. This abundance may negatively impact lake water quality because the homes and many primitive septic systems are located in close proximity to the water body. The population map also indicates that some of the highest population densities in the watershed occur along the shoreline of Oaks Pond (Figure 33). Although these results indicate that there is a relatively heavy concentration of resi-

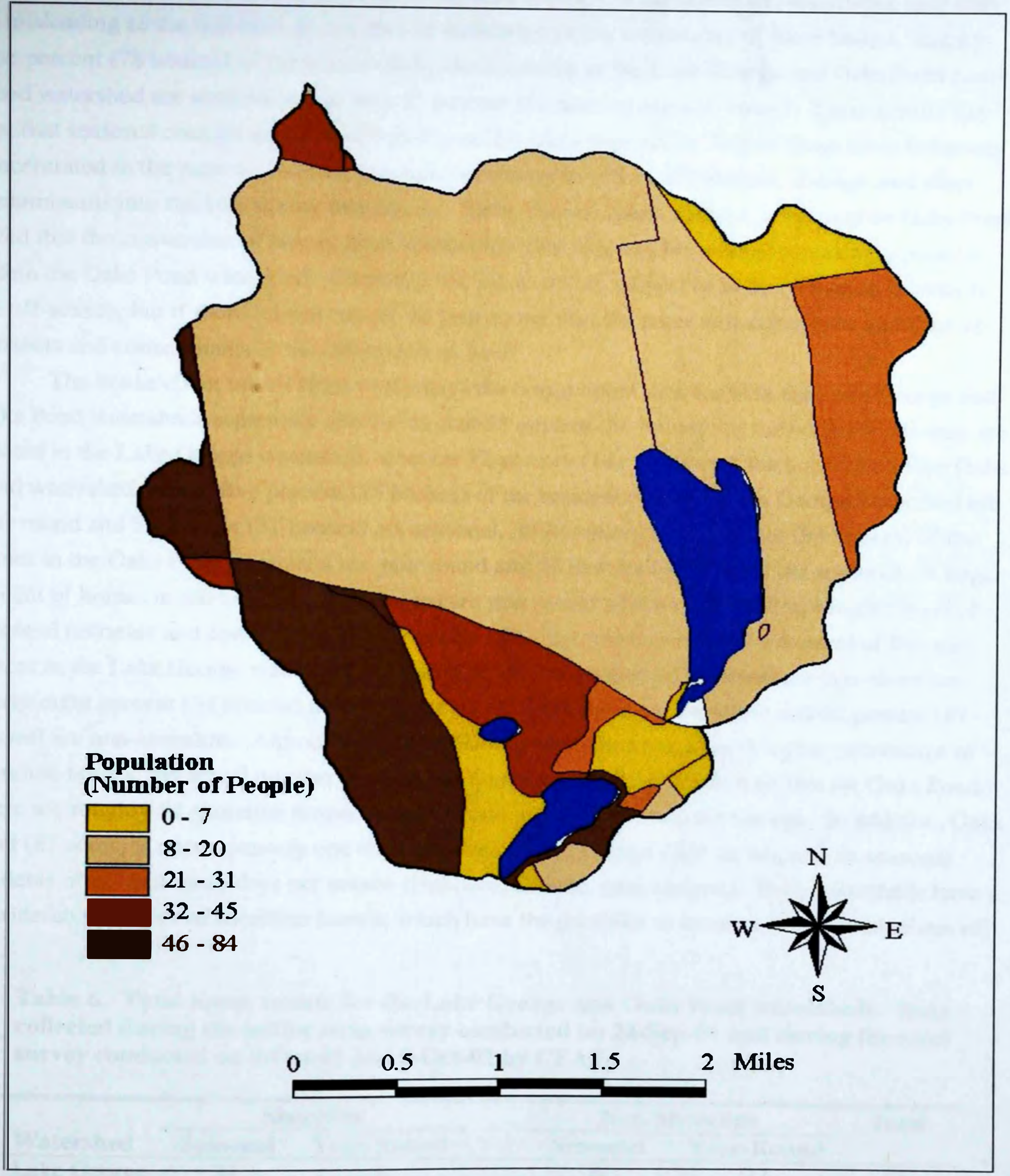


Figure 33. Population within the Lake George/Oaks Pond combined watershed. Data adapted from 1990 Topographically Integrated Geographic Encoding and Referencing (TIGER) census data (TIGER 2001).

dences along the shoreline of Oaks Pond compared to much of the rest of the watershed, they may be misleading as the numbers do not give an indication of the seasonality of these homes. Eighty-nine percent (78 houses) of the houses along the shoreline in the Lake George and Oaks Pond combined watershed are seasonal while only 11 percent (10 houses) are year round. These results suggest that seasonal changes in the water quality of the lakes may occur. Use of these lakes is heavily concentrated in the summer months, potentially causing an influx of nutrients, sewage, and other contaminants into the lake during this season. Steve Dionne (pers. comm.), a resident on Oaks Pond, noted that the conversion of homes from seasonal to year round is becoming increasingly popular within the Oaks Pond watershed. Currently, the lakes are not subject to as much human activity in the off-season, but if more homes convert to year round use, the lakes will experience an influx of nutrients and contaminants in the off-season as well.

The house count table (Table 6) displays the house count data for both the Lake George and Oaks Pond watersheds separately and shows that 28 percent (56 houses) of the homes in the area are located in the Lake George watershed, whereas 72 percent (141 houses) of the homes lie in the Oaks Pond watershed. Forty-five percent (25 houses) of the residences in the Lake George watershed are year round and 55 percent (31 houses) are seasonal. In comparison, 67 percent (94 houses) of the homes in the Oaks Pond watershed are year round and 33 percent (47 houses) are seasonal. A larger percent of homes in the Oaks Pond watershed are year round which could lead to a higher level of potential nutrients and contaminants entering this lake. Sixty-one percent (34 houses) of the residences in the Lake George watershed are shoreline and 39 percent (22 houses) are non-shoreline. Thirty-eight percent (54 houses) of the residences on Oaks Pond are shoreline and 62 percent (87 houses) are non-shoreline. Although the Lake George watershed has a much higher percentage of shoreline homes, the actual number of shoreline homes on this lake is less than that for Oaks Pond. There are roughly 54 shoreline homes on Oaks pond and only 34 on Lake George. In addition, Oaks Pond (87 acres) is approximately one third the size of Lake George (304 acres), and its seasonal residents often visit more days per season (Hubbard, Dionne, pers. comm.). Both watersheds have a considerable number of shoreline homes, which have the potential to increase the amount of run off

Table 6. Total house counts for the Lake George and Oaks Pond watersheds. Data collected during the buffer strip survey conducted on 24-Sep-01 and during the road survey conducted on 3-Oct-01 and 9-Oct-01 by CEAT.

	Shoreline		Non-Shoreline		Total
Watershed	Seasonal	Year-Round	Seasonal	Year-Round	
Lake George	31	3	0	22	56
Oaks Pond	47	7	0	87	141
Combined	78	10	0	109	197

and septic contaminants entering the lake. Oaks pond however, may be more at risk of nutrient loading due to its smaller size, the higher number of shoreline homes, lengthier resident visits, and increased septic use. The high flushing rate (4.91 flushes per year) of the lake, however, helps to alleviate some of these concerns.

Lake Wesserunsett, surveyed in 2000 by CEAT, is in the nearby Town of Madison, and makes for an interesting comparison (BI493 2001). There are 533 residences within this watershed, compared to the 197 in the Lake George and Oaks Pond combined watershed. However, the percentages of seasonal versus year round homes and shoreline versus non-shoreline homes are quite similar between the two. Just over half of the residences in the Lake Wesserunsett watershed are year round while just under half are located along the shoreline compared with sixty percent year round and forty-five percent shoreling for the combined watersheds of Lake George and Oaks Pond. Although the placement and seasonality trends are similar, the Lake Wesserunsett watershed contains nearly three times as many residences as the Lake George and Oaks Pond combined watershed. The total area of the Lake Wesserunsett watershed is 42,100,000 m^2, whereas the area of the Lake George and Oaks Pond combined watershed is 26,693,615 m^2. These figures demonstrate that the Lake Wesserunsett watershed is only one and a half times larger but holds almost three times as many residences. The Lake Wesserunsett watershed has a much larger potential for water quality degradation than the Lake George and Oaks Pond combined watershed due to higher levels of development.

Buffer strips

Shoreline residential areas can have a distinct impact on the water quality of a lake (Woodard 1989). The disturbance of natural vegetation and soil can lead to increased runoff, causing erosion and ultimately resulting in an increase of nutrients and sediments flowing into the water. These pollutants can produce a number of undesirable effects (See Introduction: Buffer Strips). Excess sedimentation can cause fish gills to clog and increase nutrient levels in the water, particularly phosphorus, which can lead to eutrophication (Schauffler 1990). Eutrophication can cause algal blooms which can destroy the habitat for other plants and aquatic life (See Introduction: Trophic Status of Lakes).

A buffer strip is one of the most economical and effective methods available to minimize the impact of runoff along the shoreline. An adequate buffer should consist of four layers: trees, shrubs, groundcover, and a duff layer. Trees have a deep root system that is particularly useful for absorbing water and nutrients. In addition to being aesthetically pleasing, shrubs can provide protection from wind and rain and serve as a refuge to many wildlife species. Groundcover is an equally significant layer. It consists of vines, grasses, and ornamental flowers, which serve to slow down runoff and allow for more water percolation into soil, trap sediment, and hold soil in place. The duff layer is composed of fallen leaves, pine needles, and other natural debris. This layer is one of the most important layers because of its sponge-like ability to absorb water. It also provides an optimal environment for microorganisms to recycle nutrients. Buffer strips have other benefits in addition to improving water quality. They can provide privacy, protect property from harsh weather, provide attractive habitats for wildlife, and cut down on yard maintenance (Hardesty and Kunhs 1998). There are a number of regulations concerning shoreline property that include policies regarding buffer strips (See Residential Survey: Shoreland Zoning).

There are three basic types of buffer strips: natural, enhanced, and landscaped. Natural buffers consist of natural vegetation that has not been mowed. This type of vegetation can take some time to grow back if extensive removal has occurred but it requires the least maintenance and is the most economical (Hardesty and Kunhs 1998). Enhanced buffers are natural buffers with some added ornamental plants that do entail additional maintenance and expense. The third option is a land-scaped buffer that consists of predominantly cultivated plants. While this option is more expensive and often requires more maintenance, it can also be established more quickly because purchasing mature plants reduces growing time (Hardesty and Kunhs 1998). When possible it is preferable to use native plants when designing a buffer strip (Appendix M). Native plants are adapted to climatic conditions and often require less maintenance. Native plants are also preferable to non-native plants because of the potential of non-native plants to become invasive species. Generally, the best option is to examine naturally growing vegetation in the area and add to it (Cumberland County Soil and Water Conservation District Fact Sheet #05).

Riprap is a method used to prevent erosion along the shoreline (See Introduction: Buffer Strips). This method protects fragile shorelines from wave damage. In comparison to vegetated buffer strips, riprap is less effective in preventing erosion; it does, however, provide another option for erosion prevention if vegetation cannot grow in the desired area. The main purpose of riprap is to protect the shoreline from wave action and subsequent erosion, particularly during storms or times of high water.

Methods

A survey was conducted on 24-Sep-01 to analyze the quality of the residential buffer strips around Lake George and Oaks Pond. The survey form was developed and used by CEAT in previ-ous studies (BI493 1999-2001; Appendix N). Survey categories include percent lakeshore coverage of buffer, buffer depth from shoreline, slope between house and shore, buffer composition (percent trees, shrubs/flowers), and need for riprap. Geographic coordinates were taken with a Garmin® GPS unit for each house surveyed and matched to a tax map to create a map illustrating where the different types of buffers were located. Survey data were analyzed using the following method: houses receiving a score of less than 7 were rated as having poor buffers, houses with a score from 8 to 14 were rated as having partial buffers, and houses with a score of 15 or higher were considered adequately buffered. This scoring system was chosen based on the scale used in the 1998 BI 493 report. The maximum score possible was 23. Characteristics of an optimal buffer would have greater than 75 percent lakeshore coverage of buffer, and buffer depth from shoreline would be four feet or more. The slope between the house and the shore would be zero, the buffer composition

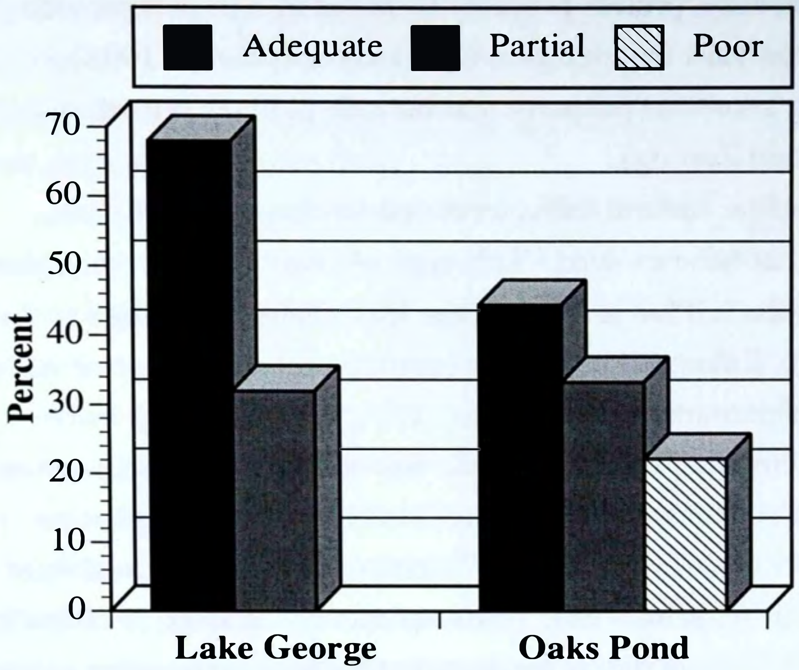


Figure 34. Percent adequacy for buffer strips on Lake George and Oaks Pond determined from the buffer strip survey taken on 24-Sep-01 (See Buffer Strip Survey: Results). Buffer strip adequacy is important to the overall health of the lake because buffers provide the last line of defense against runoff entering the water.

would be approximately 100 percent shrubs and flowers, and riprap would not be needed. The lowest score possible was zero. A property receiving this score would essentially have no buffer. There would be zero percent lakeshore coverage of buffer, no buffer depth, the slope would be greater than 22 degrees and riprap would be needed.

Results and Discussion

Both Lake George and Oaks Pond have a substantial number of shoreline residences, many not conforming to current regulations (See Residential Survey: House Counts). Of the 34 houses surveyed on Lake George, 68 percent were adequately buffered, 32 percent were partially buffered, and none were poorly buffered. Fifty-four houses on Oaks Pond were surveyed with 44 percent classified as adequate, 33 percent as partial, and 22 percent as poor (Figure 34).

Improperly buffered houses pose a distinct threat to water quality in Oaks Pond and Lake George. These buffers tend to cover an insufficient amount of shoreline, do not extend far enough back from the shoreline to the house, and have a steep, erosion prone slope (Figure 35). Without adequate buffers along the shoreline, it permits runoff to flow freely into the lake carrying nutrients and sediments that may contribute greatly to the degradation of water quality to. Although partially buffered homes are not as detrimental to water quality, one or more of the issues associated with poor buffers, such as steep slope, or lack of buffer depth was also observed (Figure 36). Adequate buffers are characterized by appropriate lakeshore coverage, depth from the shoreline and composition consisting of trees, and shrubs/flowers (Figure 37).

There are many publications available to homeowners regarding methods to improve the buffering capacity of their shoreline property. Slope, exposure, and soil type are examples of characteristics that are unique to each property. When planning buffer strip installation, it is beneficial for each homeowner to match buffer strip design to specific characteristics of their shoreline. Although certain categories such as buffer depth may be difficult to improve, small changes can have a significant beneficial effect (Hardesty and Kunhs 1998). The "before" image depicts a house close to the

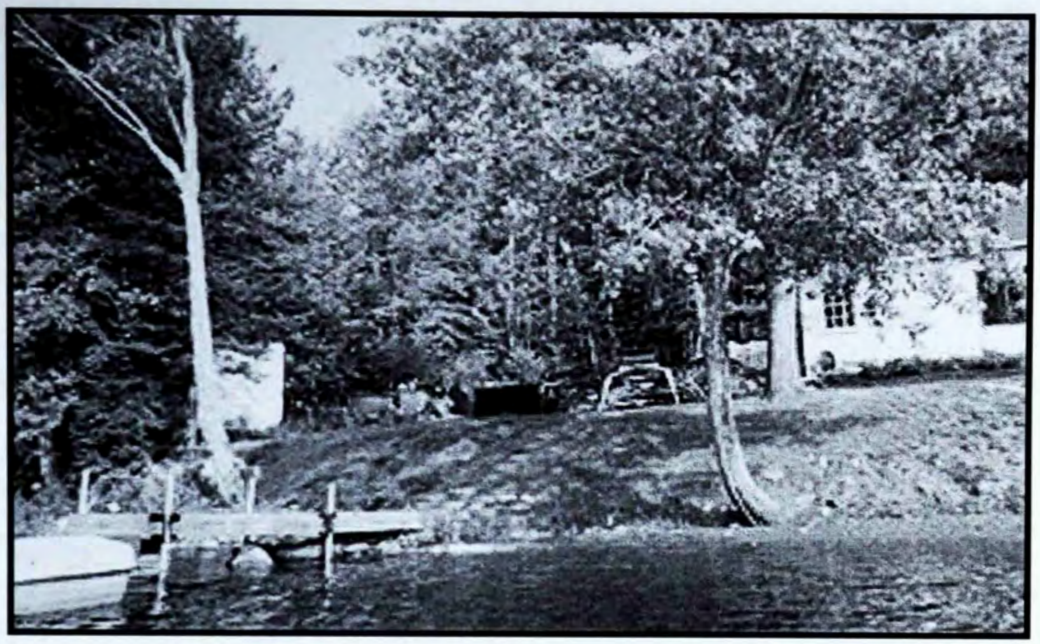


Figure 35. An example of a buffer strip rated poor by the buffer strip survey. Lakeshore coverage was between 1 and 25 percent; buffer depth was zero feet. The slope between the house and the shore is greater then 45 degrees. The combination of these factors threatens water quality because there is essentially no barrier between the house and the water to absorb runoff and prevent erosion.

Figure 36. An example of a buffer strip rated as partial by the buffer strip survey. Lakeshore coverage is between 1 and 25 percent; the buffer depth is approximately one foot. The slope between the house and the shore is between 0 and 11 degrees. The buffer composition is 50 percent trees and 50 percent shrubs/flowers. Partially buffered houses do not pose as great a threat to water quality as poorly buffered houses, however, improvements are certainly necessary to create a more effective buffer strip.

Figure 37. An example of a buffer strip rated as adequate by the buffer strip survey. Lakeshore coverage is between 26 and 50 percent; the buffer depth is approximately two feet. The slope between the house and the shore is between 0 and 11 degrees. The composition is 50 percent trees and 50 percent shrubs/flowers. This property has many of the characteristics of a good buffer, however, there are improvements that could be implemented to make this good buffer strip even more effective.

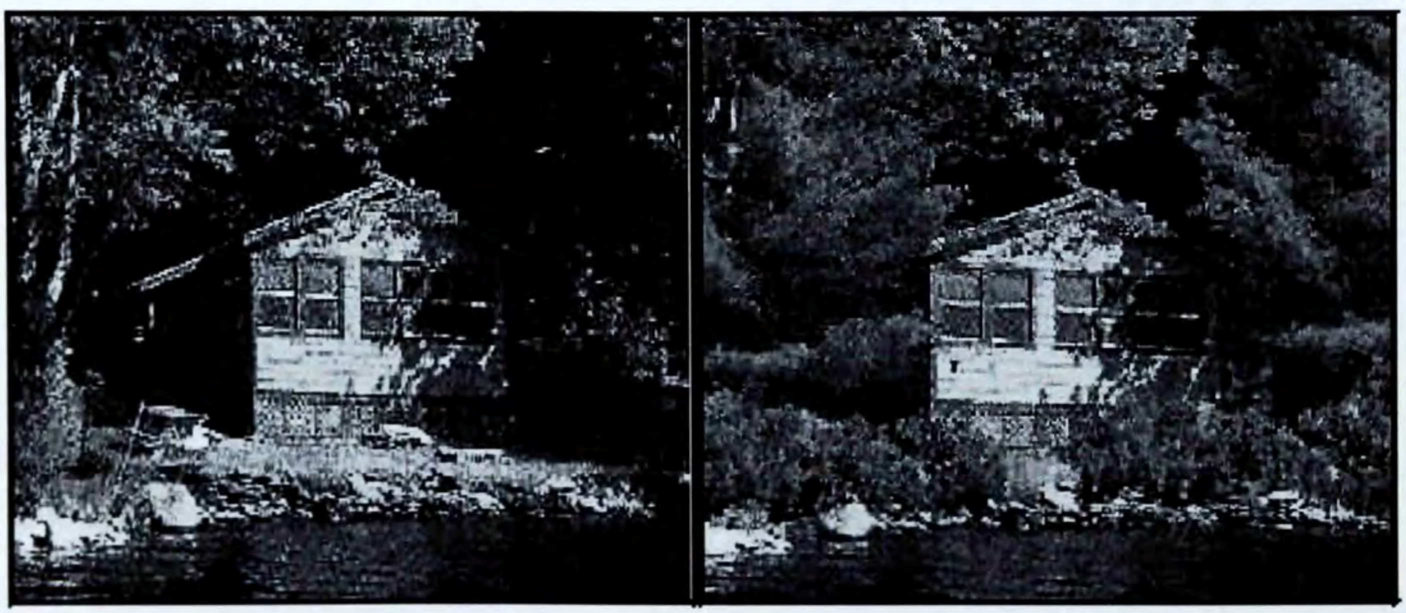


Figure 38. The same cabin before and after the addition of a computer generated buffer strip. These images illustrate how even small changes can significantly improve the buffering capacity of a previously poorly buffered property (Hardesty and Kuhns 1998).

water with no vegetation between it and the water (Figure 38). The "after" image depicts the same house with digitally added vegetation. This illustrates how simple it can be to make both aesthetic and environmental improvements resulting from the addition of a small amount of vegetation. This issue is particularly relevant for many camps on Lake George and Oaks Pond that are very close to the water's edge and considered nonconforming in regard to shoreland zoning regulations (See Residential Survey: Shoreland Zoning). To mitigate the negative effects these houses can have on water quality, implementation of the buffering techniques described above should be employed.

Figure 39 shows the location of the different categories of buffers along the shorelines. There does not appear to be any pattern of adequately buffered houses or partially buffered houses on Lake George; rather they are scattered around the lake. A scattered distribution is also seen on Oaks Pond. There does not appear to be a general pattern between location and buffer strip adequacy for either lake. In past CEAT reports (BI493 1999-2000) larger lakes were studied and divided into sections for buffer strip analysis. This analysis often showed certain areas of the lake to be at greater risk for water quality degradation due to inadequate buffers than others. The lakes considered in this report are smaller, thus a more detailed analysis was possible. One characteristic not seen in other lakes is the ownership of large stretches of shoreline by a park such as LGRP. The west side of the lake, south of the first camp, is mostly forest and naturally buffered, which contributes much less runoff in comparison to residential land (Woodard 1989). The east side shoreline is closely flanked by a dirt road and the depth of the buffer is relatively shallow making it an area of concern for erosion and runoff (See Watershed Land Use Assessment: Roads). Many steps have been taken to control erosion and runoff as illustrated by the berm construction on the east side to control parking lot runoff; however, more work is necessary to minimize threats to water quality. The willingness of LGRP to address buffering issues will have a large impact on the lake because of the extensive amount of shoreline under park management.

Subsurface disposal systems

Regulations govern construction of subsurface disposal systems to ensure that minimal amounts of nutrients are added to the environment. The Towns of Canaan and Skowhegan both conform to the regulations established by the State of Maine Subsurface Wastewater Disposal Rules for wastewater disposal (MDHS 1988). These regulations are listed in the Maine Subsurface Wastewater Disposal Rules (See Introduction: Sewage Disposal Systems). The information used in this report is based on conversations with Randy Gray, the plumbing inspector for both towns.

Problems and Recommendations

Septic systems are designed to store and treat waste. These systems are sensitive, and addition of harmful chemicals to the tank can potentially inhibit or kill bacteria that are necessary for proper function. The lack of bacteria could cause waste to accumulate in the malfunctioning system, which could lead to increased phosphorus loading and more rapid eutrophication of lakes. Residents

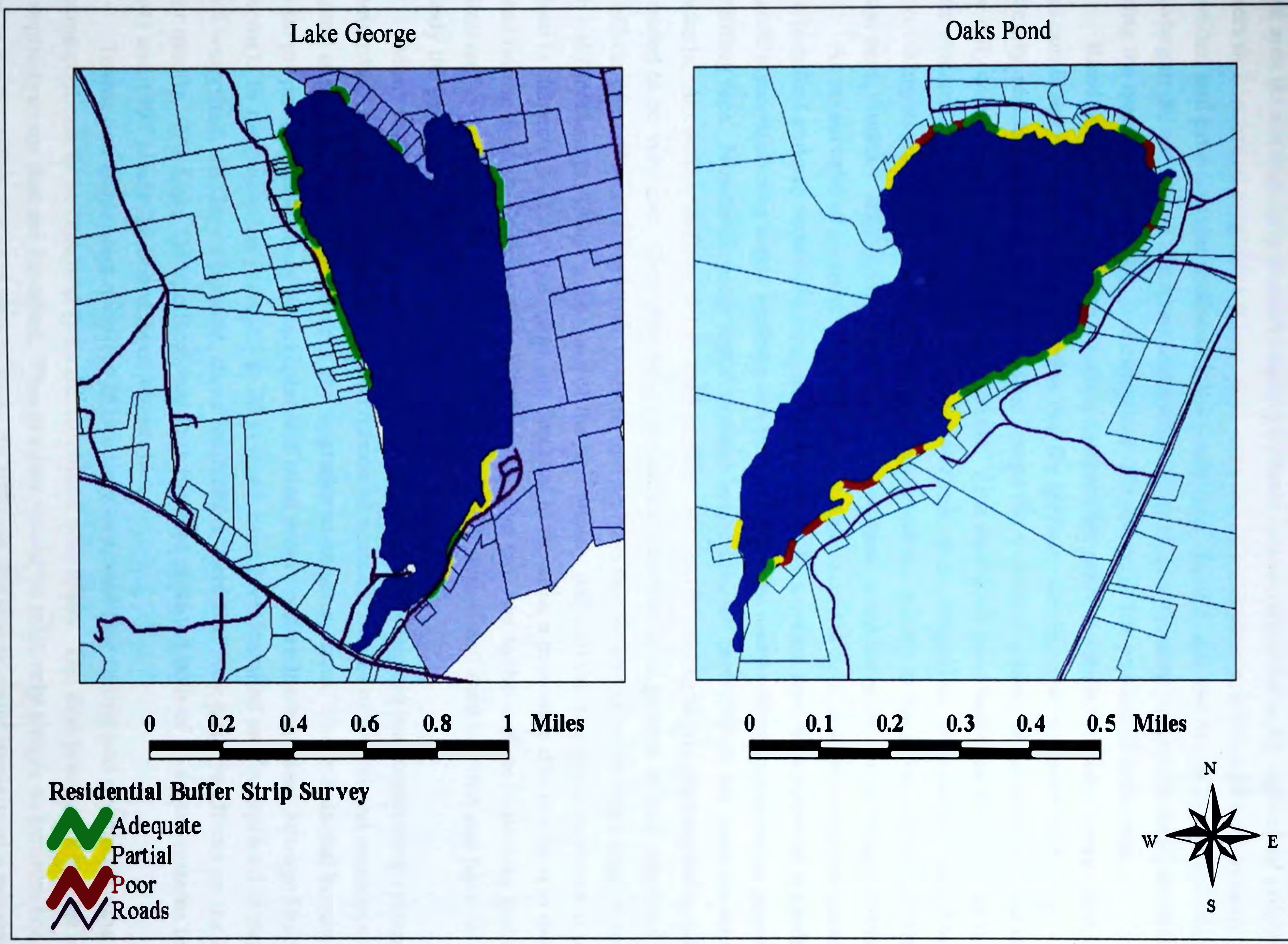


Figure 39. Illustration of buffer adequacy for Lake George and Oaks Pond as determined from the Buffer Strip Survey on 24-Sep-01. Ratings were based on percent shoreline coverage, depth of buffer, slope between house and shoreline, percent composition, and need for riprap.

need to be aware of this fact and control what is added to their septic systems. Plumbing inspectors in the area do not regularly inspect existing systems unless requested to by individual property owners or concerned neighbors (Gray, pers. comm.). Consequently, a failing septic system could go unnoticed and pose a major problem to the watershed. In addition, the towns of Canaan and Skowhegan do not record the types and installations of new systems present in their jurisdiction, leaving the quantity, condition, and efficiency of systems in the watershed unknown.

Randy Gray mentioned that failing systems are present within the Lake George and Oaks Pond combined watershed. He suggests that the primary reason septic systems are failing is overuse. Currently, residents tend to remain at their camps for months at a time, whereas in the past they may have only come to the lake for weekend visits. This increased use challenges the capacity of current septic systems. Gray suggests that people may flush up to 300 gallons of water per day. This practice is taking its toll on the existing septic systems and the quality of the Lake George and Oaks Pond (Gray, pers. comm.). The typical shoreline septic system is not designed for such high levels of use.

As no surveys of systems are conducted and no record is kept, it is possible that some people have installed and use nonconforming septic systems. This option may be somewhat appealing because nonconforming septic systems can be installed right away without approval or payment of permitting fees. Nonconforming septic systems may work, but probably do not meet the current standards. According to Gray, the overall number of nonconforming septic systems being added is estimated to be very low. Gray also believes that the community in general is well educated about the effects of malfunctioning septic systems and realizes that no one benefits from algal blooms or high coliform levels. Often a member of the community will call the plumbing inspector if a failing system is suspected. If sewage odors are detected in the area, a non-toxic dye is added to the suspected failing system. If the system is failing, the dye will rise to the surface indicating that that wastewater is not being properly treated. The property owner will then be cited and have 30 days to remedy the problem (Gray, pers. comm.).

Many individuals are installing new systems and replacing old malfunctioning systems voluntarily (Gray, pers. comm.). The conversion of seasonal homes to year round residences has resulted in septic system replacement and upgrades to larger systems. Some seasonal homes still rely on pit privies, which may be acceptable if used properly (See Introduction: Sewage Disposal Systems). In the past three years, 15 to 20 systems have been installed and/or replaced in the combined watershed. In Gray's opinion, these renovations have had very positive effects on the lake water quality. The Lake George Regional Park has also replaced both of its septic systems in 1994 (west) and 1997 (east) (Hubbard, pers. comm.).

Towns can implement a variety of practices to ensure that failing and nonconforming septic systems continue to be removed from the combined watershed. The first practice is to start recording septic systems that are installed. This practice would be relatively simple to institute because permits are necessary for each new system. In addition, the towns could implement a program where they inspect a certain area of the watershed every year to make sure that the septic systems are functioning properly. Each year they could examine a new region and keep the combined watershed in the best condition possible. This inventory should start with a survey of shoreline homes. Continued community education is also important. The town could distribute flyers with basic information on proper septic system requirements and maintenance. In addition, the towns could publicize that under certain conditions funds may be available from the state to help ease the cost of installing systems. All of these actions would enhance water quality and lead to a cleaner watershed environment.

Roads

Roads have the potential to contribute significantly to phosphorus loading (Michaud 1992). During road construction the land is cleared of vegetation potentially increasing the amount and rate of runoff water. Roads can act as channels for runoff by providing a direct path for sediment to flow into water bodies. To minimize potential runoff, roads should be kept in the best condition possible. Proper maintenance is especially important for camp roads that are located in close proximity to lakes. Camp roads are composed of sediments that hold large quantities of phosphorus. Phosphorus clings to sediments, such as dirt and gravel. If erosion occurs, these particles can easily be deposited into water bodies along with phosphorus. Roads can contribute large amounts of phosphorus to lake watersheds and are the greatest threat to the health of lakes in Maine (Michaud 1992).

Paved roads also affect overall lake water quality, particularly if they are close to the water body. Sand and salt, used on roads in the winter, remain on impenetrable road surfaces and may be washed into lakes by spring rains or snow melt. Although driveways were not surveyed in this report, driveways are similar to camp roads in that they also have the potential to add significant amounts of nutrients. Shoreline residences with driveways that lead directly down to the water are potentially quite harmful, especially if they are steeply graded.

The amount of phosphorus that a road can add increases tremendously if it is not maintained. CEAT surveyed all of the accessible paved and unpaved roads in the Lake George and Oaks Pond watersheds to gain a better understanding of the condition of the roads and their potential for phosphorus loading.

Methods

Unpaved camp roads contribute more phosphorus to the watershed than paved roads; thus they were the focus of this study. Paved roads were assessed for evidence of erosion and the condition of culverts; in addition, the number of houses on each paved road was counted. Each accessible camp road was surveyed using the Detailed Survey (Appendix O). This survey was designed by the MDEP and modified by CEAT over the years. In addition to assessing camp road quality, the length and width of paved roads in the watershed were measured. The area of all roads was determined by multiplying length by width using data acquired from the road surveys. Road surveys were conducted on 3-Oct-01 and 9-Oct-01.

The Detailed Road Survey evaluation assessed the current condition of camp roads. The investigation covered road surface quality, ditching, culverts, water diversions, and erosion potential in addition to road area (See Introduction: Roads). All of these categories were used to assign each road a score. Roads with higher scores were in worse conditions than roads with lower scores.

The length of the road was driven and the mileage recorded for each camp road that was surveyed. The road was then divided into three to five equal sections. Each section of the road was then surveyed on foot for each of the road characteristics mentioned above and the results were recorded on the survey form.

The surface total score was based on many road characteristics including crown, surface material, presence of berms, base, overall condition, and seasonal versus year round use (Appendix P). Proper crowning is necessary to divert water off the road and into ditches, or the adjacent landscape. Crowning is the first measure towards diverting runoff water into a buffer area (MDOT 1986). Water will collect on the surface of the road without proper crowning and may contribute to further deterioration of the road. Crowning was measured using a level and a string attached to a meter stick. The meter stick was held at the road's edge and the string was extended to the road center. Using the level, the string was moved to the correct horizontal position on the meter stick to make a right angle (90°) and the crown height was read. Ideal camp roads have a crowning of 0.5 to 0.75 inches for every foot of width, meaning that a twelve-foot wide road would have a crown of six inches (Figure 40; Michaud 1992).

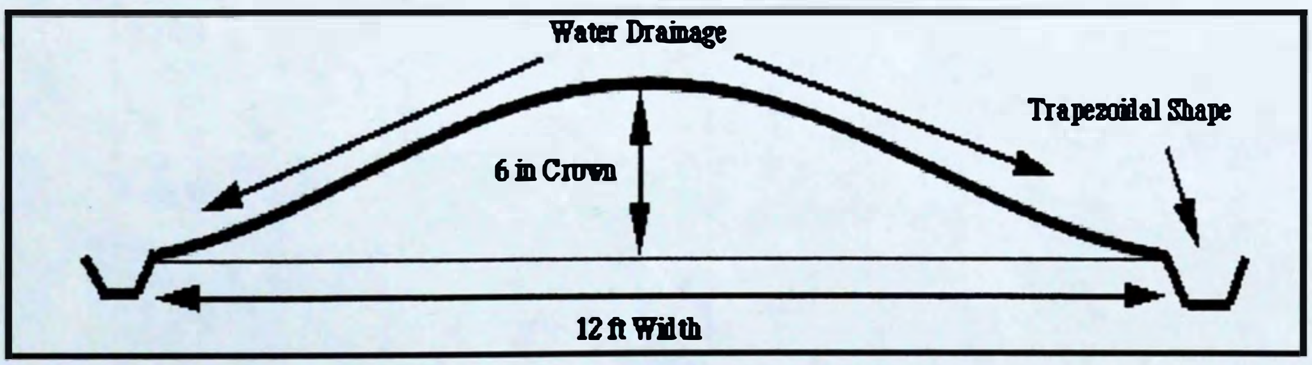


Figure 40. A good camp road has a six-inch crown for a 12 ft wide road. The crown serves to direct surface runoff into roadside ditches. Within ditches, vegetation serves as a buffer for phosphorus-containing sediments (Michaud 1992).

Ditching is another step in rerouting runoff and directing it into buffer zones. The score for ditching of each road was determined by evaluating the condition of existing ditches and assessing the need for additional ditching. An effective ditch is parabolic or trapezoidal in shape, two feet deep, fairly wide, vegetated or filled with riprap, and lined with a moderately thin layer of a natural substrate. If high flow rates are expected, riprap should be used because it slows down the flow and prevents erosion. Ditches with large amounts of sediment or bare soil received the lowest scores

Figure 41. The photograph at the left is an example of a bad ditch because it is square in shape and is composed of bare soil. The photograph at the right is an example of a good ditch because it is parabolic in shape and is vegetated.

Figure 42. The photograph at the left is an example of a bad culvert because it is exposed, caved in, rusting, and full of debris. The photographs at the upper and lower right are examples of good culverts because they are of proper size and depth and are clear of debris.

(Figure 41). Additional ditching was considered necessary if obstructions prevented water from leaving the road surface or if ditches were not present in an area that required them.

Culverts are another road feature that CEAT examined. Culverts are necessary to carry runoff and natural flowing sources of water under roads to prevent erosion of the road bed. Properly placed and functioning culverts drastically reduce the amount of sediment that could be transported by the water as it runs over the road. CEAT assessed the overall condition for every culvert present. Characteristics considered were condition, proper size, amount of sediment present inside, and amount of coverage above the culvert. Ideal culverts are large enough to carry peak flows, clear of large amounts of sediment, free of rust and holes, and covered with at least one foot of material (Figure 42). If there was any evidence of erosion, such as road washouts at low points, the road was classified as more culverts needed (Appendix O).

Water diversions direct runoff away from the road surface and into the surrounding vegetation (See Introduction: Roads). Diversions greatly reduce the amount of water traveling down road surfaces, and potentially, into a lake. Water diversions are particularly useful on steep sections of road leading directly down to a water body (Figure 43). They also help to reduce erosion of camp roads. The score for water diversions was calculated by determining the need for more diversions and the location of diverted runoff.

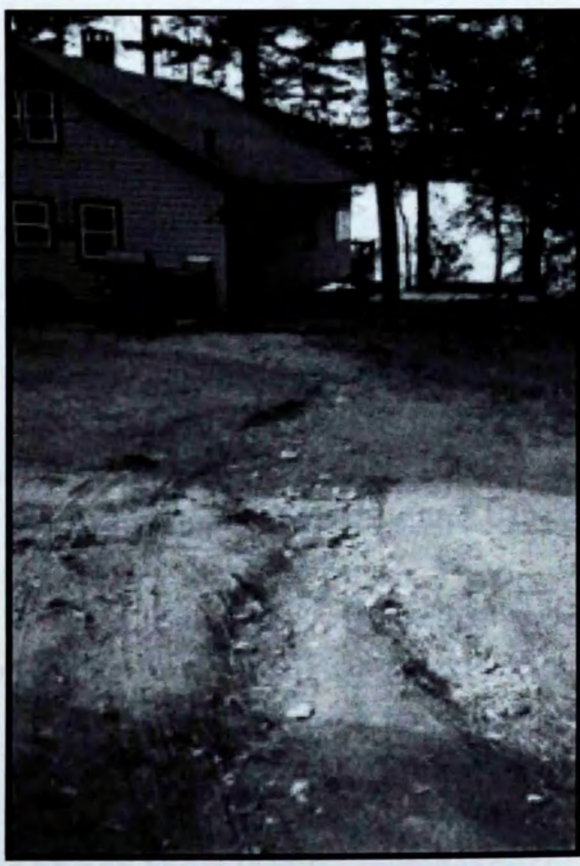


Figure 43. The photograph at the left shows an area where a water diversion is necessary due to the steep grade and existing erosion. The photograph above shows an appropriate water diversion.

Erosion potential is a measure of how much a road potentially contributes to sedimentation and runoff. The product of the road slope and length determined this number and is independent from the Erosion Potential Model created by CEAT (See GIS Assessment: Erosion Potential Model). The road slope was measured in percent grade using a clinometer. The length of each section was measured with a distance wheel. The roads segment average was calculated using the scoring grid on the detailed survey form (Appendix O). The grid weights potential phosphorus loading for longer and steeper sections to quantify the impact of erosion on each surveyed road. Weighted values can then be used to compare the erosion potential of roads.

After all of the roads were surveyed, they were divided into categories based on their total road score. The divisions are as follows: 0 to 37 ideal, 38 to126 acceptable, 127 to 312 risk, 313 to 626 high risk, 627 and above severe risk. These groupings were based on the guidelines set forth by the MDEP.

Results and Discussion

CEAT surveyed 14 camp roads and seven paved roads. Although there are only half as many paved roads, they amount to almost twice the area of the camp roads. The total area of gravel roads surveyed in the Lake George and Oaks Pond combined watersheds was 11.40 acres and paved roads surveyed comprised 22.55 acres (Appendix P). The paved roads in the watershed were generally in better condition than the camp roads. Nonetheless, proper maintenance of both road types is required to sustain road surfaces and prevent erosion and phosphorus loading.

The range of possible total road scores using this survey is 17 to 935. The totals for camp roads ranged from 84 to 514.5. Based on the total road score each road was classified as either ideal, acceptable, risk, high risk, or severe risk (Figure 44; Table 7). In this study there were two acceptable roads, nine risk roads, and three high risk roads. No roads were classified as ideal or as severe risk. There are fewer camp roads in the Lake George and Oaks Pond combined watershed in comparison to Lake Wesserunsett; however, the roads in the Lake George and Oak Pond combined watersheds are of poorer quality (BI493 2001).

The scores for erosion potential do not have a maximum value. Erosion potential is dependent on the length and slope of the road. In this survey, the values ranged from 950 to 43,050 for erosion potential. The range of the road segment average was 6.3 to 14.2. This value represents the mean erosion potential score for a section of each individual road and is useful in comparing the condition and the phosphorus loading capability of roads.

Maintenance is essential for all roads. The ratings given to the roads in the Lake George watershed can be used to help prioritize the order in which repairs should be made. Roads with high erosion potentials should be closely monitored. Proper maintenance and repair is imperative and will lead to improved water quality for the combined watershed. The following is a list of roads at risk based on our analysis by ascending total road score by category, and suggested repairs. Although not included in our ranking, roads that lead directly to the shoreline, or tributaries, should be first addressed.

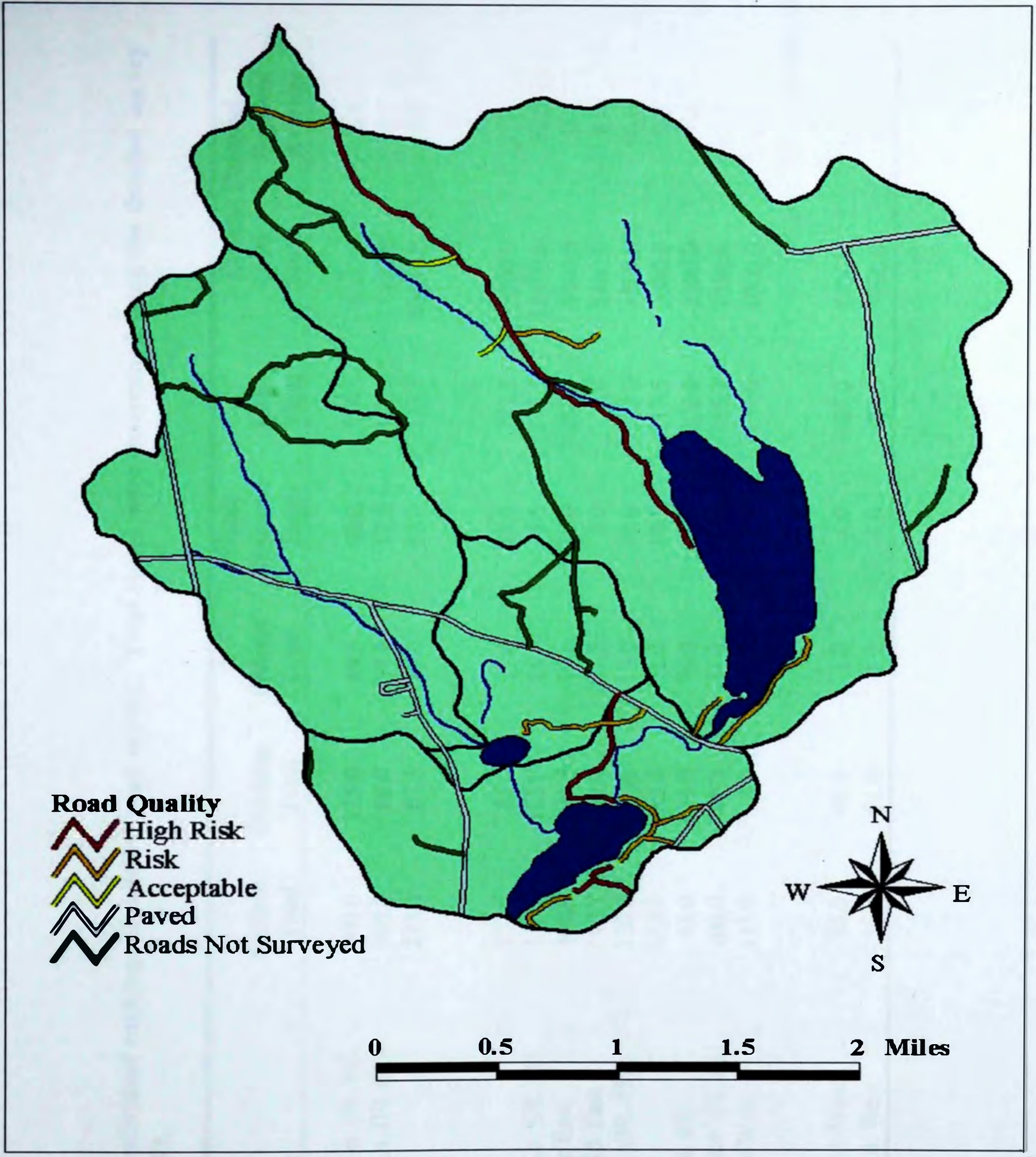


Figure 44. Condition of roads in the Lake George and Oaks Pond watersheds based on a detailed survey, which includes surface, ditching, culverts, water diversions, and erosion potential and road ranking data from Table 7. See Roads: Methods for risk assessment and Appendix O for detailed survey form.

Table 7. Individual rankings of detailed road survey. Total scores were determined using the detailed survey (Appendix P).

Road Name	Surface Total	Ditching Total	Culvert Total	Water Diversion Total	Road Total	Erosion Potential: Total Score	Erosion Potential: Segment Average
High Risk							
Woodcock Ln. (FL #4)	300.0	125.0	49.5	40.0	514.5	6100.0	6.6
Chickadee Ln. (FL #1)	300.0	88.0	57.8	12.0	457.8	11400.0	10.5
Ray's Rd.	225.0	67.5	19.0	12.0	323.5	43050.0	9.9
Risk							
Zikorus Dr.	152.5	85.0	27.0	18.0	282.5	7000.0	11.4
Kingfisher Ln. (FL #1)	110.0	125.0	24.0	16.5	275.5	11400.0	10.5
Lake George East	100.0	94.5	17.6	50.0	262.1	8400.0	9.1
South Log Rd. East	48.7	92.0	101.3	9.0	251.0	5400.0	8.4
Pheasant Ln. (FL #3)	130.0	72.0	18.0	30.0	250.0	4500.0	10.0
Notch Rd.	113.0	93.0	1.0	10.5	217.5	2000.0	9.3
Loon Ln. (FL #5)	45.0	75.0	76.0	6.0	202.0	2300.0	7.4
Blue Heron Ln. (FL #2)	100.0	46.5	31.9	7.0	185.4	1050.0	12.5
Lake George West	135.0	5.0	7.0	4.0	151.0	1000.0	8.0
Acceptable							
South Log Rd. West	56.0	48.0	1.0	4.0	109.0	7400.0	14.2
North Log Rd. West	26.0	51.0	1.0	6.0	84.0	950.0	6.3

High Risk Roads

Ray's Road

- Surface needs work – road grading, rebuild crown, and berm removal
- Water diversions need to be added to avoid road erosion
- Maintenance is necessary because of very high total erosion potential score
- High segment total, mostly due to length

Chickadee Lane (Fire Lane #1)

- Surface needs work - potholes need to be filled, crown reestablished, and berms should be removed
- Ditches need to be parabolic and vegetated
- Culverts need to be larger in diameter and buried deeper
- Particularly high total erosion potential and segment average scores reflect need for regular maintenance

Woodcock Lane (Fire Lane #4)

- Surface needs work - ruts should be filled in, crown reestablished, and berms removed
- Ditches need to be built
- Culvert needs replacing and more cover

Risk Roads

Lake George West

- Surface needs work - crown needs to be reestablished and potholes need to be filled in

Blue Heron Lane (Fire Lane #2)

- Surface needs work - berm removal needed in places and crown needs to be rebuilt
- Some ditching needed
- Additional water diversions needed
- Because of high erosion potential scores, maintenance is needed

Loon Lane (Fire Lane #5)

- Surface needs work - crown needs to be rebuilt and berms should be removed
- Culverts need to be larger and replaced deeper in the ground
- Some ditching needed

Notch Road

- Surface needs work - ruts need to be filled in and berm removal needed

- More ditches needed and current ditches need to be more parabolic

Pheasant Lane (Fire Lane #3)

- Surface needs work - potholes need to be filled, crown improved, and berm removal needed
- Needs some more ditching

South Log Road East

- Surface needs work - ruts need to be filled and berm removal needed
- Some ditching necessary
- Culverts need to be larger, replaced deeper, and cleaned regularly

Lake George East

- Surface needs work - potholes need to be filled and requires some berm removal
- Some ditching necessary
- Many additional water diversions needed as runoff water flows directly into the lake

Kingfisher Lane (Fire Lane #1)

- Surface needs work - berm removal needed
- Some ditches needed and current ditches need to be parabolic and vegetated
- Particularly high total erosion potential and segment average scores reflect need for regular maintenance

Zikorus Drive

- Surface needs work - potholes need to be filled and berms removed
- Road needs proper ditching
- Old culverts need to be replaced
- High segment average indicating a need for regular maintenance

<u>Acceptable Roads</u>

There are only two roads present in this category, North and South Log Rd. West (Table 7). The major contributor to their score was the surface and ditch total. These roads need to have their berms removed and more ditches to be built and vegetated. Additional culverts were not deemed necessary on either of these roads and both appeared to have proper water diversions. These roads also appeared to be newly built or repaired which lead to their high scores. These two acceptable roads are not a threat to the overall water quality of the lake but proper maintenance is still necessary in order to preserve water quality.

Park

Methods

CEAT created two trail maps of the west and east sides of LGRP to catalogue park resources and to help develop educational opportunities for public visitors. These maps were produced using Garmin® Global Positioning System (GPS) 12CX units. Data were collected on 19-Sep-01 and 24-Sep-01. Geographic coordinates were recorded at each of the labeled intersections and between trail intersections in LGRP. These data were saved as a database file (DBF) and imported into Environmental Science Research Institute (ESRI) ArcView® GIS 3.2 software (See GIS Assessment: Methodology).

Existing LGRP trail maps obtained from Bob Hubbard were scanned, imported, and georeferenced to the basemap using ArcView. CEAT overlaid these maps onto the watershed map containing the new geographic coordinates. A new line theme was created and used to create a best fit line based on ground truthing.

CEAT imported additional coordinates which correspond to various park resources including bathrooms, parking lots, trail heads, picnic areas, basketball and tennis courts, vernal pools, and the park office. These data were imported using the same methods for importing trail data. Symbols were imported into the legend to represent each park resource. The auto labeling function was then used to display numerical elevation values on selected USGS contour lines.

Two maps were produced and labeled Lake George Regional Park East and Lake George Regional Park West (Figures 45 & 46). These maps contain detailed information on the trail systems and locate sites of important interest within Lake George Regional Park. CEAT will present these maps to LGRP Manager, Bob Hubbard, and will recommend that they be distributed as a resource for park visitors. A natural history guide containing information about forest and vernal pool ecology was also produced (Appendix Q). CEAT will recommend that these guides be made available as an educational resource to the public.

Results and Discussion

Lake George Regional Park occupies 275 acres in the towns of Canaan and Skowhegan. The land is owned by the state and leased to the two towns (Warren 2001). The park facility is currently managed by Bob Hubbard who was hired as the principal Park Manager in 1993 by the non-profit Lake George Corporation. Nancy Warren was hired to serve as Park Director. Aside from Hubbard, Warren, and the LGRP advisory board, the park relies on part time help, volunteers, and interns. In 1994 an internship program was established in cooperation with Unity College, providing students with educational opportunities to participate in park management and service learning projects (Warren 2001). Due to limited funds which are derived mainly from entrance fees, grants and gifts, Hubbard notes the challenges that have arisen in managing the park with a small staff. Enforcing

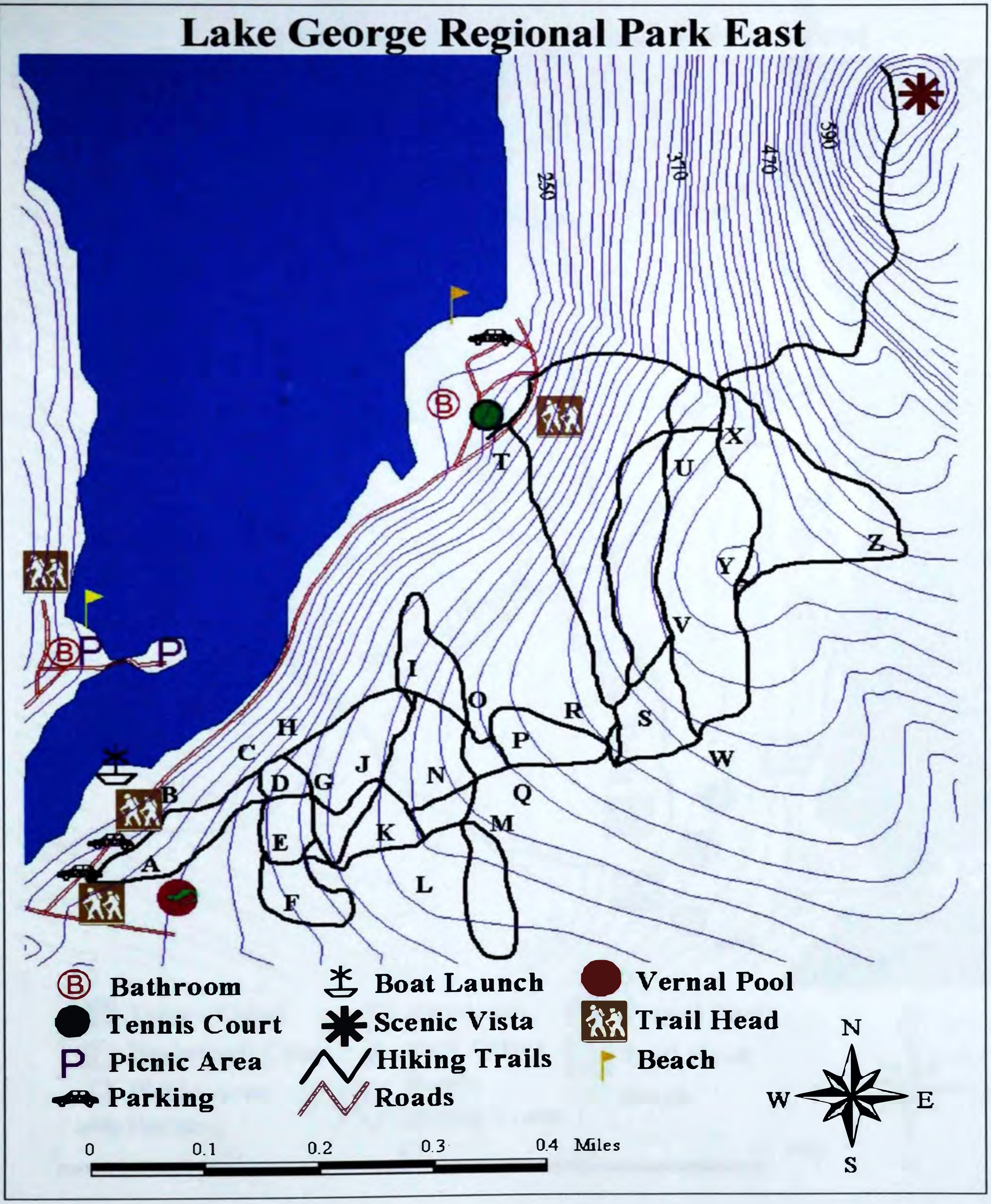


Figure 45. Map of Lake George Regional Park East including trails and sites of important interest.

Figure 46. Map of Lake George Regional Park West including trails and sites of important interest

snowmobile and four wheeling restrictions is one of these challenges. The implementation of proper drainage devises and other erosion control mechanisms have also been restricted by the park's limited funding (Hubbard, pers. comm.). Despite these limitations, LGRP has constructed a berm on the east beach which has mitigated the impact of runoff from the sloped paved parking lot.

The park is divided into two sections, Lake George East and Lake George West.

Lake George East contains the following areas of public interest (Figure 45):

- a public boat launch with a small dirt parking area
- restroom facilities
- a public beach with one large paved parking lot
- tennis courts
- a vernal pool
- a trail network with three trailheads labeled A, B, and T, and two small dirt parking areas near trailheads A and B
- a house along the shoreline for summer interns

Lake George West contains the following areas of public interest (Figure 46):

- a small public beach and picnic areas
- restroom facilities
- park office
- basketball court
- tennis court
- a paved parking lot
- a trail network with three trailheads
- two buildings between backshore trailheads
- several buildings near the shore

CEAT highlighted a number of management concerns related to their impact on the watershed in its analysis of park resources. The condition of the east side road, and the effects of parking along this road were noted by CEAT as potential sources of erosion and runoff into Lake George. The surface condition and slope of the dirt parking lots on the east side have raised additional concerns pertaining to their role in enhancing runoff. The boat launch located on the east side was also noted for its width, erosion potential, and ability to enhance nutrient loading into Lake George.

General Land Use Comparisons

Comparisons can be made between the Lake George and Oaks Pond watersheds and previous CEAT studies of other watersheds in central Maine (Table 8). The Lake George watershed has more transitional land than the other watersheds. Mature forest constitutes 52.09 percent of the watershed, which is the lowest of all previously studied watersheds. This low percentage could negatively impact water quality because mature forest is the most efficient for absorbing runoff and preventing erosion in comparison to other land use types. Developed land comprises 1.39 percent of the watershed, which is the lowest of all watersheds previously studied. Cleared land, including agricultural and logged areas, occupies 1.71 percent of the watershed, which represents the lowest percentage of cleared land of previously studied watersheds. These low percentages have a positive effect on the water quality of the lake. Developed and cleared lands lose some of the ability to absorb water and reduce erosion when trees are removed, resulting in more nutrient laden runoff entering the water body. Lake George has one of the lowest percentages of wetlands, which could negatively impact the water quality because wetlands play an important role in preventing runoff from entering the lake and act as sinks for nutrients (See Introduction: Wetlands). The Oaks Pond watershed follows the same land use patterns seen in the past studies without remarkable exception.

Table 8. Percent of watershed covered by selected land use types for Lake George, Oaks Pond, Lake Wesserunsett, Messalonskee Lake, Long Pond – South Basin and North Basin, North Pond, Salmon Lake, and East Pond watersheds. Transitional land includes reverting, regenerating, and disturbed land. Developed land includes residential, industrial, commercial, and municipal land. Cleared land includes agriculture and logged land.[1] Data were obtained from past CEAT studies (BI493 1991, 1994- 2001).

Land Use Type	Lake George	Oaks Pond	Lake Wess.	Mess. Lake	Long Pond S. Basin	Long Pond N. Basin	North Pond	Salmon Lake	East Pond
Wetlands	1.86	3.18	2.1	13.5	8.3	4.2	7.0	1.0	3.0
Mature forest	52.09	72.90	61.4	58.5	58.0	68.0	75.0	83.0	77.0
Transitional	42.66	7.53	11.8	4.0	27.0	14.5	2.0	3.0	2.0
Cleared land	1.71	7.73	18.9	13.9	4.8	3.0	10.0	9.0	14.0
Developed land	1.39	7.68	2.6	8.8	6.7	9.0	4.0	3.0	2.0
Roads	0.29	0.92	0.5	1.0	1.0	1.0	1.0	1.0	1.0

[1] The CEAT study of the Lake George and Oaks Pond combined watershed defines cleared land as logged land; for the sake of comparison to past CEAT studies, agriculture and logged land have been combined in this table.

GIS Assessment

Methodology

Geographic Information Systems (GIS) are computer hardware and software applications that combine knowledge from geography, cartography, computer science, and mathematics (ESRI 2000b). A GIS is used to collect, manipulate, analyze, and model spatially located information for the display of digital information related to the surface of the Earth (ESRI 1998). Although GIS products resemble paper maps, they are fundamentally different approaches to information organization. Paper maps provide information on different geographical features such as roads, buildings, rivers, lakes, marshes, vegetation cover, soil type, and elevation. However, the information provided is only a visual representation of spatial relationships between and among features. GIS is a 'smart map' that stores each feature as its own map or theme. These themes link to a variety of other information, allowing users to manipulate data for the creation of composite maps (Clarke 2001). Composite maps are themes layered in a manner that allows users to create multi-featured maps that display only specifically selected data necessary for specific analyses (ESRI 1998).

The methods by which features are stored are important to GIS because the program recognizes features as geographically referenced spatial data. Each data point represents a particular location on the Earth's surface (ESRI 1998). Geo-referencing data allows GIS to display theme information in the correct geographical location relative to other features on the earth. Data points were geographically referenced to information regarding the features' spatial location on the Earth's surface.

Data may either be in vector or raster format. Vector data generally consist of zero, one-, and two-dimensional objects known as points, lines, and polygons, respectively. Points are objects with discrete locations, lines are a series of spatially referenced point coordinates, and polygons are shape areas bounded by spatially referenced vertices (Clarke 2001). In contrast, raster data are based on grid cell units, or pixels. Each pixel has an assigned value and location; gridline intersections serve as spatial reference points for each pixel (ESRI 1998). The manipulation of both vector and raster data results in the effective construction of GIS products.

CEAT's study on water quality and land use patterns affecting the Lake George and Oaks Pond watersheds uses ArcView® GIS 3.2 computer program (ArcView), a product of Environmental Systems Research Institute (ESRI). ArcView manipulates both raster and vector data to create themes, composite maps, and models. Scanned images and themes downloaded from a variety of sources were imported into the ArcView program to create a variety of maps and models for this study.

Basic Maps

Relevant information was gathered to create foundation maps, including a base map of the watershed area and a soil map for the area. These maps provide general information relating to the watershed. CEAT derived and obtained additional data from these basic maps to create several models, including the development model, erosion potential model, and logging suitability model.

Methods

Base Map

Data used in base map development were acquired from the Maine Office of GIS website (MEGIS 2001). Data were referenced in Universal Transverse Mercator (UTM) Zone 19 coordinate system, in meters, and in North American Datum of 1983 (NAD83) format. Such data were partitioned by 75 minute United States Geological Survey (USGS) quadrangles. Data were also arranged by thematic content; all the streams in the area arranged into a streams theme, similarly, all the roads are represented by another theme. Because the Lake George and Oaks Pond watersheds overlap two quadrangles (Canaan and Skowhegan), data for each quadrangle were downloaded. These data include watershed boundaries, streams, rivers, lakes, roads, and elevation contours. After compressed ArcInfo® data were downloaded from the MEGIS website (MEGIS 2001), each data set was decompressed using WinZip and imported into ArcView as shape files using the Import71™ utility. The feature themes from each quadrangle were merged to create uniform features using ESRI's GeoProcessing Wizard™. These features were then combined to create a base map containing foundation data, including roads, streams, contours, lakes, rivers, and watershed boundaries. This base map is visually similar to paper maps depicting the aforementioned features.

Topographic Map

A topographic map was created using the foundation data and the ESRI extension software 3-D Analyst™. The 3-D Analyst extension creates a Triangulated Irregular Network (TIN) from the contour lines. TINs represent surfaces using contiguous, non-overlapping triangle facets. Contour lines are assigned a surface value for depth in relationship to other contour lines. An estimate of the surface value is obtained by averaging node values of surrounding triangles, with more influence attributed to the closer nodes (ESRI 1999). A 3-D geographic image is produced based on different colors assigned to a range of surface values and represented as elevation. The contour lines, upon which the topographic map was created, are instrumental in determining the slope of an area.

Soil Map

Using a flatbed scanner, soil data maps for the Lake George and Oaks Pond watersheds, provided by the United States Department of Agriculture (USDA) Soil Conservation Service (USDA 1972), were scanned into the computer as JPEG files. These scanned images were imported into ArcView and aligned to the base map. Rectification, the process of aligning scanned images to the base maps, results in the geographical referencing of scanned images to locate features according to their actual position on the Earth. The rectification process also resulted in the merging of soil map images. After rectification, the soil map was converted into a digital, geo-referenced soil map by tracing lines over the rectified images. These line segments formed polygons to represent different soil types. Once digitizing was completed, the soil map image was removed from the background. The end product was a digitized soil map for the Lake George and Oaks Pond watersheds (Figure 47). Soil types were classified based on the soil series to which each type belongs. The soil map is an important visual representation depicting the location of dominant soil series and corresponding phases within the watershed area. Soil erodibility is determined by the location of soils along slopes in conjunction with specific information regarding soil characteristics.

Soils

Soil type is an important determinant involved in potential land use decisions that will affect a given area. A number of important soil characteristics describe particular soil types and influence what land uses can be implemented on top of an underlying soil (USDA 1972). Such characteristics include soil texture, depth to bedrock, depth to water table, drainage ability, and soil slope. Soils are classified into soil series and soil phases. A soil series is comprised of soils that have similar soil profiles. All soils belonging to a series have major horizons that correspond in thickness, arrangement, and other important characteristics. Soil series are divided into soil phases by their surface texture, slope, and stoniness (USDA 1972).

Methods

CEAT digitized the soil map of the Lake George and Oaks Pond watersheds (See Methodology: Soil Map). 15 different soil series were identified in these watersheds. The 15 soil series were comprised of 21 individual soil phases. The following is a description of the characteristics of the soil series located within the Lake George and Oaks Pond combined watershed (USDA 1972).

The Adams soil series is characterized by nearly level to steep soils that are excessively drained. The depth to the bedrock is greater than 6 ft and the depth to the water table is greater than 5 ft. The Adams soil series was formed in thick deposits of sand. These soils are located on terraces, on the top and sides of eskers, on kames, and in outwash areas of rivers. Cropland and forested lands consisting primarily of white pine are the predominate land uses on Adams series soils (USDA 1972).

The Bangor soil series is characterized by low to moderate sloped soils that are well drained. The depth to both the bedrock and the water table is greater than 5 ft. The soil series is formed in silty glacial till. The Bangor series is found on smooth upland ridges east of Skowhegan. Cropland and forested lands consisting of mainly northern hardwoods, spruce, and fir are the predominate land uses on the Bangor series soils (USDA 1972).

The Biddeford soil series is characterized by nearly level soils that are very poorly drained. The depth to the underlying bedrock is greater than 6 ft and the water table remains at the soil surface for most of the year. The soils are formed in silty clay sediments consisting of a combination of marine and or lacustrine deposits. The Biddeford series is found in depressions of valleys. These

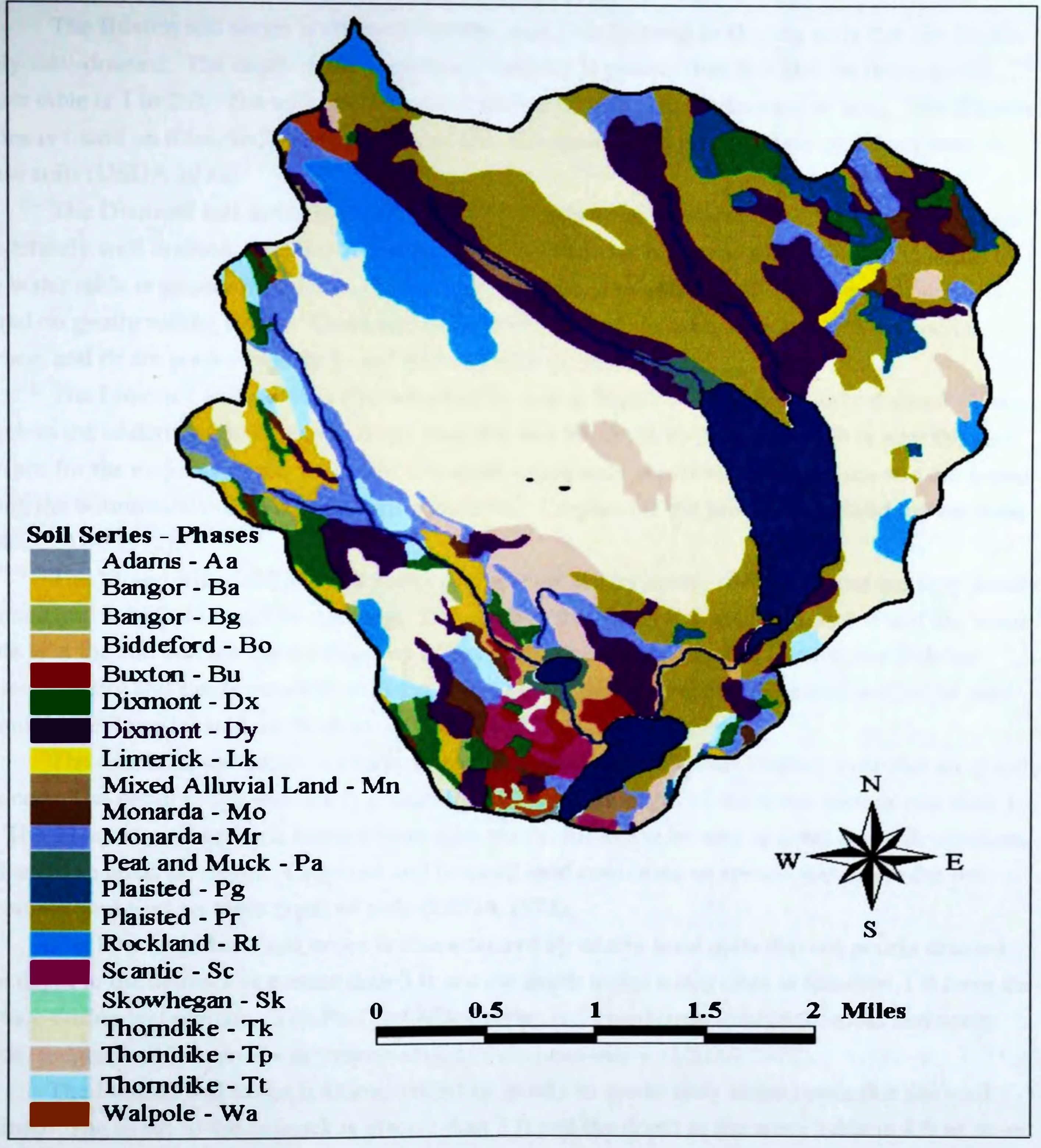


Figure 47. Soil series and corresponding soil phases in the Lake George and Oaks Pond watersheds. See GIS: Soils for description of soil series and Table 9 for information on soil phases. The Lake George and Oaks Pond watersheds are outlined in black. Data adapted from USDA Soil Survey Maps Somerset County, Maine Southern Part (USDA 1972) and Maine Office of GIS (MEGIS 2001).

soils support sedges, alders, and a few cedars (USDA 1972).

The Buxton soil series is characterized by gently undulating to sloping soils that are moderately well-drained. The depth to the underlying bedrock is greater than 6 ft and the depth to the water table is 1 to 2 ft. The soils are formed in marine or lacustrine sediments or both. The Buxton series is found on dissected benches along rivers. Cropland is the predominate land use found on these soils (USDA 1972).

The Dixmont soil series is characterized by nearly level to moderately sloping soils that are moderately well drained. The depth to the underlying bedrock is greater than 4 ft and the depth to the water table is greater than 1.5 ft. These soils are formed in glacial till. The Dixmont series is found on gently rolling ridges. Cropland and forested lands consisting of northern hardwoods, spruce, and fir are predominately found on these soils (USDA 1972).

The Limerick soil series is characterized by nearly level soils that are poorly drained. The depth to the underlying bedrock is greater than 6 ft and the depth to the water table is near the soil surface for the majority of the year. The Limerick series soils are formed in alluvium and are found along the bottomlands of rivers and their tributaries. Cropland is the predominate land use on these soils (USDA 1972).

The Mixed Alluvial Land soil series is characterized by nearly level soils that are very poorly drained and subject to frequent flooding. The depth to the bedrock is greater than 6 ft and the water table is at the soil surface for the majority of the year. The Mixed Alluvial Land series soils are formed in silty and sandy material on flood plains along narrow streams. Forested land is the predominate land use located on these soils (USDA 1972).

The Monarda soil series is characterized by nearly level to gently sloping soils that are poorly drained. The depth to the bedrock is greater than 4 ft and the depth of the water table is less than 1 ft. The Monarda soil series is formed from silty glacial till and is located in level areas, depressions, and seepage areas on ridges. Cropland and forested land consisting of spruce and fir are the predominate land uses on these types of soils (USDA 1972).

The Peat and Muck soil series is characterized by nearly level soils that are poorly drained. The depth to the bedrock is greater than 3 ft and the depth to the water table is less than 1 ft from the surface during wet periods. The Peat and Muck series is formed from sphagnum moss and some reeds, sedges, and low shrubs in various stages of decomposition (USDA 1972).

The Plaisted soil series is characterized by gently to moderately sloped soils that are well drained. The depth to the bedrock is greater than 5 ft and the depth to the water table is 4 ft or more. The Plaisted series is formed in compact glacial till and is found on ridges. The predominate land uses are croplands, pasture lands, orchards, and forested lands consisting of northern hardwoods (USDA 1972).

The Rockland soil series is composed of out-crops of bedrock material with a very shallow layer of soil. The soil is well to excessively drained and experiences rapid runoff. The depth to the bedrock is less than 1 ft and the bedrock separates the soil from the water table. This series is relatively poorly suited for all land uses (USDA 1972).

The Scantic soil series is characterized by level to slightly undulating soils that are poorly drained. The depth to the bedrock is greater than 6 ft and the depth to the water table is less than 1 ft. The Scantic series is formed in marine and lacustrine sediments and found on swales and plains. Adapted hay and pasture plants are the predominate land uses on this soil (USDA 1972).

The Skowhegan soil series is characterized by level to gently undulating soils that are moderately well drained. The depth to the bedrock is greater than 5 ft and the depth to the water table is between 1.5 ft and 2 ft. The Skowhegan series is formed in thick sandy deposits and is found in terraces of river valleys. Cropland is the predominate land use (USDA 1972).

The Thorndike soil series is characterized by level to steep soils that are well drained to excessively drained. The depth to the bedrock is about 1.5 ft and the depth to the water table is greater than 3 ft. The Thorndike series is formed in glacial till and found on ridges. The predominate land use is forestland consisting of northern hardwoods, spruce and fir; however, croplands, pastures and orchards are also found in this soil series (USDA 1972).

The Walpole series is characterized by level or depressed soils that are poorly drained. The depth to the bedrock is greater than 6 ft and the depth to the water table is near the soil surface. The Walpole series is formed in outwash sands and gravel. This series is found primarily in river valleys. The predominate land use is forested land consisting of spruce, fir and pine (USDA 1972).

Results and Discussion

<u>Lake George Watershed</u>

The Thorndike (34 percent), Plaisted (28 percent), Dixmont (17 percent), Rockland (7 percent), and Monarda (4 percent) soil series comprise the majority of the Lake George watershed (Figure 47). The Thorndike series is found on both the west and the east sides of Lake George and in the northern section of the watershed. The Plaisted series is found throughout the northern section of the watershed and immediately surrounding the southern portion of Lake George. The Dixmont series is found scattered throughout the northern section of the watershed. The Rockland series is found in the northwest and the east sections of the watershed. Monarda is found scattered throughout the northern section of the watershed. Bangor, Limerick, Mixed Alluvial land, Peat and Muck, and Walpole soil series are found in the Lake George watershed but each constitute less than one percent of the watershed.

It is apparent from analysis of the characteristics of the major soil series found within the Lake George watershed that a number of common problems exist for future development in the watershed. Such problems include a shallow depth to bedrock, rocky outcrops, low soil permeability, steep slopes, and high water tables. In addition, all of the major soil series except for Rockland have low to medium K factor values and are inherently more resistant to soil erosion (Table 9).

The K factor of a particular soil describes the soils inherent ability to erode (Lal 1990). The higher the K factor value the more susceptible the soil is to erosion.

Oaks Pond Watershed

The Thorndike (45 percent), Dixmont (14 percent), Monarda (14 percent), Bangor (9 percent), and Plaisted (6 percent) soil series comprise the majority of the Oaks Pond watershed (Figure 47). A large track of Thorndike is found along the northern section of the watershed and smaller scattered areas exist in both the west and east sections of the watershed. Dixmont is primarily found scattered throughout the west section of the watershed with some found north of Oaks Pond and in the east section of the watershed. Areas of Monarda are found scattered throughout the entire watershed. Bangor is found only west of Oaks Pond in scattered areas. Plaisted is found in the eastern section of the watershed. The Biddeford, Buxton, and Scantic soil series each comprise between one and five percent of the watershed, while the Adams, Mixed Alluvial land, Peat and Muck, Rockland, Skowhegan, and Walpole each make up less than one percent of the watershed.

A number of common problems exist for future development on the major soil series found in the Oaks Pond watershed. Problems include a shallow depth to underlying bedrock, rocky outcrops, low soil permeability, steep slopes, and high water tables. The Bangor series offers the most potential for development because it has a deep layer of soil above both the bedrock and water table. It also has a moderate permeability. With the exception of Bangor (very stony silt loam), all of the major soil series in the Oaks Pond watershed have low to moderate K factor values and are inherently resilient to soil erosion.

Development Suitability Model

Concerns have been raised that the Lake George and Oaks Pond watersheds will be unsuitably developed, having a severe impact on the watershed, in future years. The development suitability model is a crucial tool in assessing current and future development plans. From this model, potential developers can determine where suitable development, that which has the least amount of impact on the watershed, can occur. The development suitability model combines the soil type and the percent slope in a given area yielding a development suitability rating (USDA 1972). In order to combine the soil type and the slope, the GIS team used a program within ESRI's ArcView® 3.2 Spatial Analyst called ModelBuilder.

Methods

The model building process consists of four stages: converting contours of the watershed into a slope theme, converting the digitized USDA soil map into a grid based format, combining the slope map and the USDA soil map in grid format, and applying the development ratings to the soil/slope map (Figure 48). The first step in this process required converting the contours of the watershed from the Maine Office of GIS website into a TIN (See Methodology). The TIN was then converted into a grid format. Converting the vector data into a grid format was required for ModelBuilder to read the data (ESRI 2000a). This grid format was entered into a formula that calculated the percent

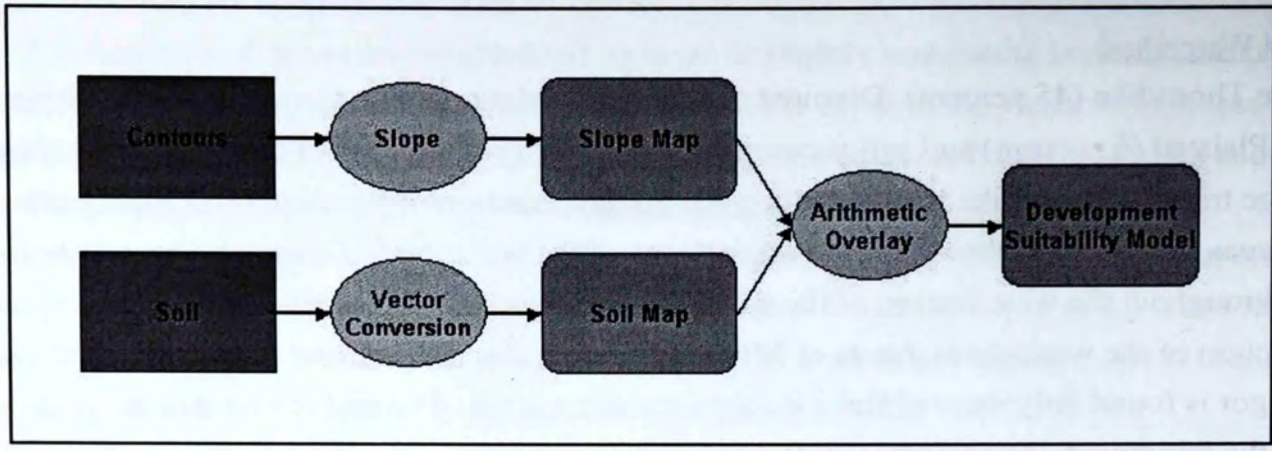


Figure 48. Flow chart depicting the steps taken in the creation of the development suitability model. Rectangular boxes indicate data that were inputted into ModelBuilder. Ovals represent functions that are performed by ModelBuilder. Rounded rectangular boxes are output data that are generated by ModelBuilder. Figure adapted from ModelBuilder.

slope, using ModelBuilder. The percent slope was divided into three categories that were used by the USDA in the development ratings: 0 to 8 percent, 8 to 15 percent, and 15 to 90 percent.

The second step required converting the digitized USDA soil map, which is in a vector format, into a grid format. This conversion was executed in ModelBuilder (ESRI 2000a). The third step required the combination of the slope map (grid based) from step one with the grid based soil map from created in two. In ModelBuilder, the arithmetic overlay function then combined the soil map with the slope map forming a new theme that contains both slope and soil type (ESRI 2000a).

The fourth step required the application of the development ratings to the map created in step three. The development suitability ratings were determined by a weighted average of the following soil potentials: 45 percent septic tank absorption fields, 20 percent dwellings with basements, and 35 percent local roads and streets (USDA 1989). The soil potentials for each criteria (septic, dwelling, and roads) were classified as slight, moderate, or severe. Slight indicates that the soil has no limitation to the specified use while severe indicates that the soil has serious limitations to the specified use (USDA 1972). The ratings for each criterion were converted into a number so that they could then be weighted (slight=1, moderate=5, and severe=9). After the three criteria were weighted, they were placed into one of five categories for the development ratings (very high=1, high=3, moderate=5, low=7, and very low=9). Very high indicates a rating that is more suitable for development, and very low indicates a rating that is less suitable for development in the current state without mitigation efforts (Appendix R).

Results and Discussion

The development suitability model (Figure 49) denotes the areas best suited for development in light red and those that are most poorly suited in dark red. The Lake George and Oaks Pond

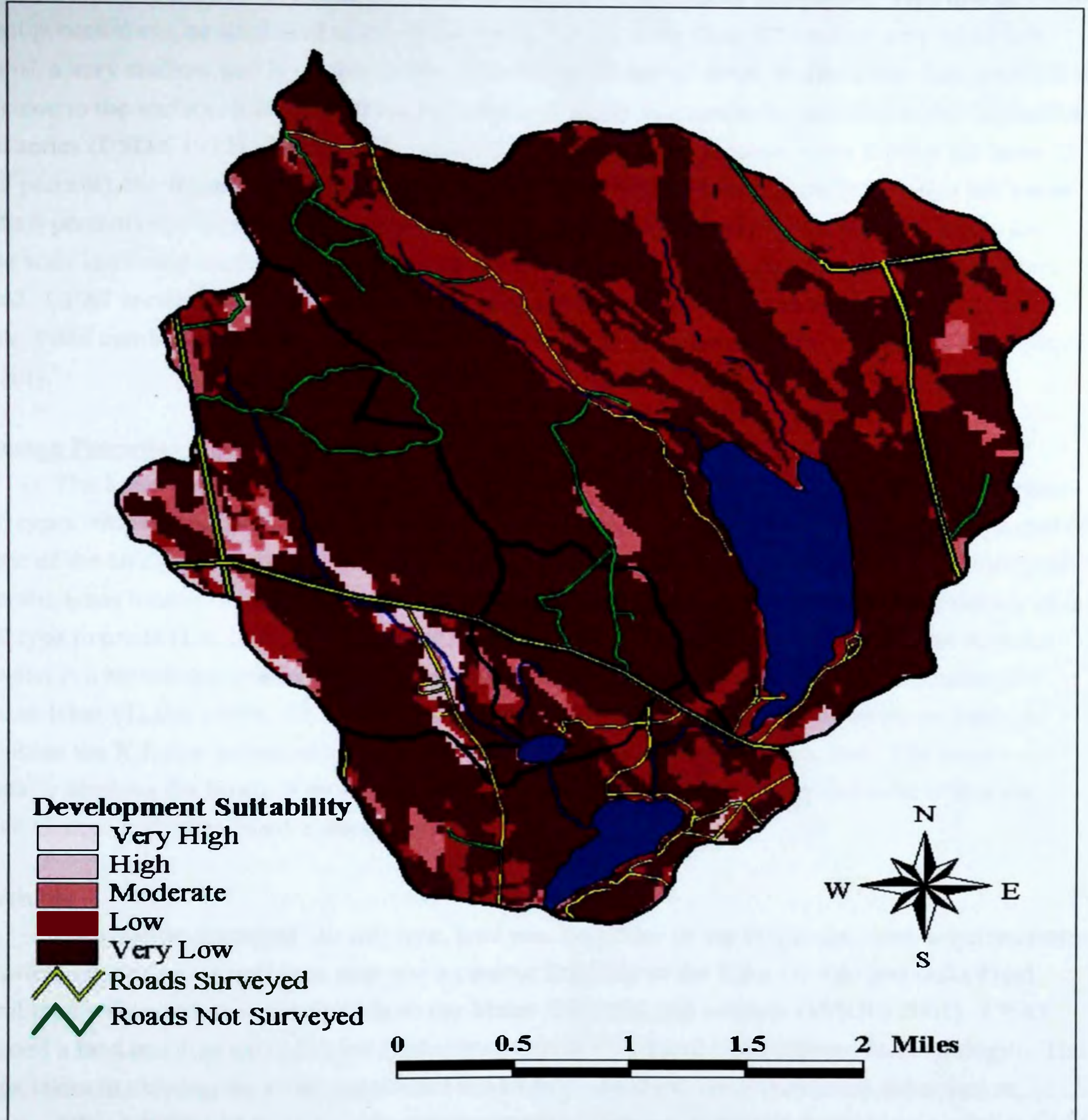


Figure 49. Development suitability model of the Lake George and Oaks Pond watersheds. Development suitability identifies areas best suited for residential development without additional mitigation efforts. These ratings were derived from slope and soil types. The Lake George and Oaks Pond watersheds are outlined in black. Data adapted from USDA Soil Survey Maps Somerset County, Maine Southern Part (USDA 1972), and Maine Office of GIS (MEGIS 2001).

combined watershed has very little potential for development without mitigation. This low development potential can be attributed to the dominant soil in the watershed (Thorndike very rocky silt loam), a very shallow soil layer that is only 8 inches to 10 inches deep. Because the shale bedrock is so close to the surface, it is difficult for basements or septic systems to be installed in the Thorndike soil series (USDA 1972). The suitable areas for development are located in the Bangor silt loam (3 to 8 percent), the Bangor very stony silt loam (3 to 8 percent), and the Thorndike-Bangor silt loams (3 to 8 percent) soil types which have a soil layer that is approximately five feet deep. These suitable soils are found scattered throughout the combined watersheds and are typically already developed. CEAT recommends that any future development that might occur in the Lake George and Oaks Pond combined watershed be carefully considered to mitigate potential impacts on lake water quality.

Erosion Potential Model

The Lake George and Oaks Pond combined watershed is composed of a variety of different soil types, slopes, and land uses. The K factors corresponding to individual soils types, the degree of slope of the landscape, and land use types are all essential elements that influence the erodibility of specific areas located within the watershed. The K factor value describes the inherent tendency of a soil type to erode (Lal 1990). Modeling the erosion potential of a watershed is important because erosion is a significant source of phosphorous loading, the major cause of the eutrophication of Maine lakes (TLEA 1999). CEAT used ArcView and ModelBuilder, an extension of ArcView, to combine the K factor values, slope, and land uses into an erosion potential model. The model visually displays the levels of erosion potential, from very low to very high, that exist within the Lake George and Oaks Pond watersheds.

Methods

Information regarding the soil type, land use, and slope of the landscape, were acquired from a variety of sources. A soil type map and a contour line map of the Lake George and Oaks Pond combined watershed were obtained from the Maine Office of GIS website (MEGIS 2001). CEAT created a land use map using Digital Orthophoto Quads (See Land Use Patterns: Methodology). The steps taken in creating the erosion potential model from the three input factors are described in (Figure 50). All three of these factors were imported as individual themes in ArcView and clipped to match the combined watershed boundary.

A slope map was generated from the contour line map that was obtained. As described previously, the contour map was first converted to a Triangulated Irregular Network (TIN) theme in ArcView. A TIN describes the elevation of a particular area by depicting geographic areas as different colors depending on which range of elevation the area lies within. The TIN was imported into ModelBuilder as a form of input data that could be processed from a vector into a grid format. Finally, ModelBuilder was used to produce output data in the form of a slope map theme in grid format (Figure 50).

The land use and soil type data were also converted from a vector into a grid format. Both themes were imported into ModelBuilder as input data and subsequently processed into output data in the grid format (Figure 50).

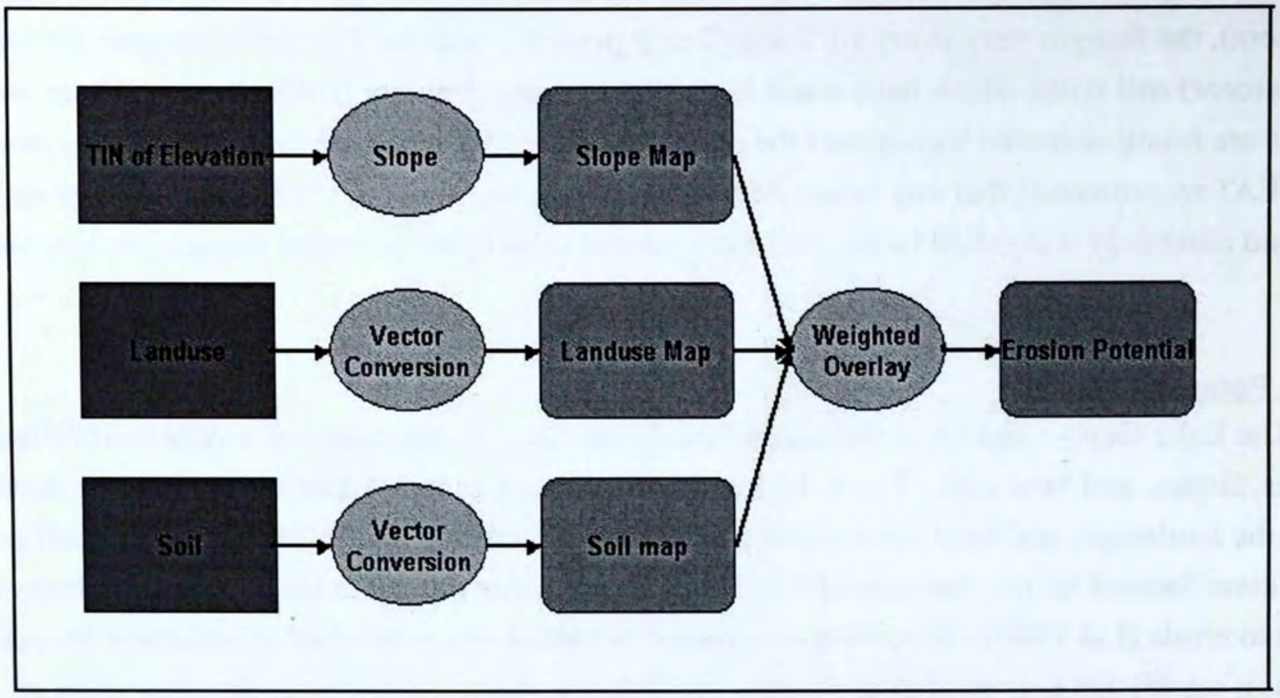


Figure 50. Flow chart depicting the steps taken in the creation of the erosion potential model. Rectangular boxes indicate data that were inputted into ModelBuilder. Ovals represent functions that are performed by ModelBuilder. Rounded rectangular boxes are output data that are generated by ModelBuilder. Figure adapted from ModelBuilder.

Soil type, land use, and slope data were then combined using the weighted overlay function in ModelBuilder to generate the erosion potential model (Figure 50). The three data types all exist on a separate set of value scales: K factor values for soil type, land use types, and degree of slope for the landscape. The three themes of data in grid format were converted into a universal erosion potential risk scale so ModelBuilder could combine the three factors in the overlay process. A scale of one to nine was assigned to all three factors in the model. One represented the least risk of erosion and nine represented the highest risk of erosion. This scale provides a wide enough range to prevent overlap in erosion potentials between different K factors, slopes, and land uses.

The slope of the landscape grid was divided into four-degree increments to assign erosion potential risk values on a scale of one to nine. Slope was divided into eight four-degree increments up to 32 degrees. Because no slope in the Lake George and Oaks Pond combined watershed was steeper than 36 degrees, the ninth increment extended from 32 to 90 degrees to include all possible slopes in the model. The slope increment of zero to four degrees was assigned an erosion potential rank of one and the increment of 32 to 90 was given an erosion risk value of nine.

Land use types were ranked on the one to nine scale based on their inherent tendency to contribute to erosion. Wetlands and mature forests were assigned the minimum risk erosion potential value of one. The dense vegetation in wetlands slows water flow and allows sediment to settle out of water column and nutrients to be absorbed and stored within plant tissues before reaching the lake. The network of root systems stabilizes and prevents the underlying soil from eroding. In mature forests, large numbers of trees and other vegetation provide vast root networks that anchor the soil and absorb nutrients from the soil. A thick stratified canopy minimizes the erosion effects of pounding rain. As a result, mature forest is the land use type that is least likely to contribute to phosphorous loading. Transitional forest land received a risk value of four because gaps exist in the canopy and there are fewer trees and other vegetation to anchor the soil and absorb nutrients. Regenerating land was given an erosion potential value of six because it is in the early to mid stages of succession and has yet to develop into a transitional forest. It is characterized by a sparse canopy and an even-aged stand of vegetation. Reverting land was assigned a value of seven because it was previously agricultural land that is now fallow and pioneer species are just beginning to colonize. It is characterized by low density, new growth and a lack of mature trees. Cleared lands, agricultural land, and ski slopes received a risk value of eight because they all consist of areas currently cleared of a large proportion of the previously existing vegetation. Roads, residential, commercial and municipal land use areas were all given a classification of nine, the highest erosion potential value. These land uses are characterized by a lack of vegetation and the presence of impervious surfaces that reduce the percolation of the water into the soil and increase runoff.

Soil types were assigned an erosion potential value based on the K factor values of specific soils. The K factor describes a soil's inherent susceptibility to erode. It is a function of soil texture, structure, permeability, organic mater content, and clay mineral content (Lal 1990). K factor values range from zero, for non-erodible soils, to one for highly erodible soils (Table 9). K factors for the soils located in the Lake George and Oaks Pond combined watershed were between 0.00 and 0.45; consequently, it was necessary to reclassify them on the universal one to nine scale by creating nine ranges of 0.05. The lowest erosion potential value of one was given to the range of 0.00 to 0.05 and 0.40 to 0.45 was given the highest erosion potential value of nine.

The final step involved in combining the soil type, the land use type, and the slope data was to assign the relative weight of influence for each of the factors on the susceptibility to erosion of a given geographic area. Slope was weighted the highest, comprising 50 percent influence, while both land use type and soil type were weighted as 25 percent influence for a total of 100 percent influence on the final erosion potential model (ESRI 2000a). Slope was weighted more heavily than both land use and soil types because a steep slope can lead to significant erosion independent of land use or soil types that exist in a specific geographic area.

Table 9. **Soil phases of Lake George and Oaks Pond watershed, their representative soil series (USDA 1972), their corresponding K factors (USDA unpublished data), and the reclassified K-factors on a 1 to 9 erosion potential scale.**

Soil Phase	Soil Series	Composition	K-factor	Reclassified K-factor
Aa	Adams	loamy sand	0.21	5
Ba	Bangor	silt loam	0.25	6
Bg	Bangor	very stony silt loam	0.41	9
Bo	Biddeford	silt loam	0.32	7
Bu	Buxton	silt loam	0.41	9
Dx	Dixmont	silt loam	0.22	5
Dy	Dixmont	very stony silt loam	0.24	5
Lk	Limerick	silt loam	0.32	7
Mn	Mixed Alluvial Land	silty and sandy material	N/A	N/A
Mo	Monarda	silt loam	0.25	6
Mr	Monarda	very stony silt loam	0.26	6
Pa	Peat and Muck	sphagnum moss and decomposing plant matter	<0.10	1
Pg	Plaisted	gravelly loam	0.26	6
Pr	Plaisted	very stony loam	0.26	6
Rt	Rockland	bedrock outcrops in Thorndike and Lyman materials	0.41	9
Sc	Scantic	silt loam	0.41	9
Sk	Skowhegan	loamy fine sand	0.17	4
Tk	Thorndike	very rocky silt loam	0.17	4
Tp	Thorndike	loam	0.17	4
Tt	Thorndike	silt loam	0.17	4
Wa	Walpole	fine sandy loam	0.24	5

Results and Discussion

The light pink areas in the erosion potential model, such as the western and southern sections of the combined watershed surrounding Lake George and Oaks Pond, indicate areas of very low erosion potential (Figure 51). Areas of low erosion potential are characterized by level to gentle slopes in combination with low erodible soils and land uses that maintain a significant amount of natural vegetation in the area. The areas of dark red, such as the western shore of Lake George, the ski slope, and the northwest portion of the watershed, indicate areas of very high erosion potential. High erosion potential areas are characterized by a steep slope in combination with highly erodible soils and land uses that remove significant portions of the vegetation in the area. A steep slope in combination with either a highly erodible soil or a land use that removes vegetation can outweigh either a low erodible soil or a natural land state. The result can be high erosion potential, as shown on the steep slopes of residences located on the low erodible Thorndike soil. The majority of the Lake George and Oaks Pond combined watershed is characterized by moderate erosion potential.

The Lake George watershed is characterized predominately by moderate erosion potential (Figure 51). Areas of high erosion potential exist along the western shoreline of Lake George, to the east of Lake George, and in the northwest corner of the watershed. These areas are characterized by steeper slopes and either a land use that involves the clearing of vegetation or an inherently high erodible soil type such as Rockland. The majority of the northeast section of the watershed has low to moderate erosion potential. This area is dominated by more gentle slopes, mature or transitional forests, and soils with low to moderate susceptibility to erosion.

The majority of the Oaks Pond watershed has low to moderate erosion potential because a significant portion of the watershed is characterized by gentle slopes (Figure 51). The ski slope represents the only area of very high erosion potential which is expected because the land has been cleared in addition to being steep. Moderately high erosion potential exists along the northeast corner of Oaks Pond. Moderately high erosion potential results from a relatively steep slope and the presence of houses in very close proximity to the pond, that often lack adequate buffer strips. Areas of low erosion potential are found in the central portion of the Oaks Pond watershed that are dominated by land characterized by level to gentle slope, mature forests, and wetlands.

A number of precautions can be taken to mitigate the negative effects that erosion can have on Lake George and Oaks Pond. The area of residential housing on the western shoreline of Lake George has a high erosion potential, and the close proximity of the lake can allow for a significant amount of nutrient loading and sedimentation into the lake. Improving the buffer strips along this area would reduce the amount of nutrients and sediment that enters the lake and would help improve or maintain the water quality. Although the area of residential housing on the northeast corner of Oaks Pond is of moderately high erosion potential, the close proximity to the lake makes it a risk for negatively impacting the pond water quality. Improving the buffer strips in this area would help protect the lake. See Appendix M for a list of species that are ideally suited for buffer strips. In areas of moderate to high erosion potential, future land use decisions should be carefully considered

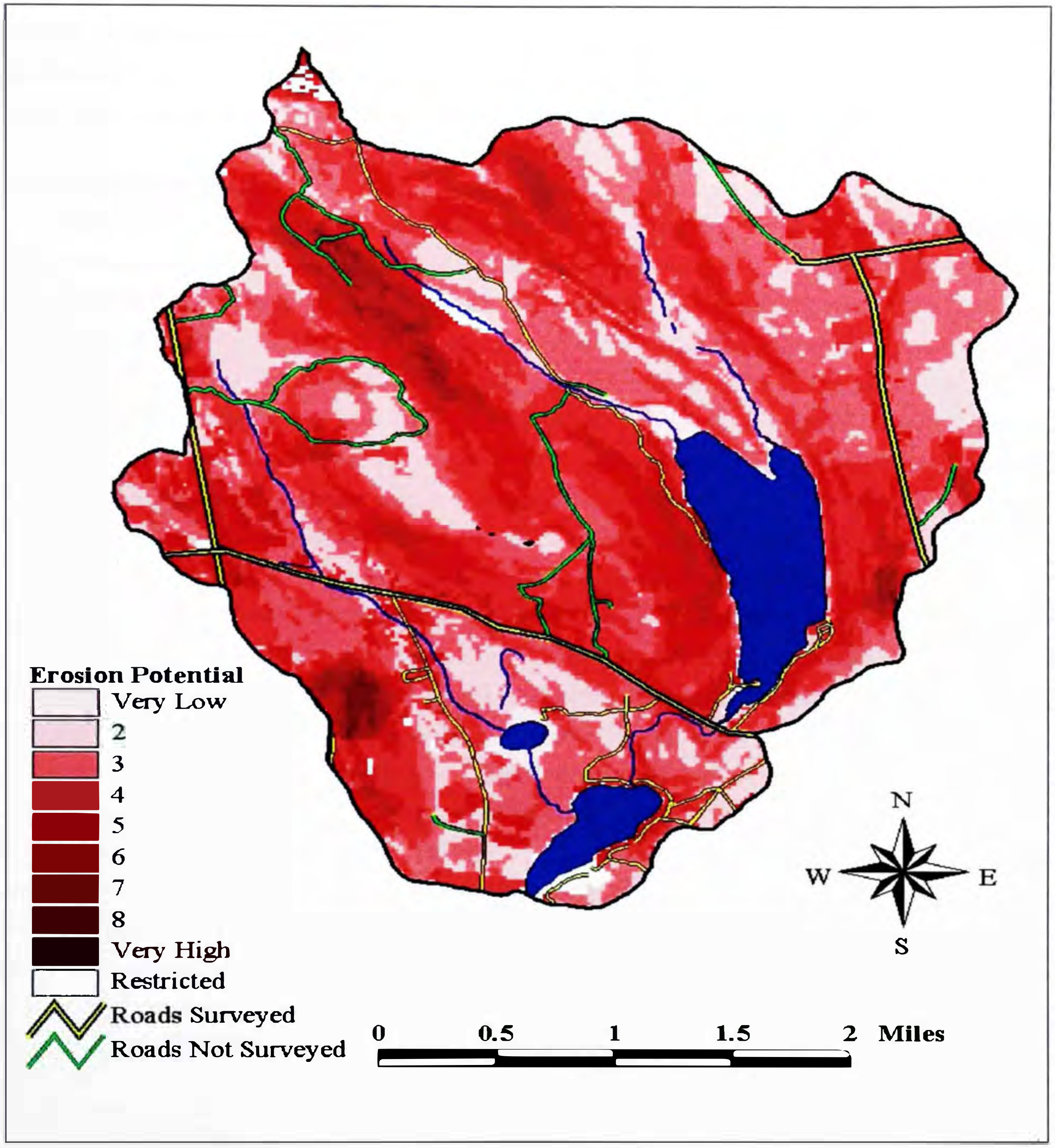


Figure 51. Erosion potential of the Lake George and Oaks Pond watersheds, with roads and streams for geographical reference. Erosion potential was derived from soil type, slope, and land use data. Restricted represents areas where the erosion potential could not be derived because the K-factor value for the Mn soil phase was not available. The Lake George and Oaks Pond watersheds are outlined in black. Data adapted from USDA Soil Survey Maps Somerset County, Maine Southern Part (USDA 1972) and Maine Office of GIS (MEGIS 2001).

to ensure that these areas do not become more of a problem for the quality of the lakes within the watershed. Areas with buffering capabilities should be established or maintained between all areas of moderate to high erosion potential and water bodies. Buffer zones can prevent erosion and absorb nutrient laden runoff before it reaches the lake (See Introduction: Buffer Strips).

Logging Suitability Model

According to 1997 DOQ and data analysis of land use, approximately 86 percent of the Lake George and Oaks Pond combined watershed is forested (See Land Use Assessment: Forestry and Logging). Nevertheless, logging in recent years has been restricted to a small area of the Lake George watershed. Much of the current logging occurs in the northern portion of the Lake George watershed, primarily in a lot owned by the logging firm, Plum Creek Timber Company, Inc. The firm has indicated a potential for additional logging (Ricker, pers. comm.). Development within either of the watersheds would necessitate additional vegetation removal. Logging suitability is an important factor in evaluating future land use decisions because it helps people to make informed choices regarding vegetation removal. Harvesting activities reduce vegetation cover and compact the soil, leading to increased runoff and erosion (Elliot, Page-Dumroese, and Robichaud 1999). Many of the nutrients released from harvesting may be carried towards lakes as a result of increased subsurface flow, streamflow, and channel erosion. These flow mechanisms are enhanced as a result of decreased evapotranspiration from vegetation loss stemming from construction of truck roads and skidder trails. Soil types and phases are important in determining the amount and rate at which nutrients are lost (See GIS Assessment: Soils). Groundcover is an essential deterrent to soil mineral loss from erosion. Vehicles used in harvesting can reduce groundcover by 35 to 90 percent (Elliot, Page-Dumroese, and Robichaud 1999). This loss of groundcover effectively increases the amount of nutrient loading into the water. A logging suitability model was created to highlight areas better suited for logging and to assist landholders in minimizing the damaging effects that often result from logging. The amount, age, and maturity of the vegetation, as well as the soil and slope of the watershed must be considered in logging suitability modeling. These criteria were considered and a logging suitability model was created using ModelBuilder.

Methods

Logging suitability modeling is a two-step process that involves importing the erosion potential model and the reclassifying of information from the land use map. A land use map and an erosion potential model were created prior to logging suitability model construction (See Methodology and Erosion Potential Model). The erosion potential model represents the soil component of the ModelBuilder flowchart (Figure 52). Data from the land use map were manipulated so that only forested areas were rated for logging suitability. These data represent the forested area map input of the ModelBuilder diagram (Figure 52). Based on a one to nine scale, forested areas were ranked in increasing order of vegetation coverage. One represents very low vegetation cover and nine repre-

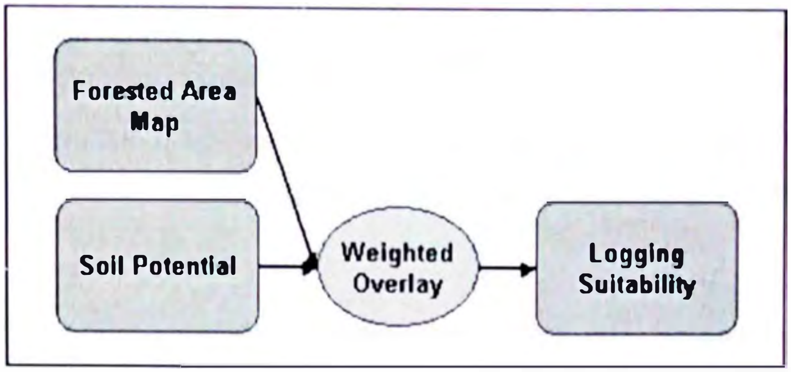


Figure 52. Flow chart depicting the steps taken in the creation of the logging suitability model. Rounded rectangular boxes are output data that are generated by ModelBuilder. Ovals represent functions that are performed by ModelBuilder. Figure adapted from ModelBuilder.

sents very high vegetation cover. Vegetation coverage was ranked in the following order of increasing coverage: reverting pasture areas, regenerating forest growth, selectively cut forests, transitional forests, and mature forests. ModelBuilder converted this vector data into raster format before a vegetation cover map was generated.

Each of the input maps was assigned a value for the relative weight of influence before the logging suitability model was created. On a 100-point scale, the vegetation cover was given 40 percent influence and the erosion potential model was allotted 60 percent influence. The erosion potential model was given more weight to reflect the high erodibility of the soils. After these criteria were weighted, ModelBuilder was run and a logging suitability model was produced.

Logging suitability is based on a nine-point scale; areas with a value of one represent areas of low logging suitability and areas with a value of nine signify areas with greatest logging suitability. Very low logging suitability indicates that the forested area is severely erodible, whereas very high logging suitability denotes forested area with slight erosion potential.

Results and Discussion

It is important to consider the logging suitability of an area when evaluating future logging plans. Logging suitability trends can be seen on the logging suitability map (Figure 53). Areas of high logging suitability are darker in color and areas of low logging potential are represented by lighter shades. In general, the Lake George and Oaks Pond combined watershed has moderate to high logging potential. Areas with lowest logging suitability, represented by the areas with the lightest shading, are typically underlain by Rockland and other shallow soils such as Thorndike, Dixmont (very stony silt loam), and Plaisted (very stony loam) (Figure 47). These areas typically have high slope and areas with reverting or regenerating forests (See Figure 31). Areas of higher logging suitability are characterized by low slope and mature forests underlain with less erodible soils.

The Lake George watershed is predominately moderately suitable for logging as a function of highly erodible soil types, slope intensity, and vegetation cover. The model shows low to moderate logging suitability in the areas east and west of Lake George. Areas of low to moderate logging suitability are dominated by transitional forests (See Figure 31) coupled with Thorndike soils (Figure

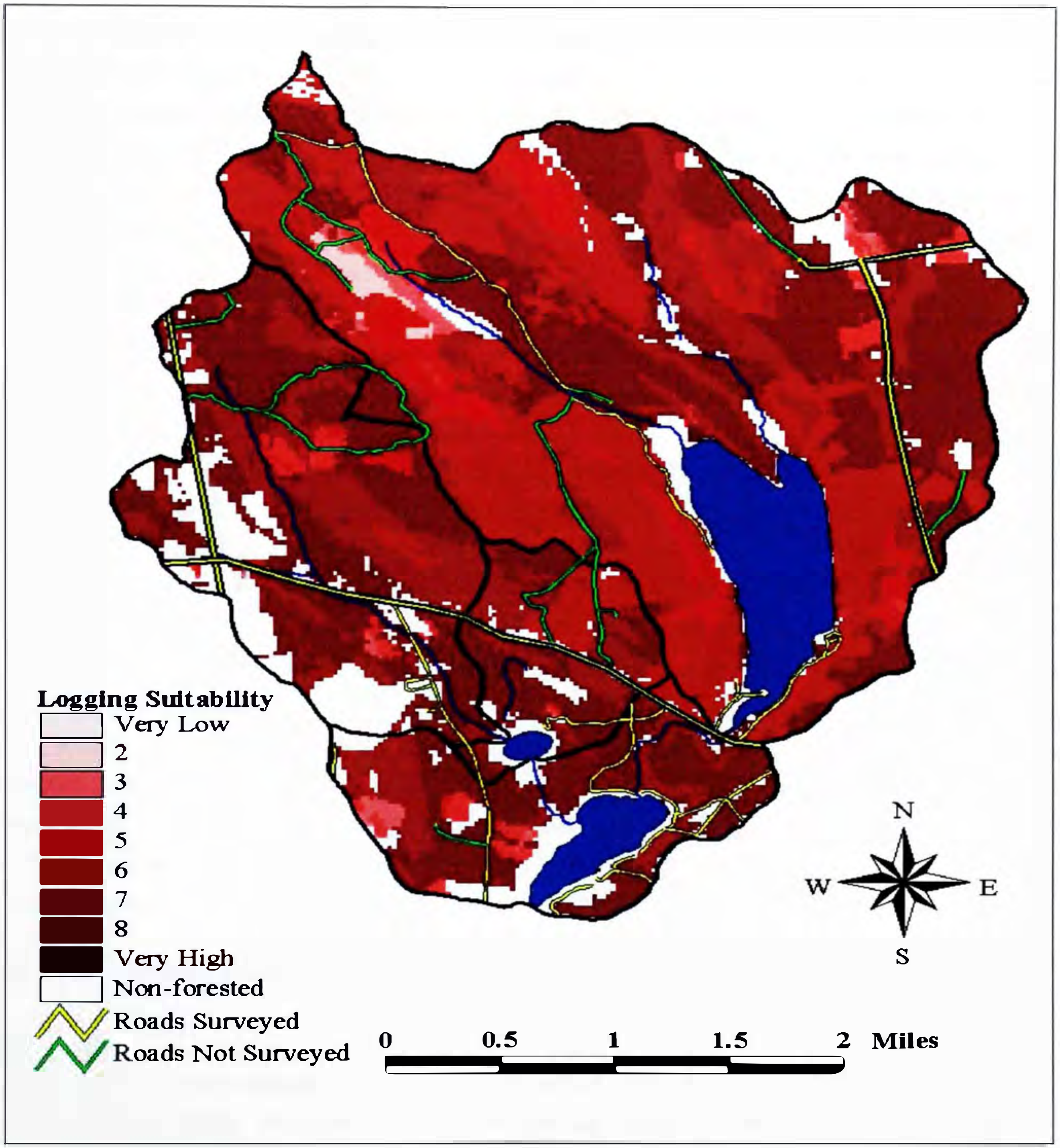


Figure 53. Logging suitability of the Lake George and Oaks Pond watersheds, with roads and streams for geographical reference. Logging suitability distinguishes areas better suited for logging from areas poorly suited for logging. Logging suitability was derived from soil type, slope, and the amount of vegetation cover. The Lake George and Oaks Pond watersheds are outlined in black. Data adapted from USDA Soil Survey Maps Somerset County, Maine Southern Part (USDA 1972) and Maine Office of GIS (MEGIS 2001).

47). Transitional forests represent patchy vegetation with incomplete canopy and medium-sized trees. These trees generally do not have an extensive root system, so the roots that are present cannot prevent the thin, 10 inch layer of Thorndike soil from eroding. These areas adjacent to Lake George are less suitable for logging due to proximity to water bodies and the low to moderate logging suitability rating. Logging of these areas could potentially increase sediment and nutrient loading into the lake. Logging should occur only in areas within the Lake George watershed with high vegetation coverage and slight slopes because these areas are better suited for logging. These areas include the western portion of the watershed as well as areas north of Lake George.

The Oaks Pond watershed is better suited for logging than the Lake George watershed. Mature forests and decreased erosion potential of the Oaks Pond watershed signify higher logging suitability potential. These areas include forested areas beyond the developed regions surrounding Oaks Pond as well as western portions of the Oaks Pond watershed.

Vegetation cover is an important indicator in determining the logging potential of the Lake George and Oaks Pond combined watershed; however, other variables not included in the logging potential model must also be considered. Harvesting techniques and equipment also contribute to the erosion that occurs as a result of logging. For example, heavy machinery used in logging may increase soil compaction, which in turn reduces the amount of available space between soil particles (Herrick et al. 1999). This compaction decreases the ability of soil to properly absorb water, accelerating erosion levels and augmenting potential runoff. Additionally, skidder trails strip soils of vegetation, resulting in the creation of erosion lanes. These lanes increase the potential for sediment and phosphorus loading into the water bodies. The logging suitability the model does not serve to promote logging, rather it highlights areas that are better suited for logging in the Lake George and Oaks Pond combined watershed. To minimize the negative impacts of logging, logging suitability should be considered if logging were to take place in the watershed area.

Qualitative Water Measurements

Water Budget

A water budget is broadly defined as a comparison of the inputs and outputs of water to and from a lake (Boyd 2000). This concept is of particular significance in determining the flow rate of nutrients such as phosphorus through a lake and is necessary for calculations of phosphorus loading. The calculation of a water budget is based on two interrelated concepts of residence time and flushing rate. Residence time of a water body is an indication of the length of time water will remain in a lake before it is replaced with new water (Chapman 1996). The residence time is inversely proportional to the flushing rate, which is defined as the number of times the total volume of lake water is replaced each year (MDEP 2000). A higher flushing rate for a lake corresponds to a lower residence time of the water. Lakes have much lower flushing rates than rivers and streams and are more vulnerable to pollutants, which can accumulate in the water column and biomagnify in aquatic life

(Duda et al. 1988). The flushing rate acts as a measure of comparison of the cleansing abilities of lakes. The mean flushing rate for Maine lakes is approximately 1 to 1.5 flushes per year (MDEP 2000). The flushing rate is an important tool in assessing the cycling of water in a lake and possible effects of changes in land use on water quality.

Methods

The net volume of water entering both Lake George and Oaks Pond was determined to calculate the water budget for both of these lakes. Information on total precipitation per year from 1990 to 2000 was obtained from the National Oceanic Atmospheric Association (NOAA 1990-2000) weather station for the town of Madison. Data for the years 1991, 1992, and 1997 were missing for Madison and were supplemented with NOAA data for Waterville (1991, 1997) and Augusta (1992). The total precipitation for each year was then averaged for a ten-year mean value, to reduce the effect of variability in precipitation levels between years (Appendix S). The runoff rate constant for both lakes was obtained from a 20-year study of the New England and New York areas (Knox and Nordenson 1955). MDEP uses this value to calculate flushing rates because the study incorporated the effects of varying topography on precipitation level. This value is considered to be an accurate measure of runoff because the study spans 20 years and accounts for environmental fluctuations (Dennis, pers. comm.). The evaporation rate was obtained from a study conducted in the Lower Kennebec River Basin (Prescott 1969). Watershed land area and lake area values for both lakes were obtained from the CEAT GIS analysts. Mean depth data were obtained from averaging depth values at different points on each lake as reported by MDEP (MDEP PEARL 2001). The net volume of water entering the lake (I_{net}) was determined by entering the precipitation data, runoff rate, evaporation rate, lake areas, and watershed land areas into the following formula:

$$\mathbf{I_{net}} = (\text{mean precipitation} * \text{lake area}) + (\text{runoff rate} * \text{watershed area}) - (\text{evaporation rate} * \text{lake area}).$$

To determine the flushing rate, the $\mathbf{I_{net}}$ of each lake was divided by the respective lake volume:

$$\textbf{Flushing Rate} = I_{net} / (\text{Mean Depth} * \text{Lake Area})$$

Results and Discussion

Lake George has a flushing rate of 0.85 flushes/yr (Table 10, Appendix S). Consequently, approximately 85 percent of the total volume of Lake George is replaced by incoming runoff and precipitation within one year. In comparison, Oaks Pond has a flushing rate of 4.91 flushes/yr (Table 10, Appendix S). At this rate, the total volume of water in Oaks Pond is replaced approximately five times a year.

The flushing rate for Lake George is within the range (0.29 to 3.55 flushes/yr) found for lakes in recent studies in central Maine (Table 10; BI493 1994 - 2001). Lake George has a lower flushing rate than Lake Wesserunsett, which flushes 1.09 times/yr (Table 10). Lake George has a lower volume than Lake Wesserunsett, which suggests that the Lake George flushing rate would be higher based solely on volume. However, the watershed area of Lake George is 62 percent smaller than the area for Lake Wesserunsett, causing the flushing rate of Lake George to be lower because of comparatively less inflow of runoff from the surrounding watershed.

Table 10. Comparison of flushing rates for selected lakes in Kennebec and Somerset Counties. Data obtained by CEAT from 1994-2001 (BI493 1994-2001).

Lake	Flushing Rate (Flushes/Yr)	Volume (m^3)	Watershed Area (m^2)
Oaks Pond	4.91	2,613,140	10,777,367
Lake George	0.85	9,151,529	15,916,248
Lake Wesserunsett	1.09	22,888,673	42,110,000
Salmon Lake	0.59	28,410,750	23,126,300
East Pond	0.30	33,848,120	10,598,777
North Pond	1.36	37,148,856	30,920,000
Long Pond			
North Basin	2.80	46,276,529	24,164,589
South Basin	3.55	47,032,200	33,700,000
Messalonskee Lake	1.59	150,249,096	125,084,285
Great Pond	0.52	209,160,000	83,124,049

Oaks Pond has a higher flushing rate than other lakes investigated in recent studies in central Maine (Table 10; BI493 1994 - 2001). For example, Oaks Pond has a higher flushing rate than East Pond. Both of these lakes have approximately equal watershed areas, however, the volume of Oaks Pond is 93 percent lower than the volume of East Pond (Table 10). The difference in the volumes creates the dramatic difference in flushing rates between these two lakes. Although the input of water from runoff is nearly equivalent for both lakes due to the similar-sized land areas, the volume of water to remove is much higher in East Pond than it is for Oaks Pond.

The higher flushing rate of Oaks Pond in comparison to Lake George is primarily due to Oaks Pond being characterized by a lower volume and a greater input of surface water from tributaries than Lake George. The difference in flushing rates of Lake George and Oaks Pond has implications for the effects of pollution on these lakes. Lake George has a lower flushing rate and higher water residence time than Oaks Pond. Lake George has a lower capacity for self-cleansing and may be more susceptible to pollution by allowing more time for excess nutrients to be incorporated in algal biomass. The lower flushing rate of Lake George also suggests that it may be more susceptible to cultural eutrophication. If the entry of nutrients and sediment were accelerated into both Lake George and Oaks Pond, Lake George would not flush these nutrients as quickly as Oaks Pond. The presence of the park protects this more vulnerable lake because it occupies a large percentage of the shoreline, preventing a large amount of shoreline development and the accompanying potential for additional nutrient sources.

Lake Level Management

There is no systematic management of water levels of Lake George or Oaks Pond; their tributaries are allowed to flow unimpeded into their respective water bodies (Stahlnecker, pers. comm.). Every few years, one of the tributaries becomes dammed or impeded by beaver dams or by the washout of a road following an exceptionally heavy rain. When damming occurs, a team of wildlife biologists from the IF&W restores the free flow of water. Dynamite was used in the past to blast the impediments from the path of a tributary; this practice ended recently because it was deemed unsafe. Consequently, two other methods have become more commonly practiced. In the first method, which pertains to both beaver dams and road washout, a series of pipes are inserted into the blockage to reinstate the flow of water through the blockage. This method prevents the pooling of water behind the dam; this is often impetus enough for the beavers to leave their dam in search of another stream. If the beavers do not leave or if they annually block streams in the region, a wildlife biologist from the IF&W will trap and relocate the beavers. The second method of flow management, relevant to road washout, is simply to dig out a blocked stream with shovels (Stahlnecker, pers. comm.).

Phosphorus Loading

The Phosphorus Loading Model predicts the total amount of phosphorus that enters into a body of water each year. It can be used to project the effects that various land uses and future development scenarios have within a watershed on phosphorus levels in a body of water. The model used by CEAT, adapted from Reckhow and Chapra (1983), considers the phosphorus inputs from various land uses, soil types, septic systems, and the atmosphere to predict total amount of phosphorus entering the lake. The model provides three predictions of phosphorus concentration: low, high, and best estimate.

Methods

The first step in creating the phosphorus model was estimating the total amount of phosphorus that enters a lake in one year in kilograms per year, as represented by the Annual Phosphorus Inflow equation (W). This equation consists of terms that represent the total amount of phosphorus released from a certain amount of area of a given land use type in one year. Each term is composed of a coefficient and Area, which represents the total area of a specific land use in the watershed. The equation is as follows:

$\mathbf{W} = (Ec_a \times A_s) + (Ec_{mf} \times Area_{mf}) + (Ec_t \times Area_t) + (Ec_{reg} \times Area_{reg}) + (Ec_{rev} \times Area_{rev}) + (Ec_w \times Area_w) + (Ec_s \times Area_s) + (Ec_n \times Area_n) + (Ec_i \times Area_i) + (Ec_r \times Area_r) + (Ec_{cm} \times Area_{cm}) + (Ec_{ag} \times Area_{ag}) + (Ec_c \times Area_c) + [(Ec_{ss} \times \#\ capita\ years_s \times (1 - SR_s)) + (Ec_{ns} \times \#\ capita\ years_n \times (1 - SR_n)) + (I \times (1 - SR_i))]$

The term Ec represents the export coefficient for inputs in kilograms of total phosphorus per hectare per year (kg ha^{-1} yr^{-1}) for the following subscripts: atmosphere (a), mature forest (mf), transitional land (t), regenerating forest (reg), reverting forest (rev), wetlands (w), shoreline development (s), non-shoreline development (n), institutional (i), roads (r), commercial and municipal land (cm), agricultural land (ag), cleared land (c), shoreline septic systems (ss), non-shoreline septic systems (ns), and institutional septic system (is).

The export coefficients (Ec) were assigned a low, high, and best estimate for each potential source of phosphorus based on comparisons with past CEAT studies in Maine (BI493 1997 – 2001) and with a study of Higgins Lake, Michigan (Reckhow and Chapra 1983). The Phosphorus Model uses a low to high range of coefficients to allow for uncertainties about the relative amount of phosphorus that each land use type contributes to a body of water. CEAT also assigned each land use and development type a best estimate (within the low to high coefficient range) for each watershed to produce the most accurate prediction of phosphorus loading possible.

In addition to export coefficients, a number of other factors are considered in the model. These factors include inputs from seasonal and year round residences based on number of residential units times the number of people per residential unit times the number of days per year the unit is in use (# capita years). Institutional # capita years was found by multiplying number of patrons to LGRP during the summer of 2001 times the average number of days per year each patron stayed at the park. According to Bob Hubbard, the average park patron stays for an average of four hours, or one-sixth of a day; therefore, each of the patrons stays at the park for an average one-sixth of a day per year. Institutional septic system export coefficient times # capita years are represented by I in the model. SR_s represents shoreline soil retention capacity, SR_n represents non-shoreline soil retention capacity, and SR_i represents soil retention capacity for Lake George Regional Park (institutional). Soil retention capacity is the percent of phosphorus that a particular soil type can retain annually; the greater the soil retention capacity, the less phosphorus flows into the lake. A_s is a constant representing the surface area of the lake.

Once a prediction of W was calculated, the total phosphorus load for any given area of lake was calculated using the equation:

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

The variable L represents total kilograms of phosphorus per square meter per year entering the lake. L is derived by dividing the annual phosphorus inflow (W) by the total surface area of the lake (A_s).

The next step in the calculations was determining the annual atmospheric water loading of the lake (q_s) in meters per year ($m\ yr^{-1}$) using the following equation:

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

Total volume of water inflow into the lake per year (Q_{total}) in cubic meters per year ($m^3\ yr^{-1}$) was divided by the total surface area of the lake (A_s) to determine q_s.

The low, high, and best estimates of total phosphorus concentration (P) in kilograms per meter cubed (kg/m^3) were calculated by dividing the annual atmospheric phosphorus loading (L) by the settling velocity of phosphorus in a lake ($11.6 + 1.2q_s$) using the following equation:

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

Results and Discussion

Lake George

Based on the Phosphorus Loading Model, the total mass phosphorus loading for Lake George ranged from 94.12 kg/yr to 344.60 kg/yr, with a best estimate of 207.88 kg/yr (Appendix T). The Phosphorus Loading Model generated a range of phosphorus concentrations from 3.94 ppb to 14.42 ppb with a best estimate of 8.70 ppb for Lake George. The mean phosphorus concentration determined from MDEP epicore samples collected between 1985 and 1996 was 8 ppb (MDEP 2000). The mean phosphorus concentration determined from CEAT surface and epicore characterization site samples for summer and fall of 2001 was 8.8 ppb (See Water Quality Methodology: Total Phosphorus). These values are within the range generated by the Phosphorus Loading Model. The 2001 CEAT mean of surface and epicore phosphorus values was only slightly higher than the best estimate predicted by the model, supporting the validity of using this model as a tool to predict phosphorus loading.

Of the land use categories in the Lake George watershed, transitional land (32.03 percent) and mature forests (29.26 percent) contributed the highest percent of phosphorus loading based on best estimates (Table 11). Transitional lands and mature forests cover approximately 90 percent of the watershed but only contribute approximately 58 percent of all phosphorus loading in the watershed (Table 12). Relative to the amount of land that these types of forests cover, they contribute little phosphorus to Lake George.

Based on best estimates, the next largest contributors to phosphorus loading in Lake George are shoreline development and the atmosphere at 5.62 percent and 5.07 percent, respectively (Table 11). Shoreline development represents approximately 0.46 percent of the total watershed indicating that shoreline development contributes disproportionately high levels of phosphorus (Table 12). This high level of contribution is the result of the relative intensity with which the land is used, proximity to the lake, and a lack of buffering. Suspended particulate matter, including phosphorus, from industry smoke stacks and wood burning residences enters the lake when washed out of the

Table 11. Low, high, and best estimates of annual percent contribution to phosphorus loading in Lake George and Oaks Pond from watershed land use types in 2001. Percentages are based on phosphorus loading projections for each land use category from the Phosphorus Loading Model (See Analytical Procedures and Findings: Phosphorus Loading).

	Lake George			Oaks Pond		
Input Categories	**Low**	**High**	**Best**	**Low**	**High**	**Best**
Atmospheric Input	5.64	9.75	5.13	1.75	2.91	1.66
Mature Forest	32.55	33.77	29.63	35.33	35.31	29.46
Transitional Land	35.63	27.93	32.43	2.77	2.22	2.20
Regenerating Forest	1.13	0.74	0.96	1.78	1.19	1.27
Reverting Land	5.29	0.45	4.01	1.82	1.21	1.30
Wetlands	0.58	1.21	0.93	1.16	1.54	0.92
Roads	4.03	3.40	4.58	10.06	6.70	9.86
Municipal/Industrial Land	0.73	0.85	0.99	5.98	6.90	4.75
Shoreline Development	3.57	4.45	5.69	6.39	6.81	10.05
Non-shoreline Development	1.43	1.98	2.60	6.18	7.68	8.83
Institutional – LGRP*	0.55	0.76	1.10	-	-	-
Agriculture	3.81	3.95	3.90	17.74	15.37	16.91
Cleared Land	1.94	1.72	1.77	1.25	1.00	0.95
Shoreline Septic	1.07	2.95	1.82	2.85	4.56	4.76
Non-shoreline Septic	1.14	2.53	1.95	4.95	6.59	7.07
Institutional Septic	0.92	3.55	2.50	-	-	-

*Lake George Regional Park

atmosphere by precipitation.

According to best estimates, the next largest contributors to phosphorus loading in Lake George are roads and reverting land at 4.52 percent and 3.96 percent, respectively (Table 11). Roads represent approximately 0.29 percent of the total watershed indicating that roads contribute disproportionately high levels of phosphorus (Table 12). Reverting land covers approximately 3.76 percent of the watershed, indicating that this land type contributes a proportional amount of phosphorus relative to its land area.

Agriculture and shoreline septic systems are the next most significant contributors to phosphorus loading, adding 3.85 percent and 3.04 percent respectively (Table 11). Agricultural land covers 1.22 percent of the Lake George watershed but contributes a moderately high level of phosphorus (Table 12). Runoff from phosphorus rich fertilizers, livestock pastures, and manure pits greatly increases the amount of phosphorus exported from agricultural lands. Shoreline septic systems contribute disproportionately high levels of phosphorus to Lake George due to the age, condition, and proximity to the lake of septic systems and pit privies.

Non-shoreline development and Lake George Regional Park (institutional) septic systems are the next most significant contributors to phosphorus loading, adding 2.57 percent and 2.47 percent respectively (Table 11). Non-shoreline development represents a relatively low phosphorus loading

Table 12. Best estimates of annual percent contribution to phosphorus loading in Lake George and Oaks Pond from watershed land use types in 2001. Phosphorus loading percentages are based on phosphorus loading projections for each land use category from the Phosphorus Loading Model (See Analytical Procedures and Findings: Phosphorus Loading). Percent of each land use pattern in each watershed is also given.

	Lake George		Oaks Pond	
Input Categories	**Best Estimate Percent Phosphorus Loading**	**Percent of watershed**	**Best Estimate Percent Phosphorus Loading**	**Percent of watershed**
Atmospheric Input	5.13	-	1.66	-
Mature Forest	29.63	52.09	29.46	72.90
Transitional Land	32.43	38.00	2.20	3.82
Regenerating Forest	0.96	0.90	1.27	1.84
Reverting Land	4.01	3.76	1.30	1.87
Wetlands	0.93	1.86	0.92	3.18
Roads	4.58	0.29	9.86	0.92
Commercial Land	0.99	0.23	4.75	3.29
Shoreline Development	5.69	0.46	10.05	1.05
Non-shoreline Development	2.60	0.61	8.83	3.34
Institutional – LGRP*	1.10	0.09	-	-
Agriculture	3.90	1.22	16.91	7.32
Cleared Land	1.77	0.49	0.95	0.41
Shoreline Septic	1.82	-	4.76	-
Non-shoreline Septic	1.95	-	7.07	-
Institutional Septic	2.50	-	-	-

*Lake George Regional Park

percentage compared to shoreline development due to increased buffering and distance from Lake George, despite constituting nearly six percent of the total area of the watershed. Lake George Regional Park septic systems (2.47 percent) contribute less phosphorus to Lake George than shoreline septic systems (3.04 percent). The septic systems in LGRP are newer than shoreline septic systems (which also include a number of pit privies) and a smaller # capita years was used for the park than for shoreline development because of the relatively short visits by patrons of the park (Appendix T). These factors contributed to a lower percent phosphorus loading by LGRP septic systems compared to shoreline septic systems.

The remaining six land use categories constitute 3.57 percent of the total area of the Lake

George watershed and contribute a total of 7.60 percent to total phosphorus loading (Table 12). Most of the eight categories were assigned low to moderate export coefficients and represented a relatively small area of the watershed.

Oaks Pond

Based on the Phosphorus Loading Model, the total mass phosphorus loading for Oaks Pond ranged from 85.59 kg/yr to 321.30 kg/yr with a best estimate of 179.71 kg/yr (Appendices U & V). The Phosphorus Loading Model generated a range of phosphorus concentrations from 4.34 ppb to 16.29 ppb with a best estimate of 9.11 ppb for Oaks Pond. The mean phosphorus concentration determined from CEAT surface samples collected in the fall of 2001 was 8.7 ppb (See Analytical Procedures and Findings: Water Quality Methodology). This value is within the range generated by the Phosphorus Loading Model. The 2001 CEAT mean of surface phosphorus values was equivalent to the best estimate predicted by the model, supporting the validity of using this model as an indicator of phosphorus loading.

Of the land use categories for Oaks Pond, mature forests (29.42 percent) and agricultural lands (16.88 percent) contributed the highest percentages of phosphorus loading based on best estimates (Table 11). According to these estimates, mature forests cover 72.90 percent of the watershed, indicating that mature forests contribute little phosphorus to Oaks Pond relative to their land area (Table 12). Agricultural land covers approximately 7.32 percent of the watershed. There is nearly six times the amount of agricultural land in the Oaks Pond watershed as the Lake George watershed; this difference accounts for the large discrepancy between the lakes in the importance of phosphorus loading. Run off from phosphorus rich fertilizers, livestock pastures, and manure pits can greatly increase the amount of phosphorus exported from agricultural lands.

Of the land use categories for Oaks Pond, shoreline development (10.04 percent) and roads (9.84 percent) contributed the next highest percentages of phosphorus loading based on best estimates (Table 11). According to these estimates, shoreline development and roads cover approximately 1.97 percent of the watershed and contribute approximately 19.88 percent of all phosphorus loading in the watershed (Table 12). In the case of shoreline development, the high phosphorus loading percent in relation to the small land area is due to inadequate buffers, erosion, and proximity to the water. Many of the roads in the watershed showed signs of major erosion and some were located very near the shore of Oaks Pond. The relatively higher phosphorus loading percent compared to the watershed coverage percent indicates that these land uses contribute moderately high amounts of phosphorus to Oaks Pond relative to their area coverage.

Non-shoreline development and non-shoreline septic systems constitute the next highest percent phosphorus loading, contributing 8.82 percent and 7.06 percent respectively (Table 11). Non-shoreline development covers only 3.34 percent of the total watershed (Table 12). The high phosphorus loading percent in relation to the small land area is due to erosion, soil unsuitable for septic systems, and the fact that all non-shoreline houses in the Oaks Pond watershed are occupied year round.

Shoreline septic systems and commercial and municipal lands constitute the next highest percent phosphorus loading based on best estimates, contributing 4.91 percent and 4.74 percent respectively (Table 11). There are nearly twice as many non-shoreline homes as shoreline homes in the Oaks Pond watershed but the non-shoreline septic systems contribute only slightly more to phosphorus loading (non-shoreline septic systems contribute 7.06 percent). This disparity exists because of the use of shoreline pit privies and because shoreline septic systems are located more closely to the shore of Oaks Pond. Commercial and municipal lands cover approximately 3.29 percent of the watershed (Table 12). Most of this land type is represented by the Eaton Mountain ski slope, which is prone to erosion and is located relatively close to Oaks Pond.

The remaining six land use categories constitute 8.30 percent of phosphorus loading and cover 11.12 percent of the watershed (Tables 11 & 12). Most of the six categories were assigned low to moderate export coefficients and represented a relatively small area of the watershed.

REGIONAL PARK ASSESSMENT

Valuing Maine Lakes

Lakes are valued in Maine for many different reasons. The abundance of lakes in Maine is a prominent feature of the state's special character. Thoughts of towering pines, the calls of loons, robust fisheries and abundant wildlife, a refreshing swim on a warm summer day, or a peaceful paddle are all attributes of the scenic and recreational qualities that people have valued for generations. Henry David Thoreau on his 1846 trip to Katahdin reported:

> The lakes (in Maine) are something which you are unprepared for: they lie up so high exposed to the light, and the forest is diminished to a fine fringe on their edges, with here and there a blue mountain, lime amethyst jewels set around some jewel of the first water... (Thoreau, 1877).

However, as human activity has expanded on these lakes and the surrounding watersheds, their health has been compromised. A growing demand for outdoor recreation and aesthetically pleasing vacation spots results in a number of Maine lakes facing growing ecological problems (State of Maine 116th Legislature 1994). Maine's lakes and ponds are highly sensitive to disturbance. Unlike coastal waters, rivers, streams, and lakes are relatively closed systems, which have comparatively slow rates of flushing. Over the past several decades, there have been mounting concerns pertaining to water pollution, water quality, public access, personal watercraft, noise levels, shoreland and surface use, and other land use issues (Tyler 1999). Policies should be implemented to balance these competing uses on the sensitive waters of Maine lakes and ponds. Though the many values and uses that people have for these lakes sometimes conflict, all of them depend on the health of the water body. Coldwater sport and anadromous fisheries, swimming and boating, water supplies and property values are all positively correlated with clean, clear, oxygenated water.

According to "Maine's Finest Lakes," a study which identifies lakes with resource values of statewide significance, both Lake George and Oaks Pond received significant ratings for their fisheries, perhaps a reflection of their deep, cold, clean waters (Parkin et al. 1989). Lake George also received a significant rating for its shoreline character. According to "Maine's Finest Lakes," a significant shoreline is defined by beaches and bedrock that are large and dominant and by opportunities that exist for public uses including swimming, fishing, hiking, and canoeing (Parkin et al. 1989). These qualities that define the Lake George shoreline make it highly valued for human use. As the demands from recreation and development continue to increase following a trend that is occurring on many of Maine's lakes, the welfare and traditional character of these lakes are being seriously threatened (State of Maine-116th Legislature 1994). These uses, which threaten many Maine lakes, are also concerns for Lake George and Oaks Pond because they are so highly valued for their recreational and aesthetic qualities.

Park Traffic

Methods

Records concerning the number of patrons visiting Lake George Regional Park were obtained from Bob Hubbard, LGRP Manager, and interpreted in the CEAT laboratory. Additional information about general park use trends was provided in follow-up phone conversations with Bob Hubbard.

Results and Discussion

Four thousand patrons visited Lake George Regional Park during its opening season in 1993; this number has steadily increased over the years (Figure 54). The park recorded its highest attendance at 26,000 patrons between the months of May and September 2001. It is unclear whether or not the attendance will continue to increase in the coming years. However, Bob Hubbard predicts that the park may see up to 5,000 to 8,000 additional patrons next season (Hubbard, pers. comm.). According to park records for the 2001 season, the maximum number of visitors in one day was 1,008 on 27-Jun-01. Although there are not necessarily 1,008 people on the beach at any one time, because patrons come and go throughout the day, this number is a considerable patron load for any natural area of this size to withstand. The beach traffic records from the 2001 season were also used to determine the distribution of patron use on each side of the park. In 2001, 8,271 patrons visited west beach; whereas 15,596 patrons visited the east beach, almost double that of the west side. Such heavily concentrated use will challenge the capacity of the septic system on east beach, as well as potentially increase the amount of erosion and deterioration taking place from human activity. Careful planning and environmentally friendly maintenance techniques are needed to ensure that negative impacts on water quality from park growth are minimized.

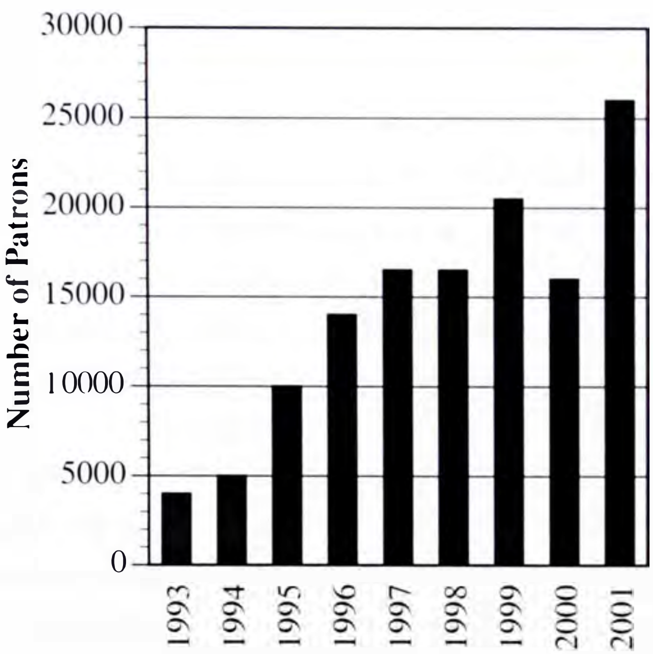


Figure 54. Number of patrons visiting Lake George Regional Park each year from 1993 to 2001. Data obtained from Bob Hubbard, Park Manager.

Lake George Regional Park is also a popular site for snowmobiling and ice fishing during the winter months. The season generally begins on the first of January and continues through mid March. Due to the easy accessibility of the public boat launch on Lake George, many huts are brought out onto the ice during the winter. Bob Hubbard stated that weekends are the most popular, with 40 to 50 people on the lake at a time. This load lightens on the weekdays with only five to six people on the lake each day. This type of winter use opens the door for additional environmental degradation. Trash and other materials left on the ice end up in the lake after the ice melts. Trucks, ATVs, and snowmobiles that drive out onto the ice also have the potential to deposit oil and gasoline into the lake. Although there are few year round houses on Lake George, this water body does experience year round use, which increases the amount of nutrients and contaminants that could potentially enter the lake.

Park Septic Systems

Lake George Regional Park recently added two new septic systems to accommodate the rise in visitors each year (east beach in 1997, west beach in 1994) (See Land Use Assessment: Residential Survey: Subsurface Disposal Systems). Bob Hubbard reported that the septic system on east beach was designed to allow up to 1500 flushes per day, and the system on west beach up to 1050 flushes per day (Hubbard, pers. comm.). He is confident that these septic systems are adequate to accommodate the number of patrons that currently use the park. However, he did wonder whether an increase in park attendance could overburden these septic systems. If it is assumed that each patron uses the restroom twice per park visit (i.e., two flushes per person), the east beach system would be able to accommodate 750 people per day and the west beach 525 people per day. An analysis of the daily attendance on each side of the lake in 2001 shows that the highest daily attendance at the east beach was 736 people on 27-Jun-01, and the highest daily attendance at west beach was 340 people on 16-Jun-01 (Figures 55 & 56). These results confirm Hubbard's belief that neither system is overburdened with the current park attendance level. However, according to CEAT estimates, the east beach is closer to reaching the threshold in which the capacity of the septic system might be challenged. In addition, the leach field for the east beach septic system, which serves the majority of park patrons, is located 120 ft from the shoreline, whereas the leach field on the west beach, where lower attendance is recorded, is located 250 ft from the shore. The close proximity of the east beach leach field to the water combined with a high number of users on this side could increase the potential for contamination of the lake.

East Beach Access Road

In addition to the number of patrons who use the park, there are also visitors who park their vehicles along the access road to the east beach entrance. The Town of Canaan owns this road and patrons who park here do not pay to enter the park; as a result, they are not included in the park traffic figure (Figure 54). The access road is in close proximity to the shoreline (often within a few feet from the water's edge) making it easy for visitors to park their cars and walk down the embankment into the lake. This type of use causes the breakdown and destabilization of the shoreline, increasing erosion. The runoff of fuel and oil that drips from cars parked along this road is also

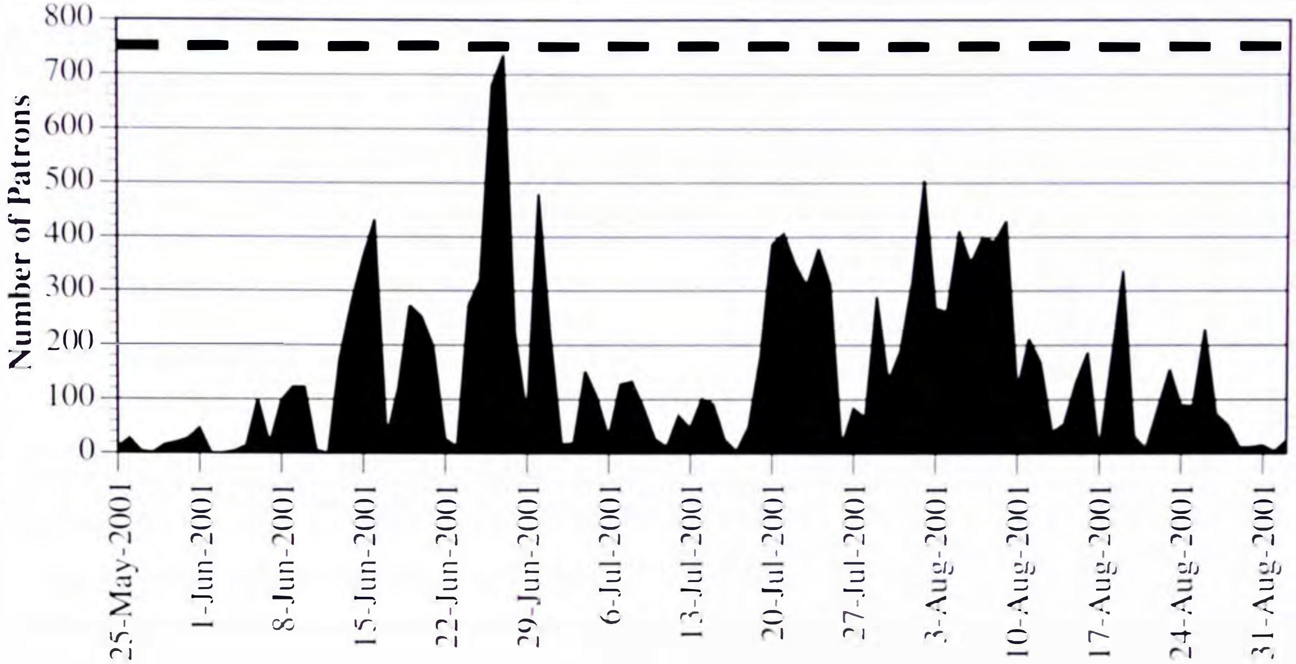


Figure 55. Daily attendance at Lake George Regional Park east beach from 25-May-01 through 02-Sep-01. Patron visits vary in length. Dashed line represents the level of patron attendance that could overburden the septic system at east beach. Data obtained from Bob Hubbard, Park Manager.

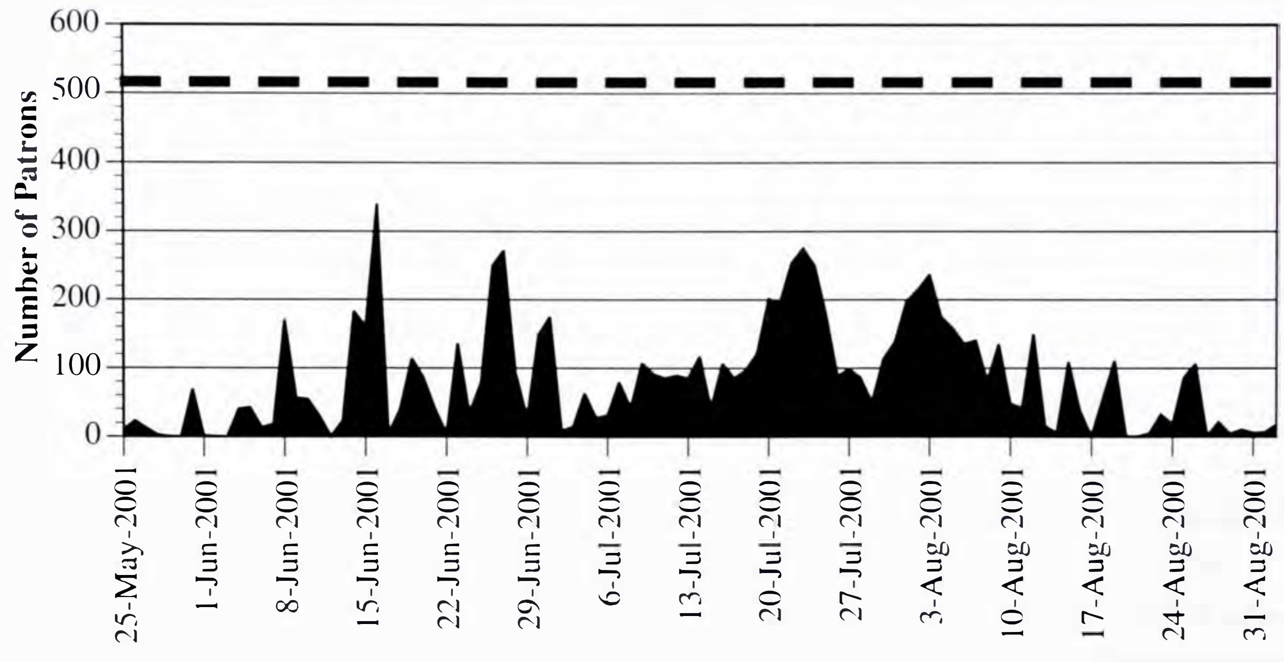


Figure 56. Daily attendance at Lake George Regional Park west beach from 25-May-01 through 02-Sep-01. Patron visits vary in length. Dashed line represents the level of patron attendance that could overburden the septic system at west beach. Data obtained from Bob Hubbard, Park Manager.

increased. The town of Canaan is currently in the process of addressing this parking issue for health and safety reasons (Hubbard, pers. comm.). Bob Hubbard is optimistic that an ordinance limiting the parking that can occur along the access road will be passed.

Lake Uses

Recreation ecology, the field of ecology that studies human-nature ecological relationships in recreational contexts, is an emerging discipline in natural resources research. Some of the goals of recreation ecology include the identification of impacts that recreational activities have on ecosystems and landscapes, the influence of use-related and environmental factors on the ecosystems and landscapes, and the roles that management can play in modifying these factors (Leung, Yu-Fai, and Marion 1996). In this study, CEAT identified some of the major concerns and management issues associated with recreational use in the Lake George and Oaks Pond watersheds.

Boat Launch

CEAT assessed the overall condition of the Lake George public boat launch (LGPBL). The LGPBL is essentially a wide camp road that leads directly into the lake. Boat launches are potentially large contributors of phosphorus to lakes (See Introduction: Roads and Boat Launch; Powell, pers. comm.). The boat launch is in moderate condition, but a few minor, inexpensive modifications could lower the risk of phosphorus loading.

Installing water diversions is an appropriate first step. The boat launch is heavily eroded and multiple rivulets have formed (Figure 57). This erosion is clearly evidence that runoff water is flowing directly into the lake. The diversions would channel water off the road into the surrounding woodland areas. A diversion can be as simple as a small rut that runs diagonally across the boat launch and channels runoff water into the surrounding area. The rubber razorblade is another type of diversion that involves a rounded piece of rubber that extends a few inches above the road surface (Hahnel, pers. comm.). The rubber razorblade is more durable and will require less maintenance. Another inexpensive modification would be to make the LGPBL narrower. This would drastically reduce the level of phosphorus loading by reducing the surface area. The boat launch is currently 20 ft wide. This width is more then ample for any boat that should be launched on a lake of this size. **A reduction of width could easily be attained by simply removing the gravel surface and placing a barrier to keep traffic off the area to allow vegetation to regenerate.** The addition of aesthetically pleasing native species is another acceptable option to provide more buffering around the boat launch.

Another alternative is to completely replace the boat launch. A boat launch similar to the Hinckley boat launch on the Kennebec River could be installed, but may be expensive (Figure 58). Positive attributes of the Hinkley boat launch are that it is narrow, made of concrete, and the surrounding areas are more vegetated and buffered then the LGPBL. A public boat launch similar to the Hinckley boat launch would likely add less phosphorus to the water than the current, or modified,

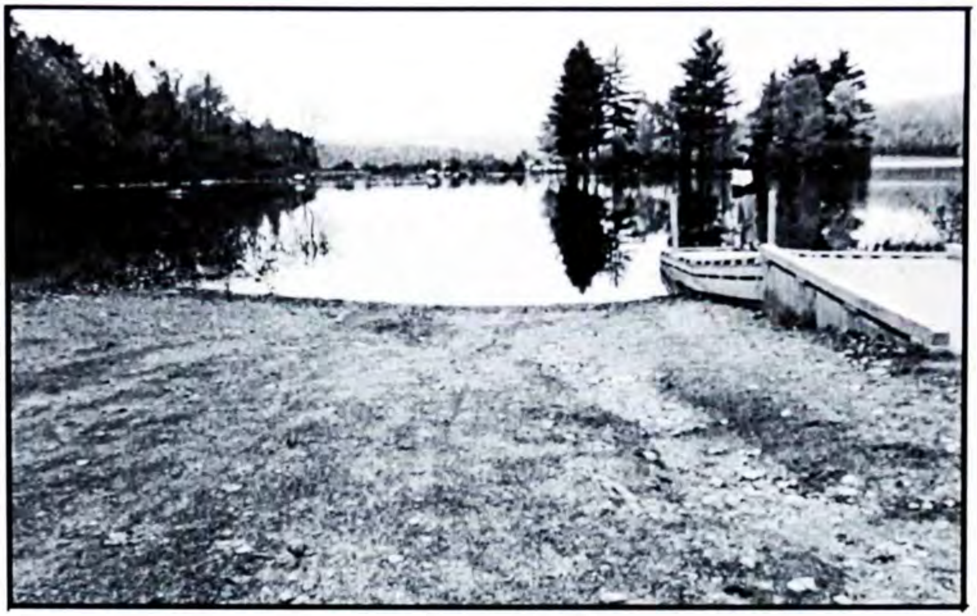


Figure 57. Lake George Regional Park public boat launch. Rivulets can be seen on the right side of figure, parallel to the dock. These are signs of erosion and runoff directly into the lake. Minimizing width may reduce erosion potential.

Figure 58. Hinckley boat launch located on the Kennebec River. This launch is more ecologically friendly than the Lake George public boat launch because it is narrow, more buffered, and made of concrete.

LGPBL. In addition to being more environmentally sound, this alternative may also be a better option for boat launch users. The LGPBL has a carry-in launch site, although according to Bob Hubbard it is more often used to launch larger motorized boats. This launch is not specifically designed to handle this level of use (Powell, pers. comm.). The LGPBL's classification does not, however, restrict users to only launching carry-in boats (Hubbard, pers. comm.). A concrete boat launch, like the Hinckley launch, may help to reduce the amount of erosion generated when people launch large boats into the water. However, Nancy Warren, the Lake George Regional Park Director, fears that this type of instillation could increase the number of large boats on the lake, which may have negative effects on water quality (Warren, pers. comm.).

Watercraft

Concerns

One major concern of lake users and residents is the use of recreational watercraft on Lake George and Oaks Pond. As the number of motor boats rises and the average motor size increases, conflicts between watercraft operators and other users of Maine lakes are becoming more prominent. 85 percent of the 126,000 motor boats registered in Maine in 1998 were used primarily on lakes (MDEP, unpublished document). As the number of motor boats increases, so does the use of personal watercraft and the safety concerns with which they are associated. Many small lakes do not contain enough surface area to allow for safe, unobtrusive operation of personalized motorcrafts. The 200 ft Water Safety Zone, which restricts boat speed within 200 ft of the shore, limits the free operation of motor boats. Motor Boating is also limited by irregularities in the shoreline, the presence of islands, exposed rocks, and shallow areas, all of which diminish the effective surface area in which motor boats can operate. These factors limit the likelihood that large, powerful motor boats will be used on Lake George and Oaks Pond. Additionally, smaller lakes are more readily disturbed by motor noise. These noises disturb people seeking a serene, peaceful environment and also have the potential to disrupt loons and other waterfowl that sometimes nest along small lakes (Tyler 1999). In addition to disturbing wildlife, motor boating contributes to shoreline erosion, the disruption of macrophytic vegetation, the re-suspension of sediments in the water column, water pollution, noise and safety hazards, and the introduction of invasive plant species (MDEP, unpublished document).

Management

An expansion of current watercraft regulations is necessary to bring Maine's regulations into compliance with national standards (Tyler 1999). Licenses are not currently required for watercraft operation. Furthermore, relatively few regulations stipulate training and education prior to operation. Speed restrictions are only implemented in the Water Safety Zone, within 200 ft of shore. Horsepower restrictions exist on only a few Maine lakes. In addition to these problems, Maine's existing watercraft enforcement laws face the problem of inadequate enforcement. Wardens from the IF&W do not have sufficient staff to enforce regulations on Maine's 2,802 Great Ponds. Great Ponds is a term that refers to natural lakes in the State of Maine that are greater than ten acres in size, and artificially formed or enlarged lakes that are greater than 30 acres (Tyler 1999). Both Lake George and Oaks Pond are classifed as Great Ponds; the State of Maine owns the water and the land under both lakes. Municipalities have the power to enforce Maine's watercraft laws under state law; however only a few inland towns have appointed harbormasters for this job. Without proper enforcement those who violate existing laws are seldom penalized (Tyler 1999).

In 1995, the Maine State Legislature established the Great Ponds Task Force in response to growing public concerns about noise, safety, and pollution hazards associated with increases in the use of motorized boats, personalized watercraft, and other issues (Tyler 1999). This task force consisted of a diverse group of representatives from organizations including the State Planning Office, the Department of Conservation (DOC), the DEP, the IF&W, and others. Fourteen public members were also appointed to serve on the task force representing the Maine Forest Product Council, the Maine Bass Federation, and the Maine Youth Camping Association, among others. The public was also given the opportunity to provide input and express ideas concerning Great Pond issues during meetings. Fifteen of the thirty-four recommendations provided by the task force were enacted into law. The Great Pond Task Force Final Report summarizes these recommendations as they pertain to recreational uses as follows (Tyler 1999):

1. Noise and safety hazards from watercraft use should be reduced by:
   a. establishing noise limits for all motorized watercraft;
   b. prohibiting the use of personal watercraft on 245 Great Ponds within the jurisdiction of the Land Use Regulation Commission (LURC);
   c. providing municipalities a two-year period to recommend regulations for the use, operation, and type of watercraft on Great Ponds.
2. Great Pond related activities should be supported by a special fund.
   A Lakes Heritage Fund to support state related projects and activities was established at the State Planning Office under the control of the Land and Water Resources Council.

The following four points summarize the 14 final recommendations and one resolve that remain to be implemented:

1. The Land and Water Resources Council should coordinate the implementation of the Final Report.
2. Water quality should be improved by better training and increasing the hours of operation for local code enforcement officers in lakeside communities.
3. Safety hazards from watercraft should be reduced by developing and promoting a code of conduct for safe, courteous boating.
4. A Watercraft Enforcement Fund should be established to support watercraft enforcement

efforts at the state and local level.

These recommendations and legislation have important ramifications for the preservation of all Maine lakes, including Lake George, which in the past, have lacked strong lake level management. Lake George and Oaks Pond are relatively small, and will be strongly impacted by an increase in the size and number of motor boats brought onto their respective waterbodies. The legislation passed as a result of the findings of the Great Ponds Task Force can help ensure that noise levels, shoreline erosion, and safety hazards are regulated on Lake George and Oaks Pond. Enforcement of these regulations is necessary, but with relatively few authorized enforcement officials from the IF&W, regulations may be a challenge, particularly on Lake George, where a public boat launch exists.

Ice Fishing

Concerns

Lake George and Oaks Pond host a variety of other recreational activities that potentially have negative effects on the lake water quality. Ice fishing on both lakes raises concerns about trash, fires, and oil leaks which threaten water quality, health of wildlife, and aesthetic enjoyment of other lake users. This activity is of particular concern on Lake George, where the LGRP sponsors an annual ice fishing carnival to raise funds. Over-fishing during the winter is also a concern (See Introduction: Lake George and Oaks Pond Characteristics: Biological Perspective).

Management

Current laws and regulations under the IF&W include daily bag limits and minimum fish lengths for fish caught on both Lake George and Oaks Pond. The State of Maine also imposes a time limit on the fishing season, which lasts from 01-Jan to 31-Mar (IF&W 2001b). The LGRP staff might minimize the impact of ice fishing on Lake George, particularly during the annual park-sponsored carnival, by ensuring that trash is cleaned up and gas and oil pollutants are closely regulated on the ice. Another possible method to lessen the impact of ice fishing on Lake George is posting signs to raise public awareness about the effects of trash and pollutants on the lake.

Trail Uses

All land resources have an inherent and variable ability to sustain recreational use without suffering damage to soils, vegetation, and water quality (Leung, Yu-Fai, and Marion 1996). The more sensitive areas tend to be located in mountain parks and in forests with steep slopes and abundant water runoff. Areas characterized by poor soils, steep slopes, high moisture content, and fragile vegetation are most vulnerable to human induced degradation. Trail management programs may be neccessary to increase the ability of the land to withstand human recreational use without resource damage. The extent of management necessary for trail programs is controlled by two factors: the volume of use and the character of the land itself (Proudman 1977). The majority of post-trail construction changes occur with initial or low levels of use and diminishes on a per-capita basis with increasing use (Leung, Yu-Fai, and Marion 1996). Further degradation on established trails is largely a function of environmental factors such as climate, geology, topography, soil and vegetation, all of which influence site durability. User type, intensity of use, and user behavior also play an important role in the potential amount of degradation (Leung, Yu-Fai, and Marion 1996).

There are three levels of trail management strategies that function to minimize the extent and rate of trail degradation (Leung, Yu-Fai, and Marion 1996). First, through careful layout and design, trail routes can be selected through relatively erosion resistant soil and vegetation types while avoiding sensitive landforms and topography. Trail managers can also modify and regulate recreational use to minimize impact on the trails. Finally, trail construction and maintenance actions can be implemented periodically to maintain the integrity of trails and to minimize wind and water erosion (Leung, Yu-Fai, and Marion 1996). Because an established trail system currently exists in LGRP, CEAT did not consider the first strategy involved with initial trail construction.

Low Impact Uses: Hiking and Cross Country Skiing

Hiking and cross-country skiing are popular activities on both the east and west sides of Lake George where existing trail networks have already been established (Hubbard, pers. comm.). Soil erosion and vegetation disturbance through trail widening are the primary impacts that these activities impose on the watershed. The implementation of appropriate trail maintenance techniques would help to mitigate these effects.

High Impact Uses: Snowmobiling, All Terrain Vehicle Use, and Mountain Bikes

Snowmobiling and illegal All Terrain Vehicle (ATV) use both have adverse effects on LGRP trails because of noise and air pollution, potential gas and oil spillage, and the compaction and widening of trails. ATVs also cause erosion and damage vegetation. These activities also threaten the safety of other park visitors such as skiers and hikers, who share the same trails. Mountain biking also can have adverse effects on the trails, resulting in soil compaction and root degradation. Park managers and volunteers, under the discretion of the park, can enforce and regulate these recreational uses. LGRP is limited by funding and small numbers of park officials, making the regulation of these uses difficult to enforce (Hubbard, pers. comm.). Signs should be posted on designated cross-country and ski trails to help inform the public of permissible activities.

Trail Construction and Maintenance Actions

Maintaining the Trail Opening

The trail opening must be maintained on a regular basis to ensure the safety and enjoyment of those who use the trail. These maintenance techniques involve clearing large rocks and trees in the corridor, brushing off overgrown sections, limbing overhead trees, and removing leaning trees (Proudman 1977).

Limiting Soil Erosion

Limiting soil erosion on trails is a crucial aspect of management. It has negative environmental consequences for the watershed, impairs trail use, and contributes to trail widening (Leung, Yu-Fai, and Marion 1996). CEAT offers some useful techniques that may be required to maintain the quality and drainage functions along the trail system in the Lake George watershed:

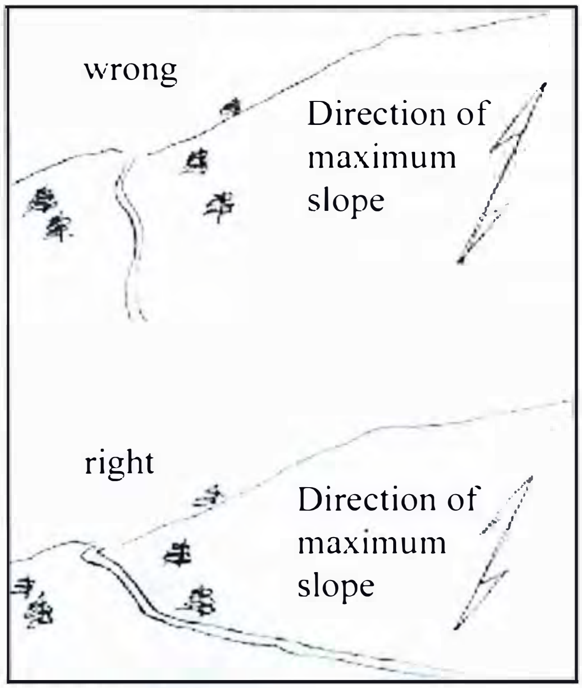


Figure 59. A comparison of the "right" way and the "wrong" way to run a trail on a steep grade. On steep slopes, sidehill trail locations are necessary to prevent water runoff down the trail (Proudman 1977).

Sidehill Trails and Switchbacks

When a trail is situated on a steep grade, sidehill locations are needed to ensure that running water will cross the trail but not run down the treadway at high velocities inducing rapid erosion. In most cases, the lateral area for the sidehill is limited and the trail must turn periodically in the opposite direction to form a switchback. The switchback ensures that water flowing down the slope crosses the trail without traveling down the treadway (Figures 59 & 60).

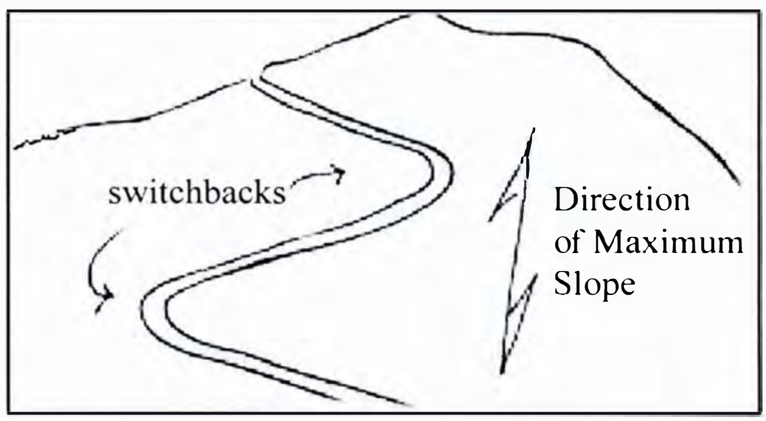


Figure 60. Switchbacks function as sidehill trails that periodically change direction on a slope (Proudman 1977).

Waterbars

Waterbars turn and direct water to the downhill side of the trail. They can be made of rock or wood, though rock is generally preferred because of its greater longevity and strength. However, wood waterbars tend to be the most common because suitable rock is often difficult to acquire (Proudman 1977). An ideal waterbar set for optimal drainage is usually placed at an angle across the trail between 15 and 40 degrees where the flow of the water off the trail keeps the waterbar clean of soil and other debris. When this type of self-maintaining waterbar cannot be created, drainage maintenance becomes necessary to allow for the natural flow of water on and off the trail. Drains should be dug wide enough to allow for a direct flow of runoff before it even reaches the waterbar. Careful placement of waterbars should allow water to be channeled from the trail without significantly impeding flow (Proudman 1977). On steep slopes that suffer erosion, water should be removed at the top of the slope to prevent further damage. The spacing of waterbars depends on the grade of the slope and the availability of water diversion sites. Generally, on grades of 20 percent or more, water removal through the implementation of waterbars should occur as often as possible. The LGRP trail systems traverse steep slopes on both sides of the lake making waterbars an important drainage and erosion control device that have yet to be implemented (Figure 61).

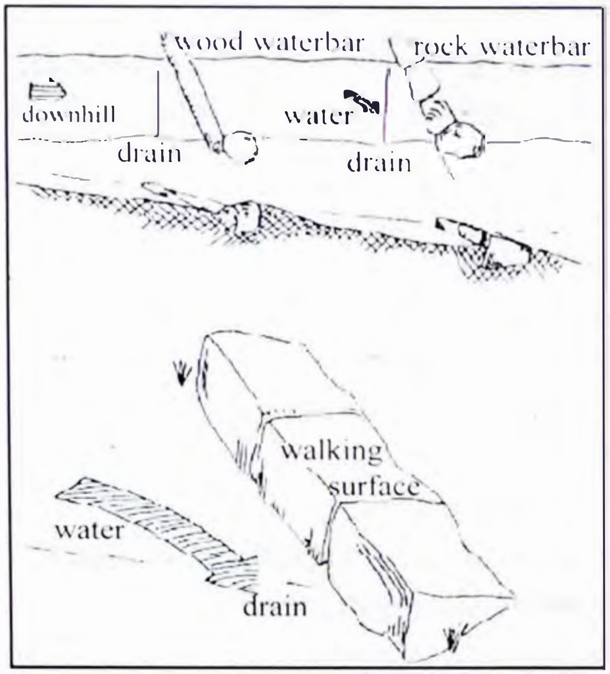


Figure 61. Waterbars set across the trail at an angle function to divert water to the downhill side of t he trail. A drain dug before the waterbar helps to ensure proper drainage (Proudman 1977).

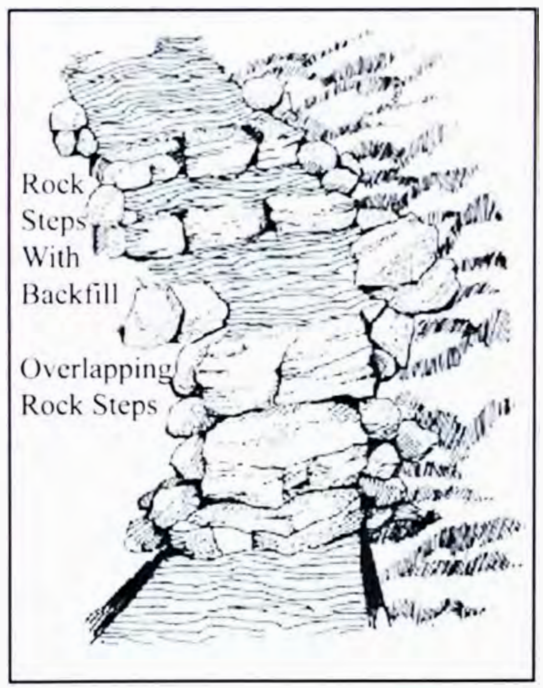


Figure 62. Steps are used on vertical rises to enhance soil retention and proper drainage. Steps take many forms and may b e overlapping or separated by backfill (Proudman 1977).

<u>Steps</u>

Steps provide a stable vertical rise on a trail, slowing water down while retaining soil (Proudman 1977). The importance of steps increases as trail slopes become steeper. Steps are seldom needed on moderate grades, except above waterbars where they serve to prevent clogging.

On steep slopes, however, steps are crucial for soil retention and stability. Rock steps are usually more desirable than wooden steps because they are both durable and aesthetically pleasing.

The trail system on the west side of LGRP contains an especially steep slope along the Fisher Trail which could benefit from the implementation of steps in certain places (Figure 62).

Berm Removal

Trails that undergo heavy use may develop a narrow trench in the center of the trail, especially in forested areas with soft, loose, sandy soils (Griswold 1996). Displaced soil then accumulates on the outer edge of the trail, forming an outside berm. The berm can potentially alter the natural drainage and runoff patterns across the trail, which can then lead to severe erosion. Management involves occasionally removing the berm and shoveling it back into the center of the trail. Crowning the center of the trail with excess material can provide further benefits by allowing for compaction (Figure 63). The build up of berm material has not presented a major problem in the LGRP. However, areas that undergo the heaviest use including ATV and other high impact uses need to be monitored to ensure that the trails are not rapidly degraded.

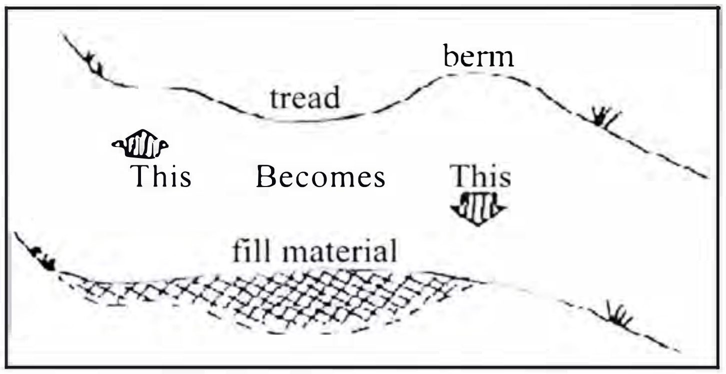


Figure 63. Displaced material forms berms on the outer edges of a heavily used trail. Remediation requires that the berm material be shoveled back into the center of the trail (Proudman 1977).

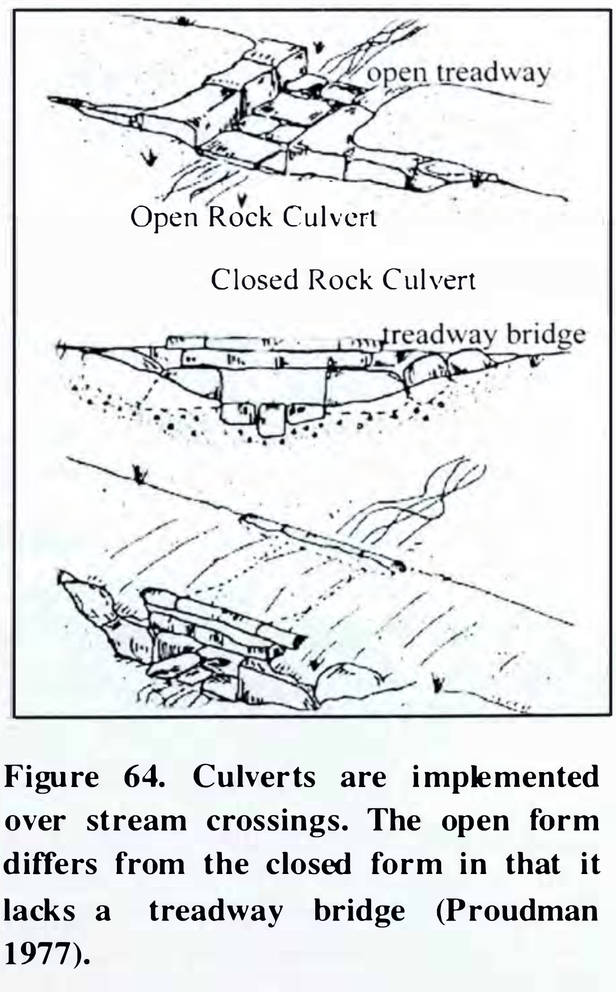


Figure 64. Culverts are implemented over stream crossings. The open form differs from the closed form in that it lacks a treadway bridge (Proudman 1977).

Culverts

Culverts allow drainage to occur where a trail crosses a stream. Natural culverts may be constructed of rock or wood and may be in an open or closed form. Open culverts do not contain a bridge over the opening; however, closed culverts provide an overlying tread for water to flow underneath (Figure 64). Rock is generally preferred because wood is prone to rapid deterioration. The depth of the open culvert depends on the anticipated waterflow. The culvert must be wide enough for the safety of travelers who may need to step down into it. Closed culverts are usually capped with slabs of rock, which are supported by side support rocks (Figure 62; Griswold 1996). Due to the high number of stream crossings in LGRP, culverts are necessary to ensure that water flows past the trails without continuing down the treadway. Because CEAT's analysis was conducted in a relatively dry autumn season, future analyses will be necessary to determine the importance of culverts in LGRP based on the amount of potential water flow in the streams.

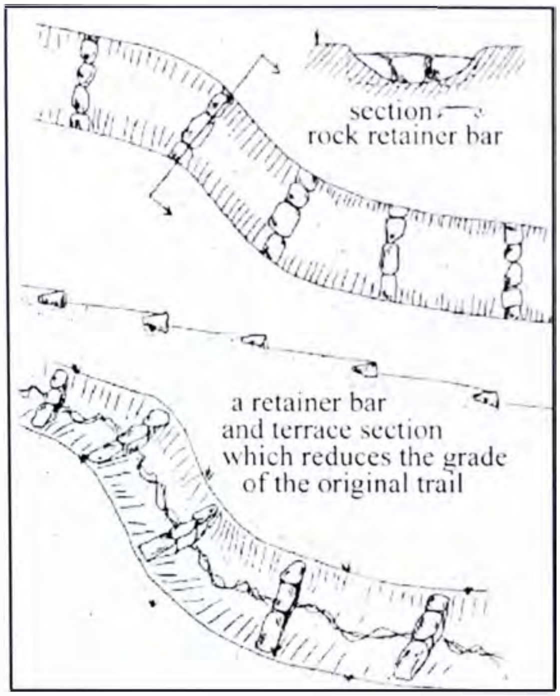


Figure 65. Retainer bars are laid across the trail and function to hold trail material in place (Proudman 1977).

Soil Retention Devices

Retainer Bars

Retainer bars are laid across the trail and hold dirt and fill material in place. They appear similar to steps, however, they are not confined to steep slopes and are often entirely buried by the trail tread material (Griswold 1996). Rock is the preferred material for retainer bars because of its high durability and strength (Figure 65). As mentioned previously, steep grades on the west side of LGRP along the Fisher Trail make the treadway prone to erosion and receptive to retainer bars.

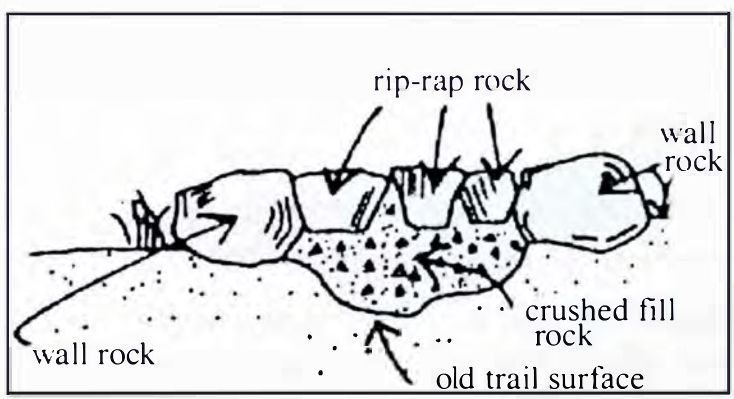


Figure 66. Rip-rap serves as a soil retention device and is made of three components: wall rocks, rip-rap rocks (or treadway rocks), and crushed fill rock (Proudman 1977).

Riprap

Riprap is another soil retention device that can be used on nearly any grade when retainer bars and steps are not appropriate. A riprap section is generally composed of rock, including wall rocks placed on either end, large, flat keystone rocks which are meant to be walked upon, and crushed rock stuffed solidly under the keystone (Figure 66).

Trail Hardening Devices

Trails lying in flat, low-lying, wet terrain, and those that pass through bogs are frequently threatened by the destruction of plants and surface soils. Wet, slippery, muddy trails develop rapidly on these locations, resulting in puddles of water on the treadway. In these areas, hikers often walk to the side of the trail leading to a destructive cycle of soil breakdown and trail widening. These effects will be most noticeable in LGRP during the spring months when the trails usually receive the highest amount of moisture. A variety of techniques can be implemented on trails in wet areas to stabilize soils and allow trailside vegetation to recover.

Wet, muddy sections often develop because the trail is lower than the surrounding terrain. Water drained through soils can become trapped on the lower surfaces of the treadway. This trapped water may indicate the need for a drainage device, which would permit water to flow off the trail. A trail that appears low and flat may have a moderate slope making it receptive to water bars and drainage ditches. This condition is especially true in LGRP where the trail systems occur primarily along the slopes of hills. Draining of an area is preferred to the bridges and other types of trail hardening techniques that follow (Proudman 1977).

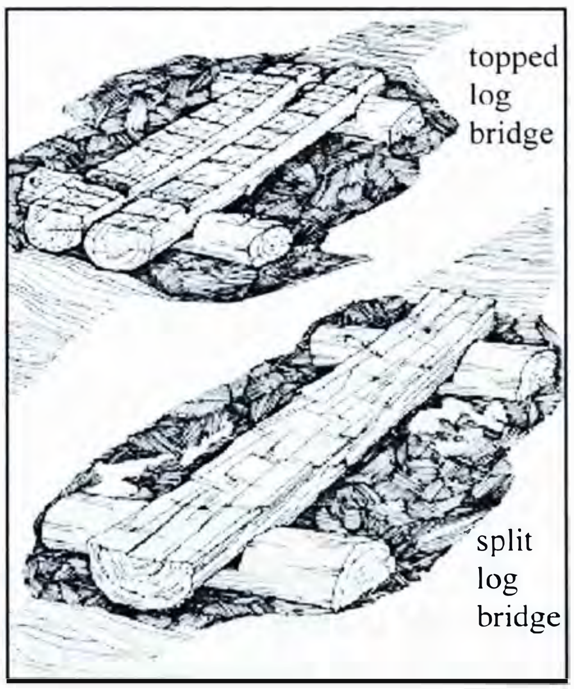


Figure 67. Topped log bridges and split log bridges are two types of common, simple bridges that can be used to form hardened treadways across wet expanses of trail (Proudman 1977).

Step Stones

Step stones set into mud form a stable, dry treadway for hikers. They may occur singly, as a rock treadway that uses many rocks set side by side, or in a rockbox framed by logs (Proudman 1977).

Bridges

Bridges are used in a variety of locations to form a hardened tread across bogs, marshes, streams or gullies. Though many types of bridges exist, there are two basic types of bridges that are simple to construct: top log bridges and split log bridges. Top log bridges tend to be stronger than split log bridges due to the amount of material removed from the treadway logs. In top log bridges, the top third of the log is removed, whereas split log bridges have as much as one half the material removed. The split log bridge is more economical and weighs less than the top log bridge, making transportation less cumbersome. In both types of bridges, the base logs are notched so that treadway logs can be set into them. Spikes are then used to hold the treadway and the base together. The bridge must be wide enough to permit safe passage, and may require more than one treading log. This treadway should also be even, rather than tilted or angled, and the entire unit should be stable. Long bridges may require three or more base logs to ensure stability (Figure 67; Proudman 1977).

FUTURE PROJECTIONS

POPULATION TRENDS

Historic Population Trends

The population growth patterns of Canaan resemble those of many rural towns in Maine. Rapid settlement took place in the early 1800s due to the lure of unsettled frontier land (Figure 68; Canaan 1997). After the Civil War, however, many of these settlers headed west bringing business and industry with them. People began to resettle Canaan in the 1960s when they realized that with reliable cars, they could work in the city of Skowhegan and still maintain a rural lifestyle in the county. Since this time, suburban lifestyles have continued to attract people to establish residency in Canaan.

The growth patterns of Skowhegan are different from those in Canaan. The population of Skowhegan rapidly increased rapidly during what are termed the "building years" between 1860 and 1890 (Figure 69; Skowhegan 1995). By the turn of the century there were more than 20 factories in the urban center surrounded by farmland and open space. Skowhegan did not experience the decline in population that Canaan did between 1860 and 1940, in fact the population increased by roughly 5000 people during this period. A brief decrease in population growth occurred in 1970, but since the construction of the S. D. Warren paper mill, growth has resumed. The population of Skowhegan is currently increasing at 0.5 percent per year (Marcotte, pers. comm.).

Future Population Projections

Population increase over time is indicative of a rise in development within an area. Regions of the watershed that may experience potential problems with nutrient loading and runoff due to development can also be identified based on population densities. In 2001 the population of Skowhegan was 8,824 and Canaan 2,017. According to Tom Marcotte, the Skowhegan Town Planner, the population of Skowhegan is currently increasing at 0.5 per year and this trend is expected to continue. Marcotte also indicated that only 100 additional people have established residency in Skowhegan within the last ten years (Marcotte, pers. comm.). Canaan, on the other hand, is experiencing 3 percent population growth per year. Marcotte stressed that Canaan is becoming a "sleeper town." People are moving into the area for its natural beauty, quiet, rural setting, while taking advantage of Skowhegan, a larger town, only minutes down the road where they can work and conduct business. Growth, whether small or large, will have environmental implications for the

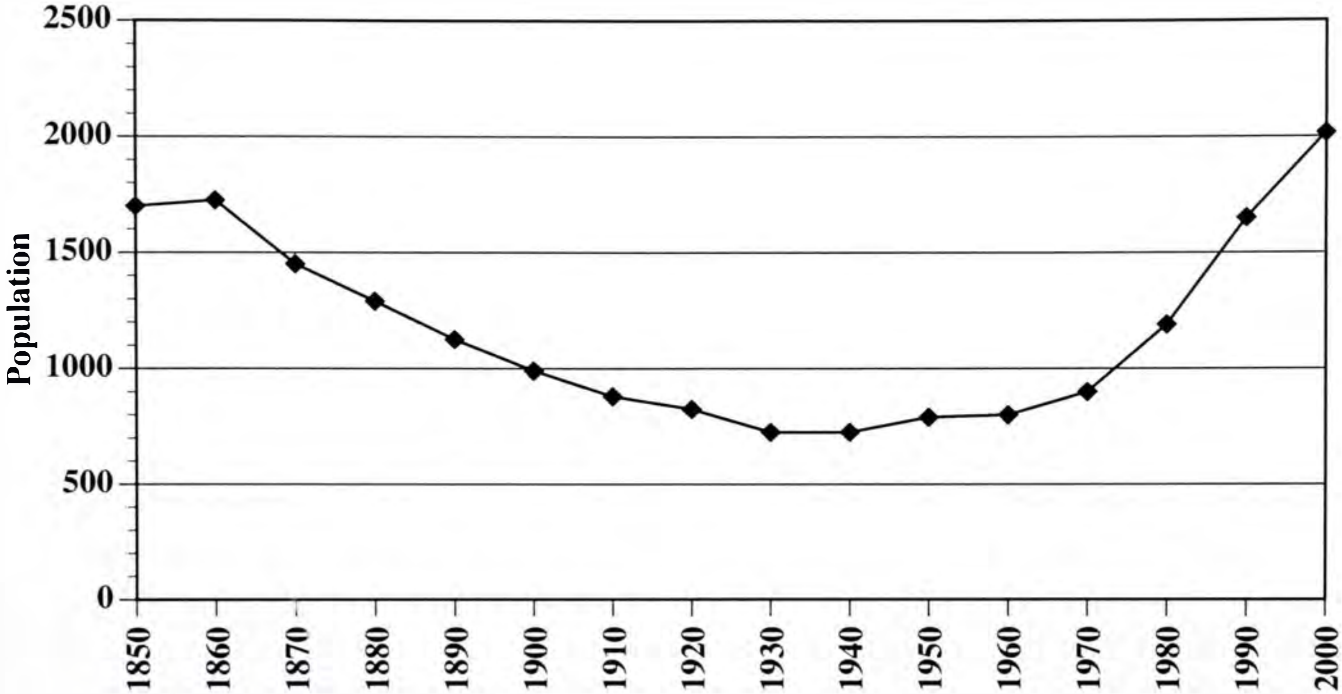


Figure 68. Population trend for the Town of Canaan from 1850 to 2000. The population of Canaan is currently increasing by 3 percent per year. Data obtained from the Comprehensive Town Plan of Canaan.

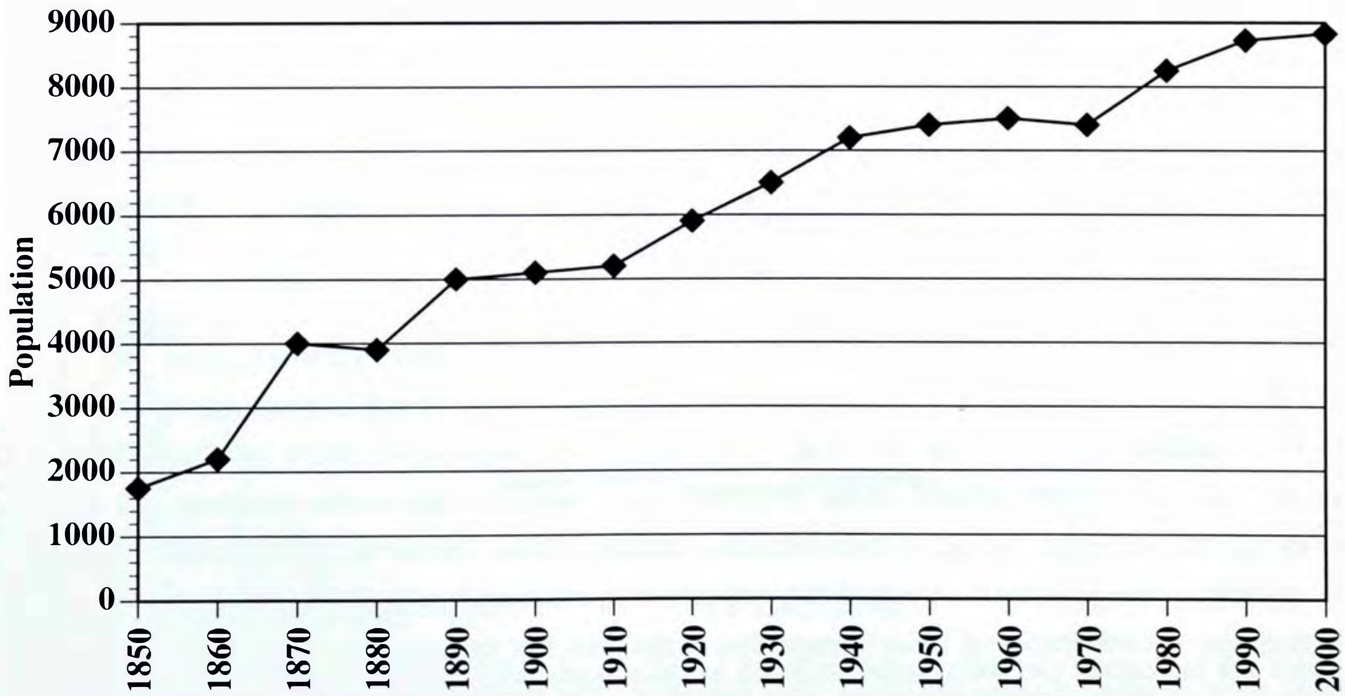


Figure 69. Population trend for the town of Skowhegan from 1850 to 2000. The population of Skowhegan is currently increasing at 0.5 percent per year. Data obtained from Town of Skowhegan 1995 Comprehensive Plan and Tom Marcotte, Skowhegan Town Planner.

Lake George and Oaks Pond combined watershed. Much of the Lake George and Oaks Pond combined watershed lies within the Town of Skowhegan and therefore the population increase in Canaan will most likely occur outside the watershed boundary. This rise could lead to an increase in the number of LGRP visitors per season however, and may affect lake water quality.

DEVELOPMENT PROJECTIONS

Methods

Using the ESRI ArcView® 3.2 program, a map of the watershed was created and used to determine areas where future growth and development is likely to occur (Figure 70). The map is a compilation of multiple layers: water bodies, roads, wetlands, and tax maps. Tax maps show how the land is subdivided into various lots. Each layer provides information regarding development potential based on lot size, land use, and availability. Meetings with both Tom Marcotte and Randy Gray provided helpful insight as to which lots are likely to be developed and why. Discussions with Bob Hubbard, Plum Creek Timber Company, Inc., and the IF&W also served as additional sources of information.

Results and Discussion

CEAT learned from Marcotte and Gray that much of the area around Lake George and Oaks Pond is a Limited Residential District. This type of land is suitable for residential and recreational growth, but not for commercial or industrial development (MDEP 1998a). Consequently, new commercial and industrial development is not expected within the watersheds. Rather, this type of development will occur through the reuse and adaptation of existing land. Marcotte and Gray also explained that the majority of the shoreline residential lots are too small to subdivide and still meet the minimum lot standards. This observation implies that little shoreline development will occur through the subdivision of existing lots.

Lake George Regional Park owns lots on the southeast and southwest portion of the lake (Figure 70). The park is currently in the process of purchasing a lot that will provide an additional 2,000 ft of shoreline frontage to the east side of the Park. This purchase will leave relatively little shoreline available for development on the east side. There are a few lots on the northeast side of Lake George that are large enough to be subdivided and developed. However, development on these lots is unlikely in the near future because they are currently inaccessible by road. Development is prohibited near the tributaries of Lake George due to the presence of wetlands. Even fewer lots are available to be developed along the Oaks Pond shoreline. The majority of shoreline lots have already been developed and the remaining land on the southwest side of the lake is largely wetland area. The Lake George and Oaks Pond combined watershed is likely to experience a different type of growth than the development of new homes. The transfer of ownership and, as mentioned earlier, the conversion of homes from seasonal to year round use is more likely in these watersheds. Even

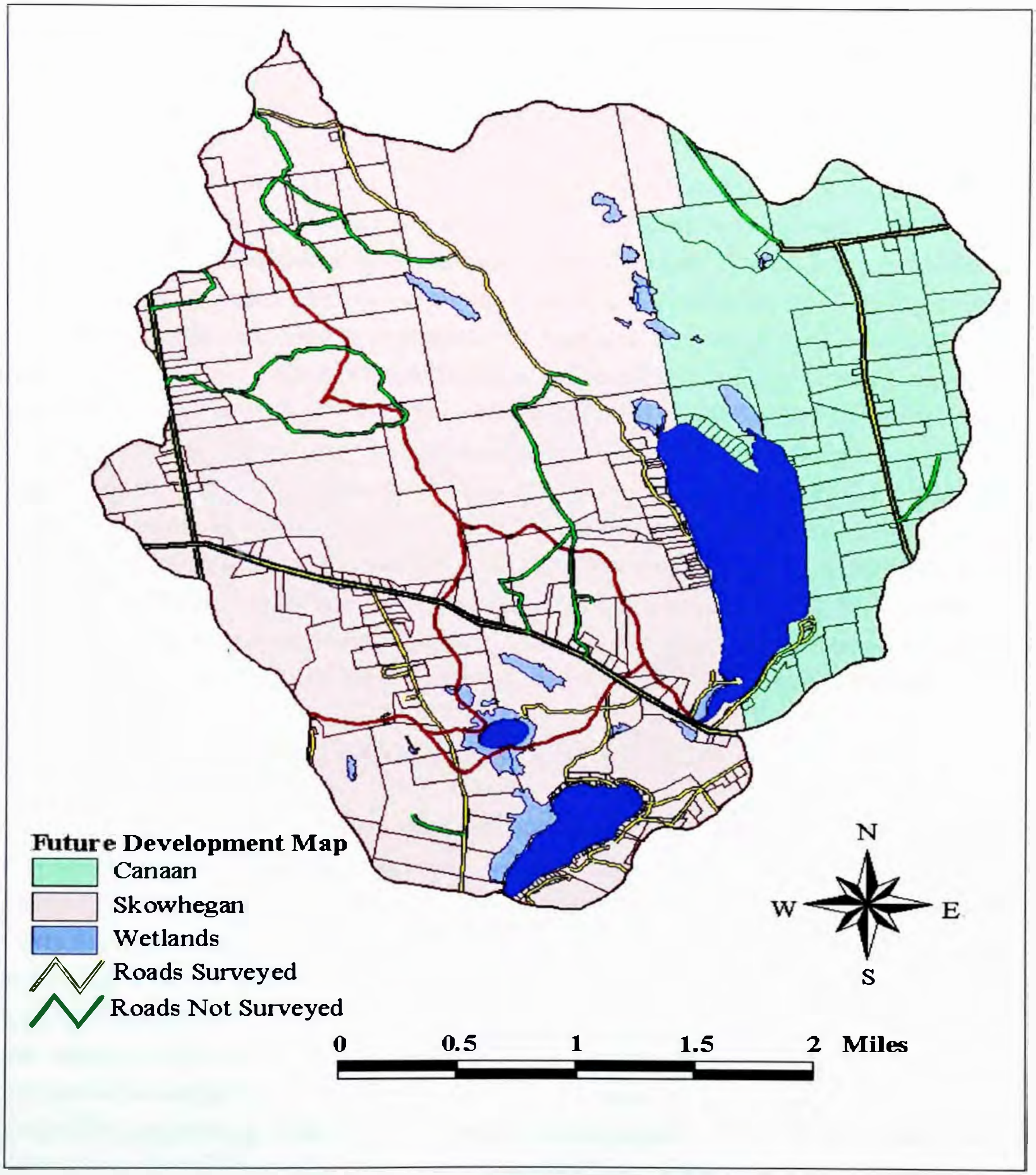


Figure 70. Future development map used to project areas with the potential for future development. Tax Maps for Canaan and Skowhegan show how the land is subdivided into various lots. Lots with road access are more likely to be developed first. Development is prohibited in wetland areas. Data obtained from the Canaan and Skowhegan town offices. The Lake George and Oaks Pond watersheds are outlined in red.

though this type of growth is not new development per se, it could have a profound effect on erosion, the potential for septic system contamination, and the overall deterioration of lake water quality due to increased human activity.

Oaks Pond is available for public fishing; however, no public boat launch or means of accessing the water's edge exists without crossing through private property. Oaks Pond has been placed at the top of the IF&W's priority list for access acquisition and development. This means that the IF&W is investigating possible sites for walk-in or car-top access to Oaks Pond. They have identified one parcel of land owned by Plum Creek Timber Company, Inc. that might be available. The land use map shows that the proposed lot, at the southwest corner of the lake, is categorized as pasture land and could potentially be developed (See Analytical Procedures and Findings: Land Use Assessment: Figure 31). However, Garnet Ricker, a forester with Plum Creek Timber Company, Inc. who is working within the Lake George and Oaks Pond combined watershed, mentioned that he has not been contacted about the matter. He suggested that a substantial amount of work is needed to improve road access into this parcel of land before it is suitable for public use. Plum Creek Timber Company, Inc. owns a few other lots of land within the combined watershed. They have announced that they plan to manage this land to maximize its value. This projection would include both future logging and the development of new residential lots in some of the non-shoreline forested land. Other than the areas mentioned, there are relatively few lots remaining to be developed, which will help to maintain the level of water quality currently present in Lake George and Oaks Pond.

RAMIFICATIONS OF PHOSPHORUS LOADING

The Phosphorus Model can be used to predict future phosphorus loading estimates based on watershed development projections (See Analytical Procedures and Findings: Land Use Assessment: Phosphorus Loading). CEAT used the future development map to determine areas in the watersheds that were likely to be developed and then proposed four development scenarios over the next 25 years for each of the watersheds (See Development Projections: Figure 70). These projections include low and high amounts of demographic change with and without heavy logging. The demographic changes proposed consisted of the conversion of homes from seasonal to year round use, and an increase in the number of shoreline and non-shoreline homes. These changes would increase both the number of people living in the watershed and the number septic systems. It was assumed that new homes would be built on what is currently agricultural land, and mature and transitional forests, decreasing these land areas by the amount that new homes were projected to cover. CEAT also assumed that additional camp roads would be developed over the next 25 years because at least some residential growth will occur in areas that are not currently accessible by roads. Finally, logging activity would decrease the area of mature and transitional forest by converting this land to cleared land followed by regenerating land.

The four future development scenarios for Lake George are listed below.

Low Demographic Change

- Three shoreline seasonal homes convert to year round.
- Six seasonal shoreline homes added.
- Eight year round, non-shoreline homes added.
- Half-mile of camp roads added.
- 30,000 visitors per season at Lake George Regional Park (5,000 person increase over the 2001 value).
- Increases in residential land and roads were offset by a decline in mature and transitional forest.

High Demographic Change

- Five year round, shoreline homes added.
- Seven seasonal, shoreline homes added.
- 20 year round, non-shoreline homes added.
- One and a half mile camp road added.
- 35,000 visitors per season at Lake George Regional Park (10,000 person increase over the 2001 value).
- Increases in residential land and roads were offset by a decline in mature and transitional forest.

Logging Scenario added to Low and High Projection

- One mile of logging roads added for logging accessibility.
- 150.96 hectares of mature and transitional forest cleared for logging.
- Two bouts of logging were assumed to be ten years apart. 75.48 hectares were added to both cleared land and regenerating land.

The Phosphorus Model for the current conditions in Lake George predicted a value of 8.6 ppb of phosphorus (Table 13). This prediction compares very closely to the phosphorus level determined by the CEAT water quality analysis (8.8 ppb). The Phosphorus Model predicted a phosphorus loading value of 9.0 ppb for the low demographic change scenario and a value of 9.5 ppb for the high demographic change scenario. These results suggests that our estimates for population growth and residential development will have a relatively low effect on phosphorus loading levels in Lake George. When logging is added to the scenarios, however, a much larger increase in phosphorus levels occurs. The low projection with logging adds 1.9 ppb of phosphorus and the high projection with logging adds 2.4 ppb of phosphorus to the current levels. These projections for Lake George indicate that logging potentially has a higher impact on lake water quality than other land uses.

The four future development scenarios for Oaks Pond are listed below.

Low Demographic Change

- Five seasonal shoreline homes convert to year round.
- One seasonal shoreline home added.

- Five year round, non-shoreline homes added.
- No roads added.
- Increases in residential land and roads were offset by a decline in mature and transitional forest.

High Demographic Change

- Ten seasonal, shoreline homes convert to year round.
- Three seasonal, shoreline homes added.
- Ten year round, non-shoreline homes added.
- One mile of camp roads added.
- Increases in residential land and roads were offset by a decline in mature and transitional forest.

Logging Scenario added to Low and High Projection

- 60.4 hectares of mature forest and agricultural land cleared for logging. Less logging was predicted in the Oaks Pond watershed because there are fewer mature forests than in the Lake George watershed.
- Two bouts of logging were assumed to be ten years apart. 30.2 hectares were added to both cleared land and regenerating land.

The Phosphorus Model for the current conditions in Oaks Pond predicted a value of 9.1 ppb of phosphorus (Table 13). This prediction compares very closely to the phosphorus level determined by the CEAT water quality analysis (8.7 ppb). The Phosphorus Model projected a phosphorus loading value of 9.3 ppb for the low demographic change scenario and a value of 9.5 ppb for the high demographic change scenario. These development scenarios had a relatively smaller affect on phosphorus loading in the Oaks Pond watershed than in the Lake George watershed. This difference is likely due to the fact that the Oaks Pond watershed, especially along the shore of the lake, is already significantly more developed than Lake George; less future development is possible in the Oaks Pond watershed. When logging is added to these scenarios, the low projection increases to 9.4 ppb of phosphorus and the high projection increases to 9.6 ppb.

The Phosphorus Model confirms that both residential development and logging in the watersheds will increase the phosphorus levels in the respective lakes. The potential for development is higher for the Lake George watershed due its larger size and the abundance of undeveloped mature and transitional forests. This possibility could elevate phosphorus concentrations in Lake George to levels higher than Oaks Ponds if development is not carefully planned. However, assuming that CEAT projections reflect future development patterns phosphorus levels are not likely to reach the critical limit (12 to 15 ppb) for potential algal blooms in either lake in the next 25 years. It is possible, however, to have underestimated the degree of future residential development, addition of roads, and logging. If a larger amount of development occurs in the next 25 years than has been projected, phosphorus levels in the lakes could indeed be higher than predicted.

Table 13. Phosphorus Model scenarios for Lake George and Oaks Pond. The Phosphorus Model was used to predict the current value of phosphorus in each lake. The predicted value and the value determined through CEAT's water quality analysis were very similar. Low and high development projection scenarios with and without logging were run for a 25-year horizon. Seasonal conversion of homes, the addition of shoreline houses, non-shoreline houses, and roads were included in each scenario. Changes in succession of forest habitats were also considered. See Future Projections: Ramifications of Phosphorus Loading for more details.

Projection Scenario	Lake George	Oaks Pond
Current Phosphorus Level*	8.6 ppb	9.1 ppb
Low Demographic Change	9.0 ppb	9.3 ppb
High Demographic Change	9.5 ppb	9.5 ppb
Low Demographic Change with Logging	10.5 ppb	9.4 ppb
High Demographic Change with Logging	11.0 ppb	9.6 ppb

*Phosphorus concentration determined by CEAT water quality analysis was 8.8 ppb for Lake George and 8.7 ppb for Oaks Pond.

SUMMARY

The water quality of Lake George and Oaks Pond is currently below the critical range for phosphorus (12 to 15 ppb), which is the primary cause of algal blooms. These low levels of phosphorus are one of several characteristics that classify both lakes as mesotrophic. The results of other physical and chemical tests were also within acceptable ranges for healthy lakes with the exception of dissolved oxygen and alkalinity. Oxygen depletion is occurring in deep areas of both lakes, which can affect the coldwater fisheries negatively and is an early warning sign of eutrophication. Alkalinity helps to buffer a lake by mitigating the effects of acid deposition. Our study indicates low alkalinity for both lakes and a resulting sensitivity to acid inputs. CEAT calculated a water budget and annual flushing rate for both lakes. The flushing rate is a measure of how fast water is replaced within the lake and reflects the nutrient/pollution cleansing ability of the lake. The flushing rate for Oaks Pond is more than five times greater than that of Lake George. Consequently, Lake George has a higher sensitivity to nutrient loading than Oaks Pond. However, the water quality of Lake George and Oaks Pond are closely related because Lake George drains into Oaks Pond.

A primary objective of our study was to identify land use patterns within the watersheds and document their effects on water quality because land use influences the magnitude of phosphorus inputs into the lakes. A Geographic Information System (GIS) was an invaluable tool for analyzing land use and development trends, through the construction of composite maps and models. Land use in the watersheds changed dramatically over the 42-year period studied. A comparison of 1955 and 1997 land use patterns, made possible from aerial photographs, showed a major increase in mature forests in the Lake George watershed and a drastic decrease in agricultural land in both watersheds. The mature forests help to mitigate erosion and phosphorus loading that can affect water quality.

Active logging of these mature forests within the Lake George watershed, particularly, is a concern and use of best management practices is recommended. Compliance with the Natural Resources Protection Act is also important. Future logging is more likely but less suitable in the Lake George watershed and more suitable but less likely in the Oaks Pond watershed as determined by the logging suitability model. The model integrates soil types and slope of the land to project areas that could support logging with minimal detrimental effects on lake water quality.

Shoreline residential land surrounding Lake George increased from very few residences in 1955 to approximately 34 houses today. Oaks Pond has experienced a similar increase in the number of shoreline residences. This land use type is of particular concern because of the greater potential for nutrient loading from shoreline development and septic systems than from these activities in non-shoreline areas of the watershed. Shoreline development may cause increased erosion and phosphorus loading caused by the presence of impervious surfaces and by disturbance of shoreline vegetation. Oaks Pond is at a higher risk for these problems because of the high number of shoreline camps and the potential for conversion of camps from seasonal to year round use. Lake George is at

less risk due to the presence of Lake George Regional Park, which owns a substantial portion of the lake shoreline and subsequently reduces the potential for problems related to shoreline development. Installation of adequate shoreline buffer strips in front of residences is an economical and effective way to mitigate erosion and subsequent nutrient loading. Based on our analysis, 68 percent of buffer strips on Lake George and 33 percent of buffer strips on Oaks Pond were adequately buffered.

Roads are significant pathways for nutrients to enter the lakes. Most of the roads surrounding Oaks Pond run in close proximity to the shoreline and are an immediate threat to water quality. Two of these roads are classified as high risk. The majority of all roads in the Lake George and Oaks Pond combined watershed were classified as being a risk to lake water quality. There is one high-risk road in proximity to Lake George.

We believe that the Lake George Regional Park has been practicing ecologically sound stewardship of the land under its control. However, the public boat launch, gravel parking lots, and the east side access road are of particular concern for water quality management. These areas all contribute to erosion and potential nutrient loading. The Regional Park can play an important role in protecting Lake George by working to enhance buffering around the boat launch, parking areas, and along the park access roads. The park septic systems on the east and west sides of the park are under their projected capacity. However, increased park visitation could threaten their ability to function optimally and result in a negative impact on lake water quality. This issue is especially of concern on the east side where visitation rates are highest and the septic field is located close to the shoreline.

The Colby Environmental Assessment Team developed a phosphorus model as part of our study to project current and future phosphorus inputs into Lake George and Oaks Pond. Current projections were approximately equal to the values determined by our chemical analysis. The greatest contributors of phosphorus to the lakes determined by the model were roads, shoreline and non-shoreline residences, commercial/municipal lands, and the park. Our phosphorus model showed current inputs to be below the critical value of 12 to 15 ppb, which is the threshold for potential algal blooms. Future predictions from our model for several development and logging scenarios suggest that resulting phosphorus inputs are not likely to exceed this critical value.

Invasive plant species are not present in either lake. However, there is the potential for accidental introduction through the launching of contaminated boats. Invasive aquatic plant species can cause serious economic and ecological damage to lake communities and to the recreational resources of the lakes. Education of boat owners is an important preventative measure that should be undertaken to address this potential threat.

In summary, Lake George and Oaks Pond are presently within acceptable ranges of good water quality as defined by the study. To maintain present levels, appropriate actions to limit erosion and nutrient loading should be taken. Community awareness through educational initiatives will help lake stakeholders prevent future degradation of water quality.

RECOMMENDATIONS

PHOSPHORUS CONTROL

Buffer Strips and Erosion Reduction

- Poor and partially buffered properties should be improved to minimize potential sedimentation and nutrient loading. The buffer depth should be increased where possible.
- Allow shoreline property to remain natural providing an effective buffer. Avoid cutting vegetation to maintain the densest buffer possible. Avoid raking fallen leaves, pine needles, and other natural debris that make up the duff layer.
- Replant sparse areas across the slope of the land with a variety of native plants, which require less maintenance and reduce the need for harmful pesticides often required for artificially planted, exotic plants. Avoid over-watering.
- Minimize impervious surfaces and lawns of shoreline residences because they do not absorb runoff efficiently.
- Footpaths should be narrow, winding and stabilized with mulch, wood chips, paving stones, bricks, or cement tiles to prevent erosion of bare soil.
- Place hay bales or silt fences below areas of exposed soil during construction to control runoff.
- Gravel trenches or rock-lined drip edges near roof gutter outlets, patios, and driveways allow rainwater to filter gradually into the ground.
- Establish or maintain areas with buffering capacity between areas of potential high erosion and water bodies.

Roads

- Consider formation of a road association to monitor camp roads within each watershed for erosion problems and lobby for maintenance.
- The Regional Park can play an important role in protecting Lake George by working to enhance buffering around the boat launch, parking areas, and along the park access roads.
- Hire DEP-certified contractors to conduct all road work.
- Higher risk roads in close proximity to the lake should receive first priority for repair and maintenance because of their potential to contribute high levels of nutrient loading.
- Switchbacks as well as water diversions should be present on steep roads and driveways that descend to the adjacent water's edge.
- Generally road repairs should be prioritized in this order: crown, ditching, water diversions and culverts, and lastly surface composition.

Boat Launches

Lake George

- Reduce width and install water diversions on boat launch.
- Consider replacing the existing gravel launch with concrete.
- Post signs warning of invasive species.

Oaks Pond

- Educate the residents about minimizing the impact of private boat launches.

Septic Systems

- The towns of Canaan and Skowhegan should conduct a survey to assess the overall condition of septic systems in the watershed.
- Encourage property owners to update grandfathered systems to meet current standards.
- The towns of Canaan and Skowhegan should apply for state grants or use property tax revenues to identify and update malfunctioning grandfathered septic systems.
- Educate the community about regular septic system maintenance.

Land Use

- The majority of the Lake George and Oaks Pond combined watershed consists of mature forest, which should be maintained because it benefits water quality. Community mem bers need to be aware of the impacts that extensive development and potential logging can have on water quality.
- Future land use decisions should be made carefully with consideration of moderate to high erosion areas and necessary mitigation procedures.

Monitoring and Education

- Consistent monitoring of phosphorus levels and transparency in the spring, summer, and fall. Continue participation in the Volunteer Lake Monitoring Program for Oaks Pond and expand participation to include Lake George.
- Limit the amount of phosphorus entering Lake George and Oaks Pond by not using fertilizer in shoreline areas. Shoreline residents should also consider using low phosphate soaps and detergents.
- Protect existing wetlands against human encroachment to maintain their capacity as a buffer and nutrient sink.
- Formation of lake associations for Lake George and Oaks Pond to promote protection and enhancement of lake water quality.
- Residents should be mindful of trash, paints, and other hazardous materials that could leach through the soil and contaminate nearby water bodies.

LAKE GEORGE REGIONAL PARK

- Continue to promote education through community programs and involvement with schools. Educational programs could emphasize natural history of the park, ecology of vernal pools, and park archaeology.
- Continue to promote environmentally sound recreational practices on park lands through out the year.
- Trail maps and natural history guides should be made available for interested visitors and teachers to learn about the surrounding forest ecology.
- The ongoing implementation of trail maintenance strategies is necessary to maintain the quality of the trails and to prevent excess surface runoff and erosion.
- Improve trail signage and post any trail restrictions in highly visible locations.

INVASIVE SPECIES

- Post signs near the public boat launches to inform boaters of the laws and regulations to help prevent the introduction of these species.
- Inform local residents of the invasive species problem and encourage cleaning of all boating and fishing equipment of all plant material before using any boat launches.
- Encourage cleaning of all boating and fishing equipment of all plant material when traveling between lakes to avoid the introduction of invasive species that threaten Lake water quality. Be sure to properly dispose of all plant material in upland areas.

FISH POPULATIONS

- Stock brown trout in both Lake George and Oaks Pond.
- Inlets and outlets of these lakes should be kept clear for passage of fish species between the watersheds and areas further downstream.
- Monitor status of fisheries in both lakes.
- If necessary, utilize strict regulations on fishing to recover fish populations.

COMMUNITY AWARENESS

- The Towns of Canaan and Skowhegan, in collaboration with the Department of Environ mental Protection, could produce a pamphlet outlining best management practices for shoreline homeowners. These guidelines would help residents to minimize phosphorus loading and maintain water quality.

ACKNOWLEDGEMENTS

This report has been made possible through the help of numerous community residents and Town Officials of the municipalities of both Canaan and Skowhegan. Roy Bouchard and Karen Hahnel from the Maine Department of Environmental Protection and Tom Marcotte and Randy Gray, town officials from Skowhegan, have been very helpful. We would particularly like to thank Bob Hubbard, William Reid, and Steve Dionne for allowing us to use their boats for water sampling and buffer strip analysis. Bob Hubbard and Nancy Warren's general knowledge of Lake George and Steve Dionne's knowledge of Oaks Pond and were invaluable.

The Colby Environmental Assessment Team would like to thank the following people who contributed their time and knowledge to this study. Without their support and cooperation this report would not have been possible.

Forrest Bonney
Roy Bouchard
Russell Cole
Jeff Dennis
Steve Dionne
David Firmage
Bev Fitzsimmons
Randy Gray
Karen Hahnel
Bob Hubbard
William Reid
Jeff Macabe
Tom Marcotte
Pam Parker
Judy Potvin
James Stahlnecker
Dan Tierney
Nancy Warren
Canaan Town Office Staff
Skowhegan Town Office Staff

PERSONAL COMMUNICATIONS

Bouchard, Roy	Maine Department of Environmental Protection
Cole, Russell	Professor of Biology, Colby College
Dennis, Jeff	Maine Department of Environmental Protection
Dionne, Steve	Volunteer Lake Monitoring Participant - Oaks Pond
Firmage, David	Professor of Biology, Colby College
Fekete, Frank	Professor of Biology, Colby College
Gray, Randy	Code Enforcement Officer for Towns of Canaan and Skowhegan
Hahnel, Karen	Maine Department of Environmental Protection
Hubbard, Bob	Lake George Regional Park Manager
Marcotte, Tom	Skowhegan Town Planner
Parker, Pamela	Maine Department of Environmental Protection
Powell, George	Department of Conservation
Reid, William	Skowhegan Conservation Commission, Chairman
Ricker, Garnet	Forester with Plum Creek Timber Company, Inc.
Stahlnecker, James	Maine Department of Inland Fisheries and Wildlife
Warren, Nancy	Director of Lake George Regional Park

LITERATURE CITED

Abramovitz, J. 1997. Valuing Nature's Services. ed. L. R. Brown. State of the World. W. Norton and Company, New York, NY.

ATSDR. 2001. ToxFAQs. Agency for Toxic Substances and Disease Registry. http://www.atsdr.cdc.gov/. updated 6/11/01 (accessed 10/27/01).

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

BI493. 1994. Land Use Patterns in Relation to Lake Water Quality in the Salmon Lake Watershed. Colby College, Department of Biology, Waterville, ME.

BI493. 1995. Land Use Patterns in Relation to Lake Water Quality in the Long Pond, North Basin Watershed. Colby College, Department of Biology, Waterville, ME.

BI493. 1996. Land Use Patterns in Relation to Lake Water Quality in the Long Pond, South Basin Watershed. Colby College, Department of Biology, Waterville, ME.

BI493. 1997. Land Use Patterns in Relation to Lake Water Quality in the North Pond Watershed. Colby College, Department of Biology, Waterville, ME.

BI493. 1998. Land Use Patterns in Relation to Lake Water Quality in the Messalonskee Lake Watershed. Colby College, Department of Biology, Waterville, ME.

BI493. 1999. Land use Patterns in Relation to Lake Water Quality in the Great Pond Watershed. Colby College, Department of Biology, Waterville, ME.

BI493. 2000. Water Quality in East Pond: Factors Contributing to Algal Blooms and Strategies for Remediation. Colby College, Department of Biology, Waterville, ME.

BI493. 2001. Land use Patterns in Relation to Lake Water Quality in the Lake Wesserunsett Watershed. Colby College, Department of Biology, Waterville, ME.

Brönmark, C. and L.A. Hansson. 1998. The Biology of Lakes and Ponds. Oxford University Press, Oxford, England.

Bouchard, R. 2000. The Economics of Lakes: More on Dollars and $ense. Maine Department of Environmental Protection Lake Assessment Program, Augusta, ME.

Boyd, C.E. 2000. Water Quality: An Introduction. Kluwer Academic Publishers, Boston, MA.

Boyle, K., J. Scheutz, and J. Kahl. 1997. Great Ponds Play an Integral Part in Maine's Economy. University of Maine Orono, Orono, ME.

Canaan, Town of. 1997. A Report on our Past, Present, and Future. Town of Canaan Comprehensive Plan, Canaan, ME.

Canaan, Town of. 2001. Town of Canaan Shoreland Zoning Ordiance. Canaan, ME.

Carpenter, S., N.F. Caraco, D.L. Correll, R.W. Howarth, A.N. Sharpley, and V.H. Smith. 1998. Nonpoint Pollution of Surface Waters with Phosphorus and Nitrogen. Issues in Ecology 3:1-12.

Cashat, J.P. 1984. Design and Maintenance of Unpaved Roads. Unpaved Roads 115:154-158.

Caswell, W.B. 1987. Groundwater Handbook for the State of Maine. Maine Geological Survey, Augusta, ME.

Chapman, D., ed. 1996. Water Quality Assessments: A Guide to the Use of Biota, Sediments and Water in Environmental Monitoring. Second ed. E & FN Spon, London, England.

Chiras, D.D. 1994. Environmental Science-Action for a Sustainable Future. Benjamin and Cummings Publishing Company, Reading, MA.

Clarke, K.C. 2001. Getting started with Geographic Information Systems. Prentice Hall, Upper Saddle River, NJ.

Clesceri, L S., A.E. Greenberg, and R R. Trussell, eds. 1989. Standard Methods for the Examination of Water and Wastewater, 17th Edition. American Public Health Association, Washington, D.C.

Cooke, G.D., E.B. Welch, S.A. Peterson, and P.R. Newroth. 1986. Lake and Reservoir Restoration. Butterworth, Boston, MA.

Cumberland County Soil and Water Conservation District and Portland Water District. Fact Sheet #05: Vegetated Phosphorus Buffer Strips, Cumberland, ME.

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 Experiment Station. Technical Bulletin 88.

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

Duda, A. M., M.L. Iwanski, R.J. Johnson, and J.A. Jaksch. 1988. Numerical standards for managing lake and reservoir water quality. In: Water Quality Standards for Lakes: a Survey. North American Lake Management Society, Merrifield, VA.

DWP. 2001. Arsenic in Drinking Water. State of Maine Drinking Water Program. http://www.state.me.us/dhs/eng/water/Arsenic%20Facts.htm. updated 9/12/01 (accessed 10/27/01).

Eaton, A.D., L.S. Clesceri, and A.E. Greenberg. 1995. Standard Methods for the Examination of Water and Wastewater. Nineteenth ed. American Public Health Association, Washington, D.C.

Elliot, W.J., D. Page-Dumroese, and P.P.R. Robichaud. 1999. The effects of Forest Management on Erosion and Soil Productivity, in R. Lal, ed. Soil Quality and Soil Erosion. CRC Press, Boca Raton, FL.

EPA. 1980. Design Manual: Onsite Wastewater Treatment and Disposal Systems. Environmental Protection Agency, Washington, D.C.

EPA. 2001. Watershed Profile. Environmental Protection Agency. http://cfpub1.epa.gov/surf/huc.cfm?huc_code=01030003. updated 11/5/01 (accessed 11/5/01).

ESRI. 1998. Getting to know ArcView GIS. Environmental Systems Research Institute Inc., Redlands, CA.

ESRI. 1999. ArcView 3D Analyst. Environmental Systems Research Institute Inc., Redlands, CA.

ESRI. 2000a. ModelBuilder. Environmental Systems Research Institute Inc., Redlands, CA.

ESRI. 2000b. What is GIS? Environmental Systems Research Institute Inc http://www.gis.com/whatisgis/whatisgis.pdf. updated 7/21/00 (accessed 9/27/01)

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

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

Griswold, S.S. 1996. A Handbook on Trail Building and Maintenance for National, State and Local Natural Resource Managing Agencies. Sequoia Natural History Association, Three Rivers, CA.

HACH. 1997. DIR 4000 Spectrophotometer Instrument Manual. Fifth ed. HACH Company, Loveland, CO.

Hardesty, C. and C. Kunhs. 1998. The Buffer Handbook. A Guide to Creating Vegetated Buffers for Lakefront Properties, Maine Department of Environmental Protection, Lewiston, ME.

Hem, J.D. 1970. Study and Interpretation of the Chemical Characteristics of Natural Water. United States Government, Printing Office, Washington, D. C.

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

Herrick, J.E., M.A. Weltz, J.D. Reeder, G.E. Schuman, and J.R. Simanton. 1999. Rangeland Soil Erosion and Soil quality: Role of Soil Resistance, Resilience, and Disturbance Regime, in R Lal, ed. Soil Quality and Soil Erosion. CRC Press, Boca Raton, FL.

IF&W. 1998. Endangered and Threatened Species. Maine Inland Fisheries and Wildlife. ist.htm" http://www.state.me.us/ifw/wildlife/endangered/slist.htm. updated 3/15/98 (accessed 11/16/01).

IF&W. 2001a. Fishing Homepage. Department of Inland Fisheries and Wildlife. http://www.state.me.us/ifw/fish/fish.htm. updated 6/27/01 (accessed 10/15/01).

IF&W. 2001b. General Laws and Regulations Pertaining to Ice Fishing. Maine Department of Inland Fisheries and Wildlife. /if-gen.html" http://www.state.me.us/ifw/fish/if-gen.html. (accessed 9/25/01).

IF&W. 2001c. Tim Obrey. Why Splake? Department of Inland Fisheries and Wildlife. http://www.state.me.us/ifw/fish/f-shysplake.htm. updated 6/28/01 (accessed 10/15/01).

Jeppesen, E. 1998. The structing role of submerged macrophytes in lakes. Springer-Verlag New York, Inc., New York, NY.

Knox, C.E. and T.J. Nordensen. 1955. Average annual runoff and precipitation in the New England-New York area. Hydrologic Investigations Atlas, Report HA-0007. U. S. Geological Survey, Reston, VA.

Lal, R. 1990. Soil Erosion in the Tropics. McGraw-Hill, New York, NY.

Lampert, W. and U. Sommer. 1997. Limnoecology: the Ecology of Lakes and Streams. Oxford University Press, New York, NY.

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

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

Leung, Yu- Fai and J.L. Marion. 1996. Trail Degradation as Influenced by Environmental Factors: A State-of-the-Knowledge Review. Journal of Soil and Water Conservation. 51:130-136

Light, D.L. 1995. The National Aerial Photography Program: An Aerial System, in Support of the United States Spatial Data Infrastructure. http://ltpwww.gfsc.nasa.gov/ISSSR-95/natl.htm. (accessed 11/8/01).

Mairs, D.F. 1966. A Total Alkalinity Atlas for Maine Lake Waters. Limnology and Oceanography. 11: 68-72.

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

Marsh-McBirney Inc. 1990. MM1 Model 200 Flo-Mate portable water flowmeter instruction manual. Marsh-McBirney Inc, Frederick, MD.

MacCallum, W.E. (Director). 2001. Guidelines for the Certification of Vernal Pool Habitat. Commonwealth of Massachusetts Division of Fisheries and Wildlife

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

MDC. 1996. Aquifer Mapping. Maine Department of Conservation. http://www.state.me.us/doc/nrimc/pubedinf/factsht/surficial/surfmap.htm. updated 5/15/96 (accessed 10/15/01).

MDEP. 1990. Comprehensive Planning for Lake Watersheds. Maine Department of Environmental Protection, Augusta, ME.

MDEP. 1991. Proposed Ammendments to the Subdivision Ordinance for the Town of Dedham. Maine Department of Environmental Pr tection, Augusta, ME.

MDEP. 1992a. State of Maine Guidelines for Municipal Shoreline Zoning Ordinances. Maine Department of Environmental Protection, Augusta, ME.

MDEP. 1992b. Phosphorus Control in Lake Watersheds: A Technical Guide to Evaluating New Development. Maine Department of Environmental Protection, Augusta, ME.

MDEP. 1998a. Maine Shoreland Zoning: A Handbook for Shoreland Owners. Maine Department of Environmental Protection, Augusta, ME.

MDEP. 1998b. MIDAS Lakes Database. Maine Department of Environmental Protection, Augusta, ME.

MDEP. 2000. MIDAS Report 2000. Maine Department of Environmental Protection, Augusta, ME.

MDEP. 2001. Natural Resources Protection Act (NRPA). State of Maine Department of Environmental Protection. http:///docstand/- nrpapage.htm" www.state.me.us/dep/blwq/docstand/-nrpapage.htm. updated10/04/01 (accessed 11/12/01).

MDEP PEARL. 2001. Public Education Access to Environmental Information Homepage. http://pearl.spatial.maine.edu/ (accessed 9/20/01).

MDHS. 1983. Site Evaluation for Subsurface Waste Water Disposal Design in Maine (second edition). Maine Department of Human Services, Augusta, ME.

MDHS. 1988. State of Maine Subsurface Wastewater Disposal Rules - Chapter 241. Department of Human Services, State House, Augusta, ME.

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

MEGIS. 2001. Maine GIS Data. Maine Office of GIS. http://apollo.ogis.state.me.us/homepage.asp. updated 7/16/01 (acessed 9/15/01).

Michaud, M., ed. 1992. Camp Road Maintenance: A Guide for Landowners. Kennebec County Soil and Water Conservation District. NTIS, 2nd Edition, Augusta, ME.

Mitsch, W.J. and J.G. Gosselink. 1993. Wetlands. Von Nostrand Reinhold, New York, NY.

MLURC. 1976. Comprehensive Land Use Plan. Maine Land Use Regulation Commission, Maine Department of Conservation, Augusta, ME.

NCSU. 2001. Heavy Metals. North Carolina State University: Water, Soil and Hydro-environmental Decision Support System. http://h2osparc.wq.ncsu.edu/info/hmetals.html. updated 10/19/01 (accessed 10/27/01). CHEM

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

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

NOAA. 1990-2000. Climatological Data Annual Summary New England. National Oceanic and Atmospheric Administration, Asheville, NC.

Norton, S.A., D.F. Bracke, J.S. Kahl, and T.A. Haines. 1989. Major Influences on Lake Water Chemistry in Maine. Maine Geological Survey: Studies in Maine Geology. 5.

NRC. 1999. Arsenic in Drinking Water. National Research Council. http://books.nap.edu/books/0309076293/html/14.html#pagetop. updated 2/11/99 (accessed 10/30/01).

NREPC. 2001a. Hardness and water quality. Kentucky Natural Resources and Environmental Protection Cabinet. http://water.nr.state.ky.us/ww/rmhard.htm. updated 09/03/97 (accessed 09/30/01).

NREPC. 2001b. Alkalinity and water quality. Kentucky Natural Resources and Environmental Protection Cabinet. http://water.nr.ky.state.us/ww/ramp/rmalk.htm. updated 09/03/97 (accessed 9/30/01).

Orion Research Inc. 1999. ORION Laboratory Products Model 840 Dissolved Oxygen Meter Instruction Manual.

Overcash, M.R. and J.M. Davidson. 1980. Environmental Impact of Nonpoint Source Pollution. Ann Arbor Science Publishers Inc., Ann Arbor, MI.

Parkin,D., J. Lortie, R. Humphrey, and F. DiBello. 1989. Woodlot Alternatives. Maine's Finest Lakes: The Results of the Maine Lakes Study. Report Prepared for the Maine Critical Areas Program, Maine State Planning Office. Planning Report No. 90. Augusta, ME.

Patrick, W.H. 1994. From Watersheds to Wetlands. Journal of Environmental Quality 23: 892-96.

Pearsall, W. 1993. Understanding Maine's Lakes and Ponds: A Guide for the Volunteer Lake Monitoring Program. Maine Department of Environmental Protection, Augusta, ME.

Prescott, G.C. Jr. 1969. Goundwater Favorability Areas and Surficial Geology of the Lower Kennebec River Basin, Maine. US Department of the Interior, US Geological Survey, Washington, D.C.

Prescott, L.M., Harley, J.P. and D.A. Klein. 2002. Microbiology. Fifth ed. McGraw-Hill, New York, NY.

Proudman, R.D. 1977. AMC Field Guide to Trail Building and Maintenance. Appalachian Moun tain Club, Pincome Notch, NH.

Reckhow, K.H., and S.C. Chapra. 1983. Engineering Approaches for Lake Management. Data Analysis and Empirical Modeling. Butterworth Publishers, Boston, MA.

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

Schauffler, F. 1990. Watershed: An Action Guide to Improving Maine Waters, Augusta, ME.

Skowhegan, Town of. 1995. Town of Skowhegan 1995 Comprehensive Plan. Skowhegan, ME.

Skowhegan. 2001. Town of Skowhegan Shoreland Zoning Ordiance. Skowhegan, ME.

Smith, R.L. and T.M. Smith. 1998. Elements of Ecology. Wesley Longman, Inc., San Francisco, CA.

Smith, R.L. and T.M. Smith. 2001. Ecology and Field Biology. Wesley Longman, Inc., San Francisco, CA.

Stahlnecker, J., M. Robillard, and T. Squiers. 1992. Kennebec River Anadromous Fish Restoration Annual Progress Report. Maine Department of Marine Resources, Augusta, ME.

State of Maine-116th Legislature. 1994. An Interim Report of the Great Pond Task Force to the Joint Standing Committee on Energy and Natural Resources, Augusta, ME.

TIGER. 2001. Topographically Integrated Geographic Encoding and Referencing-1990 Census. http://data.esri.com/data/online/tiger/index.html. (accessed 11/15/01).

TLEA. 1999. A Handy Guide for Homeowners. Thompson Lake Environmental Association. Oxford Hills Printing, Oxford, ME.

Thoreau, H.D. 1877. The Maine Woods. J.R. Osgood and Company, Boston, MA.

Tyler, H. 1999. Great Pond Task Force Final Report. Maine State Planning Office, Augusta, ME.

USDA. 1972. Soil survey of Somerset County, Maine: Southern part. United States Department of Agriculture, Washington D.C.

USDA. 1978. Soil Survey of Kennebec County, Maine, USA. Soil Conservation Service. United States Department of Agriculture, Augusta, ME.

USDA. 1989. Soil Survey Data for Growth Management in Kennebec County, Maine. Soil Conservation Service, United States Department of Agriculture, Augusta, ME.

USDA. 1992. Engineering Criteria for Soils Mapped in Maine. United States Department of Agriculture, Augusta, ME.

USDA. 2000. How Extensive is Pollution from Agriculture? United States Department of Agriculture. http://www.ers.usda.gov/briefing/conservationandenvironment/- questions/consenvwq1.htm. updated 12/19/00 (accessed 11/5/01).

USEPA. 1980. Design Manual- On Site WasteWater Treatment and Disposal Systems. United States Environmental Protection Agency, Office of Water Program Operations, Office of Research and Development, Municipal Environmental Research Laboratory, Washington, D.C.

USEPA. 1990. Chapter 4: Predicting Lake Water Quality. (ed.), The Lake and Reservoir Restoration Guidance Manual. United States Environmental Protection Agency, Washington, D.C.

USGS. 2001. Explanation of hardness. United States Geological Survey. http://water.usgs.gov/owq/Explanation.html. (accessed 10/30/01).

Warren, N. 2001. Park provides unique opportunities for interns. Northeaster. Unity College, Unity ME.

Wetzel, R.G. and G.E. Likens. 1991. Limnological Analyses. Springer-Verlag, New York, NY.

Williams, S. 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.

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

APPENDIX A. GENERALIZED CHARACTERISTICS OF OLIGOTROPHIC, EUTROPHIC, AND DYSTROPHIC LAKES (ADAPTED FROM MAITLAND 1990).

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

APPENDIX B. FISH SPECIES OF LAKE GEORGE AND OAKS POND AND ADDITIONAL SPECIAL INFORMATION FOR CERTAIN SPECIES

Information obtained from Inland Fisheries and Wildlife, unpublished document.

Species	Location	Special Characteristics
Warm Water		
Bass, Largemouth *Micropterus salmoides*	Lake George/Oaks Pond	Principle fishery, unauthorized introduction in Oaks Pond
Bass, Smallmouth *Micropterus dolomieui*	Lake George/Oaks Pond	Principle fishery
Bullhead, Brown *Ictalurus nebulosus*	Lake George/Oaks Pond	
Burbot (cusk) *Lota lota*	Lake George/Oaks Pond	
Crappie, Black *Pomoxis nigromaculatus*	Oaks Pond	Unauthorized introduction
Eel, American *Anguilla rostrata*	Lake George/Oaks Pond	
Fallfish *Semotilus corporalis*	Lake George/Oaks Pond	
Perch, White *Morone americana*	Lake George/Oaks Pond	Principle fishery
Perch, Yellow *Perca flavescens*	Lake George/Oaks Pond	
Pickerel, Chain *Esox niger*	Lake George/Oaks Pond	Principle fishery
Shiner, Common *Notropis cornutus*	Lake George/Oaks Pond	
Shiner, Golden *Notemigonus crysoleucas*	Lake George/Oaks Pond	
Smelt, Rainbow *Osmerus mordax*	Lake George/Oaks Pond	
Sucker, Common *Catostomus commersoni*	Lake George/Oaks Pond	
Sunfish, Pumpkinseed *Lepomis gibbosus*	Lake George/Oaks Pond	

APPENDIX B. (CONTINUED)

Species	Location	Special Characteristics
Warm Water		
Sunfish, Redbreast *Lepomis auritus*	Lake George	
Alewife, Sea-run *Alosa pseudoharengus*	Lake George/Oaks Pond	Discontinued stocking as of 1993
Cold Water		
Trout, Brook *Salvelinus fontinalis*	Lake George/Oaks Pond	Last stocked in 1998 in Lake George
Trout, Brown *Salmo trutta*	Lake George/Oaks Pond	Principle fishery and stocked, in both lakes
Trout, Rainbow *Salmo gairdneri*	Lake George	Stocked fall of 2001
Splake	Lake George/Oaks Pond	Stocked

APPENDIX C. QUALITY ASSURANCE

The Lake George and Oaks Pond study followed a quality assurance plan that standardized the procedures of CEAT. The following document was modified from BI493 (1998).

Bottle Preparation

1. All samples for total phosphorus analyses were triple acid rinsed with 1:1 HCL before use to prevent contamination.
2. A one to one ratio of HCL is 1 L of E-pure water and 1 L of concentrated hydrochloric acid.
3. If an epicore sample was taken, the mixing bottle was triple acid rinsed once before each sampling trip and was rinsed out with E-pure after each sampling was completed.

Approaching Site

1. When approaching the test site, speed up first, then kill the engine and coast to the sampling site.
2. Always sample from the bow of the boat, into the wind to reduce contamination.

Surface Sampling

1. Remove cap from sample bottle without touching lip of bottle or edge of cap.
2. Invert and immerse bottle to approximately 0.5 m down. Turn bottle on its side and move it through the water away from the boat.
3. Tilt bottle upright, remove from water, and cap. Place bottle in cooler.

Secchi Disk

1. Make a duplicate reading every 10^{th} reading.
2. Use Aqua-scope to view the disk.
3. Lower until the disk is out of sight, then record the depth.
4. Lower the disk an extra meter, then bring it back into sight and record the depth.

Measuring Depth

A. LCD Digital Sounder (Depth Finder)

1. Put the lanyard of the depth finder around your wrist.
2. Put the depth finder in the water and push the switch towards the bottom of the lake (in the direction of the arrow). Hold for 3 seconds.
3. The depth finder must be pointed straight down. Record this depth.

APPENDIX C. (CONTINUED)

4. Repeat this process one time.

B. Drop line/Measuring Tape

1. Drop the depth line into the water quickly and vertically until you feel slack, then gently pull the slack out of the line, bringing it through the muck and being careful not to lift the sinker off the bottom. Record this depth by counting the black tick marks on the line. Each black tick is 1 m.
2. Repeat this process one time.

Conductivity

1. Use the 250 ml Nalgene bottle labeled for conductivity test.
2. Follow surface sampling procedure.
3. Place water sample on ice in cooler.

Turbidity

1. Use the 250 ml Nalgene bottle labeled for turbidity test.
2. Follow surface sampling procedure.
3. Turbidity was measured in the field using a HACH™ 2100N Turbidimeter.

Acidification of Hardness Samples

1. Rinse bottle lids with distilled water and add a small amount of the sample to the lid.
2. Test the water's pH in the sample bottle lid. Add concentrated nitric acid (HNO_3) to your sample drop by drop until it is below a pH of 2.
3. The same number of drops of acid should be added to all the other bottles of the same size and same test.

Acidification of Nitrate Samples

1. Rinse bottle lids with distilled water, and add a small amount of the sample to the lid.
2. Test the water's pH in the sample bottle lid. Add concentrated sulfuric acid (H_2SO_4) to your nitrate test sample drop by drop until the pH is below 2.
3. The same number of drops of acid should be added to all the other bottles of the same size and same test.

APPENDIX C. (CONTINUED)

Using pH Meter

A. Proper calibration method. (Before any testing is done, the pH meter must be calibrated using a 2-point calibration method at pH 7 and pH 4. This should be done only once during the testing day, as long as the meter's calibration is not accidentally deleted).

1. Press the POWER button. The pH meter automatically enters the measurement.
2. Apply the pH 7 solution by opening the sensor guard and wetting the entire probe well.
3. Press the CAL button once. The sensor guard will display 7.0 and a CAL symbol will appear at the bottom right hand corner followed by a smiley face indicating it is done.
4. After calibration, rinse the sensor well with E-pure (highly filtered and de-ionized water).
5. Repeat calibration for pH 4.
6. Take care to rinse probe with distilled water prior to and following each measurement.

B. Measurement

1. Lift the lid to the probe well and immerse the pH meter 0.5m to 1.0 m below the surface.
2. Close the lid. Bring the meter to the surface and record the reading after the
3. Smiley face has appeared in the bottom right hand corner.

C. Quality Assurance

1. Take the pH reading twice at each site to assure accuracy.

Dissolved Oxygen (DO) Meter

1. Lower DO/Temperature meter into water, shaking it to make sure there are no bubbles around the probe.
2. Immerse probe until covered. Record DO and temperature readings.
3. Lower probe 1 m at a time. Record DO and temperature for every meter until the bottom is reached.

Mid-Depth and Bottom Sample

1. Pull rubber stoppers out of the ends of the bottom sampler.
2. Hook metal cables to the two small pegs located at the top of the sampler.
3. After taking depth reading, lower sampler to mid-depth sample depth. Release sliding weight to close water sampler.

APPENDIX C. (CONTINUED)

4. Pull out water sampler. Open air valve and open black tap by pushing outside ring of tap in. Drain tap for a few seconds.
5. Fill sample bottle to bottom of neck and cap. Place bottle in cooler.
6. Empty water sampler. Repeat sampling procedure for Bottom sample.
7. Take bottom sample 1 m above bottom.

<u>Epicore</u>

1. Rinse the tube three times by lowering it down into the lake water and pulling it back out.
2. For sites with great depth lower the tube down to 1 m below the thermocline (measured in the DO profile).
3. For shallow sites (all other sites) lower the epicore 1 m from the bottom.
4. The tape marks indicate 1 m.
5. Crimp the tubing just above the water (this is best done by bending it tightly and then holding it in your hand).
6. Pull the tubing up making sure that the excess tubing goes into the water. Be careful not to touch the end at which the water comes out.
7. Allow the water to drain into the large bottle being careful not to touch the inside of the bottle or the cap or the end of the tube.
8. Make sure to keep the non-pouring end of the tube up so the water does not drain out of it and that it does not take up surface water.
9. Hold up the crimped area and undo the crimp. Continue raising the tubing and move towards the draining end.
10. Repeat process three times, draining all of the water into the epicore mixing bottle.
11. Pour about 125 ml of this water into two Erlenmeyer flasks (fill to just below the neck). Again be careful not to contaminate the bottles by touching the inside of the bottle or the inside of the bottle cap.
12. Discard the remaining water and rinse the mixer with E-Pure water. Place all samples into the cooler.

<u>Flo-Mate</u>

1. Turn the meter on. Place the black sensor entirely underwater, with the bulb facing upstream.
2. The meter will read the flow in either ft/s or m/s. Press the on/c and off keys at the same time to switch between the two.

APPENDIX C. (CONTINUED)

3. Fixed Point Average (FPA) will take more accurate readings (hold up and down arrows at the same time). A time bar will move across the screen. When it reaches the far side, a new average velocity will be displayed.
4. Divide the topography of the stream into equal sections and measure the flow in each segment.

Global Positioning System (GPS)

1. Turn on the GPS.
2. Wait for the screen to display coordinates of position.
3. At the desired location record the coordinates or press "enter" to store the waypoint.

Quality Control Sampling

1. E-pure samples were spiked (in groups of ten) with a known amount of concentrated standard and run against a standard curve to confirm accuracy of technician before water samples were analyzed for each test. This accuracy test was run until the values of the test samples were within 10 percent of each other.
2. Duplicate samples were taken every tenth sample to test the accuracy of sampling procedures.
3. Samples were split every tenth sample in the laboratory to test lab procedure.

Total Phosphorus

1. The method used was Eaton, Clesceri, and Greenberg 1995, modified by G. Hunt and C. Elvin of the MDEP.
2. For every ten samples, splits and duplicates were collected or made.
3. Known concentrations of phosphorus in E-pure water were made on every run to test lab precision.
4. Reagent blanks were used to make a standard curve to determine the concentration of phosphorus studied. The standard curve should have a minimum of 6 points.
5. The accuracy of the Ascorbic Acid method used for total phosphorus analysis had a detection point less than 1 ppb.
6. Water samples were preserved for the analysis of total phosphorus by digesting them with sulfuric acid and ammonium peroxydisulfate, and then autoclaving at 15 psi for 30 minutes.
7. Analysis was conducted within 28 days of sampling date.

APPENDIX C. (CONTINUED)

Hardness

1. For every ten samples, splits and duplicates were collected or made.
2. The water samples were preserved for the analysis of hardness by adding nitric acid in the field until the pH was less than 2.
3. A HACH titration method, adapted from the EDTA Titrimetric Method was used to measure hardness (HACH 1997).
4. The limit of detection for the HACH DR/4000 spectrophotometer Hardness test is 0.03 ppm $CaCO_3$. The range of the test is 0.03 ppm to 4.00 ppm $CaCO_3$.
5. Analysis was conducted within 14 days of sampling date.

Alkalinity

1. One duplicate sample was taken for every ten samples.
2. The Potentiometric Method was used to analyze the samples (Eaton, Clesceri, and Greenberg 1995).
3. Analysis was conducted within 14 days of sampling date.

Color

1. One duplicate sample was taken for every ten samples.
2. Color should not vary more than ± 5 SPU.
3. Color standards were kept in the dark and protected from evaporation.
4. The HACH Platinum-Cobalt Standard Method and HACH DR/4000U spectrophotometer were used for the color test (HACH 1997).
5. The limit of detection for the test is 2 units Pt-Co. The range of the test is 0 units to 500 units.
6. Analysis was conducted within 48 hours of sampling date.

Conductivity

1. One duplicate sample was taken for every ten samples.
2. Results should not vary more than 1 μmhos/cm^2.
3. De-ionized water should read less than 1 μmhos/cm^2.
4. The water sampler was used at the desired stratification.
5. The water sample was poured into a 250 ml beaker.
6. A Model 31A YSI Conductance Bridge was used to measure conductivity in the Colby Environmental Laboratory.
7. Analysis was conducted within 24 hours of sampling.

APPENDIX C. (CONTINUED)

Nitrates

1. For every ten samples, splits and duplicates were collected or made.
2. Nitrates were analyzed using the Nitrate, Low Range Cadmium Reduction Method and the HACH DR/4000 Spectrophotometer (HACH 1997).
3. The limit of detection for the test is 0.2 ppm NO_3-N. The range for the test is 0.0 ppm to 0.50 ppm NO_3-N.

Analysis was conducted within 14 days of sampling date.

APPENDIX D. CONDUCTIVITY, COLOR, AND TURBIDITY FOR LAKE GEORGE AND OAKS POND.

LAKE GEORGE

Samples taken on 12-Sep-01 by the Colby Environmental Assessment Team. Characterization Sites were Sites 1, 2, 3, and 8. Spot Sites were Sites 4, 5, 9, 10, 11, 12, and 13. Tributary Site were Sites 6, 7, and 14. See Lake George site map for site locations (Figure 15).

Site	Location	Conductivity (µMHOs/cm)	Color (SPU)	Turbidity (NTU)
1	surface	24.7	18	0.50
1	surface	27.1 [a]	14 [a]	-
2	surface	25.4	26	1.00
3	surface	24.9	29	0.50
4	surface	26.1	-	1.00
5	surface	25.0	-	0.68
6	surface	-	-	-
7	surface	-	-	-
8	surface	25.0	27	0.40
9	surface	-	-	0.43
10	surface	26.0	-	0.40
12	surface	26.2	-	0.40
13	surface	26.0	-	1.00
14	surface	26.2	45	1.00

[a] duplicate

OAKS POND

Samples taken on 17-Sep-01 by the Colby Environmental Assessment Team. The Characterization Site was Site 8. Spot Sites were Sites 2, 3, 5, and 7. Tributary Sites were Sites 1, 4, and 6. See Oaks Pond site map for site locations (Figure 16).

Site	Location	Conductivity (µMHOs/cm)	Color (SPU)	Turbidity (NTU)
1	surface	37.5	39	0.27
2	surface	35.5	-	0.45
3	surface	35.5	-	0.58
4	surface	36.5	30	0.80
5	surface	34.0	-	0.84

APPENDIX D. (CONTINUED)

Site	Location	Conductivity (µMHOs/cm)	Color (SPU)	Turbidity (NTU)
6	surface	-	-	-
7	surface	-	-	0.98
8	surface	35.5	21	0.50

APPENDIX E. HISTORICAL CONDUCTIVITY, COLOR, pH, ALKALINITY, AND CHLOROPHYLL *A* FOR LAKE GEORGE AND OAKS POND.

LAKE GEORGE
Data obtained from MDEP for the site near CEAT Characterization Site 1 (MDEP 2000a). See Lake George site map for site location (Figure 15).

Year	Mean conductivity (μMHOS/cm)	Mean color (SPU)	Mean pH	Mean alkalinity (mg/l)	Mean chlorophyll (ppb)
1985	31	15	7.10	8.0	-
1987	36	17	6.73	8.0	2.9
1988	-	20	6.94	11.0	3.1
1989	37	17	6.98	16.6	3.9
1990	-	-	6.90	-	3.5
1991	36	15	7.30	11.0	3.1
1992	38	15	7.24	12.0	2.7
1993	33	15	6.87	12.0	3.4
1994	31	20	6.24	9.0	5.0
1995	30	-	6.60	11.0	-
1996	35	12	-	10.0	4.4
1997	-	-	-	-	-
1998	-	-	-	-	-
1999	-	-	-	-	-

OAKS POND
Data obtained from MDEP for the site near CEAT Characterization Site 8 on Oaks Pond (MDEP 2000a). See Oaks Pond site map for site location (Figure 16).

Year	Mean conductivity (μMHOS/cm)	Mean color (SPU)	Mean pH	Mean alkalinity (mg/l)	Mean chlorophyll (ppb)
1987	55	15	7.10	11.0	-
1998	60	21	-	14.0	2.3

APPENDIX F. FALL ANALYSIS OF pH, ALKALINITY (MG/L), AND HARDNESS (MG/L) LEVELS FOR LAKE GEORGE AND OAKS POND

LAKE GEORGE

Samples taken from the surface of the lake by the Colby Environmental Assessment Team on 12-Sep-01. See site map for site locations (Figure 15).

Site	pH	Alkalinity (mg/l)	Hardness (mg/l)
1	7.37	11.00	3.97
1	-	-	4.19[a]
1	-	-	4.25[a,b]
2	7.20	9.60	4.19
2	-	-	4.19[a]
2	-	-	4.14[a,b]
3	6.54	6.73	4.13
4	7.00	-	-
5	7.08	-	-
8	6.89	7.60	4.27
9	7.70	-	-
10	7.34	-	-
12	7.34	-	-
13	6.90	-	-
14	6.80	-	-

[a] duplicate
[b] split

OAKS POND

Samples taken from the surface of the lake by the Colby Environmental Assessment Team on 17-Sep-01. See site map for site locations (Figure 16).

Site	pH	Alkalinity (mg/l)	Hardness (mg/l)
1	7.09	-	-
2	6.62	-	-
3	6.99	-	-
4	6.48	-	-
5	7.16	-	-
6	6.40	-	-
7	7.33	-	-
8	7.18	3.73	3.73[a]
8	-	-	3.96[a,b]
8	-	-	3.64[a,b]

[a] duplicate
[b] split

APPENDIX G. FALL ANALYSIS OF NITRATE CONCENTRATIONS (MG/L) FOR LAKE GEORGE AND OAKS POND.

LAKE GEORGE

Samples taken on 12-Sep-01 by the Colby Environmental Assessment Team. See Lake George site map for sampling locations (Figure15).

Site	Location	Concentration
Characterization		
1	surface	0.06
1	surface	0.05[a]
1	epicore	0.04
1	epicore	0.04
2	epicore	0.04
3	epicore	0.05
8	epicore	0.04
Spot		
4	surface	0.06
5	surface	0.12
11	surface	0.06

[a] duplicate

OAKS POND

Samples taken on 17-Sep-01 by the Colby Environmental Assessment Team. See Oaks Pond site map for site locations (Figure 16).

Site	Location	Concentration
Characterization		
8	surface	0.04
8	epicore	0.05
Spot		
2	surface	0.08
3	surface	0.07
7	surface	0.05
7	surface	0.05[a]
Tributaries		
4	surface	0.05
6	surface	0.04

[a] split

APPENDIX H. TOTAL PHOSPHORUS OF SITES 1, 2, AND 3 FOR LAKE GEORGE MEASURED IN PPB.

Samples taken on 19-Jul-01 and 7-Aug-01 by the Colby Environmental Assessment Team. See Lake George site map for sampling locations (Figure 15).

Date	Site	Location	Concentration
19-Jul-01	1	surface	7.37
19-Jul-01	1	surface	10.93[b]
19-Jul-01	1	mid-depth	16.41
19-Jul-01	1	mid-depth	18.37[b]
19-Jul-01	1	mid-depth	13.48[a]
19-Jul-01	1	mid-depth	12.23[a,b]
19-Jul-01	1	bottom	17.18
19-Jul-01	1	bottom	17.94[b]
19-Jul-01	1	bottom	15.50[a]
19-Jul-01	1	bottom	16.91[a,b]
19-Jul-01	2	surface	13.64
19-Jul-01	2	surface	15.20[b]
19-Jul-01	2	mid-depth	14.42
19-Jul-01	2	mid-depth	13.26[b]
19-Jul-01	2	bottom	21.27
19-Jul-01	2	bottom	16.05[b]
7-Aug-01	1	surface	8.46
7-Aug-01	1	surface	9.47[b]
7-Aug-01	1	mid-depth	9.62
7-Aug-01	1	mid-depth	9.41[b]
7-Aug-01	1	bottom	5.01[a]
7-Aug-01	1	bottom	9.75
7-Aug-01	1	bottom	9.55[b]
7-Aug-01	1	epicore	3.61
7-Aug-01	1	epicore	7.82[b]
7-Aug-01	1	epicore	10.56[a]
7-Aug-01	1	epicore	12.85[a,b]
7-Aug-01	2	surface	3.80
7-Aug-01	2	mid-depth	5.60
7-Aug-01	2	mid-depth	7.89[b]
7-Aug-01	2	bottom	6.37

APPENDIX H. (CONTINUED)

Date	Site	Location	Concentration
7-Aug-01	2	bottom	10.08[b]
7-Aug-01	3	surface	4.65
7-Aug-01	3	surface	4.04[b]
7-Aug-01	3	mid-depth	2.96
7-Aug-01	3	mid-depth	6.14[b]
7-Aug-01	3	bottom	5.73
7-Aug-01	3	bottom	6.31[b]

[a] duplicate

[b] split

APPENDIX I. TOTAL PHOSPHORUS MEASURED IN PPB

Measured by Colby Environmental Assessment Team (CEAT) for Lake George samples taken on 28-Aug-01 and 12-Sep-01. See Lake George site map for site locations (Figure 15).

Site	Location	Concentration
Characterization		
1	surface	5.69
1	surface	6.85[a]
1	surface	7.18
1	mid-depth	11.95
1	mid-depth	9.31
1	mid-depth	10.87[a]
1	bottom	10.71
1	bottom	15.31
1	bottom	14.32
1	bottom	12.88
1	epicore	7.09
1	epicore	10.66
1	epicore	10.07
1	epicore	10.43
1	epicore	12.06
2	surface	6.29
2	surface	15.14
2	surface	13.80
2	mid-depth	10.11
2	mid-depth	7.93
2	bottom	12.78
2	bottom	5.09
2	epicore	13.43
2	epicore	11.11
2	epicore	8.77
3	surface	6.24
3	surface	6.51
3	mid-depth	8.39
3	mid-depth	8.01
3	bottom	11.46
3	bottom	10.63
3	epicore	5.81
3	epicore	4.62
3	epicore	9.28
8	surface	8.09
8	mid-depth	11.06
8	bottom	8.46
8	epicore	10.77

APPENDIX I. (CONTINUED)

Site	Location	Concentration
Spot		
4	surface	9.10
5	surface	11.71
9	surface	8.16
10	surface	12.61
10	surface	3.89
12	surface	17.85
12	surface	16.69
13	surface	9.24
Tributary		
14	surface	10.04

[a] duplicate

APPENDIX J. TOTAL PHOSPHORUS MEASURED IN PPB

Measured by Colby Environmental Assessment Team (CEAT) for Oaks Pond samples taken on 17-Sep-01. See Oaks Pond site map for site locations (Figure 16).

Site	Location	Concentration
Characterization		
8	surface	4.21
8	surface	10.85
8	mid-depth	6.77
8	bottom	40.46
8	epicore	11.00
Spot		
2	surface	5.88
2	surface	6.95
3	surface	5.67
3	surface	8.43
5	surface	10.21
5	surface	11.46
7	surface	19.27
7	surface	22.32[a]
Tributaries		
1	surface	13.92
4	surface	7.99
4	surface	10.65
6	surface	68.44

[a] duplicate

APPENDIX K. VOLATILE ORGANIC COMPOUNDS ANALYZED AT LAKE GEORGE SPOT SITE 12.

Parameter	Result	Qualifier	Unit	Detection Limit	Method	Preparation Date	Analysis Date	Analyst
2-Butanone	<10		ug/L	10	EPA 8260B	09/25/01	09/25/01	GCE
2-Nitropropane	<10		ug/L	10	EPA 8260B	09/25/01	09/25/01	GCE
Acetone	<10		ug/L	10	EPA 8260B	09/25/01	09/25/01	GCE
Acrylonitrile	<10		ug/L	10	EPA 8260B	09/25/01	09/25/01	GCE
Bromomethane	<10		ug/L	10	EPA 8260B	09/25/01	09/25/01	GCE
Chloroethane	<10		ug/L	10	EPA 8260B	09/25/01	09/25/01	GCE
Diethyl Ether	<10		ug/L	10	EPA 8260B	09/25/01	09/25/01	GCE
Tetrahydrofuran	<10		ug/L	10	EPA 8260B	09/25/01	09/25/01	GCE
2-Chloroethylvinyl Ether	<15		ug/L	15	EPA 8260B	09/25/01	09/25/01	GCE
Vinyl Acetate	<15		ug/L	15	EPA 8260B	09/25/01	09/25/01	GCE
Nitrobenzene	<25		ug/L	25	EPA 8260B	09/25/01	09/25/01	GCE
1,1,1,2-Tetrachloroethane	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
1,1,1-Trichloroethane	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
1,1,2,2-Tetrachloroethane	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
1,1,2-Trichloroethane	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
1,1-Dichloroethane	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
1,1-Dichloroethene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
1,1-Dichloropropene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
1,2,3-Trichlorobenzene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
1,2,3-Trichloropropane	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
1,2,4-Trichlorobenzene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
1,2,4-Trimethylbenzene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
1,2-Dibromo-3-Chloropropane	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
1,2-Dibromoethane	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
1,2-Dichlorobenzene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
1,2-Dichloroethane	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
1,2-Dichloropropane	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
1,3,5-Trimethylbenzene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
1,3-Dichlorobenzene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
1,3-Dichloropropane	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
1,4-Dichlorobenzene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
1-Chlorobutane	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
2,2-Dichloropropane	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
2-Chlorotoluene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
2-Hexanone	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
4-Chlorotoluene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
4-Isopropyltoluene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
4-Methyl-2-Pentanone	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Allyl Chloride	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Benzene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Bromobenzene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Bromochloromethane	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Bromodichloromethane	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Bromoform	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Carbon Disulfide	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Carbon Tetrachloride	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Chlorobenzene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Chloroform	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Chloromethane	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
cis-1,2-Dichloroethene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
cis-1,3-Dichoropropene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Dibromochloromethane	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Dibromomethane	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Dichlorodifluoromethane	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Ethyl Methacrylate	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Ethylbenzene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Hexachlorobutadiene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Hexachloroethane	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE

APPENDIX K. (CONTINUED)

Parameter	Result	Qualifier	Unit	Detection Limit	Method	Preparation Date	Analysis Date	Analyst
Iodomethane	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Isopropylbenzene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
m,p-Xylene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Methacrylonitrile	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Methyl Methacrylate	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Methylene Chloride	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
n-Butylbenzene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
n-Propylbenzene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Napthalene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
o-Xylene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Pentachloroethane	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
sec-Butylbenzene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Styrene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
t-Butyl-Methyl Ether	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
tert-Butylbenzene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Tetrachloroethene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Toluene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
trans-1,2-Dichloroethene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
trans-1,3-Dichloropropene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
trans-1,4-Dichloro-2-Butene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Trichloroethene	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Trichlorofluoromethane	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Vinyl Chloride	<5.0		ug/L	5.0	EPA 8260B	09/25/01	09/25/01	GCE
Propionitrile	<50		ug/L	50	EPA 8260B	09/25/01	09/25/01	GCE
EPA 8260 in water							09/25/01	
Toluene-d8 (Surrogate)	109		%	88	EPA 8260B	09/25/01	09/25/01	GCE
1,2-Dichloroethane-d4 (Surrogate)	115		%	76	EPA 8260B	09/25/01	09/25/01	GCE
4-Bromofluorobenzene (Surrogate)	84		%	84	EPA 8260B	09/25/01	09/25/01	GCE
Chromium Total	<0.01		mg/L	0.01	EPA 6010B	09/24/01	09/25/01	MRB

APPENDIX L. RESIDENTIAL SURVEY FORM

Residential Survey

Date:_______

Surveyor's Name(s):___________

	Residences < 200 ft from Shoreline		Residences > 200 ft from Shoreline	
Road	# Seasonal	# Year Round	# Seasonal	#Year Round
Name				

APPENDIX M. TREES, SHRUBS, AND GROUND COVER: IDEAL SPECIES FOR BUFFER STRIP COMPOSITION.

Data from Cumberland County Soil Water and Conservation District Fact Sheet #05.

Scientific Name	Common Name
TREES	
Deciduous	
Acer rubrum	Red Maple
Acer saccharum	Sugar Maple
Acer saccharinum	Silver Maple
Acer platanoides	Norway Maple
Tilia cordata	Littleleaf Linden
Fraxinus pennsylvanica	Green Ash
Malus sp.	Crabapple
Quercus rubra	Red Oak
Betula papyrifrera	Paper Birch
Gleditzia triacanthos	Honey Locust
Evergreen	
Pinus resinosa	Red Pine
Pinus strobus	White Pine
Pinus nigra	Austrian Pine
Thuja occidentalis	White Cedar
Tsuga canadensis	Eastern Hemlock
SHRUBS	
Viburnum dentatum	Arrowood
Viburnum carlesii	Korean Spice Viburnum
Viburnum tomentosum	Doublefile Viburnum
Viburnum plicatum	Cranberry Bush
Forsythia x Intermedia	Forsythia
Lonicera tatarica	Honeysuckle
Vaccinium coryimbosum	Highbush Blueberry
Cornus sericea	Red Dogwood
Cornus racemosa	Gray Dogwood
Amlelanchier laevis	Serviceberry
Rosa rugosa	Rugosa Rose
Elaeagnus umbellata	Autumn Olive
Ilex verticillata	Winterberry
Myrica pennsylvanica	Bayberry
Spiraea sp.	Spiraea
Syringa sp.	Lilacs
Potentilla fruticosa	Potentilla
Juniperus sp.	Juniper
Berberis sp.	Barberry
Euonymus alatus	Burning Bush
Rhododendron sp.	Rhododendrons
	Azaleas
VINES AND GROUNDCOVERS	
Pteropsida sp.	Ferns
Vaccinium angustifolium	Low bush Blueberry
Lonicera sp.	Honeysuckle
Celastrus scanderas	Bittersweet
Parthenocissus quinquefolia	Virgina Creeper
Hemerocallis sp.	Daylily
Hosta sp.	Plantain Lily
Coronarius sp.	Crown Vetch

APPENDIX N. BUFFER STRIP SURVEY FORM

Date:_______________ Surveyors:_______________ Section:_______________

House #:__________	0	1 - 25	26 - 50	51 - 75	> 75	Score:
Lakeshore coverage (%)	0	1	2	3	4	
Buffer depth from shore(ft.)	0	1	2	3	4	
Slope b/w shore & house:	> 50	50 - 26	25 - 1	0		
100 % equals 45° slope	0	1	2	3		
Composition:	100%	75%	50%	25%	0%	
Trees	4	3	2	1	0	
Shrubs/Flowers	10	8	6	4	0	
Riprap needed:	YES-0	NO-2				
Lot Shoreline distance	0-60'	60-120	120-180	>180'		
					Total:	

APPENDIX O. DETAILED ROAD SURVEY FORM

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

ROAD NAME/NUMBER:____

GENERAL DESCRIPTION

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

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

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

DESCRIPTION OF ROAD SURFACE

Score each 0.1 mile section of road with checkmark [√] in appropriate column of each row. For roads with uniform surface conditions, simply divide road into one to three equal sections depending upon length of road. When survey is complete compute average score for each characteristic using values shown in parentheses.

	Good	Acceptable	Fair	Poor	Big Problem		Average Score
Crown	_____(1) 6 in.	_____(2) 4 in.	_____(4) 2 in.	_____(6) 0 in./pothole s	_____(8) 0 in./ruts		_____
Surface (dry)	_____(1) hard w/o dust	ØØØØØØ ØØØØØØ	_____(3) hard w/ dust	_____(4) loose	_____(5) dusty & loose		_____
OR Surface (wet)	_____(1) hard	_____(2) hard & slick	_____(3) slick & loose	ØØØØØØ ØØØØØØ	_____(5) mud		_____
Edge	_____(0) no berm/ridge	ØØØØØØ ØØØØØØ	ØØØØØØ ØØØØØØ	ØØØØØØ ØØØØØØ	_____(5) berm/ridge prevents surface runoff		_____
Base	_____(1) gravel	_____(2) gravel/sand	_____(3) dirt	_____(4) sand/clay	_____(5) clay		_____
					SURFACE TOTAL	[a]	_____
USAGE	_____(1) seasonal	ØØØØØØ ØØØØØØ	ØØØØØØ ØØØØØØ	ØØØØØØ ØØØØØØ	_____(5) year round	[b]	_____
OVERALL SURFACE CONDITION	_____(1) 100%good	_____(2) 75%good	_____(3) 50%good	_____(4) 25%good	_____(5) 0%good	[c]	_____

_________ X _________ X ___________ = ______________

SURFACE [a] **USAGE [b]** **CONDITION [c]** **SURFACE TOTAL [d]**

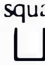
APPENDIX O. (CONTINUED)

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

ROAD NAME/NUMBER:____

DESCRIPTION OF ROAD DITCHING

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

	Good	Acceptable	Fair	Poor	Big Problem		Average Score
Need	_____(1) ample/none needed	OOOOOO OOOOOO	_____(5) some needed	OOOOOO OOOOOO	_____(15) badly needed		_____
Depth	_____(1) 2 ft. (or road slopes into adjacent land)	_____(2) 3 ft.	_____(3) 4 ft.	_____(4) 1 ft.	_____(5) no ditch present but needed		_____
Width	_____(1) 8 ft. (or road slopes into adjacent land)	_____(2) 6 ft.	_____(3) 4 ft.	_____(4) 2 ft.	_____(5) no ditch present but needed		_____
Vegetation	_____(1) turf, wooded, or rip rap	_____(2) grass	_____(3) weeds	_____(4) brush	_____(5) bare soil		_____
Sediments	_____(1) none	_____(2) 1 inch deep	_____(3) 2 inches deep	_____(4) 4 inches deep	_____(5) >4 inches deep		_____
Shape	_____(1) parabolic 	_____(2) trapezoid 	_____(3) round 	_____(4) v-shaped 	_____(5) square 		_____
					TOTAL	[e]	_____
SUMMARY OF DITCH CONDITION	_____(1) 100%good, or none needed	_____(2) 75%good	_____(3) 50%good	_____(4) 25%good	_____(5) 0%good, or no ditch present but needed	[f]	_____

_________ X ___________ = ______________

DITCHES [e] **CONDITION [f]** **DITCH TOTAL [g]**

APPENDIX O. (CONTINUED)

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

ROAD NAME/NUMBER:____

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

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

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

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

Road Segment Average ______= Total Of All Boxes _____ ÷ Total # Of Checks _____

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

ROAD NAME/NUMBER:____

DESCRIPTION OF CULVERTS

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

	Good	Acceptable	Fair	Poor	Big Problem	Ave. Score
Need	_____(1) ample/none needed	ØØØØØØ ØØØØØØ	_____(5) some not working	ØØ●ØØØ ØØØØØØ	_____(10) badly needed	____
Wear	_____(1) new	_____(2) aging (some rust)	_____(3) old (rust holes)	_____(4) bottom gone	ØØØØØØ ØØØØØØ	____
Size	_____(1) 2 ft. diam.	_____(2) 1-1/2 ft. diam	_____(3) 1 ft. diam.	_____(4) <1 ft. diam.	ØØØØØØ ØØØØØØ	____
Insides	_____(1) clean	_____(2) some rocks and/or water	_____(3) ≤2 in. silt	_____(4) >2 in. silt	ØØØØØØ ØØØØØØ	____
Covering Material	_____(1) at least 1 ft. thick or half diameter of large culverts	ØØØØØØ ØØØØØØ	_____(3) less than 1 ft. thick	_____(4) covering inadequate to prevent bent culvert	_____(5) top of culvert showing through road surface	____
					TOTAL [h]	____

OVERALL CULVERT CONDITION	_____(1)	_____(2)	_____(3)	_____(4)	_____(5)	[i] ____
	100% good, or none needed	75% good	50% good	25% good	0% good, no culvert present but needed	

__________ X __________ = ______________

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

APPENDIX O. (CONTINUED)

DATE:________________ SURVEYOR'S NAME(S):____________________________

ROAD NAME/NUMBER:____

DESCRIPTION OF WATER DIVERSIONS

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

	Good	Acceptable	Fair	Poor	Big Problem		Average Score
Need	ample/none needed (1)	ØØØØØØ	ØØØØØØ	ØØØØØØ	badly needed (5)		_____
Where does diverted water go?	woods (1)	field or lawn (2)	gully in woods (3)	Stream (4)	Lake (5)		_____
					TOTAL	[k]	_____
OVERALL WATER DIVERSION CONDITION	_____(1) 100% good, or none needed	_____(2) 75% good	_____(3) 50% good	_____(4) 25% good	_____(5) 0% good, no diversions present but needed	[l]	_____

_________ X ___________ = _______________

WATER DIVERSIONS [k] **CONDITION[l]** **WATER DIVERSIONS TOTAL [m]**

FINAL EVALUATION OF THE ROAD

_________ + ________ + __________ + ______________ = _________

[d] SURFACE + [g] DITCHES + [j] CULVERTS + [m] WATER DIVERSIONS = ROAD TOTAL

The lower the total, the better the score for an individual road. Having a low or acceptable score does not mean that road maintenance is unnecessary, but a high score indicates the need for work, and can be used as a guide for making decisions about where and what type of work is needed. <u>As a rule, if any item checked was worth more than two points, it should be given priority when developing a road maintenance plan.</u>

ROAD SEGMENT TOTAL = ____________________

ROAD SEGMENT AVERAGE = ________________________

APPENDIX P. LENGTH, WIDTH, AND AREA OF ROADS

Summary of length, width, and area for all roads surveyed. These data were collected on 3-Oct-01 and 9-Oct-01.

Road Name	Length (miles)	Length (feet)	Width (feet)	Area (acres)
Paved Surface				
Oak Pond Rd.	0.70	3,696.0	23.0	1.95
Moores Mill Rd.	0.10	528.0	14.0	0.17
East Ridge Rd.	1.20	6,336.0	24.0	3.49
Route 2	2.80	14,784.0	37.0	12.56
Pinnacle Rd.	0.70	3,696.0	26.0	2.20
Strickland Rd.	0.45	2,376.0	15.5	0.85
Lambert Rd.	0.50	2,640.0	22.0	1.33
Total	6.45	34,056.0	-	22.55
Dirt/Gravel Suface				
Ray's Road	2.50	13,200.0	12.0	3.63
Lake George East	0.60	3,168.0	18.4	1.34
Lake George West	0.20	1,056.0	20.3	0.49
Notch Rd.	0.35	18,448.0	14.0	0.59
North Log Rd West	0.10	528.0	22.0	0.27
South Log Rd East	0.40	2,112.0	12.5	0.60
South Log Rd West	0.24	1,267.2	12.0	0.35
Zikorous Ln.	0.20	1,056.0	8.0	0.19
Kingfisher/Chickadee Ln. (FL #1)	0.80	4,224.0	11.3	1.10
Blue Heron Ln. (FL #2)	0.40	2,112.0	12.7	0.62
Pheasant Ln. (FL #3)	0.20	1,056.0	13.0	0.32
Woodcock Ln. (FL #4)	0.39	2,059.2	9.0	0.43
Loon Ln. (FL #5)	0.30	1,584.0	10.0	0.36
Total	7.38	38,966.4	-	11.40

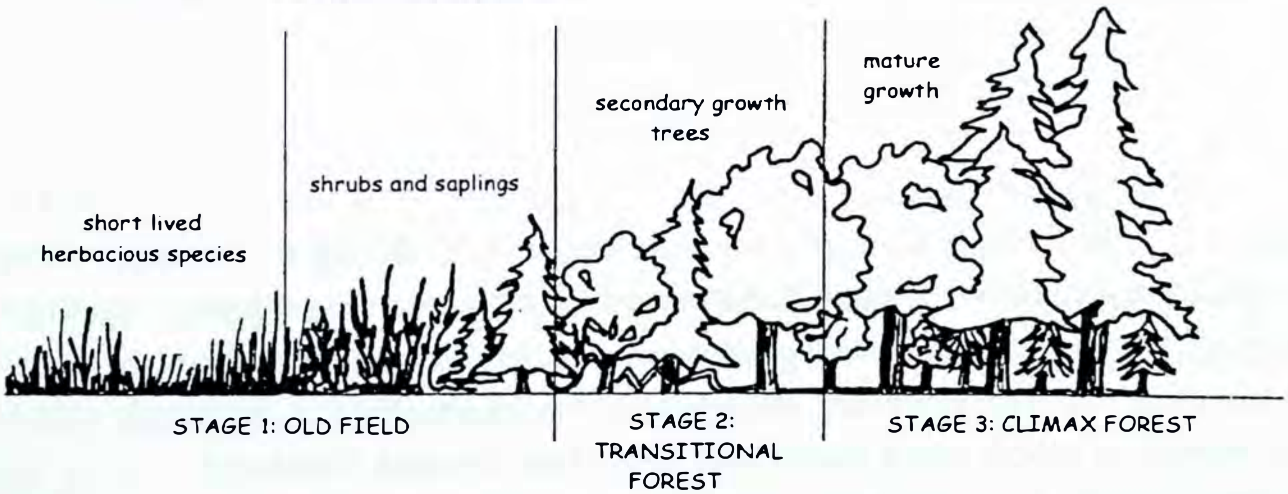
Appendix Q.

Investigating Forest Succession in Lake George Regional Park

Much of what we see in the forests surrounding Lake George was at one time agricultural fields. Old photographs of the region show that almost all of the land was small farms and even today as you hike through the forest, you will continually find the foundations and stonewalls of old farms scattered among the trees. Given the chance, cleared fields will eventually return to mature climax forests in a process known as ecological succession. Accordingly, vegetation follows established predictable patterns of re-growth and change following disturbances by farming, timber harvesting, and fire.

Lake George Regional Park (LGRP) provides excellent examples of forest succession with stages illustrating old fields, transitional forests, and mature climax forest communities.

STAGES OF FOREST SUCCESSION



Stage 1- The Old Field (visit intersection R)

Succession on abandoned fields is rapid. **Grasses** and other short-lived herbaceous species dominate at first. These are sunloving species which are able to withstand dry conditions. Next, larger species such as **Queen Anne's lace, asters, goldenrods**, and **milkweed** raise the height of the vegetation and shade out the grasses. **Blackberries**, **sumacs** and other shrubs then appear, followed by tree seedlings which rise above this shrub layer and out-compete herbaceous plants.

Animal species inhabiting the old field may include **monarch butterflies** which lay their eggs on milkweed, and **woodchucks**.

Pioneering Trees

The pioneering tree species that replace annuals and shrubs change the microclimate as they grow, casting shadows on the open field making it cooler and more difficult for sunloving species to grow beneath. While light is reduced at the soil surface, the soil becomes more able to retain water, and the presence of soil nitrogen and organic matter increases. The pioneering tree species most commonly seen in the park include **eastern red cedar, black cherry, gray birch, quaking aspen, and white pine**.

Stage 2: The Transitional Forest (majority of trails A-W)

In the transitional forest, the development of different canopy levels becomes evident. These canopy levels can survive because there is enough light penetrating through the leaves of the taller trees to allow for germination. Meanwhile the microclimate created by the forest is much more moist and cool than the old-field and therefore able to support a greater diversity of species. This diversity is enhanced by the fact that some pioneer species are still present at the same time that climax species begin to mature.

Appendix Q. (CONTINUED)

Ground cover species include **shinleaf**, **wintergreen**, and various types of ferns such as **Christmas fern, sensitive fern, and bracken fern** which thrive in moist places. At this level, animal species such as the **ruffed grouse** feed on insects, berries and seeds that are on the ground. The shrub layer consists of plants at adult chest height such as **maple leaved viburnum and hazelnut**. Here, **hairy woodpeckers** may be seen probing for insects in the bark and hollows of trees. Trees that rise between 10 and 20 ft high comprise the understory. Understory species include **hop hornbeam**, **witch hazel**, and **striped maple** which can tolerate low light conditions. The tallest trees make up the canopy. These include **paper birch, yellow birch, quaking aspen, northern red oak, white ash, white pine, and eastern red cedar**. **Gray squirrels** and **eastern chipmunks** commonly inhabit transitional forests where they actively collect and store nuts and seeds from its trees. Acorns from the northern red oak are the preferred food choice of gray squirrels and some birds because of the high energy combination of protein and fat that they provide. **Porcupines** might also be found in the transitional forest feeding on leaves, twigs and tree bark. Also keep a lookout for the **white tailed deer**, a shy herbivore that feeds mostly on dogwood, chokecherry, red cedar, pine, and other woody vegetation, as well as leaves, grasses, fruits and nuts. A rare **moose** sighting is also possible within the park. Moose tend to feed on fresh woody plant material from quaking aspen, dogwood, red maple, striped maple, white birch, hazelnut, pin cherry, and balsam fir trees. In the summer time, Moose may also be found feeding on aquatic vegetation including watershield, yellow pond lily, and pondweed.

White Pine Stands (visit Intersection I-J)

Since **white pine** grows faster than the hardwood seedlings, almost pure stands of white pine rise up in many sections of LGRP. White pine dominate the canopy for their lifespan of 80 to 120 years. Several animal species are known to inhabit these stands including **raccoons, bats, and red squirrels**. A walk through one of these white pine transitional forest communities reveals clearly how these forest stands decrease the amount of light reaching the ground. White pines also change the environment beneath them by taking up water into their root systems. This combination of shade and low moisture availability makes it impossible for most white pine seedlings to grow up underneath the parent trees. As a result, shade-tolerant hardwood species begin to grow up, setting the stage for the next phase of succession.

Stage 3- The <u>Climax Forest</u> (visit intersections X-Y-Z)

As the shade-tolerant hardwood species grow tall and wide, they begin to replace species of the transitional forest. Long-lived trees such as **beech, oak, and maple** grow best under wooded conditions of decreasing light and increasing moisture and nutrients. As the shorter lived smaller trees such as birches, cherries and pines die off, the emerging hardwood species are able to grow tall and wide. Because most of the hardwood species are able to regenerate in their own shade, the forest matures and eventually becomes open underneath dominated by tall trees.

Throughout LGRP mushrooms and shelf-like **bracket fungus** are common. These species are typically found on dead or diseased trees where they decompose dead organic matter, extracting and recycling nutrients back into the soil.

Appendix Q. (CONTINUED)

Eastern Hemlock Stands

Eastern hemlock stands represent another type of mature forest community dominated by shade tolerant trees that are able to thrive in the moist, cool, shady conditions of their environment. Since the mature trees tend to dominate most of the sunlight in a hemlock stand, younger trees which have taken root may take several years to grow tall "waiting" for the opportune time when an elder tree falls and creates a light gap.

Red Squirrels eat and store the seeds of Eastern Hemlock trees and are particularly active in the fall months. The **black-capped chickadee** is a non-migratory bird which can be heard year round in these forests and can be recognized by its call: chick-a-dee-dee-dee.

Investigating Vernal Pools in Lake George Regional Park

What is a vernal pool?

Vernal or "spring" refers to a type of temporary water body which usually contains water only during the springtime. However, vernal pools may contain water at other times of the year as well whenever the amount of rain needed to fill the pools is sufficient. Vernal Pools are located in confined basins and therefore lack a permanent outflow such as a stream.

Why are vernal pools valuable?

They are known to support the lifecycles of characteristic species, some of which are obligate. only able to reproduce in vernal pools. Because vernal pools dry out at least once annually, they are unable to support a fish population. As a result, the **wood frog** (*Rana sylvatica)* and four species of **mole salamander** (*Ambystoma* spp.) have evolved breeding strategies intolerant of fish predation on their eggs and larvae. The lack of fish predation is crucial to the breeding success of these species. Another vernal pool obligate is the fairy shrimp (*Eubranchipus* spp.) a type of invertebrate whose eggs, laid during the previous season, develop as the pool fills up the following year. Other amphibian species such as the **American toad** (*Bufo americanus)* the green frog (*Rana clamitans)*, and the red **spotted newt** (*Notophthalmus viridescens)* are facultative; they often exploit these fish-free environments but do not depend on them.

Appendix Q. (CONTINUED)

An Endangered Habitat?

A general lack of understanding about the habitat requirements and the significance of vernal pools for different species has led to the inadequate protection of vernal pools in the past. Forestry operations, development, and recreation all infringe upon these pools often unknowingly, particularly when the waters dry up leaving only small ditch like basins for a majority of the year. In addition to protecting the pool basin, it is important that a buffer be retained around the pool to avoid drastic changes in the microclimate which can have dramatic effects on the species that live there. Finally, juvenile amphibian species may disperse over half a mile from the pool itself making upland protection extremely important. Barriers to amphibian movement include agriculture, rip-rap and railroad beams, large bodies of water, and roads.

Since there are currently no strict laws in the state of Maine to protect vernal pools, the most important thing we can do is raise public awareness concerning the value of these endangered ecosystems. So step carefully!

Appendix Q. (CONTINUED)

COMMON SPECIES IN LGRP

OLD FIELD

QUEEN ANNES LACE

GOLDEN ROD

NEW ENGLAND ASTER

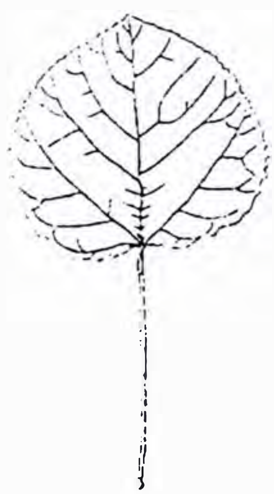
PIONEER AND TRANSITIONAL FOREST TREES

EASTERN WHITE PINE

GRAY BIRCH

PAPER BIRCH

HOP HORNBEAM



QUAKING ASPEN

WITCH HAZEL

APPENDIX Q. (CONTINUED)

FERNS

BRACKEN FERN

SENSITIVE FERN

CHRISTMAS FERN

COMMON ANIMALS

GRAY SQUIRREL

RED SQUIRREL

BLACK CAPPED CHICKADEE

EASTERN CHIPMUNK

HAIRY WOODPECKER

PORCUPINE

APPENDIX Q. (CONTINUED)

CLIMAX FOREST


EASTERN HEMLOCK


RED OAK


WHITE OAK


AMERICAN BEECH


SUGAR MAPLE


RED MAPLE


YELLOW BIRCH

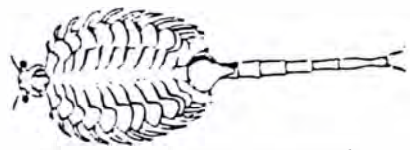

WHITE ASH

APPENDIX Q. (CONTINUED)

VERNAL POOL SPECIES

SPOTTED SALAMANDER

GREEN FROG



FAIRY SHRIMP

RED SPOTTED NEWT

AMERICAN TOAD

APPENDIX R. SOIL POTENIAL RATINGS FOR SOMERSET COUNTY, MAINE (USDA 1972).

Soil Type	Slope	Septics	Dwellings	Roads	Development
AaB- Adams loamy sand	0-8 %	Moderate	Moderate	Moderate	Moderate
AaC- Adams loamy sand	8-15 %	Moderate	Severe	Moderate	Moderate
AaD- Adams loamy sand	15-25 %	Severe	Severe	Severe	Very Low
BaB- Bangor silt loam	3-8 %	Moderate	Moderate	Slight	High
BaC2- Bangor silt loam	8-15 %	Moderate	Moderate	Moderate	Moderate
BgB- Bangor very stony silt loam	3-8 %	Moderate	Slight	Slight	High
BgC- Bangor very stony silt loam	8-15 %	Moderate	Moderate	Moderate	Moderate
BgD- Bangor very stony silt loam	15-25 %	Severe	Severe	Severe	Very Low
Bo- Biddeford silt loam		Severe	Severe	Severe	Very Low
BuB- Buxton silt loam	0-8 %	Severe	Severe	Severe	Very Low
BuC2- Buxton silt loam	8-15 %	Severe	Severe	Severe	Very Low
DxB- Dixmont silt loam	0-8 %	Severe	Severe	Moderate	Low
DxC- Dixmont silt loam	8-15 %	Severe	Severe	Severe	Very Low
DyB- Dixmont very stony silt loam	0-8 %	Severe	Severe	Moderate	Low
DyC- Dixmont very stony silt loam	8-20 %	Severe	Severe	Severe	Very Low
Lk- Limerick silt loam		Severe	Severe	Severe	Very Low

APPENDIX R. (CONTINUED)

Soil Type	Slope	Septics	Dwellings	Roads	Development
Mn- Mixed alluvial land		Severe	Severe	Severe	Very Low
Mo- Monarda silt loam		Severe	Severe	Severe	Very Low
Mr- Monarda very stony silt loam		Severe	Severe	Severe	Very Low
Pa- Peat and muck		Severe	Severe	Severe	Very Low
PgB- Plaisted gravelly loam	3-8 %	Severe	Severe	Moderate	Low
PgC- Plaisted gravelly loam	8-15 %	Severe	Moderate	Moderate	Low
PrB- Plaisted very stony loam	3-8 %	Severe	Severe	Moderate	Low
PrC- Plaisted very stony loam	8-15 %	Severe	Moderate	Severe	Very Low
PrD- Plaisted very stony loam	15-25 %	Severe	Severe	Severe	Very Low
RtC- Rock land, Thorndike and Lyman materials	0-15 %	Severe	Severe	Severe	Very Low
RtE- Rock land, Thorndike and Lyman materials	15-45 %	Severe	Severe	Severe	Very Low
Sc- Scantic silt loam		Severe	Severe	Severe	Very Low
Sk- Skowhegan loamy fine sand		Severe	Severe	Moderate	Low
TkC- Thorndike very rocky silt loam	3-15 %	Severe	Severe	Severe	Very Low
TkD- Thorndike very rocky silt loam	15-30 %	Severe	Severe	Severe	Very Low
TpB- Thorndike-Plaisted loams	0-8 %	Severe	Moderate	Slight	Moderate

APPENDIX R. (CONTINUED)

Soil Type	Slope	Septics	Dwellings	Roads	Development
TpC- Thorndike-Plaisted loams	8-15 %	Severe	Moderate	Severe	Very Low
TpD- Thorndike-Plaisted loams	15-30 %	Severe	Severe	Severe	Very Low
TtB- Thorndike-Bangor silt loam	0-8 %	Moderate	Moderate	Slight	High
TtC- Thorndike-Bangor silt loam	8-15 %	Moderate	Moderate	Severe	Low
TtD- Thorndike-Bangor silt loam	15-30 %	Severe	Severe	Severe	Very Low
Wa- Walpole fine sandy loam		Severe	Severe	Severe	Very Low

APPENDIX S. LAKE GEORGE AND OAKS POND WATER BUDGET VALUES AND CALCULATIONS

Parameters	Units	Values
Precipitation[a]	Meters/year	1.07
Evaporation[b]	Meters/year	0.56
Runoff[c]	Meters/year	0.46
Watershed Area		
Lake George	Square meters	15,916,247.91
Oaks Pond	Square meters	10,777,367.44
Lake Area		
Lake George	Square meters	1,287,134.88
Oaks Pond	Square meters	354,084.06
Mean Depth[d]		
Lake George	meters	7.22
Oaks Pond	meters	7.38
I_{net}		
$I_{net\ Lake\ George}$	Cubic meters	7,907,782.46
$I_{net\ Oaks\ Pond}$	Cubic meters	5,118,879.40
Flushing Rate		
Lake George	Flushes/year	0.85
Oaks Pond	Flushes/year	4.91

[a]Precipitation data were obtained from National Oceanic Atmospheric Administration reports (NOAA 1990-2000). Annual rainfall was calculated by averaging data from the Madison weather station and data missing from Madison from 1991, 1992, and 1997 was supplemented with data from Waterville and Augusta weather stations. A ten-year mean from these yearly averages was used to determine I_{net}.

[b]Evaporation constant was obtained from a previous study of the Lower Kennebec River Basin (Prescott 1969).

[c]Runoff constant was obtained from a twenty-year study of precipitation and runoff in New England and New York (Knox and Nordenson 1955).

[d]Average depth was obtained from the Maine Department of Environmental Protection MIDAS data (MDEP PEARL 2001).

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

Lake George Flushing Rate = $I_{net\ Lake\ George}$ / (Mean Depth * Lake Area)

Oaks Pond Flushing Rate = ($I_{net\ Oaks\ Pond}$ + $I_{net\ Lake\ George}$) / (Mean Depth * Lake Area)

APPENDIX T. PHOSPHORUS BUDGET EQUATION FOR LAKE GEORGE

The following equation was developed to calculate the total phosphorus entering Lake George on an annual basis (W). The equation incorporates land use patterns within the watershed, soil retention characteristics, population demographics, and residential development patterns as sources that contribute phosphorus to Lake George.

$$W = (Ec_a \times A_s) + (Ec_{mf} \times Area_{mf}) + (Ec_t \times Area_t) + (Ec_{reg} \times Area_{reg}) + (Ec_{rev} \times Area_{rev}) + (Ec_w \times Area_w) + (Ec_s \times Area_s) + (Ec_n \times Area_n) + (Ec_i \times Area_i) + (Ec_r \times Area_r) + (Ec_{cm} \times Area_{cm}) + (Ec_{ag} \times Area_{ag}) + (Ec_c \times Area_c) + [(Ec_{ss} \times \#\ capita\ years_s \times (1 - SR_s)) + (Ec_{ns} \times \#\ capita\ years_n \times (1 - SR_n)) + (1 \times (1 - SR_i))]$$

Ec_a = export coefficient for atmospheric input (kg/ha/yr)

Estimated Range (ER) = 0.04 to 0.25 Best Estimate (BE) = 0.08

This coefficient was modified from the coefficient used in studies of lakes in the Belgrade Lakes region of Maine (BI493 1999 – 2001). It was based on the very low amount of industrial activity in the Lake George watershed. With the relative absence of local point sources, airborne particulate phosphorus must travel from distant locations before deposition in Lake George, decreasing overall atmospheric deposition due to dispersion.

Ec_{mf} = export coefficient for mature forests (kg/ha/yr)

ER = 0.04 to 0.15 BE = 0.08

The export coefficient used by the CEAT study of Lake Wesserunsett (BI493 2001) for the forested land was 0.04 to 0.20. Their coefficient is based on the fairly equal coverage of deciduous and coniferous forest in the watershed. Deciduous forests have a higher export coefficient than coniferous forests due to the annual decay of fallen leaves in comparison to the less frequent loss and decay of needles. The coefficient for Lake George is based on nearly equal coverage of coniferous and deciduous forests in the lake's watershed.

Ec_t = export coefficient for transitional land (kg/ha/yr)

ER = 0.06 to 0.17 BE = 0.12

Transitional forests contain approximately 50 percent forest cover of mixed aged trees in addition to shrubs, bushes, and ground cover vegetation. Much of the transitional forest in the Lake George watershed is deciduous and is located near the lake on a moderate slope. These factors require that a slightly higher export coefficient be assigned to transitional land compared to mature forests.

Ec_{reg} = export coefficient for regenerating forests (kg/ha/yr)

ER = 0.08 to 0.19 BE = 0.15

The regenerating land in the Lake George watershed represents areas of forests growing back at a uniform rate after being logged. Most of the patches of regenerating forests in the watershed are at an early successional stage. This type of land use has an export coefficient similar to transitional forests because, although the regenerating land contains more patchy growth than transitional forest land, the small patches of regenerating land are buffered from the lake by mature forests.

Ec_{rev} = export coefficient for reverting lands (kg/ha/yr)

ER = 0.09 to 0.20 BE = 0.15

The export coefficient for reverting land is slightly greater than for the other stages of successional land types. Reverting land represents areas of old agricultural land currently in succession between open fields and forest. Reverting land lacks the closed protective canopy of mature forests but does contain a thick shrub and ground cover that prevents phosphorus from being exported with sediment.

Ec_w = export coefficient for wetlands (kg/ha/yr)

ER = 0.02 to 0.15   BE = 0.07

The export coefficient for wetlands is very low because wetlands act as a sink for phosphorus during the summer growing season. The wetlands in the Lake George watershed may act as a large sink for phosphorus since the tributary streams flow through wetlands before entering the lake. A small strip of wetlands also runs along the southern edge of the largest span of reverting land in the watershed. The small amount of phosphorus exported from wetland systems is more likely to occur during periods of significant biomass decomposition rather than the growing season. The export coefficients are similar to those used in past CEAT studies in the Belgrade Lakes region (BI493 1997 – 2001).

Ec_s = export coefficient for shoreline development (kg/ha/yr)

ER = 0.50 to 2.25   BE = 1.75

The high variability of buffer strip quality along Lake George's shoreline prompted a wide range for this export coefficient. Phosphorus can be deposited directly into Lake George due to shoreline development and proximity of park roads unless a sufficient buffer strip is in place. The export coefficients for Lake George shoreline development are similar to those used in CEAT studies on Lake Wesserunsett and East Pond. Like Lake George, much of the shoreline development on Lake Wesserunsett and East Pond was poorly buffered, close to the water, and built on sloping lots (BI493 2000, 2001).

APPENDIX T. (CONTINUED)

Ec_n = export coefficient for non-shoreline development (kg/ha/yr)

ER = 0.15 to 0.75 BE = 0.60

Non-shoreline development in Lake George's watershed typically does not deposit phosphorus into the lake. Usually some buffer exists between the non-shoreline development and Lake George acting as a sink for phosphorus runoff. Consequently, a lower export coefficient is assigned. Export coefficients for non-shoreline development were also based on past CEAT reports with similar non-shoreline development patterns (BI493 1999, 2000, 2001).

Ec_i = export coefficient for institutional development (Lake George Regional Park) (kg/ha/yr)

ER = 0.40 to 2.00 BE = 1.75

A small portion of LGRP is inadequately buffered and is intensively used by park visitors. Most of the remaining land within LGRP is forested and contributes relatively little to phosphorus loading. These factors, when considered together, give LGRP an export coefficient that lies between the ranges of shoreline and non-shoreline development.

Ec_r = export coefficient for roads (kg/ha/yr)

ER = 0.90 to 2.75 BE = 2.25

The export coefficient for roads was relatively high due to poor conditions of camp roads in the Lake George watershed. Poor ditching, berms, and lack of water diversions are some of the many factors that lead to increased phosphorus input into Lake George. A number of stretches of unpaved roads are located within a few feet of the lake shoreline and show signs of significant erosion and minimal vegetational buffering. The export coefficient for roads in the Lake George watershed was also based on the export coefficients used in the Lake Wesserunsett and East Pond watersheds which contained roads in similar conditions (BI493 1999, 2001).

Ec_{cm} = export coefficient for commercial and municipal lands (kg/ha/yr)

ER = 0.20 to 0.85 BE = 0.60

The export coefficient for commercial lands within Lake George's watershed was based upon the few businesses and a few small gravel pits found in the watershed. Businesses have a higher export coefficient than residential non-shoreline development due to parking lots and other impervious surfaces. Impervious surfaces will increase runoff from the land, increasing phosphorus loading into the lake. Gravel pits are open to leaching and erosion, contributing to an elevated export coefficient.

Ec_{ag} = export coefficient for agricultural lands (kg/ha/yr)

ER = 0.20 to 0.75 BE = 0.45

The land use category of agricultural land includes crops and pastures. In the Lake George watershed, there is almost twice as much cropland as pastureland. The thick grass cover of pastures retains phosphorus more effectively than cropland which typically lacks a stabilizing ground cover. Although agricultural land has the potential to annually lose a large amount of phosphorus, the majority of the agricultural land in the Lake George watershed is buffered by mature forests and is located far from the lake. The export coefficients used for agricultural type lands in past CEAT reports and in Higgins Lake, Michigan were taken into consideration when assigning the export coefficient for Lake George (Rechkhow and Chapra 1983, and BI493 1997 – 2001).

APPENDIX T. (CONTINUED)

Ec_c = export coefficient for cleared lands (kg/ha/yr)

ER = 0.25 to 0.80 BE = 0.50

This land use category contains clear cuttings, selection cuttings, and logging roads. The Lake George watershed has little cleared land, most of which is buffered by either mature forests or transitional forests. Deforested land is very susceptible to erosion, which greatly increases the export coefficient for this land use. One of the most significant contributors to a high export coefficient was the logging roads in the watershed. A number of logging roads are located within a mile of Lake George.

Ec_{ss} = export coefficient for shoreline septic systems (kg/ha/yr)

ER = 0.30 to 1.50 BE = 0.75

The conditions for septic systems along Lake George's shoreline are generally in fairly good condition (Gray, pers. comm.). However, of the 34 shoreline houses, approximately four have poor condition septic systems and eight have pit privies. Pit privies are especially problematic because their contents leach directly into the soil. Pit privies can also contaminate the lake if improperly constructed or if located too near the lake shore. The dominant soil types around Lake George are very poor for septic systems (USDA 1972) (See Land Use Assessment: Development Suitability Model). A majority of the houses along Lake George's shoreline are seasonal so their septic systems contribute less than if they were year-round. These factors result in a moderately high export coefficient for shoreline septic systems. The export coefficients were also chosen based on the range of coefficients from past reports (BI493 1997, 1999 – 2001).

Ec_{ns} = export coefficient for non-shoreline septic systems (kg/ha/yr)

ER = 0.20 to 0.80 BE = 0.50

Non-shoreline septic systems are in equally poor soil conditions as shoreline systems but their distance from Lake George lowers the export coefficient. All of the non-shoreline houses are year-round, so they contribute more phosphorus than seasonal houses. The septic systems of year round houses tend to be newer and be maintained on a more routine basis. The combination of these factors allow the export coefficient to be lower than the shoreline septic system export coefficient. Similar non-shoreline septic system parameters were used to attain a very similar range of coefficients by a CEAT study of Lake Wesserunsett in 2001 (BI493 2001).

Ec_{is} = export coefficient for institutional (LGRP) septic systems (kg/ha/yr)

ER = 0.30 to 1.50 BE = 0.90

The septic systems in Lake George Regional Park are new and efficient compared to many of the older systems of shoreline camps on the lake. The park septic systems are being used more intensively than residential camp systems and the septic system leach field on the east side of the park is fairly close to the shore of the lake. Together, these factors allow for an export coefficient very close to the coefficient for shoreline septic systems.

The term, I, in the W equation is calculated by multiplying the institutional septic system export coefficient (Ec_{is}) times the # capita years for the park.

 # Capita years $_{s,\ n,\ and\ i}$ = capita years for shoreline, non-shoreline, and institutional development

Capita years $_s$ = 16.64 Capita years $_n$ = 53.49 Capita years $_i$ = 11.42

APPENDIX T. (CONTINUED)

This term accounts for the number of people potentially contributing waste to the shoreline and non-shoreline septic systems. It is calculated using the following equation: Capita years = Average number of persons per unit * (Days in use / 365) * Total number of units.

Seasonal and non-seasonal residency was estimated to be 44 and 355 days per year, respectively (Hubbard, pers. comm.). The mean number of persons per household was estimated to be 2.5 for both shoreline and non-shoreline development (Gray, pers. comm.). The # capita years_i was calculated by assuming that the average park visitor stays for 4 hours (one-sixth of a day) and that 25,000 people per year visit the park (Hubbard, pers. comm.).

$SR_{s, n, \text{and } i}$ = soil retention constants for shoreline, non-shoreline and institutional development

Shoreline	Non-shoreline	Institutional
ER_s = 0.80 to 0.60	ER_n = 0.90 to 0.80	ER_i = 0.75 to 0.30
BE_s = 0.70	BE_n = 0.85	BE_i = 0.50

Soil retention measures the ability of soil to retain phosphorus, preventing phosphorus from entering Lake George. Soil retention is measured on a scale of zero to one with zero representing no retention and one representing full retention of phosphorus in the soil. Since shoreline soils generally have much less buffering than non-shoreline soils, the values for shoreline soils are much lower. The export coefficients for shoreline and non-shoreline soil retention were also determined based on past CEAT reports (BI493 1997, 1999 – 2001). Because LGRP is used intensively by people and has a patchy buffer strip, the values for institutional soil retention are slightly lower than shoreline soils.

APPENDIX T. (CONTINUED)

Areas for Land Use components:

$\mathbf{A_s}$ = area of Lake George = 131.66 ha

$\mathbf{A_{mf}}$ = area of mature forested lands = 760.43 ha

$\mathbf{A_t}$ = area of transitional forests = 554.81 ha

$\mathbf{A_{reg}}$ = area of regenerating forests = 13.17 ha

$\mathbf{A_{rev}}$ = area of reverting lands = 54.90 ha

$\mathbf{A_w}$ = area of wetlands = 27.16 ha

$\mathbf{A_s}$ = area of shoreline residential development = 6.68 ha

$\mathbf{A_n}$ = area of non-shoreline residential development = 8.90 ha

$\mathbf{A_i}$ = area of institutional lands = 1.29 ha

$\mathbf{A_{cm}}$ = area of commercial and municipal lands = 3.39 ha

$\mathbf{A_r}$ = area of roads = 4.18 ha

$\mathbf{A_{ag}}$ = area of agricultural lands = 17.80 ha

$\mathbf{A_c}$ = area of cleared lands = 7.25 ha

APPENDIX U. PHOSPHORUS BUDGET EQUATION FOR OAKS POND

The following equation was developed to calculate the total phosphorus entering Oaks Pond on an annual basis (W). The equation incorporates land use patterns within the watershed, soil retention characteristics, population demographics, and residential development patterns as sources that contribute phosphorus to Oaks Pond.

$\mathbf{W} = (Ec_a \times A_s) + (Ec_{mf} \times Area_{mf}) + (Ec_t \times Area_t) + (Ec_{reg} \times Area_{reg}) + (Ec_{rev} \times Area_{rev}) + (Ec_w \times Area_w) + (Ec_s \times Area_s) + (Ec_n \times Area_n) + (Ec_r \times Area_r) + (Ec_{cm} \times Area_{cm}) + (Ec_{ag} \times Area_{ag}) + (Ec_c \times Area_c) + [(Ec_{ss} \times \text{\# capita years}_s \times (1 - SR_s)) + (Ec_{ns} \times \text{\# capita years}_n \times (1 - SR_n))]$

$\mathbf{Ec_a}$ = export coefficient for atmospheric input (kg/ha/yr)

Estimated Range (ER) = 0.04 to 0.25 Best Estimate (BE) = 0.08

This coefficient was modified from the coefficient used in studies of lakes in the Belgrade Lakes Region of Maine (BI493 1999 – 2001). It is based on the very low amount of industrial activity in the Oaks Pond watersheds. Airborne particulate phosphorus must travel from distant locations before deposition in Oaks Pond because of the absence of local point sources. This decreases overall atmospheric deposition due to dispersion.

$\mathbf{Ec_{mf}}$ = export coefficient for mature forested land (kg/ha/yr)

ER = 0.04 to 0.15 BE = 0.07

The export coefficient used by the CEAT study of Lake Wesserunsett (BI493 2001) for the forested land was 0.04 to 0.20. Their coefficient is based on the fairly equal coverage of deciduous and coniferous forest in the watershed. Deciduous forests have a higher export coefficient than coniferous forests due to the annual decay of fallen leaves compared to the less frequent loss of needles by coniferous trees. The coefficient for Oaks Pond is based on nearly equal coverage of coniferous and deciduous forests in the watersheds.

Ec_t = export coefficient for transitional land (kg/ha/yr)

ER = 0.06 to 0.18 BE = 0.10

Transitional forests contain approximately 50 percent forest cover of mixed aged trees in addition to shrubs, bushes, and ground cover vegetation. There is very little transitional forest in Oaks Pond's watershed and most of the forest is buffered by mature forests. These factors require that a slightly higher export coefficient be assigned to transitional land compared to mature forests.

Ec_{reg} = export coefficient for regenerating forests (kg/ha/yr)

ER = 0.08 to 0.20 BE = 0.12

The regenerating land in the Oaks Pond watershed represents areas of forests growing back at a uniform rate after being logged. Most of the patches of regenerating forests in the watershed are at an early successional stage. This type of land use has an export coefficient only slightly higher than for transitional forests because, although the regenerating land contains more patchy growth than transitional forest land, the small patches of regenerating land are buffered from the lake by mature forests.

Ec_{rev} = export coefficient for reverting lands (kg/ha/yr)

ER = 0.08 to 0.20 BE = 0.12

The export coefficient for reverting land is slightly greater than for mature forests and transitional forests but equal to that of regenerating land. Reverting lands represent areas of old agricultural land currently in succession between open fields and forest. The thick shrub and ground cover helps prevent phosphorus from being exported with sediment.

Ec_w = export coefficient for wetlands (kg/ha/yr)

ER = 0.03 to 0.15 BE = 0.05

The export coefficient for wetlands is very low because wetlands act as a sink for phosphorus during the growing season. A large area of wetlands exists along the western shore of Oaks Pond and surrounds Round Pond and Lambert Brook, one of the major tributaries of Oaks Pond. The wetlands, especially during the growing season, may act as a nutrient filter, preventing the majority of phosphorus that enters the wetlands from continuing on to Oaks Pond. The export coefficients are similar to those used in past CEAT studies in the Belgrade Lakes region (BI493 1997 – 2001).

Ec_s = export coefficient for shoreline development (kg/ha/yr)

ER = 0.50 to 2.00 BE = 1.65

The high variability of buffer strip quality along the Oaks Pond shoreline resulted in a wide range for this export coefficient. Unless a sufficient buffer strip is in place, phosphorus can be deposited directly into Oaks Pond due to shoreline development. The export coefficients for Oaks Pond shoreline development are similar to those used in CEAT studies on East Pond and Lake Wesserunsett. Similar to Oaks Pond, much of the shoreline development on East Pond and Lake Wesserunsett was poorly buffered, very close to the water, and built on sloping lots (BI493 2000, 2001).

Ec_n = export coefficient for non-shoreline development (kg/ha/yr)

ER = 0.15 to 0.70 BE = 0.45

Non-shoreline development in Oaks Pond's watershed usually cannot directly deposit phosphorus into the lake, consequently, a lower export coefficient is assigned than for shoreline development. Usually some buffer exists between the non-shoreline development and Oaks Pond, acting as a sink for phosphorus runoff. Export coefficients for non-shoreline development were also based on past CEAT reports with similar non-shoreline development patterns (BI493 1999 – 2001).

Ec_r = export coefficient for roads (kg/ha/yr)

ER = 0.90 to 2.25 BE = 1.85

The export coefficient for roads was relatively high due to poor conditions of camp roads in the Oaks Pond sub-watersheds. Poor ditching, berms, and lack of water diversions are a few of many factors that lead to increased phosphorus input into Oaks Pond. Many of the unpaved roads show signs of significant erosion and are buffered by minimal vegetation. The export coefficient for roads in the Oaks Pond watershed was also based on the export coefficients used in the Lake Wesserunsett and East Pond watersheds, which contained roads in similar conditions.

Ec_{cm} = export coefficient for commercial and municipal lands (kg/ha/yr)

ER = 0.15 to 0.65 BE = 0.25

The export coefficient for commercial lands reflects the presence of a few businesses, a church, and a ski slope found within Oaks Pond's sub-watersheds. Businesses have a higher export coefficient than non-shoreline development due to parking lots and other impervious surfaces. Impervious surfaces increase runoff from the land, increasing phosphorus loading into the lake. The ski slope is prone to erosion but is fairly buffered from Oaks Pond by mature forest and wetlands.

APPENDIX U. (CONTINUED)

$\mathbf{Ec_{ag}}$ = export coefficient for agricultural lands (kg/ha/yr)

ER = 0.20 to 0.65 BE = 0.40

Agricultural land includes crops and pastures. In the Oaks Pond watershed, there are relatively equal amounts of land dedicated to crops and pastures. The thick grass cover of pastures retains phosphorus more effectively than cropland, which tends to lack a stabilizing ground cover. Dairy farms produce a large amount of phosphorus; one large diary farm is located in the Oaks Pond watershed. One strip of agricultural land runs adjacent to the southwestern shore of Oaks Pond. These factors in combination warrant a moderately high export coefficient. The export coefficients used for agricultural type lands in past CEAT reports and in Higgins Lake, Michigan were also taken into consideration when assigning the export coefficient for Lake George (Rechkhow and Chapra 1983, and BI493 1997 – 2001).

$\mathbf{Ec_{c}}$ = export coefficient for cleared lands (kg/ha/yr)

ER = 0.25 to 0.75 BE = 0.40

This land use category contains clear cuttings, selection cuttings, and logging roads. The Oaks Pond watershed has two main patches of cleared land. Logged land is very susceptible to erosion, which increases the export coefficient for this land use. One small logged area is located near the residential area near the northeast shoreline of Oaks Pond. This cleared area is not buffered by significant amounts of other land uses that could mitigate the potential phosphorus loading from the cleared land. This factor warrants a relatively high export coefficient.

Ec_{ss} = export coefficient for shoreline septic systems (kg/ha/yr)

ER = 0.30 to 0.90 BE = 0.70

The conditions for septic systems along Oaks Pond shoreline are generally in fairly good condition (Gray, pers. comm.). The dominant soil types around Oaks Pond are moderate to very poor for septic systems (USDA 1972). A majority of the houses along the shoreline of Oaks Pond are seasonal so their septic systems contribute less nutrients than if they were used year round. However, the average number of days per year and the average number of persons per unit is higher for shoreline seasonal houses for Oaks Pond than for Lake George. These factors result in a moderate export coefficient for shoreline septic systems. The export coefficients were also chosen based on a variety of factors that influenced the range of coefficients from past reports (BI493 1997, 1999 – 2001).

Ec_{ns} = export coefficient for non-shoreline septic systems (kg/ha/yr)

ER = 0.20 to 0.50 BE = 0.40

Non-shoreline septic systems are in equally poor soil conditions as shoreline systems but their distance from Oaks Pond lowers the export coefficient. All of the non-shoreline houses are year-round and their septic systems contribute more phosphorus than those of seasonal houses. The septic systems of year round houses tend to be newer and more routinely maintained than the septic systems of seasonal homes. The combination of these factors warrants that export coefficient be relatively lower than the shoreline septic system export coefficient. Similar non-shoreline septic system parameters were used to establish a similar range of coefficients for a CEAT study of Lake Wesserunsett in 2001 (BI493 2001).

APPENDIX U. (CONTINUED)

 # Capita years $_{s \text{ and } n}$ = capita years for shoreline and non-shoreline

Capita years $_s$ = 42.02 Capita years $_n$ = 211.54

This term accounts for the number of people and the proportion of the year that these people are potentially contributing waste to shoreline or non-shoreline septic systems. It is calculated using the following equation:

Capita years = mean number of persons per unit * (Days in use / 365) * Total number of residential units.

Seasonal and non-seasonal residency was estimated to be 60 and 355 days per year, respectively (Dionne, pers. comm.). The average number of persons per household was estimated to be 3.5 for shoreline seasonal development, 2.2 for shoreline year round development and 2.5 for non-shoreline year round development (Dionne, pers. comm.).

SR $_{s \text{ and } n}$ = soil retention constants for shoreline and non-shoreline

Shoreline	Non-shoreline
ER_s = 0.80 to 0.60	ER_n = 0.90 to 0.80
BE_s = 0.70	BE_n = 0.85

Soil retention measures the ability of soil to retain phosphorus, preventing the phosphorus from entering Oaks Pond. Soil retention is measured on a scale of zero to one with zero representing no retention and one representing full retention of phosphorus in the soil. Since shoreline soils generally have much less buffering than non-shoreline soils, the values for shoreline soils are lower. The export coefficients for shoreline and non-shoreline soil retention were also determined based on past CEAT reports (BI493 1997, 1999 – 2001).

APPENDIX U. (CONTINUED)

Areas for Land Use components:

$\mathbf{A}_s$ = area of Oaks Pond = 37.31 ha

$\mathbf{A}_{mf}$ = area of mature forested lands = 755.22 ha

$\mathbf{A}_t$ = area of transitional forests = 39.54 ha

$\mathbf{A}_{reg}$ = area of regenerating forests = 19.06 ha

$\mathbf{A}_{rev}$ = area of reverting lands = 19.41 ha

$\mathbf{A}_w$ = area of wetlands = 32.92 ha

$\mathbf{A}_s$ = area of shoreline residential development = 10.93 ha

$\mathbf{A}_n$ = area of non-shoreline residential development = 35.21 ha

$\mathbf{A}_r$ = area of roads = 9.56 ha

$\mathbf{A}_{cm}$ = area of commercial and municipal lands = 34.06 ha

$\mathbf{A}_{ag}$ = area of agricultural lands = 75.85 ha

$\mathbf{A}_c$ = area of cleared lands = 4.27 ha

APPENDIX V. PREDICTIONS FOR ANNUAL MASS RATE OF PHOSPHORUS INFLOW FOR LAKE GEORGE AND OAKS POND

The phosphorus loading model used by CEAT presents the annual total phosphorus input as loading per unit lake surface area, measured in kg/ha. The annual total phosphorus input was calculated by dividing the surface area (A_s) of the water body by total phosphorus inflow (W) (Reckhow and Chapra 1983):

$$L = W/A_s$$

L	= areal phosphorus loading (kg/ha/yr)
W	= annual mass rate of phosphorus inflow (kg/yr)
A_s	= surface area of the water body (ha)

Atmospheric phosphorus loading was calculated by dividing total inflow water volume by surface area (A_s) (Reckhow and Chapra 1983):

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

q_s	= areal water loading (m/yr)
Q_{total}	= total inflow water volume (m^3/yr)

APPENDIX V. (CONTINUED)

Low and high estimates of total phosphorus concentration were then calculated by dividing total atmospheric phosphorus loading by the approximation of the phosphorus settling velocity in the water column (Reckhow and Chapra 1983):

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

P = total phosphorus concentration (kg/m^3)

Lake George

Constants for low and high predictions:

A_s = 122,321.56 m^2

Q_{total} = 7,188,531.50 m^3

q_s = 58.77 m/yr

Low Prediction:	High Estimate:	Best Prediction:
W = 94.12 kg/yr	W = 344.60 kg/yr	W = 207.88 kg/yr
L = 0.07 kg/ha-yr	L = 0.26 kg/ha-yr	L = 0.16 kg/ha-yr
P = 3.94 ppb	P = 14.42 ppb	P = 8.70 ppb

APPENDIX V. (CONTINUED)

Oaks Pond

Constants for low and high predictions:

A_s = 41,816.66 m^2

Q_{total} = 12,828,199.69 m^3

q_s = 306.79 m/yr

Low Prediction:

W = 85.59 kg/yr

L = 0.23 kg/ha-yr

P = 4.34 ppb

High Estimate:

W = 321.30 kg/yr

L = 0.86 kg/ha-yr

P = 16.29 ppb

Best Prediction:

W = 179.71 kg/yr

L = 0.48 kg/ha-yr

P = 9.11 ppb